MANUFACTURING EXECUTION SYSTEMS LABORATORY MANUAL

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Educational Learning outcomes

This course enables the students to

- Understand MES integration with production processes and applying automation concepts.
- Gain skills in using LAN and OPC UA for industrial communication.
- Develop the ability to monitor and analyse real-time production data for process efficiency.
- Learn production control, planning, and effective teamwork in a manufacturing environment.

Industrial Learning Outcomes

This course benefits the students to

- Mastering real-time monitoring of production stages and managing energy and material usage.
- Utilizing MES data for troubleshooting, process optimization, and data-driven decisions.
- Developing skills in Industry 4.0 technologies, industrial IoT, and system communication.

Safety instructions

These operating instructions contain notes that must be observed for your personal safety and in order to prevent property damage. The notes concerning your personal safety are indicated by a safety symbol. Notes that only concern property damage are not indicated by a safety symbol. The notes below are listed in order of hazard level.

	DANGER ... indicates an imminently hazardous situation that will result in fatal or severe personal injury if not avoided.
	WARNING … indicates a potentially hazardous situation which may result in fatal or severe personal injury if not avoided.
	CAUTION ... indicates a potentially hazardous situation that may result in moderate or slight personal injury or severe property damage if not avoided.
	NOTE ... indicates a potentially hazardous situation that may result in property damage or loss of function if not avoided.

In cases where more than one hazard level applies, the safety note with the highest hazard level will be shown. A safety note may concern both personal injury and property damage.

Hazards that will only result in property damage are indicated with the word "Note".

Pictograms

This document and the hardware described in it include warnings concerning possible hazards which may arise if the system is used incorrectly.

The following pictograms are used:

Hazard warning

Warning - dangerous electric voltage

Read and observe the operating and safety instructions prior to commissioning.

Switch off the device and unplug the connection for power supply from the plug socket before commencing installation, repair, maintenance or cleaning work.

Laser 2

Warning of laser beam

Warning – optical radiation

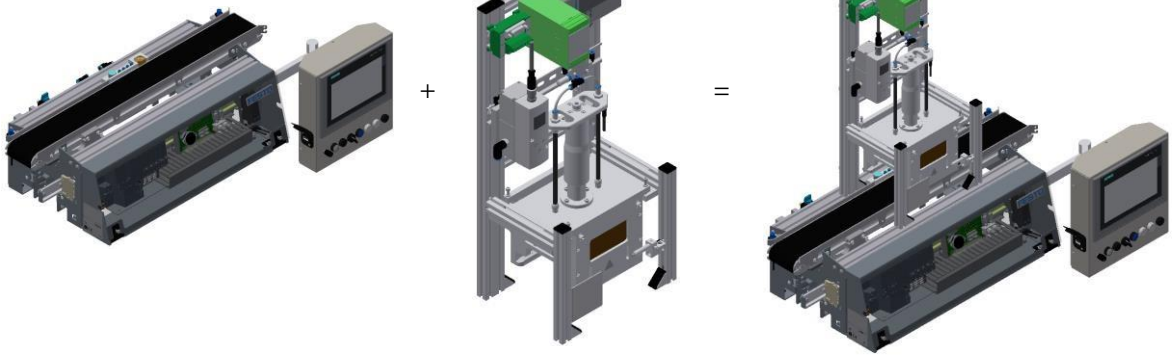
Warning – lifting heavy loads

INTORDUCTION TO MES

Overview of the System

CP Lab Conveyor, CP Factory Linear, CP Factory Shunt and CP Factory Bypass are called basic modules. If an application module, e.g. the CP Application Module muscle press is attached to a basic module, it becomes a station.

Example

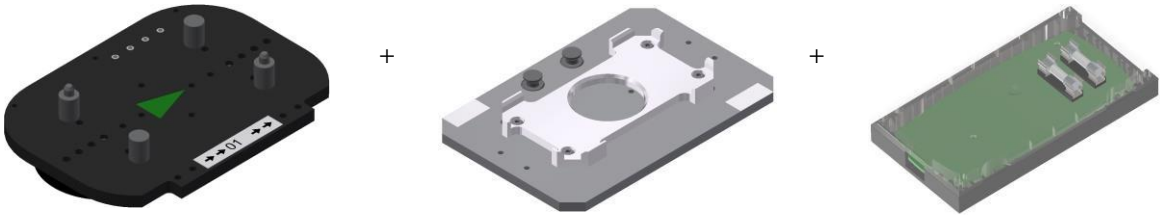


basic module, e.g. CP Lab Conveyor

application module, e.g. muscle press

station muscle press

If several stations are put in a row one behind the other, this will form a production line.



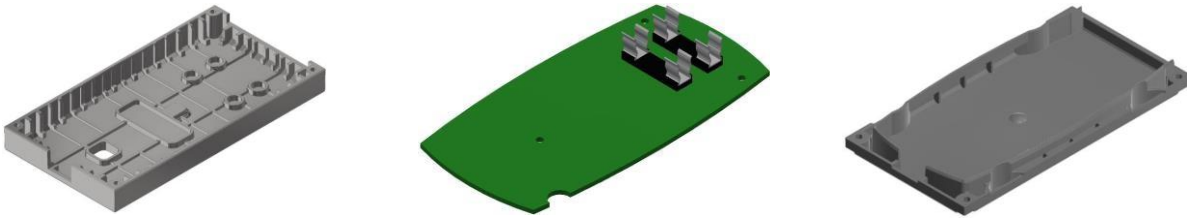
carrier

pallet

workpiece

Carriers are transported on the conveyors of the basic modules. And on the carriers, there are pallets with a fixed workpiece reception placed. The workpieces are placed on the workpiece reception or taken from it. Pallets can also be placed on a carrier in some stations or gripped from there.

The typical workpiece of a CP Factory/Lab System is the roughly simplified version of a mobile phone. The workpiece consists of a front cover, of a back cover, of a board and of a maximum of two fuses.



front cover

board

back cover

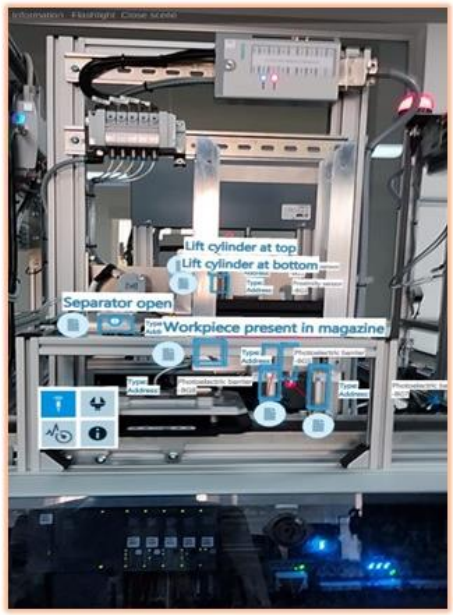
An MES is a comprehensive, real-time system that monitors, controls, and coordinates manufacturing processes. It integrates and manages different stages of production to improve efficiency, quality, and compliance.

Ex. No.	Material Synchronization and Consumption Tracking through MES: The Magazine Application
Date:	

Aim:

To utilize the Magazine Application for material synchronization and consumption tracking through CP404 MES

Magazine Application (CP_MAG_FRONT):



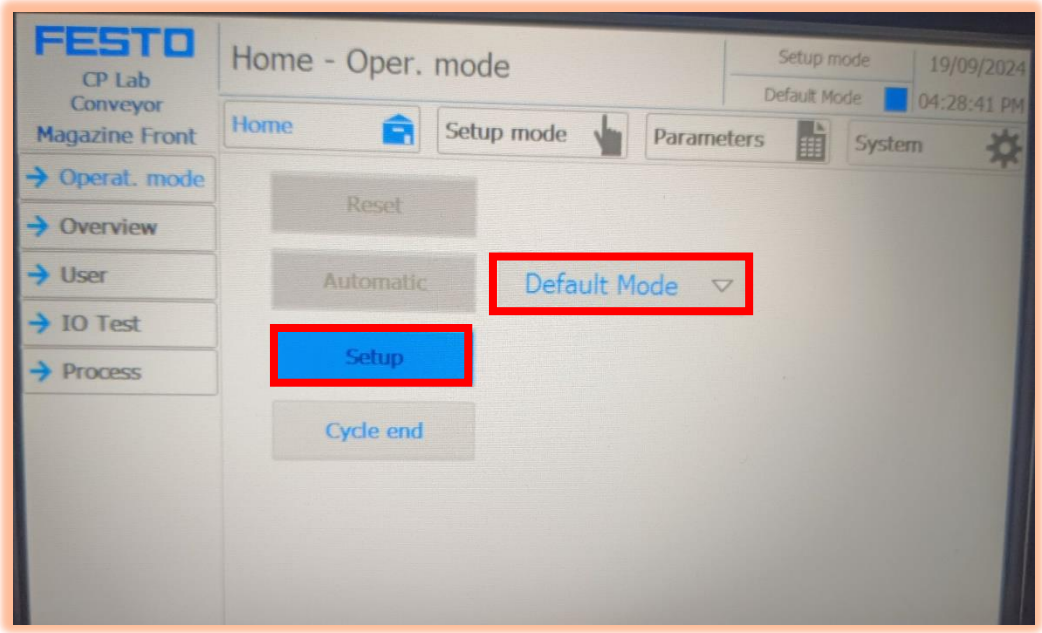
- The **CP_MAG_FRONT** station primarily focuses on loading and transferring parts from a magazine to the conveyor system. It manages parts through a controlled magazine for organized release, integrates with the conveyor for sequenced transfer, uses sensors and actuators for automated control, operates via an HMI for parameter settings, and employs stoppers for accurate positioning throughout the production sequence.
- Proximity Sensors (BG1, BG2)
- Photoelectric Sensors
- Magazine Rack/Holder
- Transfer Arm or Pick-and-Place Unit
- Position Sensors for Stopper
- Mechanical/Pneumatic Stopper

Procedure:

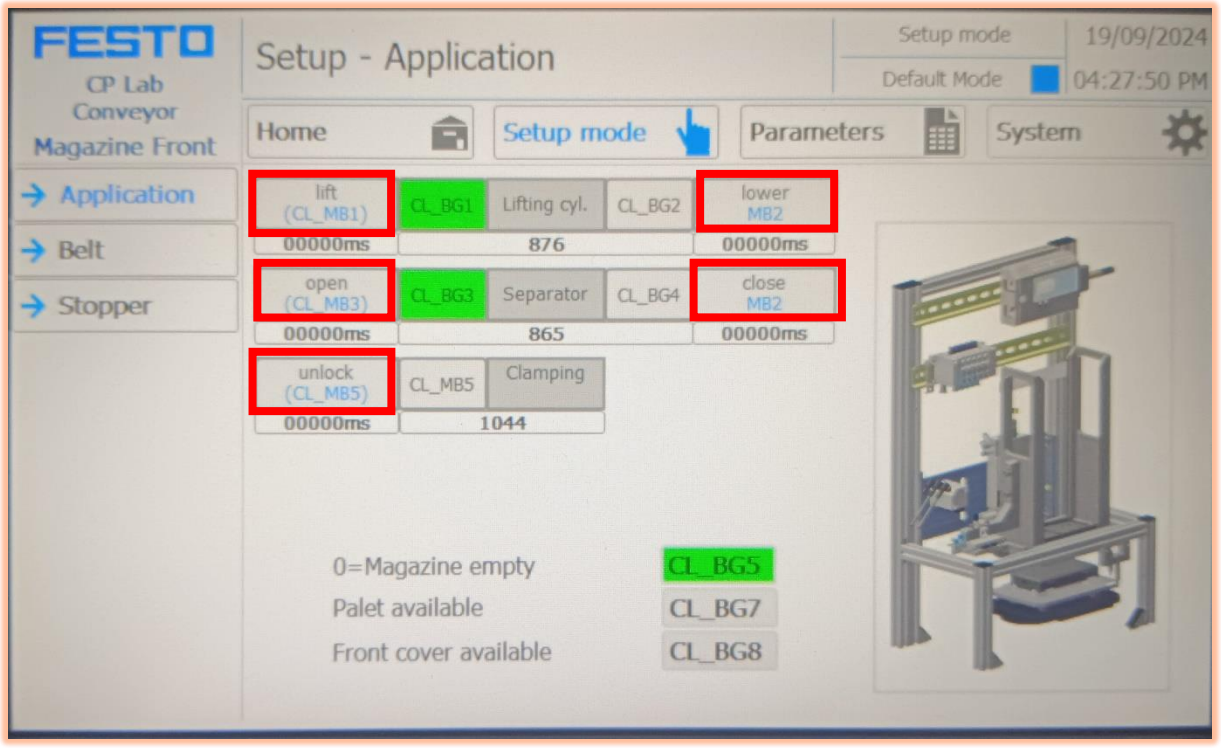
Step 1: Ensure all stations are operational and the entire system is powered on.

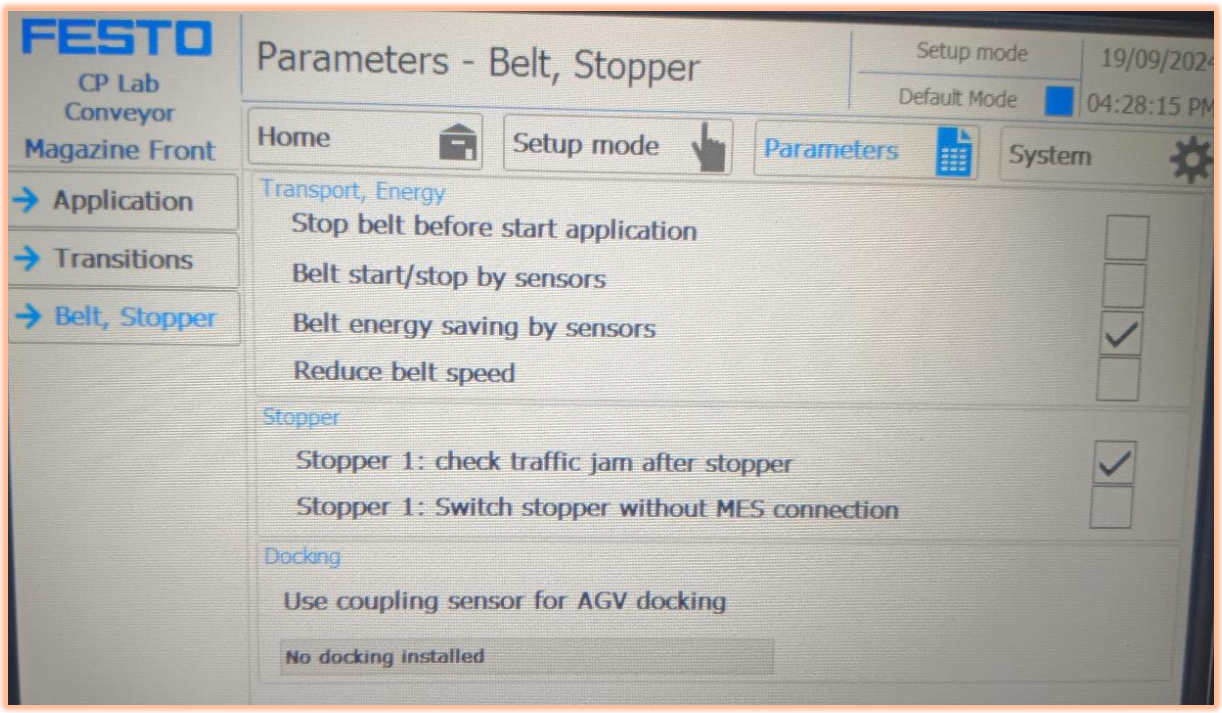
Step 2: Configure HMI Settings:

- Navigate to **Cycle end → Setup → Default mode**.



- Set **Cycle end → Setup → Default mode: STOPPER**.
- Verify that the carrier ID is correctly sensed through RFID.
- After clicking the stopper, write the state code (e.g., 10).
- Go to the conveyor's "Belt" option to understand how left and right movements operate.
- Observe how the stopper is lowered and locked when the carrier is placed.
- The pallet activates BG1, which senses the common position, enabling the stopper.
- Click on **Application**:
  - Once the stopper is enabled, BG1 reads the pallet's transition code.
- Practice the following operations for placing the product into the pallet
  - **Unlock → Lower → Open → Place the product → Close → Lock**.





Follow the sequence to place the product in the pallet:

- **Unlock** the mechanism.
- **Lower** the stopper to allow product access.
- **Open** the product holder.
- **Place** the product in the holder.
- **Close** the holder.
- **Lock** the stopper securely.
- After placing the product, BG1 and BG2 sensors verify the product's correct placement.
- **Lower the stopper,** and the conveyor resumes its motion to the next station.

