ESSCI
Skilling India in Electronics

Participant Handbook

Sector
Electronics

Sub - Sector
Industrial Automation

Occupation
Engineering-I&A

Reference ID: **ELE/Q7107, Version 1.0**
NSQF Level 6

Mechatronics Designer and System Integrator

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"
Skilling is building a better India.
If we have to move India towards
development then Skill Development
should be our mission.
"

Shri Narendra Modi
Prime Minister of India

Certificate

COMPLIANCE TO
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ELECTRONICS SECTOR SKILL COUNCIL OF INDIA

for

SKILLING CONTENT : PARTICIPANT HANDBOOK

Complying to National Occupational Standards of

Job Role/Qualification Pack

"Mechatronics Designer and System Integrator" QP No. **"ELE/Q7107, NSQF Level 6"**

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Valid up to*: June 2nd, 2025

*Valid up to the next review date of the Qualification Pack or the
 'Valid up to' date mentioned above (whichever is earlier)

Authorized Signatory
Electronics Sector Skill Council of India

Acknowledgments

About this book

This participant handbook has been designed to serve as a guide for participants who aim to obtain the required knowledge and skills to undertake various activities as a Mechatronics Designer and System Integrator. Its content has been aligned with the latest Qualification Pack (QP) prepared for the job role. With a qualified trainer's guidance, the participants will be equipped with the following for working efficiently in the job role:

- **Knowledge and Understanding:** The relevant operational knowledge and understanding to perform the required tasks.

- **Performance Criteria:** The essential skills through hands-on training to perform the required operations to the applicable quality standards.

- **Professional Skills:** The Ability to make appropriate operational decisions about the field of work.

The handbook details the relevant activities to be carried out by a Mechatronics Designer and System Integrator. After studying this handbook, job holders will be adequately skilled to carry out their duties efficiently according to the applicable quality standards, with minimum supervision.

The content in this handbook is aligned with the following National Occupational Standards (NOSs) as given in the latest version of the Qualification Pack (QP) for the job role.

- ELE/N7112: Integrate PLC with the SCADA system

- ELE/N7113: Analyse motion control

- ELE/N7114: Design the panels using AutoCAD electrical toolset

- ELE/N7115: Carry out process instrumentation

- ELE/N7116: Set up advanced automation in mechatronics

- ELE/N9905: Work effectively at the workplace

- ELE/N1002: Apply health and safety practices at the workplace

The handbook has been divided into an appropriate number of units and sub-units based on the content of the relevant QP. We hope it will facilitate easy and structured learning for the participants. We sincerely hope that participants will obtain enhanced knowledge and skills after studying this handbook and make career progress in the relevant and senior job roles.

Symbols Used

| Key Learning Outcomes | Exercise | Steps | Tips | Notes | Unit Objectives |

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Key Learning Outcomes

By the end of this module, participants will be able to:

1. Describe the size and scope of the Electronic industry and its sub-sectors.

2. Define Mechatronics.

3. Describe the evolution level of mechatronics.

4. State uses of mechatronics.

5. State the importance of mechatronics.

6. Discuss the role and responsibilities of a Mechatronics Designer and System Integrator.

7. Discuss various employment opportunities for a Mechatronics Designer and System Integrator in the Electronics industry.

8. State the organizational policies on incentives, personnel management reporting structure, etc.

UNIT 1.1: Overview of the Electronic Industry

Unit Objectives ◎

By the end of this unit, participants will be able to:

1. Describe the size and scope of the Electronic industry and its sub-sectors.

1.1.1 Definition of Electronics

Electronics is a branch of physics that studies the electrons' flow, control, and behaviour and their effects on vacuums, gases, semiconductors, and devices using such electrons.

The electrons are controlled by devices (electronic components) that resist, carry, select, steer, switch, store, manipulate, and exploit them.

1.1.2 Electronic Industry

The electronics industry comprises companies that manufacture, design, manufacture, assemble, and electronic service products. To perform their primary functions, electronic products rely on electronic principles. It consists of materials, parts, components, subassemblies, and equipment that use electronics principles.

1.1.3 Profile of Electronic Sector of India

- Globally, electronics is one of the fastest-growing industries.

- The Indian market is predicted to be second only to China's, followed by Vietnam, South Korea and Taiwan.

- The Indian government focuses on manufacturing electronics hardware at the domestic level, which appears to be the conceptual foundation of the Make in India and Digital India programmes. These initiatives seek to attain a market size of US$ 251 billion by 2023 by encouraging local production and exports across the electronics system design and manufacturing (ESDM) value chain.

- The seven key segments of the Indian electronics industry are industrial electronics, consumer electronics, communications and broadcasting electronics, strategic electronics, electronic components, computer hardware, and LED products.

- The Electronics Development Fund (EDF), the Phased Manufacturing Program (PMP), the Modified Special Incentive Package Scheme (MSIPS), Preferential Market Access (PMA), and a reduction in tariff structure have all been used by the Indian government to support the sector.

1.1.4 Size of Electronic Sector in India

- The electronics sector of India contributes around 3.4% of the country's Gross Domestic Product (GDP).

- The IT sector in India is one of the most significant contributors, with a 9% contribution to Gross Domestic Product (GDP).

- The industry size is around US$ 194 billion and is expected to cross US$ 300-350 billion by 2025.

1.1.5 Key Drivers

The following are some of the electronic industry's most important growth drivers:

- **Economic growth:** India has one of the world's fastest-growing economies, with GDP forecast to rise consistently. Demand in the industry and strategic electronics domains has been positively driven by rising economic activity and implementation of the newest automation technology across many industries.

- **Rapid urbanization and income growth:** Rapid urbanization, combined with rising incomes, has made items more affordable, resulting in increased demand for mobile phones, tablets, and other household gadgets.

- **Government initiatives:** The GST, Make in India, and other policies like Preferential Market Access have improved the business climate for domestic manufacturing. Demand for electronic items is also boosted by government flagship programmes such as Smart Cities and Digital India. The government announced three further plans in April 2020, which were notified by the Ministry of Electronics and Information Technology (MeitY), giving a total of 500 billion (US$ 7.2 billion) in incentives under the schemes. These incentives will boost domestic electronics output and encourage anchor firms in India's key electronics clusters.

  Production Linked Incentives (PLI), Modified Electronics Manufacturing Clusters (EMC 2.0), and Scheme for the promotion of manufacturing of components and semiconductors (SPECS) are the three essential schemes.

- **Evolving technology and innovation:** Rapid technological advancements and newer items with enhanced technologies have resulted in shorter product life cycles for electrical products. Customers may also replace their old electronic equipment with newer items thanks to shifting customer attitudes and consumer-to-consumer websites like Olx and Quikr.

  Demand for high-speed Internet has also fueled the growth of high-end smartphone sales. Consumer electronics has seen tremendous innovation due to this increased demand for high technological items. New technologies such as artificial intelligence (AI), the Internet of Things (IoT), and robots and analytics in the industrial and strategic electronics segment have contributed to various electronic products' overall growth, boosting local demand.

1.1.6 Scope of Electronic Industry

The electronic industry has scope in the following sector:

Telecommunication	Mobile Communication (2G, 3G. 4G or 5G)	Automotive Industry	Consumer electronics manufacture
IT industries	Petroleum and Chemical Industry	Health care equipment manufacturing	
Power Electronics	Steel Industry		

Fig. 1.1.1 Scope of the electronic industry

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.com/watch?v=JgLu40
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Scope of
Electronic Industry

UNIT 1.2: Introduction to Mechatronics

Unit Objectives ⦿

By the end of this unit, participants will be able to:

1. Define Mechatronics
2. Describe the evolution level of mechatronics
3. State uses of mechatronics
4. State importance of mechatronics

1.2.1 Mechatronics

Mechatronics is made from the words "mecha" (mechanics) and "tronics" (electronics).

In other words, technologies and produced items will increasingly incorporate electronics into mechanics, intimately and organically, making it hard to distinguish between them.

Mechatronics is a multidisciplinary field that describes the skills required in today's modern automated manufacturing industry. Mechatronics engineers produce simpler, smarter systems at the crossroads of mechanics, electronics, and computation.
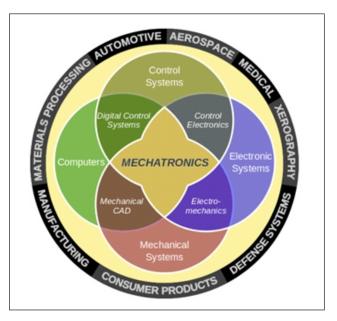
Fig. 1.2.1 Application of Mechatronics

1.2.2 Evolution Level of Mechatronics

- **Primary Level Mechatronics:** At the fundamental control levels, this level includes I/O devices such as sensors and actuators that combine electrical signals with mechanical action. Examples: Fluid valves and relays that are controlled by electricity

- **Secondary Level Mechatronics:** Microelectronics are integrated into electrically controlled devices at this level. Examples: Players for cassette tapes

- **Third Level Mechatronics:** This level combines sophisticated feedback functions into the control strategy, increasing the quality of the smart system in terms of sophistication. Microelectronics, microprocessors, and other 'Application Specific Integrated Circuits' are part of the control approach (ASIC). They control an electrical motor to operate industrial robots, hard disc drives, CD drives, and automated washing machines, for example.

- **Fourth Level Mechatronics:** This level of mechatronics includes intelligent control. It provides technologies for intelligence and failure detection and isolation (FDI).

1.2.3 Utility of Mechatronics

Mechatronics may be used in many industries and for a wide range of applications. While mechatronics is most commonly associated with the manufacturing business (which includes the manufacture of consumer products, industrial goods, automobiles, and electronics, among other things), it is also used in healthcare, transportation, and a variety of other disciplines. These are a few of the most common mechatronics applications to be aware of:

- Robotic automation

- Home and building automation

- Computer-driven machinery

- Medical imaging systems

- Robotic surgery

- Machine vision and inspection

- Various sensing and control systems

- Temperature/humidity control

- Automotive engineering

- Computer-aided design and production (such as CNC)

- Transportation

1.2.4 Importance of Mechatronics

- It has simplified the process of designing products and processes.

- The Mechatronics system aids in the improvement of performance and quality.

- The products are both cost-effective and of good quality.

- Flexibility is increased.

Notes

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Mechatronics

UNIT 1.3: Role and Responsibilities of a Mechatronics Designer and System Integrator

Unit Objectives 🎯

By the end of this unit, participants will be able to:

1. Discuss the role and responsibilities of a Mechatronics Designer and System Integrator.

2. Discuss various employment opportunities for a Mechatronics Designer and System Integrator in the Electronics industry.

3. State the organizational policies on incentives, personnel management reporting structure, etc.

1.3.1 Mechatronics Designer and System Integrator

A Mechatronic Designer and System Integrator is in charge of creating controlled motion systems by fusing together functional components from several fields of study. The person works in every stage of the manufacturing of smart machines, from design to testing, in fields including robotics, human-machine interaction, medical and assistive technology, etc.

1.3.2 Responsibilities of a Mechatronics Designer and System Integrator

A Mechatronics Designer and System Integrator should be able to:

- Contribute to the design of a module's function or the architecture of mechatronics, with a particular emphasis on dynamic architecture or a passive or active vibration control module.

- Provide signal analysis, dynamics, functional performance, functional integration, and troubleshooting.

- Participate in multidisciplinary project teams to create a mechatronics function or module.

- Develop and maintain expertise in the disciplines of dynamics, servo control, signal analysis, and testing, as well as a foundational understanding of software, mechanics, optics, electronics, actuators, and dynamics.

- Provide support to the design of mechatronics architecture and balance the mechanical, electronic, and software design.

- Plan and carry out the integration and testing of the mechatronic modules.

- Interact with people of other projects, industries, and suppliers of optics and mechatronics.

- Maintain the documentation of specifications, designs, and test outcomes.

1.3.3 Career Opportunities

A degree in mechatronics can lead to employment in management, including project management. Laboratories, industrial factories, and engineering design offices are all examples of workplaces.

Cybersecurity, computer science, automotive engineering, robotics, artificial intelligence, telecommunications, consumer products, and packaging are domains where mechatronics professionals operate.

1.3.4 Organizational Policies on incentives, Personnel Management and Reporting Structure

The organizational policies on incentives, personnel management, and reporting structure depend on the organization the individual joins. These vary across organizations.

For example, a public sector company may offer different incentives for work performance compared to a private company. The same is the case with the reporting structure.

Personnel management policies also tend to differ from organization to organization. The individual should conduct proper research before interviewing for a job at a particular company to ensure that they are satisfied with the company policies on remuneration, human resource management, career progression, etc.

Exercise

1. Explain any two key drivers of the electronics industry.

2. Define Electronics.

3. State in brief about Mechatronics.

4. State five responsibilities of a Mechatronics Designer and System Integrator.

Notes 📝

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Mechatronics Designer and
System Integrator

2. Process of Integrating Programmable Logical Controller (PLC) With the Supervisory Control and Data Acquisition (SCADA) System

Unit 2.1 - Programmable Logic Controller (PLC)

Unit 2.2 - Supervisory Control and Data Acquisition (SCADA) System

ELE/N7112

Key Learning Outcomes

By the end of this module, participants will be able to:

1. Explain the basics of digital electronics.

2. Explain the fundamentals of PLC.

3. Explain the PLC hardware and architecture.

4. Explain the source and sink concepts.

5. Describe the process of wiring different field devices to PLC.

6. Explain the use of PLC programming software.

7. Describe the process of creating a new application and addressing it in PLC.

8. Explain different programming languages and basic programming instructions.

9. Explain the advance instructions such as upload/ download/ monitoring forcing of Ios.

10. Describe the process of detecting faults in the PLC system and SCADA software, troubleshooting them and carrying out the necessary documentation.

11. Explain how to communicate with the SCADA software.

12. Explain the use of real-time applications.

13. Explain how to create a new SCADA project.

14. Describe the process of creating and editing elementary graphic displays.

15. Explain how to attach controls to graphic objects.

16. Explain how to analyze real-time and historical trends.

17. Explain the use of alarms and events.

18. Describe the application of scripts.

19. Describe the process of Net DDE Communication.

UNIT 2.1: Programmable Logic Controller (PLC)

Unit Objectives ◎

By the end of this unit, participants will be able to:

1. Explain the basics of digital electronics.

2. Explain the fundamentals of PLC.

3. Explain the PLC hardware and architecture.

4. Explain the source and sink concepts.

5. Describe the process of wiring different field devices to PLC.

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10. Describe the process of detecting faults in the PLC system and SCADA software, troubleshooting them and carrying out the necessary documentation.

2.1.1 Digital Electronics

The world of electronics becomes much more understandable if we divide it into two different categories: the "analog" world and the "digital" world. In general, the analog world refers to any natural phenomenon that changes its characteristics over time. For example, the temperature fluctuates slowly throughout the day, and a basic thermometer can be used to determine how hot or cold it is at any given time.

Digital electronics, on the other hand, is an entirely separate discipline. The two "states" that matter in the digital domain (i.e., digital electronic circuits) are ON or OFF. For example, when any light switch is flipped, there are only two potential settings for the light switch, either ON or OFF.

The field of electronics that deals with digital signals for the processing and controlling of various systems and sub-systems is known as Digital Electronics. Digital electronics is being used in various applications, such as sensors and actuators.

2.1.2 PLC

In a traditional industrial control system, all control devices are linked directly to each other based on how the system is designed to operate. However, in a PLC system, all the devise are wired to the PLC. The control program within the PLC then provides the wiring connection between all the devices.

PLCs were invented by Dick Morley in 1964. PLC has since revolutionized the industrial and manufacturing industries.

The National Electrical Manufacturers Association (NEMA) defines a PLC as a "digitally operating electronic apparatus which uses a programmable memory for the internal storage of instructions by implementing specific functions, such as logic, sequencing, timing, counting, and arithmetic to control through digital or analog I/O modules various types of machines or processes."

A programmable logic controller (PLC) is a solid-state, programmable electrical/electronic interface that can modify, execute, and monitor the state of a process or communication system at a faster rate. It runs on programmable data stored in an integrated microprocessor-based system.

A PLC receives (input) and transmits (output) numerous electrical and electronic signals, as well as operates and monitors almost any mechanical and/or electrical system. As a result, it has great flexibility when it comes to interacting with computers, machines, and a variety of other peripheral systems or devices. It is typically programmed in relay ladder logic and is designed to function in an industrial setting.

Some of the PLC manufacturers are - Allen Bradley, ABB, Siemens, Mitsubishi PLC, Hitachi PLC, Delta PLC, General Electric PLC and Honeywell PLC.

2.1.2 PLC's Hardware and Architecture

IPLC hardware consists of the physical components that make up the PLC system. Each component of PLC hardware is designed to execute a single function. A PLC system cannot function properly without all of its hardware components.

The structure of a PLC is similar to a computer's architecture. The main components of a PLC are - Processor (CPU), power supply, programming device, and input and output (I/O) modules.
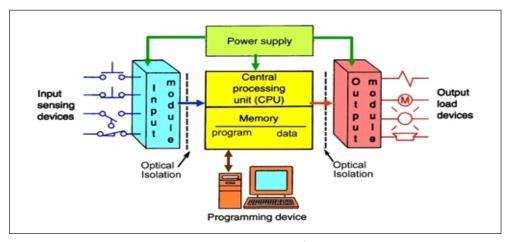
Fig. 2.1.1 Structure of PLC

Processor

A processor is at the core of any PLC system. It is undoubtedly the most important piece of PLC gear. The PLC processor is also known as the PLC controller or PLC CPU (Central Processing Unit). It executes programmed actions. These actions or outputs are carried out in response to signals and data from associated inputs.

The PLC processor can be integrated into the PLC unit or purchased separately. Fixed PLCs often have their CPU incorporated into the unit. On the other hand, the PLC processors in modular and distributed PLCs are distinct modules.

Power Supply

The PLC is powered by the power supply, which converts available incoming AC power to the DC power required by the CPU and I/O modules to function effectively. The common power supply input voltages are 120VAC, 240VAC, an AC voltage range (such as 85-265VAC), and 24VDC. In contrast, the common power supply outputs are 24DC and 5VDC.

I/O Modules

The input modules connect numerous external devices to the PLC. Depending on the field equipment, inputs and outputs might be digital or analog. An input is a field device that informs the PLC about the status of the process. A pushbutton switch, pressure sensor, or photo sensor are examples of input field devices.

A command issued by the CPU Logic to operate an output field device is referred to as an output. To control output devices, output modules transform CPU signals into digital or analog values. Relays, timers, motor starters, lights, counters, and displays are examples of field devices.

Programming Device

To be programmed, PLC requires programming devices. Handheld programming devices and personal computers are the two most common PLC programming devices (PC). These are used to create the PLC programme (similar to ladder logic) and then upload it into the PLC memory. PLC programming devices connect to the PLC through a cable and transfer the PLC program using an Ethernet or Serial communication protocol.

2.1.3 Types of PLCs

The two main types of PLCs are classified on the basis of their hardware structure. These are:

Compact PLC

A compact PLC is also called a fixed PLC or an integrated PLC. Compact PLCs are designed to perform basic functions. There are small in size. They consist of a Power Supply, the CPU and the Input/output module, which are integrated into the microcontroller itself. The number of inputs and outputs cannot be expanded in this type of PLC.
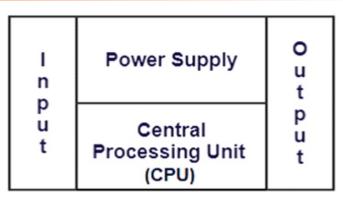
Fig. 2.1.2 Block Diagram of Compact PLC

Modular PLC

Modular PLC is also known as a rack-mounted unit. It has been termed "modular" due to its feature of allowing multiple expansions of the PLC system through the use of modules. The power supply, communication module, and Input/output module are all separate from the actual microcontroller. The number of inputs and outputs can be expanded in this type of PLC.
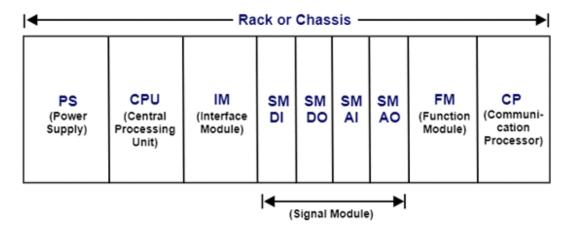
Fig. 2.1.3 Block Diagram of Modular PLC

2.1.4 The Source and Sink Concept

The sink and source concept, in general, illustrates how input and output devices in a control system interact with their power source in terms of current flow. It is based on basic electric theory, which stipulates that DC current must flow from the +ve (DC+) terminal through a load to the –ve (DC-) terminal to complete a DC circuit.

In PLC, The concept of Sinking and Sourcing is only applicable to digital DC Input/output logic circuits. In a logic circuit, the output is a function of its input. It may have a single binary (ON/OFF) output as well as one or more binary inputs. Switches, relays, and transistors are examples of such circuits.
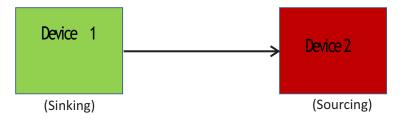
Sinking Vs Sourcing

In digital PLC I/O modules, the idea of sinking and sourcing refers to specifying the direction of conventional current flow in a logic circuit between two devices. Let's consider the following illustrations:

Illustration 1

In the above illustration, Device 1 is sourcing the current since the current is flowing from it, while Device 2 is sinking the current since the current is being flown to it.

In the second illustration, Device 2 is sourcing the current since the current is flowing from it, while Device 1 is sinking the current since the current is being flown to it.

In every condition where DC current is flowing from one digital device to another, the device sending out the current of its control terminal to another device is the current source device. The device that is receiving the current is the current-sinking device.

In PLCs, one of the potential binary states of a discrete field input device, such as Closed or Open; Energized or De-Energized; ON or OFF; High or Low, is detected by a digital input module. The DC current will either flow into or out of the digital input module depending on the type of digital input module being used in the PLC system and its connection polarity to the field input device.

Digital PLC Input Modules

Digital PLC Input modules interface with field input devices in a PLC processor, monitor their conditions and provide necessary information to the CPU regarding the status of the field devices. These devices could be switches, sensors and start/stop buttons.

Sourcing PLC Input Modules

In a sourcing PLC input module, the current flows out of its control terminal into the connected field input device. To enable the module to supply a positive voltage to an external logic DC circuit, PLC manufacturers internally connect the input cards of their digital input modules to a voltage source.

In the given logic circuit, a digital PLC input module (Device #1) is connected to a Normally Closed stop push button (Device #2)
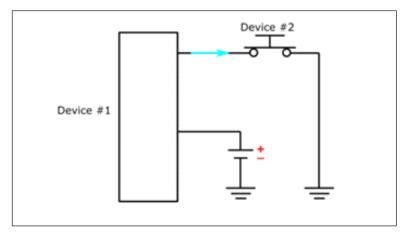
Fig 2.1.4 A sourcing PLC Input Module

While Device #2 provides the ground connection, Device #1 is linked to the voltage source's positive (+) terminal, such as a power supply, which supplies the positive voltage. Electricity is moving from Device #1's control terminal to Device #2. Therefore, the sourcing device is the digital PLC input module (Device #1). The NC Stop Push Button (Device #2), which is the Sinking device, sends the received current to the ground.

Sinking PLC Input Modules

In a sinking PLC input module, the current flows into its control terminal. The input card of this module is wired to the ground internally. The internal circuit provides the required ground connection for the external logic circuit.

The given logic circuit connects a digital PLC input module (Device #1) to a typically closed stop push button (Device #2), the field input device.
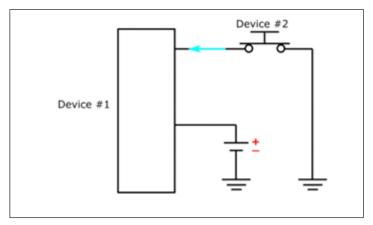
Fig 2.1.5 A sourcing PLC Input Module

Current is supplied to the PLC input module (Device #1) by Device #2 (the NC Stop Push Button). As a result, the sourcing device is the NC Stop Push Button (Device #2). The digital PLC input module is a sinking device since it discharges the received current to the earth.

Digital PLC Output Modules

The Digital PLC Output modules control the field output devices. These modules provide the PLC processor with the ability to control the connected physical devices, such as motors, electric heaters, pumps, solenoid valves, and relays.

Sinking PLC Output Modules

In the given logic circuit, a digital PLC Output Module (Device #1) is connected to a Relay Load (Device #2) which is the field input device.
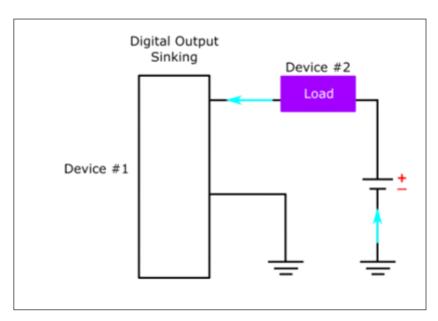
Fig 2.1.6 A sinking PLC Input Module

The PLC Output Module (Device #1), which serves as a ground connection for the circuit, is receiving current from Device #2 (the Relay Load). Thus, the digital PLC Output Module (Device #1) is the Sinking device, and the Relay Load (Device #2) is the Sourcing device.

Sourcing PLC Output Modules

In the given logic circuit, a digital PLC Output Module (Device #1) is connected to a Relay Load (Device #2) which is the field input device.
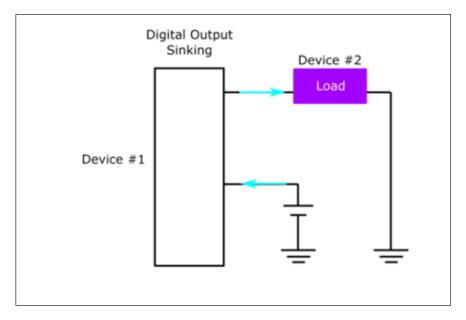
Fig 2.1.7 A Sourcing PLC Input Module

Device #1 serves as the sourcing device by supplying the current to Device #2. The Sinking device is the Relay Load because it sinks the received current into the earth.

2.1.5 Wiring of PLC

The most important and critical process in the installation of a PLC is Input/output Installation. Placing and installation mean inserting the appropriate modules in the appropriate locations. This process entails checking the slot address and module type according to the I/O address assignment document. The field devices that have been given that termination address are then wired to each terminal in the module.

Before installing and wiring any module, the user should turn off the power to the modules.

Wiring

Before connecting field equipment to a PLC, the following factors need to be taken into account:

Wire Size

In the wiring process, the size of the cable is the most important factor. One or more conductors of a specific wire size can be inserted into each I/O terminal. It must be ensured that the wire is the suitable size and gauge to carry the maximum current.

Wire and Terminal Labelling

It is necessary to label each field wire and its termination point according to a reliable labelling method. Labelling nomenclature includes wire numbers, device names or numbers, and the input/output address assignment. It simplifies maintenance and troubleshooting. Tape or shrink-tubing should be used to name the wires, and stick-on labels or tape should be used to identify each terminal block.

Wire Bundling

Wire bundling is a technique commonly used to simplify the connections to each I/O module. The wires that connect to one module are bundled, generally with a tie wrap. Wire bundles with the same characteristics are then routed through the duct with other bundles of wire. Whenever possible, input, power, and output bundles carrying the same type of signals should be kept separate to prevent interference.

Process of I/O wiring

• Before any PLC installation or wiring is done, disconnect and lock out power to the controller and I/O.

• Ensure that all modules are seated correctly. Check the I/O wiring diagram for the module type and model number. Refer to the I/O address assignment document for the slot location.

• Remove all terminal screws on each I/O module.

• Place the wire bundles corresponding to each module in the duct and route them to the module location.

• Begin with the first module and find the wire in the bundle that connects to the lowest terminal. Bend the wire at the right angle toward the terminal when it reaches a vertical height equal to the termination point.

• Cut the wire so that it is 1/4 inch longer than the terminal screw's edge. Remove around 3/8 inch of insulation from the wire's end. Place the wire's uninsulated end beneath the terminal's pressure plate, then tighten the screw.

• Jump the power cable from one module to the next if there are multiple modules that share the same power supply.

• When using shielded wire, just one end should be connected to the ground, ideally at the rack chassis. Potential ground loops will be prevented by this connection. When two or more electrical paths are generated in a ground line or when one or more paths are created in a shield, a ground loop condition is created. Unless otherwise stated, leave the other end clipped back and disconnected.

• Until the module wiring is finished, repeat the wiring process for each wire in the bundle.

• After all the wires have been terminated, gently pull on each wire to inspect the terminations for quality.

2.1.6 PLC Programming

The main components of industrial automation and control systems are programmable logic controllers (PLCs). PLCs may operate everything from a single motor to multiple complicated control systems using simple push-button switches. As a result, PLC programming is critical in designing and implementing control systems tailored to clients' demands. A PLC programme is a set of written or graphical instructions that reflect the logic that must be applied for certain real-time industrial applications.

Dedicated PLC programming software comes with a certain manufacturer's PLC hardware, and it allows users to enter and build user application code, which can then be downloaded to the PLC hardware. This programme also ensures Human Machine Interface (HMI) as a graphical representation of variables. Once this programme has been downloaded to the PLC and the PLC has been set to Run mode, the PLC will continue to operate in accordance with the programme. Let us first review the foundations of the PLC programming lesson and its essential notions before moving on to the PLC programme.

PLC Programming Basics

A CPU of the PLC executes two different programs:

1. The Operating System

2. The User Program
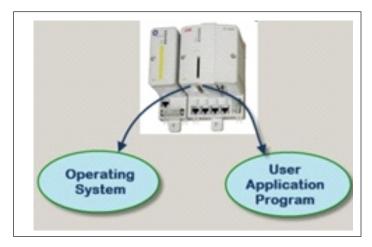
Fig. 2.1.8 PLC Programming Basics

The Operating System

The operating system groups together all of the CPU's functions, activities, and sequences that aren't related to a control job.

- Handling a hot restart and warm restart
- Updating and outputting the process image tables of input and outputs
- Executing the user program
- Detecting and calling the interrupts
- Managing the memory areas
- Establishing communication with programmable devices

The User Program

It's a set of functions that work together to complete a task that's been automated. The users must generate this and download it to the PLC's CPU. The user software can do the following tasks:

- Initiating all the conditions for starting the specified task

- Reading and evaluating all binary and analog input signals

- Specifying output signals to all binary and analog output signals

- Executing interrupts and handling errors

Several leading PLC manufacturers in the current industrial automation market create conventional PLCs ranging from tiny to high-end. Every PLC manufacturer has its own software for programming and configuring the PLC hardware. However, depending on the vendor, the PLC programming language varies. Some manufacturers use comparable programming languages, while others use different ones. PLC standard programming languages are separated into two categories, each of which is further subdivided into multiple types, as follows:

1. Textual language

    - Instructions List (IL)

    - Structured Text (ST)

2. Graphical language

    - Ladder Diagrams (LD)

    - Function Block Diagram (FBD)

    - Sequential Function Chart (SFC)

Many users prefer graphical languages to text-based languages for programming a PLC because of their easy and convenient programming capabilities. Each PLC software's standard library contains all of the essential functions and functional blocks. A timer, counters, strings, comparators, numeric, arithmetic, bit-shift, calling functions, and so on are examples of function blocks.

PLC Programming Devices

Various programming devices are employed to input, change, and debug a PLC programme. Handheld and PC-based programming terminals are among the devices available. A proprietary device is linked to the PLC through a connecting cable in the portable programming device technique. This device is made up of a set of keys that may be used to enter, modify, and dump code into a PLC. The instruction that has been programmed is displayed on these portable devices, which have a tiny display. These portable gadgets are small and simple to use, yet they have limited capabilities.
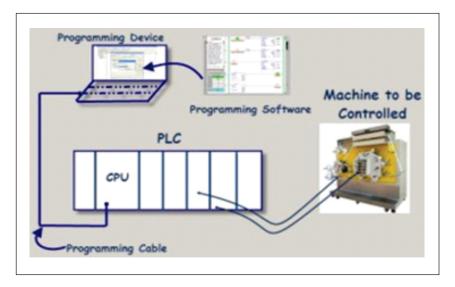
Fig. 2.1.9 PLC Programming Devices

The most common method of programming the PLC is to utilize a Personal Computer (PC) in combination with the manufacturer's software. We may use this PC to execute the software in online or offline mode and edit, monitor, debug, and troubleshoot the PLC's programme. The above diagram depicts the method of transferring the programme to the PLC, in which the PC has programme code matching the control application, which is delivered to the PLC CPU via the programming cable.

Ladder Logic PLC Programming

Ladder logic (also known as ladder diagram or LD) is a programming language used to program a PLC (Programmable Logic Controller). It is a graphical PLC programming language which expresses logic operations with symbolic notation. Ladder logic is made out of rungs of logic, forming what looks like a ladder – hence the name 'Ladder Logic'.

Ladder logic is mainly for bit logic operations, although it can scale a PLC analog input. However, even simple bit logic operations can benefit more advanced PLC programs and SCADA system programming.
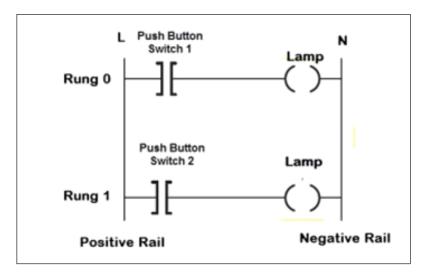
Fig. 2.1.10 Ladder Logic in PLC Programming

The most basic and simplest way of programming the PLC is the ladder logic diagram, which is one of the various programming languages. Before beginning to write a PLC with this language, it is necessary to have a fundamental understanding of it. The hardwired-ladder graphic below demonstrates how two push button switches control the same light load, with the lamp glowing if one of the switches is closed. Rungs are two horizontal lines that are joined by rails, which are two vertical lines. Each rung ensures that current flows from the input to the output devices by establishing electrical continuity between the positive (L) and negative (N) rails. The picture depicts some of the symbols used in ladder logic programming.

As indicated above, two types of input switches are generally closed and normally open. In addition to the above-mentioned functional symbols, the standard library contains various functions such as timer, counter, PID, and others that may be used to programme complicated tasks.

Steps for Programming PLC Using Ladder Logic

The technique for programming a PLC for a specific application is determined by the type of standard manufacturer software tool used and the type of control application being used.

