

1236**Code : 20ME51**Register
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V Semester Diploma Examination, June/July-2023
AUTOMATION AND ROBOTICS**Time : 3 Hours]****| Max. Marks : 100****Instruction :** Answer one full question from each section.**SECTION – I**

1. (a) Today manufacturing industries want to automate their processes to meet the ever increasing demand in the market. When it is found to be feasible solution for improved performance, quality and productivity, industries are required to study about the strategies that will give a road map to adopt automation. Discuss the ten strategies which are relevant to automation and production systems. 10
- (b) Programmable Logic Controllers (PLCs) and Programmable Automation Controllers (PACs) are considered to be the brains of the manufacturing process as they efficiently control automation equipment with high reliability. The main distinguish between PLCs and PACs is their programing language. Compare in what way PAC is different from PLC with respect to features, functions and capabilities and list additional features in PAC. 10
2. (a) Twenty first century organizations from a wide range of industries find design thinking a valuable means to solve problems for the users of their produces and services. Discuss different stages of design thinking and highlight its principles. 10
- (b) The entire automation cycle for manufacturing a product goes very smoothly through starting from small sensors, to PLC, to SCADA, to MES, and at last ERP, the process goes from local control to supervision to manufacturing control and to enterprise process management. Justify above statement with automation pyramid and list automation technologies used in the manufacturing industry. 10

SECTION – II

3. (a) Different objects are moving on a conveyor belt. Let's say, circular balls, square blocks and rectangular blocks. All three types of objects are collected in the same sized box. As these types are different in size and shapes as well, the number of objects to be placed is different for each type. Set counter valve according to different sized objects detection. Name various types of sensors used in industrial automation along with their applications and suggest a suitable sensor for the above case with justification. 10



(b) Industry 4.0. has emphasized on interlinking various systems like machines, devices, applications, etc. from plant floor to the enterprise applications to become a smart factory. This interlinking is possible through efficient connectivity solutions enabling smooth data exchange across the layers. These connectivity solutions are designed keeping the communication needs in mind. Identify the various communication protocols and network devices used in industries to interlink various systems.

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4. (a) A local food and beverage company was working with Horizon solutions on automation to upgrade projects for one of their key manufacturing facilities. One of the machines looked at upgrading was connected to a conveyor on the packing line. This machine merged three conveyor lines. Also, before packing, one among the lot had to push for inspection which is performed by actuators. Suggest a suitable actuator for the above case with justification and discuss electrical, hydraulic and pneumatic actuators with their strength and limitations.
- (b) OSI and TCP/IP are the two networking models. Describes the architecture, components and design used to establish communication between the source and destination systems. Compare TCP/IP model with OSI model.

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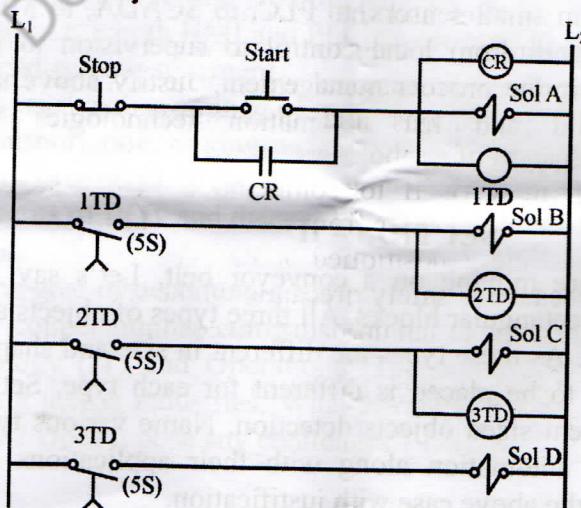
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SECTION - III

5. (a) Objects are moving on a conveyor belt 1. When an empty box is detected, conveyor belt 1 starts and 5 pcs are packed in a box. When the box is filled, it is carried to the storage area via conveyor belt 2. Suggest suitable sensor technology and drives for above case and implement automation of this process in PLC using Ladder diagram programming language.
- (b) Consider the hardwired relay operated, time delay circuit shown in figure. This circuit uses three electromechanical time delay relays to control four solenoid values.

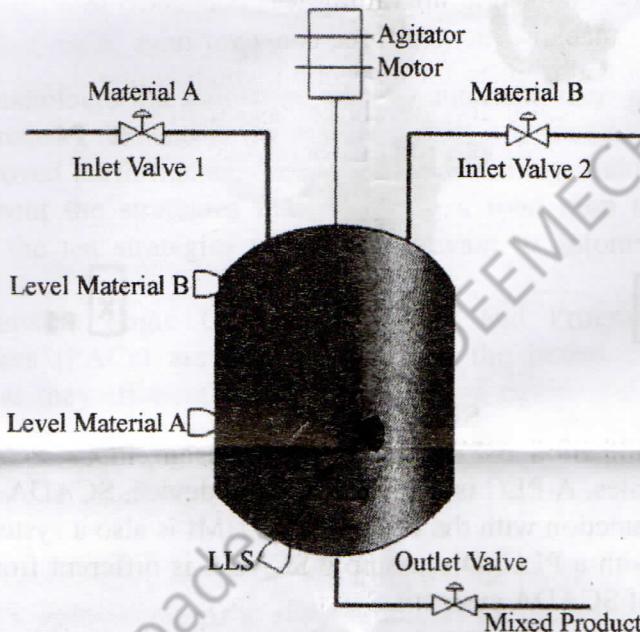
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Analyze the above circuit and develop the equivalent ladder diagram program using only one internal timer along with data compare instructions.

6. (a) Parts are moving on the conveyor from one process line to other with constant speed. Out of 1000 parts, one part is taken out for quality check. Operate solenoid a few seconds until the part is diverted for quality check. Suggest suitable sensor technology and protocols for the above case and implement automation of this process in PLC using ladder diagram programming language. 10
- (b) Material A and material B are collected in a tank. These materials are mixed for a while (20 S). Mixed product is then drained out through outlet valve. 10
Analyze above diagram and implement this in PLC using ladder logic programming language.



SECTION – IV

7. (a) Some industrial robots may not be able to scratch the back of their forearm with the same hand, just like most people cannot perform this task. However, through the attention to axes and the selection of a configuration, industrial robots can be designed to move their tools quickly, accurately and repetitively to any point within a three dimensional workspace. Discuss the various robot configurations with applications and also specify the technical features considered in the selection of a robot. 12
- (b) Develop a program in VAL II to command a PUMA robot to unload a cylindrical part of 10 mm diameter from machine 1 positioned at point P1 and load the part on machine 2 positioned at P2. The speed of robot motion is 40 in/s. However, because of safety precautions, the speed is reduced to 10 in/s while moving to a machine for an unloading or loading operation. 8
8. (a) Grippers are devices that enables robots to pick up and hold objects. When combined with a collaborative robot (or cobot) arm, grippers enable manufacturers to automate key processes, such as inspection, assembly, pick and place and machine tending. In his regard discuss different robot grippers and highlight the criteria considered in selection of right type of robot grippers. 12

- (b) Write a program for pick and place operation that operates as follows : 8
- Robot opens its gripper and goes to ready position.
 - Robot moves to safe position P1.
 - Robot moves from P1 to P2.
 - At position P3 robot picks part form Bin A.
 - Robot moves back to position P2 and then to P1.
 - Robot moves to position P4.
 - Robot drops part at position P5.
 - Robot returns to ready position.

The teachable variables you can declare are P3 and P5 only.



SECTION – V

9. (a) In process automation and advanced system design, PLCs, SCADA and HMIs play crucial roles. A PLC is a hardware based device, SCADA is a system that works in conjunction with the PLC. But, an HMI is also a system that works in conjunction with a PLC. Discuss how SCADA is different from HMI and list components of SCADA system. 10
- (b) The cutting area is an important section in the float glass production line, which includes many production control equipment such as longitudinal cutting, transverse cutting, conveying roller table, etc. The main control part of the whole system is PLC and the monitoring will be undertaken by HMI. Is it required to use both HMI and PLC, as opposed to just a PLC in this production line ? Justify your statement. 10
10. (a) IIOT is used across a range of industries from manufacturing, logistics, oil and gas, transportation, mining, aviation, energy and more. Its focus is to optimize operations particularly the automation of processes and maintenance. Highlight the benefits of IIOT and discuss the challenges and risks encountered during its adoption. 10
- (b) With the goal of becoming a leader in the use of automation in it's operations, a large copper mining company wanted to take advantage of an Information Technology (IT) and Operational Technology (OT) convergence movement sweeping across industries. What advantages does the convergence of IT/OT provide ? Does it pose any challenges ? Discuss. 10

SCHEME OF VALUATION

V Semester Diploma Examination, June/July – 2023

Programme: Mechanical Engineering

Max. Marks: 100

Course: Automation and Robotics

Course Code: 20ME51I

Instruction to the Candidate: Answer one full question from each section.

