Engineering Institute of Technology.

Codesys - SCADA, OPC and Factory IO

Software Instructions

Software used	Codesys (v3.5 SP16 with security agent addon) UaExpert KEPserver EX6 Factory IO (Ultimate Edition)		
Version #	1		
Created by	Pavel G	**Date**	28.02.2021
Edited by	James T	**Date**	23.09.21

Software Instructions: SCADA, OPC and Factory IO Using Codesys v3.5 SP16

Acknowledgments
We would like to acknowledge the following references used to compile these instructions for students:

- Codesys – Getting started.
- Factory IO – Getting started.
- Factory IO – Codesys. Setting up OPC UA.
- OPC Technologies – United Architecture.
- Kepware OPC UA
- UaExpert

See the following video for a quick summary: Codesys Project - quickstart.mp4

See the following videos to explain the steps in each section:

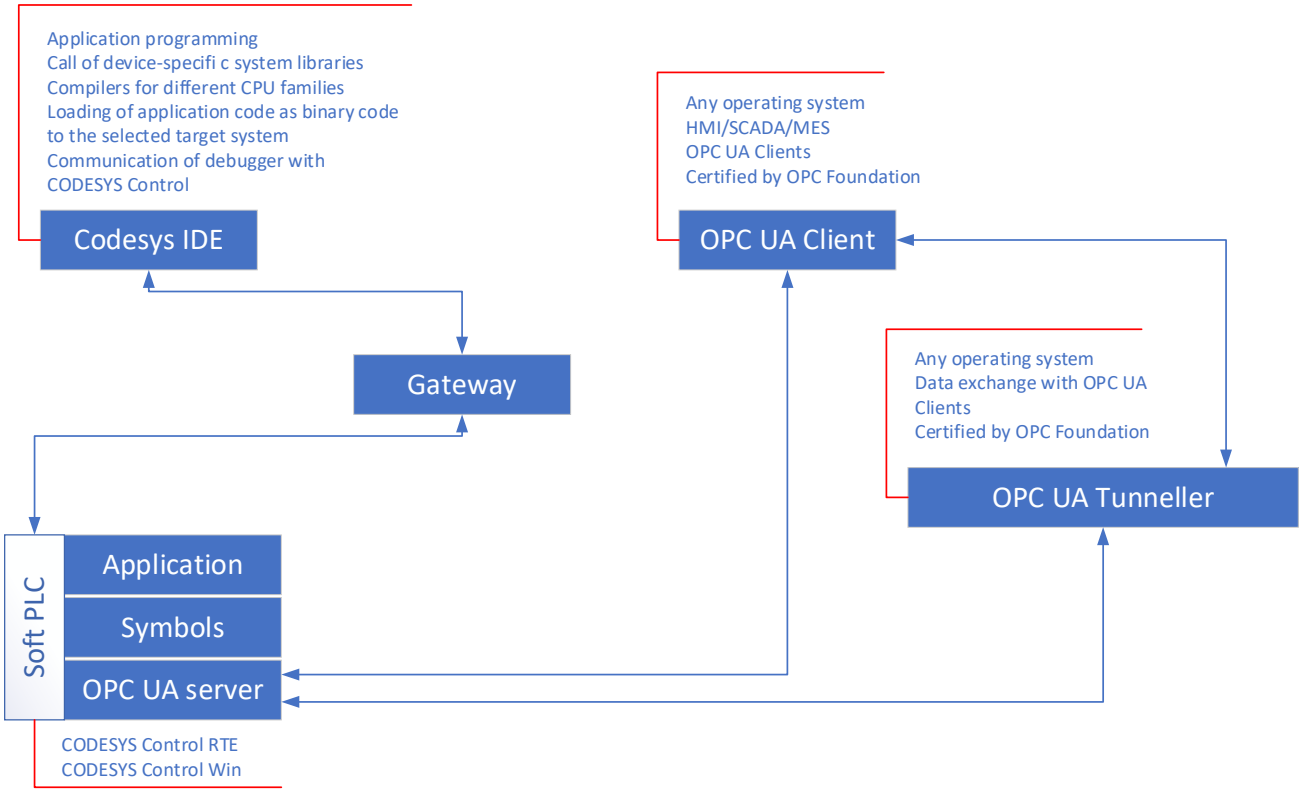
- **Codesys 1. Base Project.m4v**
- **Codesys 2. Alarm Configuration.m4v**
- **Codesys 3.1 OPC UA Settings.m4v**
- **Codesys 3.2 OPC UA Settings (Kepware).m4v**
- **Codesys 4. Factory IO.m4v**

The following software files are required to complete the assessment:

- **EIT_Tank_Level Base project**

Software Instructions: SCADA, OPC and Factory IO Using Codesys v3.5 SP16

OPC UA Architecture:



The standard installation of CODESYS includes an OPC UA server.

You can use it to access the variable interface of the controller via a client.

The OPC UA server communicates with connected OPC UA clients over a separate TCP connection, therefore, these connections have to be examined again separately with regard to security.

The OPC UA server can now be safeguarded by using encrypted communication to the client and OPC UA user management.

See the following sections for these settings.

The CODESYS OPC UA server supports the following features:

- Browsing of data types and variables
- Standard read/write services
- Notification for value changes: subscription and monitored item services
- Encrypted communication according to “OPC UA standard (profile: Basic256SHA256)”
- Imaging of the IEC application according to “OPC UA Information Model for IEC 61131-3”
- Supported profile: Micro Embedded Device Server Profile
- By default, there is not restriction in the number of sessions, monitored items, and subscriptions. The number depends on the performance of the respective platform.
- Sending of Events according to the OPC UA standard.

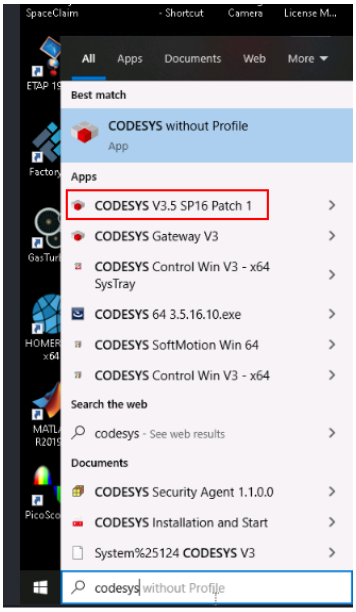
Instructions:

The following four parts walk you through a project involving a using a virtal PLC and corresponding HMI to control a simulated flow tank process, adding alarms to the HMI, and sending variables through an OPC UA server to be monitored from an OPC UA client.

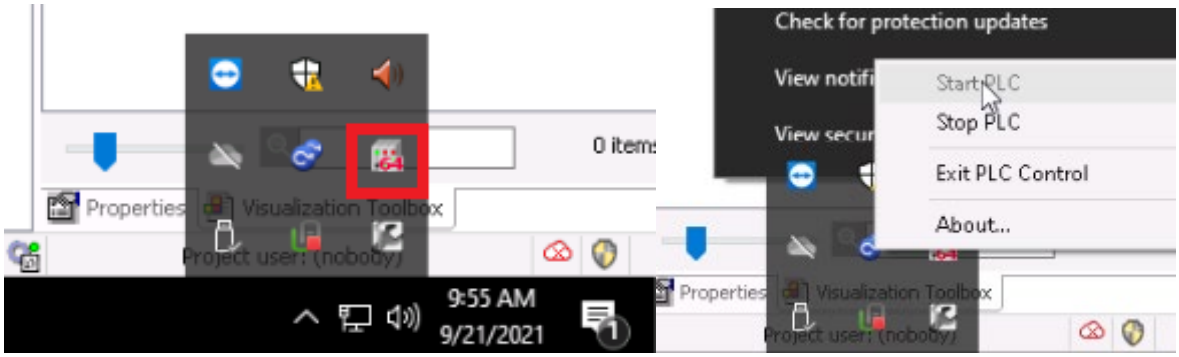
When prompted to write [Your Initials and Date] you must replace this with, in the case of John Smith completing these steps on the 01/02/21: “JS010221”.

1. Base Project

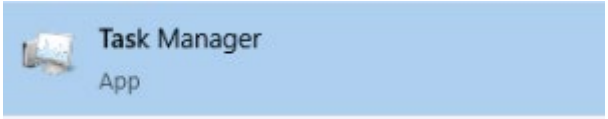
Step 1: Launch the Codesys software from the start menu or desktop.



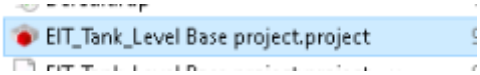
Step 2: Launch the Codesys PLC simulator by clicking “Codesys Control Win V3 – x64 SysTray” in the programs menu. Locate the icon in the start menu by expanding the icons on the right, right-click it, and select “Start PLC”.

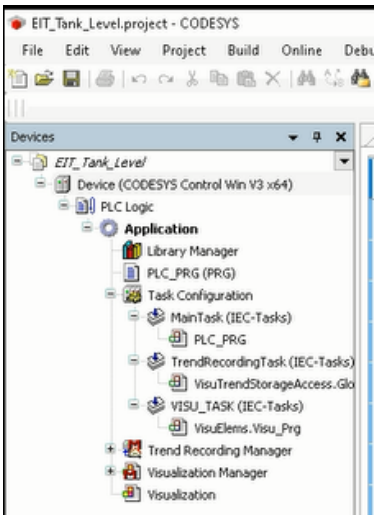


If you encounter the message “another instance … is already running” then check the start bar hidden icons and ensure that you see the PLC Control icon as shown below. If you do not see the icon, launch task manager from the start menu, locate the Codesys Control task and right-click, then select End task, and repeat step 2.

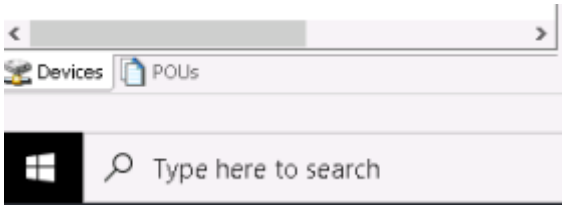


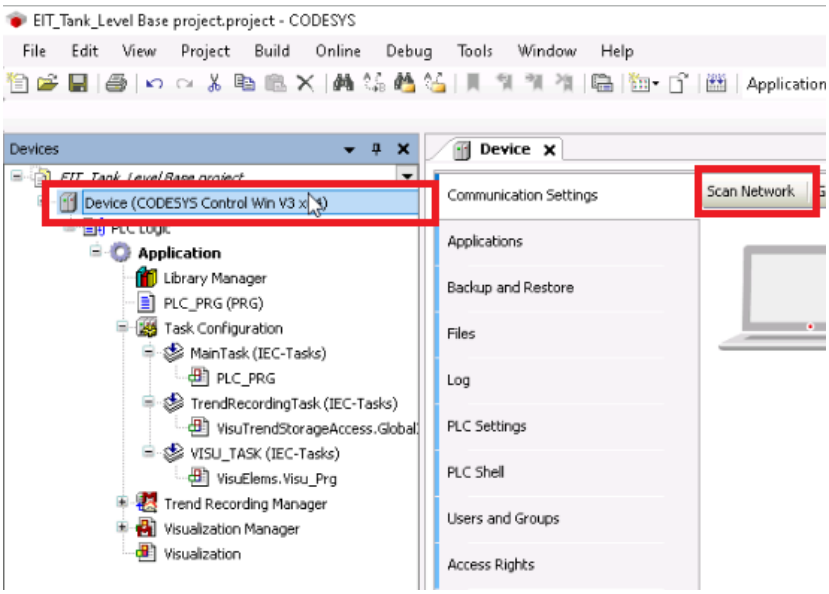
Step 3: Locate on the lab computer, or download from the CodeSys Folder in "Software and hardware documentation" on Electromeet, the file "EIT_Tank_Level Base project". This base project has essential settings and variables for further modules. In CodeSys select, "File", "Open Project", then navigate to this project and open it.

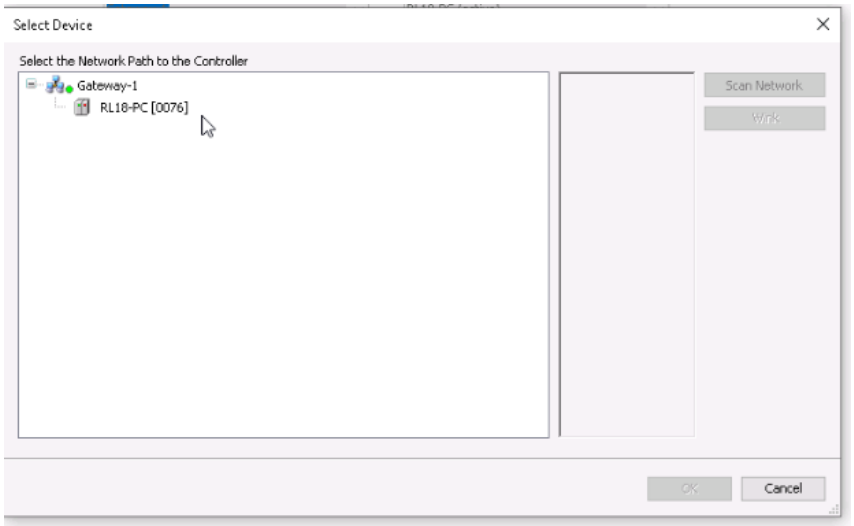




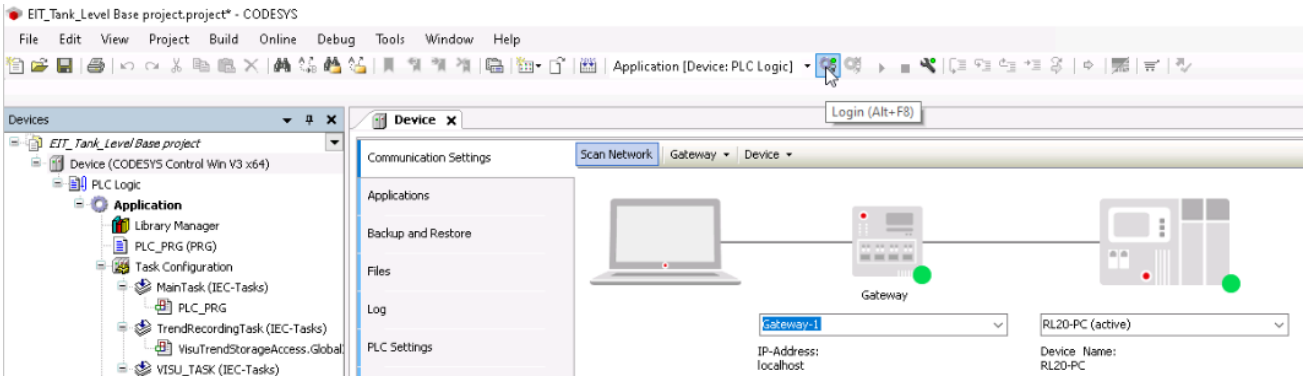
Step 4: To connect to the virtual PLC: Double-click "Device" under the "Devices" window/tab and select "Scan network". The first time scan network to find either plc or simulator devices. Select the device name corresponding with the lab computer that you are using (i.e. RL20-PC for Lab 20) and press OK.