Step 1: Analyse and Develop a Control Application Concept

The first stage in programming a PLC is to develop a concept to create an application-based programme. For example, may use a DC motor to drive a line follower robot when the push button is pressed. The LED light must reflect this state when the motor is turned on. The motor is also connected to a sensor (which may be thought of as a second switch) that detects obstructions, so when this is activated, the motor should be shut off. When the motor is shut off, the buzzer should also be turned on.
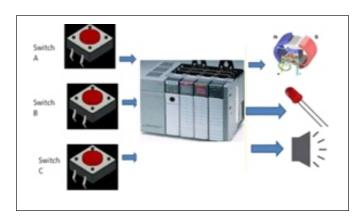
Fig. 2.1.11 PLC Control Application

Step 2: Create a flowchart to list all the conditions and choose the design.

The variables for the aforementioned project are M: Motor, A: Input Switch 1, B: Input Switch 2, L: LED, and Bu: Buzzer. Designing the logic is made simple by using the flow chart shown below for the aforementioned application.

- Flowchart of PLC Programming
- Flowchart of PLC Programming

Step 3: Install and modify the PLC programming software

Launch the programming programme on the PC that is connected to the PLC hardware. Choose the PLC hardware model in the software, then set the input and output modules accordingly. Choose the hardware processor, the ladder language (LD) from the list of programming languages, and give the programme a name.

Step 4: Add the necessary Rungs and Deal with Them

Based on the control application logic, build the necessary rungs, then assign addresses to each input and output. The ladder logic diagram for the previously mentioned example, for instance, is shown below.

Step 5: Simulate it and check for errors

Select Online from the Online section of the menu bar. After choosing Offline, check for mistakes and make the necessary adjustments. Go online once more, and this time choose the Run option to mimic it.

Step 6: Download the Program to the PLC CPU Memory

After the software has been successfully simulated, download it to the CPU by choosing the Download option over a network or communication cable.

2.1.7 Faults in PLC

Every PLC-controlled factory often has a bigger percentage of defects in its wiring, actuators, and sensors than in its PLC. Instead of the CPU itself, the PLC failures are more likely in the output-input power supply or channels.

The majority of PLCs come with built-in fault analysis methods that do self-tests and display fault codes. In addition to succinct messages that can be translated by checking up codes in the list, the fault's causes and potential recovery techniques are also indicated.

The following are potential ways of detecting motor faults:

Diagnose PLC Indicators

Field devices, wiring, and I/O modules can all be learned a lot about through LED status indicators. Most input/output modules have at least one indicator, typically a power indicator for input modules and a logic indicator for output modules.

A bright power LED on an input module denotes that the input device is active and that the module has received its signal. Some manufacturers offer an extra diagnostic indicator called a logic indicator because this indicator by itself cannot isolate errors in the module. An ON logic LED denotes that the input signal has been acknowledged by the input circuit's logic section.

The module cannot properly send the incoming signal to the processor if the logic and power indicators do not line up. Some output modules also provide a blown fuse indicator, a power indicator, or both in addition to the logic indicator. A power indication indicates that power is being provided to the load, but a blown fuse indicator displays the condition of the output circuit's protection fuse.

If neither LED is on simultaneously, the output module is failing, just like the power and logic indicators in an input module.

PLC Inputs

A problem could be present between the L1 connection and the terminal connection to the input module if the field device attached to the module doesn't appear to turn on. The status indicators on an input module can give details about the field device, the module, and the wiring from the field device to the module, which can help identify the issue.

Placing the PLC in standby mode prevents the output from being activated, which is the initial step in problem diagnosis. This makes it possible to manually activate the field device. The PLC's reading of the input module will now be evaluated.

The PLC's test mode, which reads the inputs and runs the programme but does not activate the outputs, can be used to accomplish this. The issue is not with the input module if the PLC is correctly interpreting the device. The module could be broken if it fails to accurately read the device. The module's optical isolator could be blown, or its logic side could not be properly functioning. Additionally, one of the module's interface channels can be broken. The module needs to be changed in this situation.

PLC Outputs

Status indicators are another feature of PLC output interfaces that offer helpful troubleshooting data. As with PLC input troubleshooting, isolating the issue to a module, field device, or wire is the first step in output troubleshooting.

Additionally, check the output module to see if there is a blown fuse there. Check the fuse's rated value in case of a blown fuse. Check the output device's current requirements as well to see whether it is drawing too much current.

The output module is defective if it gets the processor's command to switch on, but the output status does not change accordingly. Check for voltage at the output terminal to make sure the switching device is working if the indicator lights ON but the field device does not energise. The module needs to be replaced if there is no voltage.

If voltage is detected, the wiring or the field device are the likely culprits. At this point, verify that the field wiring is firmly attached and that no wires leading to the module's terminal or the terminal block are damaged. Check the field device's functionality after examining the module. While the output module is turned on, measure the voltage going to the field device, making sure the return line is securely attached to the object. The field device is broken if there is electricity, but the gadget is inactive. Additionally, inspect the wiring for damaged wires along the wire's course.

CPU Troubleshooting

PLCs have diagnostic indicators that display the state of the CPU and PLC. Power OK, memory OK, and communication OK conditions are a few examples of such signs. First, confirm that the transformer is providing adequate power to the PLC to support all the loads. Check for blown fuses or a power supply drop in the control circuit if the PLC is still not functioning. A problem with memory or communications will be indicated by the diagnostic indicators on the front of the CPU. The CPU might need to be replaced if one of these signs is illuminated.

Notes

Scan the QR Code to watch the related videos

https://youtu.be/cYX
qVPJDlXs

Programmable Logic Controller
(PLC)

UNIT 2.2: Supervisory Control and Data Acquisition (SCADA) System

Unit Objectives

By the end of this unit, participants will be able to:

1. Describe the process of detecting faults in the SCADA software, troubleshooting them and carrying out the necessary documentation.

2. Explain how to communicate with the SCADA software.

3. Explain the use of real-time applications.

4. Explain how to create a new SCADA project.

5. Describe the process of creating and editing elementary graphic displays.

6. Explain how to attach controls to graphic objects.

7. Explain how to analyse real-time and historical trends.

8. Explain the use of alarms and events.

9. Describe the application of scripts.

10. Describe the process of Net DDE Communication.

2.2.1 SCADA

Supervisory Control and Data Acquisition are referred to as SCADA. Automation technology is a term used to describe the control system SCADA, which mixes hardware and software. Supervisors utilise the system's data to control and optimise operations when it receives information about processes and associated equipment. A SCADA system might be contained within a single site or dispersed across a number of locations and occasionally a large geographic area. The petrochemical industry, drinking water delivery systems, wastewater collecting systems, pipelines, and a number of other industrial activities all make substantial use of SCADA.

SCADA systems can help in operation in a number of ways, including maintaining efficiency and spotting issues as they arise. They can decrease expenses while increasing production, quality, and profitability. The correct system must be chosen because SCADA is a considerable long-term investment.

SCADA Architecture

The basic SCADA architecture has two components: Programmable Logic Controllers (PLCs) and Remote Terminal Units (RTUs).

PLCs and RTUs are microcomputers that communicate with a variety of devices, including factory equipment, HMIs, sensors, and end devices, before sending the data from those devices to computers running SCADA software. Operators and other staff members can use the data processed, distributed, and displayed by the SCADA software to analyse the information and make critical decisions.

For instance, a batch of products that exhibit a high incidence of mistakes may be rapidly reported to an operator by the SCADA system. The operator pauses the process and uses an HMI to view the data from the SCADA system in order to identify the source of the issue. The operator examines the data and finds that Machine 4 was broken. The SCADA system's capability to alert the operator to a problem enables him to address it and stop additional product loss.
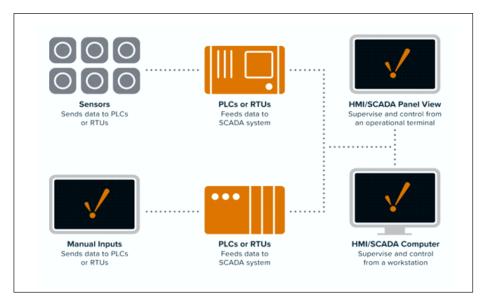
Fig. 2.2.1 A Basic SCADA Diagram

Functions of SCADA

- Data Acquisition

- Information Display

- Alarm Processing

- Information Storage and Reports

- Data Calculation

- Special RTU Control

Application of SCADA

SCADA systems are employed in both public and commercial industrial organizations to regulate and maintain efficiency, disseminate data for better decision-making, and notify system problems to assist in reducing downtime. Because they can range from small, simple installations to huge, complicated ones, SCADA systems are effective in a wide range of business settings. SCADA systems form the foundation of numerous contemporary industries, including - energy, oil and gas, transportation, food and beverages, power, water and sewage, manufacturing, recycling and many more.

Electricity generation and distribution: SCADA systems are used by electric utilities to monitor the operation of circuit breakers, detect current flow and line voltage, and bring specific portions of the power grid online or offline.

Water and Sewage: SCADA is used by state and local water utilities to monitor and control water flow, reservoir levels, pipe pressure, and other variables.

Manufacturing: The SCADA system keeps track of parts stock for just-in-time production, manages industrial automation, and monitors quality control and process flow.

Transportation: SCADA is used by transportation authorities to operate subways, trams, and trolley buses; rail traffic signals; track trains and buses and operate railroad crossing gates.

Buildings and Facilities: SCADA is used by facility managers to regulate HVAC, refrigeration units, lighting, and entrance systems.

2.2.2 Detecting faults in SCADA Software

A highly valuable skill is understanding how to debug the SCADA system. Therefore, let's look at some techniques for locating and fixing SCADA system issues.

Check for damaged or broken equipment

The majority of SCADA equipment is placed in off-site locations where it is more exposed to the environment. Therefore, it's crucial to check that all of the equipment's parts are in working order and are linked to where they should be in case an issue arises.

Check HMI

The SCADA HMI can take many different forms, from the interface display of a device to a powerful dedicated hardware and software system to which the data is being supplied.

A well-designed HMI will keep track of all system communications, offer a user-friendly graphical interface that reveals all the information about the network, and send alert warnings to the necessary individuals. The system won't operate if the HMI isn't getting data.

Simple HMI setting changes can result in issues throughout the entire SCADA system. These issues typically include a failure in data collection and improper command transmission. Therefore, it's crucial to verify that all of the settings and setups are made correctly.

Verify total field

If the monitoring technology permits, it will be feasible to observe occurrences without physically visiting faraway places. However, monitoring equipment is likely to be a problem if information cannot be obtained.

Therefore, assuming all of the earlier checks revealed that everything is in order, the following step is to travel to the remote site. Check on a few things once. First, visually check the antennas for lightning strikes if there's a radio system. Check RTU units to make sure they have power and seem to be functioning as expected if there are no obvious problems.

Maintenance

The importance of highlighting some maintenance best practices cannot be overstated. Among them are:

- Update the firmware on SCADA equipment.

- Make regular system backups. Make copies of all of the crucial data so that, in the event of a significant issue, proper settings can be restored.

- Always ensure the functionality of the power supply equipment, including UPS and batteries. Have backups available and replace them as needed.

- It's crucial to routinely examine the field devices and their connections, particularly if the network is installed at a very remote location exposed to the elements.

Maintenance services should be available from the SCADA vendor. They should visit, evaluate the network, and create a list of maintenance tasks that will boost the performance.

2.2.3 Communication with the SCADA Software

The following categories apply to the significant SCADA communication protocols:

1. DNP3 (Distributed Network Protocol)

2. IEC 60870 (International Electrotechnical Commission)

3. HDLC

4. MODBUS

DNP3: DNP3, which stands for the distributed network protocol, is a collection of communication protocols used by various parts of process automation systems, such as those used by power utilities, chemical processing facilities, etc.

DNP3 is designed to facilitate communication across many types of control, monitoring, and data gathering systems. The Inter-Control Center Communications (ICCP) protocol, which connects RTUs and IEDs, is an essential component of SCADA systems. IEC 60870's ICCP is a component that is frequently used for communications between master stations.

Features:

- The DNP3 protocol has key components that enable interoperability with related protocols like MODBUS, etc. As a result, communication between components in SCADA systems is more effective and efficient.

- DNP3, which offers to multiplex many features like error checking, connection control, data fragmentation, etc., corresponds to layer 2 in the commonly used OSI model for communicating networks.

- DNP3 offers an application layer (Layer 7) and transport function (Layer 4) that are appropriate for SCADA applications.

- DNP3 has increased bandwidth efficiency, and event-oriented data reporting is how this was done.

- DNP3 is capable of handling error detection well.

The DNP Protocol synchronises time with RTU, reconstructing all data point objects' time-stamped versions through a series of actions.

The DNP3 protocol has the additional benefit of enabling RTUs of varied natures and complexity by four levels of subsets of the protocols for RTU compliance. The complexity of this protocol, however, tends to increase with the number of RTUs and connections.

Protocol IEC60870

IEC standard 60870 is often used for the control of other process facilities and electric power transmission systems. This standard can be used to interoperate various pieces of equipment made by various manufacturers through established protocols.

The six components of IEC standard 60870 define general information about the standard, operating circumstances, electrical interfaces, performance standards, and data transfer methods. For telecontrol messages among two directly connected systems, IEC 60870 offers a communication profile. Through connected telecommunication, this protocol offers telecontrol and teleprotection of electric power networks.

HDLC

High-Level Data Link Control (HDLC) is an ISO-developed synchronous data link layer protocol that is bit-oriented and code-transparent. Both connection-oriented and connection-less services are offered by HDLC.

HDLC can be used for point-to-point multipoint connections; however, asynchronous balanced mode (ABM), or one-to-one connections, are preferred. All contemporary protocols are built upon it.

MODBUS

For use with its programmable logic controllers, MODICON first released the serial communications protocol known as MODBUS in 1979. A popular standard communication protocol for linking industrial electrical devices, the MODBUS protocol is straightforward and reliable.

Multiple devices linked to the network via RTUs in SCADA can communicate with one another thanks to MODBUS. To activate the linked element or device under this protocol, the master may send a MODBUS command.

To communicate with their hardware, businesses create proprietary software. These systems are offered as whole packages. The primary issue with this system is its extreme dependency on its source. Because they improve system interoperability, open software systems have grown in favour. The ability to use equipment from many manufacturers on the same system is known as interoperability.

2.2.4 Real-Time Application

An application that operates in a time frame that the user perceives as immediate or current is known as a real-time application or RTA. The latency must be below a predetermined threshold, typically expressed in seconds. Real-time computing includes the use of real-time applications.

Streaming data is frequently processed using real-time apps. Real-time software should be able to recognise, analyse, and react to streaming data as it enters without ingesting and storing the data in a back-end database. Event-driven architecture is frequently used by real-time applications to asynchronously process streaming data.

Characteristics and Advantages

Real-time applications include the following key characteristics and advantages:

- **Engagement**: Traditional applications cannot engage consumers the way real-time applications do because of the lack of immediacy they offer. This makes it possible for companies to engage with customers more deeply.

- **Communication:** As opposed to non-real-time applications' usual one-way communication, these apps allow for more effective two-way communication. This enhances internal communication and teamwork in firms.

- **Response Period:** Real-time apps can react to user input more quickly than conventional ones. This makes it possible for real-time systems to react to user needs more quickly and effectively.

- **Workflow:** Because workflow tasks are planned and carried out in conjunction with real-time data, real-time applications offer workflows that are more efficient.

Applications

When processing data is required instantly, real-time applications are utilised. They are frequently applied to prevent system failure or user harm.

Some examples of real-time apps include voice-over for video conferences, I.P. applications like online gaming, community storage, some e-commerce, instant messaging (IM), group collaboration, real-time operating systems, and the internet of things (IoT), business intelligence fraud detection geolocation, analytics for internet marketing, medical imaging and radiology, banking and finance.

2.2.5 Creating a New SCADA Project

In this section, we'll create a new project and assign a folder for it.

1. Run Stream Explorer

Double-click on the Stream Explorer shortcut on the desktop.

Fig 2.2.2 Opening Stream Explorer

2. Stream Explorer will open for the first time. One can select to either C**reate new project or open an existing project.**

Click on **Create new project**

Fig 2.2.3 Creating a new project

3. Create a new folder for this project. This folder will contain all application settings and data
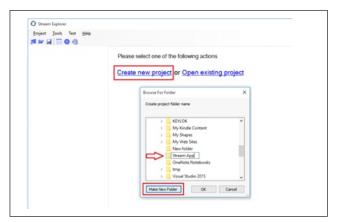
Fig 2.2.4 Creating a new folder

4. The following message will appear, click Yes if one wants to copy demo graphics and related tags to this project. For this tutorial, one can select **No.**
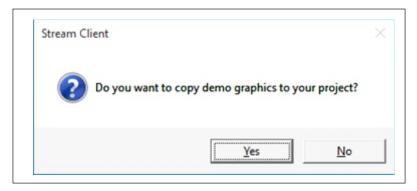
Fig 2.2.5 Step after creating a new project

5. Stream Explorer is now ready to start working. Notice the folder location.
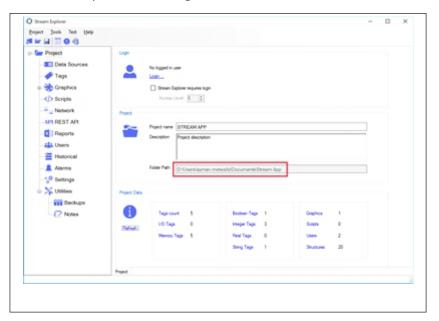
Fig 2.2.6 SCADA Stream Explorer started

2.2.6 Creating a SCADA Program

After installation of the SCADA Server, the following key process should be followed to get the end result of the new project:

1. **Defining the connections:** The SCADA server needs information about the protocol and the connection/port being used. DNP3 and Modbus are the most commonly used protocol in the SCADA server. The connection could be Serial or Ethernet, or any other.

2. **Defining the Data Source:** When a user chooses a database source, they are specifying that the SCADA data will come from a file or database rather than directly from a SCADA OPC server (whether it comes from a logger, SCADA system, or another source).

3. Defining the Tags: The placeholder of information in SCADA servers are called Tags. Every tag contains three fundamental inputs: Tag name, Tag Address and Data Type.

4. Creating the graphic displays: It's time to put this information on the screen now that the SCADA is aware of what data to obtain and how to do it. Make a new graphics display, navigate to the library of symbols, select the gauge and tank symbols, and then drag them both into the screen. Locate a property with the name Data Source, Tag, or anything similar in the gauge's setup, and enter the tag name there. At this point, the data gauge on the screen shows the data result in real-time if the user is using SCADA software in the "run mode."

2.2.7 Graphic Display

The Graphical User Interface should have a collection of tools for representing process status visually. A visual editor should be available to allow for the construction of graphic displays to reflect current process information.

The option to Create/Edit Points from within the Editor should be included in the editor software. It should also be possible to search the network for PCs and projects with access points.

To allow the insertion of pre-developed or third-party graphic objects, the editing package should contain a Wizard / Symbol / Object Library. Symbol Library items should be native to the software solution where possible, rather than just bitmap representations. The editing package should enable the creation of Objects/Wizards in the native graphics and scripting language and their addition to the Library. A process editor should be implemented to manipulate setpoints and manage windows. To create application logic, the visual editor should have a scripting expression editor.

Graphic objects on these displays can be linked by name to the actual device and virtual data via the distributed point database, direct OPC-DA, and historical expressions in either a real-time or historical sense. Objects on the graphics panels can be animated, causing them to change colour and/or position. Text information can be printed on the screen to alert workers of the current point status. Objects should be dynamically scalable, both horizontally and vertically.

The software should support the properties such as - annunciation, movement, blink, rotation and fill, object visibility, transfer tags for screen transfer or popup windows, object or application help screens, alarm information, trends charts, setpoint tags for point value changes, the procedure to tag to invoke user-defined scripts, blink fill and blink rate, resizing features, colours.

Graphic Objects should include: Imported metafile objects, Embedded OLE, sound, video, clip art, spreadsheets, etc., SPC charts, Trend charts, Historical Data displays, Alarm displays, Arcs, Lines, Circles, Ellipses, Lines, Polylines, Polygons, Rectangles, Text strings, Buttons, 3 Dimensional Piping creator, Tag types should include: constant - downloads constants to a point, variable - allows operator input of desired value, ramp - downloads values in configured increments, slide - increment/decrement of point values, toggle - sets digital points to the opposite state.

2.2.8 Real-Time and Historical Trends

In the SCADA system, the graphical display of Data is called Trends. Trends play a critical role in automation. There are two types of trends - historical trends and real-time trends.

Real-time Trends

Real-time Trends show the value of data in real-time. These are dynamic in nature as they are updated continuously during run-time. Real-time trends enable observation of the process's actual data. For example, a tag of the water level in a sewage treatment facility is made with the purpose of examining the present Water Level. Real-time trends will be used, which have configuration options for seconds, milliseconds, minutes, and hours.

Historical Trends

Historical trends are used to view past values of the Tag. These can be configured to see any past data. They may be set up in Days, Months, Years, and soon.

2.2.9 Use of Alarms and Events

Events and Alarms both serve as Notifiers, giving information about things that have happened or are currently happening in a certain industry. Alarm and event management are crucial components of SCADA software in the automation industry.

Alarm: Alarms serve as notifications of potential issue process situations that necessitate operator action. For Example, A tank's water level has risen over the required level, at which point the SCADA system should sound an alarm.

An alarm is used to indicate that something has gone wrong or that a certain processing step has been reached. An alarm may indicate that the safe temperature limit for a boiler has been reached.

Events: Events are common system status notifications that don't require an operator reaction. An event is an observable occurrence that might or might not be associated with an alarm.

A simple example of an event in industrial automation is the logging of an operator with his username to the SCADA program. If configured to do so, the SCADA system can record that event in a text file.

2.2.10 Application of Scripts

Scripts: SCADA script is a sophisticated component of a basic SCADA system. It is necessary mostly if the user has to modify the integration for a rare case or for any other special behaviour that cannot be achieved with standard settings. In SCADA, scripts are used to build specialised applications or processes that access objects, tags, databases, and reporting. The Script is written in JavaScript Language.

Process of creating a new SCADA script

1. Create a new SCADA project. Then, navigate to "Script".

2. Create a new SCADA script by adding a new row at the script table.

3. Set it to trigger by Tag. Select a tag from the list.

4. Create the type of tag and use it as a script trigger.

5. Save the project. The list will display the newly created blank script file.

2.2.11 Net DDE Communication

The network connections required for DDE discussions between programmes operating on various machines in a network are established and maintained by network DDE. The interaction of client and server apps is referred to as DDE communication. One employs the network DDE of application in addition to DDE and the DDE management library (DDEML).

DDE is a type of interprocess communication that allows apps to exchange data by using shared memory. Applications can use DDE for one-time data transfers as well as ongoing data updates and exchanges.

DDEML makes it easier to include DDE functionality into an application. Instead of sending, publishing, and processing DDE messages directly, an application uses the DDEML methods to manage DDE dialogues.

Uses of DDE

• Establishing a connection to live data sources, such as stock market updates, equipment used in science, or process control.

• Creating composite documents, such as a word processing document with a visual from a graphics program. When the source data is altered using DDE, the chart will change while the rest of the document stays the same.

• Transferring data across apps, for as, when a spreadsheet searches a database for past-due accounts.

DDE Communication

When two DDE-capable programs are conversing, it is referred to as a DDE conversation. The DDE client program starts the communication while the DDE server application answers the client. An application can participate in several conversations at once, serving as the server in some and the client in others.

The subject and application name serve as the individual identifiers for each DDE chat. The subject and application name are chosen by the client and server at the start of a DDE discussion. The server application's name is typically used as the application name.

Two windows: one for each of the involved applications—engage in a DDE dialogue. A window may be the program's main window, a window connected to a particular document, as in a multiple document interface (MDI) application, or a hidden (invisible) window whose sole function is to handle DDE messages.

No window shall participate in more than one DDE conversation with another window as a DDE discussion is identified by the pair of handles to the participating windows. For each of its discussions with a certain server or client application, the client application or the server application must offer a different window.

By establishing a hidden window for each discussion, an application may make sure that a set of client and server windows is never used for more than one chat. This window's main function is to process DDE messages.

Exercise ✎

1. What is PLC? Explain its architecture.

2. Explain Sourcing and Sinking.

3. Explain the uses of PLC Programming Software.

4. Describe the process of detecting faults in the PLC system.

5. What is SCADA?

6. Describe the process of detecting faults in the SCADA system.

7. What are Trends?

Notes

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Scan the QR Code to watch the related videos

https://youtu.be/gTBm9BlWZqs

SCADA

https://youtu.be/wolM60e05g4

Detecting faults in SCADA Software

https://youtu.be/NWxUJalyWFQ

Communication with the SCADA Software

3. Process of Analysing Motion Control

Unit 3.1 - Basics of Motor

Key Learning Outcomes 💡

By the end of this module, participants will be able to:

1. Explain the need for motors and their application in different applications.

2. Explain the concept, operations and limitations of Alternating Current (AC) and Direct Current DC) motors.

3. Explain different starters in motor and their functions in DOL & Star- Delta.

4. Explain the use of motor starters such as DOL, Star-Delta, and Auto Transformer.

5. Explain the use of motor control and interlocking circuits.

6. State the criteria for drive selection.

7. Explain the communication mechanism between PLC and SCADA software

8. Explain the advantage of using soft starters over conventional starters.

9. Explain the application of motor in different applications.

10. Explain different starters in motor and identify their function in DOL and Star-Delta.

11. Explain how to design the motor circuit and interlocking circuit.

12. Explain basic parameter programming to operate the motor.

13. Explain how to carry out drive selection for various processes.

14. Describe the concept and process of designing the control panel.

15. Describe the process of detecting faults in the real-time monitoring system and carrying out Troubleshooting.

16. Explain how to prepare for residential wiring.

17. Explain how to design digital electronic circuits.

UNIT 3.1: Basics of Motor

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3.1.1 Electric Motors

Electric motors are electromechanical devices that transform electrical energy into mechanical energy. In other words, a motor is a device that generates rotational force. The working principle of the electric motor is the interaction of magnetic and electric fields.

Applications of Electric Motor

Electric Motors are essential in modern-day life. Nearly every item being used uses motors. Some of the applications of Electrical Motors are:

- In household appliances, such as fans, blowers, pumps, washing machines, coolers, turbines, etc.

- In Heating, Ventilation, and Air-conditioning (HVAC) equipment

- In Industrial equipment, such as mills, fork mill trucks, robots, etc.

3.1.2 Types of Motors

The AC motor and the DC motor are the two basic categories of electric motors. While a DC motor uses direct current as its input, an AC motor uses alternating current.

Alternating Current (AC) Motors

Alternating current (AC) motors are low-cost and high-efficiency mechanisms. Consisting of a copper wounded stator that is magnetically driven and a rotor mechanism, AC motors offer a simple design.

AC Motor Construction

In an AC motor, there are two main parts, i.e. stator (stationary part) and rotor (rotating part).
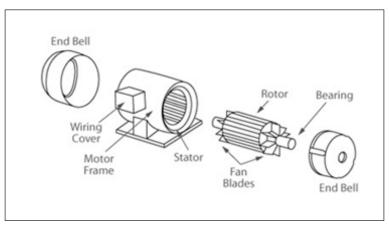
Fig 3.1.1 AC Motor Construction

- Stator: The stator, an inactive component of the AC motor, serves primarily to transfer a rotational magnetic field that interacts with the rotor.

- Rotors: The rotor, which rotates within the motor, is a crucial component attached to the shaft. The squirrel cage rotor is the most prominent type of rotor used in an AC motor. It is manufactured into a cylindrical shape by stacking thin steel laminations.

- Shaft: By applying pressure to a steel shaft that expands outside of the motor housing, the rotor assembly can be created. This connection to an external system allows the rotational power to be broadcasted.

- Bearings: Bearings are positioned on the motor's shaft to support the rotor and enable rotation. Bearings are used in AC motors to keep the shaft in place. To increase motor efficiency, the bearings lessen the friction on the shaft attached to the casing.

Types of AC Motors

From heavy industrial to household environments, various types and categories of AC motors are used.

- **Synchronous Motors:** Synchronous AC motors are mostly used in settings where accuracy is crucial, such as in high-precision drill machines and comparable equipment. Some of these include clocks, metering pumps, timers, speed controls, clocks, and electromechanical robots that are used in many industrial processes

- **Induction Motors-** These are the most typical AC motor types found in routine activities. Kitchen appliances, autos, fans, air conditioners, and other common industrial equipment like compressors and boiler pumps all employ induction motors.

- **Linear Motors-** The operational and functional features of linear AC motors differ significantly from those of ordinary AC motors. In roller coasters, monorails, ground-based rails, magnetic levitation lines, and other forms of similar transportation equipment, linear AC motors are frequently utilised.

- **Adjustable Speed Motors-** Adjustable Speed Motors are applicable to water cooling systems, electrical power plants, land and marine gear, and cargo pumps.

- **Universal Motors-** Universal Motors are used in a variety of applications, including industrial and kitchen blenders, trimmers, vacuum cleaners, dryers, high-power engineering, and railway traction mechanisms.

Advantages of AC Motors

- Easy and Simple Design

- Inexpensive

- Balanced power-to-weight ratio

- Less maintenance

- The AC source can be connected to the motor directly.

Limitations of AC Motors

- The starting torque of the AC motor is very less

- It won't operate at low speeds

- Poor Positioning Control

- Limited Speed

Direct Current Motors

A DC motor, also known as a direct current motor, is a type of electrical device that uses direct current to generate a magnetic field that converts electrical energy into mechanical energy. According to the DC motor's operating theory, a current-carrying conductor receives a mechanical force when it comes into contact with the magnetic field. Flemming's left-hand rule can be used to determine both the direction and magnitude of this force.

DC Motor Construction
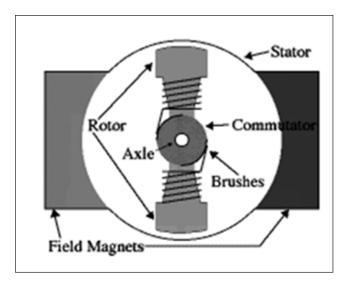
Fig 3.1.2 Parts of DC Motor

The main parts of DC Motor are:

Stator: The stator is a stationary part like one of the DC motor parts, which includes the field windings. The primary function of the stator is to get the supply.

Rotor: The rotor is the dynamic part of the DC motor that creates mechanical revolutions.

Brushes: Brushes work as a bridge to fix the stationary electrical circuit toward the rotor.

Commutator: Commutator is also one of the essential parts of a DC motor. It is a split ring that is made with copper segments.

Axle: The Axle holds the rotor and then commutator.

Types of DC Motor

DC Motors are used for a variety of applications. The different types of DC Motors are:

- **Series Motors:** In series motors, the field winding is connected to the armature winding in series. The series motors provide starting torque and can move very large shaft loads. This type of motor is used in cranes, sewing machines, vacuum cleaners, air compressors, etc.

- **Shunt Motors:** In shunt motors, the field windings are connected to the armature winding in parallel. It is famously used for its best speed regulation. Shunt Motor is used in fans, conveyors, centrifugal pumps, weaving machines, etc.

- **Compound Motors:** In Compound Motors, the field can be connected in series through the armature and shunt field as well. While the shunt field offers improved speed regulation, the series field offers a better starting torque. This type of motor is used in elevators, shears, rolling mills, etc.

Advantages of DC Motors

- High starting Torque

- Wide range of speed control

- Quick Start, Stop and Reversal.

- Free from reactive power consumption

Limitations of DC Motors

- High initial cost

- High Maintenance Cost

- The risk of commutation failure makes it non-operational in hazardous environments.

Considerations while choosing the Drive or Motor

There are several hardware variables to consider when picking a motor or drive. There are several important factors to consider, including the tasks that the motor must be able to accomplish, the position of the motor, compatibility, sustainability, and cost.

Function

The two primary types of motors are DC and AC, and one is a better choice than the other in different scenarios.

DC drives and motors are simpler and can provide higher starting and acceleration torques. They also have extra hardware that may be added for customization.

AC motors, on the other hand, are a superior choice for high-speed operations and systems that require a motor to run at low speeds for extended periods of time. Multiple motors may be conveniently controlled by an AC drive at the same time.

Location

Size is an important consideration depending on the available area. If the motor is to be installed in a difficult-to-reach location, one should go for a motor that requires less maintenance. An AC motor, for example, does not need frequent tuning and adjustments as a DC motor. Depending on the situation, motors may need to withstand severe temperatures, dampness, or dust. If the motor or drive is unable to withstand the circumstances, an enclosure must be present to protect the motor or drive.

Compatibility

All aspects of the system must be compatible. As power sources, voltage and horsepower vary depending on the application, the most appropriate motor and drive must be selected. The selected software and firmware must also be compatible in order for the system to communicate effectively.

Sustainability

Sustainability is essential in a variety of ways. One should consider the hardware's longevity. For example, a DC motor, especially a brushed DC motor, has a significantly shorter lifespan than other types of motors, although less expensive at first. Replacements, on the other hand, incur additional expenses and inconvenience. The software that operates the systems must also be considered in the long term. Software upgrades are required to keep things working as smoothly as possible. When it comes to firmware upgrades, some drives are more adaptable than others. Variable frequency drives, often known as AC drives, are more adaptable to changes.

Cost

There are several economic considerations for selecting the correct motors and drives. DC motors may be less expensive to purchase than AC motors, but AC drives are more energy-efficient, saving money during operation. Furthermore, while replacing outdated technology with newer might be pricey at first, the long-term benefits greatly outweigh the short-term costs.

3.1.3 Motor Starter

Motor Starters is one of the key inventions for motor control applications. A starter is an electrical device that controls the electrical power to start a motor. These electrical devices are also employed to stop, reverse, and safeguard electric motors. The two main parts of a starter are:

Contractor: The contactor's primary job is to control the electric current flowing to the motor. It can start or stop the flow of power to the circuit.

Overload Relay: Overheating and excessive current consumption can burn the motor and make it useless. Overload relays protect the motor from such dangers.

Features of Motor Starters

- Facilitate the starting and stopping of the motor

- Rated by power (horsepower, kilowatt) and current (amperes)

- Provide protection from overload

- Facilitates remote ON/OFF feature

- Rapid making and breaking of the current

Circuitry and Operation of Motor Starter
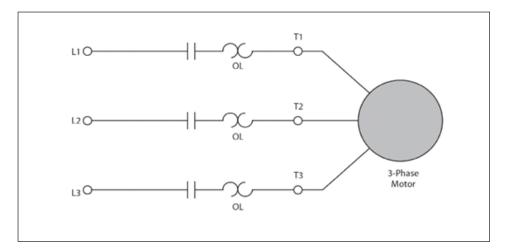
Fig.3.1.3 Motor Starter Power Circuitry

The two circuits in a Motor Starter are as follows:

- Power Circuit: It connects the line to the motor. It transmits electricity through the starters and then to the motor. The main contacts of the contactor carry the motor current.