Result:

Ex. No.	Implementing an Analog Measuring Application for Production Line Monitoring and CP404 MES-Based Reporting
Date:	

Aim:

To implement the Analog Measuring Application to monitor production line data and generate MES-based reports.

Measure station (CP_MEASURE):

CP_MEASURE

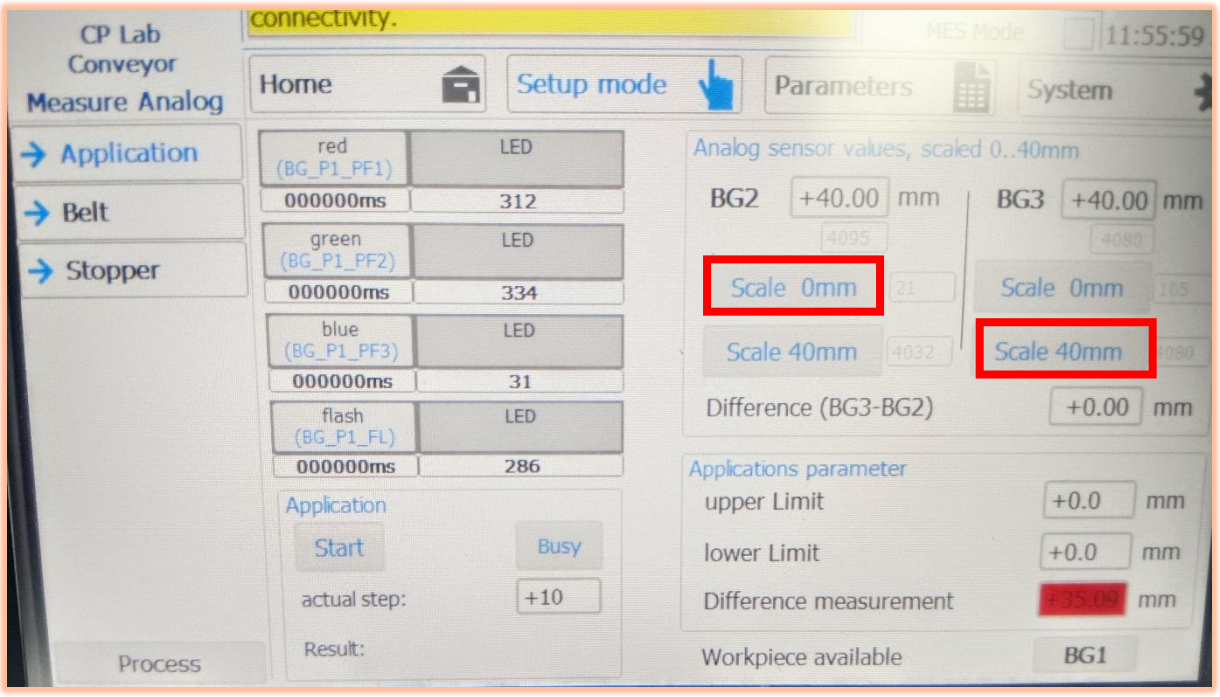
- The **CP_MEASURE** station in the CP 404 system is responsible for the measurement and inspection of parts as they proceed along the conveyor line.
- It majorly involves,
  - Signal light
  - Analog terminal
  - I/O Module
  - Analog Distance sensors(BG3, BG4)
    - Height measurement left
    - Height measurement right
  - Proximity Sensors (BG1, BG2)
  - LED Indicators & Status Displays
  - Linear Actuators or Pneumatic Cylinders

- **BG-1**: Photoelectric beam sensor
- **BG-2**: Distance sensor (for height measurement)
- **BG-3**: Distance sensor (for height measurement)
- **XD1**: I/O Module
- **XD2A**: Analog terminal
- **Siemens S7-1200 PLC and HMI**: Control and visualization

Calibration Steps:

1. Initially, set the HMI to "Home > Cycle > Setup > A-fault mode."
2. Open the setup menu on the HMI.
3. Place the calibration tool on the carrier, ensuring that one side measures 40mm and the opposite side measures 0 mm.
4. Observe the analog sensor values on the HMI screen. The values should adjust based on the position and orientation of the calibration tool.
5. Place the calibration tool on the other side and repeat the procedure to teach the sensor
6. Define the application parameters on the HMI screen according to the setup for BG-2, and BG-3.

7. Complete the calibration scaling of both the left and right analog sensors.



Procedure:

 Place the component on the carrier for an orientation check using the height measurement sensor (manual process).

 The stopper halts the carrier, and the RFID tag is read and fed into the system.

 During the measurement, the LED blinks ON/OFF until completion.

 If the specimen orientation is correct:

- The LED glows green.
- The carrier moves to the next drilling operation.

 If the specimen orientation is incorrect:

- The LED glows red.
- The carrier is directed to an alternate drilling operation.

 The conveyor starts or stops based on the position detected by the capacitive sensor at the end station.

Result:

Ex. No.	Operate Drilling Application with Program-Specific Changes and Operator Guidance via CP404 MES
Date:	

Aim:

To enable the Drilling Application with automated by specific program changes and operator guidance through CP404 MES.

Drilling station (CP_iDRILL):

CP_iDRILL

- The CP_iDRILL application performs automated drilling .
- The CP_iDRILL station typically uses the following sensors:
  - Proximity Sensors - Position
  - Inductive Sensors - Metal
  - Position Sensors - Alignment
  - Optical Sensors - Orientation
  - Pressure Sensors - Clamping
  - Force/Torque Sensors - Force

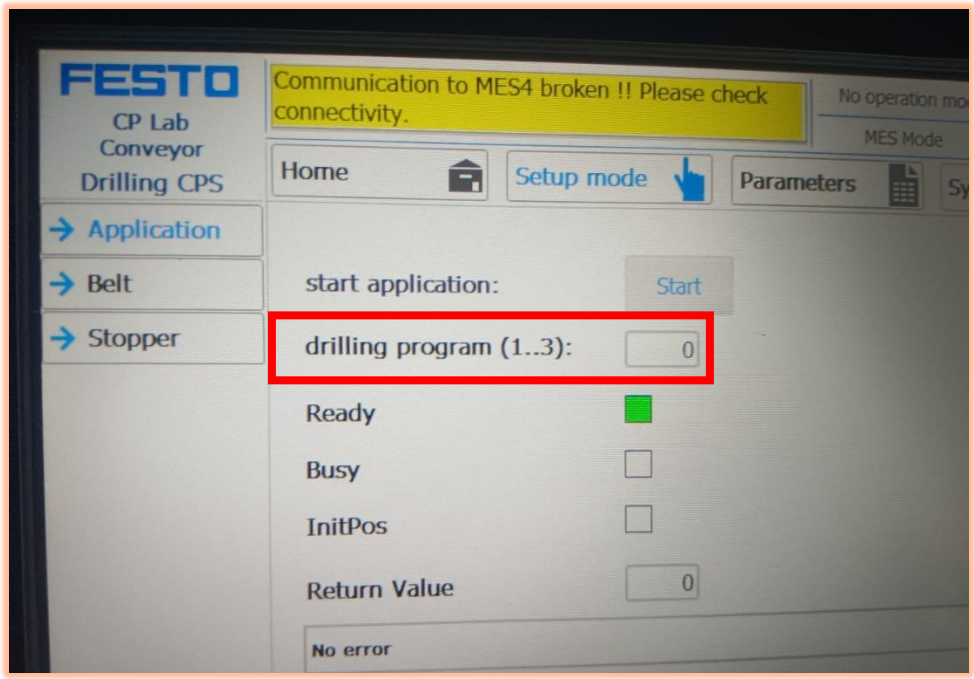
BG1, BG6, BG8 - Proximity Sensor
BG4, BG8 - Photoelectric barrier
SIEMENS S7-1200 PLC, SIMATIC HMI
CP404 - Cyber Physical System, Industry 4.0 station

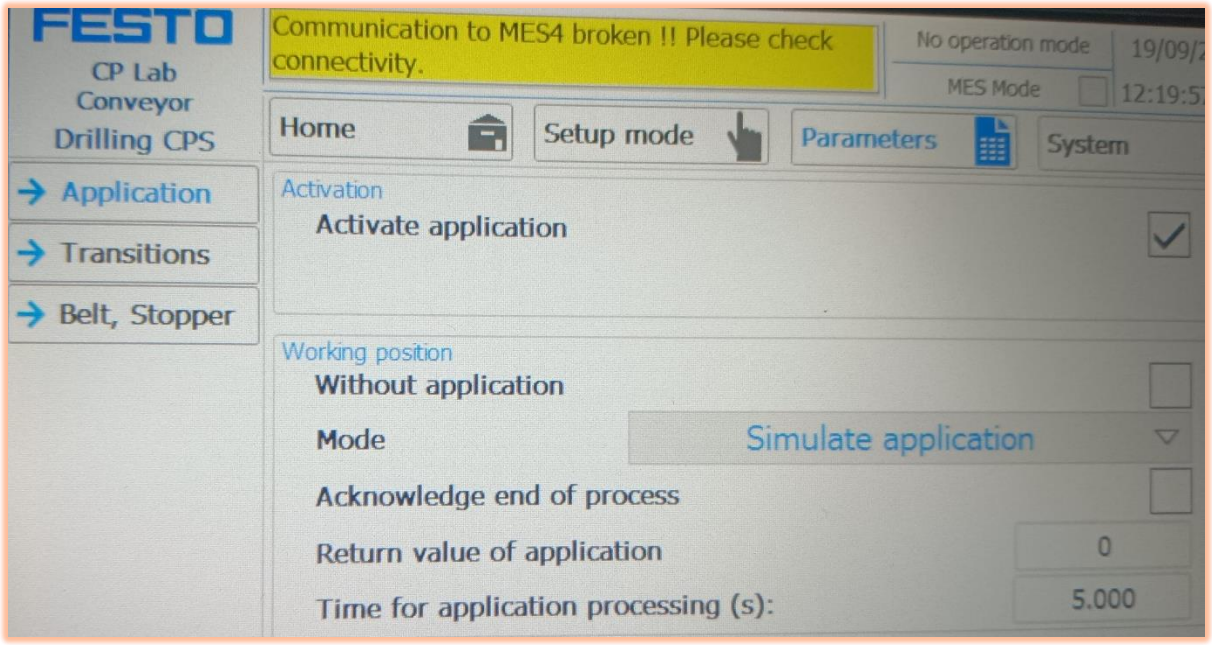
Procedure:

1. Ensure the system is ON and set the transition code in HMI.
2. The state code is checked to perform drilling operation from the measure station.
3. If the state code is (say for example) 30, it will drill both sides of the magazine.
4. If the state code is (say for example) 40, it will drill the left side of the magazine.
5. **Drilling operation**:

   1 → Drill right
   2 → Drill left
   3 → Drill both the sides.

6. According to the transition, once the operation is done, the carrier moves to the next station.


FESTO
CP Lab
Conveyor
Drilling CPS
Communication to MES4 broken !! Please check connectivity.
No operation mo
MES Mode
Home
Setup mode
Parameters
Application
Belt
Stopper
start application:
Start
drilling program (1..3):
0
Ready
Busy
InitPos
Return Value
0
No error


FESTO
CP Lab
Conveyor
Drilling CPS
Communication to MES4 broken !! Please check connectivity.
No operation mode
MES Mode
Home
Setup mode
Parameters
System
Application
Transitions
Belt, Stopper
Activation
Activate application
Working position
Without application
Mode
Simulate application
Acknowledge end of process
Return value of application
0
Time for application processing (s):
5.000

Result:

Ex. No.	To track output and stage-wise operations, such as to automate material requests and track material flow through MES synchronization
Date:	

Aim:

To track output and stage-wise operations, such as to automate material requests and track material flow through MES synchronization in conjunction with the Output Application.

Delivery station (CP_OUT):

- The CP_OUT station is the final stage where finished parts or products are collected, sorted.
- It consists of,
  - Proximity Sensors - Detection
  - Optical Sensors - Identification
  - Grippers - Transfer
  - Sorting
  - Quality Check Sensors
  - Ejector Sensor

1. BG1 – Lifting cylinder upper position.
2. BG2 – Lifting cylinder lower position.
3. BG3 – Gripper opened.
4. SIEMENS S7-1200 PLC, SIMATIC HMI.

Procedure:

1. Ensure the system is ON and set the transition code in HMI.
2. Once the pallet reaches the output station, the carrier id is sensed, and the stopper is enabled.
3. Unlock the lifting cylinder by disengaging any safety locks through the HMI.
4. Lift the cylinder to the desired position, confirming with BG1 sensor.
5. Open the gripper using a PLC command, validated by BG3 sensor.
6. Clamp the product securely in the slide for the next operation according to the transition.
7. Continue to the subsequent process stage as per transition code.

Procedure:

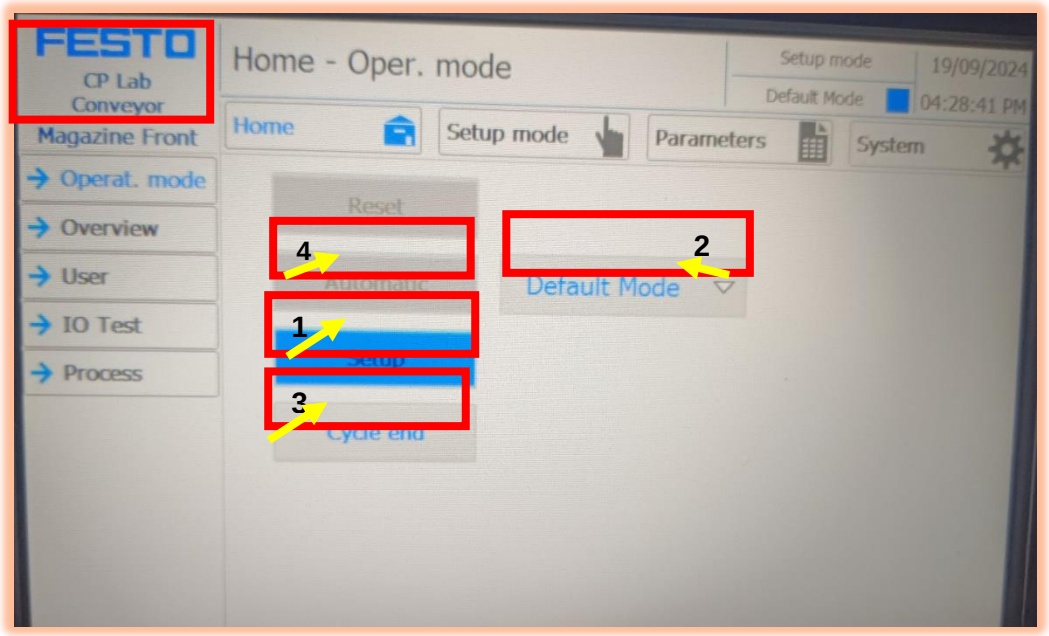
Ex. No.	To integrate the Pallet Transfer System with MES for real-time production tracking and verification through CP404
Date:	

Aim:

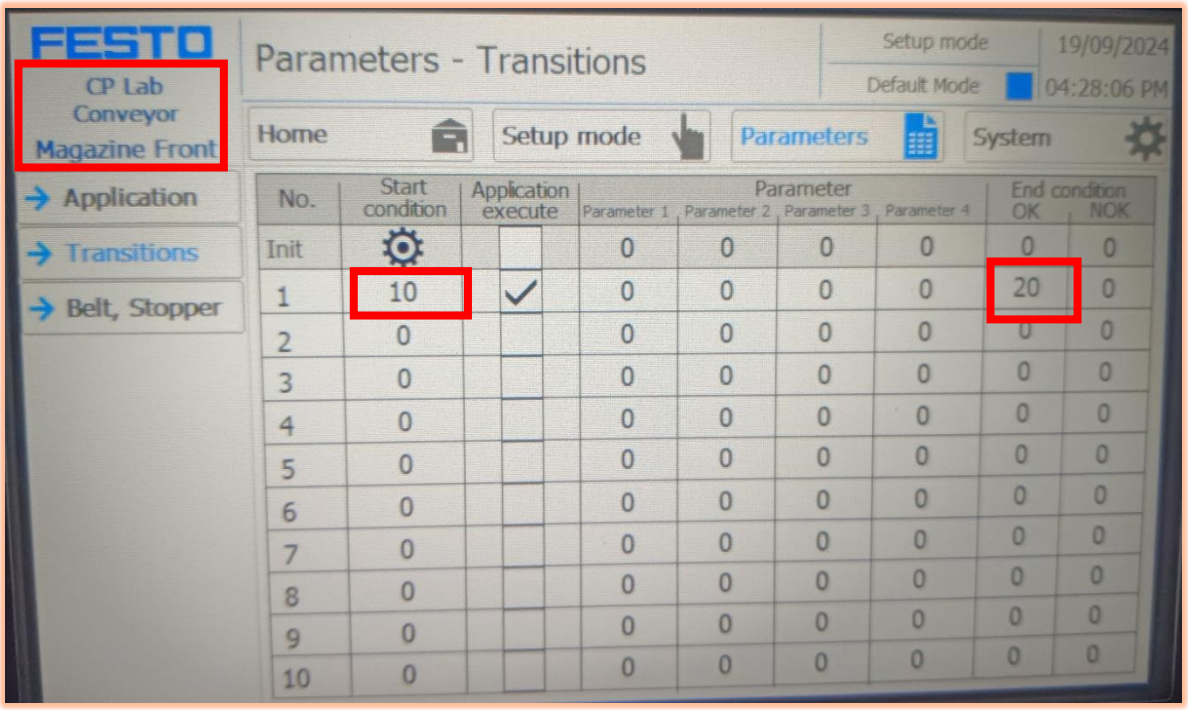
To integrate the Pallet Transfer System with MES for real-time production tracking and verification through CP404