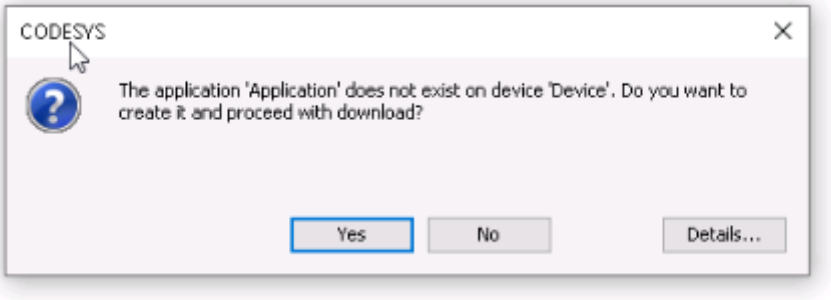




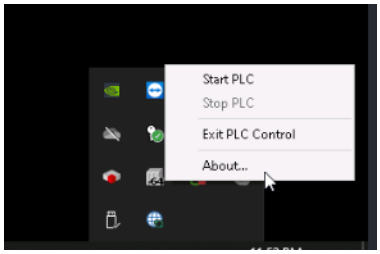


Step 5: To download the open base project to the PLC simulator, select the “Online” menu and click “Login”, or simply click the “Login” button on the menu. When prompted, click “Yes” to create the application and proceed with the download.

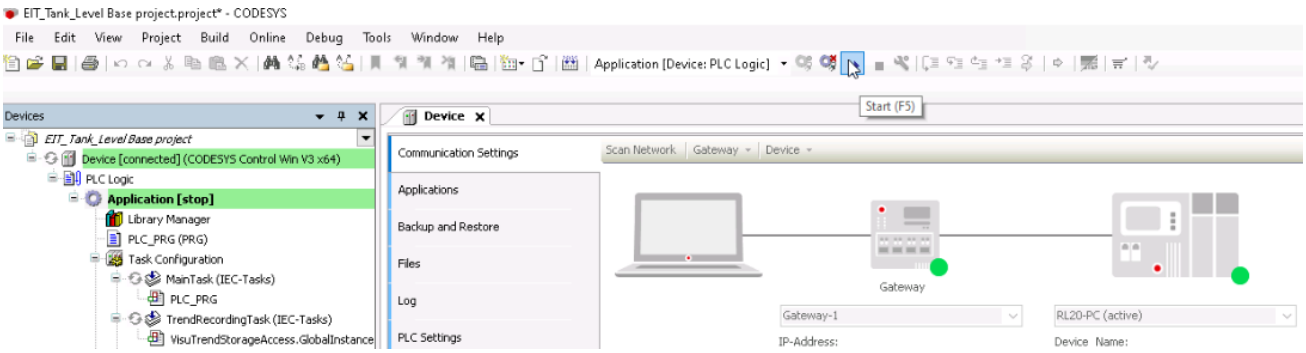


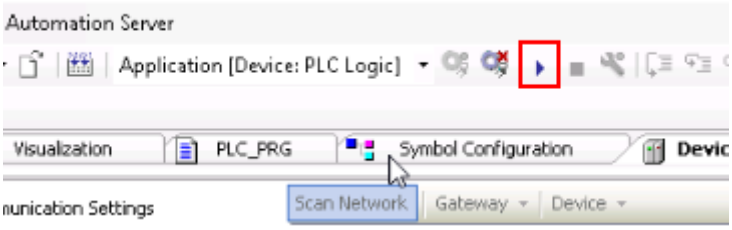


Step 6: Ensure that the PLC simulation module for Codesys (CODESYS Control Win V3 - x64) is set to “Start PLC” from Step 2.

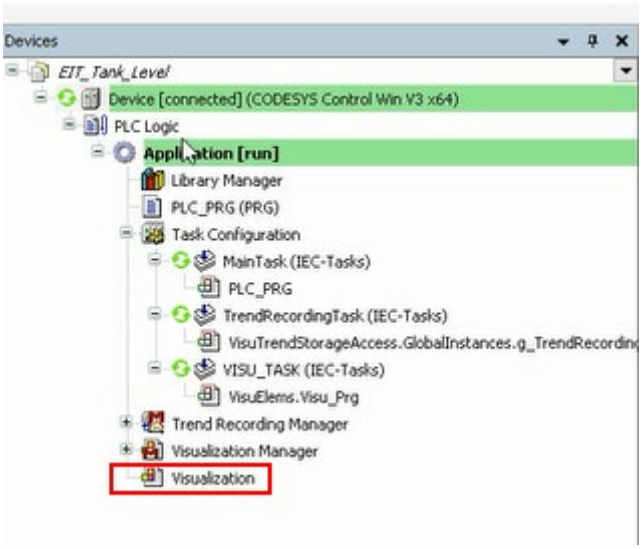


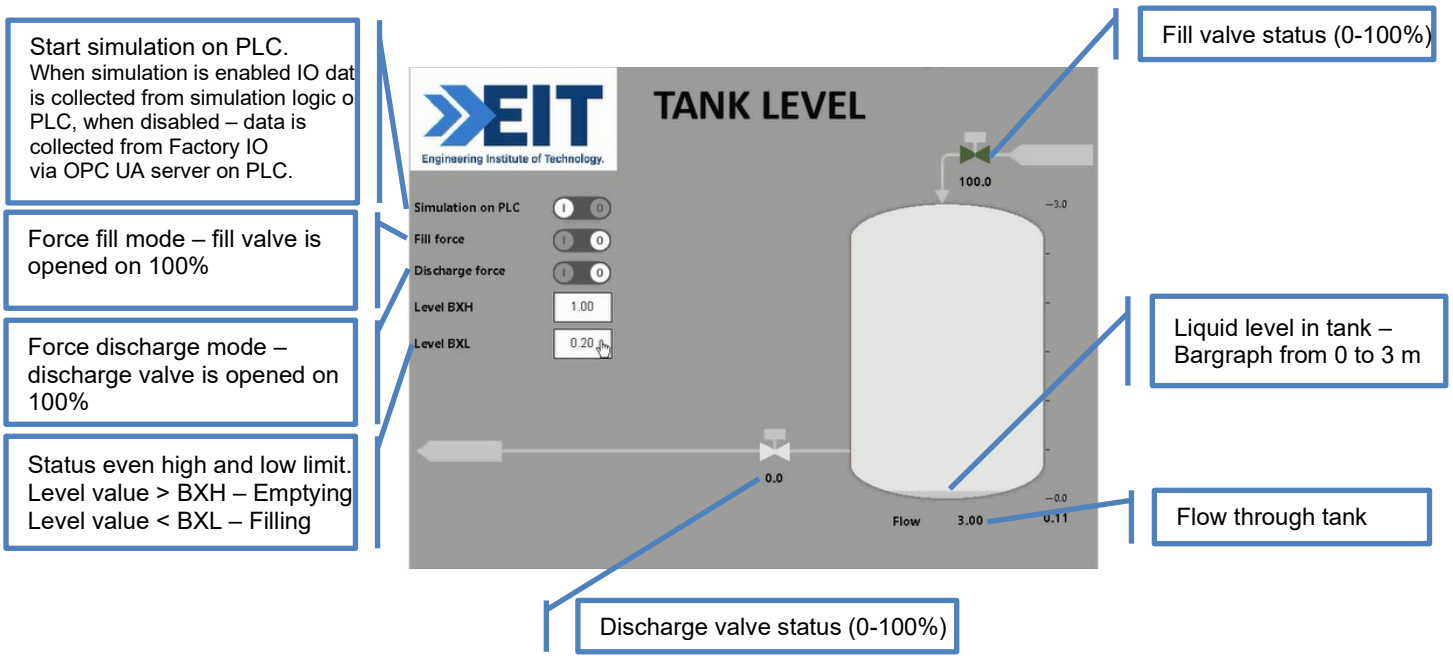
After the project has been downloaded PLC, the application is in “Stop” mode. Switch it to “Run” mode by using the button on the menu or by right-clicking Application and selecting “Start”.





Step 7: Check that the project is working by double-clicking “Visualisation”.



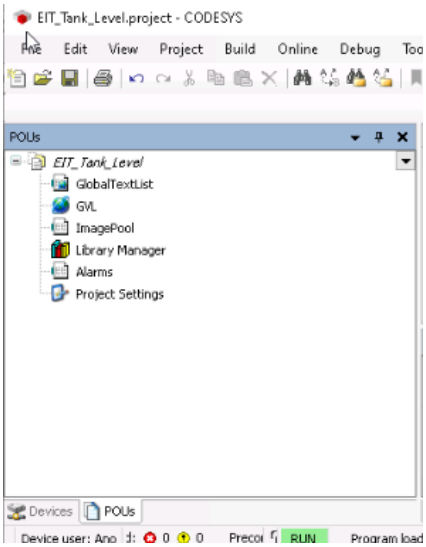


The simulation model shows the logic of filling and discharging the tank.

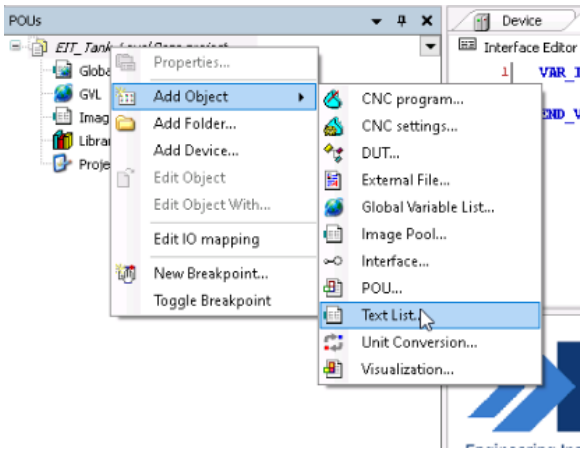
Switch on simulation on PLC (I) and observe the the process control before proceeding to Part 2 Alarm Configuration.

2. Alarm Configuration

Step 1: With the “EIT_Tank_Level Base project” open in CodeSys, click the POUs tab. Logout of the PLC simulator by , select the “Online” menu and click “Logout”, or simply click the “Logout” button on the menu (next to where Login was).

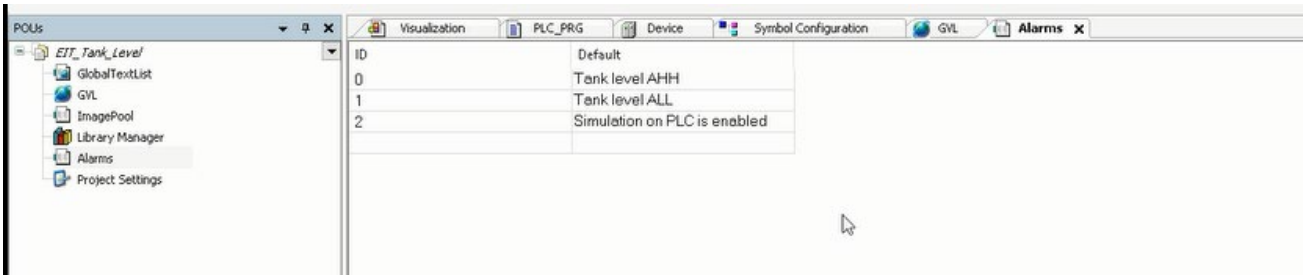


Step 2: Add a new textlist in “POUs” window by right-clicking the project, selecting “Add Object” and then “Text List”. When prompted, under name, type “Alarms” and click “Add”.



Step 3: Open new textlist and add the required numbers of alarms:

- ID: 0, Default: “Tank level AHH”
- ID: 1, Default: “Tank level ALL”
- ID: 2, Default: “Simulation on PLC is enabled”



Step 4: Add “Alarm configuration” in project tree by right-clicking on Application in the Devices tab, selecting “Add Object” and then “Alarm Configuration”. When prompted, under name, type “Alarm Configuration” and click “Add”.