- Control Circuit: It operates the contactor to turn it ON or OFF. The main contacts control whether electricity may pass to the motor and if it can be stopped. For this purpose, the contacts in the control circuit are either opened or closed. When the contactor coil is energized by the control circuit, an electromagnetic field is produced. This electromagnetic field pulls the power connections into a closed state completing the circuit between the motor and the line. The control circuit enables remote operations in this manner.

Types of Motor Starters

There are mainly two types of Motor Starters: Manual Starters and Magnetic Motor Starters.

Manual Starter: As suggested by the name, this type of motor starter is operated manually. These starters are really simple and quick to use. A button (or rotary knob) on the starter allows the user to turn the connected machine on or off. Mechanical linkages built into the buttons cause the contacts to open or close, starting or stopping the motor.

Magnetic Motor Starter: A magnetic motor starter is operated electromagnetically. The motor load attached to the motor starter is normally started and stopped using a lower and safer voltage than the motor voltage. The Magnetic starter has an electrical contractor and overload relay, which protects the device from overheating.

There are several types of magnetic motor starters, depending on how they are connected in a circuit. These are:

DOL (Direct-On-Line) Starter

DOL starter is the simplest motor starter. The controller of this starter is a simple push-button. Pressing the start button closes the contactor connected to the main supply and motor, leading to a supply of current to the motor. A stop button is provided to turn the motor off.

In order to safeguard the overload relay against overcurrent, the control circuit is routed through a normally closed auxiliary contact on the device. The typically closed auxiliary contact opens when the overload relay trips, de-energizing the contactor coil and allowing the main contacts of the contactor to open.

Star Delta Starter

Star delta starters are used more frequently than other types of starters. The three windings of the star-delta starters are connected in a star configuration. The timer or any other controller circuit sets a specific time. Once this time elapses, the windings are joined using a delta connection.

The total current drawn is 58 per cent of the normal current, and the phase voltage in the star connection is reduced to 58 per cent. As a result, the torque is decreased.

Auto Transformer Starter

In Auto Transformer Starter, a certain percentage of the primary voltage is supplied to the secondary transformer. The auto transformer is also connected in a start configuration.

In this type of starter, the three tapped secondary coils are connected to the three motor phases, which helps in the reduction of the voltage being applied to the motor terminals.

Rotor Resistance or Slip Ring Motor Starter

The Rotor Resistance Starter works on a full voltage motor starting technique. It is called a Slip Ring Motor starter because it works only on a slip ring induction motor. In this starter, the three resistances are connected in series with the rotor windings. This helps in increasing the motor torque and reducing the rotor current.

Stator Resistance Starter

It consists of three resistors which are connected with each phase of the stator windings in series. A voltage drop is brought on by each resistor, forcing the application of low voltage to each phase. During the motor start phase, these resistances are set to their starting or maximum position. This kind of starter maintains a low starting current. It is also important to maintain the motor's starting torque.

3.1.4 Soft Starter

A soft starter is an extra component that may be attached to a standard AC electric motor to enable the motor to use a different startup method. This device's objective is to lessen the strain on the motor during the regular motor power-up phase.

It is another type of reduced voltage starter. Since electric motors frequently consume large amounts of power while accelerating to the nominal speed, a soft starter can be used to reduce the electric motors' "inrush current" and torque, allowing for a safer, smoother, and more gradual start-up.

Soft Starters decrease the heat caused by frequent starts and stops, lower mechanical stress on the motor's shaft, and reduce electrodynamic loads on the power lines. This protects the electric motor from potential damage and also extends its lifespan.

Soft Starters for motors are typically used in industrial applications such as Dust Collector, Water Supply Systems, Heavy Load Conveyor Systems, etc., which demand a high inertia load and a huge inrush of current.

Internal Workings of a Soft Starter

Triac is the main component of a Soft Starter. It has been designed to limit the voltage being applied to the motor. When an internal pulse is applied, its gate permits the current to flow, which then transmits current to the motor. Since the pulses are supplied based on the ramp time, the motor will get current gradually. The soft-start motor will be able to start smoothly, minimizing torque and inrush current.

Advantages of Soft Starter

- Extends the life of the motor and the equipment by preventing jerks.

- Reduces maintenance requirement of equipment.

- Ensures smooth and uniform start by torque control.

- Prevents mechanical, electrical, and thermal weakening of electrical devices.

- Facilitates power factor correction.

3.1.5 Motor Circuit

A motor circuit is that section of an electrical motor circuit that delivers current to the electric motor. It consists of a switch, control transformer, protective devices such as fuses, a motor starter and a motor.

Interlocking Circuit

To link the motor circuit in a way that the second motor won't run until the first one does, and the third motor won't run until the second one does, and so on. The term "interlocking" refers to this particular motor circuit connection.

Electrical interlocking is achieved by connecting the ordinarily closed contact of one direction's coil to the normally open contact of the other direction's coil and vice versa. When the forward coil is powered, pressing the reverse pushbutton does not energize the reverse coil. When the reverse coil is turned on, the same thing happens. In both cases, the stop button must be pushed in order to de-energize the running coil and restore all of its auxiliary connections to their original condition. The coil in the opposite direction can then be engaged. One of the Electric Interlock examples is the thermal overload on a motor starter.

When the current is too high, the coil circuit opens, causing the motor to shut down.
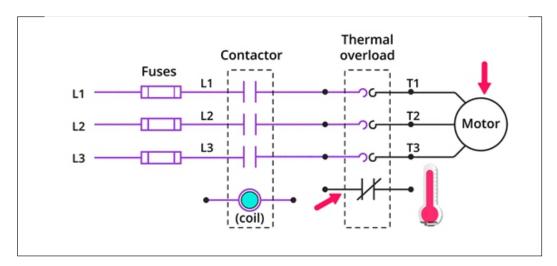
Fig.3.1.4 Open Coil Circuit

Once cooled, the thermal overload permits the current to flow again. This is an electrical interlock because the electricity to the motor coil is lost, preventing it from turning on.
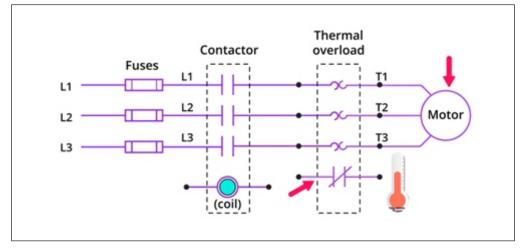
Fig.3.1.5 Interlock Coil Circuit

3.1.6 PLC Motor Control Ladder Logic Programming

Prerequisites/ Assumptions of the Process

- When the Start button is hit, a Motor must be started by a PLC. There are three interlocks: high motor vibration, overload, and high motor temperature.

- The motor must be stopped promptly by the PLC if any interlocks are engaged.

- If the stop button is pressed, the PLC is required to stop the motor.

- Only when the motor is in remote mode must PLC trip logic or an interlock be enabled.
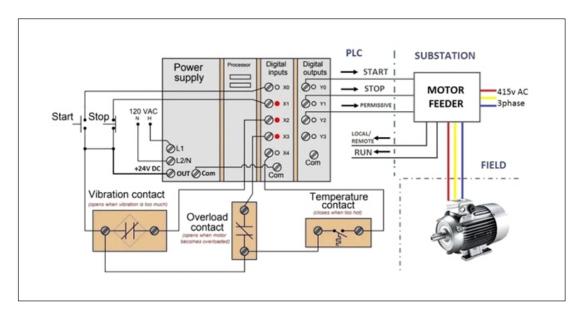
Fig. 3.1.6 Motor Control

In fig. 3.1.6, Red LED indicator lights on the PLC's input and output cards show if the corresponding I/O channels are activated.

PLC Inputs

- Start Push Button

- Stop Push Button

- Vibration High

- Temperature High

- Overload Trip

- Run Feedback

- Remote Status

The motor is a three-phase, 415V AC-powered device. High voltage equipment will thus, by default, be powered by substations or motor control centres (MCC) that are kept up by electricity. It is considered that the motor is connected to a simple motor feeder.

The motor feeder often receives inputs from the field (local control panel) and PLC as well, which are depicted in the diagram below.
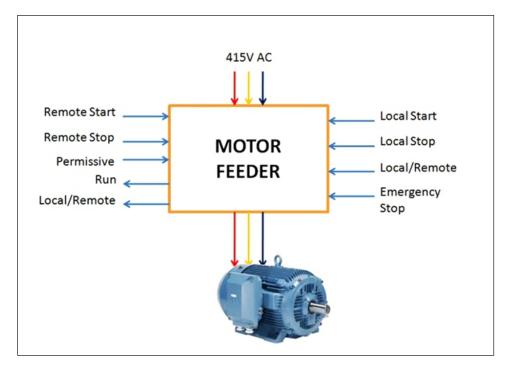
Fig. 3.1.7 A Motor Feeder

If the motor feeder receives the start and stop command inputs from the PLC, the signals are referred to as remote start and stop signals. It is referred to as local start and stop signals if the motor feeder gets the start and stop command inputs from a local control panel (LCP) that is positioned in the field close to the motor.

This LCP often has both a Local/Remote selection switch and an emergency stop.

A Local/Remote status is also sent from the motor feeder to the PLC. The motor feeder will only take into account signals from the LCP if the Local/Remote selection switch is set to Local mode, ignoring directives from the PLC. Similar to this, if the Local/Remote Selection switch is set to Remote Mode, the motor feeder will only take into account signals from Remote or PLC and disregard signals from LCP.

For Example, if Local/Remote selection, turn on the remote mode; since the choice is in remote mode, the motor will not start if the field operator presses the start push button from the field LCP.

How PLC controls a motor

Since Remote selection is in Remote Mode, a Permissive signal (Start Permissive) to the motor, under PLC, as an additional measure of safety and to monitor the interlock's status, start permissive will be implemented. The motor feeder will only receive permissible signals if every interlock is functioning properly.

After the Start Push Button is pressed, PLC checks the status and proceeds further if it is Remote.

If there is no interlock or everything is working properly, the PLC sends a start instruction to the substation where the motor feeder is placed. After receiving the start order from the PLC, the motor feeder will energize and turn on the motor. Following motor start-up, the motor feeder will communicate Run feedback to the PLC. The visuals will display the run feedback.

Some PLCs automatically transmit a Stop signal to the motor feeder if the Run feedback is not received within a certain time range. In normal PLC applications, this is an optional function but compulsory in safety PLCs.

If Vibration High is received, the PLC sends a stop instruction to the motor feeder, stopping the motor instantly. The run feedback status is updated in line with this.

We must establish an appropriate communication channel or bus in order to connect a PLC with SCADA. The SCADA software-equipped monitoring PC has to be connected to this communication channel through its communication port.

The first stage in testing the PLC and SCADA's communication protocols is verifying that PLC and SCADA have common communication portals. Some of the communication protocols used by SCADA software are - MPI/DP, Profibus, Ethernet, OPC, etc. Common PLC protocols include MPI/DP, Ethernet, Serial Port, and others.

Process of connecting PLC with SCADA:

- Create a new project in the TIA portal.

- Add an HMI application. Using, ***Add new device >> HMI >> Simatic HMI application.***

- Select any WinCC version. In the following process, the WinCC RT Advance has been selected.

- Provide a communication channel in SCADA by adding an Ethernet. Drag and drop IE General here.

- Add a PLC controller to interface WinCC RT Advanced with PLC. Go to ***Add new device >> Controllers***. Here, an S7 1200 series ***CPU 1212 DC/DC/DC*** has been added.

- Go to PLC ***CPU Properties >> General >> Ethernet addresse***s to connect PLC with SCADA through Ethernet protocol

- A simple logic has been created to start and stop the motor. Create a simple logic and then download it into PLC.

- Prepare a graphic to control and display the status of the motor.

- Go to ***HMI Application >> Connection*** to configure a connection between PLC and SCADA.

- Select communication driver as Simatic S7 1200 as we have selected plc controller is of S7 1200 series.

- Now, the motor can be started and stopped from the SCADA, and the online status in PLC can also be checked.

- Start/Stop buttons and the motor indication will be visible.

When the operator presses the start button, it will activate the output Q0.0 bit and will start the motor. The motor's image will appear in green colour, which indicates that the motor is running.

3.1.7 Control Panel

The control panel is the point at which people control industrial motors and automated operations. The control panel is where ideas emerge from need, and new processes are put in place to optimise and boost efficiency.

Electrical motor control panels are designed to hold motor controllers, drives, relays, switches, and transformers used to operate motor equipment. They may be utilised in both low and medium-voltage applications and can be adapted for a variety of motor controllers and starters.

Control panels are typically enclosed printed circuit boards that link to all peripheral devices in their vicinity. Door hardware (such as a door position switch, card reader, or door strike) and additional inputs and relays as needed are examples of peripheral devices. The control panel handles peripheral devices and interacts between them and the host computer. The following functionalities are available on the control panels:

- Consolidation of all peripheral device connections
- Provision of electricity to peripheral devices as needed
- Management of peripherals in the absence of communications with the host computer or while working in a dispersed manner

The process of Control Panel Designing should always begin with a review of the specifications, requirements, and regulatory standards. Following the evaluation of these factors, drawings are generated to detail the particular arrangement of wiring, circuits, controls, and every other feature of the final control panel. A good design considers both electrical and physical needs. These designs should include:

- Functional diagram
- I/O (Input/Output) diagram
- Power distribution
- Control cabinet and back panel layouts
- Material list

A table of contents is also advised as there are so many components in a proper schematic. The schematic serves as the basis for the later design of an industrial control panel.

A standard industrial control panel has an average lifespan of around 20 years. A well-designed panel will be as sharp and efficient on its last day of duty as it was on the first. The following are good indicators of the durability of the design:

- **Heavy Duty Power Grid:** Functionality begins with the primary power supply, circuit breakers, fuses, connectors, grounding components, and contacting devices. This is where the control panel will begin, so don't scrimp on hardware here.
- **Wiring Grid:** Investing in a good cabling management system here is money well spent. Interfaces that are neatly connected are significantly easier to maintain and service.
- **Human-Machine Interfaces:** The more complex the interface, the more likely the system will meet and surpass future standards. This comprises all analog or digital switches, lights, visual displays, and gauges.
- **Sensing and command controls:** all sensors, relays, transmitter assemblies, receiver assemblies, and any input/output (IO) modules, as well as all hardwired logic components.

3.1.8 Detecting Faults in the Real-Time Monitoring System and Carrying Out Troubleshooting

One of the most important concerns in automated system design nowadays is system reliability and accessibility. Traditional methods for increasing system reliability and availability include improving the quality, reliability, and resilience of individual system components such as sensors, actuators, controllers, and/or computers, which are crucial to current monitoring operations. Even yet, the perfect operation cannot be assured. Process monitoring and fault diagnostics are critical components of innovative and sophisticated systems of automated management of production system operation.

The block diagram below depicts the macro-level sequential structure of an intelligent monitoring and supervisory system.
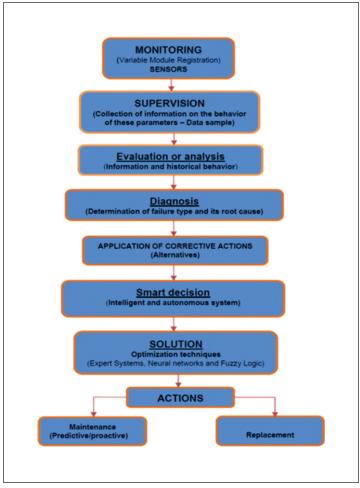
Fig. 3.1.8 Flowchart of intelligent monitoring and supervision system

Monitoring: The changes are noted during this time. These changes must be recorded in a data-gathering system known as the Database, which allows to build a history of a specific variable's or parameter's behaviour through time in relation to a reference level or threshold of behaviour. This procedure is only carried out with a strong system of sensors located at crucial places of equipment or systems, allowing for continuous-time observability. Monitoring is carried out using Digital and Remote Digital Recorders.

Digital recorders—digitally record all information from the sensors. These devices are used to create a history of the behaviour of a parameter or variable through time. This data is often stored in the binary system.

Remote digital sensors (threshold) - A transducer is a sensor or actuator that is used for detection and actuation in a particular process.

Supervision: Monitoring System sends information to the Supervision Area. With this information, A "Knowledge Bank" must be managed using intelligent software, where information obtained from various physical parameters is crossed and integrated, yielding a result that is closer to what is truly desired: an effective decision-making aid.

Using intelligent approaches, the supervisory system automatically processes the information acquired by the monitoring system via internal procedures (Computational Intelligence). The goal is to detect incipient problems automatically, that is, to discover faults early, identify them, locate them, and estimate their severity.

Evaluation: At this stage, deviations or alterations in the typical behaviour of a parameter are detected. A comparison procedure using a previously established reference value is used for this. This revision is conducted in real-time, and the results are compared to previous behaviour to determine whether it is truly exhibiting an anomaly or merely an isolated occurrence.

There are tools or approaches that allow the database assessment procedure to be performed using the historical behaviour of the parameters of interest in an optimum and efficient way. These methods are Statistical and Probabilistic Techniques, Kalman Filter, Fourier Transform, Wavelet Transform and ARMA (p, q) model.

Diagnosis: At this step, the kind and degree of variation, the type of failure, its location, severity, and impact on the performance of an element or component are assessed, and the root cause of the disturbance is discovered.

Application of Corrective Measures: Among the various alternatives available to remove these fluctuations, the best from a technical and economic viewpoint is sought that could be implemented in real-time, either online or offline. This is determined by the severity of the failure, such as whether it is a likely failure and the catastrophic implications or indications of an impending failure. This optimum solution is discovered by the use of intelligent optimization techniques such as:

- Neural networks
- Neural networks
- Fuzzy Logic

Solution: The intelligent monitoring and supervisory system achieves the ability to decide on its own. This decision should specify the appropriate course of action to minimize or eliminate a specific change. This intervention must occur in real-time and online. It should show the sort of application that will be conducted, the moment at which the intervention will be made, the components that will be reached, and their intervention time. The solution can be given by: Maintenance, Predictive and proactive maintenance & Element or device replacement.

Innovation: The ultimate solution will illustrate the adaptability, autonomy, and efficiency of monitoring and supervisory systems when they operate and are structured as intelligent systems. Errors in procedures using these technologies will be kept to a minimum to maintain safety and accuracy.

3.1.7 Residential Wiring

Residential wiring is the process of connecting numerous accessories for the distribution of electrical energy from the source to various appliances and equipment at home, such as televisions, lights, air conditioners, and so on. The process of Residential Wiring includes:

- **Load Calculation:** It is preferable to estimate the electrical requirements before buying house wiring. Make a list of all the electrical appliances that will be utilised in the specific household. Check the wattage capacity of each equipment. Calculate the average consumption in terms of hours per day. Finally, specify how many days per year the appliance will be used. Multiply these three figures and divide the total by 1,000 to get the kilowatt-hours (kWh) number. Future requirements must be considered. The gauge of the wire can be chosen by calculating the kWh.

- **Placing the concealed conduit PVC pipes in position:** This is the most crucial aspect of home wiring. Mark the locations of power points, electrical outlets, modular boards, and distribution boards. Chiselling the walls and placing the conduit pipes are frequent steps in this process. PVC pipes with concealed conduit reduce the risk of electrocution while also being aesthetically beautiful. One must save a Single Line Diagram (SLD) of the pipes and wiring because it will be needed for any future electrical or civil work.

- **Colour coding of wires:** This is by far one of the most critical aspects of house rewiring. Colour coding of wires aids in detecting or identifying the cables even after years of use. Several colours, including red, green, blue, black, and yellow, are available for wires. A separate colour for each operation is ideal if there is a lot of wire.

- **Passing wires through the pipes:** Pass cables from ceilings, walls, etc., to the master distribution box as needed. Assemble the wires and run them through a GA wire.

- **Earthing:** Earthing is required for both human safety and the protection of electrical appliances. When electrical equipment, such as a washing machine, develops a fault, the electricity travels down the earthing channel. Without the earthing connection, the washing machine's exterior metal body would become live. And simply touching the equipment might result in an electrical shock.

- **Fixing the switchboard:** Switches, plugs, fan regulators, and maybe light dimmers should now be installed on the switchboard. Remember to plan ahead and create preparations for future needs while making decisions about load, switches, and wiring. Use caution while handling live wires, and be certain that all electrical equipment is used to meet stringent safety requirements.

3.1.8 Digital Electronics Circuit

Digital Circuit

A digital circuit is an essential part of digital electronics. It is used in a variety of devices for a variety of applications. The primary function of this circuit is to transmit power to the circuit's many components.

A digital circuit is a type of circuit that operates using different logic gates. Different power signals are distinguished using logic gates. It can be used to send power signals through various gates to different parts of electrical equipment. This will make it easier to produce an output signal whose energy level is proportional to the input signals. Most of the components in these circuits are analogue. Compared to analogue circuits, its architecture is more complex.

Components of Digital Circuit

- **Diodes:** Diodes are used to let the current flow in just one direction. Diodes are constructed using semiconductor materials.

- **Transistor:** A transistor is essentially a three-terminal semiconductor device. It may function as both a switching device and an amplifier.

- **Resistor:** A resistor is a passive component that is used in a circuit to oppose the passage of electricity. The two types of resistors are fixed and variable resistors. A fixed resistor's resistance value cannot be altered. The resistance value of a variable resistor may be modified to meet the needs. Ohm's law is followed by resistors.

- **Capacitor:** Two conducting plates and an insulator separate the plates that make up a capacitor. In an electric field, capacitors primarily store electrical energy.

- **Inductors:** Inductors are devices that store electric energy in a magnetic field. It is also used to fight current developments.

- **Battery:** The battery is another essential part of an electrical circuit that acts as a power source. A battery is a device that transforms chemical energy into electrical energy.

- **Logic Gates:** The most fundamental components of a digital circuit are logic gates. They take two or more inputs and output one output.

There are three types of logic gates:

- **Basic gates:** These gates can express Boolean functions in either the sum of products or the product of sums form. AND, OR, and NOT gates are the most fundamental logic gates.

- **Universal gates:** These are the logic gates that can be used to build all other gates. The two universal gates are NAND and NOR.

- **Special gates:** EX-OR and EX-NOR are the two exceptional gates because they are special instances of the OR and NOR gates.

- **Switch:** A switch is another element of an electric circuit that has the potential to control how much current travels through the circuit.

Digital Circuit Design

Digital circuits may be created utilising the numerous components that are often used in the circuit. In the following circuit, a diode, a resistor, an inductor, a capacitor, and a power supply have been used.
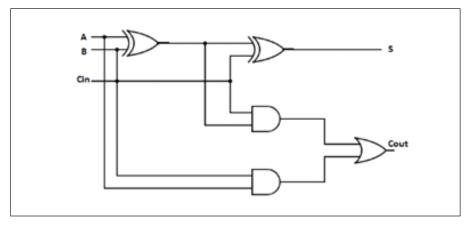
Fig. 3.1.9 Digital Circuit Design

The following circuit is a full-adder that may be used to add the circuit's bits. To get the output, the circuit conducts a Boolean operation on the input bits. There are two XOR gates, two AND gates, and an OR gate in the circuit.

Applications of Digital Circuits

- Digital circuits are essential components of electrical gadgets.

- It may be used to create a watch display or a countdown timer.

- Digital circuits are used in sophisticated operations such as rocket science and quantum computing.

- Traffic lights and automated glass doors in workplaces and restaurants also employ digital circuits.

Exercise

1. Explain electric motors and their types.

2. State the features of motor starters.

3. Explain in brief the interlocking circuit.

4. What are the components of a digital circuit?

Notes

Scan the QR Code to watch the related videos

https://youtu.be/ihEglecTl3Y

Electric Motors

https://youtu.be/skmZbcEsyIo

Types of Motors

https://youtu.be/ETb4UJ9VYw8

Selection of Sensors

https://youtu.be/zIEgEyZCahE

Soft Starter

https://youtu.be/grtKSnwbDaA

Motor Circuit

https://youtu.be/MBT7KxQTCw0

Control Panel

https://youtu.be/pyFyUsAeYPQ

Digital Electronics Circuit

4. Process of Designing the Panels Using AutoCAD Electrical Toolset

Unit 4.1 - Process of Designing Panels

ELE/N7114

Key Learning Outcomes 💡

By the end of this module, participants will be able to:

1. Explain the functions of switch gears and relevant accessories.

2. Explain the basics of control and power drawings.

3. State the applicable protective measures to be taken during panel designing.

4. Explain the need and application of panel designing.

5. Explain the use of relevant indicating devices such as Ammeter, Volt Meter, Power Factor (PF) & Kilowatts (KW) Meter for measuring various parameters in the panel design.

6. Explain the functioning of the load management system in designing the panel.

7. Explain the practice of load management, i.e. connected load, running load, load factor, etc.

8. Describe the process of preparing general arrangement and busbar sizing diagrams.

9. Describe the process of preparing power and control circuits.

10. Explain how to maintain and troubleshoot control circuits in live panels.

11. Describe the process of designing power and control drawings through AutoCAD.

12. Explain the function of various devices in designing an electrical circuit.

13. Explain how to create, modify, and document electrical control systems with AutoCAD Electrical toolset.

14. Explain how to create the electrical and power circuits.

15. Explain general wiring guidelines and practices.

16. Describe the process of maintaining and troubleshooting control circuits in live panels.

17. Describe the process of designing power and control diagrams.

UNIT 4.1: Process of Designing Panels

Unit Objectives ◎

By the end of this unit, participants will be able to:

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10. Explain how to maintain and troubleshoot control circuits in live panels.

11. Describe the process of designing power and control drawings through AutoCAD.

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13. Explain how to create, modify, and document electrical control systems with AutoCAD Electrical toolset.

14. Explain how to create the electrical and power circuits.

15. Explain general wiring guidelines and practices.

16. Describe the process of maintaining and troubleshooting control circuits in live panels.

17. Describe the process of designing power and control diagrams.

4.1.1 Electrical Panel

The electrical panel is the principal component of an electrical distribution system that splits electrical power to branch circuits while providing protective devices for each circuit in a single enclosure. Electrical panels, in essence, are used to prevent overloads and short circuits while distributing power across a structure or business.

It is an enclosure that contains switchgear, control and power units to conduct the needed function.

An electrical panel, according to the National Electrical Code® (NEC®), is a single panel or group of panel units designed for assembly in the form of a single panel; including buses, automatic overcurrent devices, and equipped with or without switches for the control of light, heat, or power circuits; designed to be placed in a cabinet or cutout box placed in or against a wall or partition and accessible only from the front.

All electrical operations, such as power distribution, power transmission, and power system protection, are carried out only via the use of an electrical panel. The electrical system (wiring diagram) will be developed utilising the electrical panel & Electrical panels are the practical implementation of an electrical wiring schematic. It is made up of trip circuits, closure circuits, busbars, cables, MCCBs, MCBs, MPCBs, NO & NCs, and so on. Electrical panels ensure that electricity is safely distributed to the load. Electrical panels are made of rolled steel and are either rectangular or square in form.

Electrical panels are categorised into many categories based on their application.

- Control Panel

- PCC – Power Control Center

- MCC – Motor Control Center

- MLDB – Main Lighting Distribution board

Control Panel: Control Panels are made up of circuit control elements such as relays, metres, alarm circuits, PLCs, SMPS, and small power sources. These panels are positioned near the maintenance operator's station.

PCC: Power Control Center is abbreviated as PCC. This is the heart of the control circuit. The output of the generators or transformers is sent into the PCC. This panel will house the main power circuit equipment. It comprises of circuit breakers, Busbar, PTs (Potential Transformers), CTs (Current Transformers), insulators, and other components. Major safety circuits will be built in this panel to safeguard transformers, motors, generators, and other components. Power from the PCC panel will be supplied to MCC panels through feeders.

MCC: MCC is an abbreviation for Motor control centre. It is made up of Feeders, and the feeder includes the motor starter, SFU, MCB, MCCB, MPCBs, control transformer, meters, and so on. One may access all of the circuit breakers or fuses by opening the MCC panel doors. Typically, one of these panels feeds all of the circuits in the power plant or other electrical applications, but in other cases, another "sub-panel" such as a welding distribution board or lighting distribution board serves a dedicated region.

MLDB- Main Lighting Distribution Board: Distributes power to the lighting circuits. An MDB is a panel or enclosure that holds the fuses, circuit breakers, and ground leakage protection devices where the electrical energy is received in from the transformer or an upstream panel and distributed to multiple individual circuits or consumer points. An MDB usually contains one or more incoming power sources and comprises primary circuit breakers as well as residual current or earth leakage prevention devices. A free-standing enclosure, a bus bar system, MCCBs, metering and support equipment, and needed current transformers compose an MDB. Panels are organised in a systematic fashion, such as incomer and outgoing sections.

Components of Electrical Panel

Within an electrical panel enclosure, there are eight main sorts of electrical components that define and arrange the panel's many functions. These elements are as follows:

- **Main Circuit Breaker:** Most installations have a single bigger circuit breaker at the top of the panel, which is normally situated dead centre in the panel. This huge circuit breaker is known as the main breaker. It serves an important function in the electrical system by providing a way to disconnect electricity to the whole circuit breaker panel and therefore turning down power to the entire house.

- **Surge protectors:** This component prevents overvoltage from harming the electrical components inside the panel caused by lightning strikes or utility power surges.

- **Transformers:** Transformers may lower voltage to 120V for various components depending on the incoming voltage or step down the voltage to 24V when the incoming power is 120V.

- **Terminal elements:** These blocks aid in the organization and distribution of wires from numerous sources to various electrical equipment.

- Programmable Logic Controller (PLC): This is essentially a CPU that is housed within the control panel. This device is the control panel's brain, monitoring and controlling the numerous mechanical operations. It will incorporate numerous inputs and outputs to and from automated manufacturing equipment operations.

- **Contactors and Relays:** These on/off switches regulate automated functions based on PLC orders. Smaller relays regulate functions such as lighting and fans. Larger relays, known as contacts, regulate more sophisticated operations such as motors.

- **Switches for networks:** The control panel's communication hub and network switches enable communication between the PLC and the different network-compatible devices on the production line.

- **Human-Machine Interaction (HMI):** This component enables the operator to monitor and control certain operations of the machinery. Video displays, joysticks, buttons, switches, and keyboards are examples of common HMIs.

Considerations in Panel Designing

Control panels comprise electrical components and gadgets that enable the automation of industrial processes and equipment. A number of essential things must be considered when creating a bespoke control panel to ensure the panel runs effectively, is safe to use, and remains trustworthy. Understanding the fundamentals of what to consider in industrial control panel design ensures that the panel satisfies particular needs and decreases the likelihood of costly mistakes throughout the project.

Panel Layout and Design: When designing an industrial control panel, one must take into account every facet of the production process, equipment, and plant environment. This knowledge is required when deciding the type of enclosure required, the available space for installing the control panel, the electrical requirements, and the hardware and software components required to provide the desired functionality. While each custom control panel is tailored to a unique purpose, most follow a similar general appearance.

- **Enclosure Type and Sizing:** Determining the kind and size of the control panel enclosure is a critical stage in the design process. When deciding on an enclosure type, one should consider the environment in which the panel will be installed. A panel exposed to corrosive chemicals, for example, will require a fully sealed stainless-steel casing, whereas a panel put in an area with high ambient temperature may require a ventilation fan or air conditioner.

  Once the enclosure type is determined, the appropriate size is determined based on the space needed to install and connect the anticipated control panel components. Furthermore, the National Electric Code (NEC) specifies sufficient wiring area and wire bending radius.

- **Power and Circuit Protection:** Another crucial stage in building a custom control panel is determining the power needs, which are best handled by a qualified controls engineer. Full-load calculations assist in establishing how many amps must be provided to the panel. Furthermore, depending on the voltage of the power supplied by your facility, a transformer to convert the voltage to 120V AC and/or a power supply to convert to 24V DC may be required in your panel.

  For example, if the panel will be operating motors, contactors, overload relays, or motor starters may be required to prevent the motor from drawing too much electrical current and overheating.

  Determining the suitable wire diameters to enable the delivery of the appropriate load current, as well as incorporating the necessary circuit protection, are important parts of your panel's electrical design. Circuit protection is critical for maintaining consistency and avoiding high voltages or currents from damaging your cables and components. Circuit breakers, surge protectors, and fuses are examples of circuit protection components.

- **Control Components:** Another stage in developing a custom control panel is selecting the appropriate components and devices to achieve the required control functionality. Control components such as relays or timers can be utilised in simple control applications where the ability to turn something on or off depending on an input signal is all that is required.

  More complicated applications, such as those requiring the capacity to regulate a series of events, may necessitate the use of a programmable logic controller (PLC), which is a microprocessor developed specifically for use in severe industrial settings.

- **Operator Interfaces:** The operator interface on the control panel can take many various forms, such as pushbuttons, switches, indication lights, digital metres, or a human-machine interface (HMI) display. Depending on the amount of capability required, any of these interfaces can be utilised independently or in combination with one another. The ability to merge all pushbuttons, switches, and metres into a single digital touch screen display is one of the benefits of employing an HMI in the design. Furthermore, when combined with SCADA software, HMIs give an overview and management of your facility and current operations, as well as alarm indications, machine metrics visualisation, and production reports.

Safety and Regulations: Certain control panel and electrical regulations must be complied with to ensure safety. The main industrial control panel codes and standards include:

- UL 508A – "Standard for Industrial Control Panels intended for general use.

- UL 698A – "Standard for Industrial Control Panels Relating to Hazardous (Classified) Locations."

- NFPA 70 – "Standard for the safe installation of electrical wiring and equipment."

- NFPA 79 – "Electrical Standard for Industrial Machinery to protect operators, equipment, facilities, and work-in-progress from fire and electrical hazards."

When creating a control panel, safety is of the utmost importance. Using a disconnect switch to completely turn off electricity before doing maintenance or in an emergency is one technique to enhance safety. Furthermore, adopting the lowest practicable voltages, touch-safe components, and adhering to NEC and UL norms all contribute to a safer control panel.

- **Control Panel Maintenance:** Keeping bugs away from panel wiring and out of the enclosure.

- Cleaning up dust on a regular basis. Vacuuming near circuit boards should be avoided unless electrostatic discharge (ESD) guidelines are followed.

- Checking terminal connections on a regular basis to ensure they are appropriately tightened.

- Keep the enclosure door closed at all times.

- Contacting systems integrator to execute any required software updates.

4.1.1 Electrical Panel

An electric circuit is a path for the transmission of electric current. An electric circuit consists of a device that provides energy to the charged particles that make up the current, such as a battery or a generator, as well as equipment that consume current, such as lights, electric motors, or computers, and the connecting wires or transmission lines. Ohm's law and Kirchhoff's rules are two fundamental laws that quantitatively define the behaviour of electric circuits.
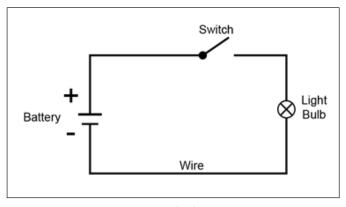
Fig. 4.1.1 A Simple Electric Circuit

There are various types of electric circuits.