Q.No.	Description	Marks
Section 1		
1.a	Explanation of ten strategies, 1 mark for each	$10 \times 1 = 10$
b	Compare PAC and PLC (any 7 points) + Listing of any three additional features of PAC = $7 \times 1 + 3 \times 1 = 10$ marks	$7 \times 1 + 3 \times 1 = 10$
2.a	Listing Five stages of design thinking + Explanation of five stages + Highlighting any three Principles of design thinking	$2 + 5 \times 1 + 3 \times 1 = 10$
b	Writing automation pyramid + Explanation + Listing any three automation technologies used in the manufacturing industry.	$4 + 3 + 3 \times 1 = 10$
Section 2		
3.a	Naming of any 5 sensors with application used in industrial automation + Suggest suitable Sensor + justification	$5 \times 1 + 2 + 3 = 10$
b	Identification of various Communication protocols (any 5) + Identification of Network devices (any 5)	$5 \times 1 + 5 \times 1 = 10$
4.a	Suggest suitable actuator + justification + Explain three (Electrical, Hydraulic and Pneumatic) actuators with their strength and limitations	$2 + 3 + 5 = 10$
b	Compare OSI and TCP/IP model (Ten Points)	$10 \times 1 = 10$
Section 3		
5.a	Suggestion of Sensor Technology + Suggestion of Drives + Ladder diagram (Each correct rung carries 1 mark, Award 8 marks for full ladder diagram)	$1 + 1 + 8 = 10$
b	Listing operations of given hardwired relay-operated, time-delay circuit + Writing equivalent ladder diagram (Rung 1&5 – 1 mark each, Rung 2,3 &4 – 2 marks each)	$2 + 8 = 10$
6.a	Suggestion of Sensor Technology + Protocols + Ladder diagram (Each correct rung carries 1 mark, Award 7 marks for full ladder diagram)	$1 + 2 + 7 = 10$
b	Analysing the problem + Ladder diagram (Rung 1-3: 4 Marks, Rung 4-6: 4 Marks)	$2 + 8 = 10$

Section 4		
7.a	Explanation of any four configuration with applications + Specifying any four technical features considered in the selection of a robot	$4 \times 2 + 4 \times 1 = 12$
b	Writing Robot Program	8
8.a	Explanation any Four Grippers + Highlighting of any 4 criteria considered in selection of right type of robot grippers	$4 \times 2 + 4 \times 1 = 12$
b	Writing Robot Program	8
Section 5		
9.a	Any six difference between SCADA and HMI + Any four components of SCADA system	$6 + 4 \times 1 = 10$
b	Is it required to use both HMI and PLC, As opposed to just a PLC in this Production line? + Explanation with justification	$2 + 8 = 10$
10.a	Highlighting any 5 benefits + Discussion about Challenges and risks	$5 \times 1 + 5 = 10$
b	Any five advantages + Challenges	$5 \times 1 + 5 = 10$

NOTE: The model answers are given for reference to valuers for valuation. The valuator may also consider answers, suitable sketches, PLC Programs and Robot programs based on different software's and explanation which are most appropriate and relevant.

MODEL ANSWERS

V Semester Diploma Examination, June/July – 2023

Course: Automation and Robotics

Course Code: 20ME51I

NOTE: The model answers are given for reference to valuers for valuation. The valuer may also consider answers, suitable sketches, PLC Programs and Robot programs based on different software's and explanation which are most appropriate and relevant.

Section - 1

Q1. a) Today manufacturing Industries want to automate their processes to meet the ever-increasing demand in the market. When it is found to be a feasible solution for improved performance, quality and productivity, industries are required to study about the strategies that will give a road map to adopt automation. Discuss the ten strategies which are relevant to automation and production systems. – 10 M -

Scheme:

Explanation of ten strategies, one mark for each – $10 \times 1 = 10$ Marks

Answer:

1. Specialization of operations. The first strategy involves the use of special-purpose equipment designed to perform one operation with the greatest possible efficiency. This is analogous to the specialization of labor, which is employed to improve labor productivity.

2. Combined operations. Production occurs as a sequence of operations. Complex parts may require dozens or even hundreds of processing steps. The strategy of combined operations involves reducing the number of distinct production machines or workstations through which the part must be routed. This is accomplished by performing more than one operation at a given machine, thereby reducing the number of separate machines needed. Since each machine typically involves a setup, setup time can usually be saved by this strategy. Material handling effort, nonoperation time, waiting time, and manufacturing lead time are all reduced.

3. Simultaneous operations. A logical extension of the combined operations strategy is to simultaneously perform the operations that are combined at one workstation. In effect, two or more processing (or assembly) operations are being performed simultaneously on the same work part, thus reducing total processing time.

4. Integration of operations. This strategy involves linking several workstations together into a single integrated mechanism, using automated work handling devices to transfer parts between stations. In effect, this reduces the number of separate work centers through which the product must be scheduled. With more than one workstation, several parts can be processed simultaneously, thereby increasing the overall output of the system.

5. Increased flexibility. This strategy attempts to achieve maximum utilization of equipment for job shop and medium-volume situations by using the same equipment for a variety of parts or products. It involves the use of programmable or flexible automation. Prime objectives are to reduce setup time and programming time

for the production machine. This normally translates into lower manufacturing lead time and less work-in-process.

6. Improved material handling and storage. A great opportunity for reducing nonproductive time exists in the use of automated material handling and storage systems. Typical benefits include reduced work-in-process, shorter manufacturing lead times, and lower labor costs.

7. On-line inspection. Inspection for quality of work is traditionally performed after the process is completed. This means that any poor-quality product has already been produced by the time it is inspected. Incorporating inspection into the manufacturing process permits corrections to the process as the product is being made. This reduces scrap and brings the overall quality of the product closer to the nominal specifications intended by the designer.

8. Process control and optimization. This includes a wide range of control schemes intended to operate the individual processes and associated equipment more efficiently. By this strategy, the individual process times can be reduced and product quality can be improved.

9. Plant operations control. Whereas the previous strategy is concerned with the control of individual manufacturing processes, this strategy is concerned with control at the plant level. It attempts to manage and coordinate the aggregate operations in the plant more efficiently. Its implementation involves a high level of computer networking within the factory.

10. Computer-integrated manufacturing (CIM). Taking the previous strategy one level higher, CIM involves extensive use of computer systems, databases, and networks throughout the enterprise to integrate the factory operations and business functions.

Q1.b) Programmable Logic Controllers (PLCs) and Programmable Automation Controllers (PACs) are considered to be the brains of the manufacturing process as they efficiently control automation equipment with high reliability. The main distinguish between PLCs and PACs is their programming language. Compare in what way PAC is different from PLC with respect to features, functions and capabilities and List additional features in PAC.

-10 M-

Scheme:

Compare PAC and PLC (any 7 points) + Listing of any three additional features of PAC = $7 \times 1 + 3 \times 1 = 10$ marks

Answer:

	PLC	PAC
Processor Module	It is a single microprocessor device. 1 Per Rack module and 1 Microprocessor	It is a multiprocessor device which is built with two or more number of processors like any other personal computers. Multi-processor per Rack and 2+ High Performance multitasking

Architecture	Designed to replace the relay-based systems	Designed with user-friendly hardware and software architecture which are easier to operate by IT Programmers.
Usage	PLC has built-in networks which enable them to communicate between multiple PLCs, I/Os, HMIs and SCADA systems.	PAC is incorporated with modular design open architecture use for communicating, monitoring, and controlling equipment covering multiple networks and devices.
Memory	Limited memory Up to 64K and separate I/O device.	Huge memory size Up to 32000K for larger projects and systems.
Programming	Uses Ladder Logic Diagram Programming.	Done through structured text, function block diagrams, ladder logic diagram and also other programming languages like C or C++ etc.
Reliability	PLC normally has a fixed memory map and address depending on its programming capability.	PACs permits tag naming, giving users a chance to characterize and define the data categories as they program. Thus, providing a greater adaptability feature, particularly while extending the framework.
Features	Advanced PLCs comes with good control communication and data handling options	Built-in with more features such as Data USB ports, a high-quality LCD screen for better user interface and a web server for seeing system data log files.
Communication	Typical Single option	PACs utilize standard protocols and network technologies like Ethernet, OLE for Process Control (OPC) and Structured Query Language (SQL) for multitasking operations. Multiple options like Ethernet/IP etc.
Functionality	Sequential scan up to 64K	Dual logic scan, motion control. Process control and Data acquisition.
Input Outputs	3000	128000
Applications	PLCs are the perfect model for simple and high-speed machinery controlling. automated spray equipment, assembly equipment, dispensing systems and motion control systems. used to control manufacturing, infrastructure, transportation and machine/station control automation equipment operation	PACs are ideal for large-scale automation projects and operations. As the architecture of PAC is enabled with various PC-based software programs, it helps them in handling complex automation system. PACs are equipped with multitasking capabilities to control automation of various pieces of equipment

Additional features of PAC

Depending on controller vendor, additional features of PACs are

- Motion control
- Robotic control
- Hydraulic and temperature controls

- Safety monitoring
- access to a local area network for equipment maintenance and diagnostics
- Multi-domain functionality
- A single, multi-discipline development platform
- Flexible software tools that maximize process flow across machines or processes
- An open, modular architecture
- Compatibility with enterprise networks

Q2.a) Twenty-first century organizations from a wide range of industries find design thinking a valuable means to solve problems for the users of their products and services. Discuss different stages of design thinking and highlight its principles. -10 M-

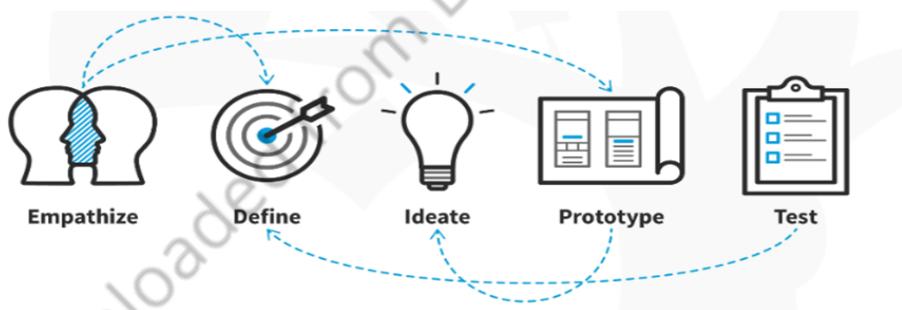
Scheme:

Listing Five stages of design thinking + Explanation of five stages + Highlighting any three Principles of design thinking = $2 + 5 \times 1 + 3 \times 1 = 10$ Marks

Answer:

Design thinking is an iterative and non-linear process that contains five phases:

1. Empathize
2. Define
3. Ideate
4. Prototype and
5. Test



Stage 1: Empathize (Research Your Users' Needs)

Design thinking begins with empathy to gain an insight into the problem that it sets out to resolve. However, more than understanding the problem, this step is crucial to understanding the requirements of the user, to deliver a more customized solution. This step involves observing and engaging with the user to understand their behavior patterns, inclinations, preferences, and likely reactions to situations. Only when businesses have fully grasped the user environment and behavioral patterns, will they be able to tailor solutions to fit user needs.

Stage 2: Define (State Your Users' Needs and Problems)

The next step in the process is organizing all the information collected during the previous phase. This will eventually help you to define the problem statement from a more human-centric perspective. Define stage not only helps in breaking down obscure ideas and issues but also helps to form a structured approach towards

solving it. This is when you lay down the plan and frame questions that need to be answered in order to resolve the issue at hand.