PROCEDURE:

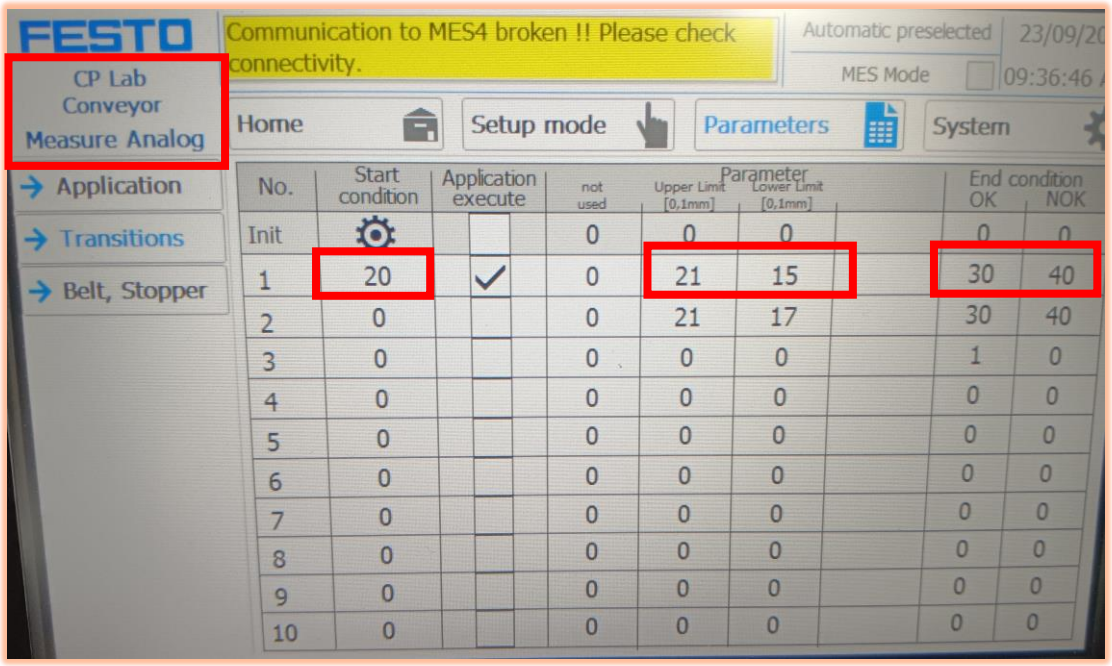
1. Ensure the system is ON and set the transition code in the HMI.
2. Once the pallet reaches the output station, the carrier ID is detected, and the stopper is enabled.
3. Set the state code for the carrier by navigating to **Setup -> Default**.
4. Go to **Stopper -> State Code**; for example, set it to 10 and press "Write."
5. Ensure the carrier ID is detected through the RFID reader. Press "Read" to verify.



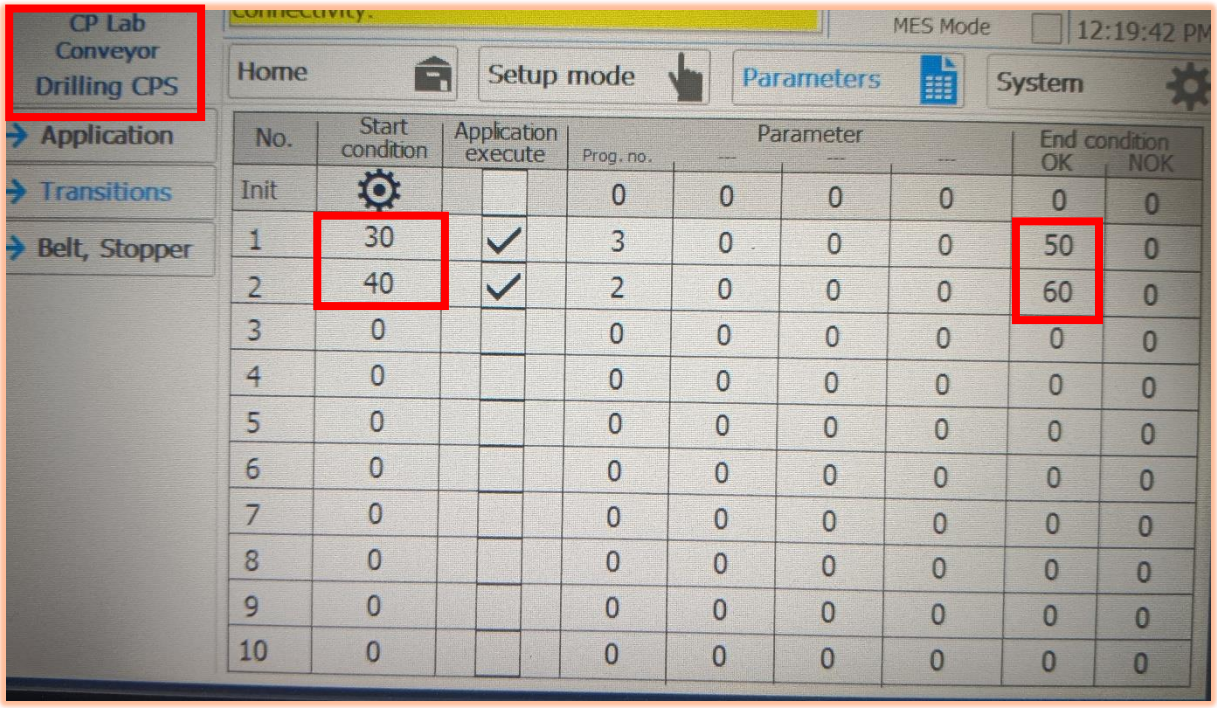
6. Set the state code to 10 through **Parameters -> Transitions**. Make sure Application execute check box should be enabled for executable row.
7. Set the transition code to the starting state code of the measure station, for example, 20.



8. Set the starting state code of the measurement station (e.g., 20) and transition to the drilling station (e.g., 30, 40) according to the orientation check. Set the lower and upper limits after calibration.

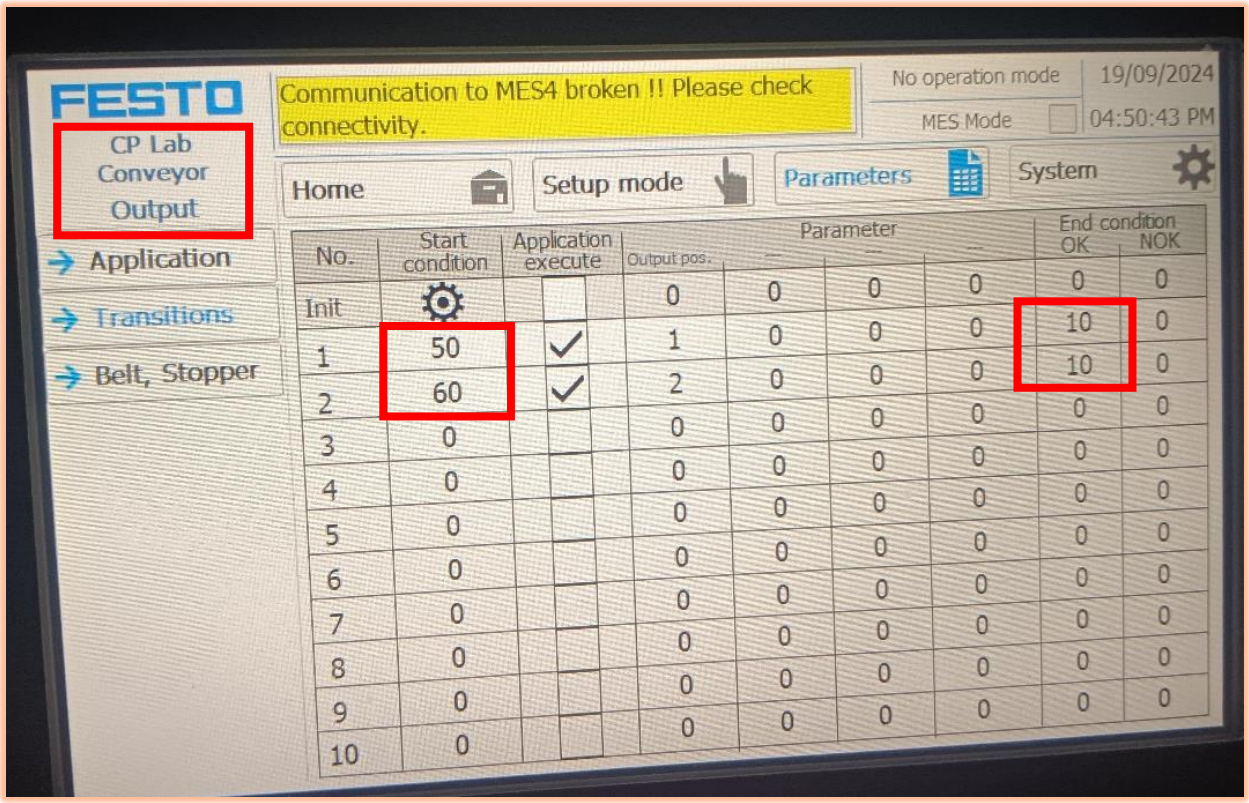


9. For the starting state code of the drilling station (e.g.,30) Set the drilling program from (1,2, or 3) and transition to the output station (e.g., 30, 40) according to the drilling operation.



No.	Start condition	Application execute	Parameter Prog. no.	---	---	---	End condition OK	NOK
Init			0	0	0	0	0	0
1	30	✓	3	0	0	0	50	0
2	40	✓	2	0	0	0	60	0
3	0		0	0	0	0	0	0
4	0		0	0	0	0	0	0
5	0		0	0	0	0	0	0
6	0		0	0	0	0	0	0
7	0		0	0	0	0	0	0
8	0		0	0	0	0	0	0
9	0		0	0	0	0	0	0
10	0		0	0	0	0	0	0

10. For the starting state code of the output station (e.g.,50,60) Set the delivery of the product by output pos. to slide 1 or slide 2 and transition to the magazine station (e.g.,10) to automate the process.



No.	Start condition	Application execute	Output pos.	Parameter ---	---	---	End condition OK	NOK
Init			0	0	0	0	0	0
1	50	✓	1	0	0	0	10	0
2	60	✓	2	0	0	0	10	0
3	0		0	0	0	0	0	0
4	0		0	0	0	0	0	0
5	0		0	0	0	0	0	0
6	0		0	0	0	0	0	0
7	0		0	0	0	0	0	0
8	0		0	0	0	0	0	0
9	0		0	0	0	0	0	0
10	0		0	0	0	0	0	0

Result:

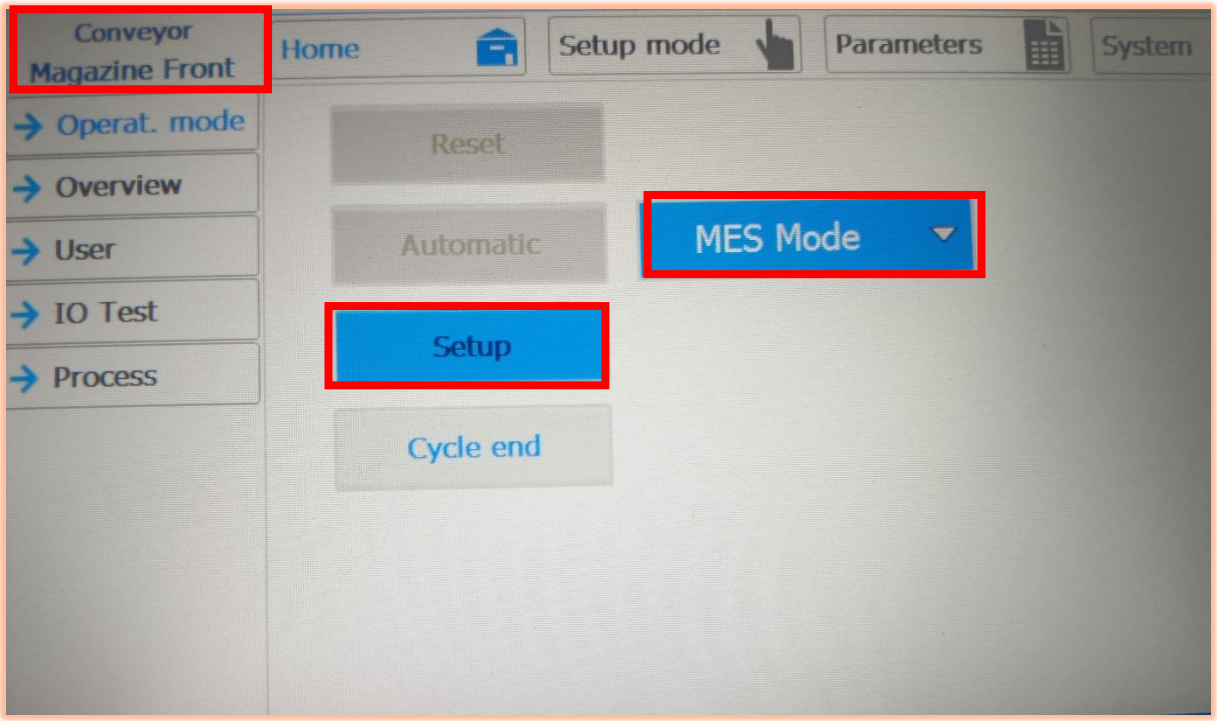
Ex. No.	Establish networked equipment communication with MES for efficient production plan adjustments and revisions via MES4.
Date:	

Aim

To establish networked equipment communication with MES for efficient production plan adjustments and revisions via MES4.

Apparatus Required:

1. PC with factory views software installed.
2. Applications used: Magazine, Measure, Drill, Output Station.
3. Ethernet Cable.



Procedure:

1. **Set the System to MES Mode:**
   - Navigate to the HMI (Human-Machine Interface).
   - Select *Cycle End*, then click on *Automatic* mode and switch to *MES Mode*.
2. **Configure the PC for MES Connection:**
   - Open *Settings* on your PC and go to *Network & Internet*.
   - Under *Ethernet*, modify the IP settings to connect to the MES network:

        - Set the *IP Address* to 172.21.0.90.
        - Configure the *Subnet Mask* to 255.255.192.0.
    - Save the changes to apply the new network configuration.
3. **Disable Unnecessary System IP Connections:**
    - Open the Command Prompt as an Administrator.
    - Type the command: net stop http, then confirm by pressing *Y* to stop unnecessary services like HTTP, printers, and SSDD.
4. **Start the Factory Views Software:**
    - Launch the Factory Views software and verify that both the Node Server and MES Core are enabled.
    - Open the start page to begin the production control process.
5. **Log in to the MES System:**
    - In the Factory Views software, click on *MES4*.
    - Log in using the credentials:
        - Username: admin
        - Password: *******
6. **Monitor and Control Production:**
    - Once logged in, use the MES system to control and monitor the production process, ensuring all systems are functioning correctly.

System Configuration and Layout Adjustment for MES Integration

1. **Module Installation**:
    - Begin by adding the application modules to each station:
        1. **CP-AM-MAG_FRONT** (Front Cover)
        2. **CP-AM-MEASURE**
        3. **CP-AM-iDRILL**
        4. **CP-AM-OUT**

    Note: CP stands for Cyber Physical, and AM refers to the Application Module.

2. **IP Configuration**:
    - Assign the following IP addresses to each station:
        1. **Magazine**: 172.21.1.1
        2. **Measure**: 172.21.2.1
        3. **idrill**: 172.21.3.1
        4. **Output**: 172.21.4.1

    Ensure that the layout is activated upon completing the IP configuration.