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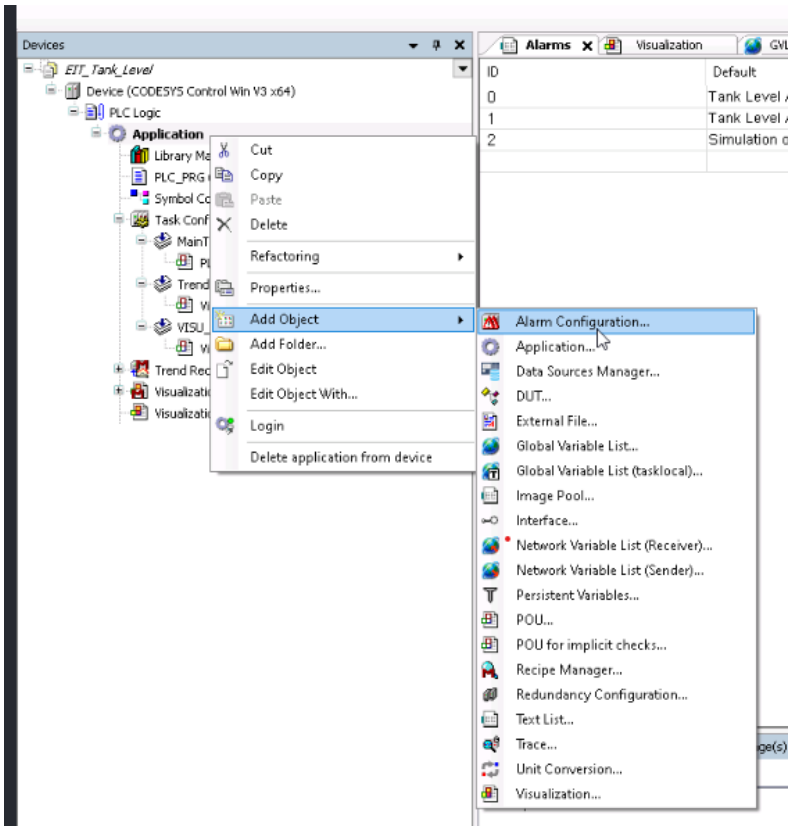
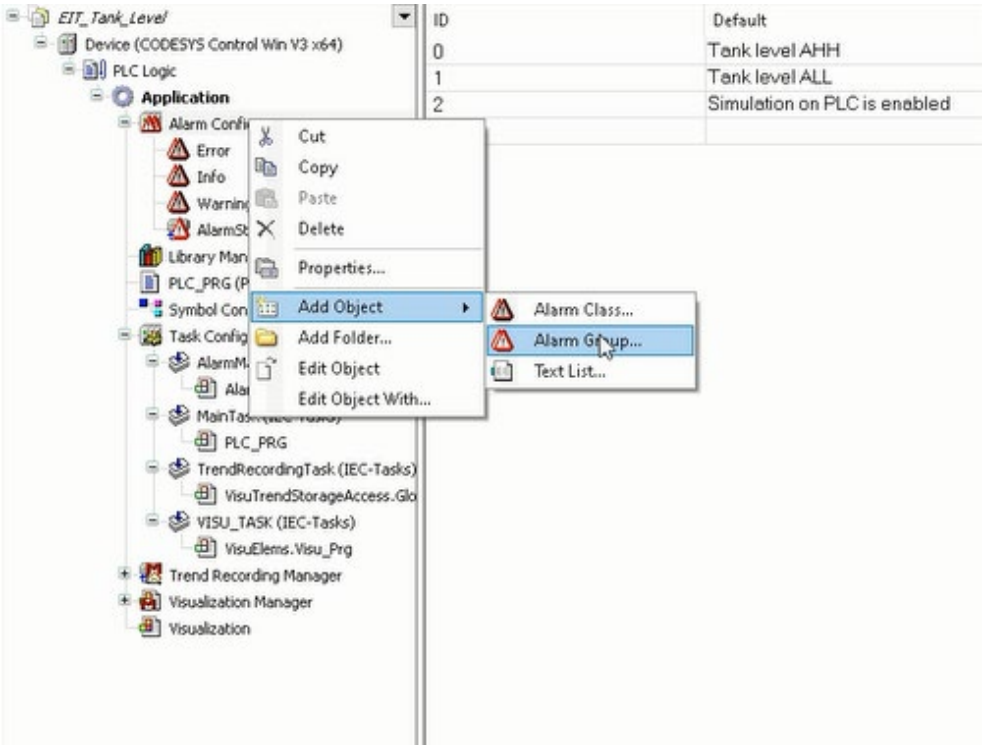
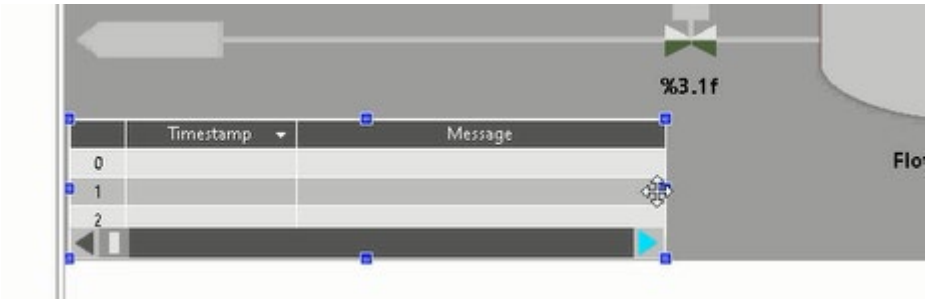


Right-click “Alarm configuration” and click “Add Object”, then “Alarm group”. When prompted, under name call it “Alarms” and click “Add”.

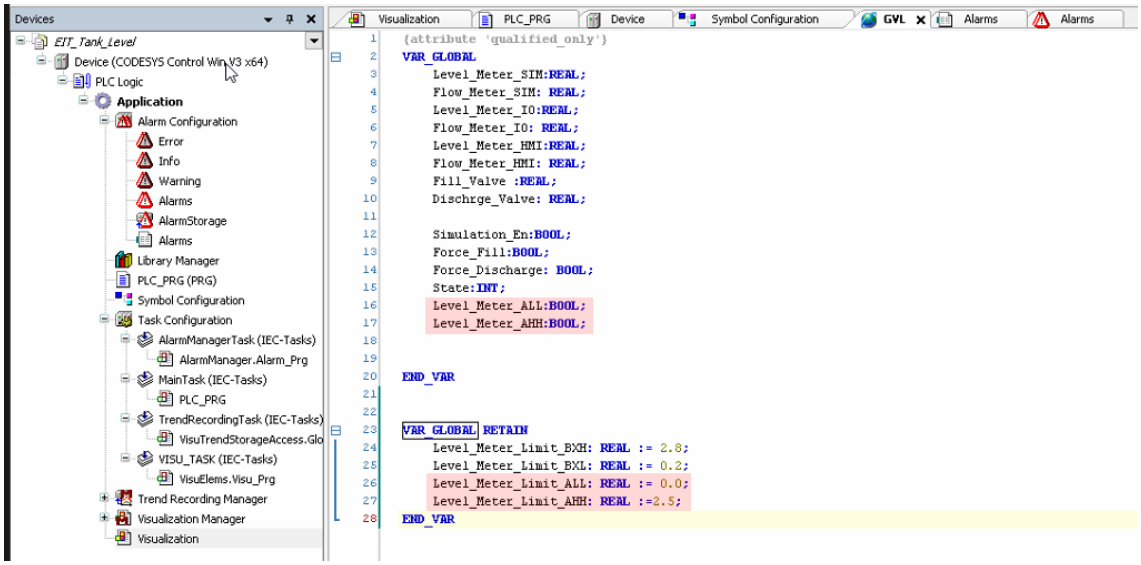


Step 5: Open the “Visualisation”. Add the widget “Alarm table” on HMI Tank Level display by opening the “Alarm Manager” in the “Visualisation Toolbox” tab shown below in green, then clicking and dragging the “Alarm Table” icon shown below, selected, onto the Tank Level HMI screen to add the widget to the simulation display.

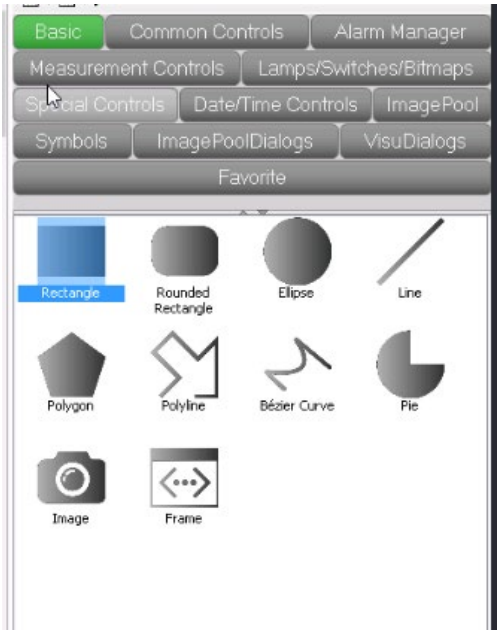


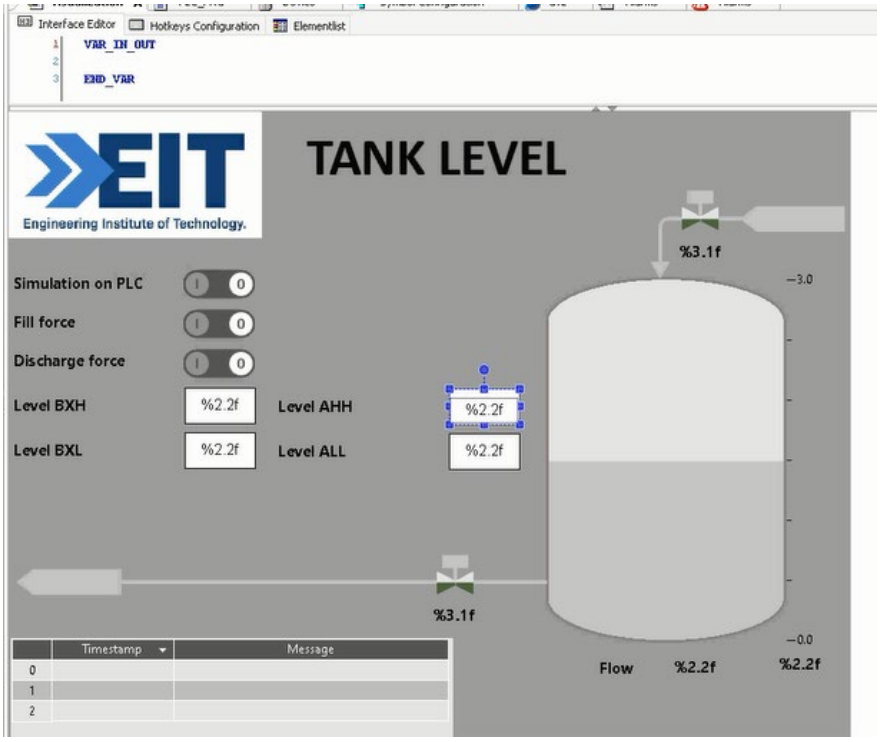
Step 6: Click on the “POUs” tab and then open the global variable list by double-clicking “GVL”. Add the following two alarms and two limits:

- “Level_Meter_ALL[Your Initials and Date]” – Low low level alarm
- “Level_Meter_HH[Your Initials and Date]” – High high level alarm
- “Level_Meter_Limit_ALL[Your Initials and Date]” – setpoint for ALL alarm
- “Level_Meter_Limit_AHH[Your Initials and Date]” – setpoint for AHH alarm



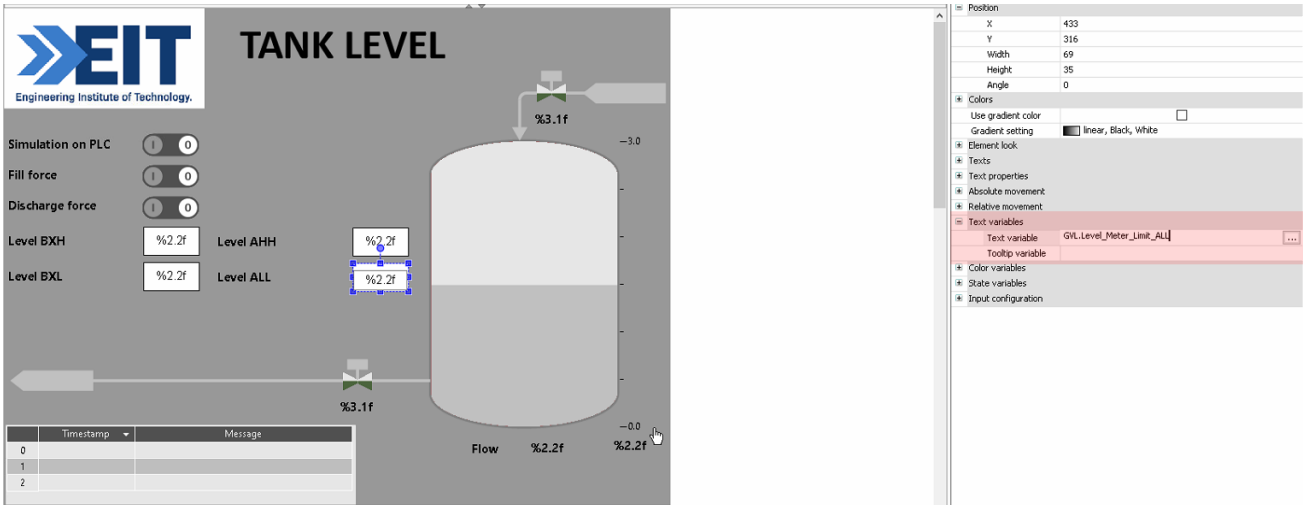
Step 7: To add the alarm setpoints on HMI, in the “Visualisation Toolbox” tab, with Visualisation open, click “Basic” then select the rectangle tool and drag it into the HMI Tank Level space, adding the field. Shape and align them with the other setpoints already there. Type “2.2f” in the text field of each rectangle. Add the label Text Fields by clicking next to the rectangles, naming them “Level AHH [Your Initials and Date]” and “Level ALL [Your Initials and Date]”.

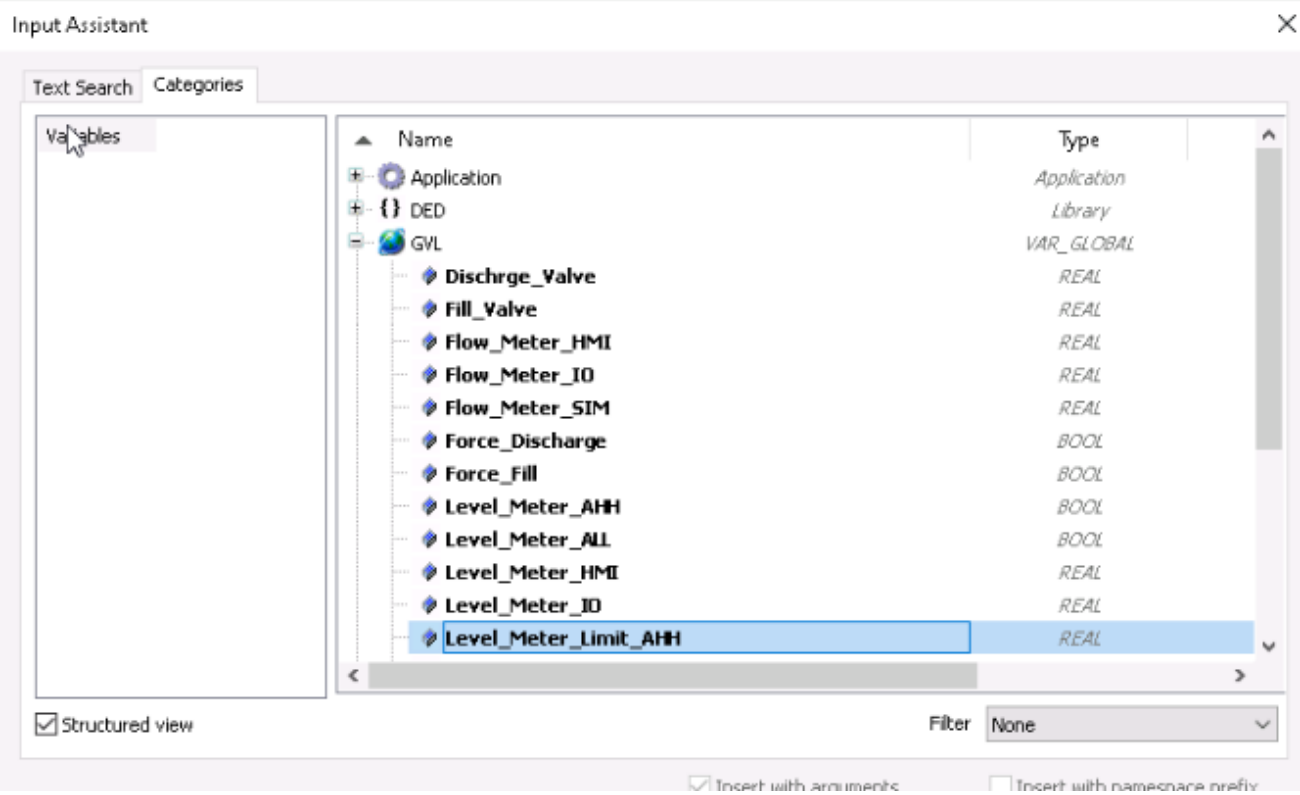




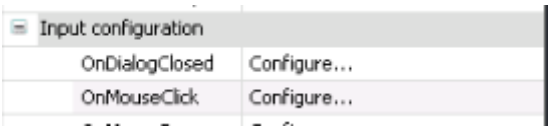
Select the rectangle, then in the “Properties” tab, next to the “Visualisation Toolbox” tab, under “Text variables”, select the text variable field to link the set points for each of the added rectangle text fields. Be sure to add ‘GVL.’ before the variable name. Note the element name at the top of the Properties for each:

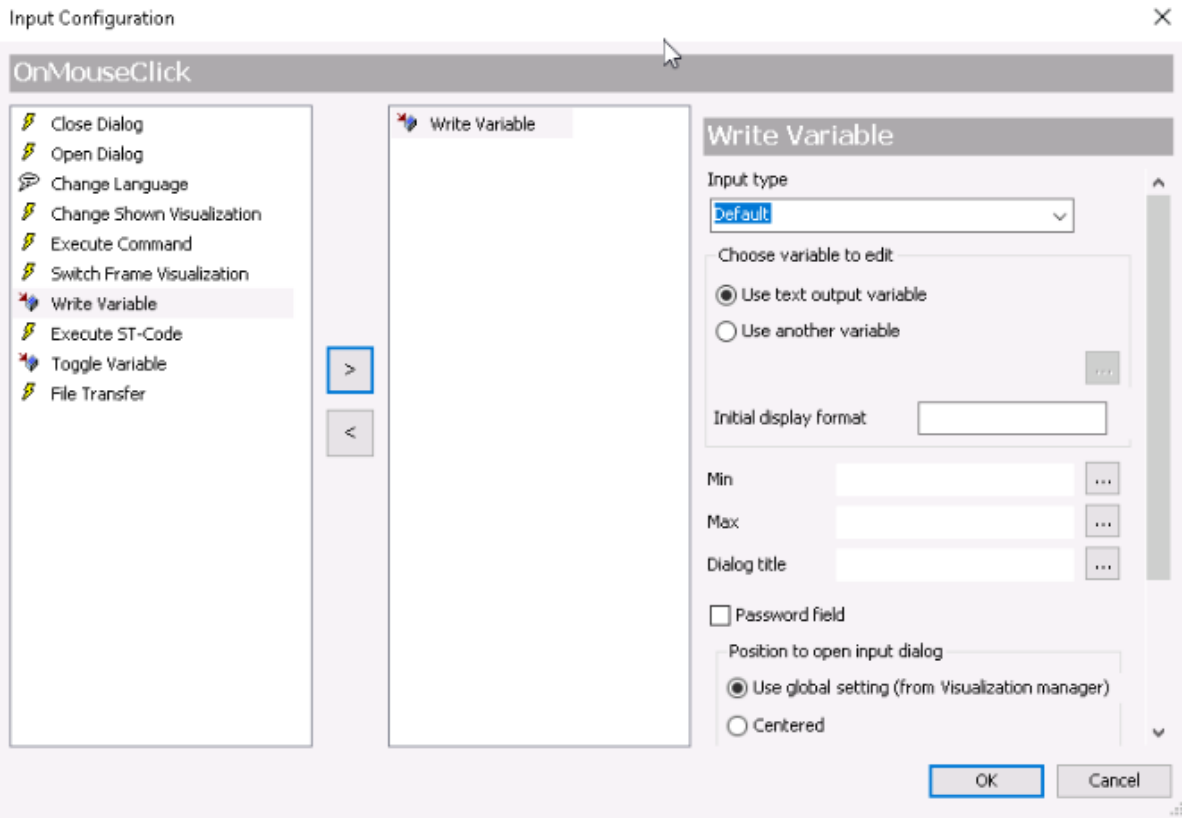
- “GVL.Level_Meter_Limit_ALL[Your Initials and Date]”
- “GVL.Level_Meter_Limit_AHH[Your Initials and Date]”





You will also need to enable the mouse to change the fields on the HMI. With a rectangle selected, in the “Properties” tab, expand “Input configuration” and click on “Configure”. Select “Write Variable” and the right arrow to move it across, and then click OK. Do this for each added rectangle text.

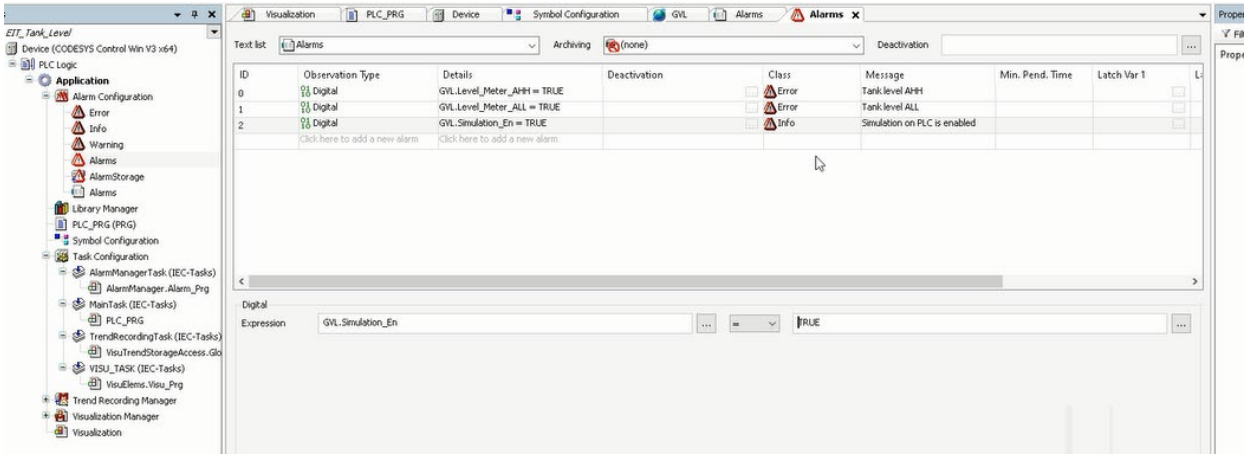




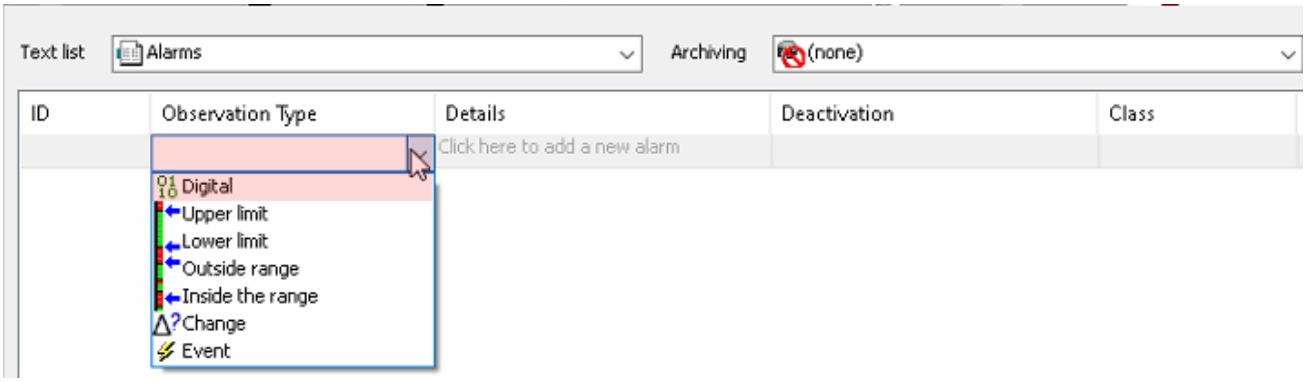
Step 7: In the Devices tab, open the previously created Alarms, under Alarm Configuration, by double-clicking it.

Step 8: Add the following alarms, populating “Observation Type” with Digial, Details with the respective variable condition where the boolean = TRUE, class with the type, and the message to display, as below in steps 7.1-7.3:

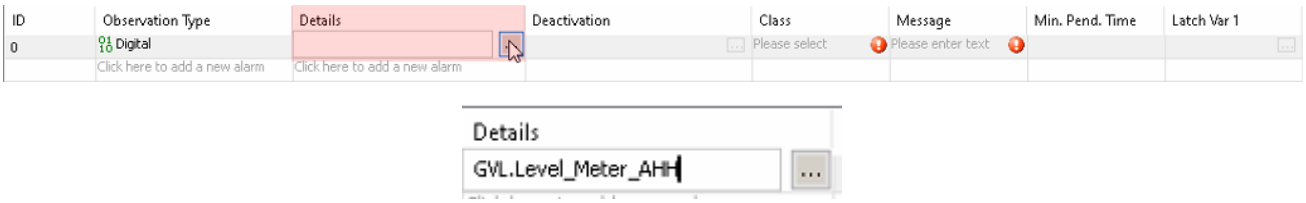
- Observation Type: Digital, “GVL.Level_Meter_AHH[Your Initials and Date] = TRUE”, Class = “Error”, Message = “Tank level AHH”
- Observation Type: Digital, “GVL.Level_Meter_ALL[Your Initials and Date] = TRUE”, Class = “Error”, Message = “Tank level ALL”
- Observation Type: Digital, “GVL.Simulation_En = TRUE”, Class = “Info”, Message = “Simulation on PLC is enabled”



Step 7.1 Add alarm and select required alarm type in field “Observation Type” as Digital.

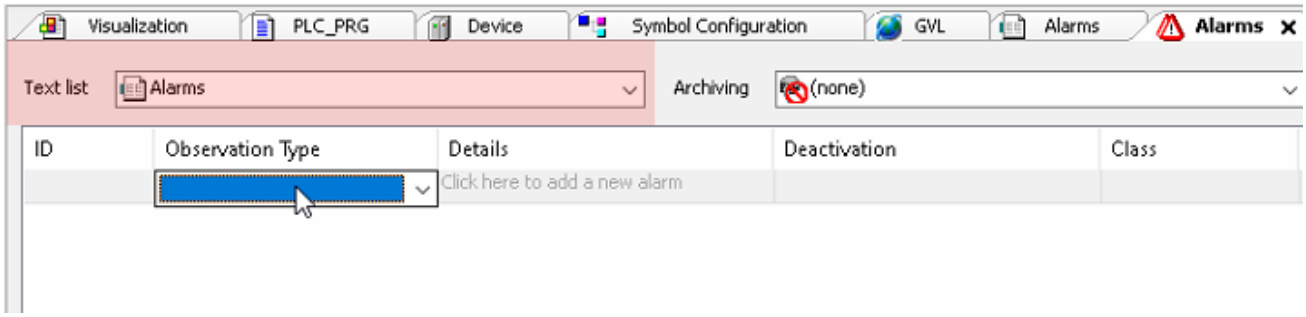


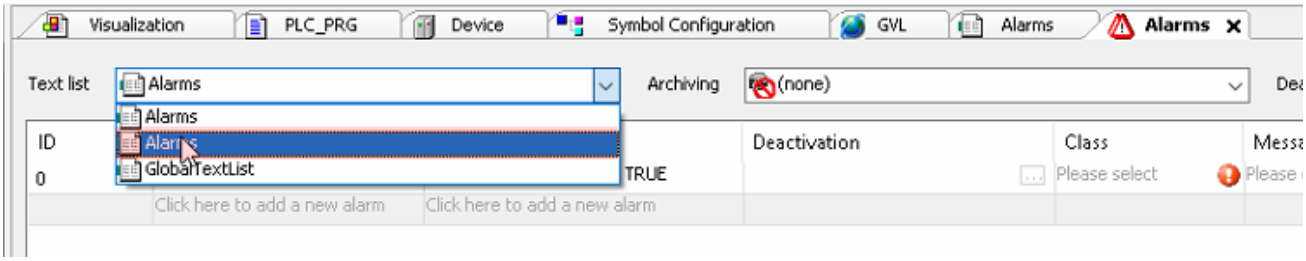
Step 7.2 Select the alarm variable in the “Details” field and add the required condition to activate the alarm.

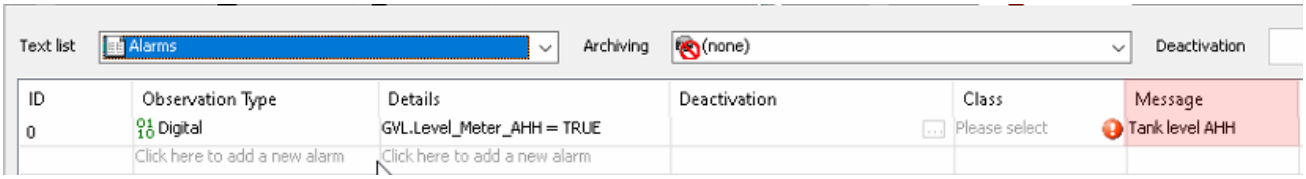


Note: In this project, alarms are activated by a positive front of chosen variables.

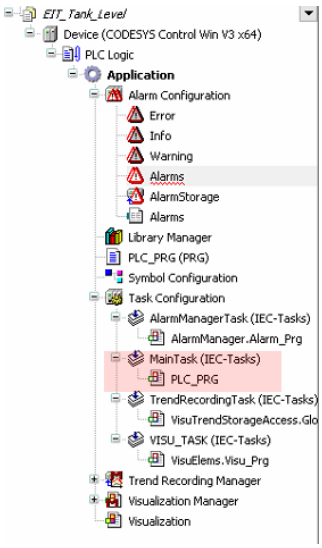
Step 7.3 Select the “Alarms” text list in the “Text list” field to fill the message with the text list created in Step 3, note that the ID of the alarm corresponds to the ID number in the text list “Alarms”:







Step 8: To add the alarm logic to the PLC program, under the Device tab, under Application, double-click “PLC_PRG” to open the code.