Stage 3: Ideate (Challenge Assumptions and Create Ideas)

This is probably the most crucial phase of all and interestingly, allows a lot of room for creativity. This is when you think radically and prepare for experimentation to champion the user experience. It's important to bring fresh perspectives to the table at this stage and think of new ways of resolving the issue. It's also equally important to consider probable obstacles both from the user's end and environmental while suggesting these solutions. Brainstorming is particularly useful here.

Stage 4: Prototype (Start to Create Solutions)

This is an experimental phase. The aim is to identify the best possible solution for each problem found. Prototyping involves curating your best ideas and putting them into shape. This stage allows designers to test the effectiveness of the solution internally in a small-scale environment before presenting it for implementation. An important part of this phase is eliminating all the failed/ less effective options and moving forward with the best ones. Prototyping allows designers to understand how users would typically behave or react to any particular solution, thereby helping them form a more realistic solution that can be adopted on a larger scale

Stage 5: Test (Try Your Solutions Out)

Evaluators rigorously test the prototypes. Although this is the final phase, design thinking is iterative. Teams often use the results to redefine one or more further problems. So, return to previous stages to make further iterations, alterations and refinements to find or rule out alternative solutions.

Four principles of design thinking

1.The Human Rule: “All design is social in nature.” The problems must be solved by satisfying the human requirements and recognizing the human element in all technologies.

2.The Ambiguity Rule: “Ambiguity is inevitable.” We perform experiments to the limits based on our knowledge, control events based on our limits, and liberty to see things from different perspectives.

3.The Redesign Rule: “All design is redesign.” In today’s world, technology and social events have been consistently evolving. We must study and analyze how the requirements of humans were met in earlier times.

4.The Tangibility Rule: “Making ideas tangible facilitates communication.” If we make our ideas tangible for prototypes, it facilitates designers to communicate effectively.

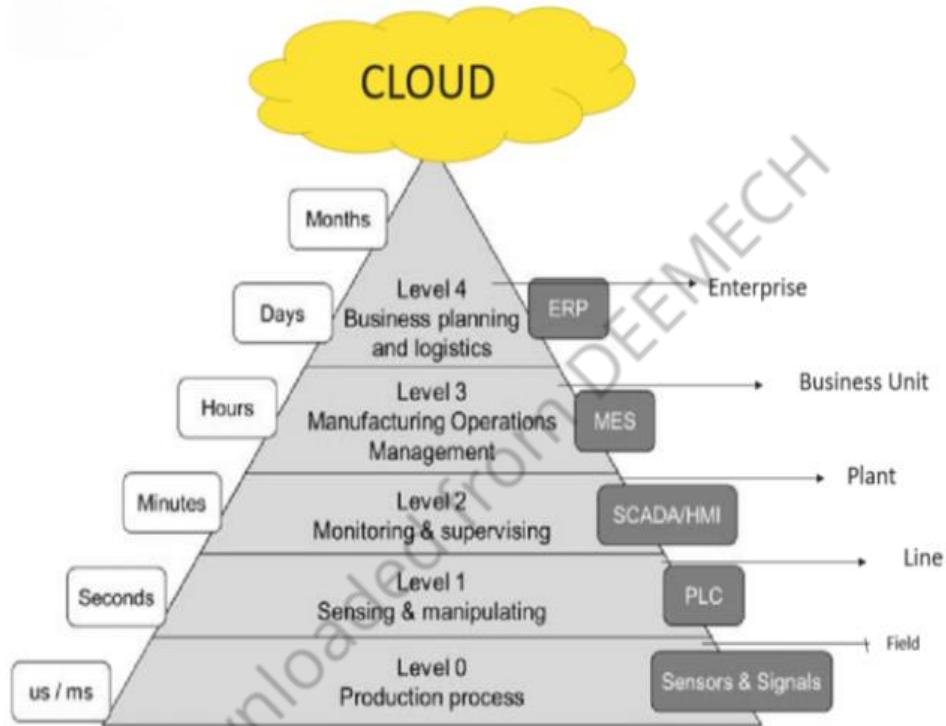
4.The Tangibility Rule: “Making ideas tangible facilitates communication.” If we make our ideas tangible for prototypes, it facilitates designers to communicate effectively.

Q2.b) The entire automation cycle for manufacturing a product goes very smoothly through starting from small sensors, to PLC, to SCADA, to MES, and at last the ERP, the process goes from local control to supervision to manufacturing control and to enterprise process management. Justify above statement with automation pyramid and list automation technologies used in the manufacturing industry. - 10 M-

Scheme :

Writing automation pyramid + Explanation + Listing any three automation technologies used in the manufacturing industry. = $4+3+3\times1 = 10$ Marks

Answer:



Field Level/Production Process

This level has devices, actuators, and sensors that are found in the field or on the production floor. The field level is the production floor where physical work and monitoring happens. Electric motors, hydraulic and pneumatic actuators to move machinery, proximity switches to detect movement of certain materials, photoelectric switches that detect similar things are some examples at the field level.

Control Level/Sensing and Manipulation

PLC's and PID's operate at this level. At this level, control and manipulate the devices in the field level that actually do the physical work. They take in information from all of the sensors, switches, and other input devices to make decisions on what outputs to turn on to complete the programmed task. PLCs contain a processor, memory to hold their programming and other data and input and output modules.

Supervisory Level/Monitoring and supervising

This level is known as the supervisory level. Where the previous level utilizes PLCs, this level utilizes SCADA which is used to access data and control systems from a single location. It usually adds a graphical user interface called an HMI, to control functions remotely. The important thing to remember about SCADA is that it can monitor and control multiple systems from a single location. It isn't limited to a single machine.

Planning level/Operations Management

The fourth level of the automation pyramid is called the planning level. This level utilizes a computer management system known as manufacturing execution system(MES). MES monitors the entire manufacturing process in a plant or factory from the raw materials to the finished product. This allows management to see exactly what is happening and allows them to make decisions based on that information. They can adjust raw material orders or shipment plans based on real data received from the systems

Enterprise level (Business Planning and Logistics)

The top of the pyramid is called the management level. This level uses the companies integrated management system which is known as enterprise resource planning (ERP). This is where a company's top management can see and control their operations. ERP is usually a suite of different computer applications that can see everything going on inside a company. It utilizes all of the previous levels technology plus some more software to accomplish this level of integration.

Automation technologies used in the manufacturing industry

- The Industrial Internet of Things
- Robotics
- Artificial Intelligence
- Big Data
- Modeling, Simulation, Visualization, And Immersion.
- The Cloud
- Advanced Materials and Additive Manufacturing
- Cybersecurity

Section – 2

Q3.a) Different objects are moving on a conveyor belt. Let's say, circular balls, square blocks and rectangular blocks. All three types of objects are collected in the same sized box. As these types are different in size and shapes as well, the number of objects to be placed is different for each type. Set counter value according to different sized objects' detection. Name the various types of sensors used in industrial automation along with their applications and suggest a suitable sensor for the above case with justification. – 10 M -

Scheme:

Naming of any 5 sensors with application used in industrial automation + Suggest suitable Sensor + justification = $5 \times 1 + 2 + 3 = 10$ Marks

Answer:

Various types of sensors used in industrial automation

Sensor	Application
Positioning and Displacement Linear Position (LVDT) and Angular Position Sensor.	Used in motion control of a robot, tank-level sensing and in semiconductor process equipment.
Capacitive displacement sensors	Used in the precision positioning of objects at the nanometer level and in the measurement of precision thickness of disk drives, assembly line testing and machine tool metrology. It is widely used in machining.
Magnetostrictive linear position sensor	Used in handicapped lift for van or bus apart from sensing the cylinder position in pneumatic cylinders, sensing position in material handling equipment's, for detecting the traffic light burnouts.
Proximity Inductive Sensors	Used in metal detectors to detect metallic objects without any physical contact. They are also used in car washes and in industrial applications where dirt is prevalent.
Proximity Capacitive Sensors	Used in pipeline and vessel leak detection as they can sense both metallic and non-metallic materials. Used to control the level of liquids and solids and in pile-up controls in the automation industry.
Magnetic Sensors	Used to measure speed and the position of the devices.
Photoelectric Sensors	They are also used for the precise positioning of the objects in the printing machines and to periodically scan the target material on the R, G, B colour channels in order to detect the taught in color.
Vision Sensor	Used for monitoring purpose in different security cameras at homes, offices, etc. Detecting shapes and dimensions through visual feedback
Ultrasonic sensors — positioning or proximity	These sensors are used for detecting objects where the normal photocells cannot be used like for level measurement of solids and liquids, diameter or loop detection for materials like paper, sheet iron, and for the detection of transparent objects like plastic, glass bottles, plastic filters, etc.

Temperature Sensing	The temperature sensor is used in the refrigerators and in boilers in the HVAC systems apart from other applications in the Automation industry.
MEMS Based Sensors	Used for rollover or stability control along with monitoring of patients
Humidity Sensors	They are used in the HVAC systems so as to detect the humidity level in the industry and in transmission lines, antennas, and waveguides used in telecommunications.
Pressure Sensor	Used in weather instrumentation, aircrafts, vehicles, and any other machinery that has pressure functionality implemented Pressure sensors can be used in systems to measure other variables such as fluid/gas flow, speed, water level, and altitude
Torques Sensor	Used to Measure the speed of rotation and maintenance necessities, Measure Mass and mass moment of inertia. Used in Automotive and Aerospace engineering.

Suggest a suitable sensor for the above case with justification.

Suitable Sensor: Vision sensor

Justification: It is a sensor that identifies the shape, dimension, orientation or location of an object through visual feedback. A very good example of such sensors is the camera in our laptop. Vision sensors are more flexible and efficient than the light barriers and are simpler in design due to the configuration for one special field of application. Many difficult applications that required multiple photoelectric or proximity sensors for their work before can now be handled with just one vision sensor, at a low cost. Depending upon the graphic card the application is working on, or on the complexity of the objects sensed, the vision sensors may be little bit slower than the proximity sensors.

Q3.b) Industry 4.0 has emphasized on interlinking various systems like machines, devices, applications, etc. from plant floor to the enterprise applications to become a smart factory. This interlinking is possible through efficient connectivity solutions enabling smooth data exchange across the layers. These connectivity solutions are designed keeping the communication needs in mind. Identify the various communication protocols and network devices used in industries to interlink various systems. – 10 M -

Scheme:

Identification of various Communication protocols (any 5) + Identification of Network devices (any 5) = 5×1+5×1=10 Marks

Answer

Various Communication Protocols		Various network devices
<ul style="list-style-type: none"> • Ethernet/IP • Modbus • Profibus • Optomux • DF-1 • Interbus • HostLink • Data Highway (DH+) 	<ul style="list-style-type: none"> • Point to Point (PP) • Actual Sensor Interface (ASI) • Open Smart Grid Protocol • CAN (Controller Area Network) Open • HART (Highway Addressable Remote Transducer) 	<ul style="list-style-type: none"> • Access point • Bridge • Gateway • Hub • Modem • Router • Repeater • Switch

Q4.a) A local food and beverage company was working with Horizon Solutions on automation to upgrade projects for one of their key manufacturing facilities. One of the machines looked at upgrading was connected to a conveyor on the packing line. This machine merged three conveyor lines. Also, before packing, one among the lot had to push for inspection which is performed by actuators. Suggest a suitable actuator for the above case with justification and discuss Electrical, Hydraulic and Pneumatic actuators with their strength and limitations.

– 10 M -

Scheme:

Suggest suitable actuator + justification + Explain three (Electrical, Hydraulic and Pneumatic) actuators with their strength and limitations. =2+3+5 =10 Marks

Answer:

Suitable Actuator: Electrical Actuator

Justification:

- Existing system uses Pneumatic air cylinder which were costly and required a lot of maintenance.
- The cylinders needed to be replaced annually and required much downtime for maintenance.
- Electric actuator system is more reliable, cleaner, quieter, and requires less maintenance

Electrical Actuators:

An actuator obtaining electrical energy from the mechanical system is called electric actuators. Electric actuators are generally referred to as being those where an electric motor drives the robot links through some mechanical transmission i.e., gears.

Advantages of Electrical Actuators:

- High power conversion efficiency.
- The widespread availability of power supply.
- No pollution of the working environment.
- The basic drive element in an electric motor is usually lighter than that for fluid power.
- Structural components can be lightweight.
- The drive system is well suited to electronic control.

Disadvantages of Electrical Actuators:

- A larger and heavier motor must be used which is costly.
- Poor dynamics response.

- Compliance and wear problems are causing inaccuracies.
- Conventional gear-driven creates a backlash.
- Electric motors are not intrinsically safe. They cannot, therefore, be used in explosive atmospheres.

Hydraulic Actuators:

Hydraulic actuators transform the hydraulic energy stored in a reservoir into mechanical energy by means of suitable pumps. Hydraulic actuators are also fluid power device for industrial robots which utilize high-pressure fluid such as oil to transmit forces to the point of application desired.

Advantages of hydraulic actuators:

- It has the advantage of generating extremely large force from a very compact actuator.
- It can also provide precise control at low speeds
- robust.
- self-lubricating.
- Due to the presence of an accumulator that acts as a storage device the system can meet sudden demand in power

Disadvantages of hydraulic actuators:

- The hydraulic system is required for a large infrastructure is high-pressure pump, tank, and distribution lines.
- Leakage can occur causing a loss in performance.
- High maintenance.
- Not suitable for a clean environment.

Pneumatic actuators

Pneumatic actuators utilize pneumatic energy provided by a compressor and transform it into mechanical energy by means of a piston or turbines. Pressurized air is used to transmit and control power. Pneumatic actuators are devices that cause things to move by taking advantage of potential energy.

Advantages of Pneumatic Actuators:

- Control is simple.
- When the source of compressed air is readily available, as they often are in engineering related facilities, pneumatic actuators may be a good choice.
- It is the cheapest form of all actuators
- Pneumatic actuators have very quick action and response time, thus allowing for fast work cycles.
- No mechanical transmission is usually required.

Disadvantages of Pneumatic Actuators:

- More noise and vibration.
- Since air is compressible, pneumatic cylinders are not typically used for applications requiring accurate motion between two well-defined endpoints.
- Pneumatics is not suitable for heavy loads.
- If mechanical stops are used, resetting the system can be slow

Q4.b) OSI and TCP/IP are the two networking models, describes the architecture, components and design used to establish communication between the source and destination systems. Compare TCP/IP model with OSI model.

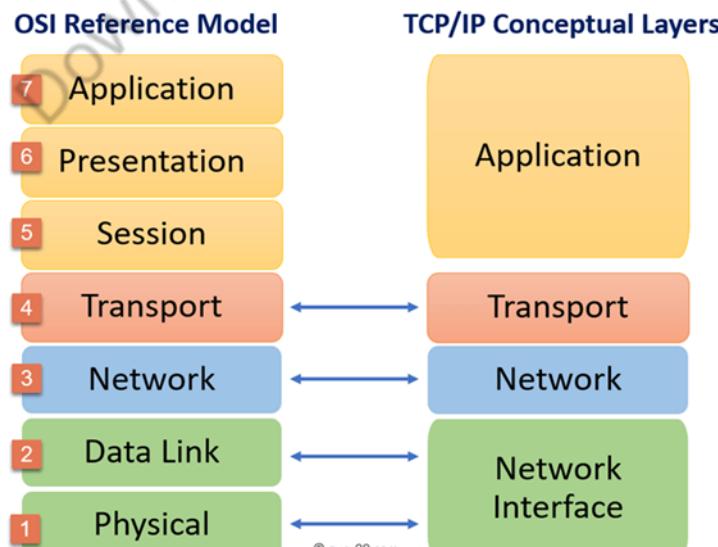
- 10 M -

Scheme:

Compare OSI and TCP/IP model (Ten Points) = $10 \times 1 = 10$ Marks

Answer:

Sl. No.	OSI Model	TCP/IP model
1	It is developed by ISO (International Standard Organization)	It is developed by ARPANET (Advanced Research Project Agency Network)
2	OSI model provides a clear distinction between interfaces, services, and protocols.	TCP/IP doesn't have any clear distinguishing points between services, interfaces, and protocols
3	Reference model	Implementation of OSI model
4	It follows a vertical approach	It follows a horizontal approach
5	It is a structured model which deals with the functioning of a network	It is a communication protocol that is based on standard protocols and allows the connection of hosts over a network.
6	It is protocol independent.	It is protocol dependent.
7	OSI layers have seven layers	TCP/IP has four layers
8	In the OSI model, the transport layer is only connection-oriented.	A layer of the TCP/IP model is both connection-oriented and connectionless.
9	In the OSI model, the data link layer and physical are separate layers.	In TCP, physical and data link are both combined as a single host-to-network layer.
10	Session and presentation layers are a part of the OSI model.	There is no session and presentation layer in the TCP model.
11	It is defined after the advent of the Internet.	It is defined before the advent of the internet.
12	The minimum size of the OSI header is 5 bytes	The minimum header size is 20 bytes
13	OSI uses the network layer to define routing standards and protocols	TCP/IP uses only the Internet layer



Section – 3

Q5.a) Objects are moving on a conveyor belt 1. When an empty box is detected, conveyor belt 1 starts and 5pcs are packed in a box. When the box is filled, it is carried to the storage area via conveyor belt 2.
 Suggest Suitable sensor technology and drives for above case and implement automation of this process in PLC using Ladder Diagram programming language.

– 10 M –

Scheme:

Suggestion of Sensor Technology + Suggestion of Drives + Ladder diagram (Each correct rung carries 1 mark, Award 8 marks for full ladder diagram) = 1+1+8 = 10 Marks

Answer:

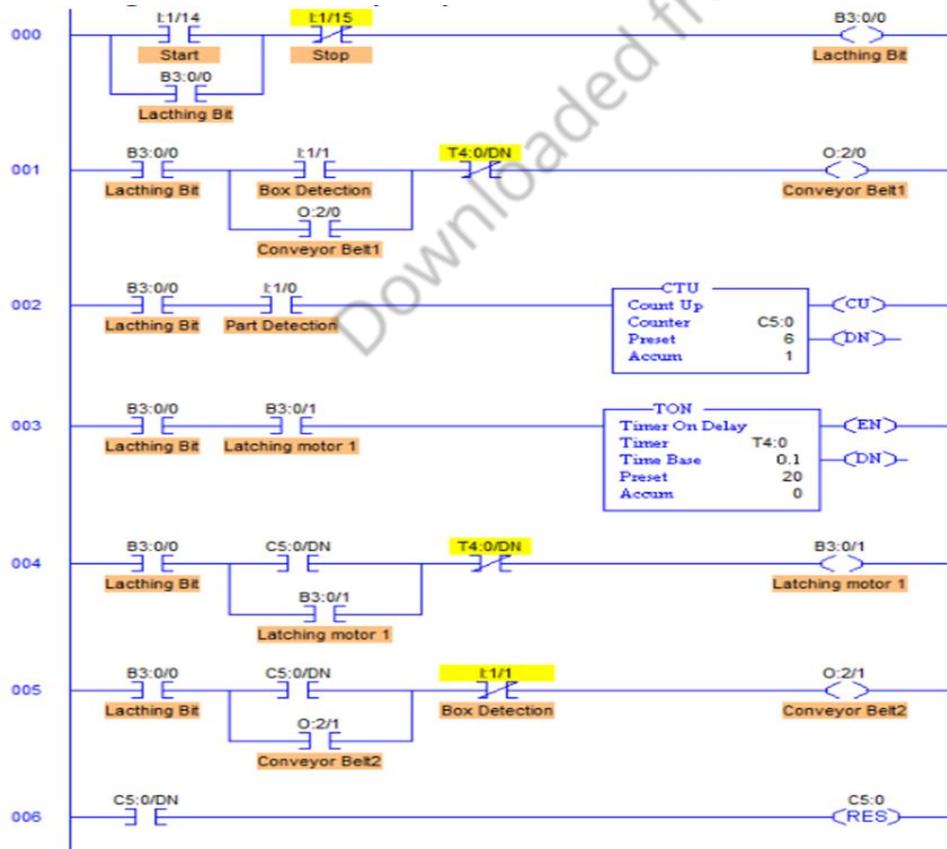
Sensor Technology used: Proximity sensor to detect object and box (Inductive/Capacitive/optical proximity sensor)

Drives: DC motor to run conveyor

Program Solution

- Use proximity switches to detect moving objects on the conveyor belt 1 and to detect an empty box on conveyor belt 2.
- Use counter to count number of objects to be packed.
- Use timer such that when 5pcs are detected, conveyor runs for a while and stops when 5th object is finally collected in the box. Assume time by calculating conveyor belt speed.
- When number of parts to be packed are detected timer is activated. When timer is over, it stops the conveyor until next empty box is detected.
- Assuming time taken by the last 5th object is 2secs to be collected.