A direct-current circuit only allows current to travel in one direction. An alternating-current circuit transports a current that pulsates back and forth numerous times each second.

A series circuit is made up of a channel through which the entire current goes through each component. A parallel circuit has branches that split the current such that just a portion of it passes through each branch. The voltage (or potential difference) between each branch of a parallel circuit is the same, but the currents might differ.

In a device such as a radio, the electronic components such as transistors, transformers, capacitors, and connecting wires form an electric circuit.

Electric Circuit Devices

Electrical circuit devices are critical components of both electrical and electronic circuits. Various devices can be found in electrical and electronic circuits. The following are some key circuit devices:

- Sources

- Switches

- Connectors

- Circuit Protection Devices

- Loads

Sources: A device that supplies energy into a system is referred to as an electrical energy source. These devices generate potential differences, causing electric current to flow through a circuit. Typical electrical sources include generators, cells, batteries, photovoltaic cells, etc.

Generators: There are two types of electric generators: AC generator and DC generator.
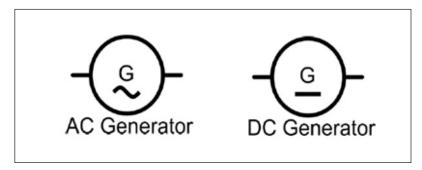
Fig. 4.1.2 AC and DC Generator

Cells and Batteries: An electrical cell is a device that can create electricity through chemical processes. As a result, a cell is also known as an electrochemical cell. A battery is a combination of electric cells.
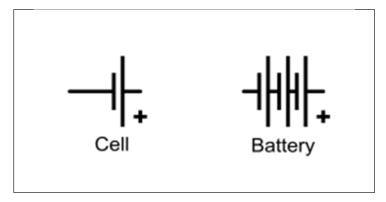
Fig. 4.1.3 Cell and Batteries

Photovoltaic Cell: A photovoltaic cell, often known as a solar cell, is an electric device that directly transforms sunlight into electricity.
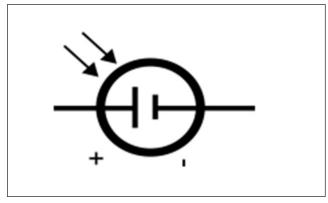
Fig. 4.1.4 Photovoltaic Cell

Switches: A switch is a device that is used to connect or disconnect a circuit, i.e. to interrupt the current flow in a circuit. A switch has two functions: ON (by shutting its connections) and OFF (by opening its contacts).

Type Switches:

• Single Pole Single Throw (SPST) Switch- This is a simple ON/OFF switch with one input and one output terminal. It can only switch one circuit.
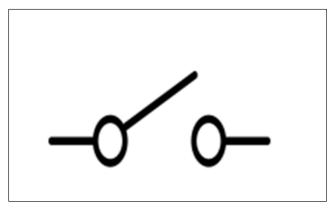
Fig. 4.1.5 SPST Switch

- Single Pole Double Throw (SPDT) Switch- This switch has three terminals: one input terminal and two output terminals. This switch serves as a changeover device, connecting the input to two separate outputs.
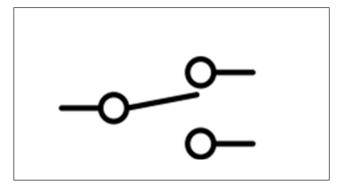
Fig. 4.1.6 SPDT Switch

- Double Pole Single Throw (DPDT) Switch- This is a four-terminal switch with two input and two output terminals. It functions as two distinct SPST switches that are both turned on at the same time.
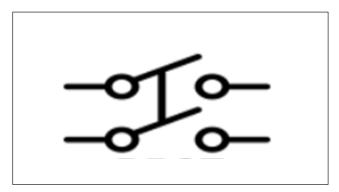
Fig. 4.1.7 DPST Switch

- Double Pole Double Throw (DPDT) Switch - It is a six-terminal switch with two input terminals and four output terminals.
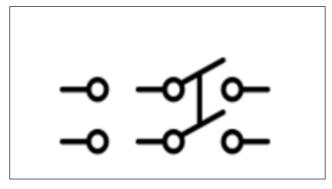
Fig. 4.1.8 DPDT Switch

- Push Button Switches: When the button is pressed, it is a transient contact switch that may make or break connections. They are classified as usually open (NO) or typically shut (NC) push buttons.
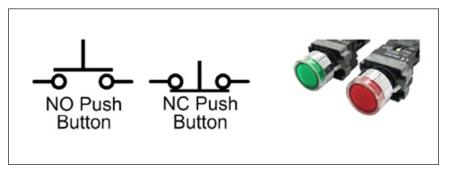
Fig. 4.1.9 Push Button Switch

- Toggle Switches- This switch is manually actuated by a lever.

Fig. 4.1.10 Toggle Switches

- Limit Switches- Limit switches are controlled by the presence or absence of items or by the motion of the machine.
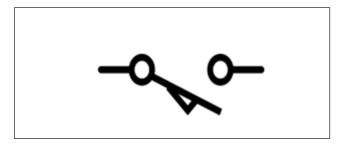
Fig. 4.1.11 Limit Switch

- Float Switches- Float switches are activated when the float in the container moves upward or downward, depending on the fluid level. Limit Switch
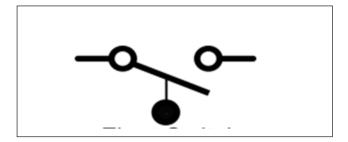
Fig. 4.1.12 Float Switch

- Pressure Switches- Pressure switches are mostly used in industrial applications to detect pressure in hydraulic or pneumatic systems.
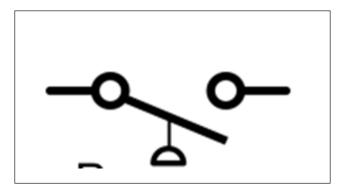
Fig. 4.1.13 Pressure Switch

- Temperature Switches- Temperature switches are activated when the bimetallic strip bends due to temperature.
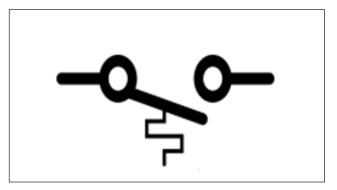
Fig. 4.1.14 Temperature Switch

- Rotary Switches- These switches are used to link one line to many lines, such as fan controllers. These switches are made up of a moving contact and many stationary contacts.
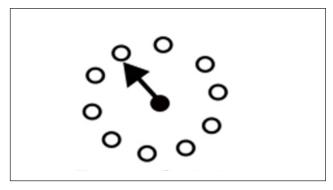
Fig. 4.1.15 Rotary Switches

Connectors: Conductor terminal connections are utilised in joint and termination applications. Conductor connectors are in charge of transmitting current between cables and electrical equipment such as transformers and switchgears. Types of Conductor Connectors:

Type of Connectors	Image
Ring Terminal	
Flange Terminal	
Inline Splice	
Fork Terminal	
Wire Nut Connector	
Split-Bolt Connector	
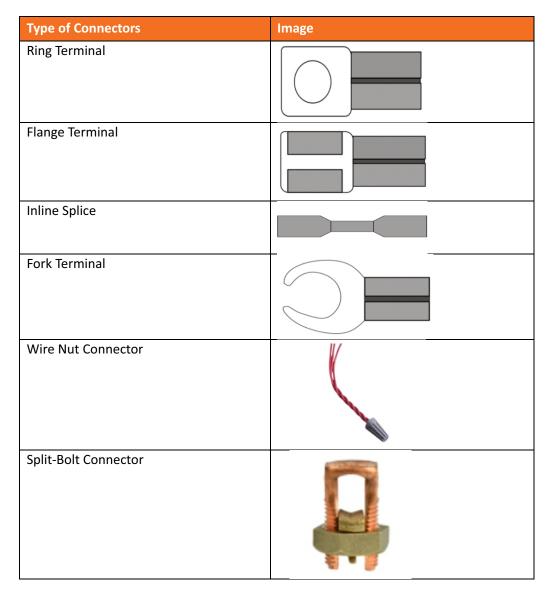
Table 4.1.1 Types of Connectors

4.1.3 Circuit Protection Devices

Circuit Protection Devices stop the flow of current by opening the circuit. Fuses and Circuit Breakers are the most common circuit protection devices.

Fuses: An electrical fuse is a type of electrical safety device that protects an electric circuit against overcurrent. Its most important component is a metal wire or strip that melts when a significant current flows through it.

- **Cartridge Type Fuse -** These are fuses that are completely encased in a container and include the fuse element.

Fig. 4.1.16 Cartridge type fuse

- Kit-Kat Type Fuse - In this type of fuse, the fuse base serves as the input and output terminal and is constructed of porcelain, while the fuse carrier holds the fuse element (made of tin, copper, lead etc.).

Fig. 4.1.17 Kit-kat type fuse

- Drop Out Fuse - The melting of the fuse in these sorts of fuses causes the element to drop under gravity around its lower support. They are used to safeguard outdoor transformers.

Fig. 4.1.18 Drop-out fuse

4.1.4 Circuit Breakers

An electric breaker is a type of electrical switch intended to safeguard a circuit from damage caused by high current due to overload or short circuit. Its primary role is to interrupt current when a defect is detected by breaking the circuit.

Circuit breakers are classified into several categories.

- Oil Circuit Breaker - The arc extinguishing medium in these circuit breakers is dielectric oil.

Fig. 4.1.19 Oil Circuit Breake

- Air Circuit Breaker - The arc extinguishing medium in air circuit breakers is air.

Fig. 4.1.20 Air Circuit Breaker

- Sulphur hexafluoride (SF6) Circuit Breaker - Sulphur hexafluoride (SF6) is utilised as an arc extinguishing medium in these.

Fig. 4.1.21 Sulphur hexafluoride (SF6) Circuit Breaker

- Vacuum Circuit Breaker - The vacuum is utilised as an arc extinguishing medium in these circuit breakers.
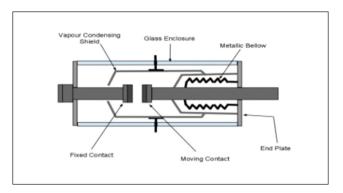
Fig. 4.1.22 Vacuum Circuit Breaker

4.1.5 Electrical Load

- An electrical load is a device that uses electricity. The following sorts of electrical loads are possible:

- Resistive load - A resistive load inhibits the passage of electric current in a circuit, converting electrical energy into heat and light. A resistive load is anything like electric light or a heater.

Fig. 4.1.23 Resistive Load

- Inductive Load - An inductive load transfers electrical energy into a magnetic field in order to do work. An example of the inductive load is an induction motor.

Fig. 4.1.24 Inductive Load

- Capacitive Load - In a capacitive load, current precedes voltage. Capacitive loads include capacitor banks.

4.1.6 Switchgears

A device that switches, controls, and protects both devices and circuits is called Switch Gear. This is concerned with switching and stopping currents under various operating circumstances, such as normal or abnormal. It is a configuration of electrical disconnect switches, circuit breakers, and fuses used in an electric power system to safeguard, regulate, and isolate electrical devices.

Fig. 4.1.25 Switch Gears

A switchgear is made up of switching and protection devices such as circuit breakers, regulating panels, fuses, potential transformers, isolators, switches, current transformers, lightning arrestors, and other similar gadgets.

Functions of Switchgear

- Protects equipment from faults and short-circuits

- Increases the availability of the system by permitting more than one loading source

- Isolates circuits belonging to the power supplies

- Opens and closes electrical circuits under both normal and abnormal conditions.

4.1.7 Indicating Instruments

ndicating instruments are those that show the amount of an electrical quantity as it is being measured. Their indicators are provided by a moving pointer over a calibrated dial. Indicating instruments include ammeters and voltmeters.

Ammeter

An ammeter is a device that measures direct or alternating electric current in amperes. An ammeter can measure a wide range of current values because, at high levels, only a tiny amount of the current is routed via the meter mechanism; the majority is carried by a shunt connected in parallel with the meter.

Fig. 4.1.26 Ammeter

The working principles and accuracy of different ammeters differ. Different types of Ammeters are:

- The **D'Arsonval-movement** ammeter monitors direct current with 0.1 to 2.0 per cent accuracy

- The **electrodynamic ammeter** makes use of a moving coil that rotates in the field created by a stationary coil. It measures direct and alternating current with 0.1 to 0.25 per cent accuracy.

The measured current warms a thermoconverter (thermocouple) in the thermal ammeter, which is used to power a millivolt meter and is used to measure alternating current with accuracies ranging from 0.5 to 3 per cent

Digital ammeters, which have no moving components, employ a circuit called a dual-slope integrator to convert analogue (continuous) current to its digital counterpart. The accuracy of many digital ammeters is better than 0.1 per cent.

Volt Meter

A voltmeter, often known as a voltage metre, is a device that measures the potential difference, or voltage, between two points in an electrical or electronic circuit. Some voltmeters are built for direct current (DC) circuits, while others are for alternating current (AC) circuits. Radio frequency (RF) voltage may be measured using specialised voltmeters.

Fig. 4.1.27 Volt Meter

A simple analogue voltmeter is made up of a sensitive galvanometer (current metre) connected in series with high resistance. A voltmeter's internal resistance must be high. Otherwise, it will consume a substantial amount of current and disrupt the operation of the circuit under test. The range of voltages that the metre can show is determined by the sensitivity of the galvanometer and the magnitude of the series resistance.

A digital voltmeter displays voltage as numbers. Some of these metres can calculate voltage readings to multiple decimal places. Maximum ranges for practical laboratory voltmeters range from 1000 to 3000 volts (V). Most commercially available voltmeters have several scales that increase in powers of ten, such as 0-1 V, 0-10 V, 0-100 V, and 0-1000 V.

Power Factor

Fig. 4.1.28 Power Factor Meter

A power factor meter is a device that monitors the power factor of a transmission system. A load's (or a circuit's) power factor (P.F) is defined as the "cosine of the phase angle" between voltage and current. It is also equivalent to the proportion of true power to apparent power. i.e.

$$P.F. = \cos \phi = \frac{\text{True power}}{\text{Apparent power}} = \frac{W}{V.A}$$

As the true power can be measured by a wattmeter and apparent power can be obtained by the product of voltage and current, the P.F. can be calculated by connecting a watt meter, voltmeter and an ammeter. P.F meters are of two types: Dynamometer type and Moving iron type.

Kilowatts Meter

Fig. 4.1.29 Kilowatts Meter

Kilowatts or kWh metres are small electronic monitoring devices that measure the amount of energy consumed as it flows through a circuit, such as a normal 120V or 240V line, and serve as a kWh calculator. The meter is connected to the circuit delivering the power, such as the main panel or distribution sub panel, and accumulates a totalized reading that accounts for the consumption passing through. The entire power in kilowatts utilized over a period of time is represented by the cumulative number, which gives the energy in kilowatt-hours.

4.1.8 Power and Control Circuits

Power Circuit: A power circuit is any circuit that transports electricity that activates a load. This may appear to be a simple concept, but it is critical to distinguish between power and control circuits since they perform different functions

A power circuit is illustrated with an outlet for the source, two wires for the path, a switch for the control device, and a motor for a load. When the switch is closed, electrons travel via the route and directly into the motor windings, causing the motor to run.

Control Circuit: A control circuit is a sort of circuit that is used to regulate the operation of a completely independent power circuit. Consider a huge industrial motor with 1,000 horsepower running a water pump. The motor is powered by a 2,400-volt high-voltage power source.

When this motor is turned on, it must draw enough current to move the water, and it is customary for a motor to draw around six times its regular working current for a short amount of time. A control circuit ensures that the motor starts and stops safely for both the user and the equipment.

4.1.9 Load Management System

Load management, often known as demand-side management (DSM), is the technique of balancing the energy supply on the network with the electrical load by altering or managing the load rather than the power station output. This can be accomplished by direct involvement of the utility in real-time, using frequency-sensitive relays activating circuit breakers (ripple control), time clocks, or using specific rates to influence consumer behaviour. Load management enables utilities to lower the demand for electricity during peak consumption times (peak shaving), which can save costs by removing the need for peaking power units. Furthermore, some peaking power plants might take more than an hour to come online, making load management even more crucial if, for example, a plant goes offline suddenly. Finally, because peaking facilities or backup generators are frequently dirtier and less efficient than base load power plants, load management can also assist in minimising harmful emissions.

Connected Load: The connected load is the total of the continuous ratings of all the equipment connected to the supply system. In other words, the connected load is the total of all the nameplate ratings of the equipment in the consumer installation.

Load Factor

The Load Factor, which is used in electrical engineering, is calculated as the average load divided by the maximum (or peak) load for a specific period of time. To put it another way, the load factor is the proportion of total energy (kWh) consumed over a given time period to the total energy that could have been made available during that time (i.e. peak demand over that specific time period). You can compute the load factor on a daily, monthly, or annual basis.

The utilisation rate is calculated using the load factor (means the efficiency of usage of electrical energy). The load factor's value is never more than one because the maximum demand will never exceed the average load.

Calculation of Load Factor

The load factor is determined by multiplying the total amount of electrical energy consumed during a certain time period (kWh) by the product of the greatest demand (kW) and the number of hours during that time period.

- Daily Load Factor = Total kWh 24 Hours of the day/Peak Load in kW X 24Hr

- Monthly Load Factor = Total kWh a month/Peak Load in kW X 720Hr

- Annual Load Factor = Total kWh a year/Peak Load in kW X 8760Hr

Any time period can be used to calculate the load factor. It is typically computed on a daily, weekly, monthly, or annual basis. The load factor is displayed in the equations below for various times.

4.1.10 Electrical Control Systems with AutoCAD Electrical Toolset

AutoCAD is primarily developed for technical drawings in the instrumentation and electrical fields. The electrical CAD drawings produced by the AutoCAD program are of the highest quality and precision. The purpose of such designs is to modify electrical systems. AutoCAD is an excellent tool for producing panel layouts, electrical meanings, and line diagrams.

The following are some of the advantages of utilising AutoCAD in electrical drawings:

- The ability to design personalised symbols

- Wire-numbering instruments

- Tools for managing title blocks

- Bill of materials creation and report generation

- Standard blocks in an interactive icon menu (IEEE, JIC, IEC standard symbols)

- There are up to 2 million pieces in the collection.

- It is simple to include additional components into it.

- Personalized naming scheme

- Hydraulic, pneumatic, and P&ID systems are all available in the library.

Designing Panel with AutoCAD

Panel Layouts

Panel symbols can be added using a list of schematic components or the panel icon menu. Add nameplates, item numbers, and balloons as desired. Terminal Strip Editor is a tool for managing terminal strips.

Drawing Properties

A few drawing characteristics are unique to panel layouts. These characteristics may be defined on a drawing or set up on a drawing template at any moment. Set the initial item number, item balloon parameters such as shape and text size, footprint layers, and more with the Panel Configuration command.
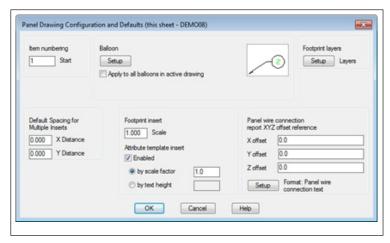
Fig. 4.1.30 Panel Drawing Configuration and Defaults

Insert from Schematic List

If the schematic drawings are created first, create panel layouts by selecting from a list of schematic component. Find
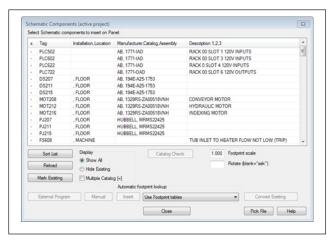
Fig. 4.1.31 List of Schematic Components

- AutoCAD Electrical locates the right panel footprint by using the catalogue assignment on the schematic component.
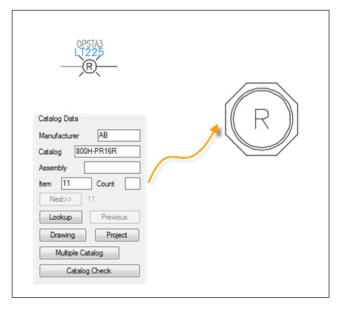
Fig. 4.1.32 Catalog Data

- If a footprint sign cannot be identified, search for one or draw one on the fly. AutoCAD Electrical adds any necessary intelligence so that it is recognised as a panel sign. This method allows you to get panel symbols from suppliers and use them in AutoCAD Electrical.

- The dialogue box reveals which schematic components are already present on a panel layout.
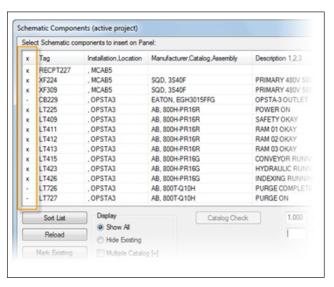
Fig. 4.1.33 Schematic Components

- The panel footprint receives all values from the schematic component. If one of them is modified later, the other will be updated.

Panel Icon Menu

Insert panel footprints using the Panel Icon Menu for panel components not displayed on the schematic.

Find

Fig. 4.1.34 Panel Layout Symbols

• Select a catalogue value and insert the footprint associated with that value when inserting a footprint from the icon menu. If no panel symbol is connected with that library, look for one or design one on the fly.

Nameplates

Use the panel icon menu to insert a nameplate.
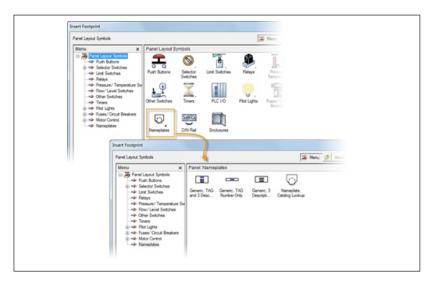
Fig. 4.1.35 Inserting Panel Nameplates

• When placing a nameplate, one may correlate it with a panel footprint. Values from the footprint, such as Tag, installation, location, and descriptions, are duplicated. However, one may add a unique item number and catalogue value to the nameplate.
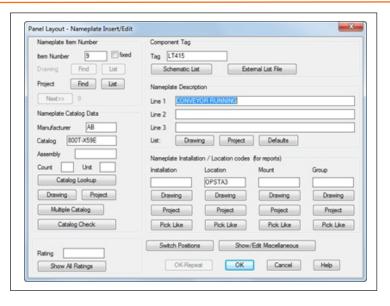
Fig. 4.1.36 Edit Panel Nameplates

Item Numbers

Panel and schematic symbols can both have item numbers applied to them when a catalogue value is assigned to a component, the software checks to see if the same catalogue value is allocated to another component. If it is, the item number is automatically assigned. If the item number is not automatically assigned, it can be changed while editing the component. One may also use the Re-sequence Item Numbers command to allocate them to the whole project.

Fig. 4.1.37 Resequence Item Number

The panel components are handled first, followed by the schematic components. Components with the same catalogue assignment are assigned the same item number.

A few project parameters influence item numbering. Before resequencing the item numbers, ensure that these attributes are adjusted to your specifications.
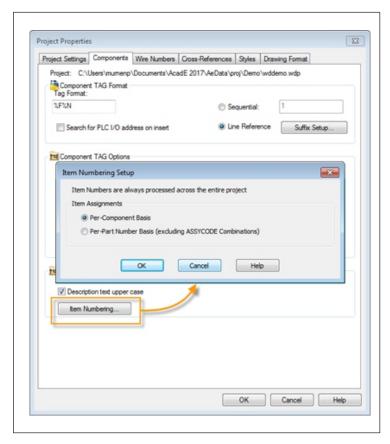
Fig. 4.1.38 Item Numbering Setup

Item Balloons

Once an item number has been assigned to a component, a balloon may be placed to make the item number visible.

Take note of the instructions at the command prompt. If the selected component contains several catalogue values with item numbers, you may choose which way to position the extra balloons.
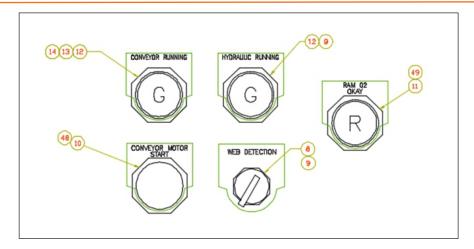
Fig. 4.1.39 Item Balloons

Terminal Strip Editor

The Terminal Strip Editor allows handling the whole terminal strips rather than just one terminal. The editor provides data on catalogue values, connected components, connected wires, wire numbers, and other topics.
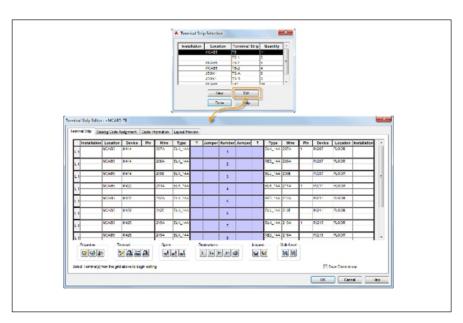
Fig. 4.1.40 Terminal Strip Editor

Use Terminal Strip Editor to:

- Resequence terminals numbers

- Reorder terminals in the strip

- Add or edit catalogue assignments and terminal block properties

- Add spares and accessories (requires inserting the graphical terminal strip layout)

- Add, edit, and remove jumpers between terminals

- Define connected components as internal or external

- Insert a graphical terminal strip layout

- Insert a tabular terminal strip

- Insert a jumper chart

- Create a terminal strip

Panel terminals and schematic terminals are included in the list of terminals displayed in a strip. If the editor inserts both a schematic representation and a panel terminal for a terminal, it is only shown once in the editor. Any modifications are applied to both representations.

Using the Layout Preview tab, Insert the terminal strip after selecting the type and annotation style. Use the preview to ensure that everything is set up correctly.
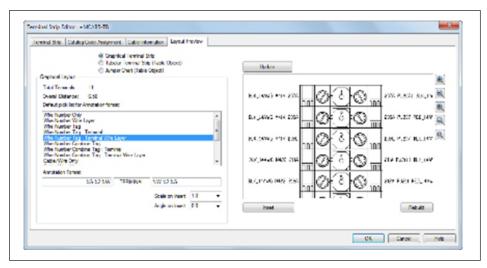
Fig. 4.1.41 Inserting Terminal Strip

- One may also use the Terminal Strip Table Generator to insert tabular terminal strips for one or more strips.
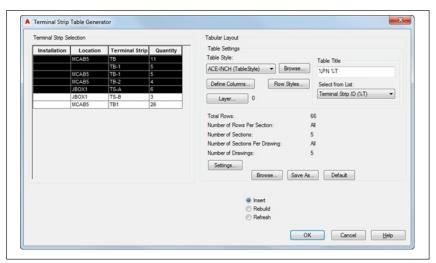
Fig. 4.1.42 Terminal Strip Table Generator

Exercise

1. Define Electrical Circuits. Name a few electrical circuit devices.

2. What do you understand by an Electrical Panel?

3. Explain in detail any two indicating instruments.

4. What are power and control circuits?

Notes 🗒

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https://youtu.be/tDhyy72peJ0	https://youtu.be/YM7SdHj7Tuo	https://youtu.be/DMG2jd6RUSE	https://youtu.be/hhehRnIYZss	https://youtu.be/oCBIX0K53IQ
Electrical Panel	Circuit Protection Devices	Circuit Breakers	Electrical Load	Switchgears

5. Carrying Out Process Instrumentation

Unit 5.1 - Process Instrumentation

Key Learning Outcomes

By the end of this module, participants will be able to:

1. Explain the basic functions of electrical components.

2. Explain the function of different types of electrical components, transmitters and sensors used in industrial applications.

3. Explain different types of position sensors and their applications.

4. Explain the working principle and selection criteria for a flow measurement device.

5. Explain the working principle and selection criteria for a pressure measurement device.

6. Explain the working principle of load cells and the load measurement process.

7. Explain the working principle and selection criteria for a level measurement device

8. Explain the working principle of solenoid valves, control valves, smart transmitters and instrument transformers such as Current Transformer (CT) and Voltage Transformer (VT).

9. Explain the functions of closed and open-loop controls.

10. Describe the process control basics and process controllers (on-off, proportional, PID).

11. Explain how to identify the change in light intensity using a photo-electric sensor.

12. Explain how to estimate the flow measurement, its working principle, types and selection guidelines.

13. Explain how to measure the linear, nonlinear, mass or volumetric flow rate of a liquid or gas using a flow sensor.

14. Explain different types of sensors used in flow and load measurement.

15. Explain how to measure pressure by using various pressure measurement devices.

16. Explain how to measure the load parameters using load cells.

17. Explain the functions of the smart transmitters.

18. Explain the technique to be used to protect the power system through instrument transformers (CT, VT).

UNIT 5.1: Process Instrumentation

Unit Objectives ⊚

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2. Explain the function of different types of electrical components, transmitters and sensors used in industrial applications.
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5. Explain the working principle and selection criteria for a pressure measurement device.
6. Explain the working principle of load cells and the load measurement process.
7. Explain the working principle and selection criteria for a level measurement device
8. Explain the working principle of solenoid valves, control valves, smart transmitters and instrument transformers such as Current Transformer (CT) and Voltage Transformer (VT).
9. Explain the functions of closed and open-loop controls.
10. Describe the process control basics and process controllers (on-off, proportional, PID).
11. Explain how to identify the change in light intensity using a photo-electric sensor.
12. Explain how to estimate the flow measurement, its working principle, types and selection guidelines.
13. Explain how to measure the linear, nonlinear, mass or volumetric flow rate of a liquid or gas using a flow sensor.
14. Explain different types of sensors used in flow and load measurement.
15. Explain how to measure pressure by using various pressure measurement devices.
16. Explain how to measure the load parameters using load cells.
17. Explain the functions of the smart transmitters.
18. Explain the technique to be used to protect the power system through instrument transformers (CT, VT).

5.1.1 Process Instrumentation

Process Instrumentation is a collective term for sensors incorporated into measuring instruments used for indicating, measuring and recording physical quantities. Forming the basis of process control, instruments continue to improve their capability, repeatability, accuracy, reliability and cost.

Process Control: Process control refers to the procedures used to keep the output of process variables like temperature, pressure, flow, or level within a certain range. In industrial contexts, precise management of these variables is crucial since it improves product quality while enabling automation, allowing fewer personnel to monitor and operate complicated operations from a single location.

The foundation for process control is instrumentation. It gives the operator numerous indicators for regulating the process. Instrumentation is employed in nearly every industrial process and power generation system where consistent and reliable functioning is required. Instrumentation allows one to monitor, record, and regulate a process in order to keep it in the intended condition.

The first stage in any process control is, of course, measurement. What cannot be measured cannot be controlled. The most often measured parameters are pressure, flow rate and level.

Process Controllers: Process controllers keep process variables like temperature, pressure, flow, or level within a predefined range. They employ sensor feedback to detect deviations from a setpoint and automatically modify output until the parameters are back within range. This tight control increases quality control while also allowing for the automation of complicated procedures. This increases efficiency and safety without requiring more manpower.

Types of Control Action

Process controllers, depending on the unit, can provide many methods of control that are appropriate for various applications and process variables.

ON-OFF Control: The most basic sort of control is on-off control, often known as hysteresis control. On-off controllers, as predicted, transition suddenly between two states with no intermediate state. They are intended for use with equipment that takes binary input, such as a furnace that can only be turned on or off.

When the set point is reached, the output of an on-off controller is switched. In the instance of heating control, the controller turns on when the temperature falls below the set point and off when it rises over the set point. Hysteresis, or on-off differential, is introduced to the controller operations to avoid fast cycling of the system, which can cause damage. The difference avoids cycling by slightly exceeding the set point before the controller turns on or off.

On-off controllers are commonly employed in applications that do not require precise control, in systems that cannot withstand having energy turned on and off frequently, and in systems with such a large mass that temperatures change relatively slowly.

PID Control: To help the controller's algorithms give a more precise reaction to deviations from the set point, PID control employs three separate control terms: proportional (P), integral (I), and derivative (D).

When a controller gets information indicating that a process variable has deviated from its set point, instructions are given to the final control element for rectification. For example, if a controller gets a signal from a thermocouple indicating that a process temperature is too low, the controller will activate a heater to bring it up to temperature.

PID controllers employ the algorithm developed from its three control terms to ensure system stability by reducing overshoot and resultant oscillation. The proportional variable regulates the pace of correction such that it is proportionate to the mistake. The integral and derivative variables are time-based and assist the controller in automatically compensating for changes in the system. The derivative variable considers the pace at which the error is rising or decreasing, whereas the integral variable applies knowledge of cumulative errors to the amount of time the process is not at the fixed point. This data is needed to adjust the proportionate value.

PID controllers are often regarded as the most efficient controller type. They are commonly seen in industrial environments. PID controllers give exceptionally accurate and reliable control despite the fact that each variable must be tailored to a specific system.

Profile Control: Controlling a changing process variable against time is referred to as profile control. Users enter the required time and process profile using a broad instruction set that includes jump, loop, loop with count, ramp, and soak control.

Profile control is particularly beneficial for cycle applications that require numerous temperature profiles as well as precise on and off times.

Limit Control: Limit control entails a separate switch that shuts down the system if a process variable exceeds a predetermined threshold. Limit controllers are used in operations where a process variable must be kept within defined tolerance limits for safety or quality reasons.

Limit controllers are intended to function in tandem with another controller. To accept that the limit relay has been triggered, these machines also require a manual rest.

5.1.2 Control System

A control system is a group of devices that controls, commands, or regulates the behaviour of other devices or systems in order to achieve a certain goal. Control loops, which are processes meant to keep a process variable at a specified set point, are how a control system does this.

In daily life, examples of control systems include an air conditioner, a refrigerator, an air conditioner, a bathroom toilet tank, an automated iron, and various procedures within a car, such as a cruise control.

Control systems may be found in a variety of industrial situations, including product quality control, weapons systems, transportation systems, power systems, space technologies, robots, and much more.

Types of Control System

The two main types of control systems are:

- Open Loop Control Systems

- Closed-Loop Control Systems

Open Loop Control System: An open-loop control system is one in which the control action is completely independent of the output of the system. An open-loop control system is also a manual control system.
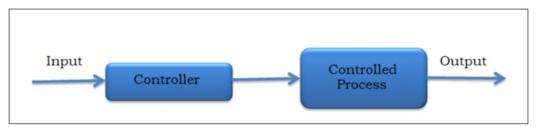
Fig. 5.1.1 Open-loop control system

Examples of Open-loop control systems:

- Electric Hand Drier - Regardless of how much the hand is dried, hot air (output) flows out as long as one keeps their hand beneath the machine.