At the end of the code, add the following to enable the alarms:

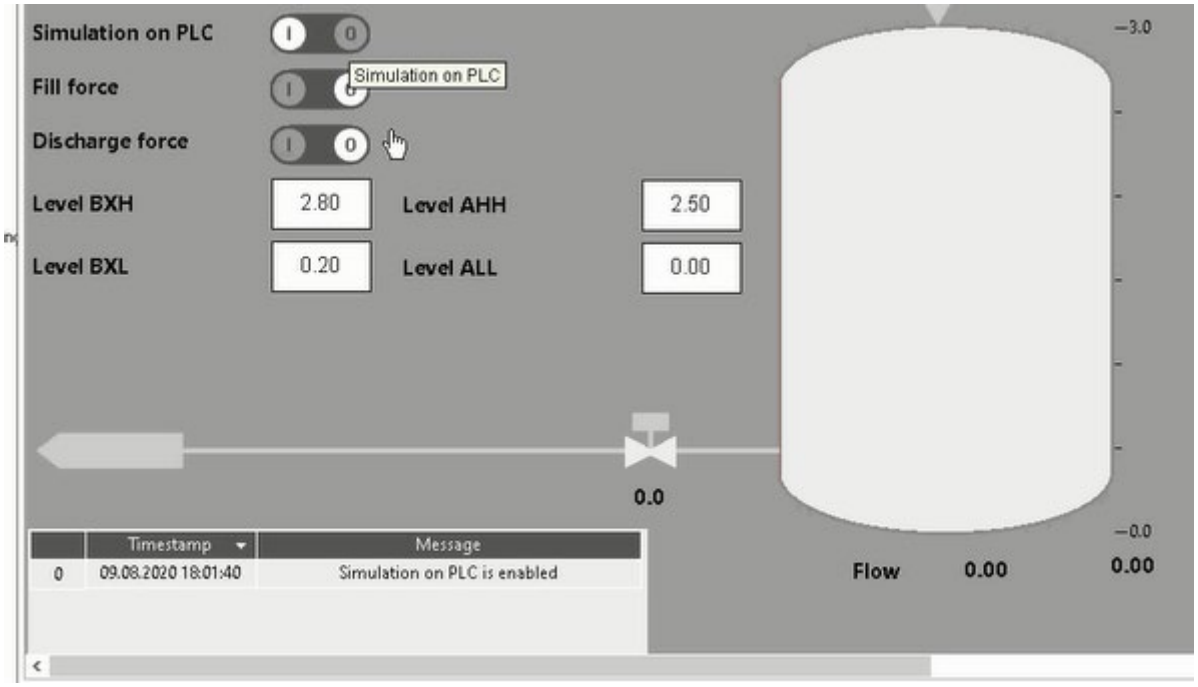
```
IF GVL.Level_Meter_HMI  > GVL.Level_Meter_Limit_AHH THEN
    GVL.Level_Meter_AHH := 1;
ELSE
    GVL.Level_Meter_AHH := 0;
END_IF

IF GVL.Level_Meter_HMI  < GVL.Level_Meter_Limit_ALL THEN
    GVL.Level_Meter_ALL := 1;
ELSE
    GVL.Level_Meter_ALL := 0;
END_IF
```

Step 9: Download program to the PLC by selecting the “Online” menu and click “Login”, or simply click the “Login” button on the menu. When prompted, click “Yes” to create the application and proceed with the download.

Switch it to “Run” mode by using the button on the menu or by right-clicking Application and selecting “Start”.

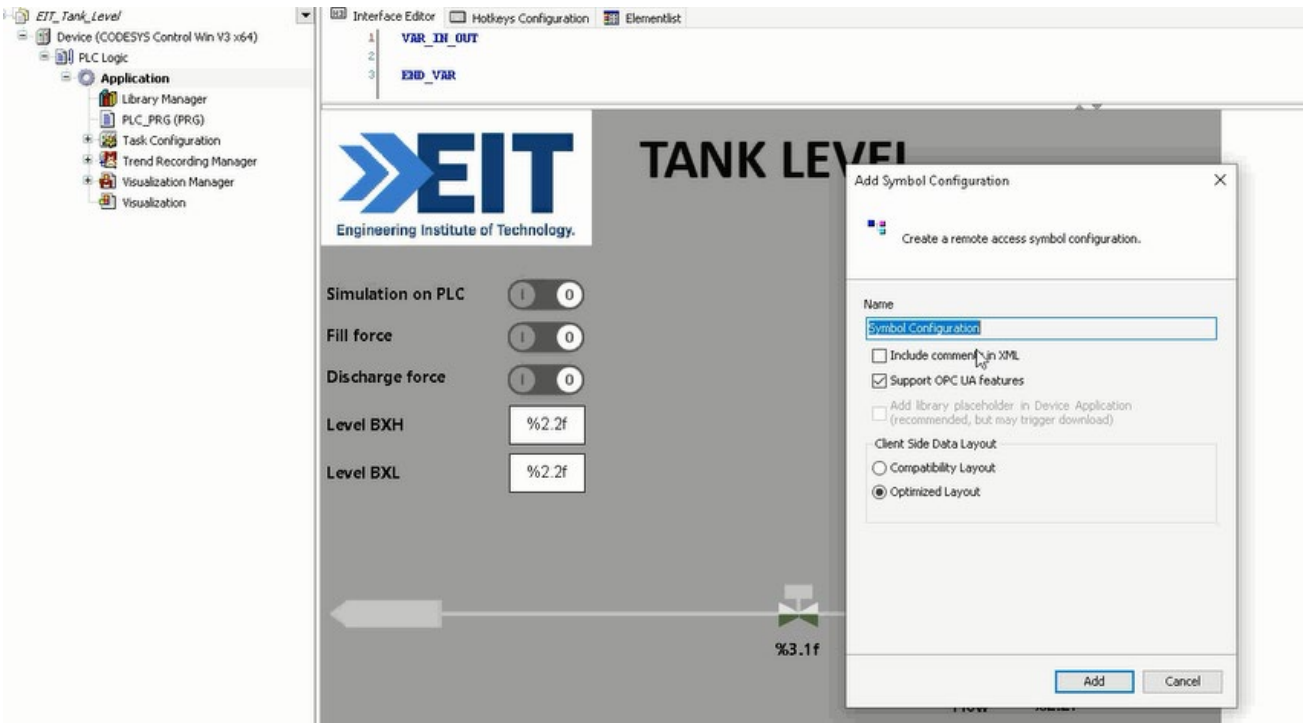
Check that the project is working by double-clicking “Visualisation”. Edit the text fields, by clicking in them and typing a new value, for Level AHH, Level ALL, and toggle the Simulation on PLC to verify that your alams are being triggered at the correct inputs/values in the alarm table.


Simulation on PLC
Fill force
Discharge force
Simulation on PLC
Level BXH
2.80
Level AHH
2.50
Level BXL
0.20
Level ALL
0.00
0.0
Timestamp
Message
0
09.08.2020 18:01:40
Simulation on PLC is enabled
Flow
0.00
3.0
0.0
0.00

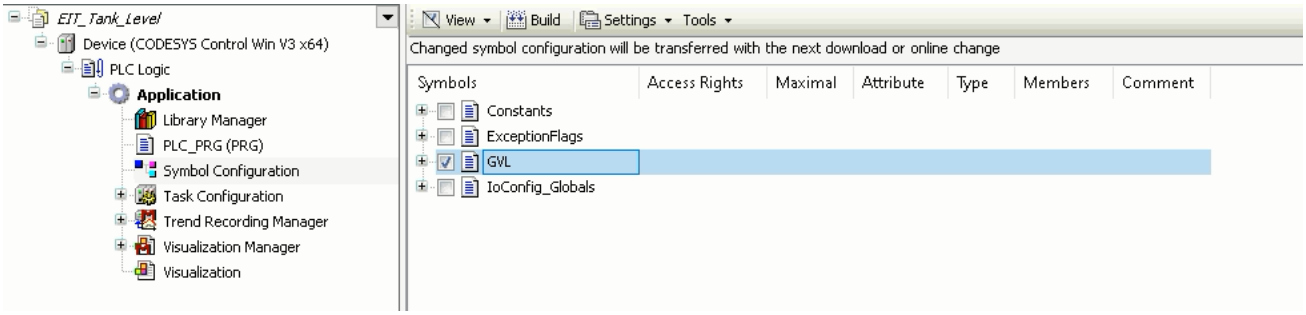
3. OPC UA Configuration

The Codesys OPC UA Server

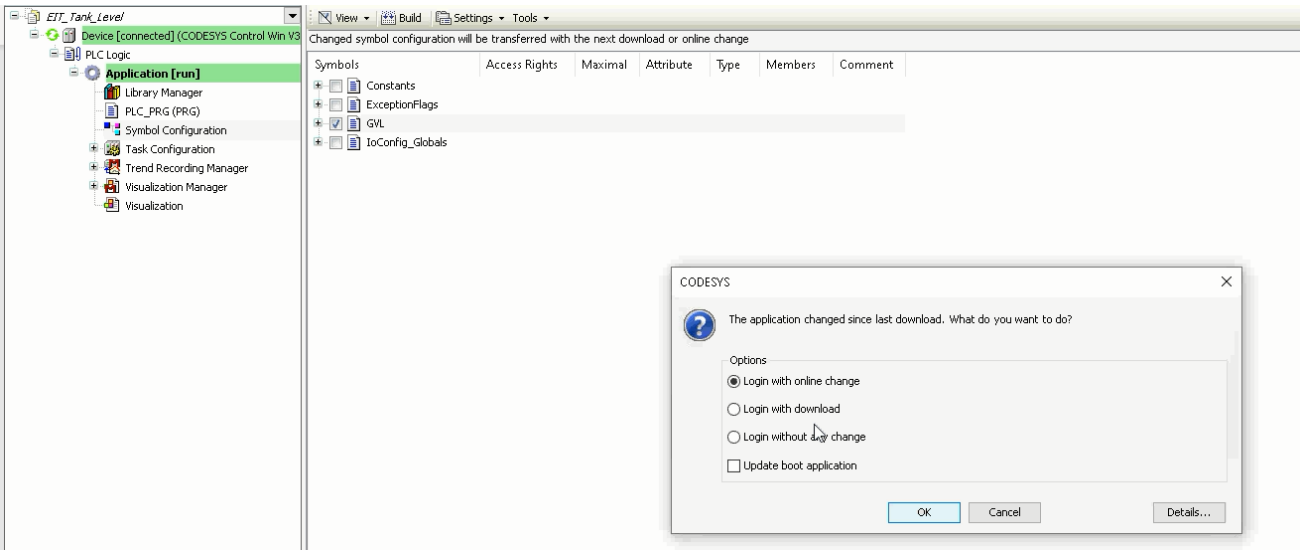
Step 1: With the “EIT_Tank_Level Base project” open in CodeSys, logout of the PLC simulation, then add a Symbol Configuration object below the application by right-clicking “Application”, then selection “Add Object” and then “Symbol Configuration”. When prompted, name it “Symbol Configuration” and ensure that the “Support OPC UA Features” option is selected:



Step 2: Double-click the newly created “Symbol Configuration” under “Application” to open the symbol configuration editor. Here is where we configure which variables we want to change using the OPC UA client and specify access rights. Click “Build” then once complete, check the box next to “GVL” to add them to the configuration.



Step 3: Click Login and then Login with download to download the updated project.



Step 4: In order to encrypt data and exchange it with the client safely, the server needs a certificate that the client must classify as trusted when a connection is established for the first time. To create a certificate for the CODESYS OPC UA server:

Requirement: The active path to the controller must be set, done by scanning and selecting the PLC, and the the Codesys Security agent add-on must be installed.

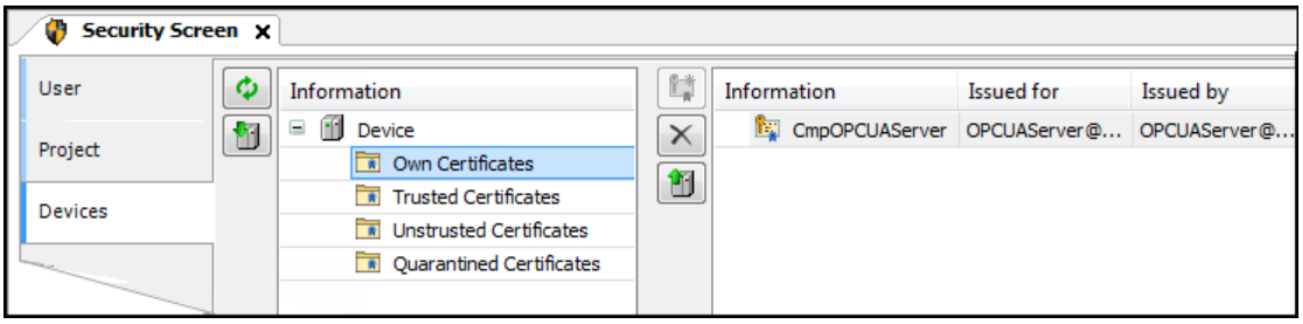
Step 4.1 Click “View” then “Security Screen”.

Step 4.2 Select the “Devices” tab Under the “Security Screen” tab.

Step 4.4 Select “Device” (the controller) under “Information”; then all services of the controller that require a certificate are displayed next to it.

Step 4.5 Select the service “OPC UA Server”.

Step 4.7 Define the certificate parameters (default will be fine) and click OK to close the dialog; the certificate is created on the controller and can be seen under “Device” in the “Own Certificates” group. If there are any visible in red, select them then click the X to remove them.



Step 4.8 Click refresh next to Information to restart the runtime system.

Note: A non-encrypted connection has been used here and works properly without any certificates; if you are trying to establish an encrypted connection the certificate appears in the "untrusted" folder in Codesys and should be moved to “trusted” folder.

Note: only either 5.1-5.12 or 6.1-6.6 is necessary to complete the rest of section 3.

