Course Outline - Industrial Controls and Instrumentation

Course Topic: Industrial Controls and Instrumentation
Contact Hours: 60 hours

Course Description:

Controls and Instrumentation explores automation input and output devices including AC and DC motors, variable speed drives, relays, motor starters and sizing of components for various applications. Typical control circuits are examined along with component selection and control documentation.

Course Outcomes and Objectives

CI-1 Apply electrical laws and basic circuit theory to correctly design, build, install, and Troubleshoot electrical applications and components

1. Identify electrical circuit types
2. Trace power flow (current & voltage)
3. Calculate expected circuit characteristics
4. Select appropriate components
5. Calculate total current, total resistance and individual voltages and currents of series and parallel circuits. Construct, measure and verify calculations related to the following:
   - Voltage, Current and Resistance
   - Ohm's Law
   - Power Calculations
   - Series and Parallel circuits

CI-2 Interpret, utilize, pictorial, wiring, schematic, line, block diagrams, and flow charts to correctly identify components, connect the devices and loads, and troubleshoot a control system

1. Apply the JIC/NEMA standards to a basic control circuit
2. Apply the IEC standards to a basic control circuit
3. Interpret a Ladder Logic Diagram, JIC/NEMA standard
4. Interpret a Ladder Logic Diagram IEC standard
5. Interpret a Wiring Diagram, JIV/NEMA standard
6. Demonstrate the use of the following items to navigate, identify, and describe the function of electrical circuits:
   - Symbols
   - Electrical diagrams
   - Schematics
   - Line diagrams

Course Outline - Industrial Controls and Instrumentation

- Applications

7. With the use of a control diagram, construct and debug circuits using the following items:
   - Line diagram rules & numbering
   - Load and control connections
   - Logic functions (Relay)

CI-3 Properly select appropriate electrical test equipment to monitor and troubleshoot the operation of an industrial electrical control system.

1. Use test equipment safely
2. Select the appropriate test equipment
3. Interpret the information provided by test equipment
4. Demonstrate the proper use of the following tools & test equipment in performing electrical measurements, repairs, and installations.
   - Hand tools and related safety
   - Power tools and related safety
   - Electrical & electronic testers, and meters

CI-4 Properly define ESD and the precautions taken to avoid damage to equipment. Identify the appropriate PPE required in a given work situation and identify the safety issues related to confined spaces.

1. Apply job appropriate safety procedures
2. Select appropriate PPE for work situation
3. Locate and attach appropriate grounds as required for the specific task and location
4. Recognize Hazardous locations and apply proper work precautions and follow correct working restrictions
5. Identify power hazards in lab circuits and describe the proper safety precautions related to the following:
   - Electrical safety practices used in Industry
   - NEC
   - PPE
   - Lockout/Tag-out
   - Confined spaces
6. Demonstrate Electrostatic Discharge prevention while working with drive components.

Course Outline - Industrial Controls and Instrumentation

CI-5 Interpret, design, modify, and troubleshoot an electrical control circuit using control logic (line diagrams)

1. Apply rung numbers, wire numbers, reference numbers, component naming, abbreviations, and symbols in a ladder diagram.
2. Place the input, decision/logic, and output devices in the appropriate locations in a ladder logic diagram.
3. Identify the logic processes contained in a ladder logic diagram.
4. Develop a functional ladder logic diagram with specific input, decision/logic, and output devices.
5. Locate and correct problems with a ladder logic diagram
6. Construct a three phase motor starter control that can reverse the direction of rotation. Document the circuit through the generation of an appropriate diagram. Must apply overloads and conventional start/stop circuitry
7. Given a circuit description containing several differing sensors for inputs and a sequence chart for the outputs, develop a control circuit to achieve the desired output, construct and debug the circuit. Document the circuit through the generation of an appropriate diagram

CI-6 Identify, select and apply mechanical Input devices to correctly achieve a desired result

1. Develop ladder logic diagrams utilizing common control devices to meet specific parameters of operation (logic)
2. Apply troubleshooting tactics to isolate defective components or logic functions

CI-7/8 Identify, select, and apply electromagnetic output devices to correctly achieve a desired result