3. **Product Parts Creation**:
    - Navigate to "Parts" > "Product" > "New Parts."
    - Provide relevant details, such as the part name, generation, and the default resource ID.
    - Optionally, include an image of the component if required.

4. **Workplan Editing**:
    - Select "Edit Workplan," then proceed through the following steps:
        - Feed Front Cover → Measure → Drill → Delivery → Save.
    - Ensure the work plan is edited to meet specific operational requirements.

Result :

Ex. No.	Integration of CP Lab Model Library with MES4 for Realistic Industrial Process Modelling and Simulation
Date:	

Aim

To integrate the CP Lab Model Library for realistic modelling and simulation of industrial processes in conjunction with MES4, enhancing hands-on learning and system performance analysis.

Apparatus Required:

1. **PC with Factory Viewer Software**
2. **Magazine, Measuring Station, idrill, and Output Station**
3. **Ethernet Cable**

Procedure:

1. Follow the procedure outlined in Experiment 6.
2. Navigate to the "Order" section, then select "New Order." Click on "Order Placement" and enter the required quantity to be produced.
3. Open the command prompt and type **ping 172.21.1.1** to initialize the magazine station.
4. Once the order is placed, the station begins operating automatically.
5. The system will continue processing until the specified number of orders is completed.
6. Observe the process flow in CP-404 MES.

Result:

Ex. No.	**Simulation of Manufacturing Processes in CIROS Studio with MES Integration**
Date:	

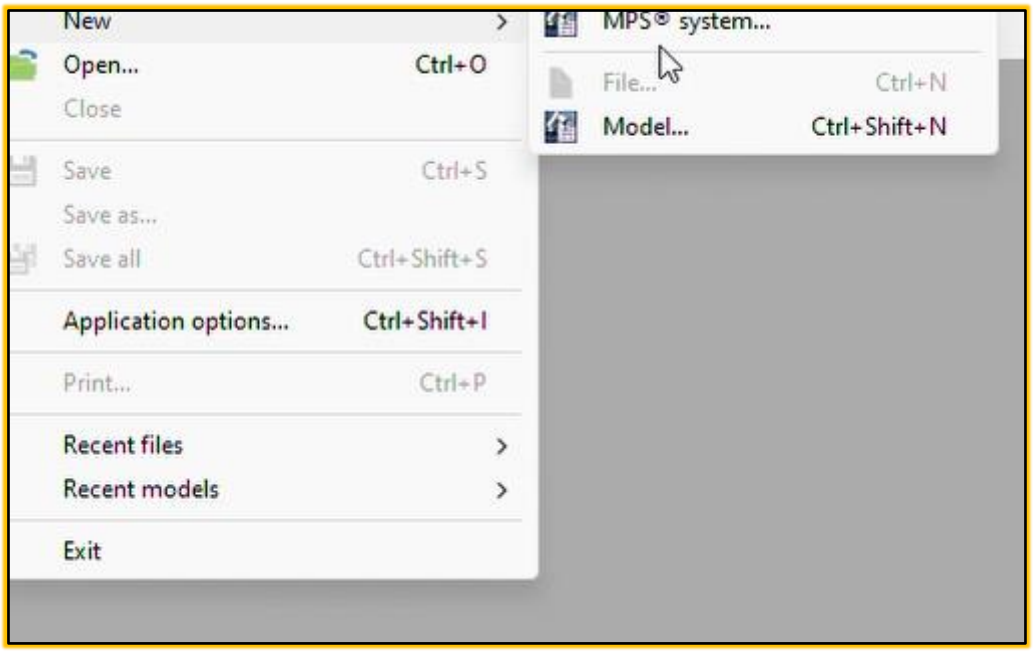
Aim:

To simulate and analyse the manufacturing processes using CIROS Studio, integrating the MES (Manufacturing Execution System) for efficient process control and monitoring.

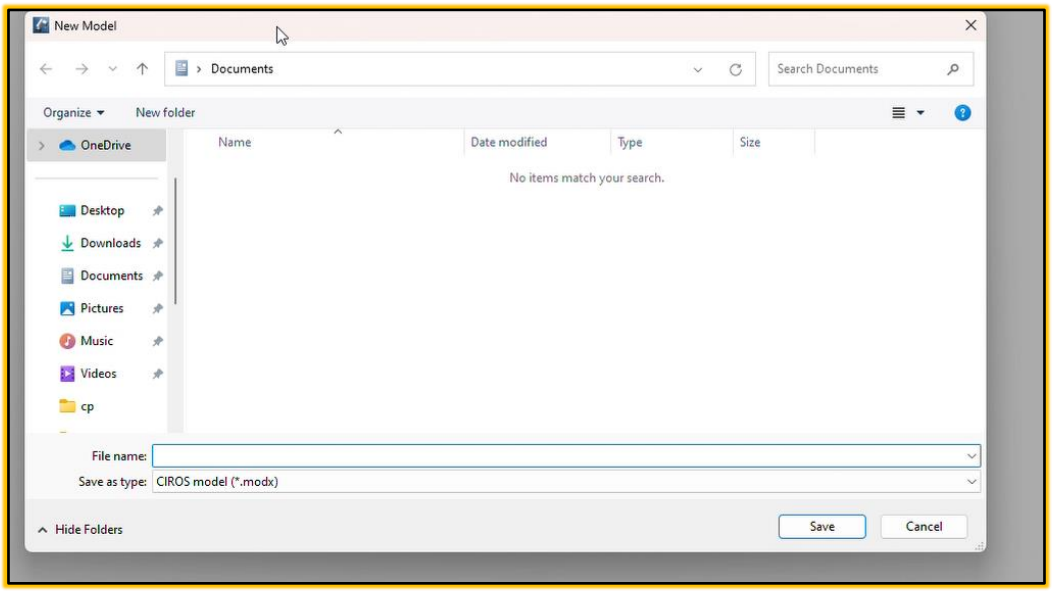
Procedure:

Create a New Project: Open CIROS and create a new project.

Select the "New" option and choose the "MPS system."

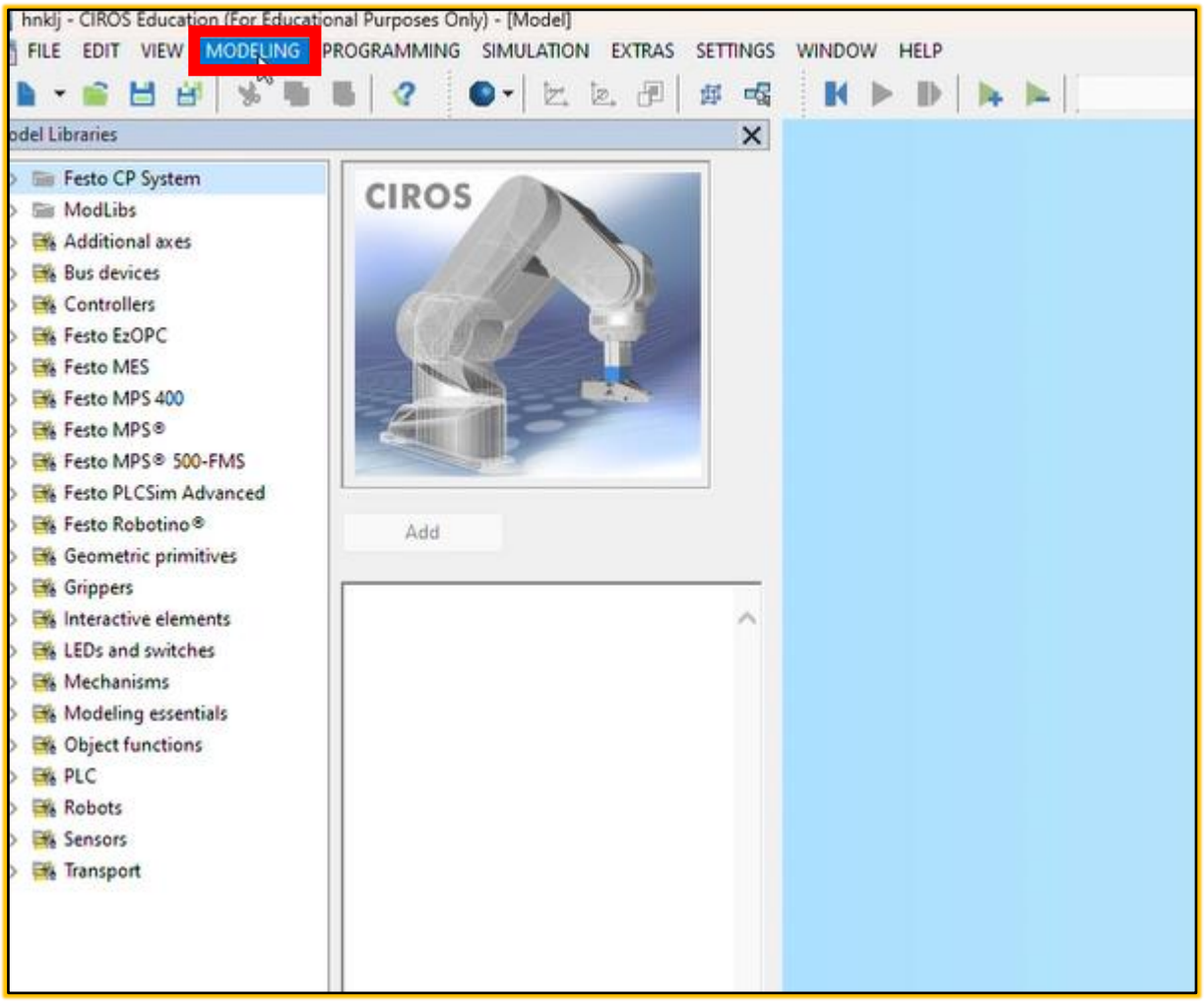


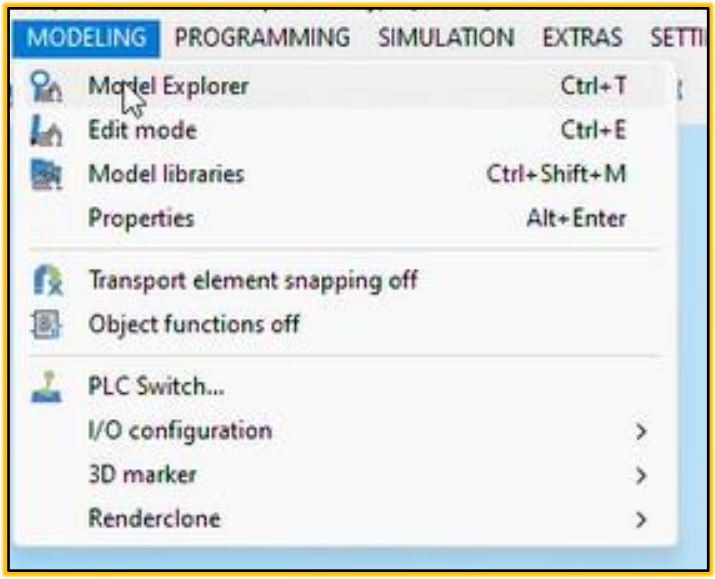
Save the project file in your desired location.



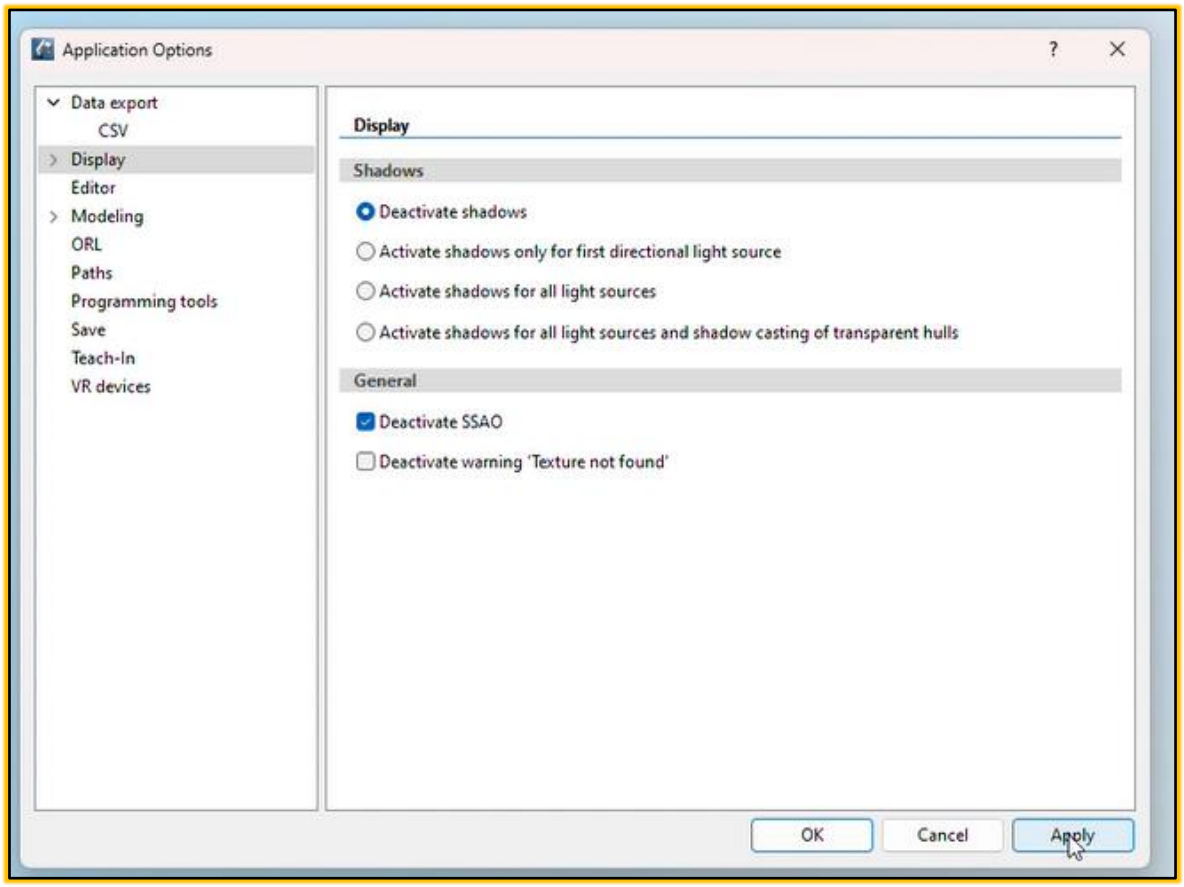
Model Explorer Setup:

Navigate to **Modelling -> Model Explorer**.



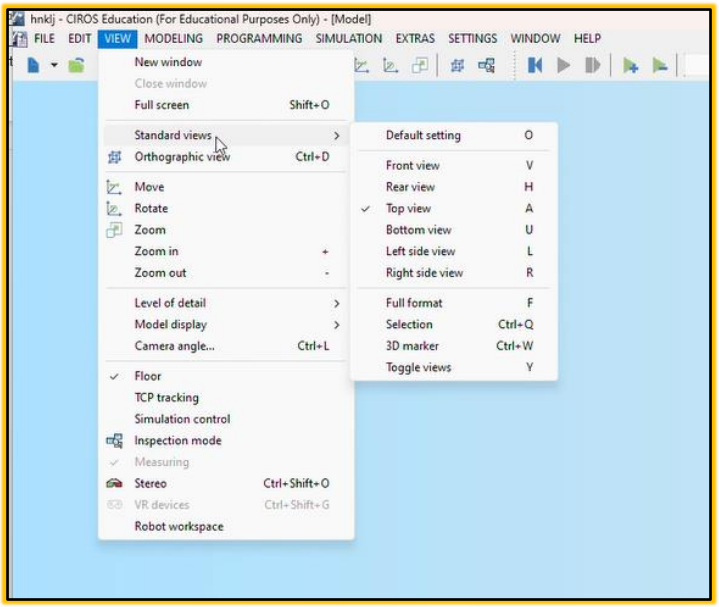


Go to **Application Options** and ensure that both **Deactivate Shadows** and **Deactivate SSAO** options are enabled for better visualization and performance.