Ladder diagram



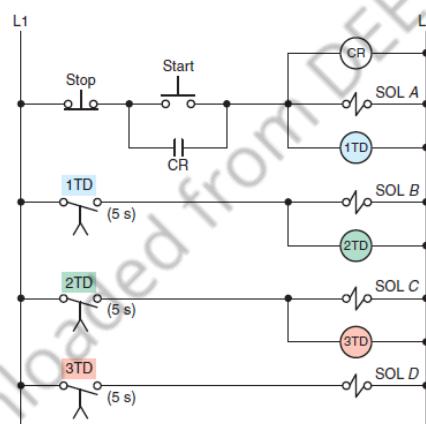
List of Inputs and Outputs

I:1/14 = Start (Input),
 B3:0/0 = Latching Bit (Bit),
 I:1/0= Part detection (Input),
 T4:0= Timer
 I:1/15= Stop (Input),
 B3:0/1= Latching Motor 1 bit (Bit),
 I:1/1= Box detection (Input)
 O:2/0 = Conveyor Belt 1 (Output),
 O:2/1= Conveyo2 Belt 2 (Output), C5:0= Part counter (Counter)
 T4:0 = Timer

Program Description

- RUNG000 - To start and stop the process using master switches/Push buttons.
- RUNG001 – To control Conveyor Belt 1 (motor M1) which is operated by Box Detection proximity switch/sensor. When the process is started and empty box is detected (I:1/1), drives the Motor M1 moving objects on the conveyor belt 1.
- RUNG002 – To count the part which is detected by I:1/0 Part detector/sensor, Counter C5:0 is incremented by 1. Counter has a preset value of 6. Here that means when total 5 parts are detected, counter done bit C5:0/DN is set to 1.
- RUNG003 – To activate the timer T4:0 for 2 secs (which is an assumption that the part will take approximately 2secs to fall into the box after it is detected by the Pat Detector proximity switch I:1/0.) when C5:0/DN bit is set
- RUNG004 - When C5:0/DN goes true. It latches the Latching Motor1 bit before it goes false.
- RUNG005 - Conveyor Belt 2 motor M2 (O:2/1) is operated when counter value reaches to 6 that is when total 5 parts are detected. and it is stopped when an empty box is detected again and the process is repeated.
- RUNG006 - Counter is immediately reset when C5:0/DN goes true.
- Here the Counter Preset is set 6 that is because when the counter is reset, the value is the accumulator is set to 1 because of latching bit.

Q5.b) Consider the hardwired relay-operated, time-delay circuit shown in Figure. This circuit uses three electromechanical time-delay relays to control four solenoid valves.



Analyze the above circuit and develop the equivalent ladder diagram program using only one internal timer along with data compare instructions.

– 10 M –

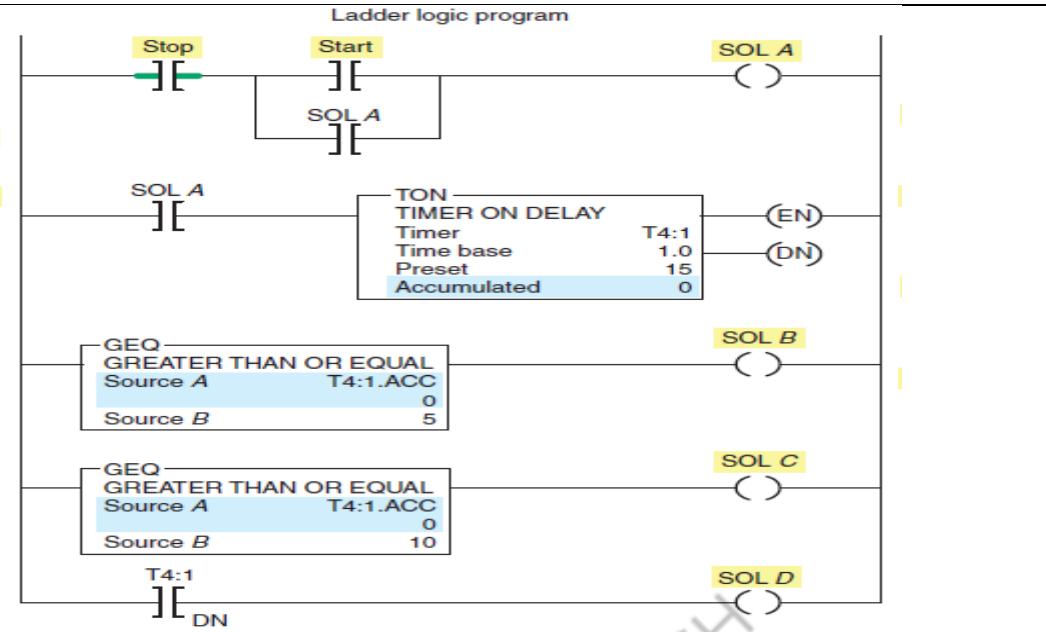
Scheme:

Listing operations of given hardwired relay-operated, time-delay circuit + Writing equivalent ladder diagram (Rung 1&5 – 1 mark each, Rung 2,3 &4 – 2 marks each) = 2+8 = 10 Marks

Answer:

As per the given hard wired relay operated time delay circuit. the operation of the hardwired circuit can be summarized as follows:

- When the momentary start pushbutton is pressed Solenoid A is energized immediately.
- Solenoid B is energized 5 s later than solenoid A.
- Solenoid C is energized 10 s later than solenoid A.
- Solenoid D is energized 15 s later than solenoid A.



Q6.a) Parts are moving on the conveyor from one process line to other with a constant speed. Out of 1000 part, one part is taken out for quality check. Operate Solenoid for a few seconds until the part is diverted for quality check.

Suggest Suitable sensor technology and protocols for the above case and Implement automation of this process in PLC using Ladder Diagram programming language. - 10 M -

Scheme:

Suggestion of Sensor Technology + Protocols + Ladder diagram (Each correct rung carries 1 mark, Award 7 marks for full ladder diagram) = 1+2+7 = 10 Marks

Answer:

Sensor Technology used: Proximity sensor to detect object (Inductive / optical / Capacitive proximity sensor)

Protocols: Ethernet IP/Profibus/Modbus/RS232

List of Inputs and Outputs

I:1/14 = Start (Input), I:1/15 = Stop(Input), I:1/0 = Detector input (Input) ,

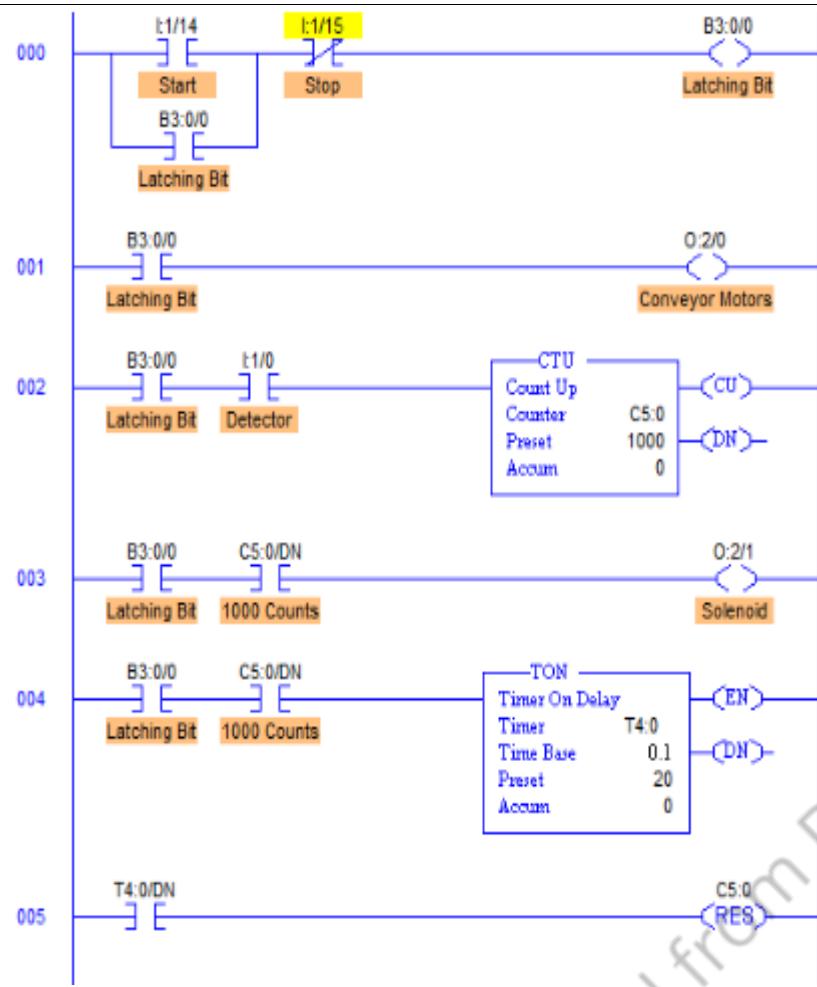
B3:0/0 = Latching Coil (Bit), O:2/0 = Conveyor Motors (Output), O:2/1 = Solenoid (Output)

C5:0 = Up Counter to count 1000 parts (Counter), T4:0 = Timer to operate solenoid (Timer)

-(RES)- = Reset counter value (Timer/Counter)

Problem Solution

- To detect the parts, detector such as proximity switch, optical sensors or any other sensor is used.
- Connect output of this detector to Input Module of PLC which sets and resets image memory according to parts' detection.
- Give this detection, as an input to Up Counter which is incremented with each part's detection.
- Set counter preset value to 1000.
- Operate Solenoid for a few seconds until the part is diverted for quality check



•RUNG000 - Master Start and Stop switches/push buttons for the process.