1. Select and install appropriate electromagnetic devices as appropriate to the power source, circuit design, and outputs.
2. Apply appropriate testing procedures and troubleshooting methods to isolate wiring, component, and load defects
3. Locate and correct problems associated with electromechanical rely applications

CI-9/10 Identify, select, and apply electrical generation equipment correctly to achieve a desired result

1. Apply the knowledge of DC generation to select appropriate applications, operational inspections, and location of faults
2. Apply the knowledge of AC generation to select appropriate applications, operational inspections, and location of faults
3. Distinguish between different forms of AC electrical power

Course Outline - Industrial Controls and Instrumentation

4. Select appropriate wiring devices for AC systems
5. Match these DC electrical devices: DC Generators, DC Motors, & Solenoids to a list of their characteristics in the areas of:
   - Magnetism &Electromagnetism principles
   - Operating Characteristics
   - Applications
   - Connections/wiring
   - Maintenance &Troubleshooting
6. Construct a DC generator circuit. Predict and verify the output changes as related to speed
7. Match these AC electrical devices: AC Generators, AC Motors, Transformers, & Solenoids to a list of their characteristics in the following areas:
   - Single and three phase AC applications
   - Magnetism & Electromagnetic principles
   - Operating Characteristics
   - Applications
   - Connections/wiring
   - Maintenance & Troubleshooting
8. Construct AC single phase and three phase motor circuits and compare the operating speed and currents to the faceplate information
9. Match the following devices used in motor installations to their proper description:
   - Line Protection
   - Filtering Devices
   - Surge protectors
   - Disconnects
   - Contactors & relays
   - Overloads

CI-11 Identify, select, and apply transformers correctly to achieve a desired result

1. Identify specific transformer designs
2. Select appropriate transformers for specific applications
3. Setup and connect appropriate transformers for specific applications
4. Inspect an operation transformer based system, determine operational specifications, identify operational problems, and devise correction process required

CI-12 Identify, select, and apply contactors and magnetic motor starters correctly to achieve a desired result.

1. Identify and select appropriate methods of starting motor loads.
2. Draw appropriate motor starter circuits, with appropriate wiring and protection (overloads)

Course Outline - Industrial Controls and Instrumentation

3. Identify recommended maintenance inspections and service on NEMA standard motor starters
4. Inspect an operating system, measure operating parameters, compare to specifications, and isolate/repair any problems
5. Attach power and motor power wiring to a motor drive device (VFD)

CI-13/14 Identify, select, and apply electric motors correctly to achieve a desired result

1. Identify DC motors by their construction, operating characteristics, measuring the resistance and voltage of an unknown DC motor
2. Inspect a DC motors component parts to determine operational condition
3. Select the appropriate DC motor for a specific application
4. Inspect and isolate operational problems with a DC motors system
5. wire a stepper motor to controller, predict direction of rotation based upon signal input
6. Identify AC motors by their construction, operating characteristics, measuring the resistance and voltage of an unknown AC motor
7. Inspect an AC motors component parts to determine operational condition
8. Select the appropriate AC motor for a specific application
9. Inspect and isolate operational problems with a AC motors system
10. Construct a DC Motor control circuit (Relays); demonstrating speed control, starting current control, reversing and braking. Change the configurations (series to shunt to compound) of the DC motor and verify the characteristics of each configuration
11. Predict the direction of rotation of a stepper motor when given a drawing of the motor's windings and the polarity of the applied voltage
12. List and interpret motor nameplate data. (Written exercise using motor nameplates)
13. Predict an AC motors amount of slippage and expected current under varying load conditions
14. Identify & match NEMA classification ratings of motors to name plate information

CI-15 Identify, select, and apply motor reversing methods to correctly achieve desired results

1. Identify reversing systems utilized within a control/wiring diagram select appropriate reversing methods to meet specific applications and operating characteristics
2. Inspect, test, and isolate problems in a motor reversing circuit
3. Match the following motor reversing methods and control schemes to their proper description:
   - Reverse motors using manual starters
   - Reverse motors using drum switches
   - Reverse motors using magnetic motor starters
   - PLC control
   - Magnetic reversing starter applications
   - Wiring methods
   - Troubleshooting