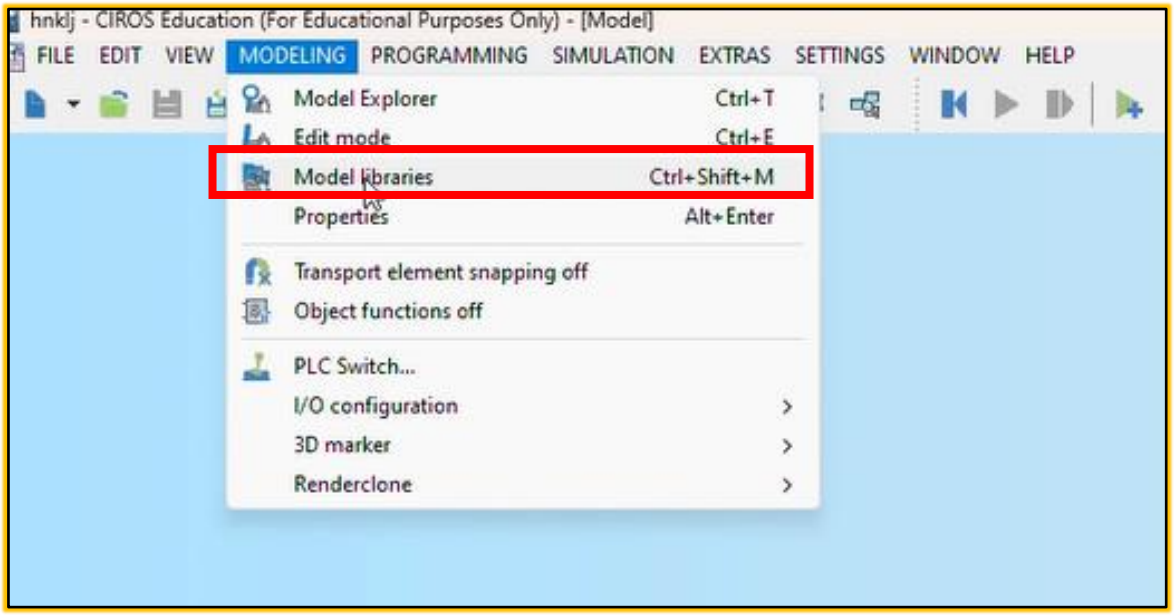
Set the View:

- Go to **Views** -> **Standard Views** -> **Top View** to get a top-down view of the workspace for easier object placement.

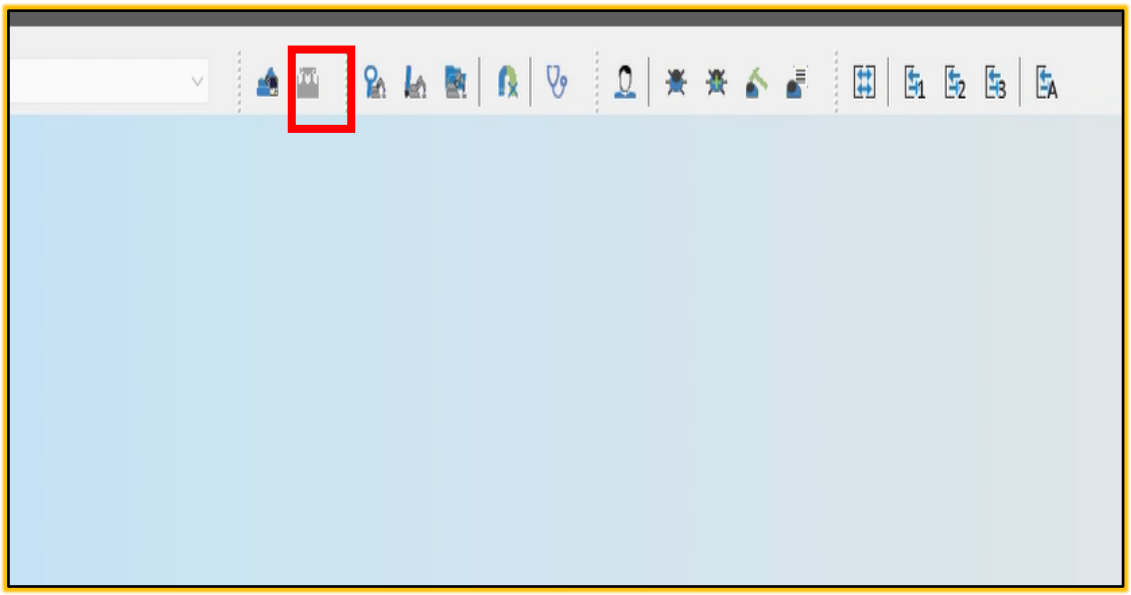


Add Conveyor Setup:

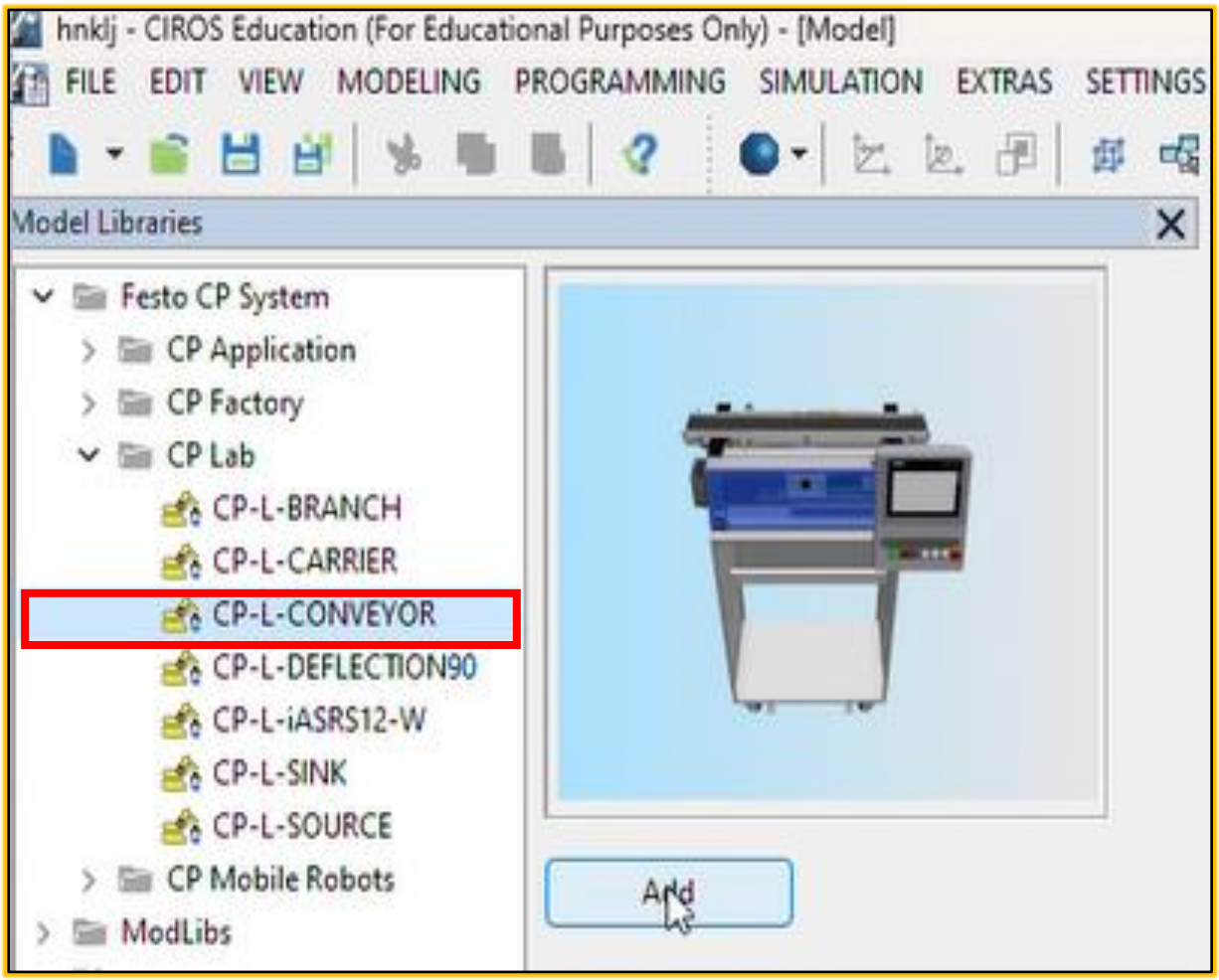
- Navigate to **Modelling** -> **Model Libraries**.

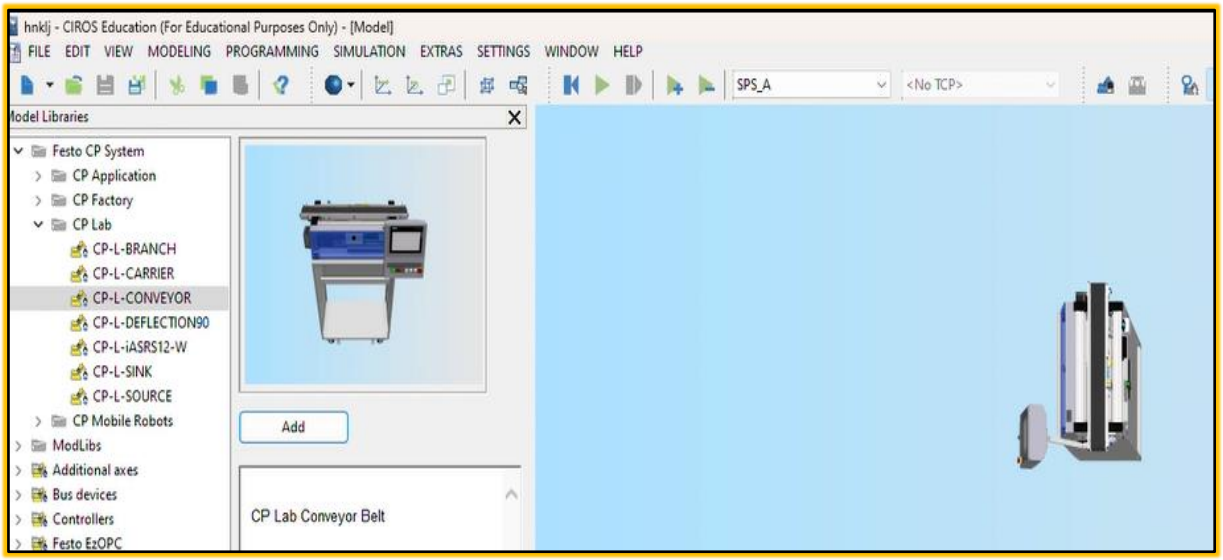


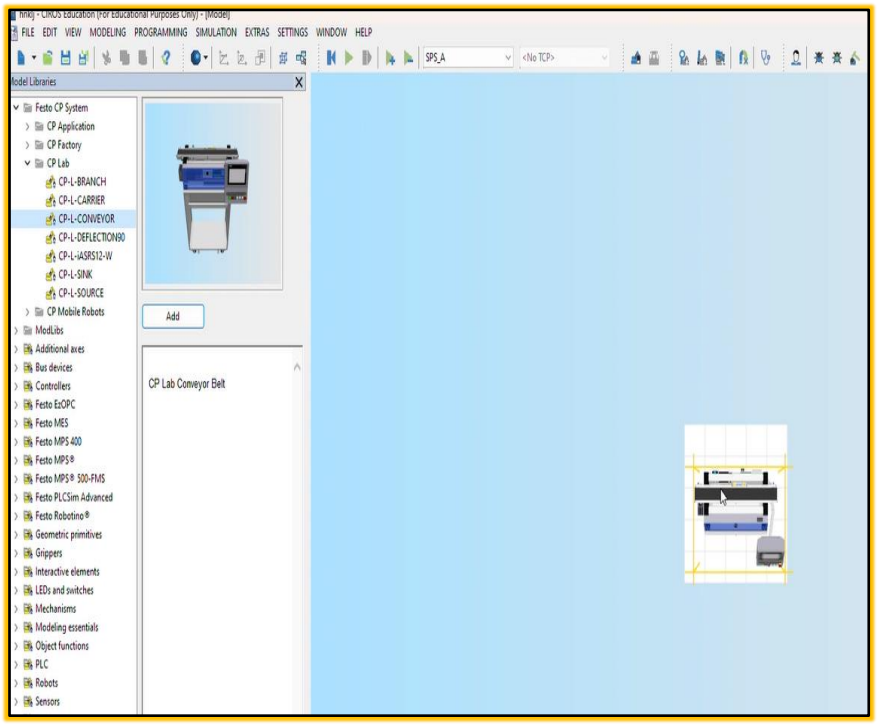
- Click the edit mode icon



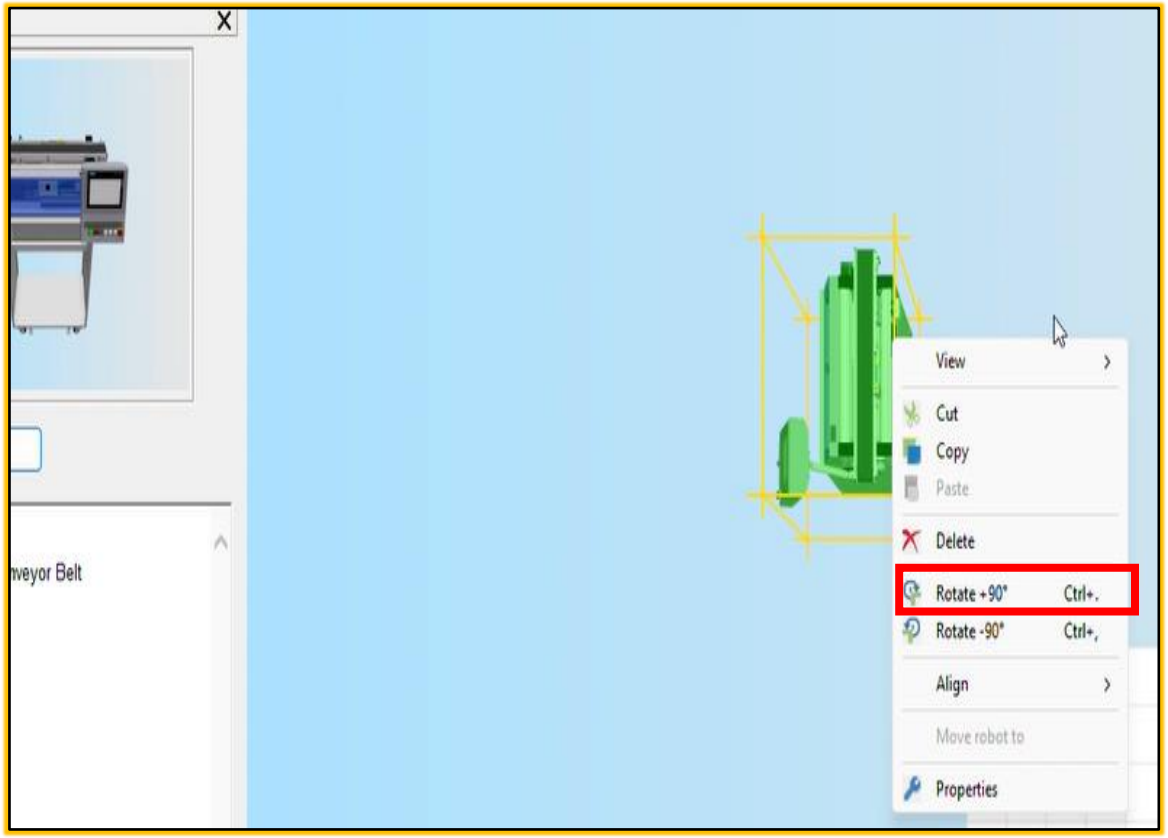
- Right-click and disable the **Floor Option**.
- In the model library, go to **FESTO CP System** -> **CP Lab** -> **CP-L-Conveyor**.
- Drag the conveyor to the workspace by clicking "Add."