•RUNG001- To operates Conveyor Motors (O:2/0) for moving parts to other process. This is started as soon as Start button I:1/14 is pressed.

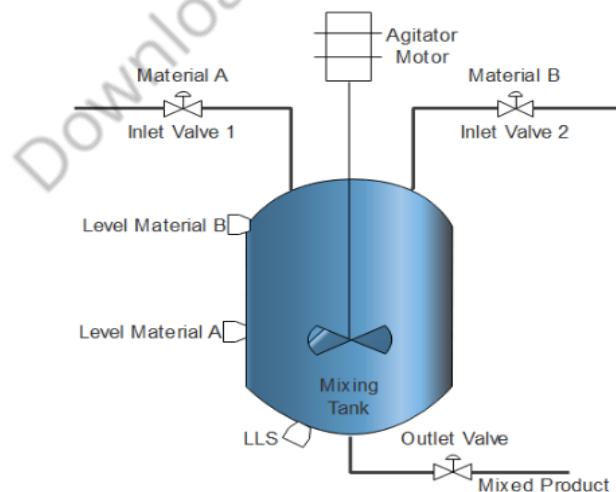
•RUNG002 - Consists Up Counter to count the number of parts detected by the detector which is connected to I:1/0. Whenever a part is detected, I:1/0 goes high incrementing accumulator value of C5:0 Counter.

•RUNG003 – To operate Solenoid coil when 1000 parts are counted, done bit activated.

•RUNG004 – To Activate the Timer (T4:0) for 2secs to divert the part for quality check.

•RUNG005 – To Reset the counter to 0 when timer bit T4:0/DN (after 2 sec) which in turn unlatches solenoid coil O:2/1 taking gate to its main position.

Q6. b) Material A and Material B are collected in a tank. These materials are mixed for a while (20s). Mixed product is then drained out through Outlet valve.



Analyze above diagram and Implement this in PLC using Ladder Logic programming language. -10 M-

Scheme:

Analyzing the problem + Ladder diagram (Rung 1-3: 4 Marks, Rung 4-6: 4 Marks) = 2+8 = 10 Marks

Answers:

- To detect level of Material A and Material B, two separate level switches are used.
- To detect low level, one more level switch is used at the bottom of the tank.
- These give output in digital terms that is when corresponding levels are detected.
- To control level of this system, Single Acting valve can be used which has two states, either fully open or fully close.
- To control mixing, agitator is used which is connected with Motor shaft.
- Particular time delay is generated to mix the materials for a definite time.
- Control inlet valves on the basis of Level Material switches A and B.
- Outlet valve is then operated to drain the mixed product.

List of Inputs and Outputs

I:1/14 = Start (Input), I:1/15 = Stop (Input),

B3:0/0= Master Coil Bit (Bit)

I:1/0 = Level of Material B (Input),

I:1/1= Level of Material A (Input),

I:1/2= Low Level Switch (detects empty tank) (Input),

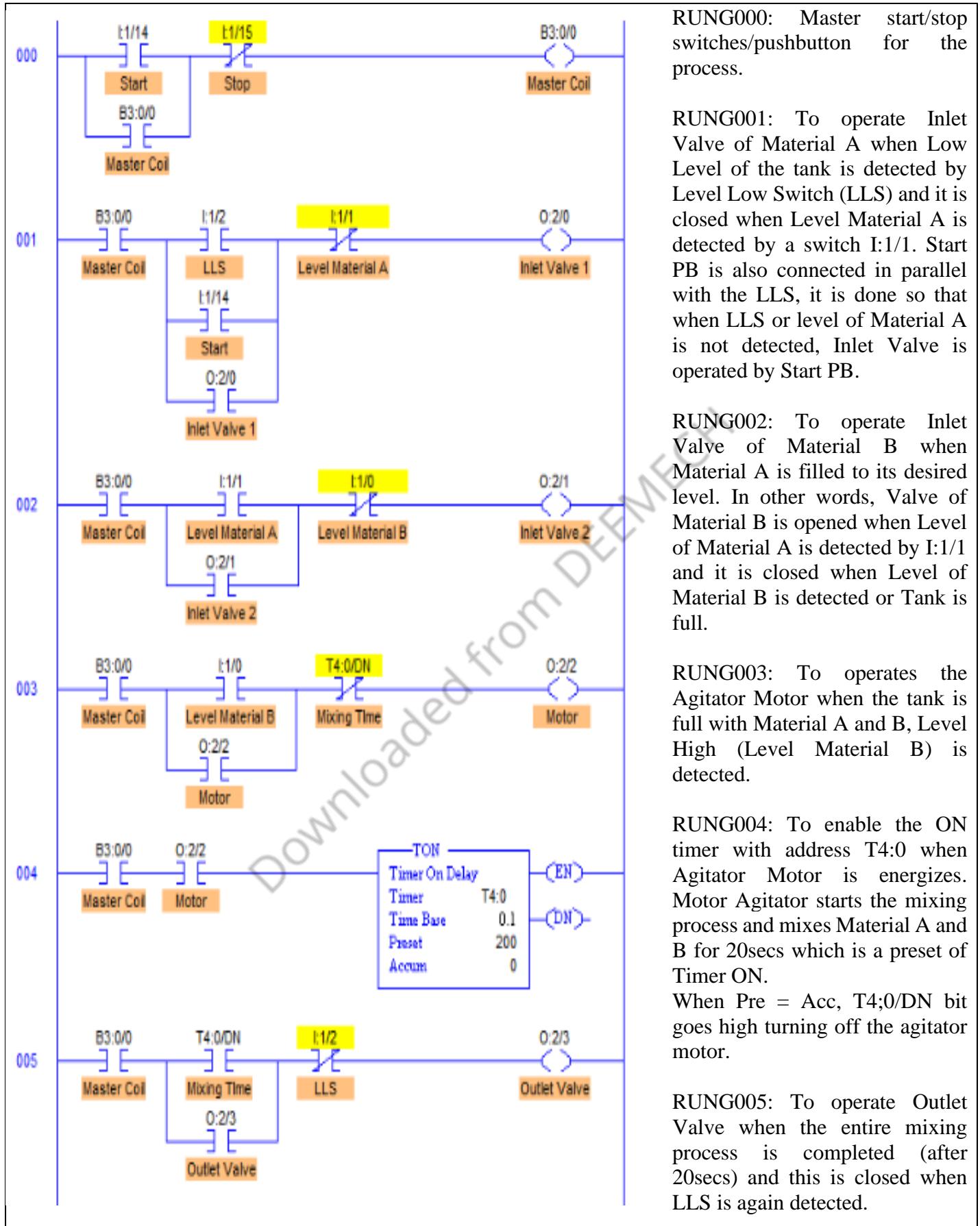
O:2/0= Inlet Valve 1 (Material A Feed) (Output),

O:2/1= Inlet Valve 2 (Material B Feed) (Output)

O:2/2= Agitator Motor (Mixing) (Output),

O:2/3= Outlet Valve (Product Outlet) (Output)

T4:0= Time to mix Materials (Timer)



Section – 4

Q7.a) Some industrial robots may not be able to scratch the back of their forearm with the same hand, just like most people cannot perform this task. However, through the attention to axes and the selection of a configuration, industrial robots can be designed to move their tools quickly, accurately, and repetitively to any point within a three-dimensional workspace. Discuss the various robot configurations with applications and also specify the technical features considered in the selection of a robot. – 12 M –

Scheme:

Explanation of any four configuration with applications + Specifying any four technical features considered in the selection of a robot = $4 \times 2 + 4 \times 1 = 12$ Marks

Answers:

Technical features considered in the selection of a robot

- Degrees of freedom (No. of axes)
- Reach
- Speed
- Kinematics
- Control system to be adopted,
- work volume,
- load-carrying capacity (Pay load), and
- Accuracy and repeatability.

Robot Configuration	Explanation	Common Uses
Cartesian	Has the robot's tool moving in a linear motion along each of the Cartesian coordinates (x, y, z). This type of configuration can sweep out a box-like work envelope.	Many 3D printers have their print nozzles mounted on a Cartesian configuration.
Cylindrical	Allows its tool to rotate around a central axis. The tool can also move towards and away from the central axis, plus up and down the central axis. This configuration creates a work-volume in the shape of a cylinder.	This configuration is typically used for assembly operations, handling of machine tools and die-cast machines, and spot welding.
Spherical	The tool motion created by this configuration sweeps out a workspace shaped like a sphere. It has its tool rotate around a central axis, and the tool can also rotate around a second axis which is placed at a 90 degree angle on the central axis. In addition, the tool can move back and forth along an axis.	They are commonly used for die casting, injection molding, welding, and material handling
Selective Compliance Articulated Robot Arm (SCARA)	Uses pivot points to allow its tool to move in a combination of the Cartesian and the cylindrical motions. This allows the tool to move more quickly, and move more easily in certain motions, such as moving in an arc.	SCARA robots are used for assembly and palletizing, as well as bio-medical applications.

Articulated	This type of robot is the most commonly pictured when referring to an industrial robot. As a minimum, it needs to have at least a shoulder joint, an elbow joint, and a wrist joint. Many examples of these configurations can have both major and minor axes.	Typical applications for articulated robots are assembly, arc welding, material handling, machine tending, and packaging. The VEX V5 Workcell is an example of an Articulated configuration.
Delta (Parallel)	Can move the robot's tool the fastest of all of the robot configuration types. It uses parallel linkages to allow its tool to quickly sweep out its workspace.	Pick and Place, Adhesive dispensing, Soldering, High precision assembly.

Q7.b) Develop a program in VAL II to command a PUMA robot to unload a cylindrical part of 10 mm diameter from machine 1 positioned at point P1 and load the part on machine 2 positioned at P2. The speed of robot motion is 40 in/s. However, because of safety precautions, the speed is reduced to 10 in./s while moving to a machine for an unloading or loading operation.
– 8 M –

Scheme:

Writing Robot Program – 8 Marks

Answer:

- SIGNAL 5 (This allows the signal from output port 5 to be turned on at one point in the program)
- SPEED 40 IPS (This instructs the robot to operate 40 inch/sec speed)
- OPEN 100 (Instructs end effector to open during the execution of the next motion)
- APPRO PI, 50 (This command instructs the robot to move near to the location P1)
- SPEED 10 IPS (This instructs the robot to operate 10 inch/sec speed)
- MOVE PI (Robot to move in joint interpolation motion from its present location to location P1.)
- GRASP 10, 100 (Gripper to close immediately and checks whether the final opening is less than the specified amount of 10 mm f it is, the program branches to statement 100 in the program)
- DEPART P1, 50 (Robot to depart by a specified distance (50 mm) from its present position)
- SPEED 40 IPS (This instructs the robot to operate 40 inch/sec speed)
- APPRO P2, 50 (This command instructs the robot to move near to the location P2)
- SPEED 10 IPS (This instructs the robot to operate 10 inch/sec speed)
- MOVE P2 (Robot to move in joint interpolation motion from its present location to location P2.)
- BELOW (Instruct the elbow of the robot to point down)
- OPENI 100 (Causes the action to occur immediately.)
- ABOVE (Instruct the elbow of the robot to point up)
- DEPART P2, 50 (Robot to depart by a specified distance (50 mm) from its present position)
- STOP

Q8.a) Grippers are devices that enable robots to pick up and hold objects. When combined with a collaborative robot (or 'cobot') arm, grippers enable manufacturers to automate key processes, such as inspection, assembly, pick & place and machine tending. In this regard discuss different robot grippers and highlight the criteria considered in selection of right type of robot grippers

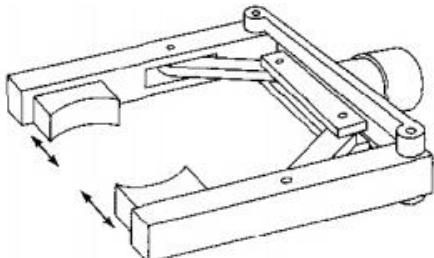
- 12 M -

Scheme

Explanation any Four Grippers + Highlighting of any 4 criteria considered in selection of right type of robot grippers = $4 \times 2 + 4 \times 1 = 12$ Marks

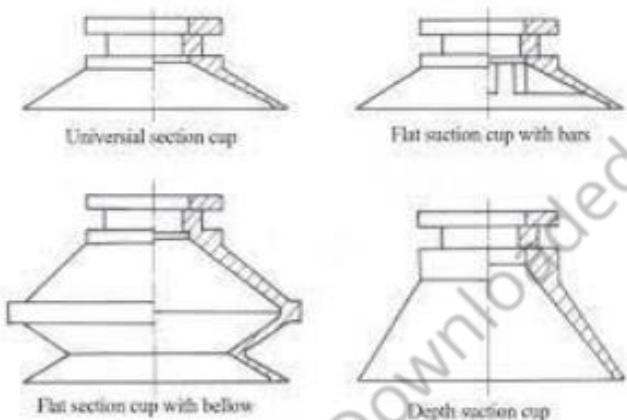
Answer:

1. Mechanical grippers:



- These consist of two or more fingers that can be actuated by the robot controller to open and close to grasp and place the work.
- The open and closing of fingers is implemented by certain mechanical mechanisms like gear mechanisms and rack and pinion.

2. Vacuum grippers:



- In these grippers suction cups are used to hold the flat objects like sheet metals.
- Vacuum is created in the cups thorough integrated motor and pump.
- Plug and Play
- Easy programming
- Fast installation
- Full customization and perfect fit for their applications
- Low noise
- Efficient and easy automation
- Quick response time

Vacuum Grippers – Suction Cups

3. Magnetic grippers:

- These are used to hold only ferromagnetic parts.
- Makes use of magnetic attractive force to grip the part and move.
- For lighter objects permanent magnets grippers are used.
- For heavier objects electrically excited magnets are used.
- Doesn't usually incorporate fingers or jaws.
- Sheet metal and automotive parts are moved along an assembly line.
- Small collisions with nearby objects presence of oil could cause the workpiece to fall from the flat surface.
- Drawbacks of magnetic grippers for manufacturing applications is that pieces can easily dislodge, causing parts to slip out of the gripper's grasp.

4. Adhesive Gripper:

- Used to handle fabric and lightweight materials.
- Adhesive substance can be used for grasping action.
- One contact surface is needed.
- The performance diminishes with successive operation.
- It is used to lift light weight objects only.
- Microfibres help in increasing the adhesion area and also to grip irregular shaped objects

5. Hooks and Scoops gripper:

- Hooks and scoops are the simplest type of end effector.
- A scoop/ladle is commonly used to scoop up molten metal and transfer it to the mould.
- Used when precise position is not required.
- Hooks are used to load and unload parts.
- The parts to be handled by a hook must have handle, eyebolt or ring to enable the hook to hold it.
- Scoops are used to handle liquid and powder form material.
- With scoop gripper it is difficult control the material quantity being handled.
- Spilling of material in scoops is another problem during handling.

6. Interchangeable Fingers:

- These can be used on one gripper mechanism.
- Fingers are changed on the gripper to accommodate different shaped parts

7. Sensory feedback fingers:

- The sensory feedbacks are provided in the finger gripper to:
- Sense the presence of work part to grip.
- Applying a specified limited force to the delicate objects during gripping by sensing the force.

8. Hydraulic Grippers:

Hydraulic Grippers are the ones that can apply the most strength and often are used in applications that require a huge amount of force. The force is provided from pumps that can generate up to 13789.51 kPa. Although their strength, they are messier than any other gripper due to the oil that the pumps are using. Also they need more maintenance because of the huge amount of force that they can apply.

9. Pneumatic Grippers:

Pneumatic grippers are popular due to their light weight and compact size. They can be design for tight spaces, which can be helpful in manufacturing industry. This kind of gripper can be open and close; because of this their nickname is “bang bang” actuators, given by the sound they do when the metal-on-metal is operating.

10. Servo-electric Grippers:

The servo-electric grippers are becoming more used in the industry; thanks to their easy control. The gripper jaw movements are controlled by electronic motors. These grippers are highly flexible and good for handling different material tolerances. Also they are cost effective because they don't have air lines and are clean.

Criteria considered in selection of right type of robot grippers

1. Part Shape
2. Accessibility and Part Consistency
3. Part weight
4. Orientation and Dimensions
5. Size
6. Variation
7. Air Pressure
8. Grip on OPEN or CLOSE
9. Velocity
10. Tooling Length
11. Tooling configuration
12. Product Retention
13. Environment
14. Synchronous Operation
15. Switching Options

Q8.b) Write a program for pick and place operation that operates as follows.

a) Robot opens its gripper and goes to ready position.

b) Robot moves to safe position P1

c) Robot moves from P1 to P2.

d) At position P3 Robot picks part from Bin A.

e) Robot moves back to position P2, and then to P1.

f) Robot moves to position P4

g) Robot drops part at position P5.

h) Robot returns to ready position.

The teachable variables you can declare are P3 and P5 only.

- 8 M -



Scheme:

Writing Robot Program – 8 Marks

Answer:

MOVJ VJ=7.00	(Work Home Position)
DOUT OT # (2) = OFF	(Gripper Open)
MOVL VJ=70.0	(Move to point P1)
MOVL VJ=70.0	(Move to point P2)
MOVL VJ=70.0	(Move to point P3)
TIMER T=2.00 sec	(Timer to 2 sec)
DOUT OT # (2) = ON	(Gripper close)
TIMER T=2.00 sec	(Timer to 2 sec)
MOVL VJ=70.0	(Move to point P2)
MOVL VJ=70.0	(Move to point P1)
MOVJ VJ=70.0	(Move to point P4)
MOVL VJ=70.0	(Move to point P5)
TIMER T=2.00 sec	(Timer to 2 sec)
DOUT OT # (2) = OFF	(Gripper Open)
TIMER T=2.00 sec	(Timer to 2 sec)
MOVL VJ=70.0	(Move to point P4)
MOVJ VJ=7.00	(Return to Home Position)
END	

Section - 5

Q9.a) In process automation and advanced system design, PLCs, SCADA, and HMIs play crucial roles. A PLC is a hardware-based device, SCADA is a system that works in conjunction with the PLC. But, an HMI is also a system that works in conjunction with a PLC. Discuss how SCADA is differing from HMI and list components of SCADA system.

-10 M -

Scheme:

Any six difference between SCADA and HMI + Any four components of SCADA system = $6+4\times1=10$ Marks

Answer:

- SCADA stands for Supervisory Control and Data Acquisition. These are used for monitoring and controlling large areas, typically a full site or plant. SCADA systems are a combination of many systems including sensors, RTUs or Remote Terminal Units, and PLCs. Data from all of these systems is then sent to the central SCADA unit. That SCADA unit has its own HMI
- Human Machine Interface (HMI) unit is used to monitor and control anything that is connected to it. Hence HMI can be part of SCADA but SCADA cannot be part of a HMI.
- While working for a water and wastewater treatment facility the HMI was located at the main water plant building. This HMI was connected to the main SCADA unit at the water plant. At each location there was a PLC that was connected to some sensors to monitor water flow, pressure, and other things, and it was able to run and control the pump itself.
- The remote SCADA unit was connected to the PLC system and allowed operators to control and monitor each pump station from the main plant.
- HMIs are limited to one or two processes/systems whose monitoring and control are performed locally.
- SCADA is commonly used to control and monitor more complex systems located in a broader area and requires advanced control tools and techniques
- An HMI is essentially a user control station, usually in the form of a touch screen or a screen with some buttons attached. They are typically tied to a machine or process where as SCADA would be set up in a control room, far away from the machine itself.
- The HMI is one – to – one relationship that is between the operator and the machine but the SCADA system can involve and handle a lot of several machines and processes.
- HMI is a Hardware and Software, but SCADA is only the software.
- HMI is attached to a machine, SCADA is always away from the machine.
- HMI never stores the data, but SCADA stores the data.

Components of SCADA

A basic SCADA system consists of following components:

- | | |
|----------------------------|--|
| 1. Human Machine Interface | 4. Programmable Logic Controllers (PLCs) |
| 2. Supervisory System | 5. Communication Infrastructure |
| 3. Remote Terminal Units | 6. SCADA Programming |

Q.9 b) The cutting area is an important section in the float glass production line, which includes many productions control equipment, such as longitudinal cutting, transverse cutting, conveying roller table, etc. The main control part of the whole system is PLC, and the monitoring will be undertaken by HMI. Is it required to use both HMI and PLC, As opposed to just a PLC in this Production line? Justify your statement.

-10 M -

Scheme:

Is it required to use both HMI and PLC, As opposed to just a PLC in this Production line? + Explanation with justification = 2+ 8 = 10 Marks

Answer:

Yes, Providing PLC in the production line is not sufficient. HMI also need to be incorporated. Both HMI and PLC is required to use in the production line.

Justification

HMI is short for Human Machine Interface. We use HMIs in industry to control and monitor machines. It would be hard to have a good automated process in industry without an HMI. Operator or maintenance personnel can operate and monitor the machine from the HMI. They may include information like temperature, pressure, process steps, and material counts. They can also show very precise levels in tanks and exact positioning of machines. Where machine information used to be viewed on multiple indicators can now be viewed on one screen.

HMIs and PLCs work together to monitor and control the machine. Engineers can program an HMI to perform almost any function that can be controlled or information that can be monitored by a PLC.

This means they have to be compatible and they also have to speak the same language so to speak. This comes in the form of a Protocol (Modbus, Ethernet/IP, and Profibus) which is just an industrial network.

For maintenance personnel, many HMIs can also connect to PLC logic and display it on the screen for troubleshooting purposes. This can save valuable time compared to connecting a computer or laptop every time.

For Example: Water and wastewater facilities have utilized this for years by coupling an HMI with a PLC. They are able to monitor remote locations, like water pumps, as well as equipment inside the plant.

An HMI can also have the start and stop button displayed and usable on the screen next to the pump. This display would be able to actually turn the pump on and off.

HMIs are used to optimize an industrial process by digitizing and centralizing data for a viewer. By leveraging HMI, operators can see important information displayed in graphs, charts, or digital dashboards, view and manage alarms, and connect with SCADA, ERP, and MES systems.

HMI device enables visualization and control of applications. By using resources such as I/O and operating systems (even better if embedded), it allows you to communicate with any production system. In order to simplify even more the operators' job, the touch screen technology (capacitive or resistive) is available, allowing an intuitive interaction with machines and production plants.

10 a) IIoT is used across a range of industries from manufacturing, logistics, oil and gas, transportation, mining, aviation, energy, and more. Its focus is to optimize operations particularly the automation of processes and maintenance. Highlight the benefits of IIoT and discuss the Challenges and risks encountered during its adoption.

– 10 M –

Scheme:

Highlighting any 5 benefits + Discussion about Challenges and risks = $5*1+5=10$ Marks

Answer:

Benefits

- Improving Inventory Management – Cloud-Based Inventory Systems
- Gain Supply Chain Visibility
- Improves Product Design & Quality Controls
- Predictive maintenance and repair
- Shorter time to market
- Increased customization
- Asset tracking along supply chains
- Optimal facility management
- Safer workplaces
- More user-friendly interfaces
- Increase productivity and uptime.
- Improve process efficiencies.
- Accelerate innovation.
- Digital twins
- Enhance operational efficiency.
- Create end-to-end operational visibility.
- Reduce operating costs.
- Optimize production scheduling.
- Improve overall equipment effectiveness (OEE).

Challenges and risks

Without the creation of an infrastructural network, the adoption of industrial IoT solutions will be impossible.

A few other key challenges prevent the widespread adoption of IoT solutions at the time being:

Security vulnerabilities: IoT devices communicate automatically with each other. In the absence of a secure and properly encrypted network, the adoption of IoT could lead to brand new security challenges and vulnerabilities. Standalone security elements will have to be introduced in the network to enable adoption without a higher risk of hack attacks or data leaks.

Absence of IoT standards: Many automation devices already operate in an array of industrial and manufacturing settings. The problem is that various protocols are being utilized and there's no standardization that will ensure interoperability.

The cost of implementing IoT solutions: This is another essential element that cannot be underestimated. The cost of implementing the IoT infrastructure is often perceived as overwhelming. Many companies worry about the return on such an investment and so remain hesitant. This is where the importance of choosing the right IoT solutions comes to the stage center. Ease of use, ease of training and the development of more readily adoptable products could also help eliminate some of the hesitation in the future.

High-Investment and Ownership Cost: The cost of industrial IoT products and their deployment are obviously very high. One of the main promises of industry is to improve manufacturing efficiencies and reduce costs through better asset management, access to business intelligence, and productivity gains. However, not only development but support should be considered along with high skill resources who are expert in IoT. So, the overall cost of industrial IoT application implementation is very high.

Connectivity

One of the main requirements for adopting the IIOT is having reliable data networks with sufficient capacity. IIoT connectivity should be a forethought before deployment, not an after thought.

Data Analysis

A common method for implementing IoT solutions in industrial environments is to expand manufacturing facilities with tools for data acquisition, analysis and visualization. These include sensors, IoT gateways, human-machine interfaces and cloud-based analysis tools that transform raw data from devices into usable insights.

Skill Gap

Industrial IOT project owners realize that one of the most challenging issues with industrial IoT is the skills gap and how to address this issue. Industry is undergoing a rapid change right now and companies have been raising worries of a lack of technical staff. Absence of qualified staff is impacting many areas within the company. For many manufacturers, finding qualified staff to design, deploy and maintain modern industrial networks and the urgent need to update and transform business operations is huge challenge.

Risks:

- Device hijacking
- Data siphoning
- Denial of service attacks
- Data breaches
- Device theft
- Man-in-the-Middle or Device “spoofing”

10.b With the goal of becoming a leader in the use of automation in its operations, a large copper mining company wanted to take advantage of an information technology (IT) and operational technology (OT) convergence movement sweeping across industries. What advantages does the convergence of IT/OT provide? Does it pose any challenges? Discuss.

– 10 M -

Scheme:

Any five advantages + Challenges = $5 \times 1 + 5 = 10$ Marks

Answer:

Integrating IT and OT into a seamless system that encompasses production and business functions gives companies access to real-time, actionable data and analytics organization-wide, enabling them to:

- **Opportunities for automation**

Relying on human operators creates bottlenecks. While OT personnel have the expertise and insights to make nuanced decisions about how to manage equipment and keep processes running smoothly, IT/OT convergence enables OT professionals to predetermine actions based on specific conditions, from scheduling maintenance based on a decline in performance to shutting down machinery due to a hazardous environment. Automation can reduce damage and costs associated with delays, allow OT departments to manage far more resources at once, and dramatically reduces costs associated with routine processes.

- **Better visibility into operations**

convergence allows businesses to constantly collect data, it also creates opportunities to recognize patterns and build a profile of what normal operations look like in a facility. For example, throughout the month, a factory will have certain days and times where it uses significantly more resources, or where particular equipment runs for longer periods. Understanding these usage patterns empowers OT employees to recognize anomalies faster. Combining real-time visibility and a database of information over time, IT/OT convergence opens the door to predictive maintenance, where technicians use equipment's current performance to plan and schedule maintenance, rather than scheduling maintenance at fixed intervals (preventative maintenance).

- **Lower costs**

There are several ways that IT/OT convergence helps businesses lower costs. Through automation, businesses can reduce the amount of time technicians spend manually facilitating operations. This also ensures that the business can react to problems faster, before they waste more resources or cause more damage. Since IT/OT convergence enables predictive maintenance, it can prevent unplanned downtime from disrupting daily operations and while preventative maintenance helps reduce unscheduled downtime as well. Between automating operations and enabling predictive maintenance, IT/OT convergence can yield considerable cost savings.

- **Potential for new services or pricing models**

Depending on business, IT/OT convergence could enable to offer different pricing structures and services based on how the equipment is used, instead of requiring customers to purchase equipment outright, which may be excessive for their short-term needs or limited budget.

- Make better decisions faster
- Automate processes effectively
- Anticipate and solve for production and supply chain issues
- Scale production up or down on demand
- Minimize the impact of planned downtime
- Identify areas of underutilization
- Centralize asset tracking
- Simplify process control
- Improve service-level agreements and regulatory compliance
- Manage operations from a centralized dashboard

Challenges in IT/OT convergence.

There can be significant barriers to implementation of IT/OT convergence. It may require restructuring the relationship between IT and OT, investing in new tools, or modernizing old ones.

- **Siloed processes and expertise**

Operations technicians need training in IT processes, and IT technicians need training in OT processes—so that each department understands how their decisions impact the other. And while IT and OT don't necessarily need to share the same workspace and work together on everything, IT/OT convergence creates a significant enough overlap that will require them to consult one another more often.

IT/OT convergence requires a shift in mindset and merging of these traditionally siloed processes. IT and OT professionals will need to trust and turn to each other's expertise to create solutions that support operations without compromising security

- **IoT security**

Historically, IoT devices have been notoriously vulnerable to hacking. IT departments need to be intimately familiar with how each connected device fits into the business' tech ecosystem and any threats it poses to the network. In some cases, this may mean that operations teams will have to compromise some of the

functionality they want to go with a more secure solution, and they'll always need IT to be involved in selecting converged technology.

- **Integration**

IT/OT convergence works best when a facility's connected devices integrate with the operations team's tech stack. Otherwise, technicians have to constantly jump in and out of multiple portals and solutions, and some critical information is bound to fall through the cracks. This often requires businesses to manually develop integrations, but many IoT businesses provide APIs and other solutions to help facilitate this process.

- **IoT connectivity**

Every IoT device is built to operate on a particular connectivity solution, such as cellular, WiFi, Bluetooth, ethernet, or WAN. That means it's also limited by the capabilities of this underlying technology. Some solutions, like WiFi, can only provide coverage in a very limited area, and don't penetrate walls well or handle much interference.

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