Course Outline - Industrial Controls and Instrumentation

CI-16 Identify, select, and apply timing and counting functions to correctly achieve desired results

1. Identify the type of timing devices employed in a control circuit by symbol and coding
2. Design control circuits using appropriate timing devices
3. Select appropriate timer specifications for a specific timing application.
4. Inspect, test, and identify timer operational faults
5. Match the following Timing and Counting items to their proper description.
   - Timers
   - Counters
   - Wiring
   - Applications
   - Troubleshooting
6. Given an output timing diagram, develop a control circuit to achieve the desired output, construct and debug the circuit

CI-17 Identify, select, and apply motor stopping methods to correctly achieve desired results

1. identify physical braking system components
2. identify control symbols and configurations associated with specific braking systems
3. design a braking system control circuit to meet specific specifications
4. select appropriate braking components and configurations to meet specific application requirements
5. inspect the operation of a braking system, measure operating characteristics using appropriate methods, identify and correct system faults
6. Match the following AC and DC motor braking methods to their proper description:
   - Friction Brakes
   - Plugging
   - Electrical Braking
   - Dynamic Braking

CI-18 Identify, select, and apply motor load, torque, and power quality requirements to correctly achieve desired results

1. Determine appropriate operational requirements for motor loads based upon application characteristics
2. Select appropriate motor using motor specifications and application
3. Inspect, measure operational characteristics, identify any faults, and apply corrective measures

CI-19 Identify, select, and apply reduced-voltage starting circuits to correctly achieve desired results

Course Outline - Industrial Controls and Instrumentation

1. Identify method of reduced-voltage starting from control diagram
2. Locate the components of a reduced-voltage starting system in a control panel
3. Design a reduced-voltage starting system to meet specific system requirements
4. Select method and devices to meet specific reduced-voltage starting specifications
5. Wire and operate a reduced-voltage starting system to meet a specific application
6. Inspect, measure/test, operating characteristics of a reduced-voltage starting system
7. Identify problems in a reduced-voltage starting system and apply corrective actions
8. Match these motor controls (switches, relays, contactors, starters, & intelligent devices) to a list describing the following items:
   - Operating characteristics (including manual operation)
   - Applications
   - Connections/wiring
   - Troubleshooting
9. Match the following reduced-voltage starting circuits to their proper description:
   - Reduced-voltage starting method comparison
   - Solid-state switching & starting
   - DC motor reduced-voltage starting
   - Reduced-voltage starting for three-phase induction motors
   - Primary resistor starting
   - Autotransformer starting
   - Part-winding starting
   - Wye-Delta starting
   - Troubleshooting"

CI-20 Identify, select, and apply DC power sources correctly to achieve desired result

1. Identify the physical component and its schematic symbol
2. Identify the various methods of generating DC power by inspecting the physical construction of the power supply
3. Select an appropriate DC power supply for a specific application
4. Measure the DC output power of a DC supply, compare to power supply specifications, isolate faults or overloads

CI-21 Identify, select, and apply semiconductor input devices

1. Identify physical and symbols for common electronic components utilized in control circuits

Course Outline - Industrial Controls and Instrumentation

2. Select electronic components for a specific application using device information sheets And circuit parameters
3. Draw functional control circuits utilizing electronic components to meet specific operating specifications.
4. Wire control circuits with electronic components to achieve a specific outcome
5. Inspect, measure control circuit diagrams and operation characteristics to confirm circuit operational
5. Respond to control circuit problems using diagrams, data sheets, cycle graphs and circuit measurements to isolate the problem

CI-24 Identify, select, and apply photoelectric semiconductors, fiber optics, and light based application to correctly achieve a desired result

1. Identify electronic sensors by their symbolic and physical appearance
2. Utilize data sheets and control circuit parameters to select appropriate application of sensor electronics
3. Inspect, measure, operating parameters of control circuit, identify and isolate any abnormalities, and prescribe a repair process
4. Match the following Sensing devices to a list of their proper descriptions.
    - Photoelectric
    - Ultrasonic
    - Proximity
    - Sensor installation and wiring
    - Indicators

CI-25 Identify, select, and apply solid-state relays and starters to correctly achieve a desired result

1. Identify electronic control devices (solid state relays) by their symbolic and physical appearance
2. Utilize data sheets and control circuit parameters to select appropriate application of solid state relay electronics
3. Inspect, measure, operating parameters of control circuit, identify and isolate any abnormalities, and prescribe a repair process

CI-26 Identify, select, and apply motor drive to correctly achieve a desired result.