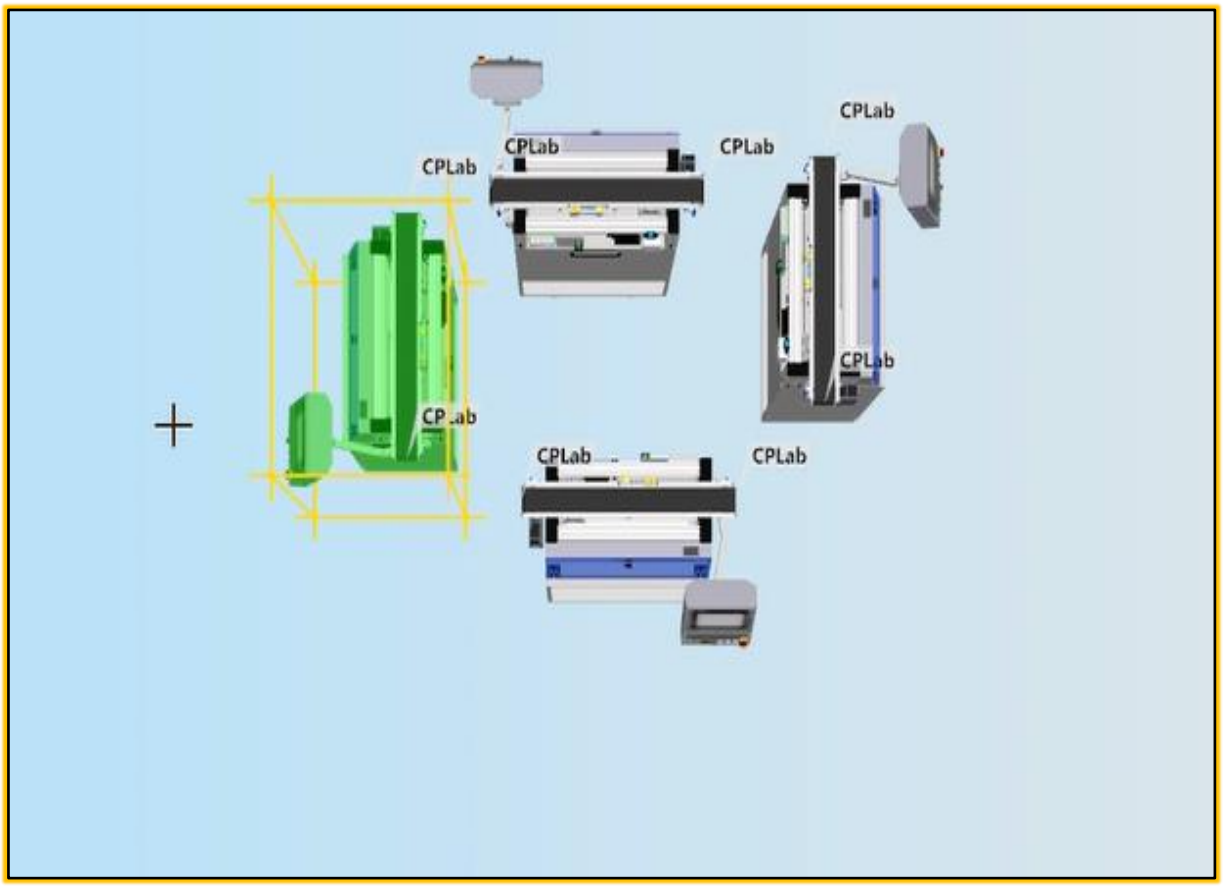

hnklj - CIROS Education (For Educational Purposes Only) - [Model]
FILE EDIT VIEW MODELING PROGRAMMING SIMULATION EXTRAS SETTINGS
Model Libraries
Festo CP System
CP Application
CP Factory
CP Lab
CP-L-BRANCH
CP-L-CARRIER
CP-L-CONVEYOR
CP-L-DEFLECTION90
CP-L-iASRS12-W
CP-L-SINK
CP-L-SOURCE
CP Mobile Robots
ModLibs
Add


hnklj - CIROS Education (For Educational Purposes Only) - [Model]
FILE EDIT VIEW MODELING PROGRAMMING SIMULATION EXTRAS SETTINGS WINDOW HELP
SPS_A
<No TCP>
Model Libraries
Festo CP System
CP Application
CP Factory
CP Lab
CP-L-BRANCH
CP-L-CARRIER
CP-L-CONVEYOR
CP-L-DEFLECTION90
CP-L-iASRS12-W
CP-L-SINK
CP-L-SOURCE
CP Mobile Robots
ModLibs
Additional axes
Bus devices
Controllers
Festo EzOPC
Add
CP Lab Conveyor Belt



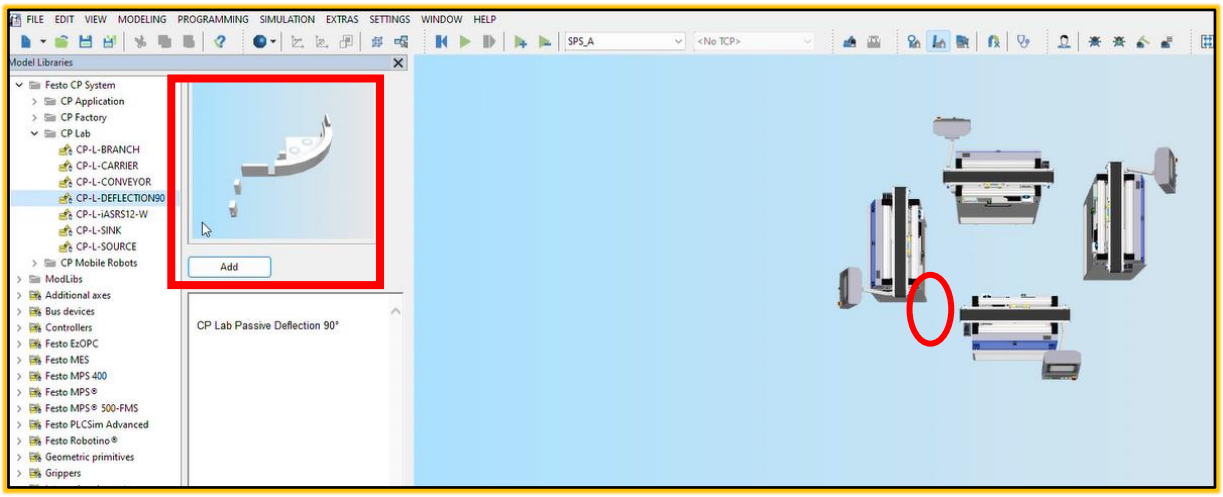
- Drag towards the workspace by clicking add and Rotate the conveyor 90 degrees to mimic the setup.



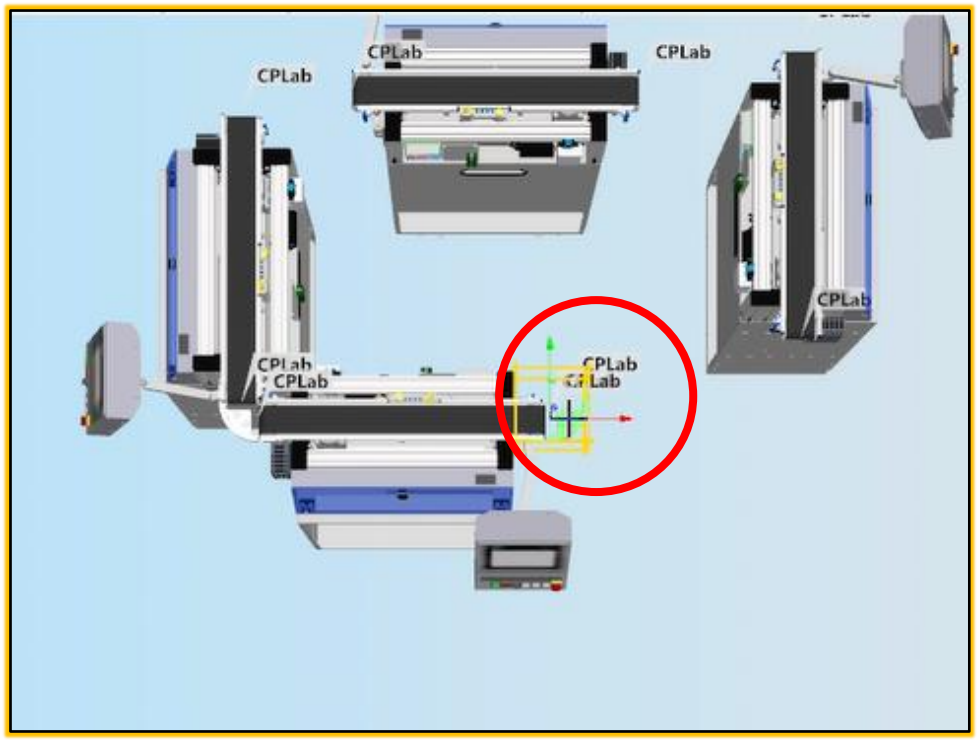


Join Conveyors:

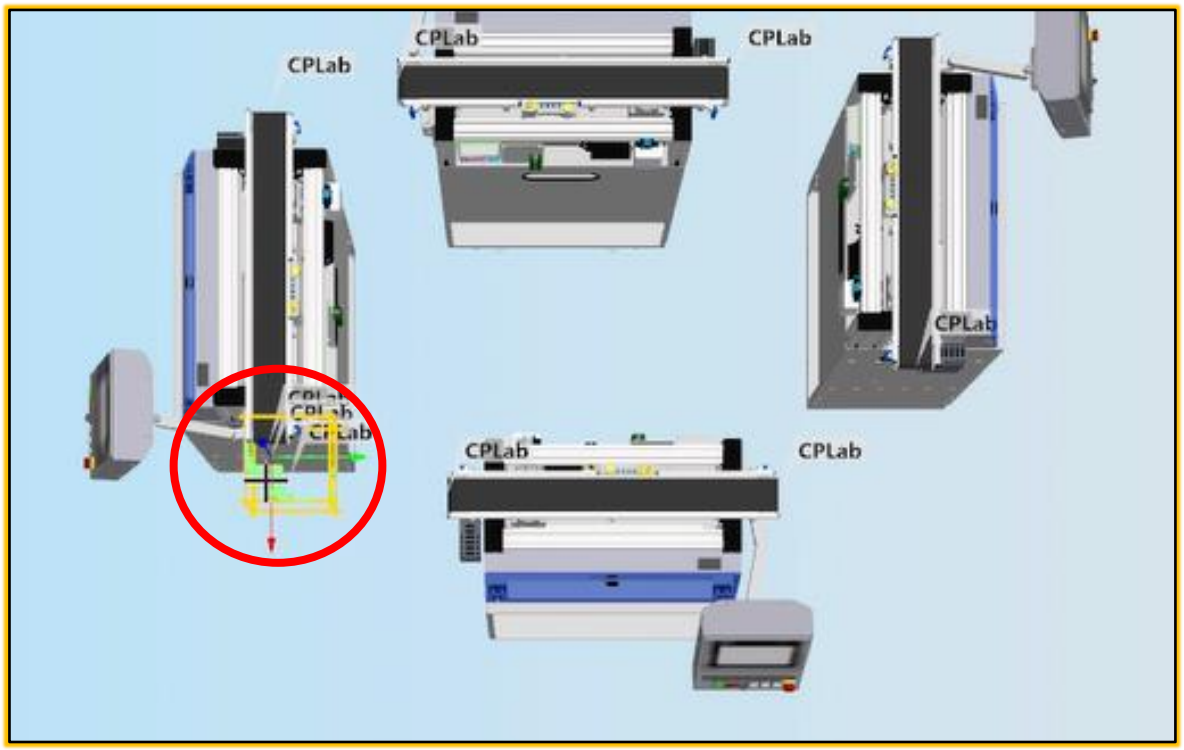
- After placing the conveyor setup, choose **CP-L-DEFLECTION90**.



- Use the **DEFLECTION** panel to join all the conveyors correctly and ensure they are aligned.



- Join all the conveyors correctly

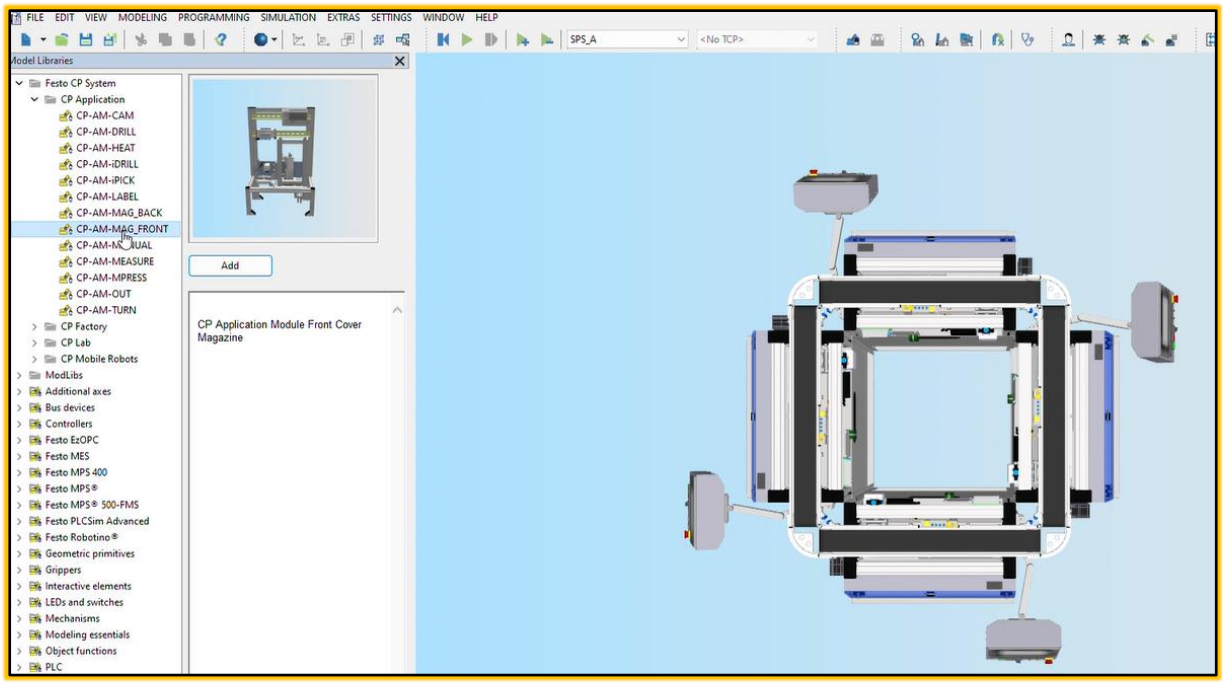


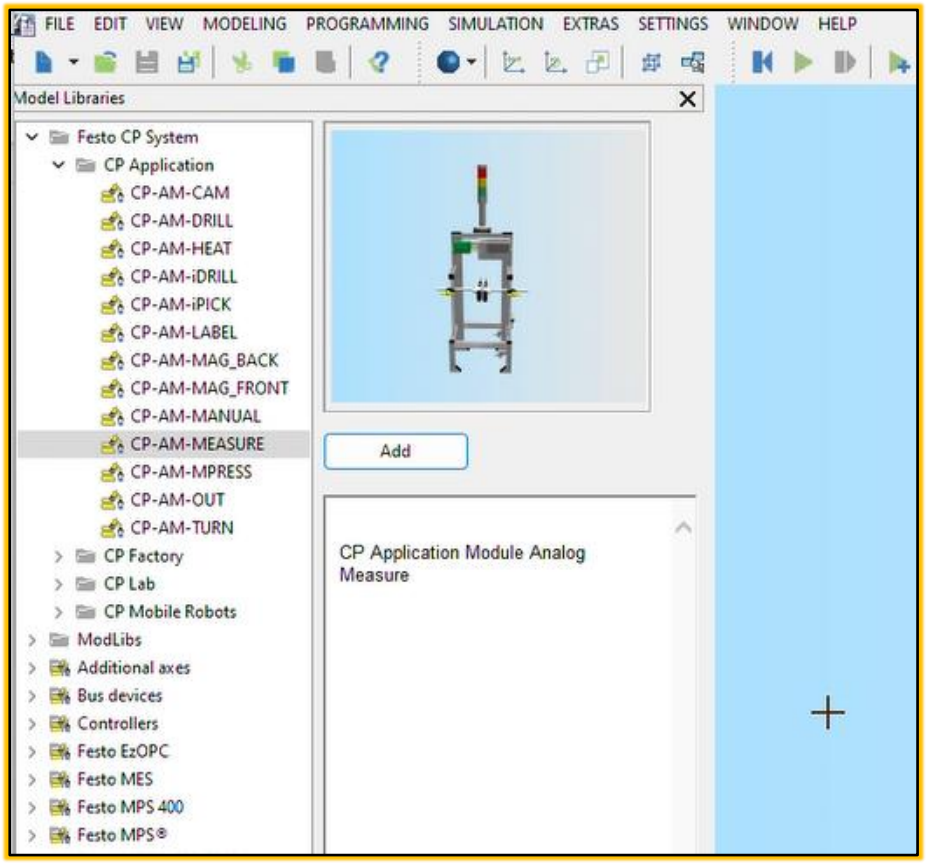
Now add the application on the top of conveyor. In order to do that, perform the following steps.