Using UaExpert as the OPC UA Client

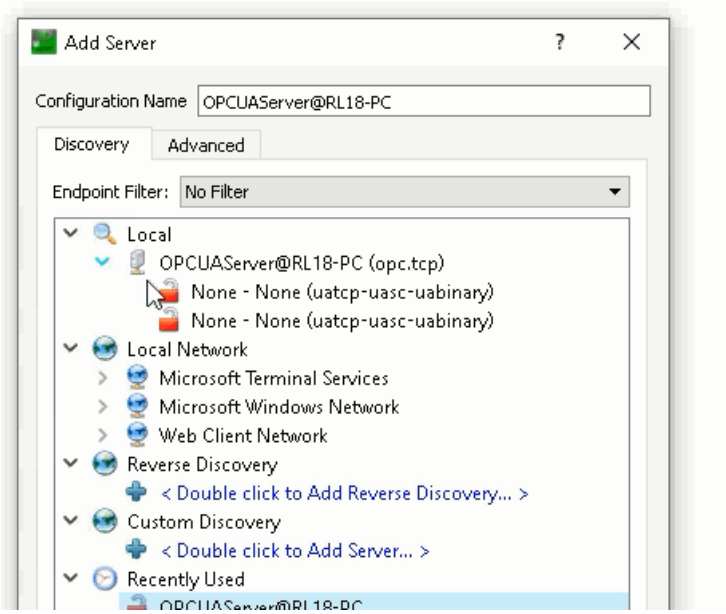
Setting up an encrypted connection with the “UaExpert” client.

Note: The OPC UA client “UaExpert” is freely accessible software that you can download from the Internet. Using this client, you can connect to the Codesys OPC UA server. The following description refers to this program. Other OPC UA clients work in a similar way.

Step 5.1 Start the “UaExpert” program.

Step 5.2 Click “Server”, then “Add” and the “Add Server” dialog will open:

Step 5.3 Expand the “Local” drop-down, then expand the “OPCUAServer@...” dropdown under “Discovery” in the tree view:

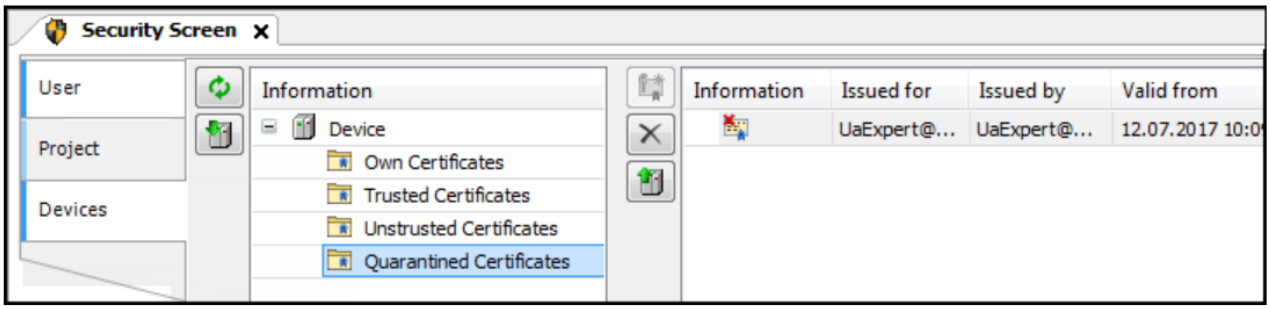


Step 5.4 Select the connection type "None-None (uatcp-uasc-uabinary)" and click OK to close the dialog. You will see it added under "Project" "Servers".

Step 5.5 Click "Server", then "Connect" and the Certificate Validation dialog opens with an error message.

Step 5.6 Click the check box down the bottom called "Accept the server crtificate temporarily for this session" and click "Continue".

Step 5.8 Check the certificate folder "Quarantined Certificates" to see if the client certificate "UaExpert@..." is displayed.

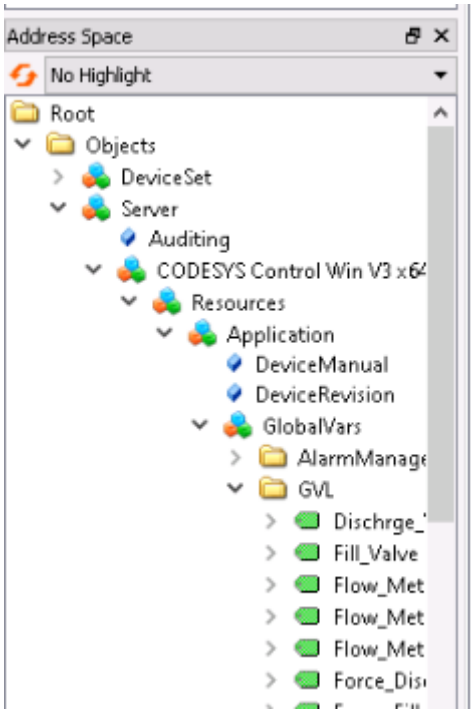


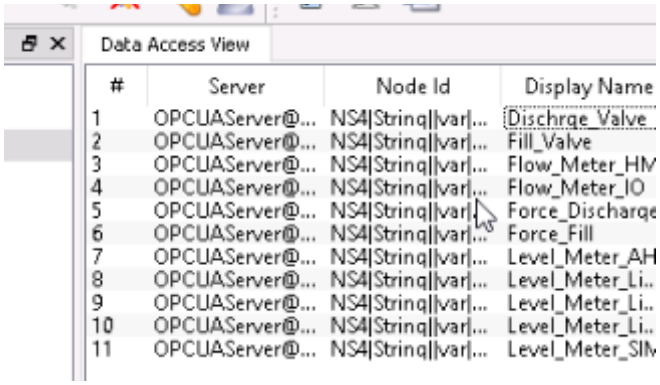
Step 5.9 If it is present, drag the certificate to the certificate folder "Trusted Certificates" to classify the client certificate as trusted by the server.

Step 5.10 Click "Server", then "Connect" in the UaExpert client. The Certificate Validation dialog opens with an error message.

Step 5.11 Activate the option "Accept the server certificate temporarily" for this session and click "Continue" to establish the connection. Objects are displayed in the Address Space view.

Step 5.12 To read the tags from the Codesys OPC Server, in the UaExpert, under "Address Space, expand "Root" "Objects", then "Server", " CODESYS Control Win V3 x64", "Resources", "Application", "GlobalVars", then "GVL". You can then drag the variables you wish to monitor over OPC UA with the client, from the server, into the "Data Access View" section and the values will be displayed (in CodeSys the Visualization must be running and "Simulation on PLC" set to on).



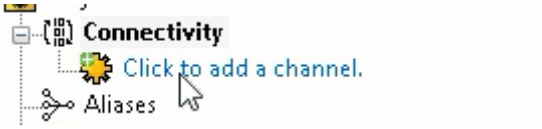


Using Kepware KEPServerEX6 as the OPC UA Server and Client

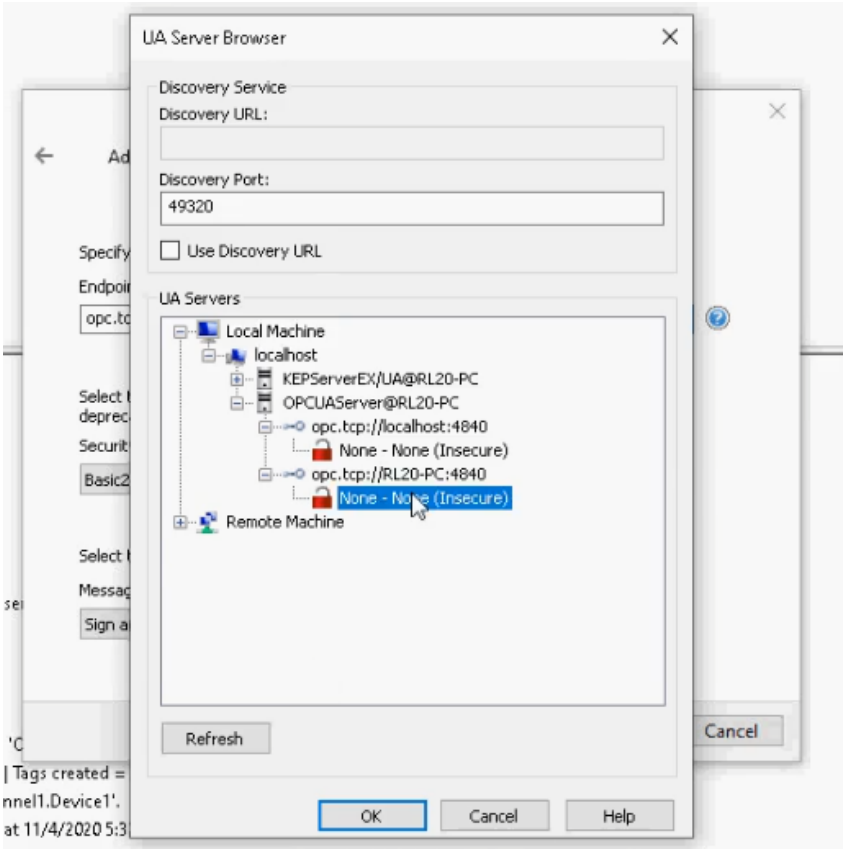
Setting up an encrypted connection with the Kepware client.

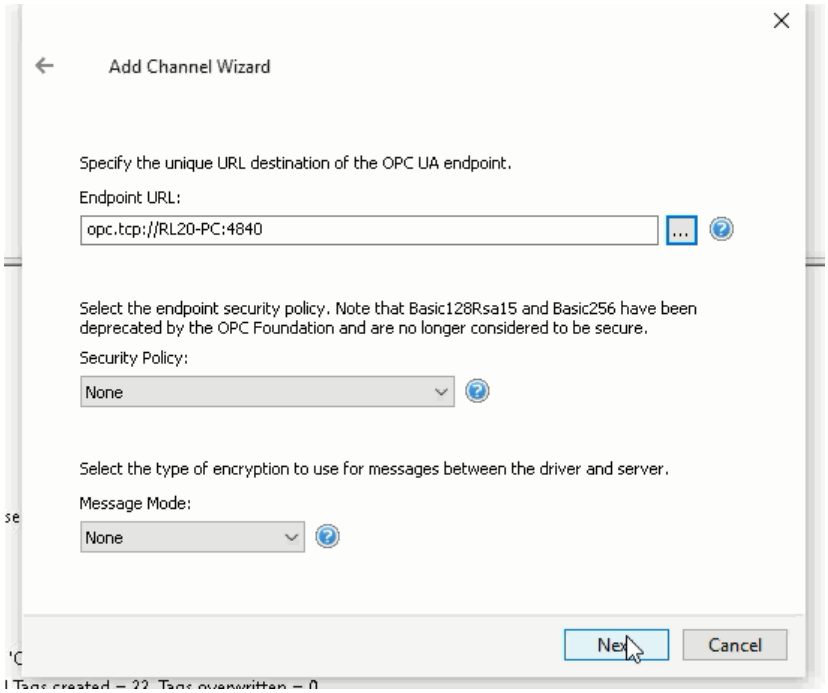
Step 6.1 Start the “Kepware 6 Configuration” program.

Step 6.2 Under “Project”, right-click “Connectivity” and select “Add Channel”. Under the type of channel to be created, select “OPC UA Client” driver from the drop-down menu, then click “Next”. Under “Name” type “Channel1 [Your Initials and Date]” then click “Next” and “Next” again on the screen asking “Choose how write data…” to use the default settings.



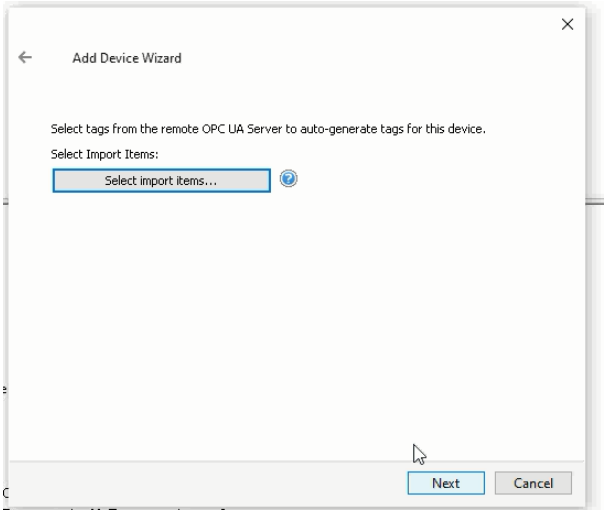
Step 6.3 On the screen asking “Specify the unique URL destination of the OPC UA endpoint”, click the “…” icon next to the “Endpoint URL” and expand “Local Machine”, then “localhost”, “OPCUAServer@...”, then expand the “opc.tcp://…” option corresponding to the RL computer and port number 4840, then elect “None – None (Insecure)” and click OK. Leave “Security Policy” and “Message Mode” as “None” and click “Next”. Leave the default values on the following screen and click “Next” and again leave the “Username” and “Password” fields blank and click “Next” then click “Finish”. The channel will be created under “Connectivity” in “Project”.

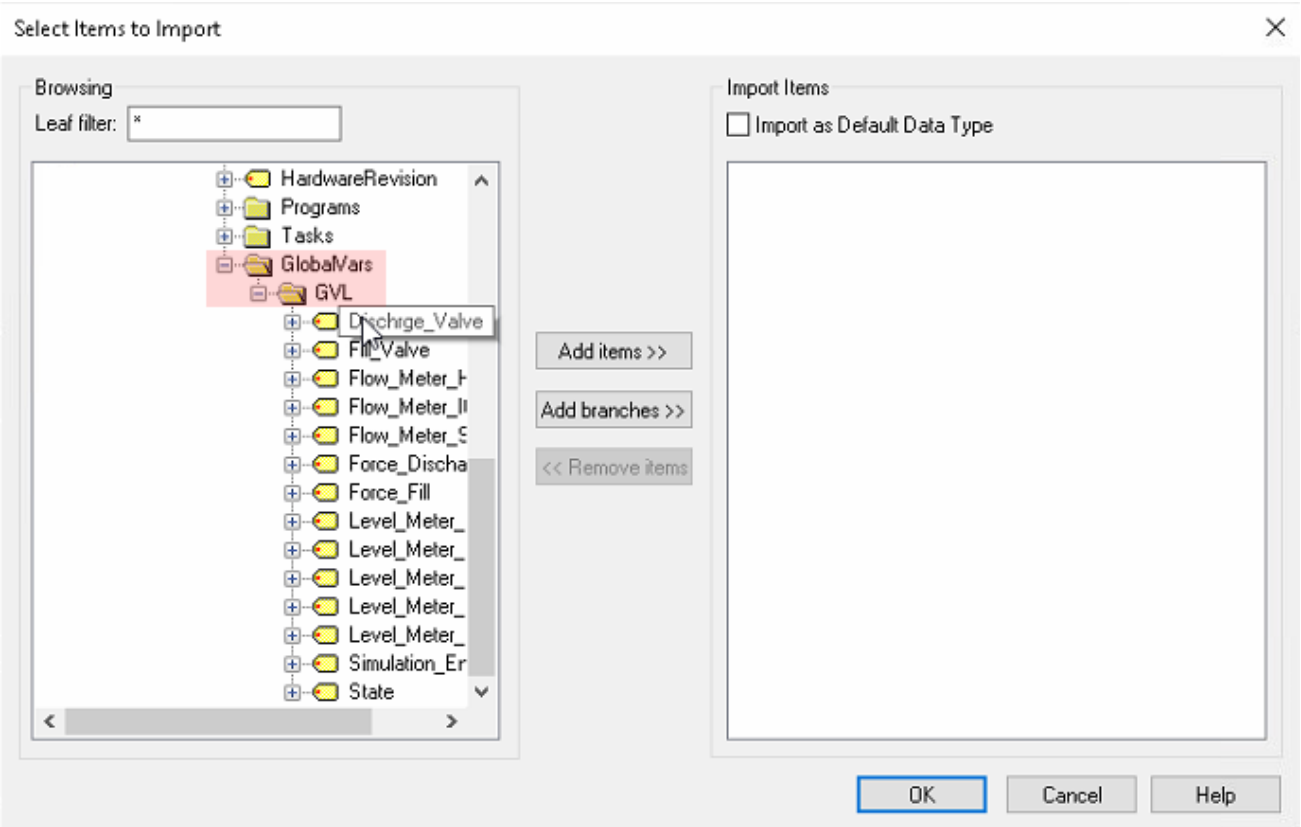

UA Server Browser
Discovery Service
Discovery URL:
Discovery Port:
49320
Use Discovery URL
UA Servers
Local Machine
localhost
KEPServerEX/UA@RL20-PC
OPCUAServer@RL20-PC
opc.tcp://localhost:4840
None - None (Insecure)
opc.tcp://RL20-PC:4840
None - None (Insecure)
Remote Machine
Refresh
OK
Cancel
Help
Cancel

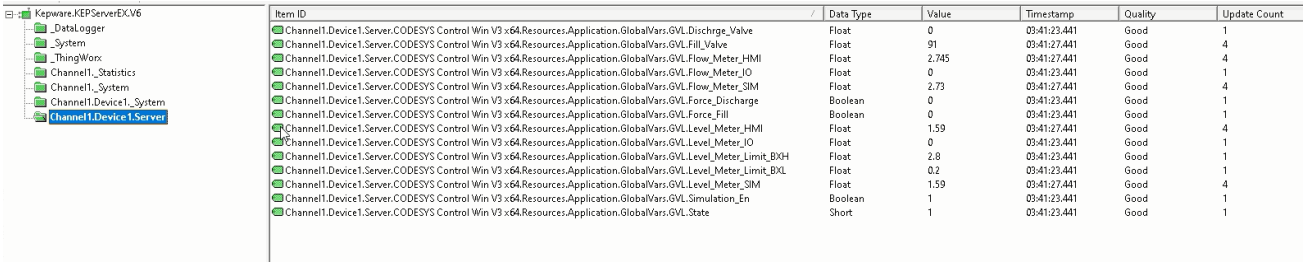

Add Channel Wizard
Specify the unique URL destination of the OPC UA endpoint.
Endpoint URL:
opc.tcp://RL20-PC:4840
Select the endpoint security policy. Note that Basic128Rsa15 and Basic256 have been deprecated by the OPC Foundation and are no longer considered to be secure.
Security Policy:
None
Select the type of encryption to use for messages between the driver and server.
Message Mode:
None
Next
Cancel

Step 6.4 Under “Runtime” select “Connect” then “Yes” when asked to “Update the runtime with the loaded project following connect” and “No” when asked to save changes.

Step 6.5 Under the newly created channel, click “Click to add a device” and name the device “Device1 [Your Initials and Date]” then keep clicking “Next” leaving the default values until you reach the screen prompting you to “Select tags from the remote OPC UA Server…” then click the button that says “Select import items…”. Expand “ocp.tcp://…”, “Server”, “CODESYS Control Win V3 x64”, “Resources”, “Application”, “GlobalVars”, then “GVL”. You can then highlight the variables you wish to monitor over OPC UA with the client and click “Add branches >>” then “OK”, “Next” and “Finish”. You will see “Server” appear under your Device.

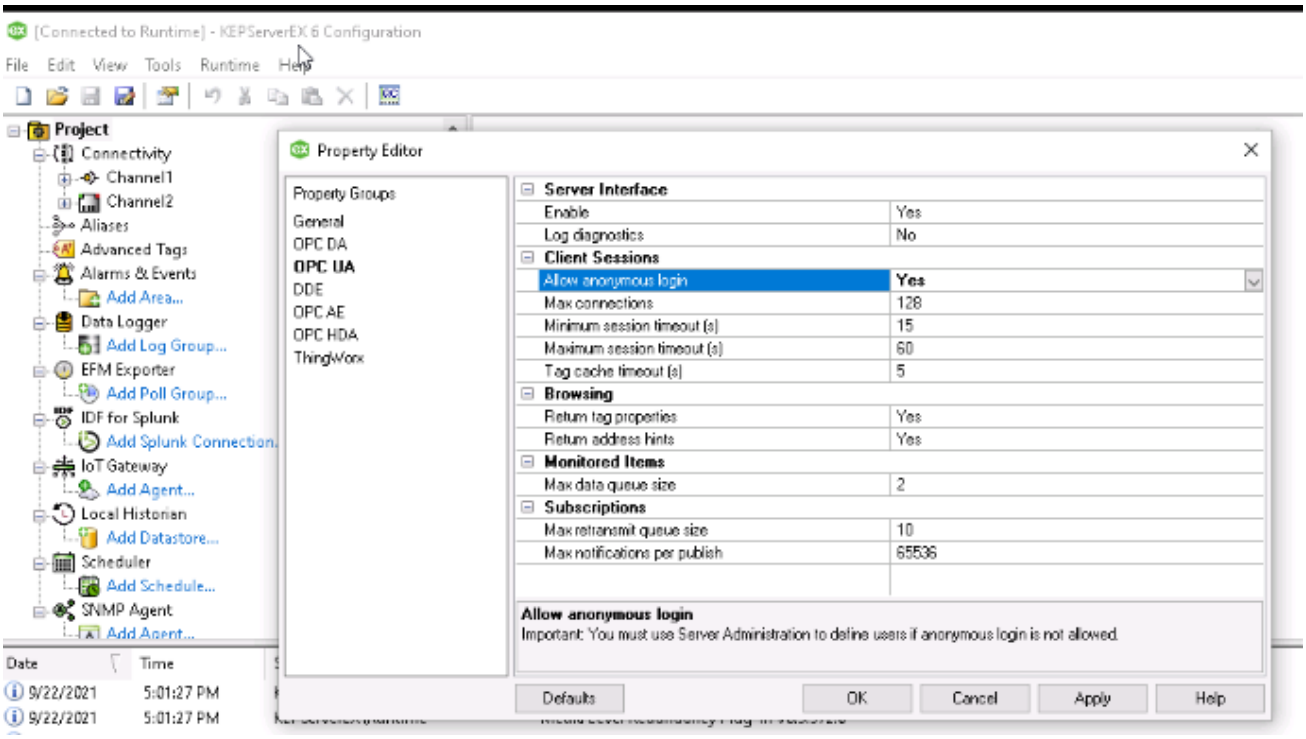




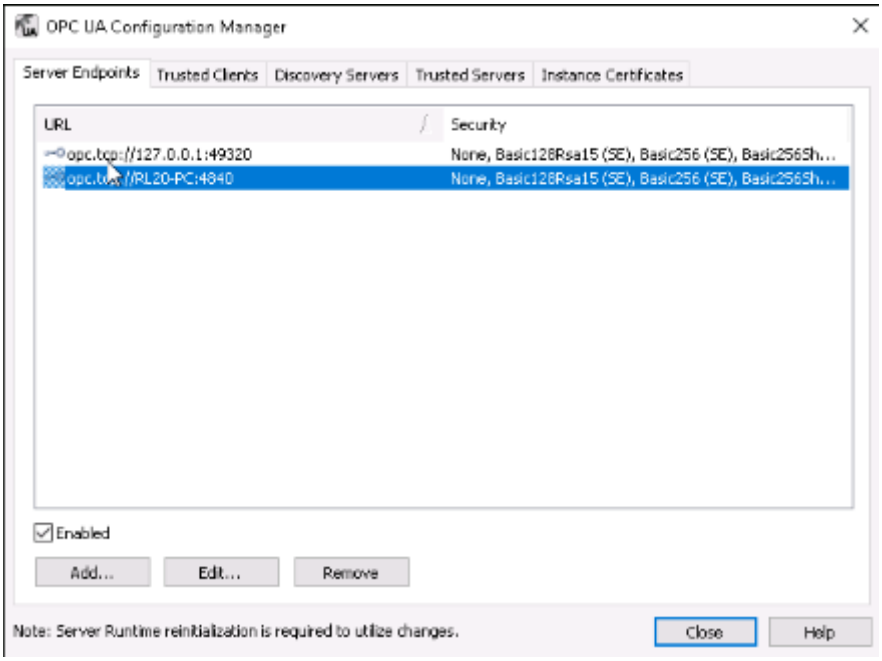


Note: The following steps 6.7-6.11 are not required to be completed and are here for reference only. Since we are using Kepware as the OPC server, it is now possible to see the variables using the UaExpert OPC client, as follows:

Step 6.7 In KEPServerEX 6, right-click “Project” and select “Properties”. Click “OPC UA” and under “Client Sessions”, next to “Allow anonymous login” select “Yes”.



Step 6.8 In the Windows start menu, open programs, Kepware folder, and launch “OPC UA Configuration”. Under the “Server Endpoints” tab, click to highlight the option specifying the remote lab “opc.tcp:// …” and then click “Enabled”. Leave this window open.



Step 6.9 Open “Windows Defender Firewall with Advanced Security” by searching it in the start bar. Click “Inbound Rules”. Search for a rule with a green tick “OPC UA Server Interface (Kepware)”. If it is not there, we will add it to allow inbound local traffic; in which case click “New Rule…”, under “Rule Type” click “Port” and “Next”, ensure that “TCP” is selected and next to “Specific local ports” type “49320” and click “Next”. Select “Allow the connection” then “Next”. De-select “Public” so that only “Domain” and “Private” are selected and click “Next”. Finally under “Name” type “OPC UA Server Interface (Kepware)” then click “Finish”. Close the firewall window.

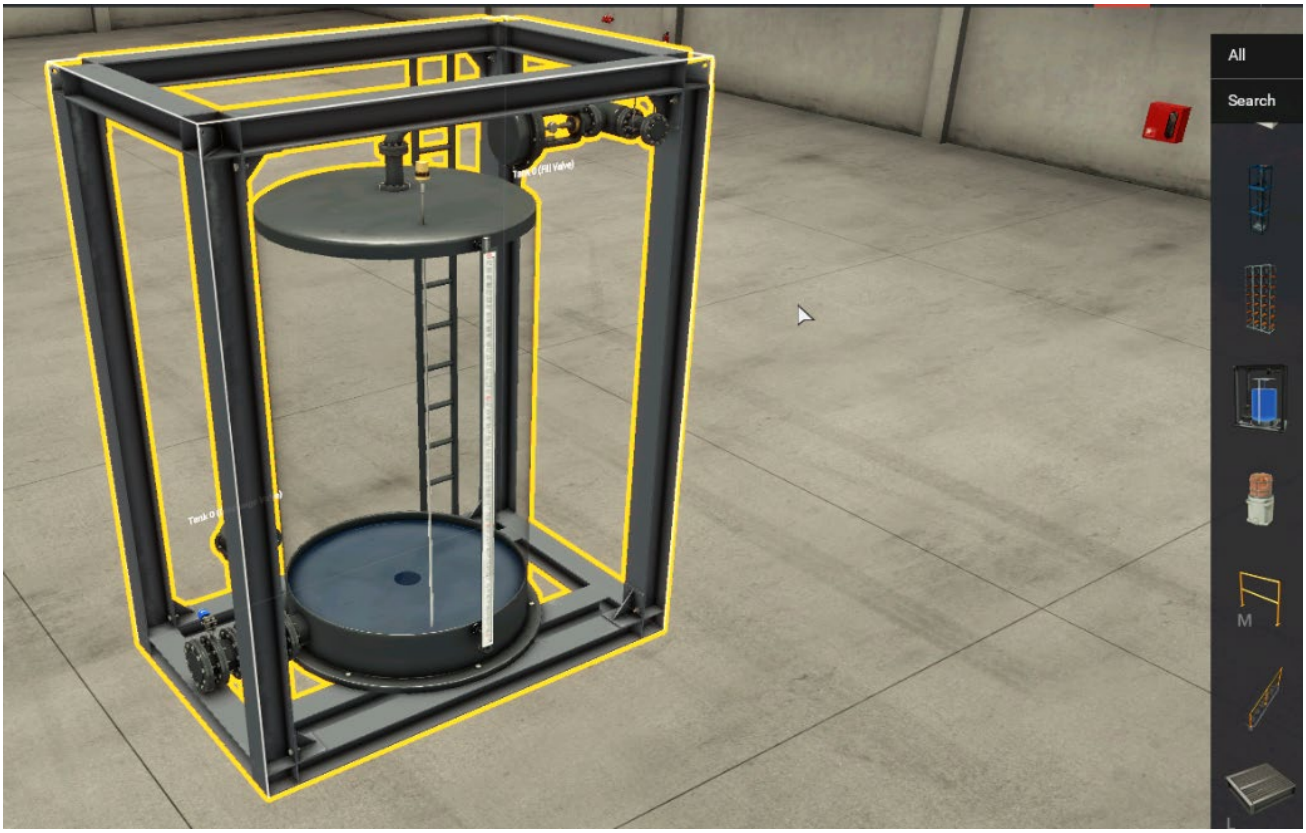
Step 6.10 Open UaExpert and click “Server” then “Add”. Under “Custom discovery” double-click to Add Server, then enter “opc.tcp://127.0.0.1:49320”. It will be added under “Custom Discovery”, now expand the arrow next to it and you should see “KEPServerEX…”. Expand that arrow and select “None – None…” then click “OK”.

Step 6.11 Right-click the newly added “KEPServerEX…” under “Servers” in UaExpert and click “Connect”; you will likely get an error in the log, or be unable to connect.

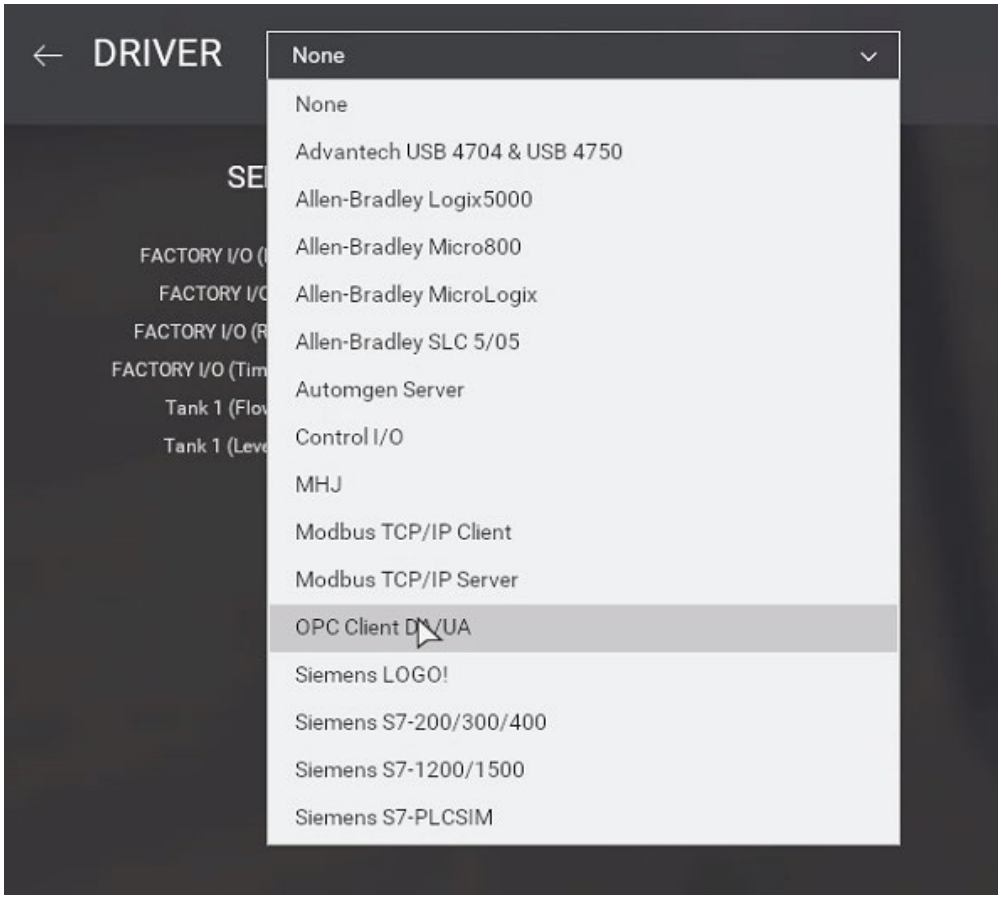
Back in the (still open) “OPC UA Configuration Manager”, click on the “Trusted Clients” tab; you should see under Client Name, “UaExpert”. Right-click it and click “Accept” (or Trust). Back in KEPServerEX 6, you may need to click “Runtime” then “Reinitialize” and repeat this step. In UaExpert the server should eventually connect and appear in the Address Space, following these steps, at which point you can navigate to the GVL file and monitor the variables as before (with Codesys as the OPC UA server).

4. Factory IO Configuration

Step 1: Launch Factory IO from the desktop or start menu as Administrator (**right-click, run as Administrator**) and select “New” (or “File” then “New”) to create a new scene. Save it as “EIT_Tank_Level[Your Initials and Date]” using “File” then “Save As…”, overwrite if prompted. Note, controls can be found by clicking “File”, then “Options”, then “Controls”.

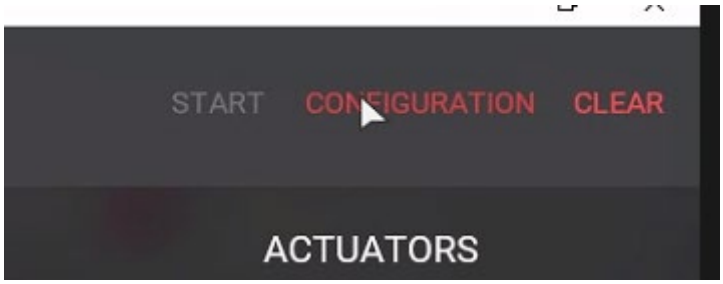


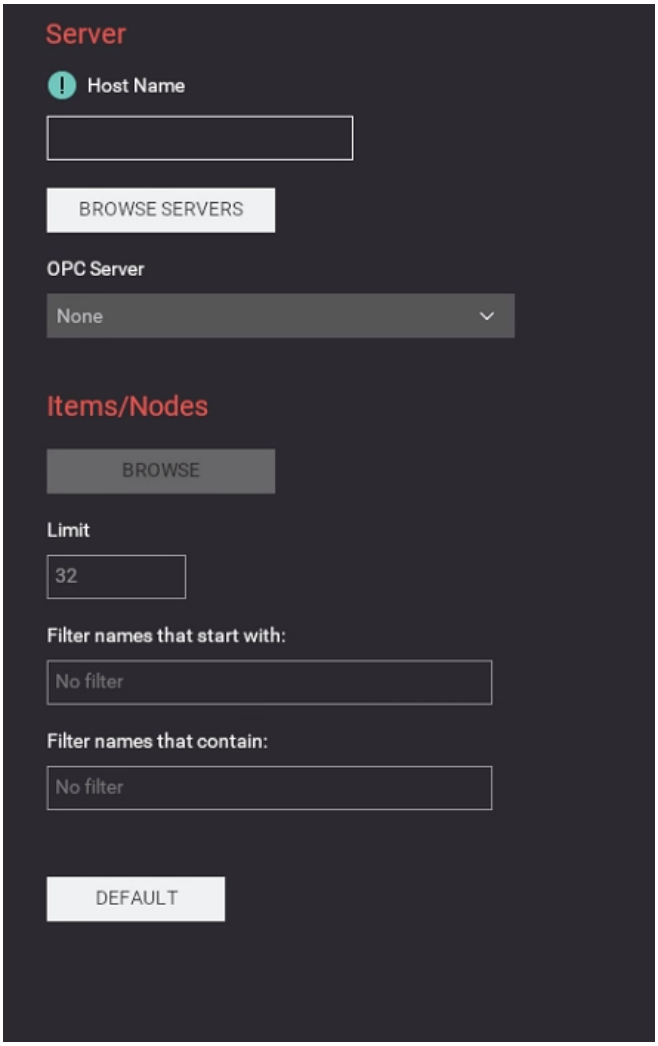
Step 2: Open driver settings by clicking “File” then “Drivers”. Next to “DRIVER” click the drop-down arrow and select “OPC client DA/UA”.

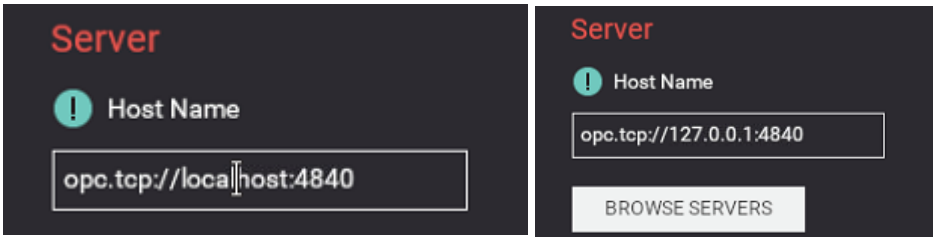


Step 3: In the top right of the window, click “CONFIGURATION”. The side-bar should have “OPC Client DA/UA” selected in red. Under “Server” “Host Name” type the

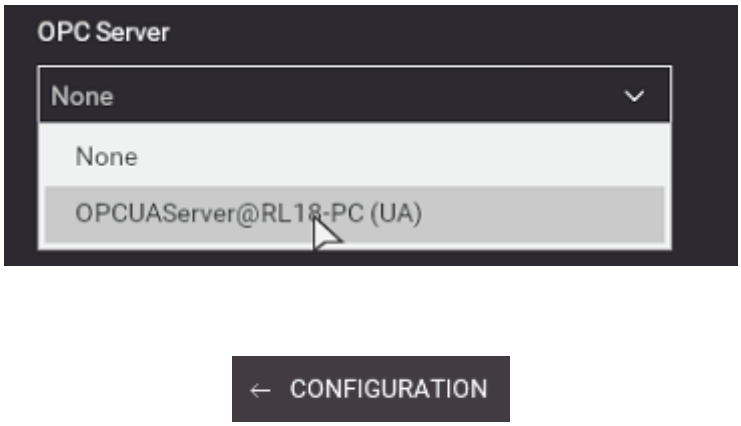
following details (in CodeSys the Visualization must be running and “Simulation on PLC” set to on): “opc.tcp://127.0.0.1:4840” (note that localhost can be used instead of the IP address).





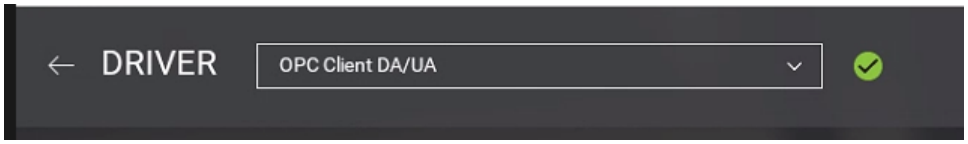


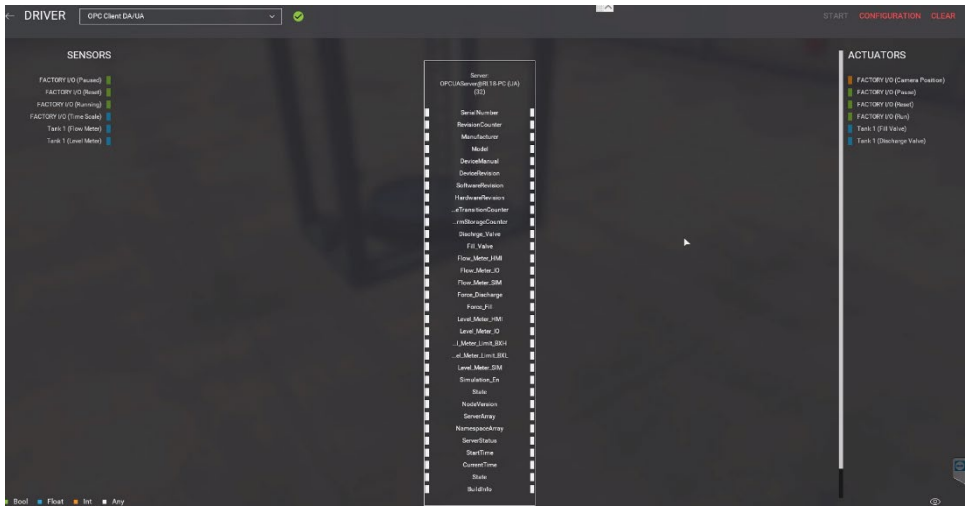
Step 4: Click “BROWSE SERVERS” and then under “OPC Server” click the drop-down and select “OPCUAServer@...”. Ensure that it is selected and under “Items/Nodes” click “BROWSE” then click the back arrow next to “CONFIGURATION”.

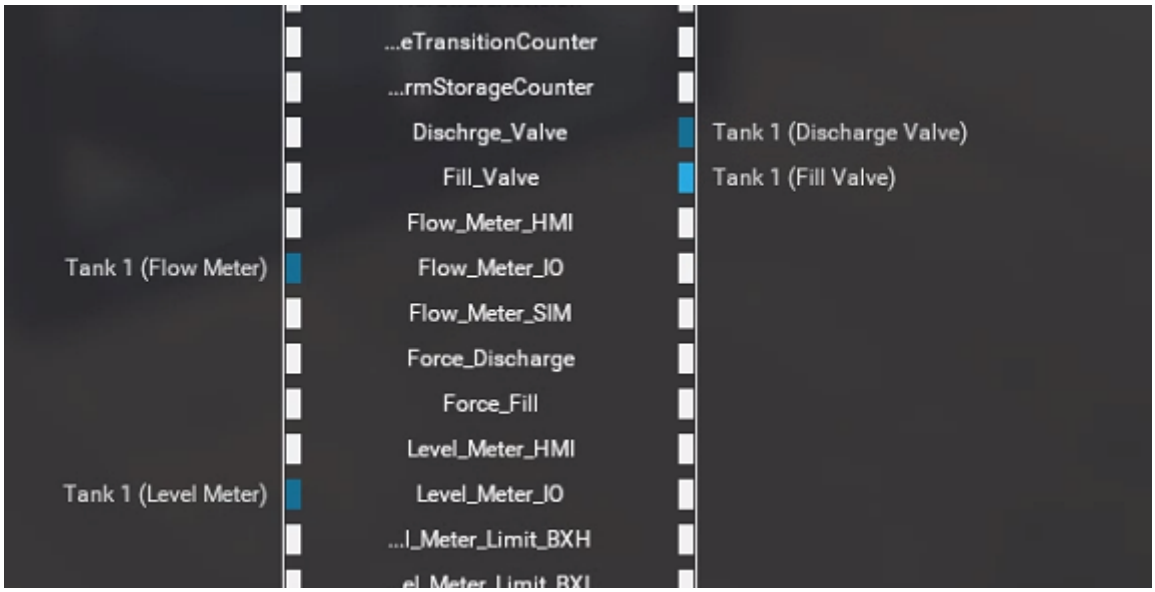


Step 5: You should see the newly added variables and established connection. If not, ensure that you are running Factory IO as Adminstrator. Match the Factory IO SENSORS and ACTUATORS to the OPC UA Variables by clicking them and dragging them onto the corresponding OPC UA Variables from the server:

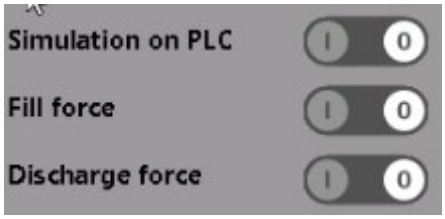
- “Tank … (Flow Meter)” to “Flow_Meter_IO”
- “Tank … (Level Meter)” to “Level_Meter_IO”
- “Dischrge_Valve” to “Tank … (Discharge Valve)”
- “Fill_Valve” to “Tank … (Fill Valve)”







Step 6: Click the back arrow next to “DRIVER” to return to the scene. In CodeSys Visualization, ensure that the PLC switch is off so the values can be obtained from the tank in Factory IO. In the Factory IO scene, click the play button to start the runtime.



Step 7: In Factory IO click “View” then “Dock All Tags”. You can change these values, as well as those on the HMI to affect the filling and discharging of the tank. This will be observable over an OPC UA client, should you open UaExpert and connect to the OPC UA server.

End of Document