1. Identify the operational characteristics and the advantages, disadvantages of electronic motor drives.
2. Select the appropriate motor drive / electric motor for a given application utilizing control circuit description, motor and drive data sheets
3. Program the functions required for a specific motor control, (starting, braking, current protection, speed, etc.)

Course Outline - Industrial Controls and Instrumentation

4. Wire the drive per specification to the power source (single and poly phase), external controls, and motor (DC, AC single or poly phase)
5. Inspect, measure, operating parameters of motor drive system, identify and isolate any abnormalities, and prescribe a repair process
6. Match AC&DC Motor Drive hardware, wiring, and related features to their proper description
7. Demonstrate Motor Drive Pre-Power and Power-On checks
8. Navigate Motor Drive Control operator interfaces, software, and menus
9. Demonstrate the Upload & Download procedures of Motor Drive parameters
10. Monitor and edit drive parameters of a VFD to affect the motor's operation
11. Write a description of the motor regeneration principle
12. Match the following accelerating and decelerating methods to a list of their proper description:
    - Braking and speed control
    - Multi speed motors
    - DC motor speed control
    - AC motor speed control
    - Troubleshooting
13. Using diagnostic LEDs and Fault Codes on a motor drive, select the appropriate corrective action
14. Program a variable frequency drive to control the speed, acceleration and deceleration of an induction motor. Write a program to start, stop, and reverse the motor.

CI-28 Identify, select, and apply power distribution systems to correctly achieve a desired result

1. Identify the systems utilized to move electrical energy from the point of generation to the point of use
2. Identify the symbols used to represent electrical components and wiring systems (NEEMA and IEC)
3. Identify electrical distribution systems by their physical characteristics
4. Select wiring systems and components required to deliver power within an industrial setting to the production equipment
5. Select wiring method (hard, plug and receptacle) to meet specific needs of equipment utilizing data sheets and NEEMA or IEC standards.
6. Inspect, measure, operational characteristics, compare to equipment specification, identify and isolate problems, prescribe correction process if required
15. Match the following Power Distribution items to a list of their proper description:
    - Transformers and sub-stations
    - Switch boards and Panel boards
    - Branch circuits
    - Motor control centers
    - Feeders and Bus-ways
    - Grounding

Course Outline - Industrial Controls and Instrumentation

- Fuses and circuit breakers

Manufacturing Labs

Lab 1: Calculate total current, total resistance and individual voltages and currents of series and parallel circuits, construct, measure and verify calculations. 4 circuit variations. (4 LABS)CI-1, CI-3, CI-20

2) Electrical tools and test equipment
   a) Hand tools and related safety
   b) Power tools and related safety
   c) Electrical and electronic testers

Lab 2: Demonstrate the proper use of electrical testers in making voltage, current and resistance measurement. CI-3, CI-4

3) Electrical safety
   a) Electrical safety
   b) NEC
   c) PPE
   d) Lockout/tagout
   e) Confined spaces

Lab 3: Identify power hazards in lab circuits and describe proper safety precautions and the necessary PPE.CI-3, CI-4

4) Electrical symbols and diagrams
   a) Symbols
   b) Electrical diagrams
   c) Schematics
   d) Line diagrams
   e) Applications

Lab 4) Using line diagrams demonstrate the understanding and navigation of the diagram. From an understanding of the symbol function, describe the action/purpose of the circuit. 3 Circuit variations. (3 Labs) CI-2

5) Control Logic
   a) Line diagram rules & numbering
   b) Load and control connections
   c) Logic functions
   d) Common circuits

Course Outline - Industrial Controls and Instrumentation

Lab 5) Demonstrate an understanding of a control diagram through construction and debugging of given circuits. 2 Circuit variations. CI-5