- Automatic washing machine - This machine operates according to a pre-set time, whether or not the washing is done.

- Bread Toaster - This machine operates according to the time set, whether or not toasting is completed.

Closed-Loop Control System: A closed-loop control system is one in which the output influences the input quantity in such a way that the input quantity adjusts itself based on the output created. An open-loop control system can become a closed-loop control system by providing feedback. Due to external disturbances, this feedback automatically modifies the output. A closed-loop control system is hence referred to as an automated control system.
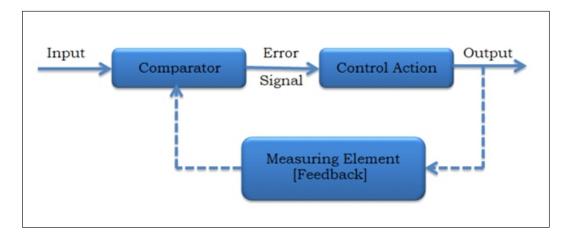
Fig. 5.1.2 Closed-loop control system

Examples of Closed-loop control system

- The output temperature of the iron controls the heating components in an automatic electric iron.

- Servo Voltage Stabilizer - A voltage controller acts in response to the system's output voltage.

- Water Level Controller - The reservoir's water level controls the input water.

5.1.3 Flow Measurement Device

A flow measurement device is used to determine the volume or mass of a gas or liquid. Flow metres are known by a variety of names, including flow gauge, flow indicator, liquid metre, flow rate sensor, and so on.

The flow metre measures the amount of gas or liquid that flows around the gadget. These gadgets achieve the same aim in various ways. They provide reliable and precise flow measurements for a variety of applications such as semiconductor production and process control.

This metre can compute either mass or volume. The liquid flow in the pipe can be equal to the cross-sectional area inside a metre and the velocity of the liquid flow ($Q = A * v$). The flow of mass can be calculated by using this formula like $\dot{m} = Q \cdot \rho$ (Q = the flow rate of liquid & ρ is the density of the fluid)

In many circumstances, the flow of mass is the most important factor, notably in the sale and purchase of gases, chemical processes, combustion, and so on.

The following flow quantities must be measured: -

- The actual fluid velocity at a given point (measured in metres per second).

- The flow volume rate (measured in metres cubed per minute).

- The rate of mass flow (measured in kilograms per second).

Types of Flow Measurement Devices/ Flowmeters

There are two types of flowmeters that are used widely in industries:

- **Volumetric Flowmeters:** Volumetric flow metres measure the amount of fluid that passes through a specified spot in a certain amount of time. Volumetric flow metres produce an immediate analog, digital, or pulse output of the liquid or gas's volumetric flow rate. Volumetric Flowmeters are classified into the following categories: Differential Head type, Venturi meters, Orifice plates, Annubar, Electromagnetic flowmeters, Differential Area type (Rotameters), Ultrasonic flowmeters, Vortex flowmeters, Turbine flowmeters, Positive Displacement Meters

- **Mass Flowmeters:** Mass flowmeters measure the fluid mass flow rate through a tube per unit of time. There are two types of mass flowmeters: Thermal mass flowmeters and Coriolis mass flowmeters.

Working Principle of Flow Measurement Devices

Mass flow transmitters calculate the mass flow of any fluid passing through a tube at a given time. In brief, it does not measure the volume per unit time (e.g., cubic metres per second) that flows through the tube but rather the mass per unit volume (e.g., kilogrammes per second).

The volumetric flow rate is the mass flow rate divided by the fluid density. Variables such as pressure, temperature, and composition all affect fluid density. The fluid may have a mixture of phases, such as a fluid with bubbles.

Flow Sensors

Flow sensors are a type of equipment that measures the flow rate of a gas, such as air, or a liquid, via a pipe or conduit. Flow measurement is critical for the management of various industrial processes as well as the operation of machines at peak performance and efficiency. Flow sensors are used in automobiles to monitor air intake to the engine and alter fuel supply to fuel injectors to get the correct fuel mixture to the engine. Flow sensors are used by medical ventilators to determine the proper rate of supply of air or oxygen to patients for respiratory aid.

Types of Flow Sensors

The different types of flow sensors are:

- Positive displacement flow sensors

- Mass flow sensors

- Velocity flow sensors

Application of Flow Measurement Devices

- Water Distribution Networks

- Water Leakage

- Wastewater Treatment

- Sludge Monitoring

- Methanol Measurement

- Aeration Process

- Bio gas Measurement and many more

5.1.4 Pressure Measurement Device

Pressure is a measure of the force exerted over a unit area. Pressure in its many forms is involved in a large amount of all industrial measurements. Flow, for example, is frequently quantified by calculating the pressure difference between two sites in a system.

Types of Pressure:

- Atmospheric Pressure

- Absolute Pressure

- Gauge Pressure

- Vacuum Pressure

- Static and Dynamic Pressure

Measurement of Pressure

Many devices for measuring pressure have been developed, each with its benefits and limitations. Pressure range, sensitivity, dynamic response, and cost all vary by orders of magnitude amongst sensor designs. The liquid column manometer (a vertical tube filled with mercury) is the earliest kind.

Types of Pressure Sensors

Pressure sensors are classified based on how they detect pressure changes. Sensors can detect and quantify a variety of physical responses. The following are some of the most important types of pressure sensors:

- Strain Gauge
- Piezoelectric
- Capacitive
- Manometers
- Vacuum pressure
- Bourdon Tube
- Aneroid Barometer

Application of Pressure Sensors

- Pipeline or Hydraulic Hose Pressure
- Electronic Transmitter set norms
- Low to High Vacuum Pressure
- Energy conservation applications
- Technology Industry Applications
- Manufacturing Applications

5.1.5 Level Measurement

The basic concept of level measurement is the linear distance between the top surface of a liquid or solid and a predefined reference point, such as in a tank. In industrial operations, many types of level measuring instrumentation equipment are employed.

Level sensors are simple level indicators that monitor the amount of liquid or solid in operation. These levels can be communicated to a central computer for historical tracking and utilised in process automation and control.

Level switches are sensors that provide an electrical signal when a certain liquid, powder, or bulk level is reached.

Level transmitters are sensors that send an electrical signal to a remote recording site after measuring the level of a liquid, powder, or solid. Level measurement transmitters are utilised in a variety of applications where level measurement within containers or tanks is required. Material handling, power, chemical, and water treatment sectors frequently use these transmitters.

Working Principle of Level Measurement Device

The working principle of the level transmitters differs depending on their underlying principle. In order to estimate the level, for instance, capacitance level transmitters utilise a capacitor; hydrostatic level transmitters use the fluid's pressure inside a storage container to do so; ultrasonic level transmitters use the distance an ultrasonic wave travels to do so; and so forth. All of these level transmitters, however, measure the level in one of three ways:

- The liquid's weight
- The fluid's pressure head
- The fluid's location in a container

Level Measurement Methods

Depending on the application's needs, level instrumentation provides several measuring techniques.

- Capacitive
- Conductive
- Electromechanical
- Float switch
- Free space radar
- Guided wave radar
- Hydrostatic
- Microwave barrier
- Paddle
- Piezoresistive
- Pressure differential
- Radiometric
- Servo
- Ultrasonic
- Vibronic

5.1.6 Load Measurement

Load Cells: A load cell or a load sensor is a type of force transducer. It converts a force—such as tension, compression, pressure, or torque—into a measurable electrical signal. As the force applied to the load cell rises, so does the electrical signal. Strain gauges, pneumatic, and hydraulic load cells are the most frequent types of load cells utilized.

Load cells are one type of equipment used to measure weight. They can measure objects as small as a needle and as large as large drilling machines. Load cells may be found anywhere, even in the local grocery shop, to weigh the purchases; however, they are located within the equipment. Load cell sensors are always connected with elastic material, known as strain gauges.

Application of Load Cells

Load cells have applications in geotechnical engineering and are typically used to monitor:

- To calculate the load in rock bolts, tiebacks, foundation anchors, cables, or struts.
- Proof testing and long-term performance monitoring of several types of anchor systems
- Compressive load measurement between structural components, such as tunnel supports or the junction of a beam and the top of a pile strut.
- Correlating data from borehole extensometers is a common use.
- Load determination in experimental research, pile testing, and rock thrust measuring
- Measurement of the compressive load between structural components.
- Compressive load and axial forces in struts are measured.
- Load testing in heaps.
- Determination of roof convergence in underground mines.

Working Principle of a Load Cell

The load cell principle necessitates the employment of several geotechnical instruments. It cannot function without the assistance of sensors, one of which is a strain gauge.

Strain gauges are thin elastic stainless steel materials that are attached to load cells using proprietary adhesives. The resistance of the strain gauge is directly proportional to its length and breadth.

When one applies a force to the load cell, it bends or stretches, causing the strain gauge to move along with it. And, when the strain gauge's length and cross-section vary, its electrical resistivity changes, causing the output voltage to fluctuate.

Load Measurement Process

- Ensure that connections are proper and the electronic display reports gentle pressure at the cantilever
- Adjust '0.0' reading on display with empty pan hooked
- Measure bridge excitation on DMM
- Observe bridge output on DMM
- Place calibration weight in a pan and observe the display reading
- Keep on adding the weights and record the reading
- Reverse the procedure by removing the weights one by one

5.1.7 Electronic Components

Electronic components are the elements of the circuit that help in its functioning. They can be classified into two types, i.e. Active Components and Passive Components. Active components include transistors, batteries, etc., while passive components include transformers, inductors, resistors, capacitors, etc.

The electronic components and their functions are:

1. **Resistors:** In an integrated circuit, a resistor is one of the components that will be encountered. The gadget, as its name implies, opposes current flow. Power ratings (the amount of power they can withstand without exploding) and resistance values are used to grade resistors (capacity to resist current). Ohms are the units used to measure resistance. The unit's electrical symbol is O.
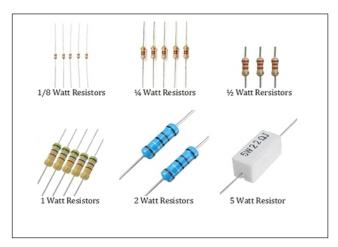
Fig. 2.2.5. Resistors

2. **Capacitors:** These components have the ability to temporarily store electric charge. The components come in a variety of shapes and sizes, with electrolytic and ceramic discs being the most popular. A component's capacity is commonly expressed in microfarads (ÂμF).
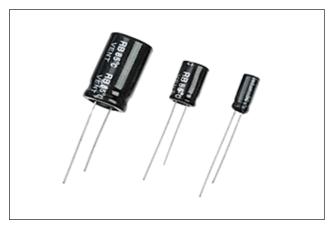
Fig. 2.2.6. Capacitor

3. **Diodes:** Electric current can only travel in one way through diodes. The anode and cathode are the two terminals of each diode. When the anode is charged with a positive voltage and the cathode is charged with a negative voltage, an electric current can flow. The current will not flow if these voltages are reversed.

Fig. 2.2.7. Diode

4. **Transistors:** The three terminals on these components make them easier to spot. Voltage must be provided to one of the components, the base terminal, in order for it to function. The current flow in the two additional terminals can then be controlled by the base (the emitter and collector).

Fig. 2.2.8. Transistors

5. **Inductors:** These are energy-storing components that take the shape of a magnetic field. An inductor is basically a coil of wire coiled around a core of some sort. A magnet or air might be used as the core. A magnetic field is formed around the inductor as electricity passes through it. If a magnet is employed as the core, the magnetic field is greater.

Fig. 2.2.9. Inductors

6. **Integrated Circuits:** An integrated circuit is a particular device containing all electronic circuit components. Diodes, transistors, and other devices are all etched on this component's small piece of silicon. Many electrical gadgets, like watches and computers, employ the components.
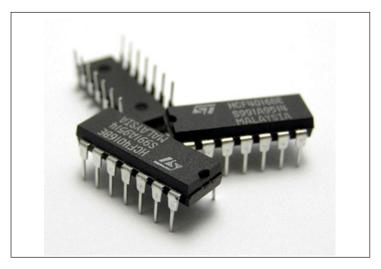
Fig. 2.2.10. Integrated Circuits

7. **Microcontrollers:** Microcontrollers are tiny computers that control a wide range of devices, including power tools, remote controls, medical equipment, and office machinery.

Fig. 2.2.11. Microcontrollers

8. **Transformers:** Transformers are regularly used to step up or down power and are made up of two coils of wire.

Fig. 2.2.12. Transformers

9. **Batteries:** Chemical energy is converted to electrical energy by batteries. Anode (+) and cathode (-) are the two types of cells in a battery (-).

Fig. 2.2.13. Batteries

10. **Fuses:** Fuses protect components from overheating due to excessive current. A fuse comprises a connecting body, support, contacts, and a zinc or copper-based metal fuse material.

Fig. 2.2.14. Fuse

11. **Relays:** These electromechanical switches turn on and off the electricity. An electromagnet, an armature, a set of electrical connections, and a spring make up a relay.
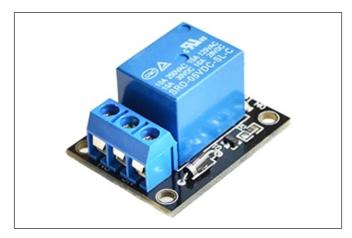
Fig. 2.2.15. Relays

12. **Switches:** The current is interrupted by switches. Single pole single throw (SPST), double pole single throw (DPST), single pole double throw (SPDT), and double pole double throw (DPDT) are the four types of switches (DPDT).
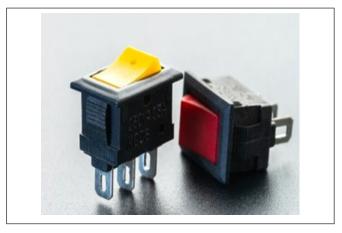
Fig. 2.2.16. Switches

13. **Motors:** Electrical energy is converted into mechanical energy by motors. A rotor, bearings, stator, conduit box, enclosure, and eye bolt are all important components.

Fig. 2.2.17. Motors

14. **Circuit Breakers:** A circuit breaker can be operated using a remote switch as a safety precaution. Its purpose is to prevent the circuit from being overloaded or short-circuited.

Fig. 2.2.18. Circuit Breakers

Semiconductor

A semiconductor is a material with an electrical resistance that is halfway between that of metals and insulators, allowing it to "semi"-conduct electricity. Because we can regulate the flow of electrons in this material, such as with a regulating current, semiconductors are employed in many electrical circuits.

Semiconductors are also employed for a variety of other purposes. In actuality, a solar cell is made up of light-sensitive semiconductors. The quantity of light energy that strikes the semiconductors determines how much electrical current is created by the solar cells' semiconductors.

5.1.8 Transmitters

A transmitter is a device used in the field of process control that transforms the signal generated by a sensor into a common instrumentation signal that represents a process variable being measured and controlled.
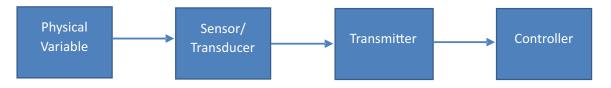
Fig. 5.1.17 Process control by Transmitters

Types of Transmitters

Transmitters can be segregated into several types depending on the process application. Broadly, transmitters are divided into three groups – type, signal production, and process instrumentation

Transmitters which are used for process instrumentation are:

Flow: Flow transmitters provide measurements of the flow of liquid or fluid. This particular transmitter type is a combined transmitter and flow sensor. This enables it to provide outputs of up to 20 mA. Different technologies are used in the design of flow transmitters, such as velocity, differential pressure, and ultrasonic flow sensors.

Temperature: The temperature transmitter calculates temperature in different processes. Temperature transmitters include a transmitter and a temperature sensor built into their construction. In order to calculate the temperature and produce an output signal, the transmitters receive a signal from the sensor and calculate it. Temperature transmitters are of two types:

Thermocouple Type: It calculates temperature by measuring the electromotive force that is generated by a change in process temperature.

RTD Type: This temperature transmitter uses RTD sensors, whose electrical resistance alters as the process temperature changes. The correlation between these two factors is analysed to measure the temperature.

Pressure: Pressure transmitters are used to measure pressure in different processes. These are divided into three types:

- **Absolute Transmitter:** It measures process pressure by taking vacuum pressure as its base.

- **Gauge Transmitter:** It measures process pressure by taking the location's atmospheric pressure as the base.

- **Differential Transmitter:** It measures the differences between the various pressures when sensing units are exposed to several pressures as inputs.

Level Transmitters

These transmitters are made to calculate the amount of a liquid or solid inside a container or enclosed environment. The seven different kinds of level transmitters are as follows:

- **Point Level:** These are intended to emit a signal when a specific measurement level is attained. The output signal may be an alarm sound or an electrical signal that activates a switch.

- **Continuous Level:** This transmitter determines the level within a certain range. Additionally, it delivers updated measurements as the level shifts.

- **Ultrasonic Level:** It allows non-contact measurements of viscous liquids or bulk solids.

- **Conductive:** It is applied to the point level measurement of various liquid types. It can measure corrosive fluids like caustic soda, hydrochloric acid, and water.

- **Pneumatic:** Slurry or sludge-containing applications are perfect for these transmitters. They can be utilised in non-electrical applications.

- **Capacitance:** With the help of this transmitter, non-conductive liquids with high dielectric constants can be continuously measured.

- **Hydrostatic:** To measure a liquid's level, this transmitter uses hydrostatic pressure.

5.1.9 SMART Transmitter

SMART Transmitter stands for Single Modular Auto-ranging Remote Transducer. It is a cognitive transmitter that continuously transmits digital communication signals based on the FOUNDATION FIELDBUS, PROFIBUS, or HART protocol and has an analog output. It comprises of a sensor, the microprocessor, memory and communication block.

Input:

1. The sensor may also be integrated in the smart transmitters. (optional)

2. The input either receives from a integrated sensor or external sensing element.

- ADC - Analog to Digital Converter
- DAC - Digital to Analog Converter

Output:

1. The output is in the form of 4 to 20 mA standard loop current.

2. The output can also be in the form of pulse, digital output (foundation fieldbus, Profibus, wirelessHART, etc.) depends on the smart transmitter.

Fig. 5.1.18 Smart Transmitter

SMART Transmitter measures absolute pressure, process temperature and differential pressure. The output of this transmitter includes primary process variables as well as secondary process variables.

The information extracted from the measurements is used employed to optimize the process and improve the instrument's effectiveness while extending its life.

Advantages of SMART Transmitter

- Bi-directional communication

- Measures and Compensates for environmental disturbance

- Multiple sensors allow covering various measurement ranges

- Removal of zero and sensitivity drift errors.

- Self-Diagnostic

- Adjustment of non-linearities giving linear output

- Improved accuracy and reliability

- Reduction in maintenance costs.

5.1.10 Sensors

A sensor is a device that recognises changes in electrical, physical, or other quantities and does so in a way that produces a yield that serves as a confirmation of the progress in the amount. Industrial Automation Sensors are input devices that produce an output (signal) in relation to a particular physical quantity, to put it simply (input).

Sensors are a key component of industrial automation because they give items intelligence and outstanding automaticity. These enable the detection, analysis, measurement, and processing of a wide range of transformations, including changes in position, height, length, exterior, and dislocation that take place at industrial manufacturing sites.

The following are the various types of sensors used in automation:

- Temperature Sensors

- Pressure sensors

- MEMS Sensors

- Torque Sensors

1. Temperature Sensors:

A temperature sensor is a gadget that gathers temperature data from a source and converts it into a format that can be interpreted by another gadget. These are a class of sensors that are frequently used; they measure a medium's temperature and detect temperature or heat.

Digital Temperature Sensors:

Digital temperature sensors, which are silicon-based temperature sensing ICs, deliver precise output by representing the temperatures they measure in digital form. Comparatively to methods that involve external signal conditioning and an analog-to-digital converter, this simplifies the design of the control system (ADC).
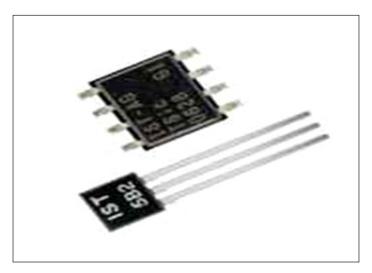
Fig. 5.1.19 Digital temperature sensors

2. Humidity & Temperature Sensors

The temperature and humidity sensors produce measured digital signals using a complex of temperature and humidity sensors. It offers excellent consistency and exceptional long-lasting stability by applying the approach and temperature & restricted digital-signal-acquisition humidity sensing technology.

Fig. 5.1.20 Humidity & temperature sensors

Applications of Temperature Sensors:

- Weatherproof & designed for continuous temperature measurement

- Exceptional precision and accuracy

- In complex industrial applications

- Under rough operating conditions

3. Pressure Sensors:

The pressure sensor is a device that senses applied pressure and converts it into an electric signal, the quantity of which is dependent on the pressure. One or two of the most common pressure sensors used in industrial automation are high vacuum sensors and turned parts for pressure sensors.

Turned parts for Pressure Sensors

These high-pressure industrial automation sensors are employed in climate control systems and are widely used in hydraulic and industrial systems.

Fig. 5.1.21 Pressure Sensor

4. Vacuum Sensors

Vacuum Sensors are used when the vacuum pressure is below atmospheric pressure levels. These sensors typically rely on a heated wire with temperature-related electrical resistance. Convection decreases, and wire temperature rises as vacuum pressure rises. In order to accurately measure the vacuum, electrical resistance rises proportionately and is calibrated next to pressure.

Fig. 5.1.22 Vacuum sensors

Applications of Pressure Sensors:

- To measure pressure below the atmospheric pressure at a given location

- Used in weather instrumentation, aircraft, vehicles, and any other machinery that has pressure functionality implemented

- To measure other variables such as fluid/gas flow, speed, water level, and altitude

MEMS Sensors (Micro-electro-mechanical Systems)

MEMS Sensors transform mechanical impulses that have been measured into electrical signals. A few significant MEMS sensors used in industrial automation include those for acceleration and motion.

5. Acceleration sensors

One of the most common inertial sensors is the Acceleration Sensor. It is a dynamic sensor with a wider range of sensing capabilities.

Fig. 5.1.23 Acceleration Sensor

6. Motion sensors

Motion sensors employ data processing techniques created on a platform for motion interaction that incorporates several inexpensive MEMS motion sensors. Systems for processing sensor signals deal with signal smoothing, noise cancellation, dividing the influence of gravity, changing the coordinate system, and location.

Fig. 5.1.24 Motion sensors

Applications of MEMS Sensors:

- Several applications in fields like industry, entertainment, sports, and education. Example: triggering airbag deployments or keeping an eye on nuclear reactors

- Measuring static acceleration (gravity), the tilt of an object, dynamic acceleration, vibrations, etc.

- Detecting motion

6. Torque sensors

The torque sensors increase overload capacity and provide an additional layer of protection during installation and use. Among the crucial sensors utilised in industrial automation are rotating torque and torque transducers.

Rotating Torque Sensors

These are used for measuring the reaction of rotating torque. These torque metres provide more mounting and operating safety while increasing surplus capacity.

Fig. 5.1.25 Rotating torque sensors

Torque Transducers

Torque Transducers use cutting-edge strain gauge technology to meet the most demanding requirements for sensors used in static and dynamic applications.

Fig. 5.1.26 Torque Transducers

Applications of Torque Sensors:

• Measuring the speed of rotation and maintenance necessities

• Measuring Mass and mass moment of inertia

• Measuring the torque from the point of vision of a quasi-static process

• Measuring the highest speed of rotation, oscillating torque

Position Sensor

Any device that detects an object's movement in a linear or rotary motion and transforms it into output signals appropriate for processing, transmission, or control, depending on the application, is referred to as a position sensor.

Potentiometric, Magneto-Restrictive, Hall Effect, Encoder, and LVDT/RVDT position sensors are among the non-contacting and contacting technologies that are available in a variety of sensor packages. The most precise measurements are provided by several technological kinds for various uses.

Use of Position Sensors

- Steering systems on agricultural machinery

- Electric cart throttle control

- Conveyor speed measurement

- Printing process control

- Labelling control

- Ramp and bridge positioning

- Ticket barrier opening angles

- Measuring the thickness of dough in baking machines

- MRI machines

- CCTV camera positioning

The two types of position sensors are - Linear sensors and Rotary sensors.

Linear Position Sensors: These sensors convert linear movements or measurements into output signals for processing. There are linear position sensors everywhere. In order to guarantee that they are taking measurements in the most effective manner for the application at hand, linear position sensors make use of many sorts of technologies.

They can be contacting or non-contacting; non-contacting linear position sensors normally cost more but are wear-free and hence provide a longer life.

Rotary Position Sensors: Rotational motions are converted into output signals using rotary position sensors. Rotary position sensors can also be contacting or non-contacting, much as linear position sensors.

One sort of rotary position sensor will be more appropriate based on the degree of rotation or number of turns since rotary position sensors may also be single-turn or multi-turn.

Photo-electric sensors

Photoelectric sensors, also known as photo eyes, produce a beam of light that can detect the presence or absence of things and equipment, as well as changes in surface conditions. When the transmitted light is stopped or reflected by an item, a receiver detects the change in light patterns and recognizes the target object or surface. Photoelectric sensors are widely used in a variety of industrial production industries, including material handling, packaging, food and beverage, medical, and many more.

Depending on the model chosen, they can be used with or without a reflector, self-contained, long-range, heavy-duty, or small. There are several housing and mounting choices available to provide a proper fit that matches the demands of each application.

The sensor comprises the following components: the transmitter, which is the light source (LED); the receiver (phototransistor); a signal converter; and an amplifier. The phototransistor analyses incoming light, confirms that it is from the LED and then generates an output.
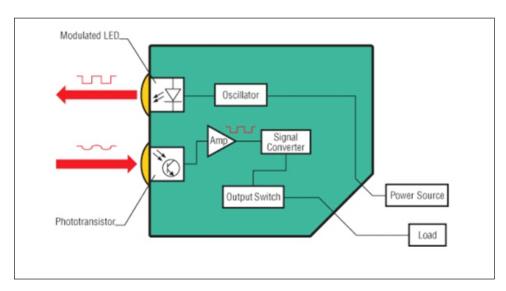
Fig. 5.1.27 Photo Electric Sensors

Light Intensity and Photoelectric Sensor: The phototransistor determines how much current may flow through the circuit based on the amount of light it detects. As a result, if the sensor is placed in a dark environment, it only allows a little amount of electricity to pass. When it senses a strong light, it will enable more electricity to flow. A photoresistor is formed of cadmium sulphide and has the highest resistance when the sensor is in the dark. When exposed to light, the photoresistor's resistance decreases in proportion to the intensity of the light. When connected to a circuit and balanced using a potentiometer, changes in light intensity are reflected in voltage. These sensors are frequently used for detecting light intensity because they are simple, dependable, and inexpensive.

Proximity Sensors

A proximity sensor is a non-contact sensor that detects the presence of an object or target when it enters its field of view. Depending on the type of proximity sensor, the sensor may detect a target via sound, light, infrared radiation (IR), or electromagnetic fields. Phones, recycling factories, self-driving vehicles, anti-aircraft systems, and assembly lines all use proximity sensors. There are several types of proximity sensors, and each uniquely detects targets. The inductive proximity sensor and the capacitive proximity sensor are the two most prevalent types of proximity sensors.

An inductive proximity sensor can only detect metal targets. This is because the sensor makes use of an electromagnetic field. When a metallic object enters the electromagnetic field, its inductive qualities modify the field's properties, alerting the proximity sensor to the presence of a metallic target. The target can be detected at a more considerable or lesser distance depending on how conductive the metal is.

In contrast, capacitive proximity sensors are not confined to metallic objects. These proximity sensors can detect anything that can conduct an electrical charge. In liquid-level sensing, capacitive sensors are often utilised. Capacitive sensor targets include but are not limited to glass, plastic, water, wood, metals, and other materials.

Proximity sensors are widely utilised in industrial and consumer robots. They are also employed in automobiles to determine the physical proximity of other vehicles and for parking assistance features.

5.1.11 Instrument Transformers

Instrument transformers play a significant part in the protection systems used in alternating current techniques to assess different electrical characteristics.

The variables are voltage, current, power, power factor, frequency, and energy. As the name indicates, these transformers are used in conjunction with appropriate instruments such as ammeters, voltmeters, wattmeters, and energy meters.

Instrument transformers are also employed with protective circuits to run relays, circuit breakers, and other devices to safeguard power systems; their operation is similar to regular transformers.

The Instrument transformer's primary function is to scale down the alternating (ac) power system voltage and current and measure the resulting signal.

Types of Instrument Transformers

Current Transformer (CT): A current transformer is used to reduce the power system's current to a lower level that may be monitored by a tiny rated ammeter (5A).

The load is linked in series with the primary winding of a current transformer (C.T). The load current is carried by the primary winding.

The primary winding has few turns, but the secondary winding has many more. The ammeter is linked straight across the secondary winding.

A current transformer can be considered a series transformer, with the primary winding connected in series with the circuit whose current has to be measured.

Voltage Transformers (VT): These are used to test high voltages with low-range voltmeters. The voltage transformer's primary winding is linked across a supply line (R, Y, and B) whose voltage is to be measured. The voltage measurement circuit is linked across the secondary winding. A voltage transformer is a parallel transformer, with the primary voltage transformer connected in parallel to the circuit whose voltage must be measured.

Voltage transformer transformation ratio = (Primary winding voltage/Secondary winding voltage).

5.1.12 Valves

Solenoid Valve: A solenoid valve is a valve that is operated by electricity. A solenoid, which is an electric coil with a moveable ferromagnetic core in the middle, is used in the valve. The plunger is the name given to this core.

The plunger shuts a tiny aperture while at rest. A magnetic field is created by passing an electric current through the coil. The magnetic field pulls on the plunger. As a result, the plunger is drawn into the centre of the coil, allowing the orifice to open. This is the fundamental concept that enables solenoid valves to open and close.

Solenoid valves are used in pipes to shut, dose, distribute, or mix gas or liquid flow. The circuit function of a solenoid valve expresses its specialised purpose. A 2/2-way valve has two positions and two ports (inlet and exit) (open or closed). A two-way valve can be 'usually closed' (closed when de-energized) or 'normally open' (open in a de-energized state).

Since it has three ports and two locations, a 3/2-way valve may switch between two circuits. 3/2-way valves can perform a variety of tasks, including generally closed, normally open, diverting, and universal. More ports or valve combinations are available in a single structure.
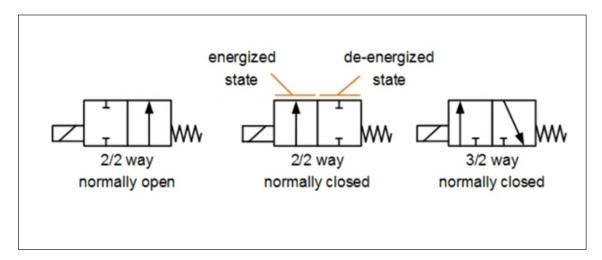
Fig. 5.1.28 Valve switches

The examples show a 2/2-way Normally Open (NO) valve, a 2/2-way Normally Closed (NC) valve and a 3/2-way Normally Closed valve.

Control Valve: A control valve is a mechanical device that regulates or manipulates the flow of fluids such as gas, oil, water, and steam. It is an example of a final control element and an essential control loop aspect. By far, the most frequent last control device utilised in the industry today is the control valve.

Electricity, pneumatics, or hydraulics can power control valves. A control valve receives a signal from a controller, such as a PLC, to move, causing a change in flow. Because the PLC signal is electrical, the control valve may require a device to convert it before it can function. A control valve comprises two parts: the valve and the actuator.

Linear Motion and Rotary Motion are the two types of control valves. A linear motion valve's stem and valve movement are up and down. The Gate Valve is a popular form of sliding control valve. A rotary motion valve rotates 90 degrees from open to closed. The Butterfly Valve is a popular type of rotary valve.

Exercise 🖊

1. Name five electrical components.

2. What do you understand by process instrumentation?

3. Explain Load Management Process.

4. What are open-loop and closed-loop control systems?

Notes

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Scan the QR Code to watch the related videos

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Process Instrumentation

6. Process of Setting Up Advanced Automation in Mechatronics

Unit 6.1 – Process of Setting Up Human Machine Interface (HMI)

Unit 6.2 – Automate the Material Handling System

Unit 6.3 – Automate the Material Handling System

Key Learning Outcomes

By the end of this module, participants will be able to:

1.   Explain the working of PLC and SCADA with HMI.
2.   Explain the concept of HMI and HMI operations in an automation environment.
3.   Describe the process of creating applications and tags.
4.   Explain the use of different monitoring systems
5.   Explain the working principle of the automatic storage and retrieval system.
6.   Explain how to download/upload programs.
7.   Explain how to create alarm messages.
8.   Describe the process of communication with PLC.
9.   Describe the process of detecting faults through diagnostics.
10. Explain the use of different monitoring systems.
11. Explain the functioning of relevant material handling systems used in the industry.
12. Explain the basic knowledge of automated material handling systems and various material transport systems.
13. Explain the function of a conveyor system and the working of cranes and hoists for lifting objects on the shop floor.
14. Explain the need for a conveyor system and rails for an automated material handling system.
15. State the relevant considerations to be made while selecting a material handling system.
16. Explain the use of automated guided vehicle systems.
17. Explain the functioning of monorails and rail-guided vehicles.
18. Explain different conveyor systems such as cranes and hoists.
19. Describe the process of analysing the material transport system.
20. Describe the process of carrying out engineering analysis of the automated storage system.
21. Explain the role of automated storage and retrieval system in Industry 4.0.
22. State the working principle of the carousel storage system.
23. Explain different barcode and RFID techniques.
24. Explain the use of robotics in material handling systems.
25. Explain the architecture of IoT and applicable trends.
26. Explain the IoT architecture and relevant platforms.
27. State the relevant trends in the adoption of IoT.
28. Describe the process of basic programming of controllers.
29. Explain the use of appropriate hardware platforms such as Intel Galileo, Edison, Arduino, Beaglebone, and Black & Raspberry Pi.
30. Explain the use of appropriate software platforms such as Intel XDK, Node-RED, VISUINO, Fritzing, and 123 circuits.
31. Explain the applicable machine-to-machine integration concepts.
32. Explain the basics of Python.

UNIT 6.1: Process of Setting up Human Machine Interface (HMI)

Unit Objectives ◎

By the end of this unit, participants will be able to:

1. Explain the working of PLC and SCADA with HMI.
2. Explain the concept of HMI and HMI operations in an automation environment.
3. Describe the process of creating applications and tags.
4. Explain the use of different monitoring systems
5. Explain the working principle of the automatic storage and retrieval system.
6. Explain how to download/upload programs.
7. Explain how to create alarm messages.
8. Describe the process of communication with PLC.
9. Describe the process of detecting faults through diagnostics.
10. State the working principle of the carousel storage system.
11. Describe the process of carrying out engineering analysis of the automated storage system.
12. Explain the role of automated storage and retrieval system in Industry 4.0.