Add Applications to the Conveyor:

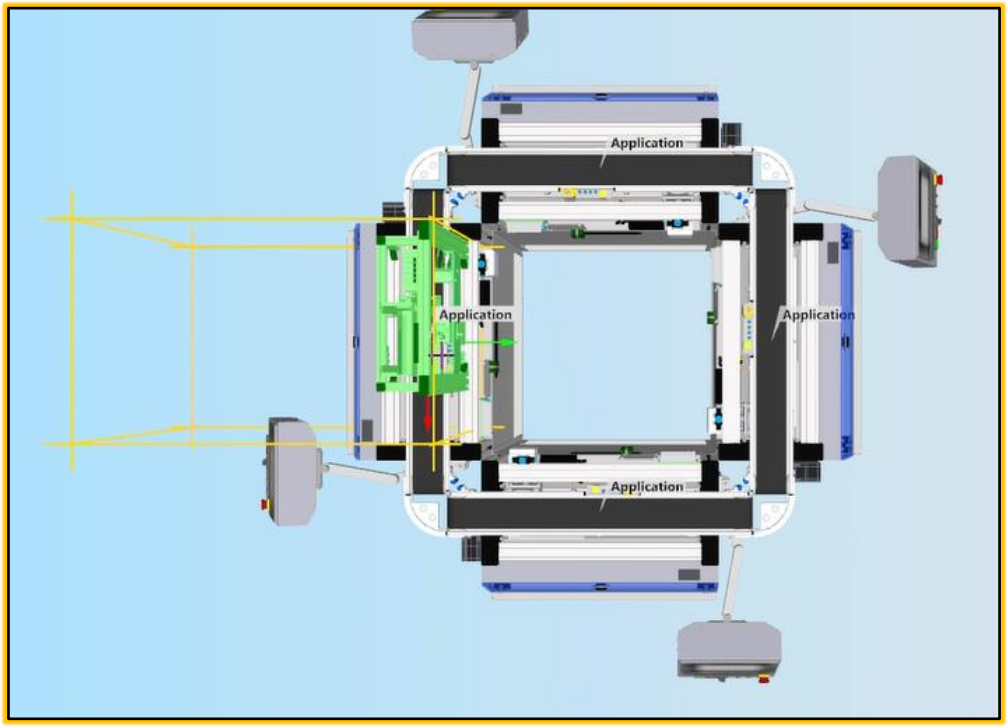
- From the model library, select the following applications:
  - **CP-AM-MAG-FRONT**
  - **CP-AM-MEASURE**
  - **CP-AM-iDRILL**
  - **CP-AM-OUT**
- Drag these applications one by one to the top of the conveyor setup.
- Match the word “application” from the newly added applications with the existing “application” points on the CP Conveyor.
- Release the mouse button to drop the applications into place

- **MAG-FRONT**


FILE EDIT VIEW MODELING PROGRAMMING SIMULATION EXTRAS SETTINGS WINDOW HELP
Model Libraries
Festo CP System
CP Application
CP-AM-CAM
CP-AM-DRILL
CP-AM-HEAT
CP-AM-iDRILL
CP-AM-iPICK
CP-AM-LABEL
CP-AM-MAG_BACK
CP-AM-MAG_FRONT
CP-AM-MANUAL
CP-AM-MEASURE
CP-AM-MPRESS
CP-AM-OUT
CP-AM-TURN
CP Factory
CP Lab
CP Mobile Robots
ModLibs
Additional axes
Bus devices
Controllers
Festo EzOPC
Festo MES
Festo MPS 400
Festo MPS®
Festo MPS® 500-FMS
Festo PLCSim Advanced
Festo Robotino®
Geometric primitives
Grippers
Interactive elements
LEDs and switches
Mechanisms
Modeling essentials
Object functions
PLC
Add
CP Application Module Front Cover Magazine

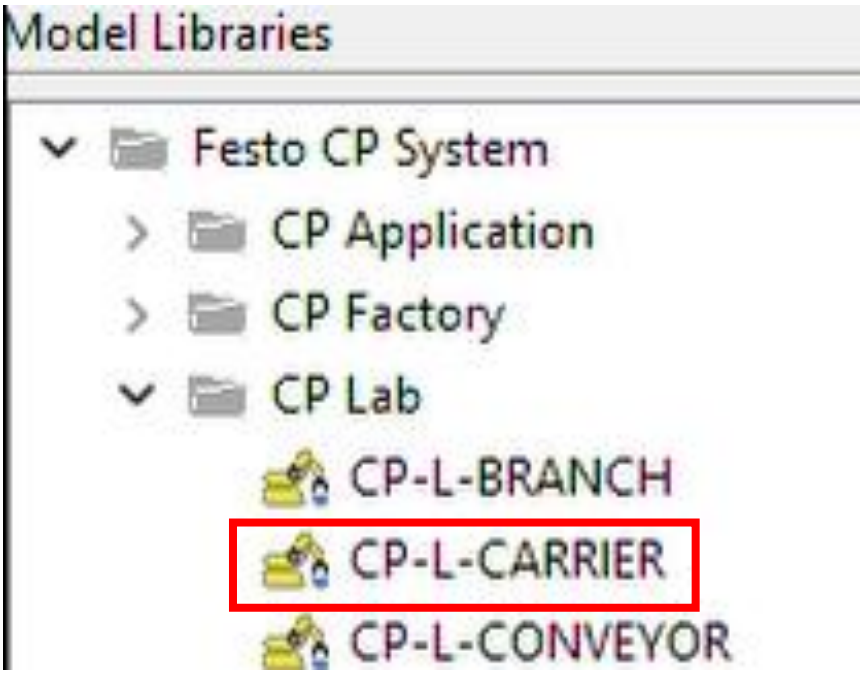

FILE EDIT VIEW MODELING PROGRAMMING SIMULATION EXTRAS SETTINGS WINDOW HELP
Model Libraries
Festo CP System
CP Application
CP-AM-CAM
CP-AM-DRILL
CP-AM-HEAT
CP-AM-iDRILL
CP-AM-iPICK
CP-AM-LABEL
CP-AM-MAG_BACK
CP-AM-MAG_FRONT
CP-AM-MANUAL
CP-AM-MEASURE
CP-AM-MPRESS
CP-AM-OUT
CP-AM-TURN
CP Factory
CP Lab
CP Mobile Robots
ModLibs
Additional axes
Bus devices
Controllers
Festo EzOPC
Festo MES
Festo MPS 400
Festo MPS®
Add
CP Application Module Analog Measure

Similarly, do it for CP-AM-MEASURE, CP-AM-iDRILL and CP-AM-OUT

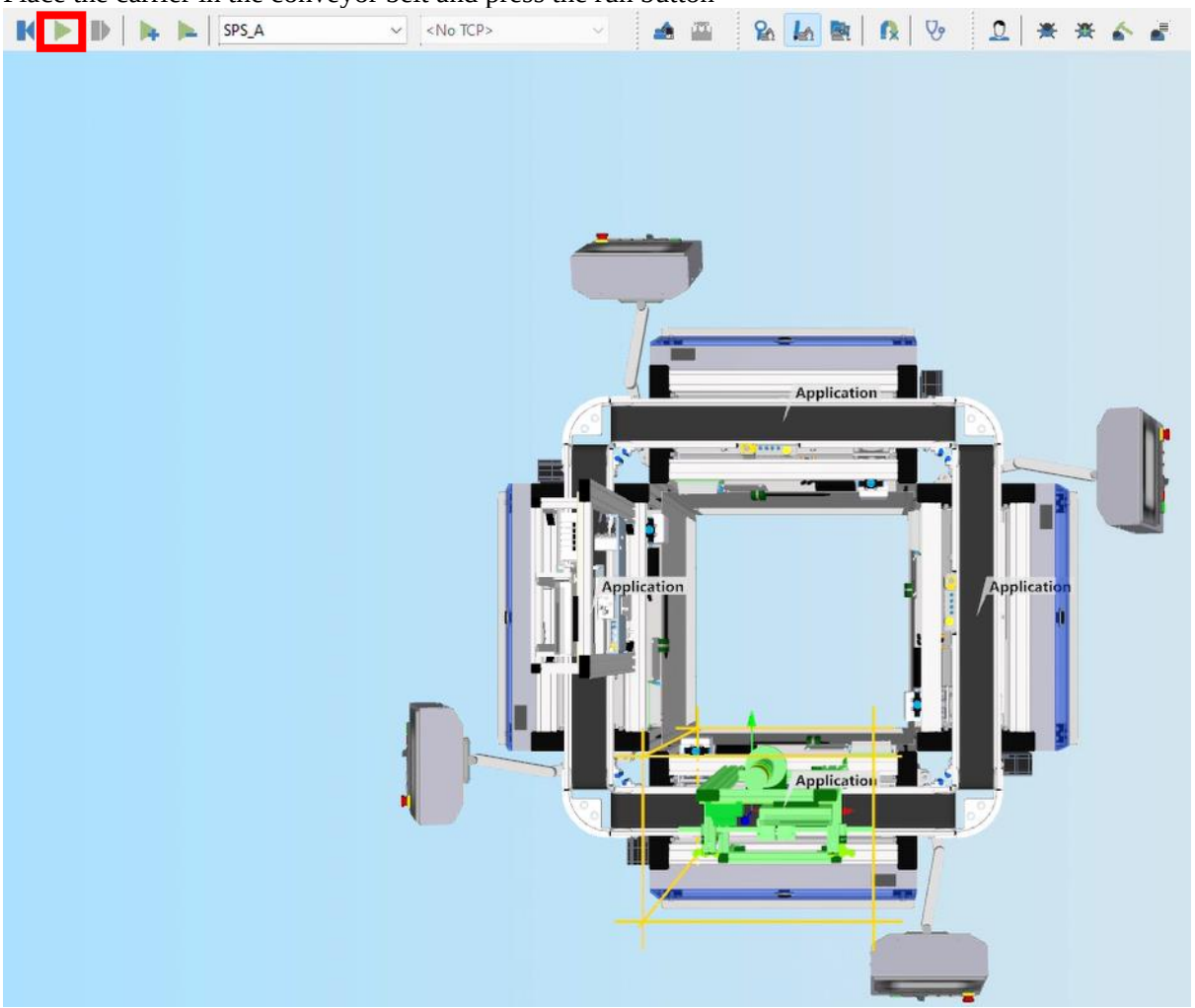


Add the Carrier:

- From **CP LAB** -> **CP-L-CARRIER**, select a carrier.
- Place the carrier on the conveyor belt.



Place the carrier in the conveyor belt and press the run button



Run the Simulation:

- After setting up all components, press the **Run** button to start the simulation and observe the interaction between the conveyor and the applications.

Result:

The CP 404 MES system has been successfully set up in CIROS, with all applications and carriers functioning. The carrier moved along the conveyor, interacted with each application and reached the output, completing the simulation successfully.

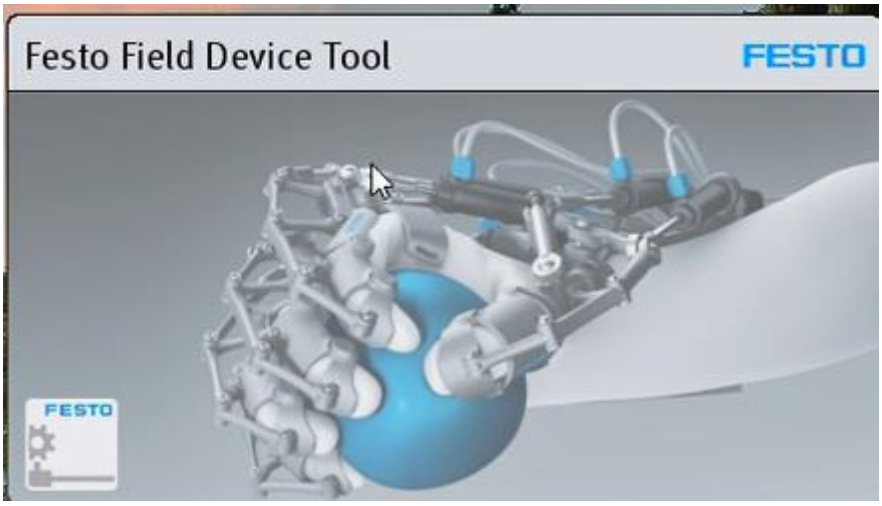
Ex. No.	**To implement energy monitoring and tracking in a manufacturing system using OPC UA for efficient energy management.**
Date:	

Aim:

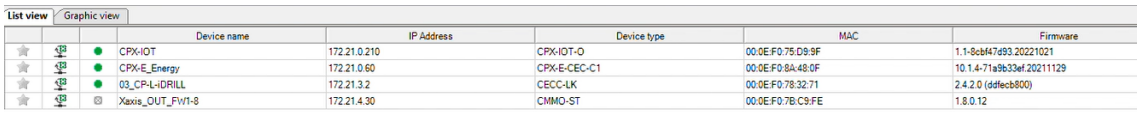
To track the real-time energy consumption across all CP 404 production stages through MES by analyzing data on pressure, flow, and energy monitoring to identify areas for energy optimization.

Procedure:

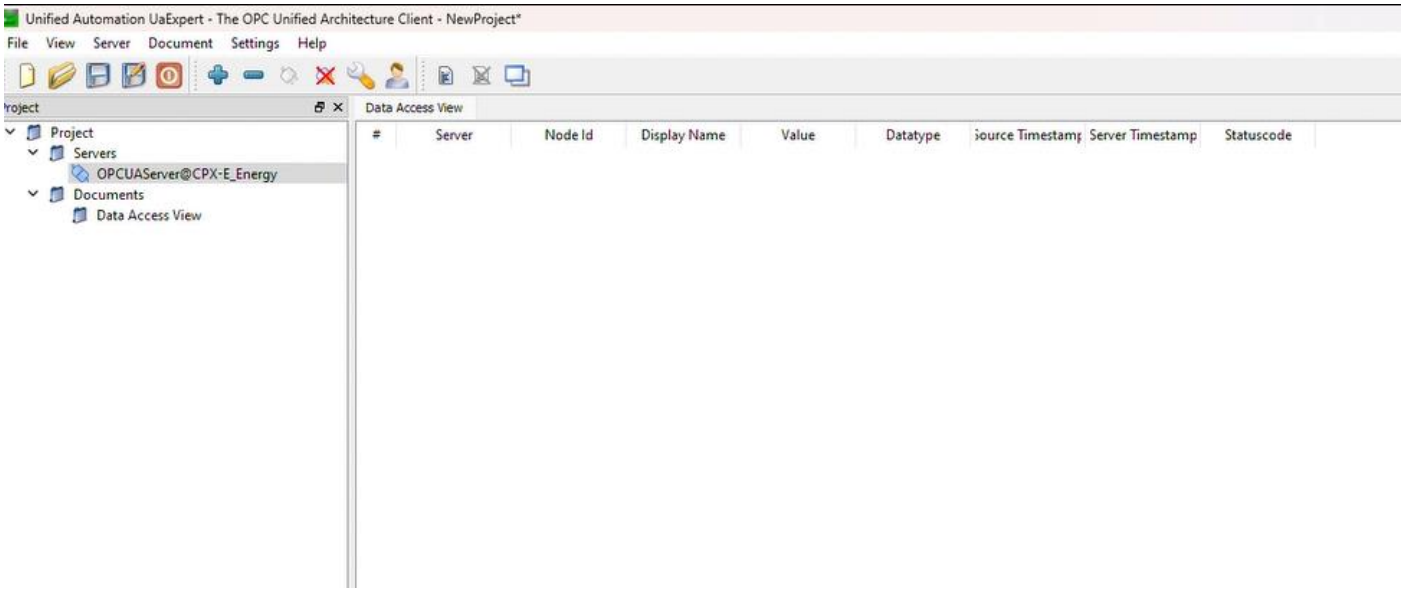
1. Connect CP 404 modules to the LAN network.
2. Ensure the MES system is online and capable of communicating with the connected devices.
3. Open the Festo Field Device Tool on your computer.