6) Solenoids, DC Generators, DC Motors
   a) Magnetism and electromagnetism
   b) Solenoids, characteristics and applications
   c) DC Generators and Motors
   d) Troubleshooting

Lab 6) Construct a DC generator circuit. Predict and verify the output changes related to speed and field strength variations.CI-9/10

   a) AC Generators, Motors and transformers
   b) Single and three phase AC generation
   b) Transformer operation and connections
   c) Control Transformers
   d) Single and three phase AC motors
   e) Maintenance and troubleshooting of motors

Lab 7) Construct single phase and three phase motor circuits and contrast operating speed and currents as predicted on the faceplate information.CI-18

   a) Power distribution systems
   b) Power distribution
   c) Transformers and sub-stations
   d) Switch boards and Panel boards
   e) Branch circuits
   f) Motor control centers
   g) Feeders and Busways
   h) Grounding
   i) Fuses and circuit breakers
   j) Testing and troubleshooting
   k) Contactors and Magnetic Motor Starters (Manual operation)
   l) Contactors and starters

Troubleshooting

   a) 10 AC and DC Motor controls
   b) Motor Drive control circuits
   c) DC Motor drives
   d) AC motor drives
   e) Controlling Speed, Torque, Acceleration and Deceleration times

Course Outline - Industrial Controls and Instrumentation

f) Load tests

Lab 8) Construct a DC Motor control circuit (Relays); demonstrating speed control , starting current control, reversing and braking. Change the configurations of the DC motor and verify the characteristics of each configuration. 4 Circuit variations (4 Labs) CI-13/14, CI-17

11) Control devices
    a) Switches (all)
    b) Intelligent devices
    c) Troubleshooting
12) Reversing motor controls
    a) Control schemes
    b) PLC control overview
    c) Wiring methods
    d) Troubleshooting

Lab 9) Construct a three phase motor starter control that can reverse the direction of rotation. Document the circuit through the generation of an appropriate diagram. Must apply overloads and conventional start/stop circuitry.CI-12, CI-15

13) Solid state devices and systems integration
    a) Electronic control systems
    b) Related electronic components
    c) Power supplies
    d) Input/output/Display devices
    e) Troubleshooting
14) Timing and Counting functions
    a) Timers
    b) Wiring
    c) Applications
    d) Troubleshooting

Lab 10) Given an output timing diagram, develop a control circuit to achieve the desired output, construct and debug the circuit. Document the circuit through the generation of an appropriate diagram. 3 Circuit variations. (3 Labs) CI-5, CI-7/8 CI-15 CI-16

15) Relays and solid state starters
    a) Electromagnetic Relays
    b) Solid state relays
    c) Solid state motor starters
    d) Troubleshooting

Course Outline - Industrial Controls and Instrumentation

16) Sensing devices and controls
    a) Photoelectric
    b) Ultrasonic
    c) Proximity
    d) Sensor installation and wiring
    e) Indicators
    f) Ladder logic
    g) Troubleshooting

Lab 11) Given a circuit description containing several differing sensors for inputs and a sequence chart for the outputs, develop a control circuit to achieve the desired output, construct and debug the circuit. Document the circuit through the generation of an appropriate diagram. 2 circuit variations CI-6, CI-5, CI-7/8, CI-21

17) Programmable controllers- an overview
    a) PLC introduction
    b) I/O interfacing
    c) Logic and timer applications
    d) Trouble shooting

18) Reduced Voltage starting
    a) DC motor starting circuits
    b) Solid state switching and starting
    c) Starting method comparison
    d) Troubleshooting

19) Accelerating and decelerating methods
    a) Braking and speed control
    b) Multi speed motors
    c) DC motor speed control
    d) AC motor speed control
    e) Troubleshooting

Lab 12) Program a variable frequency drive to control the speed, acceleration and deceleration of an induction motor. CI-26

20) Preventive and predictive Maintenance systems

Course Outline - Industrial Controls and Instrumentation

a) Preventive Maintenance and scheduled maintenance
b) Predictive Maintenance including Vibration analysis
c) Maintenance technical resources
d) Trouble shooting

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