6.1.1 Human Machine Interface

Human Machine Interface (HMI) systems can be considered a "window" into a process. It is used in industrial settings. This window could be on specialized equipment like operator panels or a computer. To enable information exchange between the user and the system, an HMI system has connections to an industry's hardware and software components.

A user interface or dashboard that enables human interaction with a machine is known as a human-machine interface. HMIs are utilised in various technologies around the world, from power plants to cellphones.
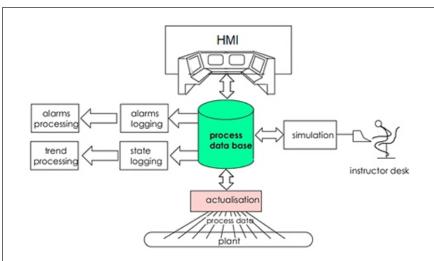
Fig. 6.1.1 HMI Process

The signals from the process are transmitted to the HMI using PLCs, RTU (remote units), drives, or devices with input/output cards in the computer. All of these devices must have a communication protocol that the HMI can comprehend.

HMIs are used for human-machine interaction but are not a component of any one piece of software. HMIs primarily assist users in comprehending and manipulating data through communicable devices like:

- Screens
- Buttons
- Levers
- Computer mouse
- Keyboards

6.1.2 HMI Software Functions

The functions of an HMI Software are:

- **Monitoring:** It is the process of getting instantaneous plant data and displaying it. To make reading easier to understand, this data can be presented as numbers, text, or images.

- **Supervision:** In addition to monitoring, this function also enables the possibility of changing the process's operating conditions from the computer.

- **Alarm:** The capacity to identify and communicate extraordinary events occurring during a process.

- **Control:** The capacity to use algorithms that modify the process's values and keep them within predetermined bounds.

- **Historian:** The capacity to show, store, and process data on a regular basis is known as historian. This data storage is a potent instrument for process improvement and correction.

6.1.3 Types of HMI

1. **Developed to measure:** They are created in a graphical programming environment like VC++, Visual Basic, Delphi, etc., to be measured.

2. **HMI canned packages:** The majority of the common SCADA system functions are covered by these software packages.

6.1.4 Working of PLC and SCADA with HMI

SCADA is the central database that houses and manages all of the operations. In order for the system to operate and communicate within the operational environment, it communicates with the PLC. The SCADA-PLC system may have an HMI, which could be in the form of a screen, buttons, levers, or a keyboard, allowing people to interact with it. Machines used in industries, computers, and automobiles are a few examples.

HMIs play a crucial role in providing information to the operator in industrial manufacturing. Any problems with the SCADA system can be found by the PLC system, which then presents them to the human operator through the HMI so they can be fixed.
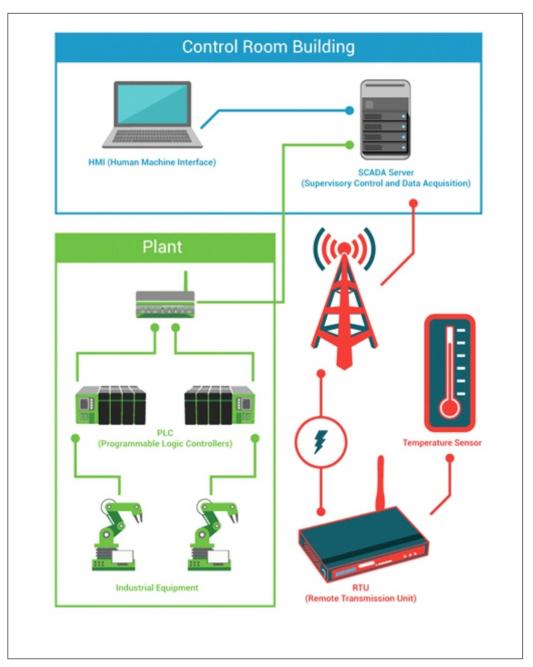
Fig. 6.1.2 Working of PLC and SCADA with HMI

6.1.5 Creating an App

The following steps should be followed to create an App

1. Generate an app idea

2. Conduct competitive market analysis

3. List the characteristics of the app in writing.

4. Create mockups of the app's design.

5. Create the graphic design of the app

6. Create an app marketing strategy.

7. Use one of these strategies to create the app.

8. Submit the app to the App Store

9. Market the app for maximum exposure

10. Improve the app with user feedback

6.1.6 Tagging

Tagging is a technique for adding more context to the applications so that one can examine and organise them more precisely in accordance with their needs and requirements.

There are two categories of tags:

- Application tags are a method for application filtering.

- Workflow tags make it easy to organise a collection of apps.

6.1.7 System Monitoring

System monitoring software is an umbrella category of software that enables organizations to manage, operate, and monitor IT systems in a centralized manner. Software that belongs under the general category of system monitoring enables businesses to centrally manage, run, and monitor their IT systems. Many managed service providers include system monitoring as a core service, in addition to various types of monitoring for applications, infrastructure, and services. IT teams employ system monitoring for a variety of tasks, including configuration and security management, backup and restore capabilities, patch management, and more.

System monitoring is used by IT companies to:

- Identify a system health baseline for comparison going ahead

- Identify fundamental issues before they have a negative effect on internal and external users.

- When a problem arises for the first time, gather data to enable continued development.

- Boost system performance and security.

6.1.8 Automated Storage and Retrieval System (AS/RS)

An Automated Storage and Retrieval System (AS/RS) is a set of tools and controls that work together to handle, store, and retrieve materials quickly, accurately, and precisely as needed. Smaller automated systems to bigger computer-controlled storage/retrieval systems that are fully integrated into manufacturing and/or distribution process are examples of systems. AS/RS is a general term for a number of computer-controlled techniques for automatically depositing and retrieving loads to and from specified storage locations.

Uses of Automated Storage and Retrieval System (ASRS)

In several locations throughout a plant, automated storage and retrieval systems are employed to support processing and picking:

- Order Picking: Order picking involves retrieving and presenting pickers with the necessary inventory.

- Storage: Providing extensive long-term buffering for slow to medium-moving tiny or large objects.

- Kitting: Providing a space for assembling component pieces in packages

- Consolidation: Creating a flexible space to store components and goods until a complete order can be put together and shipped. Used frequently for the store, B2B, and consumer orders.

- Assembling: preserving parts of the work piece for later manufacture.

- Production: Storage of equipment and parts needed for manufacturing processes.

- Replenishment: Storing extra stock to replenish auxiliary picking systems

- Security: Enclosing the storage area and adding software access controls.

6.1.9 Download/Upload PLC program directly from/to USB through HMI

The steps are as follows:

1. Copy the PLC program to a USB memory stick (.DVP).

2. Connect the memory stick to the HMI's USB port.

3. To access the HMI's system menu, press the "SYSTEM" button for a few seconds (at the back of the HMI). A "beep" sound will be heard.
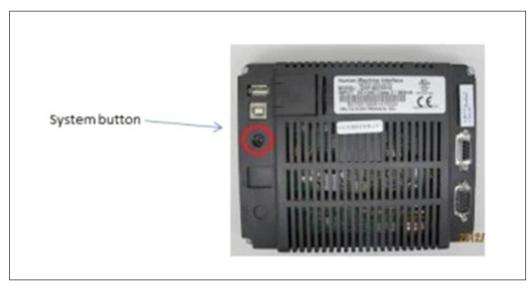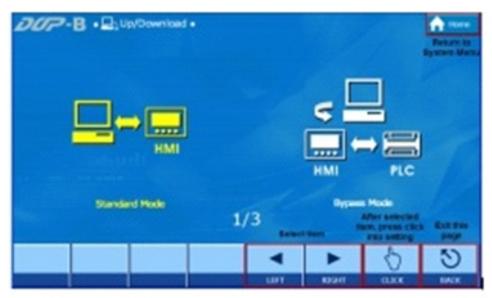
Fig. 6.1.3 System Button

4. Select the "Up/Download" menu option.

5. Using the "LEFT" and "RIGHT" buttons at the bottom, select "HMI *->PLC" as the transfer mode.
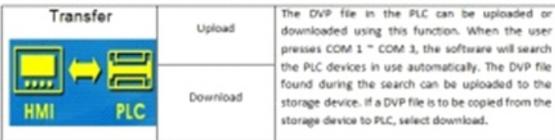
Fig. 6.1.4 Translator

6. Select the PLC program file which needs to be downloaded from "USB:/" on the left of the screen

7. Select the COM port connected to the PLC on the right side of the screen

Fig. 6.1.5 COM Port

8. After selecting COM1, HMI will automatically look up the PLC.

Fig. 6.1.6 Locking of PLC

9. After the HMI finds the PLC, the user can download the program by pressing the "Download" button
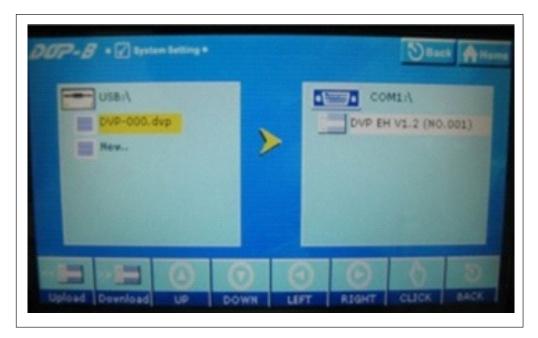
Fig. 6.1.7 Download Program

6.1.10 Alarm System

Every automated system must have alarms, errors, and cautions. They are used to monitor the system's operation as well as to avoid machine damage, which could result in catastrophic failures or the injury of an operator.

These alerts must be defined in PLC/HMI alarm systems close to the source in order to be effective. They frequently provide information to anyone using the equipment and are simple to troubleshoot.

What is an Alarm?

An alarm is a recognisable issue that prevents a machine from operating and necessitates rapid operator action to prevent the machine from shutting down. Similar to alarms, warnings don't necessarily call for operator action. Cycles that are already in motion—like when a gripper is not moving—are stopped by an alarm. A warning could prevent a cycle from the beginning.

Programming Alarms in PLC and HMI

Although the PLC is frequently integrated, there are possibilities to configure alarms in the HMI. To indicate that something is wrong, users can write functionality in the PLC. The HMI reads this information and flashes a LED indication. Locally, the alarm can now be seen at the HMI panel or another type of indication close to the machine.

Users must consider alternate techniques, such as email or push notifications, to add additional ways of informing engineers, managers, or operators who are not there.

6.1.11 PLC Communication

When the application needs to share data outside of the process, PLC communication is required. The data will be shared with an outside electronic device through a PLC communication. Twisted-pair wire can be used for PLC communication, or it can be done remotely using a phone or radio modem. A built-in communication interface using RS232, RS422, RS485, or Ethernet is present in many different types of PLC. A network can be used by the modern PLC to connect to other systems. Peer-peer communication between processors might be possible in PLCs used in big I/O systems. By doing this, each component of the intricate process would have individual control, and the communication link would allow the subsystems to cooperate.

6.1.12 Fault Diagnosis

Based on the data that are currently available for the system, the major goal of fault diagnosis is to identify the kind, size, and location of the defect as well as the time at which it was discovered. Figure 6.1.8 displays a general model-based fault diagnosis approach. Fault diagnosis is often accomplished in two steps. Utilizing the relevant input-output measurements from the system under consideration, a signal termed residual is first generated. The residual should be zero or very close to zero when the system is fault-free, and when the fault is present, the residual should be different from zero. Residual can be either a vector providing information about many faults or a scalar signal carrying information about a single failure.

The residual generator might be either a black-box model of the system or an analytical mathematical model. The decision-making process, which takes place in the second step, involves assessing the possibility of errors in the residuals. The kind of decision-making mechanism might range from a straightforward threshold to several complex statistical methods.
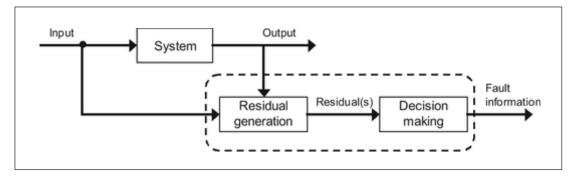
Fig. 6.1.8 Fault Diagnosis Process

6.1.13 Carousel Storage System

A dynamic approach known as a carousel storage system brings stored objects to the system operator using vertically revolving shelves. The "goods to man" idea governs how a carousel storage system operates. The time-consuming procedure of having employees trek back and forth across the warehouse in search of items that are stored is eliminated. To ensure that stored objects are readily located and recovered, specialised software is used to handle and manage the carousel storage system.

Storage and retrieval chores are safer thanks to carousel storage systems, which offer automated put and pick operations. Warehouse workplace mishaps are a thing of the past. All of this can be incorporated into the overall production process so that requested goods are rapidly discovered and sent to the system access point for retrieval. Carousel storage systems increase the effectiveness and economy of operations and production processes. Additionally, stored goods are delivered to the access point at an ergonomic height, improving worker health and safety.

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https://youtu.be/d9X
wKgSD3lo

Human Machine
Interface

https://youtu.be/AQ6
N1SmYyRc

Types of HMI

https://youtu.be/AQ6
N1SmYyRc

System
Monitoring

https://youtu.be/hjTg
h8Hjx24

Alarm System

UNIT 6.2: Automation of Material Handling System

Unit Objectives 🎯

By the end of this unit, participants will be able to:

1. Explain the functioning of relevant material handling systems used in the industry.
2. Explain the basic knowledge of automated material handling systems and various material transport systems.
3. Explain the function of a conveyor system and the working of cranes and hoists for lifting objects on the shop floor.
4. Explain the need for a conveyor system and rails for an automated material handling system.
5. State the relevant considerations to be made while selecting a material handling system.
6. Explain the use of automated guided vehicle systems.
7. Explain the functioning of monorails and rail-guided vehicles.
8. Explain different conveyor systems such as cranes and hoists.
9. Describe the process of analysing the material transport system.
10. Explain the use of robotics in material handling systems.

6.2.1 Material Handling System

The term "material handling" refers to the activities, tools, and processes involved in transporting, storing, safeguarding and managing materials inside a system.

The supply chain, which effectively covers the journey a product takes from the factory to your doorstep, is really a collection of procedures that cover everything from a product's production through distribution.

There are many stages in the supply chain. A supplier first sources the raw materials, which are subsequently produced. Before a distributor sends them to the direct customer or a sales facility, connecting with the consumer, these products are frequently delivered to a storage facility.

The protection, control, storage, and transfer of the materials and products are all done through the use of material handling systems, from production to consumption.

The route that goods follow to reach you is known as the supply chain. The machinery that transports them there are material handling systems. In addition, the disposal of these materials is a part of material handling.

6.2.2 Automated Material Handling System

An automated process that reduces or eliminates the need for people to check items in and out, organise materials, or transport totes and bins storing library material is known as Automated Material Handling System.

Check-in devices, sorters, conveyors, singulators, stackers and unstackers, totes, bins, trolleys, and tote carriers are just a few examples of the mechanical equipment used in AMH systems. There must be a scanner to read the bar code or a reader to read the RFID tag anywhere along with the procedure (or both). To prevent bins from overfilling and guarantee that each item is appropriately orientated and pushed or transported into the appropriate tote or bin, a variety of belts, pulleys, chutes, slides, and laser beams are used. Because they remove the check-out process from the staff's control, self-checkout machines are occasionally included in the AMH category. But they let the customer do it themselves, making it more of a self-service function than an automated feature.

6.2.3 Function of Automated Material Handling System

The operator places material at a "pick-up" site, which is where AMHSs may detect it, process the material identification to determine the next destination, and then deliver the material. These systems work best when the material information is, at the very least, accessible and visible in the systems used by manufacturing personnel, regardless of the mode of conveyance. In a completely functional AMHS, there would be no human contact with carriers, transport systems, or material. Instead, the AMHS would autonomously handle material identification, routing, and delivery to the proper tool, including loading and unloading the tool's load ports.

6.2.4 Selection of Material Handling System

Every enterprise that has to store or transfer commodities has a critical component called material handling. The safe, quick, and effective transportation of materials across a variety of operations, from production to distribution, storage, and delivery, is guaranteed by reliable material-handling equipment.

For selecting an appropriate material handling system, it is vital to select the appropriate equipment.

A list of the qualities of the materials to be handled is the first step in selecting the appropriate material handling equipment.

- Is the substance gas, liquid, or solid?

- What are the material's dimensions and shape?

- What is the weight of each material unit?

- Are the substances hazardous, sensitive, or corrosive?

- Do fragile materials require particular handling techniques?

Users can narrow down the variety of available material handling gear and equipment by taking into account these key variables. Let's say users are relocating food. They are renowned for being fragile and sensitive to the environment. Consider starting the search for equipment by looking at solutions made of sanitary stainless steel.

The choice of equipment that can be used narrows down if the materials are corrosive, poisonous, or delicate because only particular equipment can meet these requirements.

6.2.5 Material Transport System

All the regions utilised for receiving goods, producing items, picking orders, and shipping materials are quickly and effectively connected by the System Logistics handling and transportation systems, which also optimise storage and transport inside the warehouse.

The variety of material handling and transport system consists of:

- AGV (Automated Laser Guided Vehicles)

- SVL (System vehicle loops)

- Shuttle cars

- Pallet conveyors

6.2.6 Conveyor System

A conveyor system is a mechanical handling device for rapidly and effectively moving loads and materials automatically. Among other advantages, this technology minimises human error, lowers workplace risks, and lowers labour expenses. They are helpful for transporting large or heavy objects from one place to another. To move objects, a conveyor system may employ a belt, wheels, rollers, or a chain.

Benefits of Conveyor System

The primary function of a conveyor system is to move objects from one place to another. The structure enables the movement of items that are too big or heavy for people to handle by hand.

When moving products between locations, conveyor systems reduce the amount of time required. Conveyor systems make it easier to transfer objects up and down floors, a chore that is physically taxing when done manually by humans because they can be inclined to traverse numerous levels. Material can be automatically unloaded using inclined belts, negating the need for a receiver to be present at the other end.

Functioning of Conveyor System

Generally, a stretched belt across pulleys can be used to design conveyor systems. There are two or more pulleys available here. The belt can be formed into a closed loop around the pulleys to allow for frequent rotation. The drive pulley is one of the pulleys used to drive the belt that moves the objects from one location to another.

The drive pulley in the majority of conveyor systems is driven by a rotor in addition to a belt. Through the friction between the two faces, the belt is held to the rotor.

Fig. 6.2.1 Conveyor Belt

While traditional conveyor systems like moving walkways and grocery store conveyors are straight, the unit occasionally needs to revolve to transport the items to the proper place. For the belt to rotate properly, both the idler and drive pulley should run in a similar path, either in a clockwise direction or counterclockwise. There are special cone-shaped wheels and rotors for rotates that allow the belt to track a bend or twist without becoming twisted.

Types of Conveyor System

1. **Belt Conveyor:** The most popular and basic type of conveyor, belt conveyors may transport goods at a variety of speeds. They use a moving belt that is supported by a steel frame, which also holds the materials being transported. Sliding style refers to those that have a frame underneath providing support. A roller belt style refers to a belt that is held in place by several closely spaced rollers.
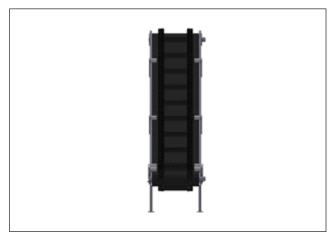
Fig. 6.2.2 Sliding Belt Conveyor

2. **Gravity Roller Conveyors:** A series of evenly spaced rollers coupled to a side frame make up gravity roller conveyors. A surface to place things on for movement is provided by the placement of the rollers. Materials move by gravity if a gravity roller conveyor is slanted or positioned at an angle. While different-sized components can be loaded onto a gravity roller conveyor, operators must be careful to prevent larger materials from colliding with smaller ones. Shipping businesses employ gravity roller conveyors to load and unload trucks.
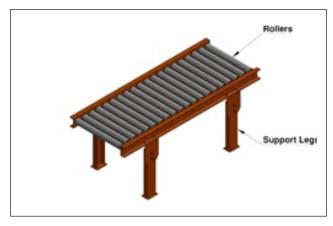
Fig. 6.2.3 Gravity Roller Conveyor

3. **Chain Conveyors:** The bottom of the goods to be moved can be made to touch by two or more sets of chains on chain conveyors. As they are moved, the materials rest on the chains. For products with uneven bottom surfaces or ones that are quite heavy, chain-driven conveyors are the best option. Pallets can be put directly on the ones with heavy frames. Chain conveyors move a variety of objects, which makes them work quite slowly.
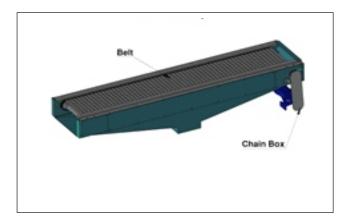
Fig. 6.2.4 Chain Conveyor

4. **Motorized Roller Conveyors:** In motorised roller conveyors, the regularly spread rollers are powered by motors that are mounted along with the conveyor frame. With the inclusion of motors, the concept is comparable to a gravity conveyor. The system's overall design and the load that needs to be transported will determine how many motors are needed. A chain or belt may be used to link the rollers. In order to prevent components from being packed together, some systems have a sensor that begins and stops the motor.
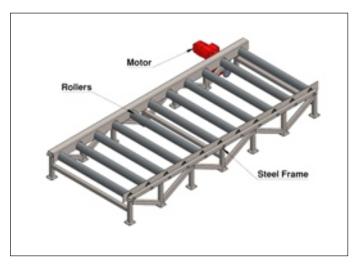
Fig. 6.2.5 Motorized Roller Conveyor

5. **Monorail Conveyors:** Monorail conveying systems are perfect for use over large distances and have carriers to carry items. Signal wires from conductor lines inside the mounted rails provide electricity to the rails, which are suspended from the structure of the building. Utilizing the space above the production area are monorail conveyors. In certain designs, the carriers descend to the production level before rising and moving out of the way.
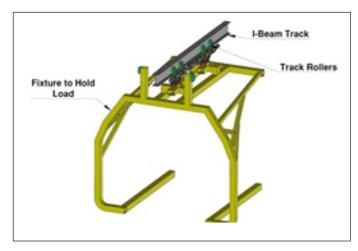
Fig. 6.2.6 Monorail Conveyor

6. **Pneumatic Conveyors:** Bulk goods are transported using pneumatic conveyors, which pressurise a gas to force the material through a pipeline. Powders or granular materials are raised and pushed through the pipe when the pipeline's pressure increases.

Fig. 6.2.7 Pneumatic Dense Phase Conveying System

6.2.7 Automated Guided Vehicle System

Automatic guided vehicles (AGVs) are load carriers that move along a facility's floor without a driver or operator on board. They are computer-controlled and wheel-based. Software-based guidance systems, as well as sensor-based guiding systems, control their movement. AGVs offer safe load transportation because they follow a predetermined path, accelerate and decelerate precisely, and have bumpers that automatically detect obstacles. Transportation of raw materials, work-in-progress, and finished goods in support of manufacturing production lines, as well as storage/retrieval or other movements in support of picking in warehousing and distribution applications, are typical applications for automated guided vehicles (AGVs).

There are many kinds of AGVs. These consist of:

* **Automated carts:** These are the most basic type of AGV with the fewest functionality for the most affordable deployment.

* **Unit load AGVs:** Individual vehicles that transport goods on forks or on the AGV's deck (usually pallets, bins, carts, or bundles). Roll-handling AGVs are designed specifically to handle large steel or paper rolls.

* **Tugger AGVs:** Powered vehicles known as "tugger AGVs" pull a line of non-motorized trailers, each towing a load.

* **Automated forklifts (AGVs):** These are forklift trucks that have had their controls modified to operate automatically.

AGV systems are composed of several vehicles that go along pre-established guide lines and are often battery-powered. The facility's vehicles use a variety of guiding systems, such as lasers, optical sensors, magnet/gyroscope-based inertial guidance, floor-surface mounted magnetic tape or bars, to navigate. For a scalable and flexible material handling solution, these guidance technologies make it simple to alter the paths and expand the AGV system in response to facility modifications.

Computer-based software uses wireless connections to gather information about each AGV's present location for real-time control and monitoring of many AGVs, then communicates with software for destination and routing logic. By wirelessly conveying specified duties to the AGVs through radio frequency, the software controls how the vehicles move (RF). Stops, starts, speed changes, lifting, lowering, multi-point turns, reverses, leaving the guidance path, and interacting with other material handling machinery and systems — both automated and static — are all examples of instructions.

6.2.8 Rail Guided Vehicle System

The foundation of the Rail Guided Vehicle System is a fleet of high-speed, floored, intelligent rail-guided vehicles equipped for a variety of cargo handling tasks. This technology is a quick, affordable, and effective solution for linking extremely far-flung sites or performing sophisticated sorting tasks. When the load handling units are not standardised, it is also a fascinating substitute for lengthy conveyor lines. The Rail Guided Vehicles (RGVs) and their floor-fixed track rail make up the system (including running rails, rail switching devices, lifts and maintenance areas, among others). Additionally, we might supply particular components (such as fences, access controls, or light barriers) necessary to guarantee an entirely safe working environment for operators.

Regardless of how complicated the route is, due to the modular and adaptable architecture, smooth and consistent transportation can be ensured. Due to the interchangeability of all RGVs in the system, redundancy is another important aspect of this handling approach.

Principal programmable characteristics:

- Performance of the RGV system; Pallets, containers, totes, cartons, frames; Types of handled load units;

- Quantity and kind of load-handling equipment;

- Total weight is the load capacity.

- Working circumstances.

6.2.9 Robotic Material Handling

In the industrial sector, robotic material handling and tending systems are prevalent. Robotic arms transferring production parts—typically on or off a conveyor belt or to hold a part in place for manufacture—are referred to as material handling. Similar but more precise, machine tending describes the use of a robotic arm to load and unload a stationary industrial machine.

Systems for robotic machine tending and material handling are in high demand because they consistently increase productivity across a wide range of applications.

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Scan the QR Code to watch the related videos

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oSSJn6oM

Automation of Material Handling
System

UNIT 6.3: Internet of Things (IoT) in Mechatronics

Unit Objectives ◎

By the end of this unit, participants will be able to:

1. Explain the architecture of IoT and applicable trends.

2. Explain the IoT architecture and relevant platforms.

3. State the relevant trends in the adoption of IoT.

4. Explain the use of appropriate hardware platforms such as Intel Galileo, Edison, Arduino, Beaglebone, and Black & Raspberry Pi.

5. Explain the use of appropriate software platforms such as Intel XDK, Node-RED, VISUINO, Fritzing, and 123 circuits.

6. Explain the applicable machine-to-machine integration concepts.

7. Explain the basics of Python.

8. Explain different barcode and RFID techniques.

6.3.1 Internet of Things (IoT)

The Internet of Things (IoT) is a concept in which things with sensors, actuators, and processors interact with each other in order to accomplish a task.

There are different IoT architecture strategies, and their success and applicability are strongly correlated with the calibre of their constituent parts and how they work together.

Basic Elements of IoT Architecture

IoT architecture consists of a number of interconnected IoT system building elements that work together to ensure that sensor-generated device data is gathered, processed, and stored in the big data warehouse and that commands issued by a user application are carried out by actuators on devices.

The elements of IoT architecture

Things - An item that has actuators that enable things to act and sensors that collect data to be shared across a network is referred to as a "thing" (such as turning on or off the light, opening or closing a door, changing the engine's rotational speed, and more). This idea encompasses everything that can be imagined, including refrigerators, street lighting, structures, cars, production equipment, medical equipment, and more. Sensors may need to keep track of, for example, what occurs in the environment that is closest to a thing, as they are not always physically related to the items they are monitoring.

Gateways. Through the gateways, data is transferred from things to the cloud and vice versa. A gateway facilitates data pretreatment and filtering before moving it to the cloud (to reduce the amount of data needed for thorough processing and storage), permits connectivity between things and the cloud component of the IoT system, and delivers control orders from the cloud to things. Then, using their actuators, things carry out commands.
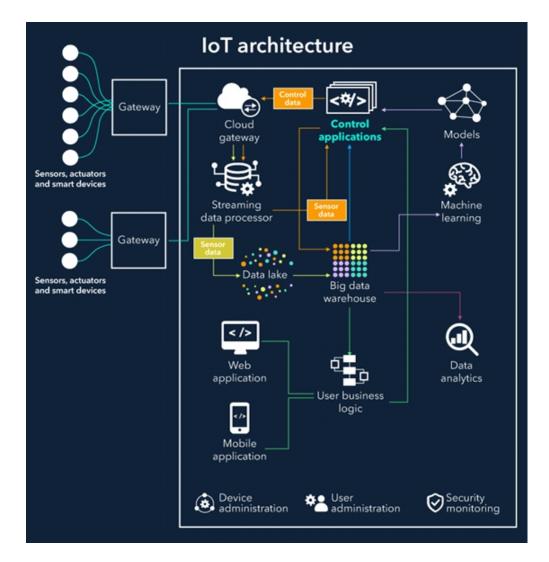
Fig. 6.3.1 IoT Architecture

Cloud gateways enable data compression and secure data transmission between field gateways and cloud IoT servers. Additionally, it makes sure that multiple protocols work together and communicate with field gateways using the protocol that the gateways support.

The efficient transfer of input data to a data lake and control applications is ensured by a streaming data processor. The rare loss or corruption of data is impossible.

Lake of data. The data produced by linked devices is kept in its original format in a data lake. Big data is delivered in "streams" or "batches." The data is extracted from a data lake and loaded into a big data warehouse when it is required for insightful analyses.

Big data storage. A big data warehouse receives the filtered and pre-processed data from a data lake that is required for useful insights. All of the data in a massive data warehouse has been cleansed, structured, and matched (compared to a data lake which contains all sorts of data generated by sensors). Additionally, data warehouses keep track of the commands control programmes provide to objects as well as context information about items, sensors, and sensors' installation locations.

ML-generated models and machine learning. It is possible to develop more accurate and effective models for control applications using machine learning. Based on the historical data gathered in a big data warehouse, models are routinely updated (for instance, once a week or once a month). New models are employed by control applications after being evaluated for applicability and efficacy by data analysts.

6.3.2 Hardware Platforms

A hardware platform is a collection of compatible hardware that enables the use of software programmes. Programs must be created specifically for a platform that uses a specified type of processor and related hardware components since each unique hardware platform has its own machine language.

A few examples of Hardware Platforms are:

Fig. 6.3.2 Hardware Platforms

6.3.3 Software Platforms

A platform is an ecosystem of resources and a collection of software that enables you to expand your business. The value of a platform derives not only from the capabilities it offers but also from the connections it can make across internal tools, teams, data, and processes.
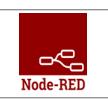
Fig. 6.3.3 Software Platforms

6.3.4 IoT Trends

Some commonly adopted trends are:

1. **Facial and objection recognition:** These recognition technologies have led to an increase in the use of video for tracking and monitoring faces and objects. IoT-enabled cameras use thermal imaging, which measures heat and creates images, to assure visibility in harsh settings like heavy rain, snow, or foggy conditions.

2. **Telematics video surveillance:** The telematics video monitoring sector could undergo a revolution because of 5G networks' increased capacity and decreased latency. It will make sure that consumers always have a link to their fleet video systems, no matter the weather or the flow of traffic.

3. **Wireless BLE-powered devices:** Wireless data transport is made simpler by BLE and wireless sensors. Because the technologies are simple enough to incorporate an expanding number of sensors, they are employed in various industries, including security, retail, and healthcare.

4. **4G LTE-M networks:** Since 2G and 3G networks are unable to handle the rising number of linked IoT devices, the 4G LTE-M network is quickly replacing them.

   The ideal option for IoT devices is 4G LTE-M networks because they have a larger range and reduced power consumption. In several nations, including the US, Mexico, France, Germany, Canada, and India, the 2G and 3G networks will soon be phased out.

5. **Zero-risk eco-driving:** Eco-driving is a cutting-edge approach that enables organisations to better manage employee safety and fleet maintenance. Employers can use the technology to track when drivers accelerate quickly, stop forcefully, or drive irresponsibly by gathering data from sensors.

6.3.5 Machine-to-Machine Integration Concepts

The term "Machine-to-Machine Communication," or M2M, refers to the exchange of data between two machines without the use of a human interface or other human involvement. In the industrial Internet of Things, this includes wireless communications, powerline connections (PLC), and serial connections (IoT). By moving to wireless, M2M communication has become considerably simpler, and more applications can now be connected.

In general, cellular communication for embedded devices is often meant when someone mentions M2M communication. In this instance, M2M communication examples include vending machines transmitting inventory data or ATMs receiving authorization to dispense cash.

6.3.6 Python

Simple object-oriented programming techniques and very effective high-level data structures are used in the Python programming language. Dynamic typing and a very short and basic syntax are also used in Python programming. You would be hard-pressed to find a better choice than Python if you want a language for quick application development and scripting in a number of domains.

The interpretive aspect of Python programming is one of its main advantages. On all popular operating systems, the Python interpreter and standard library run without issue and are available on the Python website in binary or source form. The Python programming language is also available for free distribution, and the same website also offers hints and links to more third-party tools, applications, modules, and documentation.

It is simple to add new data types or functions to the Python interpreter in C++, C, or any other language that can be called from C. For adaptable applications, the Python programming language serves as an extension.

It is used for:

- Web development (server-side),

- Software development,

- Mathematics,

- System scripting.

6.3.7 Barcodes

A barcode is essentially a licence plate that connects to data files. All kinds of information can be represented by these character strings. This information is encoded in barcode languages (symbologies) for quick transfer through a scanner to a computer rather than physically writing and copying it. Each symbology has a specific algorithm to uniformly encode and save these characters.

UPC is one of the most widely used barcode kinds (Universal Product Codes). Retail products are labelled with the help of this barcode. Almost every sale item in the market and in every grocery store in the US has it. It is a 12-digit number with just numeric characters. The first six digits of the barcode are a unique number that GS1 assigns to each product. The following five digits are assigned by the product's maker. Each product has a distinct UPC that is used by its producers to identify it.
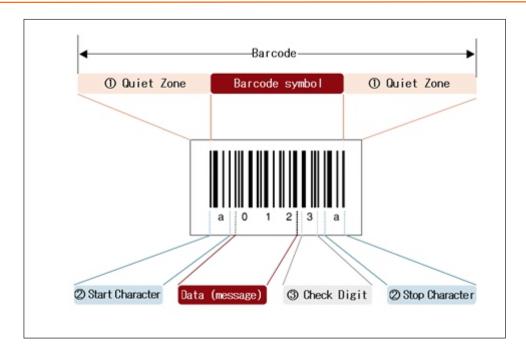
Fig. 6.3.4 Barcode description

They can digitally scan and trace the product with the use of these barcodes. The ability to scan these barcodes to track mail and parcels is provided by many top-notch management programmes, like PackageX. Users may simply monitor where their stuff is and when they will receive it. Other forms of barcodes that are frequently used are:

1. Code 39

2. Code 128

3. GS1-128

4. Codabar

5. EAN-13 and EAN-8

6. ITF-14

6.3.8 Radio Frequency Identification (RFID)

RFID is the name given to a wireless technology that consists of two parts: tags and readers. A reader is an electronic gadget with one or more antennas that transmit radio waves and take in signals from RFID tags. Tags can be passive or active, using radio waves to transmit their identity and other information to adjacent readers. Without a battery, passive RFID tags are powered by the reader. The batteries are used to power active RFID tags.

RFID tags can contain a variety of data, ranging from a single serial number to many pages of information. Readers can be fixed on a post or suspended from the ceiling, or they can be portable so they can be carried by hand. Reader systems may also be included in the design of a cabinet, room, or structure.

Radio waves with a variety of frequencies are used by RFID systems to send data. RFID technology has the following uses in medical facilities and healthcare facilities:

- Inventory control

- Equipment tracking

- Out-of-bed detection and fall detection

- Personnel tracking

- Ensuring that patients receive the correct medications and medical devices

- Preventing the distribution of counterfeit drugs and medical devices

- Monitoring patients

- Providing data for electronic medical records systems

Exercise

1. Explain the functioning of the HMI System?

2. Explain what a Material Handling System is.

3. Name the Conveyor Systems.

4. Explain the IoT Architecture.

Notes

7. Soft Skills and Work Ethics

Unit 7.1 - Effective Communication and Coordination at Work

Unit 7.2 - Working Effectively and Maintaining Discipline at Work

Unit 7.3 - Maintaining Social Diversity at Work

ELE/N9905

Key Learning Outcomes

By the end of this module, participants will be able to:

1. State the importance of work ethics and workplace etiquette.
2. State the importance of effective communication and interpersonal skills.
3. Explain ways to maintain discipline in the workplace.
4. Discuss the common reasons for interpersonal conflict and ways of managing them effectively.

UNIT 7.1: Effective Communication and Coordination at Work

Unit Objectives ◎

By the end of this unit, participants will be able to:

1. Work effectively at the workplace.
2. Demonstrate practices related to gender and PwD sensitization.

7.1.1 Importance of Work Ethics and Workplace Etiquette

Workplace ethics are a set of moral and legal guidelines that organizations follow. These guidelines influence the way customers and employees interact with an organization. Workplace ethics essentially guide how an organization serves its clients and treats its employees.

For example, if a company seeks to fulfil the promises it makes, it may develop processes and set up a robust support system to address this policy and build customer/client loyalty. To achieve this goal, the company may implement specific incentive programs for employees to encourage them to produce high-quality work and ensure the organization fulfils the promises it makes to its clients/ customers.

Many organizations, often the large ones, set detailed ethical codes to guide their operations and control how the organizational processes impact the stakeholders. These ethics usually help organizations maintain certain standards of responsibility, accountability, professionalism and among others, as they navigate through different challenges and day-to-day circumstances. By following these guidelines, organizations often experience several benefits that improve the lives of stakeholders, such as customers, employees, leaders, etc.

Examples of Common Workplace Ethics

Accountability
Responsibility
Equality
Transparency
Trust
Fulfilling promises
Loyalty
Fairness
Cooperation
Dedication
Discipline
Professionalism

Fig. 7.1.1 Examples of Common Workplace Ethics

Workplace ethics are essential for a successful organization with a satisfied and loyal team. High ethical standards help in ensuring all stakeholders, such as customers, investors, employees, and other individuals involved in the workplace operations, feel the organization is safeguarding their interests. By creating and implementing ethical guidelines, organizations can keep the best interests of their employees in mind while maintaining a positive influence on those they impact through their processes.

As a result, employees maintain the organization's best interests by being ethical in their daily work duties. For example, fairly-treated employees of an organization who understand the organization's commitments to environmental sustainability are usually less likely to behave in a manner that causes harm to the environment. Thus, they help maintain a positive public image of the organization. It means that workplace ethics help in maintaining reciprocal relationships that benefit organizations at large and the individuals associated with and influenced by the organizational policies.

Benefits of Workplace Ethics

There are various benefits of implementing workplace ethics. When organizations hold themselves to high ethical standards, leaders, stakeholders, and the general public can experience significant improvements. Following are some of the key benefits of employing ethics in the workplace:

| Employee satisfaction |
| Improved workplace culture |
| Legal compliance |
| Improved public reputation |
| Customer engagement and loyalty |
| Streamlined decision-making processes |

Fig. 7.1.2 Benefits of Workplace Ethics

7.1.2 Interpersonal Communication

Interpersonal communication is a process that involves sharing ideas and emotions with another person, both - verbally and non-verbally. It is essential to interact effectively with others in both personal and professional lives. In professional life or the workplace, strong interpersonal skills play a crucial role in achieving effective collaboration with colleagues.

Interpersonal Skills

Interpersonal skills, in other terms, are known as people skills, which are used to communicate and interact with others effectively. These are soft skills one uses to communicate with others and understand them. One uses these skills in daily life while interacting with people.

Examples of Interpersonal Skills

- Active listening
- Teamwork
- Responsibility
- Dependability
- Leadership
- Motivation
- Flexibility
- Patience
- Empathy
- Conflict resolution
- Negotiation

Fig 7.1.3 Examples of Interpersonal Skills

Numerous interpersonal skills involve communication. Communication can be verbal, such as persuasion or tone of voice — or non-verbal, such as listening and body language.

Importance of Interpersonal Skills

Interpersonal skills are essential for communicating and collaborating with groups and individuals in both personal and professional life. People with strong interpersonal skills often are able to build good relationships and also tend to work well with others. Most people often enjoy working with co-workers who have good interpersonal skills.

Among other benefits of good interpersonal skills is the ability to solve problems and make the best decisions. One can use the ability to understand others and good interpersonal communication skills to find the best solution or make the best decisions in the interest of everyone involved. Strong interpersonal skills help individuals work well in teams and collaborate effectively. Usually, people who possess good interpersonal skills also tend to be good leaders, owing to their ability to communicate well with others and motivate the people around them.

Interpersonal communication is the key to working in a team environment and working collectively to achieve shared goals. Following are the interpersonal communication skills that vital for success at work:

Verbal Communication

The ability to speak clearly, appropriately and confidently can help one communicate effectively with others. It is vital to select the appropriate vocabulary and tone for the target audience.

For example – one should speak formally and professionally in the work environment, while informal language is acceptable in an intimate environment with close friends and family. Also, one should avoid using complex or technical language while communicating with an audience that may not be familiar with it. Using simple language in a courteous tone helps achieve better communication, irrespective of the audience.

Active Listening

Active listening is defined as the ability to pay complete or undivided attention to someone when they speak and understand what they are saying. It is important for effective communication because without understanding what the speaker is saying, it becomes difficult to carry forward a conversation. One should ensure to use appropriate verbal and non-verbal responses, e.g. eye contact, nodding, or smiling, to show interest in what the speaker says. Active listening is also about paying attention to the speaker's body language and visual cues. Asking and answering questions is one of the best ways to demonstrate an interest in conversing with the other person.

Active listening is critical for communicating effectively without ambiguity. It helps one understand the information or instructions being shared. It may also encourage co-workers to share their ideas, which ultimately helps achieve collaboration.

Body Language

One's expression, posture, and gestures are as important as verbal communication. One should practice open body language to encourage positivity and trust while communicating. Open body language includes - maintaining eye contact, nodding, smiling and being comfortable. On the other hand, one should avoid closed body language, e.g. crossed arms, shifting eyes and restless behaviour.

Empathy

Empathy is the ability to understand the emotions, ideas and needs of others from their point of view. Empathy is also known as emotional intelligence. Empathetic people are good at being aware of others' emotions and compassionate when communicating with them. Being empathetic in the workplace can be good to boost the morale of employees and improve productivity. By showing empathy, one can gain the trust and respect of others.

Conflict Resolution

One can use interpersonal communication skills to help resolve disagreements and conflicts in the workplace. This involves the application of negotiation and persuasion skills to resolve arguments between conflicting parties. It is also important to evaluate and understand both sides of the argument by listening closely to everyone involved and finding an amicable solution acceptable to all.

Teamwork

Employees who communicate and work well in a team often have better chances of achieving success and common goals. Being a team player can help one avoid conflicts and improve productivity. One can do this by offering to help co-workers when required and asking for their feedback and ideas. When team members give their opinions or advice, one should positively receive and react to the opinions/advice. One should be optimistic and encouraging when working in groups.

Improving Interpersonal Skills

One can develop interpersonal skills by practising good communication and setting goals for improvement. One should consider the following tips to improve their interpersonal skills:

- One should ask for feedback from co-workers, managers, family or friends to figure out what needs improvement concerning their interpersonal skills.

- One can identify the areas of interpersonal communication to strengthen by watching others.

- One can learn and improve interpersonal skills by observing co-workers, company leaders and professionals who possess good interpersonal skills. This includes watching and listening to them to note how they communicate and the body language used by them. It is vital to note their speed of speaking, tone of voice, and the way they engage with others. One should practice and apply such traits in their own interactions and relationships.

- One should learn to control their emotions. If stressed or upset, one should wait until being calm to have a conversation. One is more likely to communicate effectively and confidently when not under stress.

- One can reflect on their personal and professional conversations to identify the scope of improvement and learn how to handle conversations better or communicate more clearly. It helps to consider whether one could have reacted differently in a particular situation or used specific words or positive body language more effectively. It is also vital to note the successful and positive interactions to understand why they are successful.

- One should practice interpersonal skills by putting oneself in positions where one can build relationships and use interpersonal skills. For example, one can join groups that have organized meetings or social events. These could be industry-specific groups or groups with members who share an interest or hobby.

- Paying attention to family, friends and co-workers and making efforts to interact with them helps a lot. One should complement their family, friends and co-workers on their good ideas, hard work and achievements. Trying to understand someone's interests and showing interest in knowing them can help one build strong interpersonal skills. Offering to help someone, especially in difficult situations, helps build stronger and positive workplace relationships.

- One should avoid distractions, such as a mobile phone, while interacting with someone. Giving someone full attention while avoiding distractions helps achieve a clear exchange of ideas. By listening with focus, one can understand and respond effectively.

- One can attend appropriate courses on interpersonal skills or sign up for workshops at work to improve interpersonal skills. One can find many resources online also, such as online videos.

- For personal mentoring, one can approach a trusted family member, friend, co-worker, or current/ former employer. A person one looks up to with respect and admires is often a good choice to be selected as a mentor. One can even hire a professional career or communication coach.

Interpersonal communication skills often help one boost their morale, be more productive in the workplace, complete team projects smoothly and build positive and strong relationships with co-workers.

Good conflict resolution skills can help one contribute to creating a collaborative and positive work environment. With the ability to resolve conflicts, one can earn the trust and respect of co-workers.

Notes

UNIT 7.2: Working Effectively and Maintaining Discipline at Work

Unit Objectives ⊚

By the end of this unit, participants will be able to:

1. Discuss the importance of following organizational guidelines for dress code, time schedules, language usage and other behavioural aspects.

2. Explain the importance of working as per the workflow of the organization to receive instructions and report problems.

3. Explain the importance of conveying information/instructions as per defined protocols to the authorised persons/team members.

4. Explain the common workplace guidelines and legal requirements on non-disclosure and confidentiality of business-sensitive information.

5. Describe the process of reporting grievances and unethical conduct such as data breaches, sexual harassment at the workplace, etc.

6. Discuss ways of dealing with heightened emotions of self and others.

7.2.1 Discipline at Work

Discipline is essential for organizational success. It helps improve productivity, reduce conflict and prevent misconduct in the workplace. It is important to have rules concerning workplace discipline and ensure that all employees comply with them. In the absence of discipline, a workplace may experience conflicts, bullying, unethical behaviour and poor employee performance. An efficient workplace disciplinary process helps create transparency in the organization. Benefits of disciplinary standards:

> **All employees follow the same rules which helps establish uniformity and equality in the workplace**

> **Managers and supervisors have defined guidelines on what action to take while initiating disciplinary action**

> **With well-defined and enforced disciplinary rules, an organization can avoid various safety, security, rupational risks**

Fig 7.2.1 Benefits of Disciplinary Standards

Maintaining an organized and cohesive workforce requires maintaining discipline in both personal and professional behaviour. It is important to follow the appropriate measures to keep employees in line without affecting their morale.

Defining Discipline

The first and crucial step in maintaining workplace discipline is to define what is meant by discipline. It helps to evaluate common discipline problems and devise guidelines for handling them effectively.

Among a number of areas, discipline usually covers:

Attendance

Deadlines

Dress code

Company processes and procedures

Harassment

Personal time use in the office

Personal use of company assets

Fig 7.2.2 Examples of Workplace Discipline

According to demography and local issues, it may also include substance use and related issues.

It is vital for a workplace to have an employee handbook or company policy guide, to serve as a rulebook for employees to follow. The employee handbook/ company policy guide should be reviewed and updated periodically according to any issues or areas, or concerns identified concerning workplace discipline. Such manuals should also cover all the laws and regulations governing workplace behaviour.

Defining and documenting workplace rules aids in their implementation, ensuring little or no ambiguity. All employees in a workplace should also have easy access to the workplace guidelines so that they can refer to them to get clarity whenever required. To maintain discipline at work, it is also critical to ensure uniform application of workplace guidelines to all employees without exception.

7.2.2 Employee Code of Conduct

The employee code of conduct manual serves as a guide for employees to inform them regarding the behaviour expected from them at work. It helps create a good work environment with consistent behaviour from employees. The manual should list examples of acceptable and not acceptable behaviours at work. The code of conduct should be discussed with employees so that they have the clarifications required.

For example, an organization may create guidelines concerning the conduct with clients to ensure no contact is made with them except for business purposes, also prescribing the use of appropriate means of communication.

Employees should have a clear understanding concerning their job responsibilities and the behaviour expected from them with all stakeholders, e.g. company personnel, clients and associated third parties. It is critical to have documented guidelines for employees to follow concerning all aspects of work.

It should also document the disciplinary action to be followed in case of non-compliance, e.g. verbal and then written warning, temporary suspension or eventual termination of service in case of repeated non-compliance with the employee code of conduct. Employees should know what the company rules are and what will happen if they break the rules. However, disciplinary action should be initiated only when reasonably required to avoid its misuse for employee harassment.

There should also be an effective mechanism for employees to raise their concerns/ grievances and have them addressed while maintaining privacy, as required, e.g. raising concerns regarding the behaviour of a co-worker.

The employee code of conduct manual must be duly reviewed and approved by the concerned stakeholders, such as the Human Resources (HR) department and company executives.

7.2.3 Interpersonal Conflicts

Interpersonal conflict is any type of conflict between two or more people. These are found in both - personal and professional relationships - among friends, family, and co-workers. In the workplace, interpersonal conflict is often observed when a person or group of people interfere with another person's attempts at completing assignments and achieving goals. It is critical to resolve conflicts in the workplace to boost the morale of employees, repair working relationships among them, and improve customer satisfaction.

Reasons for Workplace Conflicts

Workplace conflicts are often observed when two or more people have different points of view. This can happen between managers, co-workers, or clients and customers. In general, interpersonal conflicts are caused by a lack of communication or unclear communication.

Some of the leading reasons for workplace conflicts are:

- Difference in values

- Personality clashes

- Poor communication

Example of poor communication – if a manager reassigns a task to another employee without communicating with the employee to whom it was originally assigned, interpersonal conflict can arise among them. This may potentially make the first employee, i.e. who was originally assigned the task, feel slighted and mistrusted by the manager. It may even cause animosity in the first employee toward the employee who has now been assigned the task.

Types of Interpersonal Conflict

Following are the four types of interpersonal conflicts:

1. **Policy-related interpersonal conflict**

    When a conflict relates to a decision or situation that involves both parties, it can be called a policy-related interpersonal conflict. Example – two people or groups working on the same project, trying to adopt different approaches. To resolve policy-related interpersonal conflicts, the parties involved should try to look for a win-win situation or make a compromise. This is especially critical to resolve trivial issues so that work is not affected and common goals are achieved.

2. **Pseudo-conflicts**

    Pseudo-conflict arises when two people or groups want different things and cannot reach an agreement. Pseudo-conflicts usually involve trivial disagreements that tend to hide the root of the issue.

3. **Ego-related interpersonal conflicts**

    In ego conflicts, losing the argument may hurt or damage a person's pride. Sometimes ego conflicts arise when a number of small conflicts pile up on being left unresolved. To resolve ego-related conflicts, it's best to find the root of the issue and work towards a resolution.

4. **Value-related interpersonal conflicts**

    Sometimes conflicts may occur between people when they have different value systems. Such conflicts can be difficult to identify initially, making the people involved think the other party is being disagreeable or stubborn, wherein they just have different values. Some co-workers may highly value their personal/ family time after office that they may be unreachable to clients during non-office hours, while others may place a high value on client satisfaction and may still be available for clients during non-office hours. Conflict may arise among such people when they may be required to coordinate to help a client during after-office hours. Value-related interpersonal conflicts are often difficult to settle since neither party likes to compromise.

Resolving Interpersonal Conflicts

Conflicts are usually likely in the workplace; they can, however, be prevented. Often resolving interpersonal conflicts through open communication helps build a stronger relationship, paving the way for effective coordination and success. Some ways to resolve interpersonal conflict:

-   **Communication:** A great way to resolve interpersonal conflicts is for the opposing parties to listen to one another's opinions and understand their viewpoints. Meeting in person and keeping the conversation goal-oriented is important. One can have effective communication by following some measures, e.g. staying on the topic, listening actively, being mindful of the body language, maintaining eye contact, etc.

- **Active Listening:** One should patiently listen to what the other person is saying without interrupting or talking over them. It helps one display empathy and get to the root of the issue. Asking questions to seek clarification when required helps in clear communication and conveys to the other person that one is listening to them. Practising active listening is a great way to improve one's communication skills.

- **Displaying Empathy:** Listening attentively and identifying the anxieties/ issues of co-workers is a great way to show empathy and concern. It is essential to understand their feelings and actions to encourage honesty and avoid future conflict.

- **Not Holding Grudges:** With different types of people and personalities in a workplace, it is common for co-workers to have conflicts. It is best to accept the difference in opinions and move on. Being forgiving and letting go of grudges allows one to focus on the positive side of things and perform better at work.

Work-related interpersonal conflicts can be complicated because different people have different leadership styles, personality characteristics, job responsibilities and ways in which they interact. One should learn to look above interpersonal conflicts, resolving them to ensure work goals and environment are not affected.

7.2.4 Importance of Following Organizational Guidelines

Policies and procedures or organizational guidelines are essential for any organization. These provide a road map for the operations of the organization. These are also critical in ensuring compliance with the applicable laws and regulations by guiding the decision-making process and business operations.

Organizational guidelines help bring uniformity to the operations of an organization, which helps reduce the risk of unwanted and unexpected events. These determine how employees are supposed to behave at work, which ultimately helps the business achieve its objectives efficiently.

However, organizational guidelines are ineffective and fail to serve their purpose if they are not followed. Many people don't like the idea of following and abiding by specific guidelines. Such people should be made to understand the benefits of following the organizational guidelines. Some of the key benefits are given below:

With well-defined organizational guidelines in place, no individual can act arbitrarily, irrespective of their position in the organization. All individuals will know the pros and cons of taking certain actions and what to expect in case of unacceptable behaviour. Benefits of following organizational guidelines:

- **Consistent processes and structures:** Organization guidelines help maintain consistency in operations, avoiding any disorder. When all employees follow the organizational guidelines, an organization can run smoothly. These ensure that people in different job roles operate as they are supposed to, knowing what they are responsible for, what is expected of them, and what they can expect from their supervisors and co-workers. With clarity in mind, they can do their jobs with confidence and excellence. With every person working the way intended, it's easy to minimise errors.

  With all the staff following organizational guidelines, the organization has a better scope of using time and resources more effectively and efficiently. This allows the organization to grow and achieve its objectives.

- **Better quality service:** By following organizational guidelines, employees perform their duties correctly as per the defined job responsibilities. It helps enhance the quality of the organization's products and services, helping improve the organization's reputation. Working with a reputable organization, employees can take pride in their work and know they are contributing to the reputation.

- **A safer workplace:** When all employees follow organizational guidelines, it becomes easy to minimise workplace incidents and accidents. It reduces the liabilities associated with risks for the organization and limits the interruptions in operations. Employees also feel comfortable and safe in the workplace, knowing their co-workers are ensuring safety at work by following the applicable guidelines.

Different organizations may have different guidelines on dress code, time schedules, language usage, etc. For example – certain organizations in a client-dealing business requiring employees to meet clients personally follow a strict dress code asking their employees to wear formal business attire. Similarly, organizations operating in specific regions may require their employees to use the dominant regional language of the particular region to build rapport with customers and serve them better. Certain organizations, such as banks, often give preference to candidates with knowledge of the regional language during hiring.

Working hours may also differ from one organization to another, with some requiring employees to work extra compared to others. One should follow the organizational guidelines concerning all the aspects of the employment to ensure a cohesive work environment.

7.2.5 Workflow

Workflow is the order of steps from the beginning to the end of a task or work process. In other words, it is the way a particular type of work is organised or the order of stages in a particular work process.

Workflows can help simplify and automate repeatable business tasks, helping improve efficiency and minimise the room for errors. With workflows in place, managers can make quick and smart decisions while employees can collaborate more productively.

Other than the order that workflows create in a business, these have several other benefits, such as:

- **Identifying Redundancies:** Mapping out work processes in a workflow allows one to get a clear, top-level view of a business. It allows one to identify and remove redundant or unproductive processes.

Workflow gives greater insights into business processes. Utilizing such useful insights, one can improve work processes and the bottom line of the business. In many businesses, there are many unnecessary and redundant tasks that take place daily. Once an organization has insight into its processes while preparing workflow, it can determine which activities are really necessary.

Identifying and eliminating redundant tasks creates value for a business. With redundant tasks and processes eliminated, an organization can focus on what's important to the business.

- **Increase in Accountability and Reduction in Micromanagement:** Micromanagement often causes problems in a business setting as most employees don't like being micromanaged, and even many managers don't like the practice. Micromanagement is often identified as one of the reasons why people quit their job.

However, the need for micromanagement can be minimized by clearly mapping out the workflow. This way, every individual in a team knows what tasks need to be completed and by when and who is responsible for completing them. This makes employees more accountable also.

With clearly defined workflow processes, managers don't have to spend much time micromanaging their employees, who don't have to approach the manager to know what the further steps are. Following a workflow, employees know what is going on and what needs to be done. This, in turn, may help increase the job satisfaction of everyone involved while improving the relationships between management and employees.

- **Improved Communication:** Communication at work is critical because it affects all aspects of an organization. There are instances when the main conflict in an organization originates from miscommunication, e.g. the management and employees disagreeing on an aspect, despite pursuing the same objectives. Poor communication is a common workplace issue that is often not dealt with.

This highlights why workflow is important. Workplace communication dramatically can increase with the visibility of processes and accountability. It helps make the daily operations smoother overall.

- **Better Customer Service:** Customers or clients are central to a business. Therefore, it is imperative to find and improve ways to improve customer experience. Relying on outdated manual systems may cause customer requests or complaints to be overlooked, with dissatisfied customers taking their business elsewhere. However, following a well-researched and defined workflow can help improve the quality of customer service.

By automating workflows and processes, an organization can also reduce the likelihood of human error. This also helps improve the quality of products or services over time, resulting in a better customer experience.

7.2.6 Following Instructions and Reporting Problems

All organizations follow a hierarchy, with most employees reporting to a manager or supervisor. For organizational success, it is vital for employees to follow the instructions of their manager or supervisor. They should ensure they perform their duties as per the given instructions to help achieve the common objectives of the organization and deliver quality service or products. This consequently helps maintain the reputation of the organization.

It is also important to be vigilant and identify problems at work or with the organizational work processes. One should deal with the identified within their limits of authority and report out of authority problems to the manager/ supervisor or the concerned person for a prompt resolution to minimise the impact on customers/clients and business.

7.2.7 Information or Data Sharing

Information or data is critical to all organizations. Depending on the nature of its business, an organization may hold different types of data, e.g. personal data of customers or client data concerning their business operations and contacts. It is vital to effective measures for the appropriate handling of different types of data, ensuring its protection from unauthorized access and consequent misuse.

One should access certain data only if authorised to do so. The same is applicable when sharing data which must be shared only with the people authorised to receive it to use it for a specific purpose as per their job role and organizational guidelines. For example – one should be extra cautious while sharing business data with any third parties to ensure they get access only to the limited data they need as per any agreements with them. It is also critical to monitor how the recipient of the data uses it, which should strictly be as per the organizational guidelines. It is a best practice to share appropriate instructions with the recipient of data to ensure they are aware of the purpose with which data is being shared with them and how they are supposed to use and handle it. Any misuse of data must be identified and reported promptly to the appropriate person to minimise any damage arising out of data misuse.

These days most organizations require their employees and business partners or associated third parties to sign and accept the relevant agreement on the non-disclosure of business-sensitive information. In simple terms, business-sensitive information is confidential information. It is proprietary business information collected or created during the course of conducting business, including information about the business, e.g. proposed investments, intellectual property, trade secrets, or plans for a merger and information related to its clients. Business-sensitive information may sometimes also include information regarding a business's competitors in an industry.

The release of business: Sensitive information to competitors or the general public poses a risk to a business. For example, information regarding plans for a merger could be harmful to a business if a competitor gets access to it.

7.2.8 Reporting Issues at Work

Most organizations have defined guidelines on appropriate reporting processes to be followed for reporting different types of issues. For example – one can report any grievances or dissatisfaction concerning co-workers to their manager/supervisor, e.g. data breaches or unethical conduct. If the concern is not addressed, then the employee should follow the organizational guidelines and hierarchy for the escalation of such issues that are not addressed appropriately.

For example: Any concern related to sexual harassment at the workplace should be escalated to the concerned spokesperson, such as Human Resources (HR) representative, and if not satisfied with the action taken, it should be reported to the senior management for their consideration and prompt action.

7.2.9 Dealing with Heightened Emotions

Humans are emotional beings. There may be occasions when one is overwhelmed by emotions and is unable to suppress them. However, there may be situations when one must manage emotions well, particularly at work.

Stress in one's personal and professional life may often cause emotional outbursts at work. Managing one's emotions well, particularly the negative ones, is often seen as a measure of one's professionalism. Anger, dislike, frustration, worry, and unhappiness are the most common negative emotions experienced at work.

Ways to manage negative emotions at work:

- **Compartmentalisation:** It's about not confining emotions to different aspects of one's life. For example, not letting negative emotions from personal life affect work-life and vice versa. One should try to leave personal matters and issues at home. One should train their mind to let go of personal matters before reaching work. Similarly, one can compartmentalise work-related stresses so that negative emotions from work don't affect one's personal life.

- **Deep breathing and relaxation:** Deep breathing helps with anxiety, worry, frustration and anger. One should take deep breaths, slowly count to ten - inhaling and exhaling until one calms down. One can also take a walk to calm down or listen to relaxing music. Talking to someone and sharing concerns also helps one calm down.

- **The 10-second rule:** This is particularly helpful in controlling anger and frustration. When one feels their temper rising, they should count to 10 to calm down and recompose. If possible, one should move away to allow temper to come down.

- **Clarify:** It is always good to clarify before reacting, as it may be a simple case of misunderstanding or miscommunication.

- **Physical activity:** Instead of losing temper, one should plan to exercise, such as running or going to the gym, to let the anger out. Exercise is also a great way to enhance mood and release any physical tension in the body.

- **Practising restraint:** One should avoid replying or making a decision when angry, not allowing anger or unhappiness to cloud one's judgement. It may be best to pause any communication while one is angry, e.g. not communicating over email when angry or upset.

- **Knowing one's triggers:** It helps when one is able to recognise what upsets or angers them. This way, one can prepare to remain calm and plan their reaction should a situation occur. One may even be able to anticipate the other party's reaction.

- **Be respectful:** One should treat their colleagues the same way one would like to be treated. If the other person is rude, one need not reciprocate. It is possible to stay gracious, firm and assertive without being aggressive. Sometimes, rude people back away when they don't get a reaction from the person they are arguing with.

- **Apologise for any emotional outburst:** Sometimes, one can get overwhelmed by emotions, reacting with an emotional outburst. In such a case, one should accept responsibility and apologise immediately to the affected persons without being defensive.

- **Doing away with negative emotions:** It is recommended to let go of anger, frustration and unhappiness at the end of every workday. Harbouring negative emotions affects one emotionally, affecting their job performance also. Engaging in enjoyable activities after work is a good stress reliever.

Notes

UNIT 7.3: Maintaining Social Diversity at Work

Unit Objectives ◎

By the end of this unit, participants will be able to:

1. Explain the concept and importance of gender sensitivity and equality.
2. Discuss ways to create sensitivity for different genders and Persons with Disabilities (PwD).

7.3.1 Gender Sensitivity

Gender sensitivity is the act of being sensitive towards people and their thoughts regarding gender. It ensures that people know the accurate meaning of gender equality, and one's gender should not be given priority over their capabilities.

Fig 7.3.1 Gender Equality

Women are an important source of labour in many sectors, yet they have limited access to resources and benefits. Women should receive the same benefits and access to resources as men. A business can improve its productivity and quality of work by providing better support and opportunities to women.

Important Terms:

• **Gender Sensitivity:** Gender sensitivity is the act of being sensitive to the ways people think about gender.

• **Gender Equality:** It means persons of any gender enjoy equal opportunities, responsibilities, and rights in all areas of life.

• **Gender Discrimination:** It means treating an individual unequally or disadvantageously based on their gender, e.g. paying different wages to men and women for similar or equal job positions.

Strategies for Enhancing Gender Equity

To enhance gender equity, one should:

- Follow gender-neutral practices at all levels at work.

- Participate together in decision-making.

- Help in promoting women's participation in different forums.

- Assist women in getting exposure to relevant skills and practices.

- Assist women in capacity building by mentoring, coaching or motivating them, as appropriate.

- Assist in the formation and operation of women support groups.

- Assist in the implementation of women-centric programmes.

- Combine technical training with reproductive health and nutrition for coffee farming households.

- Assist in making a work environment that is healthy, safe, and free from discrimination.

Bridging Gender Differences

Men and women react and communicate very differently. Thus, there are some work differences as both genders have their style and method of handling a situation.

Although, understanding and maturity vary from person to person, even between these genders, based on their knowledge, education, experience, culture, age, and upbringing, as well as how one's brain functions over a thought or problem.

In order to bridge the gap, one should:

- Not categorize all men and women in one way.

- Be aware of the verbal and non-verbal styles of communication of every gender to avoid any miscommunication and work better.

- Be aware of partial behaviour and avoid it.

- Encourage co-workers of different genders to make room by providing space to others.

Ways to reduce Gender Discrimination

- Effective steps against sexual harassment by the concerned authorities and general public.

- Gender stereotypes are how society expects people to act based on their gender. This can only be reduced by adopting appropriate behaviour and the right attitude.

- Objectification of females must be abolished.

Ways to Promote Gender Sensitivity in the Workplace

- Practices that promote gender diversity should be adopted and promoted.

- All genders should receive equal responsibilities, rights, and privileges.

- All genders should have equal pay for similar or the same job roles/ positions.

- Strict and effective workplace harassment policies should be developed and implemented.

- An open-minded and stress-free work environment should be available to all the employees, irrespective of their gender.

- Women should be encouraged to go ahead in every field of work and assume leadership roles.

- Follow appropriate measures for women's empowerment.

- Men should be taught to be sensitive to women and mindful of their rights.

7.3.2 PwD Sensitivity

Some individuals are born with a disability, while others may become disabled due to an accident, illness or as they get old. People with Disabilities (PwD) may have one or more areas in which their functioning is affected. A disability can affect hearing, sight, communication, breathing, understanding, mobility, balance, and concentration or may include the loss of a limb. A disability may contribute to how a person feels and affect their mental health.

Important Terms

- **Persons with Disabilities (PwD):** Persons with Disabilities means a person suffering from not less than 40% of any disability as certified by a medical authority.

- **Types of Disability:**

  a. Blindness – Visually impaired

  b. Low Vision

  c. Leprosy Cured

  d. Hearing impairment

  e. Locomotor disability

  f. Mental retardation

  g. Mental illness

PwD Sensitivity: PwD sensitivity promotes empathy, etiquette and equal participation of individuals and organizations while working with individuals with a disability, e.g. sensory, physical or intellectual.

Ways to be PwD Sensitive

To be sensitive to PwD, one should:

- Be respectful to all Persons with Disabilities (PwD) and communicate in a way that reflects PwD sensitivity.

- Always be supportive and kind towards a PwD with their daily chores.

- Be ready to assist a PwD to help them avail of any benefit/ livelihood opportunity/ training or any kind that helps them grow.

- Encourage and try to make things easier and accessible to PwD so that they can work without or with minimum help.

- Protest where feasible and report any wrong act/behaviour against any PwD to the appropriate authority.

- Learn and follow the laws, acts, and policies relevant to PwD.

Appropriate Verbal Communication

As part of appropriate verbal communication with all genders and PwD, one should:

- Talk to all genders and PwD respectfully, maintaining a normal tone of voice with appropriate politeness. It is important to ensure one's tone of voice does not have hints of sarcasm, anger, or unwelcome affection.

- Avoid being too self-conscious concerning the words to use while also ensuring not to use words that imply one's superiority over the other.

- Make no difference between a PwD and their caretaker. Treat PwD like adults and talk to them directly.

- Ask a PwD if they need any assistance instead of assuming they need it and offering assistance spontaneously.

Appropriate Non-verbal Communication

Non-verbal communication is essentially the way someone communicates through their body language. These include:

- **Facial expressions:** The human face is quite expressive, capable of conveying many emotions without using words. Facial expressions must usually be maintained neutral and should change according to the situation, e.g. smile as a gesture of greeting.

- **Body posture and movement:** One should be mindful of how to sit, stand, walk, or hold their head. For example - one should sit and walk straight in a composed manner. The way one moves and carries self, communicates a lot to others. This type of non-verbal communication includes one's posture, bearing, stance, and subtle movements.

- **Gestures:** One should be very careful with their gestures, e.g. waving, pointing, beckoning, or using one's hands while speaking. One should use appropriate and positive gestures to maintain respect for the other person while being aware that a gesture may have different meanings in different cultures.

- **Eye contact:** Eye contact is particularly significant in non-verbal communication. The way someone looks at someone else may communicate many things, such as interest, hostility, affection or attraction. Eye contact is vital for maintaining the flow of conversation and for understanding the other person's interest and response. One should maintain appropriate eye contact, ensuring not to stare or look over the shoulders. To maintain respect, one should sit or stand at the other person's eye level to make eye contact.

- **Touch:** Touch is a very sensitive type of non-verbal communication. Examples are - handshakes, hugs, pat on the back or head, gripping the arm, etc. A firm handshake indicates interest, while a weak handshake indicates the opposite. One should be extra cautious not to touch others inappropriately and avoid touching them inadvertently by maintaining a safe distance.

Rights of PwD

PwD have the right to respect and human dignity. Irrespective of the nature and seriousness of their disabilities, PwD have the same fundamental rights as others, such as:

- Disabled persons have the same civil and political rights as other people

- Disabled persons are entitled to the measures designed to enable them to become as self-dependent as possible

- Disabled persons have the right to economic and social security

- Disabled persons have the right to live with their families or foster parents and participate in all social and creative activities.

- Disabled persons are protected against all exploitation and treatment of discriminatory and abusive nature.

Making Workplace PwD Friendly

- One should not make PwD feel uncomfortable by giving too little or too much attention

- One should use a normal tone while communicating with a PwD and treat them as all others keeping in mind their limitations and type of disability

- Any help should be provided only when asked for by a PwD

- One should help in ensuring the health and well-being of PwD.

Expected Employer Behaviour

Some of the common behavioural traits that employees expect from their employers are:

- **Cooperation:** No work is successful without cooperation from the employer's side. Cooperation helps to understand the job role better and complete it within the given timeline.

- **Polite language:** Polite language is always welcomed at work. This is a basic aspect that everybody expects.

- **Positive Attitude:** Employers with a positive attitude can supervise the work of the employees and act as a helping hand to accomplish the given task. A person with a positive attitude looks at the best qualities in others and helps them gain success.

- **Unbiased behaviour:** Employers should always remain fair towards all their employees. One should not adopt practices to favour one employee while neglecting or ignoring the other. This might create animosity among co-workers.

- **Decent behaviour:** The employer should never improperly present oneself before the employee. One should always respect each other's presence and behave accordingly. The employer should not speak or act in a manner that may make the employee feel uneasy, insulted, and insecure.

Exercise ✎

1. List down three examples of workplace ethics.

2. List down three examples of interpersonal skills.

3. Identify two reasons for workplace conflicts.

4. Identify two ways of resolving interpersonal conflicts.

5. List down two ways of dealing with heightened emotions at work.

6. List down two types of non-verbal communication.4. Basic Health and Safety Practices.

Notes
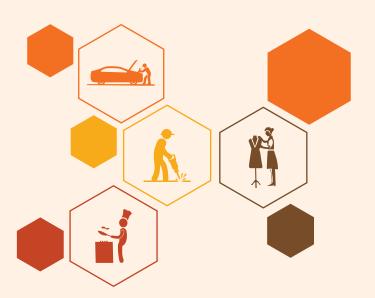
8. Basic Health and Safety Practices

Unit 8.1 - Workplace Hazards

Unit 8.2 - Fire Safety

Unit 8.3 - First Aid

Unit 8.4 - Waste Management

Key Learning Outcomes 💡

By the end of this module, participants will be able to:

1. Discuss job-site hazards, risks and accidents.

2. Explain the organizational safety procedures for maintaining electrical safety, handling tools and hazardous materials.

3. Describe how to interpret warning signs while accessing sensitive work areas.

4. Explain the importance of good housekeeping.

5. Describe the importance of maintaining appropriate postures while lifting heavy objects.

6. List the types of fire and fire extinguishers.

7. Describe the concept of waste management and methods of disposing of hazardous waste.

8. List the common sources of pollution and ways to minimize them.

9. Elaborate on electronic waste disposal procedures.

10. Explain how the administer appropriate first aid to victims in case of bleeding, burns, choking, electric shock, poisoning and also administer first aid to victims in case of a heart attack or cardiac arrest due to electric shock.

UNIT 8.1: Workplace Hazards

Unit Objectives ◎

By the end of this unit, participants will be able to:

1. Discuss job-site hazards, risks and accidents.
2. Explain the organizational safety procedures for maintaining electrical safety, handling tools and hazardous materials.
3. Describe how to interpret warning signs while accessing sensitive work areas.
4. Explain the importance of good housekeeping.
5. Describe the importance of maintaining appropriate postures while lifting heavy objects.
6. Explain safe handling of tools and Personal Protective Equipment to be used.

8.1.1 Workplace Safety

Workplace safety is important to be established for creating a safe and secure working for the workers. The workplace has to be administered as per the rules of the Occupational Safety and Health Administration (OSHA). It refers to monitoring the working environment and all hazardous factors that impact employees' safety, health, and well-being. It is important to provide a safe working environment to the employees to increase their productivity, wellness, skills, etc.

The benefits of workplace safety are:

- Employee retention increases if they are provided with a safe working environment.

- Failure to follow OSHA's laws and guidelines can result in significant legal and financial consequences.

- A safe environment enables employees to stay invested in their work and increases productivity.

- Employer branding and company reputation can both benefit from a safe working environment.

8.1.2 Workplace Hazards

A workplace is a situation that has the potential to cause harm or injury to the workers and damage the tools or property of the workplace. Hazards exist in every workplace and can come from a variety of sources. Finding and removing them is an important component of making a safe workplace.

Common Workplace Hazards

The common workplace hazards are:

- **Biological:** The threats caused by biological agents like viruses, bacteria, animals, plants, insects and also humans, are known as biological hazards.

- **Chemical:** Chemical hazard is the hazard of inhaling various chemicals, liquids and solvents. Skin irritation, respiratory system irritation, blindness, corrosion, and explosions are all possible health and physical consequences of these dangers.

- **Mechanical:** Mechanical Hazards comprise the injuries that can be caused by the moving parts of machinery, plant or equipment.

- **Psychological:** Psychological hazards are occupational hazards caused by stress, harassment, and violence.

- **Physical:** The threats that can cause physical damage to people is called physical hazard. These include unsafe conditions that can cause injury, illness and death.

- **Ergonomic:** Ergonomic Hazards are the hazards of the workplace caused due to awkward posture, forceful motion, stationary position, direct pressure, vibration, extreme temperature, noise, work stress, etc.

Workplace Hazards Analysis

A workplace hazard analysis is a method of identifying risks before they occur by focusing on occupational tasks. It focuses on the worker's relationship with the task, the tools, and the work environment. After identifying the hazards of the workplace, organisations shall try to eliminate or minimize them to an acceptable level of risk.

Control Measures of Workplace Hazards

Control measures are actions that can be taken to reduce the risk of being exposed to the hazard. Elimination, Substitution, Engineering Controls, Administrative Controls, and Personal Protective Equipment are the five general categories of control measures.

- **Elimination:** The most successful control technique is to eliminate a specific hazard or hazardous work procedure or prevent it from entering the workplace.

- **Substitution:** Substitution is the process of replacing something harmful with something less hazardous. While substituting the hazard may not eliminate all of the risks associated with the process or activity, it will reduce the overall harm or health impacts.

- **Engineering Controls:** Engineered controls protect workers by eliminating hazardous situations or creating a barrier between the worker and the hazard, or removing the hazard from the person.

- **Administrative Controls:** To reduce exposure to hazards, administrative controls limit the length of time spent working on a hazardous task that might be used in combination with other measures of control.

- **Personal Protective Equipment:** Personal protective equipment protects users from health and safety hazards at work. It includes items like safety helmets, gloves, eye protection, etc.

8.1.3 Risk for a Drone Technician

A drone technician may require to repair the propeller, motor and its mount, battery, mainboards, processor, booms, avionics, camera, sensors, chassis, wiring and landing gear. A technician may face some risks while repairing the drones' equipment.

- The technician is susceptible to being physically harmed by propellers.

- Direct contact with exposed electrical circuits can injure the person.

- If the skin gets in touch with the heat generated from electric arcs, it burns the internal tissues.

- Major electrical injuries can occur due to poorly installed electrical equipment, faulty wiring, overloaded or overheated outlets, use of extension cables, incorrect use of replacement fuses, use of equipment with wet hands, etc.

8.1.4 Workplace Warning Signs

A Hazard sign is defined as 'information or instruction about health and safety at work on a signboard, an illuminated sign or sound signal, a verbal communication or hand signal.'

There are four different types of safety signs:

- Prohibition / Danger Alarm Signs

- Mandatory Signs

- Warning Signs

- And Emergency

1. **Prohibition Signs**

   A "prohibition sign" is a safety sign that prohibits behaviour that is likely to endanger one's health or safety. The colour red is necessary for these health and safety signs. Only what or who is forbidden should be displayed on a restriction sign.

Fig. 8.1.1. Prohibition warning signs

2. Mandatory Signs

Mandatory signs give clear directions that must be followed. The icons are white circles that have been reversed out of a blue circle. On a white background, the text is black.

Fig. 8.1.2. Mandatory signs

3. Warning Signs

Warning signs are the safety information communication signs. They are shown as a 'yellow colour triangle'.

Fig. 8.1.3. Warning signs

4. Emergency Signs

The location or routes to emergency facilities are indicated by emergency signs. These signs have a green backdrop with a white emblem or writing. These signs convey basic information and frequently refer to housekeeping, company procedures, or logistics.
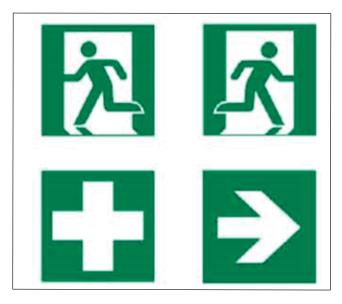
Fig. 8.1.4. Emergency signs

8.1.5 Cleanliness in the Workplace

Workplace cleanliness maintenance creates a healthy, efficient and productive environment for the employees. Cleanliness at the workplace is hindered by some elements like cluttered desks, leftover food, waste paper, etc. A tidy workplace is said to improve employee professionalism and enthusiasm while also encouraging a healthy working environment.

Benefits of cleanliness in the workplace:

1. **Productivity:** Cleanliness in the workplace can bring a sense of belonging to the employees, also motivating and boosting the morale of the employees. This results in increasing their productivity.

2. **Employee Well-being:** Employee well-being can be improved by providing a clean work environment. Employees use fewer sick days in a workplace where litter and waste are properly disposed of, and surfaces are cleaned regularly, resulting in increased overall productivity.

3. **Positive Impression:** Cleanliness and orderliness in the workplace provide a positive impression on both employees and visitors.

4. **Cost saving:** By maintaining acceptable levels of cleanliness in the workplace, businesses can save money on cleaning bills and renovations, which may become necessary if the premises are not properly kept.

Reasons for Cleaning the Workplace

- Cleaning of dry floors, mostly to prevent workplace slips and falls.

- Disinfectants stop bacteria in their tracks, preventing the spread of infections and illness.

- Proper air filtration decreases hazardous substance exposures such as dust and fumes.

- Light fixture cleaning improves lighting efficiency.

- Using environmentally friendly cleaning chemicals that are safer for both personnel and the environment.

- Work environments are kept clean by properly disposing of garbage and recyclable items.

8.1.6 Lifting and Handling of Heavy Loads

Musculoskeletal Injuries (MSIs), such as sprains and strains, can occur while lifting, handling, or carrying objects at work. When bending, twisting, uncomfortable postures and lifting heavy objects are involved, the risk of injury increases. Ergonomic controls can help to lower the risk of injury and potentially prevent it.

Types of injuries caused while lifting heavy objects:

- Cuts and abrasions are caused by rough surfaces.

- Crushing of feet or hands.

- Strain to muscles and joints.
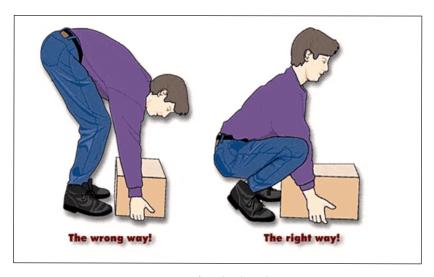
Fig. 8.1.5. Lifting loads technique

Preparing to Lift

A load that appears light enough to bear at first will grow increasingly heavier as one carries it further. The person carrying the weight should be able to see over or around it at all times.

The amount of weight a person can lift, depends on their age, physique, and health.

It also depends on whether or not the person is used to lifting and moving hefty objects.

Common Causes of Back Injuries

The Most Common Causes of Back Injuries are:

1. **Inadequate Training:** The individual raising the load receives no sufficient training or guidance.

2. **Lack of awareness of technique:** The most common cause of back pain is incorrect twisting and posture, which causes back strain.

3. **Load size:** The load size to consider before lifting. If the burden is too much for one's capacity or handling, their back may be strained and damaged.

4. **Physical Strength:** Depending on their muscle power, various persons have varied physical strengths. One must be aware of their limitations.

5. **Teamwork:** The operation of a workplace is all about working together. When opposed to a single person lifting a load, two people can lift it more easily and without difficulty. If one of two people isn't lifting it properly, the other or both of them will suffer back injuries as a result of the extra strain.

Technique	Demonstration
1. Ensure one has a wide base of support before lifting the heavy object. Ensure one's feet are shoulder-width apart, and one foot is slightly ahead of the other at all times. This will help one maintain a good balance during the lifting of heavy objects. This is known as the Karate Stance.	
2. Squat down as near to the object as possible when one is ready to lift it, bending at the hips and knees with the buttocks out. If the object is really heavy, one may wish to place one leg on the floor and the other bent at a straight angle in front of them.	

4. By straightening one's hips and knees, slowly elevate the thing (not the back). As one rises, they should extend their legs and exhale. Lift the heavy object without twisting the body or bending forward.	
5. Do not lift bending forward.	
6. Hold the load close to the body.	
7. Never lift heavy objects above the shoulder	

7. Never lift heavy objects above the shoulder	
8. Use the feet (not the body) to change direction, taking slow, small steps.	
9. Set down the heavy object carefully, squatting with the knees and hips only.	

Table 8.1.1 Techniques for lifting heavy objects[1]

[1]Source:https://www.braceability.com/blogs/articles/7-proper-heavy-lifting-techniques

8.1.7 Safe Handling of Tools

Workers should be trained on how to use tools safely. When tools are misplaced or handled incorrectly by workers, they can be dangerous. The following are some suggestions from the National Safety Council for safe tool handling when they are not in use:

• Never carry tools up or down a ladder in a way that makes it difficult to grip them. Instead of being carried by the worker, tools should be lifted up and down using a bucket or strong bag.

• Tools should never be tossed but should be properly passed from one employee to the next. Pointed tools should be passed with the handles facing the receiver or in their carrier.

• When turning and moving around the workplace, workers carrying large tools or equipment on their shoulders should pay particular attention to clearances.

• Pointed tools such as chisels and screwdrivers should never be kept in a worker's pocket. They can be carried in a toolbox, pointing down in a tool belt or pocket tool bag, or in hand with the tip always held away from the body.

- Tools should always be stored while not in use. People below are put in danger when tools are left sitting around on an elevated structure, such as a scaffold. In situations when there is a lot of vibration, this risk increases.

8.1.8 Personal Protective Equipment

Personal Protective Equipment, or "PPE," is equipment worn to reduce exposure to risks that might result in significant occupational injuries or illnesses. *Chemical, Radiological, Physical, Electrical, Mechanical,* and other job dangers may cause these injuries and diseases.

PPE used for protection from the following injuries are:

Injury Protection	Protection	PPE
Head Injury Protection	Falling or flying objects, stationary objects, or contact with electrical wires can cause impact, penetration, and electrical injuries. Hard hats can protect one's head from these injuries. A common electrician's hard hat is shown in the figure below. This hard hat is made of nonconductive plastic and comes with a set of safety goggles.	
Foot and Leg Injury Protection	In addition to foot protection and safety shoes, leggings (e.g., leather) can guard against risks such as falling or rolling objects, sharp objects, wet and slippery surfaces, molten metals, hot surfaces, and electrical hazards.	
Eye and Face Injury Protection	Spectacles, goggles, special helmets or shields, and spectacles with side shields and face shields can protect against the hazards of flying fragments, large chips, hot sparks, radiation, and splashes from molten metals. They also offer protection from particles, sand, dirt, mists, dust, and glare.	

Protection against Hearing Loss	Hearing protection can be obtained by wearing earplugs or earmuffs. High noise levels can result in permanent hearing loss or damage, as well as physical and mental stress. Self-forming earplugs composed of foam, waxed cotton, or fibreglass wool usually fit well. Workers should be fitted for moulded or prefabricated earplugs by a specialist.	
Hand Injury Protection	Hand protection will aid workers who are exposed to dangerous substances by skin absorption, serious wounds, or thermal burns. Gloves are a frequent protective clothing item. When working on electrified circuits, electricians frequently use leather gloves with rubber inserts. When stripping cable with a sharp blade, Kevlar gloves are used to prevent cuts.	
Whole Body Protection	Workers must protect their entire bodies from risks such as heat and radiation. Rubber, leather, synthetics, and plastic are among the materials used in whole-body PPE, in addition to fire-retardant wool and cotton. Maintenance staff who operate with high-power sources such as transformer installations and motor-control centres are frequently obliged to wear fire-resistant clothes.	

Table 8.1.2 Personal protective equipment

Notes

UNIT 8.2: Fire Safety

Unit Objectives ⌾

By the end of this unit, participants will be able to:

1. List the types of fire and fire extinguishers.

8.2.1 Fire Safety

Fire safety is a set of actions aimed at reducing the amount of damage caused by fire. Fire safety procedures include both those that are used to prevent an uncontrolled fire from starting and those that are used to minimise the spread and impact of a fire after it has started. Developing and implementing fire safety measures in the workplace is not only mandated by law but is also essential for the protection of everyone who may be present in the building during a fire emergency.

The basic Fire Safety Responsibilities are:

- To identify risks on the premises, a fire risk assessment must be carried out.
- Ascertain that fire safety measures are properly installed.
- Prepare for unexpected events.
- Fire safety instructions and training should be provided to the employees.

8.2.2 Respond to a Workplace Fire

- Workplace fire drills should be conducted on a regular basis.
- If one has a manual alarm, they should raise it.
- Close the doors and leave the fire-stricken area as soon as possible. Ensure that the evacuation is quick and painless.
- Turn off dangerous machines and don't stop to get personal items.
- Assemble at a central location. Ascertain that the assembly point is easily accessible to the employees.
- If one's clothing catches fire, one shouldn't rush about it. They should stop and descend on the ground and roll to smother the flames if their clothes catch fire.

8.2.3 Fire Extinguisher

Fire extinguishers are portable devices used to put out small flames or minimise their damage until fire-fighters arrive. These are maintained on hand in locations such as fire stations, buildings, workplaces, public transit, and soon. The types and quantity of extinguishers that are legally necessary for a given region are determined by the applicable safety standards.

Types of fire extinguishers are:

There are five main types of fire extinguishers:

1. Water.

2. Powder.

3. Foam.

4. Carbon Dioxide (Co2).

5. Wet chemical.

1. **Water:** Water fire extinguishers are one of the most common commercial and residential fire extinguishers on the market. They're meant to be used on class-A flames.

2. **Powder:** The L2 powder fire extinguisher is the most commonly recommended fire extinguisher in the Class D Specialist Powder category, and is designed to put out burning lithium metal fires.

3. **Foam:** Foam extinguishers are identified by a cream rectangle with the word "foam" printed on it. They're mostly water-based, but they also contain a foaming component that provides a quick knock-down and blanketing effect on flames. It suffocates the flames and seals the vapours, preventing re-ignition.

4. **Carbon Dioxide (Co2):** Class B and electrical fires are extinguished with carbon dioxide extinguishers, which suffocate the flames by removing oxygen from the air. They are particularly beneficial for workplaces and workshops where electrical fires may occur since, unlike conventional extinguishers, they do not leave any toxins behind and hence minimise equipment damage.

5. **Wet Chemical:** Wet chemical extinguishers are designed to put out fires that are classified as class F. They are successful because they can put out extremely high-temperature fires, such as those caused by cooking oils and fats**.**

Notes

UNIT 8.3: First Aid

Unit Objectives ◎

By the end of this unit, participants will be able to:

1. Explain how the administer appropriate first aid to victims in case of bleeding, burns, choking, electric shock, poisoning.

2. Explain how to administer first aid to victims in case of a heart attack or cardiac arrest due to electric shock.

8.3.1 First Aid

First aid is the treatment or care given to someone who has sustained an injury or disease until more advanced care can be obtained or the person recovers.

The aim of first aid is to:

- Preserve life
- Prevent the worsening of a sickness or injury
- If at all possible, relieve pain
- Encourage recovery
- Keep the unconscious safe.

First aid can help to lessen the severity of an injury or disease, and in some situations, it can even save a person's life.

8.3.2 Need for First Aid at the Workplace

- In the workplace, first aid refers to providing immediate care and life support to persons who have been injured or become unwell at work.

- Many times, first aid can help to lessen the severity of an accident or disease.

- It can also help an injured or sick person relax. In life-or-death situations, prompt and appropriate first aid can make all the difference.

8.3.2 Need for First Aid at the Workplace

In the workplace, first aid refers to providing immediate care and life support to persons who have been injured or become unwell at work.

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It can also help an injured or sick person relax. In life-or-death situations, prompt and appropriate first aid can make all the difference.

8.3.3 Treating Minor Cuts and Scrapes

Steps to keep cuts clean and prevent infections and scars:

- **Wash Hands:** Wash hands first with soap and water to avoid introducing bacteria into the cut and causing an infection. One should use the hand sanitiser if one is on the go.

- **Stop the bleeding:** Using a gauze pad or a clean towel, apply pressure to the wound. For a few minutes, keep the pressure on.

- **Clean Wounds:** Once the bleeding has stopped, clean the wound by rinsing it under cool running water or using a saline wound wash. Use soap and a moist washcloth to clean the area around the wound. Soap should not be used on the cut since it may irritate the skin. Also, avoid using hydrogen peroxide or iodine, as these may aggravate the wound.

- **Remove Dirt:** Remove any dirt or debris from the area. Pick out any dirt, gravel, glass, or other material in the cut with a pair of tweezers cleaned with alcohol.

8.3.4 Heart Attack

When the blood flow carrying oxygen to the heart is blocked, a heart attack occurs. The heart muscle runs out of oxygen and starts to die.

Symptoms of a heart attack can vary from person to person. They may be mild or severe. Women, older adults, and people with diabetes are more likely to have subtle or unusual symptoms.

Symptoms in adults may include:

- Changes in mental status, especially in older adults.

- Chest pain that feels like pressure, squeezing, or fullness. The pain is most often in the centre of the chest. It may also be felt in the jaw, shoulder, arms, back, and stomach. It can last for more than a few minutes or come and go.

- Cold sweat.

- Light-headedness.

- Nausea (more common in women).

- Indigestion.

- Vomiting.

- Numbness, aching or tingling in the arm (usually the left arm, but the right arm may be affected alone, or along with the left).

- Shortness of breath.

- Weakness or fatigue, especially in older adults and in women.

First Aid for Heart Attack

If one thinks someone is experiencing a heart attack, they should:

- Have the person sit down, rest, and try to keep calm.

- Loosen any tight clothing.

- Ask if the person takes any chest pain medicine, such as nitro-glycerine for a known heart condition, and help them take it.

- If the pain does not go away promptly with rest or within 3 minutes of taking nitro-glycerine, call for emergency medical help.

- If the person is unconscious and unresponsive, call 911 or the local emergency number, then begin CPR.

- If an infant or child is unconscious and unresponsive, perform 1 minute of CPR, then call 911 or the local emergency number.

Notes

UNIT 8.4: Waste Management

Unit Objectives ⊚

By the end of this unit, participants will be able to:

1. Describe the concept of waste management and methods of disposing of hazardous waste.
2. List the common sources of pollution and ways to minimize them.
3. Elaborate on electronic waste disposal procedures.

8.4.1. Waste Management and Methods of Waste Disposal

The collection, disposal, monitoring, and processing of waste materials is known as waste management. These wastes affect living beings' health and the environment. For reducing their effects, they have to be managed properly. The waste is usually in solid, liquid or gaseous form.

The importance of waste management is:

Waste management is important because it decreases waste's impact on the environment, health, and other factors. It can also assist in the reuse or recycling of resources like paper, cans, and glass. The disposal of solid, liquid, gaseous, or dangerous substances is the example of waste management.

When it comes to trash management, there are numerous factors to consider, including waste disposal, recycling, waste avoidance and reduction, and garbage transportation. Treatment of solid and liquid wastes is part of the waste management process. It also provides a number of recycling options for goods that aren't classified as garbage during the process.

8.4.2 Methods of Waste Management

Non-biodegradable and toxic wastes, such as radioactive remains, can cause irreversible damage to the environment and human health if they are not properly disposed of. Waste disposal has long been a source of worry, with population increase and industrialisation being the primary causes. Here are a few garbage disposal options.

- **Landfills:** The most common way of trash disposal today is to throw daily waste/garbage into landfills. This garbage disposal method relies on burying the material in the ground.

- **Recycling:** Recycling is the process of transforming waste items into new products in order to reduce energy consumption and the use of fresh raw materials. Recycling reduces energy consumption, landfill volume, air and water pollution, greenhouse gas emissions, and the preservation of natural resources for future use.

3. **Composting:** Composting is a simple and natural bio-degradation process that converts organic wastes, such as plant remnants, garden garbage, and kitchen waste, into nutrient-rich food for plants.

4. **Incineration:** Incineration is the process of combusting garbage. The waste material is cooked to extremely high temperatures and turned into materials such as heat, gas, steam, and ash using this technology.

8.4.3 Recyclable, Non-Recyclable and Hazardous Waste

1. **Recyclable Waste:** The waste which can be reused or recycled further is known as recyclable waste.

2. **Non-recyclable Waste:** The waste which cannot be reused or recycled is known as non-recyclable waste. Polythene bags are a great example of non-recyclable waste.

3. **Hazardous Waste:** The waste which can create serious harm to the people and the environment is known as hazardous waste.

8.4.4 Sources of Pollution

Pollution is defined as the harm caused by the presence of a material or substances in places where they would not normally be found or at levels greater than normal. Polluting substances might be in the form of a solid, a liquid, or a gas.

- **Point source of pollution:** Pollution from a point source enters a water body at a precise location and can usually be identified. Effluent discharges from sewage treatment plants and industrial sites, power plants, landfill sites, fish farms, and oil leakage via a pipeline from industrial sites are all potential point sources of contamination.

  Point source pollution is often easy to prevent since it is feasible to identify where it originates, and once identified, individuals responsible for the pollution can take rapid corrective action or invest in longer-term treatment and control facilities.

- **Diffuse source of pollution:** As a result of land-use activities such as urban development, amenity, farming, and forestry, diffuse pollution occurs when pollutants are widely used and diffused over a large region. These activities could have occurred recently or in the past. It might be difficult to pinpoint specific sources of pollution and, as a result, take rapid action to prevent it because prevention often necessitates significant changes in land use and management methods.

Pollution Prevention

Pollution prevention entails acting at the source of pollutants to prevent or minimise their production. It saves natural resources, like water, by using materials and energy more efficiently.

Pollution prevention includes any practice that:

- Reduces the amount of any hazardous substance, pollutant, or contaminant entering any waste stream or otherwise released into the environment (including fugitive emissions) prior to recycling, treatment, or disposal;

- Reduces the hazards to public health and the environment associated with the release of such substances, pollutants, or contaminants (these practices are known as "source reduction");

- Improved efficiency in the use of raw materials, energy, water, or other resources, or Conservation is a method of safeguarding natural resources.

- Improvements in housekeeping, maintenance, training, or inventory management; equipment or technology adjustments; process or method modifications; product reformulation or redesign; raw material substitution; or improvements in housekeeping, maintenance, training, or inventory control.

8.4.5 Electronic Waste

Lead, cadmium, beryllium, mercury, and brominated flame retardants are found in every piece of electronic waste. When gadgets and devices are disposed of illegally, these hazardous compounds are more likely to contaminate the earth, pollute the air, and leak into water bodies.

When e-waste is dumped in a landfill, it tends to leach trace metals as water runs through it. The contaminated landfill water then reaches natural groundwater with elevated toxic levels, which can be dangerous if it reaches any drinking water bodies. Despite having an environmentally benign approach, recycling generally results in international shipment and dumping of the gadgets in pits.

Some eco-friendly ways of disposing of e-waste are:

- Giving back the e-waste to the electronic companies and drop-off points.

- Following guidelines issued by the government.

- Selling or donating the outdated technology-based equipment.

- Giving e-waste to a certified e-waste recycler.

Exercise ✎

1. Name all five types of fire extinguishers.

2. Explain PPE in brief.

3. List the common workplace hazards.

4. Fill in the Blacks:

   i. A "_____ sign" is a safety sign that prohibits behaviour that is likely to endanger one's health or safety.

   ii. _____ entails acting at the source of pollutants to prevent or minimise their production.

   iii. _____ is the treatment or care given to someone who has sustained an injury or disease until more advanced care can be obtained or the person recovers.

   iv. The threats caused by biological agents like viruses, bacteria, animals, plants, insects and also humans, are known as _____.

   v. The workplace has to be administered as per the rules of the _____.

Notes

Annexure of QR Codes for Mechatronics Designer and System Integrator

Chapter Name	Unit Name	Topic Name	URL	Page No.	QR Code	Video Duration
Chapter 1: Introduction to the Electronics Sector in India	Unit 1.1: Overview of the Electronics Industry	1.1.6 Scope of Electronic Industry	https://www.youtube.com/watch?v=JgLu40JBa-c	6	Scope of Electronic Industry	00:06:05
	Unit 1.2: Introduction to Mechatronics	1.2.1 Mechatronics	https://youtu.be/af9xQznYQAw	10	Mechatronics	00:15:37
	Unit 1.3: Role and Responsibilities of a Mechatronics Designer and System Integrator	1.3.1 Mechatronics Designer and System Integrator	https://youtu.be/ilonmpLQ8vc	14	Mechatronics Designer and System Integrator	00:20:22
Chapter 2: Process of Integrating Programmable Logical Controller (PLC) With the Supervisory Control and Data Acquisition (SCADA) System	Unit 2.1: Programmable Logic Controller (PLC)	2.1.2 PLC	https://youtu.be/cYXqVPJDlXs	33	Programmable Logic Controller (PLC)	00:47:03
		2.1.2 PLC's Hardware and Architecture				
		2.1.3 Types of PLCs				
		2.1.5 Wiring of PLC				
		2.1.6 PLC Programming				
	Unit 2.2: Supervisory Control and Data Acquisition (SCADA) System	2.2.1 SCADA	https://youtu.be/gTBm9BlWZqs	47	SCADA	00:12:32
		2.2.2 Detecting faults in SCADA Software	https://youtu.be/wolM60e05g4	47	Detecting faults in SCADA Software	00:18:51
		2.2.3 Communication with the SCADA Software	https://youtu.be/NWxUJalyWFQ	47	Communication with the SCADA Software	00:13:08
Chapter 3: Process of Analysing Motion Control	Unit 3.1: Basics of Motor	3.1.1 Electric Motors	https://youtu.be/ihEglecTl3Y	71	Electric Motors	00:12:08
		3.1.2 Types of Motors	https://youtu.be/skmZbcEsylo	71	Types of Motors	00:07:48

Chapter Name	Unit Name	Topic Name	URL	Page No.	QR Code	Video Duration
		3.1.3 Selection of Sensors	https://youtu.be/ETb4UJ9VYw8	71	Selection of Sensors	00:06:43
		3.1.4 Soft Starter	https://youtu.be/zIEgEyZCahE	71	Soft Starter	00:11:53
		3.1.5 Motor Circuit	https://youtu.be/grtKSnwbDaA	71	Motor Circuit	00:11:01
		3.1.7 Control Panel	https://youtu.be/MBT7KxQTCw0	71	Control Panel	00:13:21
		3.1.10 Digital Electronics Circuit	https://youtu.be/pyFyUsAeYPQ	71	Digital Electronics Circuit	00:28:09
Chapter 4: Process of Designing the Panels Using AutoCAD Electrical Toolset	Unit 4.1: Process of Designing Panels	4.1.1 Electrical Panel	https://youtu.be/tDhyy72peJ0	103	Electrical Panel	00:04:21
		4.1.3 Circuit Protection Devices	https://youtu.be/YM7SdHj7Tuo	103	Circuit Protection Devices	00:28:05
		4.1.4 Circuit Breakers	https://youtu.be/DMG2jd6RUSE	103	Circuit Breakers	00:06:06
		4.1.5 Electrical Load	https://youtu.be/hhehRnIYZss	103	Electrical Load	00:07:31
		4.1.6 Switchgears	https://youtu.be/oCBIX0K53IQ	103	Switchgears	00:10:00
Chapter 5: Carrying Out Process	Unit 5.1: Process Instrumentation	5.1.1- Process Instrumentation 5.1.2 Control System	https://youtu.be/sP3Omzjw63U	135		00:33:40

Chapter Name	Unit Name	Topic Name	URL	Page No.	QR Code	Video Duration
Instrumentation		5.1.3 Flow Measurement Device			Process Instrumentation	
		5.1.4 Pressure Measurement Device				
		5.1.5 Level Measurement				
		5.1.6 Load Measurement				
		5.1.7 Electronic Components				
		5.1.8 Transmitters				
		5.1.9 SMART Transmitter				
Chapter 6: Process of Setting Up Advanced Automation in Mechatronics	Unit 6.1: Process of Setting up Human Machine Interface (HMI)	6.1.1 Human Machine Interface	https://youtu.be/d9XwKgSD3lo	149	Human Machine Interface	00:10:53
		6.1.3 Types of HMI			Types of HMI	
		6.1.7 System Monitoring	https://youtu.be/AQ6N1SmYyRc	149	System Monitoring	00:13:26
		6.1.10 Alarm System	https://youtu.be/hjTgh8Hjx24	149	Alarm System	00:07:48
	Unit 6.2: Automation of Material Handling System	6.2.1 Material Handling System	https://youtu.be/Up1oSSJn6oM	159	Automation of Material Handling System	01:10:58
		6.2.2 Automated Material Handling System				
		6.2.3 Function of Automated Material Handling System				
		6.2.4 Selection of Material Handling System				
		6.2.5 Material Transport System				

Chapter Name	Unit Name	Topic Name	URL	Page No.	QR Code	Video Duration
		6.2.6 Conveyor System				
		6.2.7 Automated Guided Vehicle System				

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