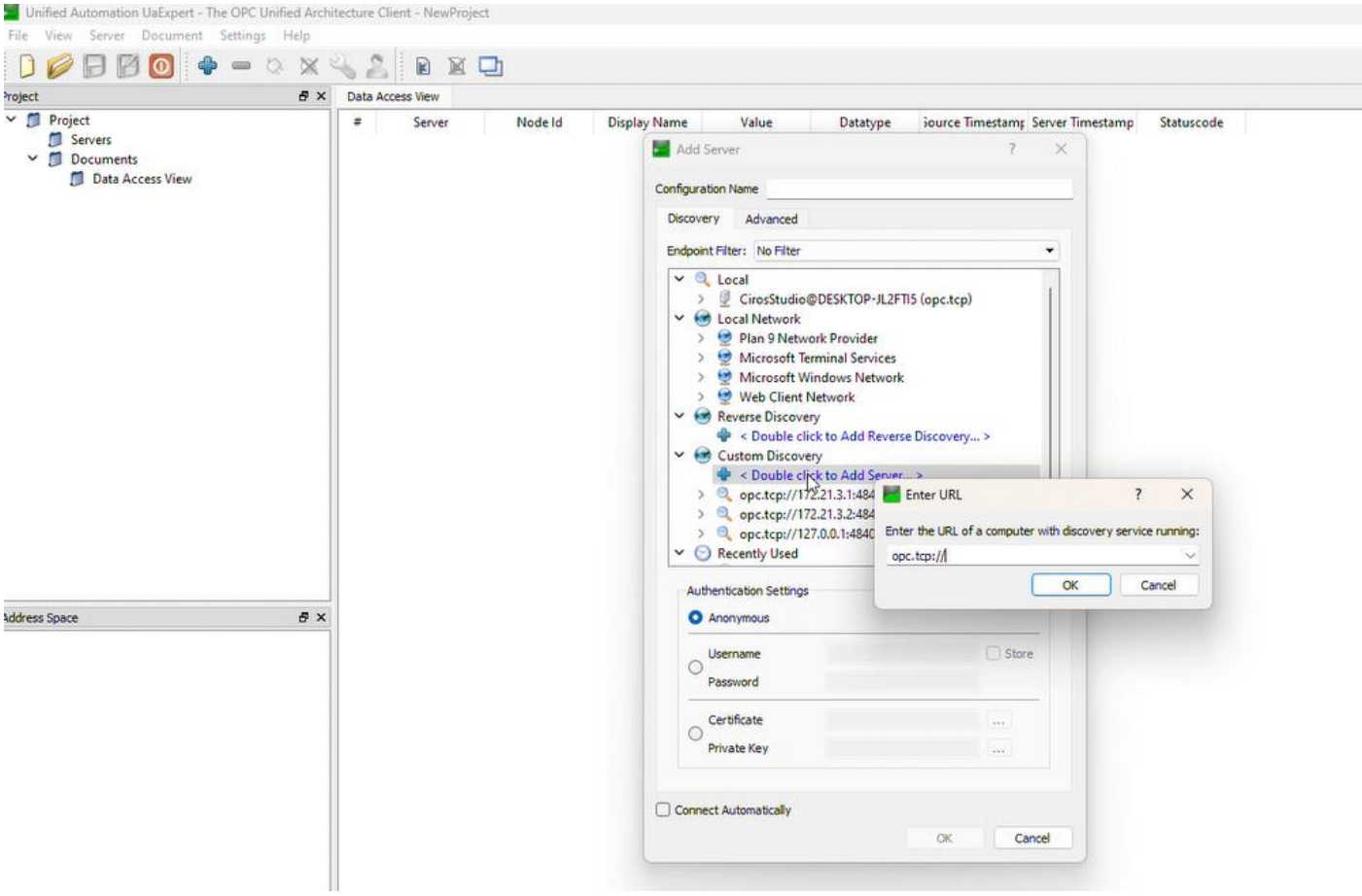
4. Verify that all CP 404 field devices are recognized by the FDT. Observe the energy monitoring unit IP address **172.21.0.60**



5. Open the UA Automation Expert Tool on the same or connected system.

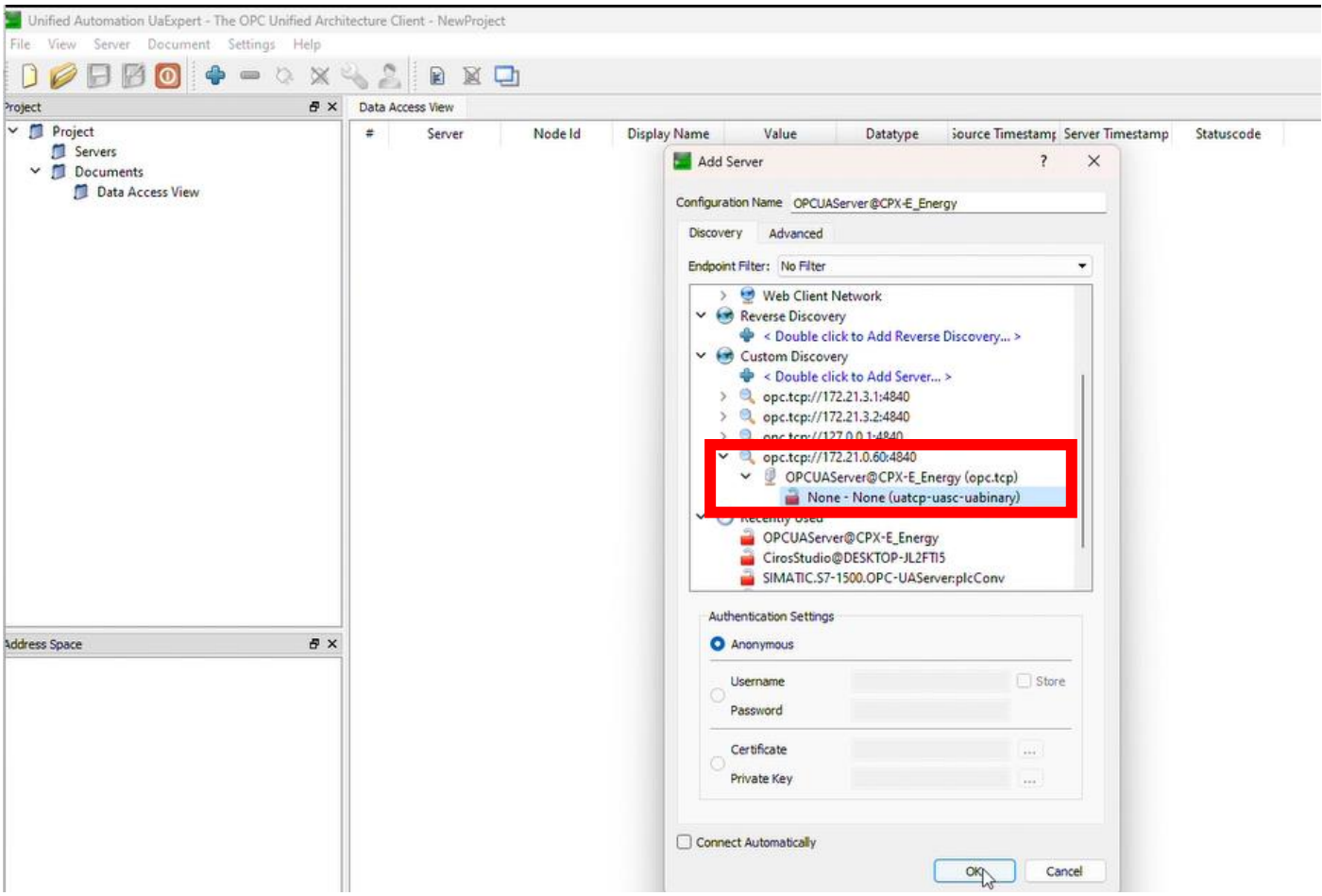


6. Navigate to the **Add Server** option to establish an OPC UA server connection.

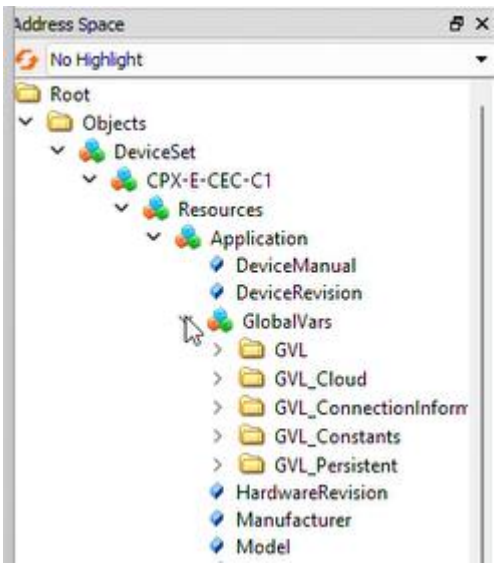


7. In the **Add Server** window, input the required server address and credentials for the CP 404 system.

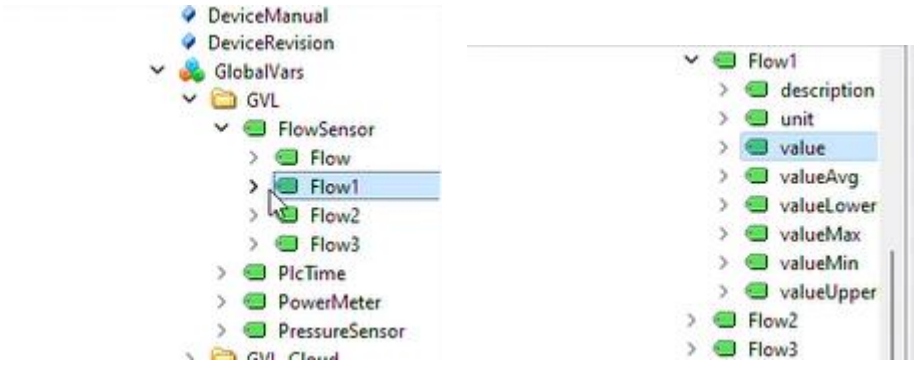
8. Confirm the server connection **172.21.0.60:4840** to enable data exchange between the MES and UA Expert Tool.



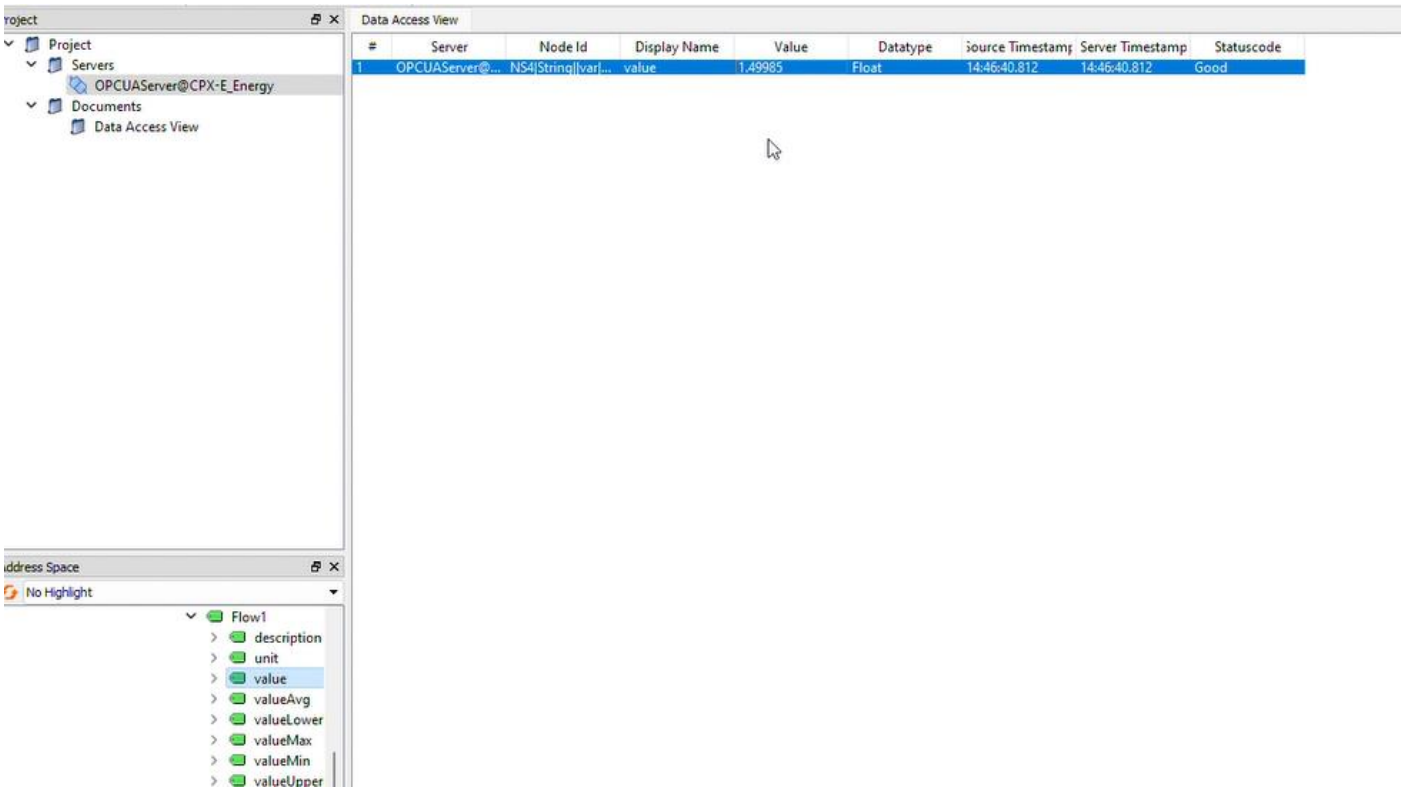
9. To **Access Resources and Variables,** Navigate to **Address space**



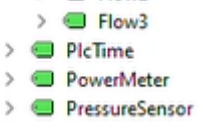
10. Go to the **Resources** section within the UA Automation Expert Tool.



11. Open the **Global Variables** panel to access live data streams from CP 404 by dragging the value variable.

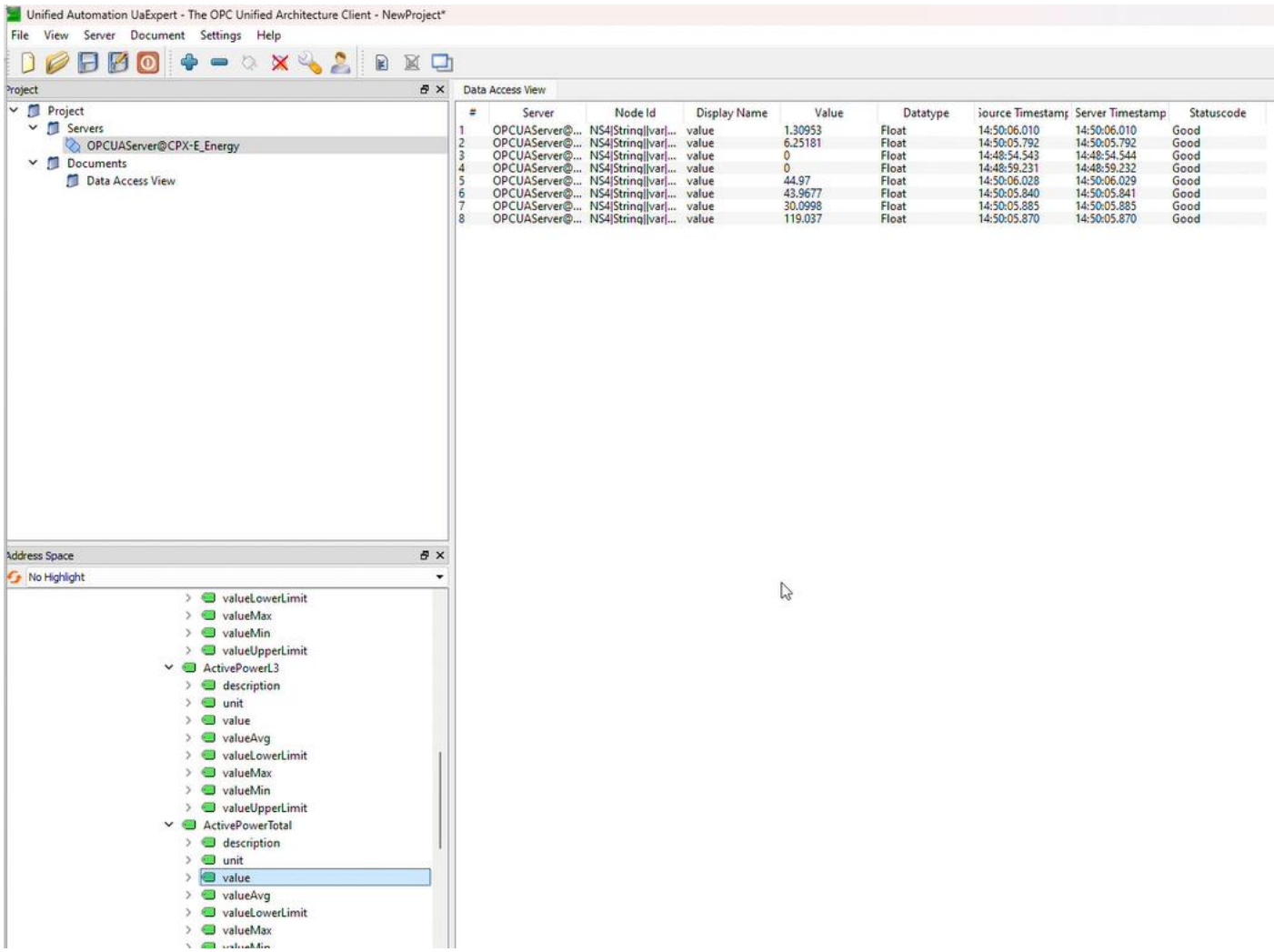


12. Identify variables corresponding to pressure, flow, and energy consumption.



13. Drag and drop the relevant variables into the active monitoring workspace.

14. View the data update frequency by the fetch interval **1 second**.



15. Ensure that the system is prepared to handle real-time data acquisition at the set interval.

16. Monitor the mapped variables to observe real-time changes in pressure, flow, and energy usage.

Result: