A Project Report

On

Automated Storage and Retrieval System

Submitted in partial fulfilment of the requirement for the course of

INSTITUTIONAL SPONSORED PROJECT

21EARW492

Department of Automation & Robotics

Under the guidance of

Prof. Arun C Giriyapur
Prof. Sachin Karadgi
Kartik Lakamanhalli

Department of Automation & Robotics,
KLE Technological University, Hubballi - 580031

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2021 - 2022

This is to certify that Amogh Sutar (01FE18BAR005), Amrut Kurtkoti (01FE18BAR007), Anant Maliye (01FE18BAR008), K V S S Prathyush (01FE18BAR021), Malhar Kulkarni (01FE18BAR022), Prasad Basaragi (01FE18BAR027), Ranjeet Shingade (01FE18BAR031) and Ritika Javalagi (01FE18BAR032) has satisfactorily completed the course INSTITUTIONAL SPONSORED PROJECT (21EARW492).

Staff in-charge **Head of the Department**

ABSTRACT

Warehouse management has been a key factor in ensuring that the company attains its efficiency and meets its productivity goals. The storing of the goods from the reception to the dispatch plays an important role in maintaining the shelf life of the goods and ensuring the proper dispatch of them as well. Due to the human errors and the mishaps by the labour involved in the warehouse, the automation of all the processes involved stands to be a more efficient and time-saving job. An Automated Storage and Retrieval System, can substitute this in the warehouse management. Amazon warehouse, with its five-story plant, where the processes from the reception, storage, retrieving, and packing to dispatching have been automated, and has been a key motivation to build ASRS.

Here, the designing, fabrication, and integration of ASRS is done to store and retrieve the goods into the respective racks of the warehouse automatically. The proposed ASRS can move in 3 dimensions with 3 DOF, and can pick or place, i.e., store good in the rack or retrieve them from the rack. The implications are the ASRS should learn about the possible trends of goods regularly stored and retrieved for faster storing in the forthcoming cycles ASRS can account for all the goods, and maintain the warehouse by itself, substituting human effort and human error with accuracy and efficiency.

ACKNOWLEDGEMENT

We would like to take this opportunity to thank the following for the unique opportunity created through the institutional sponsored project to work on the given need statements.

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Chapter 1

Introduction

Automatic storage and retrieval system (ASRS) consists of various computer-controlled systems to automatically place and unload loads at designated locations as illustrated in Figure 1. Automatic storage and retrieval systems (ASRS) are commonly used in systems where:

- There is a very large amount of luggage loaded and unloaded
- Storage capacity is important due to space constraints
- There is no additional value for this process (no processing, storage and transport only)
- Accuracy is important because of the potential damage to the load.

The (ASRS) can be used with standard and non-standard loads, which means that each standard load can fit into a volume of the same size.

1.1. Problem Statement

Design a course on Digital Twin and development of automated storage and retrieval systems as an educational kit to complement the course on Digital Twin. Designing Digital Twin encompassing digital thread, monitoring and control of production processes and integrating the virtual world and physical world.

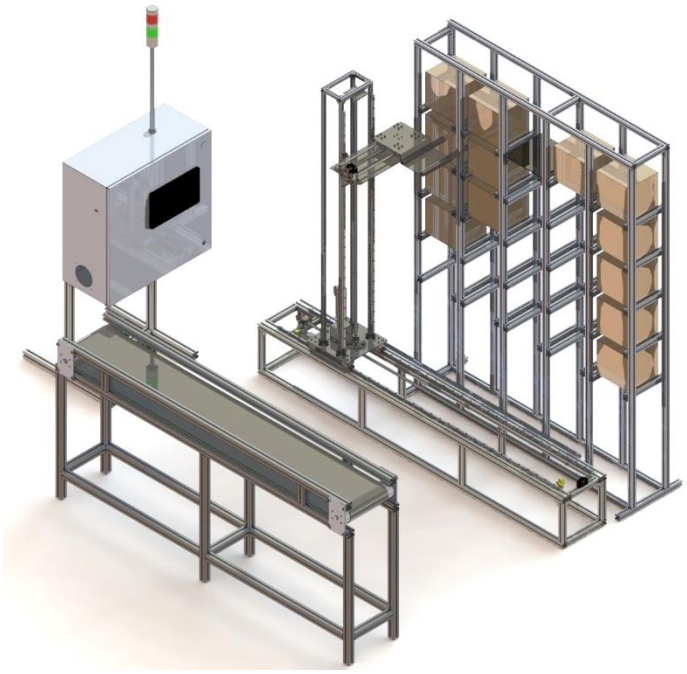


Figure 1 Automated Storage and Retrieval System

Chapter 2

Literature Survey

Automatic storage and retrieval systems have been widely used in distribution and production facilities since their inception in the 1950s. Between 1994 and 2004, there was a significant increase in the number of AS / RS used in distribution facilities in the United States (Production Phase for the American Automated Retail Industry Recovery System, 2005). The use of AS / RS has a few advantages over non-automated systems. Examples are savings on labour costs and floor space, increased reliability and reduced error rates [1].

Design and building a framework for automated equipment asset management system by reducing the lead time in the movement or development of thing and moreover to focus on improving Automatic Storage as well Retrieval System in the businesses to increase productivity and in addition improve asset management in the warehouse. The purpose is to plan and implement Automated Storage and Retrieval system of stockroom equipment and development, redesigning depends on parameters such as the point of the deal, the desired tone of the object or the visual parameters such as length, width, weight etc. using simplification procedures. Usage of SWARM optimisation algorithm can improve the overall performance of the system [2]. Particle swarm optimization (PSO) is a global optimization algorithm for dealing with problems where the best solution can be represented as a point or location in an n-dimension area. The trends of ASRS in the future years is depicted in Figure 2.

Goods such as spare parts and small goods cause significant management problems. Because of the amount of space use and termination of filtering, this program is proposed handling goods properly by storing them in a specified location places safely and return them quickly without being damaged. A solid three-dimensional model of the proposed system is developed using computer-assisted drawing software. A program is written and a microcontroller is used to control the stepper motor for storage and retrieval of three dimensions. A basic idea about controlling scheme that is used in microcontrollers is obtained [3].

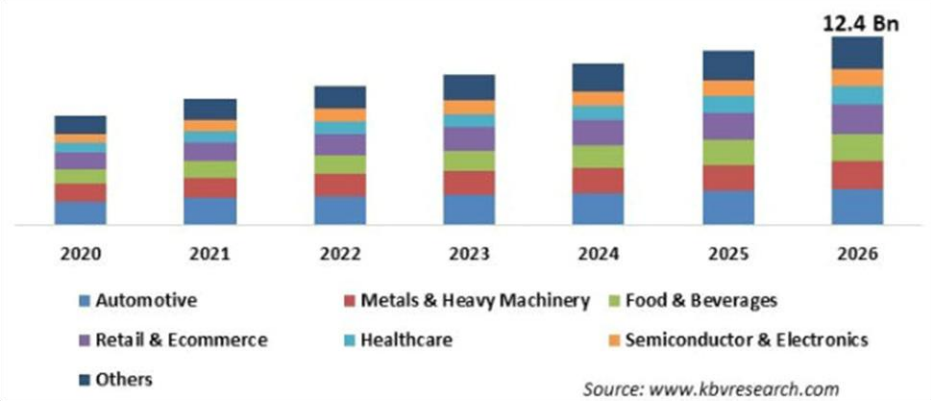


Figure 2 Automated storage and retrieval system market size 2026

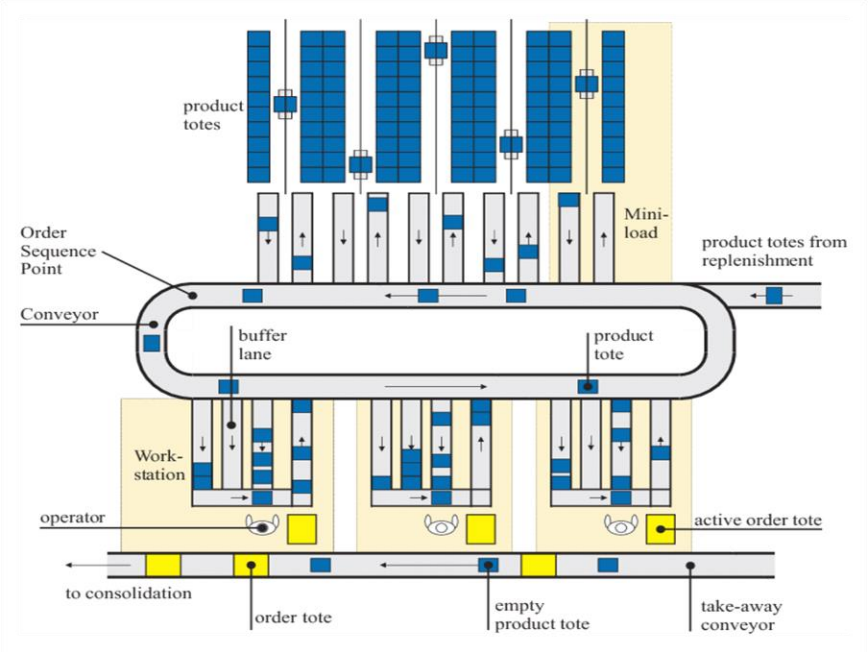


Figure 3 Automated Warehouse Layout

ASRS constitutes equipment and control which will handle the storage and retrieval of required material with great accuracy and precision. There are different variety of ASRS systems that vary from small automated systems to large automated systems which are usually an integral part of distribution & manufacturing process. Layout of ASRS is shown in Figure 3.

They are widely used in the logistics as well. Rising trend of e-commerce has demanded these logistics and warehouse companies to work faster in order to satisfy the customers and keep up the company's reputation. In order to keep up with the orders these firms also follow some key performance indicators (KPIs). Some of the KPIs are Average Hourly Usage, Average Weekly Usage, Shortest Path, Cycle Time, and Accuracy, etc.

Based on these KPIs we can analyse the performance of the machine and we can carry out predictive maintenance activity so that there is no wearing away of machine parts [4].

Depending on the load, we can classify them into two types of AS/RS machines:

1. **Mini-Load AS/RS Machine**: This machine is meant for small load usually which weighs less than 1000 pounds. They are typically for lighter loads as depicted in Figure 4.

2. **Unit-Load AS/RS Machine**: This machine is typically is meant for heavy loads which usually weighs more than 1000 pounds and more as shown in Figure 5. The pallet and the whole structure will be as tall as 100 feet or even more than that [5].

Figure 4 Mini Load AS/RS Machine

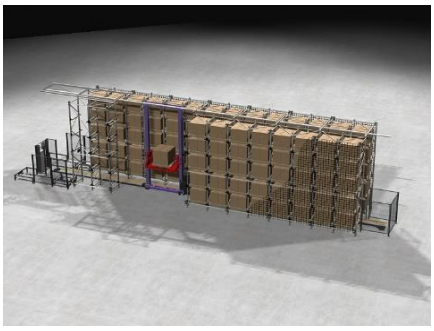


Figure 5 Unit Load AS/RS Machine

Chapter 3

Design, Fabrication and Architecture

3.1. Design

An abstract idea for the design of an Automated Storage and Retrieval system would be the combination of equipment and controls which handles, stores, and retrieves materials with precision, accuracy and speed under a defined degree of automation and a rugged industrial environment [6].

3.1.1. Mechanical

The mechanical task included for the designing phase of our Automated Storage and Retrieval system deals mainly on the design and fabrication and analysis of the materials used for the assembly [7] [9]. The complete mechanical work followed here is based on the V- model for manufacturing of products [8]. The ASRS designing and assembly is followed by parts, it is divided among X-axis, Y-axis and Z-axis and rack assemblies as shown in Figure 6.

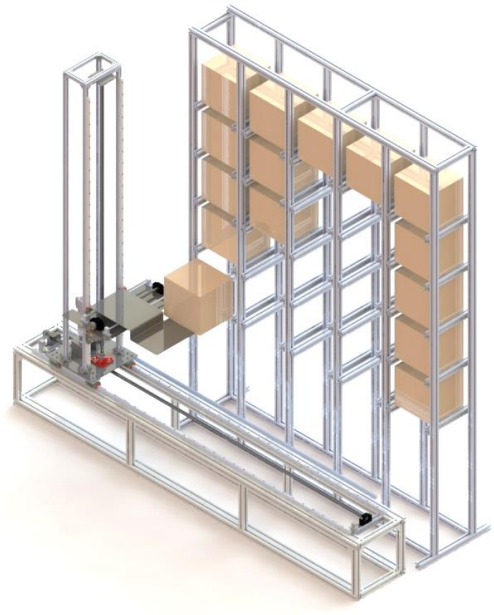
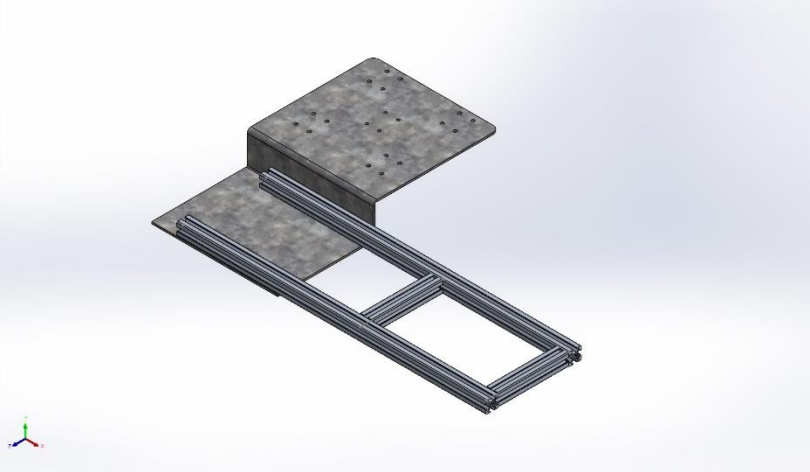


Figure 6 ASRS Solidworks Rendered Image

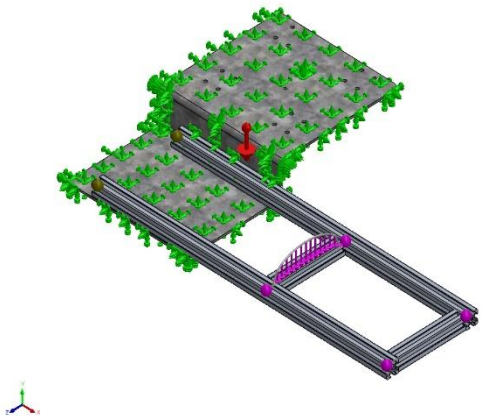
Static Analysis of Z - Axis Carrier



Analysed with SOLIDWORKS Static Analysis

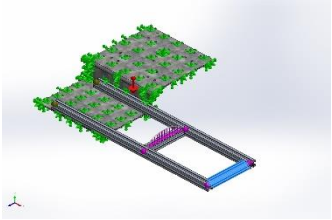
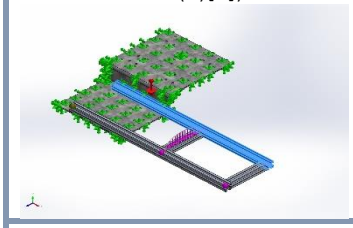
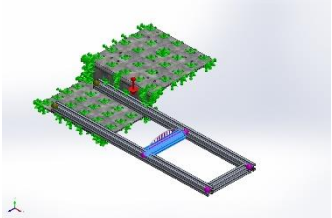
Study Properties

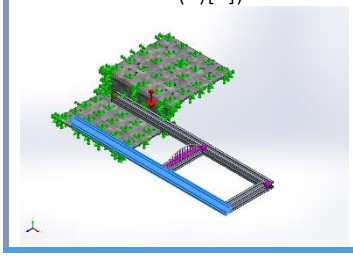
Study name	Static 1
Analysis type	Static
Mesh type	Mixed Mesh
Thermal Effect:	On
Thermal option	Include temperature loads
Zero strain temperature	298 Kelvin
Include fluid pressure effects from SOLIDWORKS Flow Simulation	Off
Solver type	Direct sparse solver
Inplane Effect:	Off
Soft Spring:	Off
Inertial Relief:	Off
Incompatible bonding options	Automatic
Large displacement	Off
Compute free body forces	On
Friction	Off
Use Adaptive Method:	Off



Model name: Z axis Carrier
Current Configuration: Default

Beam Bodies:

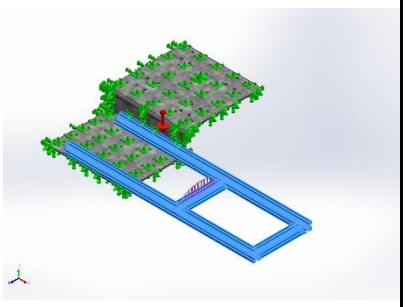
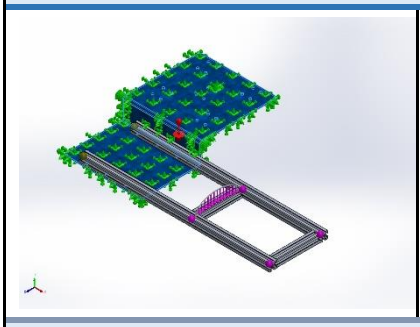
Document Name and Reference	Formulation	Properties
SolidBody 1(20_series 20-2020(3)[3]) 	Beam – Uniform C/S	Section Standard-Bosch Profiles/20_Series/20-2020 Section Area: 0.000159407m^2 Length:111.5mm Volume:1.77738e-05m^3 Mass Density:2,700kg/m^3 Mass:0.0479894kg Weight:0.470296N
SolidBody 2(20_series 20-2020(3)[1]) 	Beam – Uniform C/S	Section Standard-Bosch Profiles/20_Series/20-2020 Section Area: 0.000159407m^2 Length:490mm Volume:7.81093e-05m^3 Mass Density:2,700kg/m^3 Mass:0.210895kg Weight:2.06677N
SolidBody 3(20_series 20-2020(3)[4]) 	Beam – Uniform C/S	Section Standard-Bosch Profiles/20_Series/20-2020 Section Area: 0.000159407m^2 Length:111.5mm Volume:1.77738e-05m^3 Mass Density:2,700kg/m^3 Mass:0.0479894kg Weight:0.470296N

SolidBody 4(20_series 20-2020(3)[2]) 	Beam – Uniform C/S	Section Standard-Bosch Profiles/20_Series/20-2020 Section Area: 0.000159407m^2 Length:490mm Volume:7.81093e-05m^3 Mass Density:2,700kg/m^3 Mass:0.210895kg Weight:2.06677N

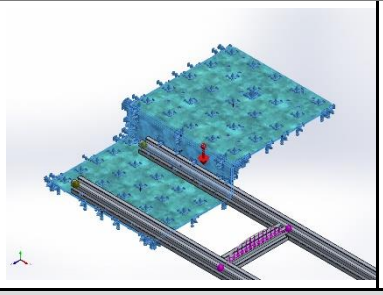
Units

Unit system:	SI (MKS)
Length/Displacement	mm
Temperature	Kelvin
Angular velocity	Rad/sec
Pressure/Stress	N/m^2

Material Properties

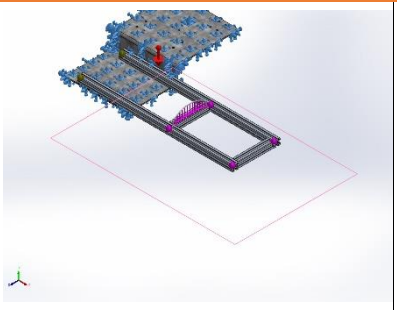
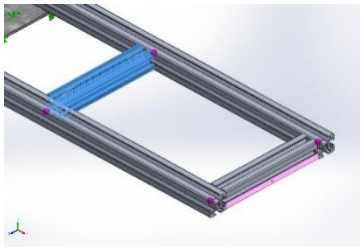
Model Reference	Properties	Components
	Name: **1060 Alloy** Model type: **Linear Elastic Isotropic** Default failure criterion: **Unknown** Yield strength: **2.75742e+07 N/m^2** Tensile strength: **6.89356e+07 N/m^2** Elastic modulus: **6.9e+10 N/m^2** Poisson's ratio: **0.33** Mass density: **2,700 kg/m^3** Shear modulus: **2.7e+10 N/m^2** Thermal expansion coefficient: **2.4e-05 /Kelvin**	**SolidBody 1(20_series 20-2020(3)[3])(2020 Extractor-1), SolidBody 2(20_series 20-2020(3)[1])(2020 Extractor-1), SolidBody 3(20_series 20-2020(3)[4])(2020 Extractor-1), SolidBody 4(20_series 20-2020(3)[2])(2020 Extractor-1)**
Curve Data:N/A		
	Name: **Galvanized Steel** Model type: **Linear Elastic Isotropic** Default failure criterion: **Unknown** Yield strength: **2.03943e+08 N/m^2** Tensile strength: **3.56901e+08 N/m^2** Elastic modulus: **2e+11 N/m^2** Poisson's ratio: **0.29** Mass density: **7,870 kg/m^3**	**SolidBody 1(M4 Clearance Hole3)(main_plate-1)**
Curve Data:N/A		

Loads and Fixtures

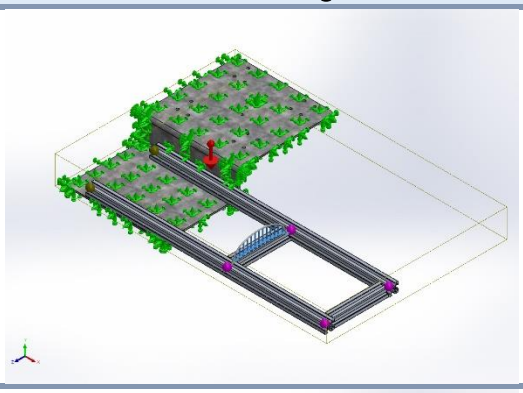
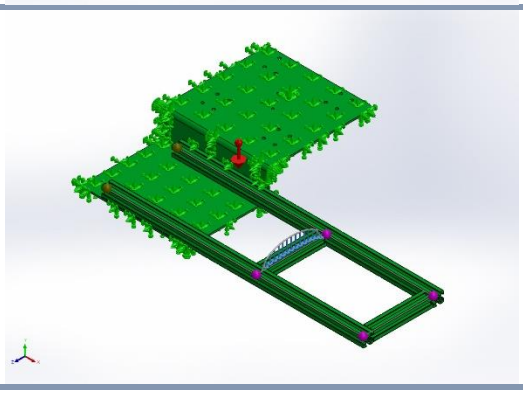
Fixture name	Fixture Image	Fixture Details
Fixed-1		**Entities:** 19 face(s) **Type:** Fixed Geometry

esultant Forces

Components	X	Y	Z	Resultant
Reaction force(N)	1.75699e-05	72.5308	-6.94224e-06	72.5308
Reaction Moment(N.m)	0.142337	-0.0148238	5.84329	5.84505

Load name	Load Image	Load Details
Gravity-1		**Reference:** Top Plane **Values:** 0 0 -9.81 **Units:** m/s^2
Force-1		**Entities:** 1 Beam (s) **Reference:** Face< 1 > **Values:** ---, -5, --- kgf **Moments:** ---, ---, --- kgf.cm **Non uniform load options:** Total Load Distribution **Type:** Elliptical distribution

Contact Information

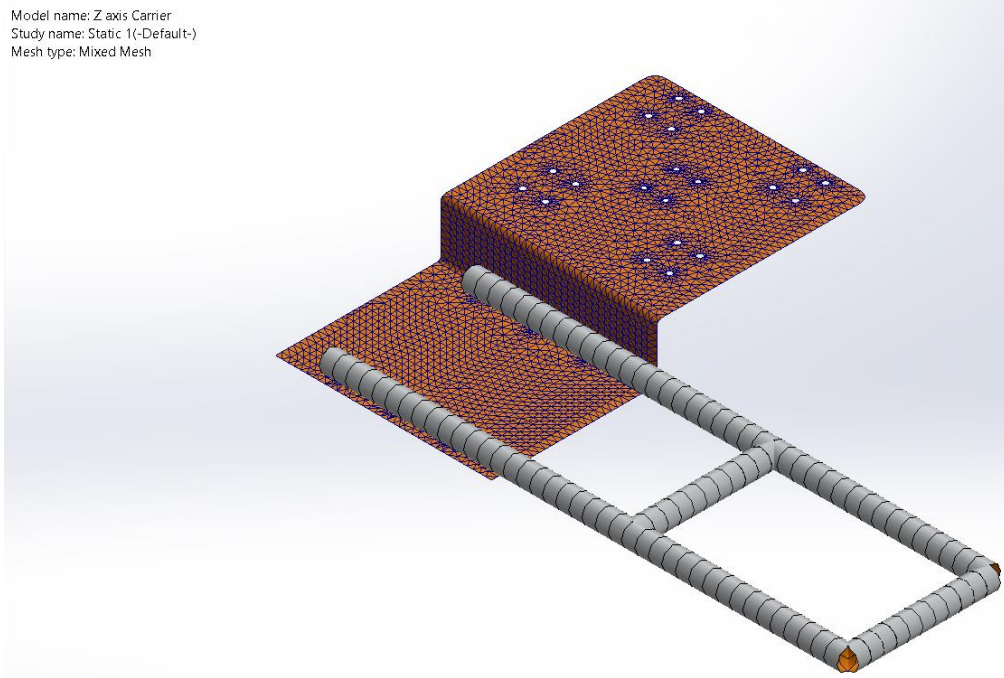
Contact	Contact Image	Contact Properties
Global Contact		**Type:** **Bonded** **Components:** **1 component(s)** **Options:** **Incompatible mesh**
Component Contact-1		**Type:** **Bonded** **Components:** **2 component(s)** **Options:** **Incompatible mesh**

Mesh information

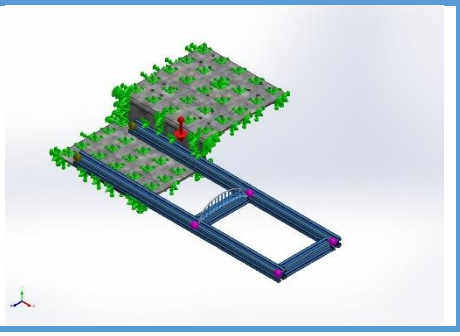
Mesh type	Mixed Mesh
Mesher Used:	Standard mesh
Automatic Transition:	Off
Include Mesh Auto Loops:	Off
Jacobian points for High quality mesh	16 Points
Jacobian check for shell	Off
Element Size	5.72054 mm
Tolerance	0.286027 mm
Mesh Quality	High
Remesh failed parts with incompatible mesh	Off

Mesh information - Details

Total Nodes	11542
Total Elements	5619
Time to complete mesh(hh;mm;ss):	00:00:05



Sensor Details

Sensor name	Location	Sensor Details
Stress1		Value : 1.628e+01 N/m^2 Entities :1 component(s) Result :Stress Component :VON: von Mises Stress Criterion :Max over Selected Entities Step Criterion : Across all Steps Step No.:1 Alert Value: NA

Resultant Forces

Reaction forces

Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N	1.75699e-05	72.5308	-6.94224e-06	72.5308

Reaction Moments

Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N.m	0.142337	-0.0148238	5.84329	5.84505

Free body forces

Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N	1.82145e-07	-2.01762e-06	-8.18012e-07	2.18474e-06

Free body moments

Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N.m	8.11192e-09	-1.56776e-09	3.15595e-09	8.84427e-09

Beams

Beam Forces

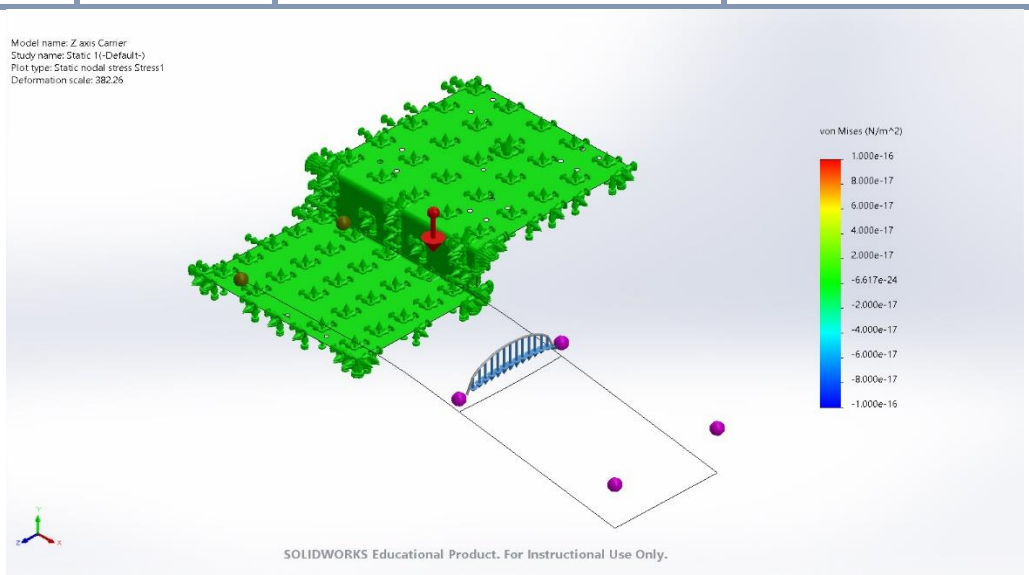
Beam Name	Joints	Axial(N)	Shear1(N)	Shear2(N)	Moment1(N.m)	Moment2(N.m)	Torque(N.m)
Beam-1(20_series 20-2020(3)[3])	1	0.071715	-0.266408	-0.024222	0.00100958	-0.00673055	0.000672792
	2	-0.071715	-0.288812	0.024222	-0.00419476	0.00525743	-0.000672798
Beam-2(20_series 20-2020(3)[1])	1	0.00253554	-0.0262037	-0.00022165	1.97418e-06	4.56519e-05	1.03871e-07
	2	0.024222	0.266408	0.071715	-0.00100958	0.000672792	0.00673055
	3	-0.024222	-1.11085	-0.071715	-0.0133334	0.137053	-0.00673055
Beam-3(20_series 20-2020(3)[4])	1	-1.0794	-24.757	-0.19673	-0.0242319	0.0157862	0.000843455
	2	1.0794	-24.7686	0.19673	-0.00163809	-0.0165458	-0.000843717
Beam-4(20_series 20-2020(3)[2])	1	0.000138279	-0.025973	0.000339026	-2.86165e-06	4.2645e-05	-1.34846e-07
	2	-0.024222	0.288812	-0.071715	0.00419476	-0.000672798	-0.00525743
	3	0.024222	-1.13325	0.071715	0.0101482	0.142879	0.00525743

Beam Stresses

Beam Name	Joints	Axial(N/m^2)	Bending Dir1(N/m^2)	Bending Dir2(N/m^2)	Torsional (N/m^2)	Upper bound axial and bending(N/m^2)
Beam-1(20_series 20-2020(3)[3])	1	449.887	1,462.1	9,747.41	16,463.9	11,659.4
	2	449.887	6,075	7,613.99	-16,464	14,138.9
Beam-2(20_series 20-2020(3)[1])	1	15.9061	2.85907	-66.1146	2.54181	84.8798
	2	-151.951	1,462.1	974.361	164,703	2,588.41
	3	-151.951	-19,309.9	-198,485	-164,703	217,946
Beam-3(20_series 20-2020(3)[4])	1	-6,771.34	-35,093.5	-22,862.1	20,640.1	64,726.9
	2	-6,771.34	2,372.34	-23,962.2	-20,646.5	33,105.9
Beam-4(20_series 20-2020(3)[2])	1	0.867461	-4.14434	-61.76	-3.29981	66.7718
	2	151.951	-6,075	-974.37	-128,654	7,201.32
	3	151.951	14,697	-206,923	128,654	221,772

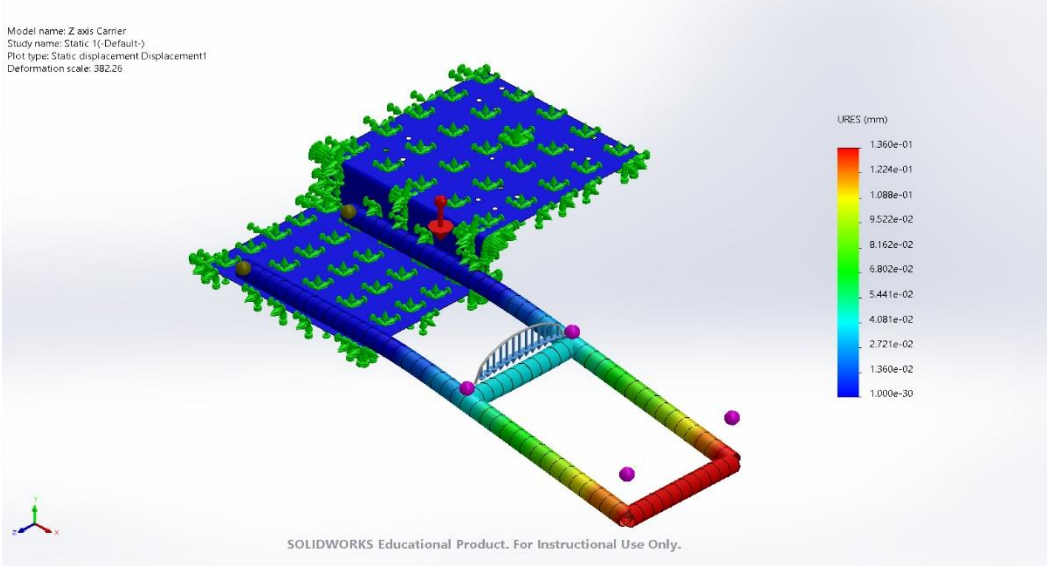
Study Results

Name	Type	Min	Max
Stress1	VON: von Mises Stress	0.000e+00N/m^2 Node: 1	0.000e+00N/m^2 Node: 1



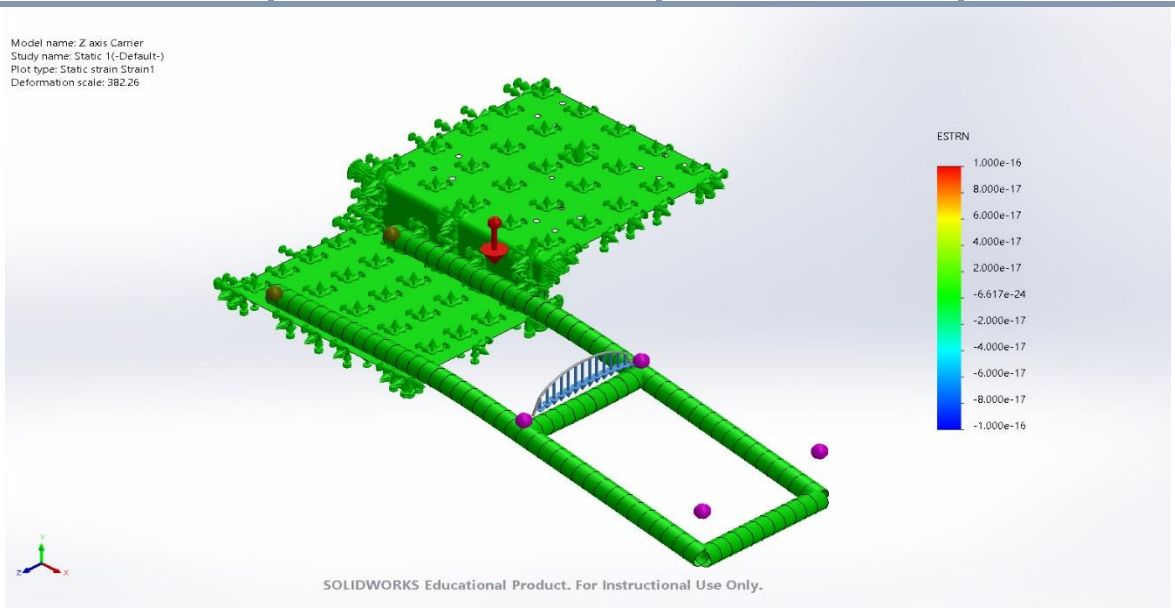
Z axis Carrier-Static 1-Stress-Stress1

Name	Type	Min	Max
Displacement1	URES: Resultant Displacement	0.000e+00mm Node: 1	1.360e-01mm Node: 11450



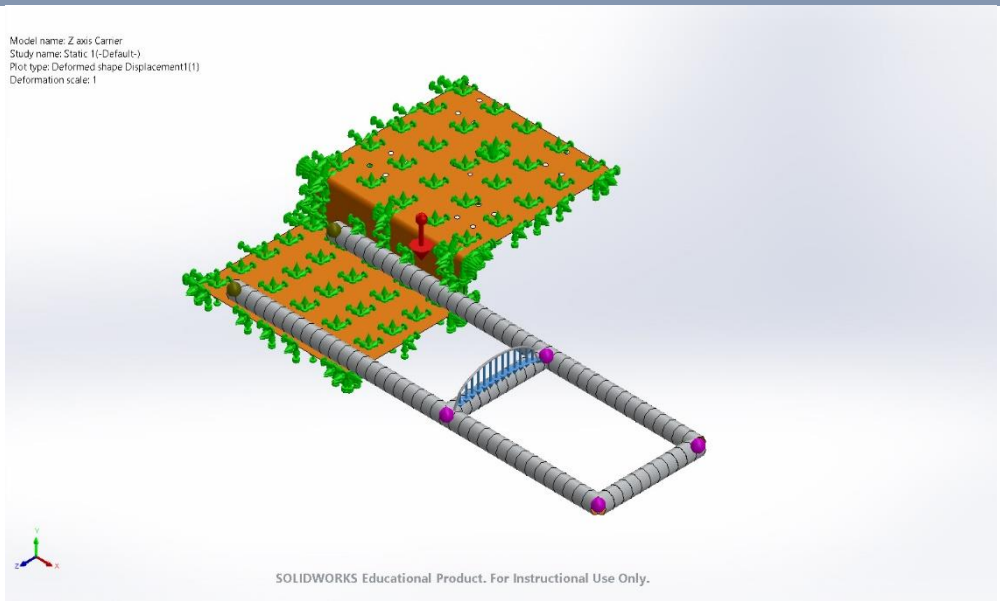
Z axis Carrier-Static 1-Displacement-Displacement1

Name	Type	Min	Max
Strain1	ESTRN: Equivalent Strain	0.000e+00 Element: 1	0.000e+00 Element: 1



Z axis Carrier-Static 1-Strain-Strain1

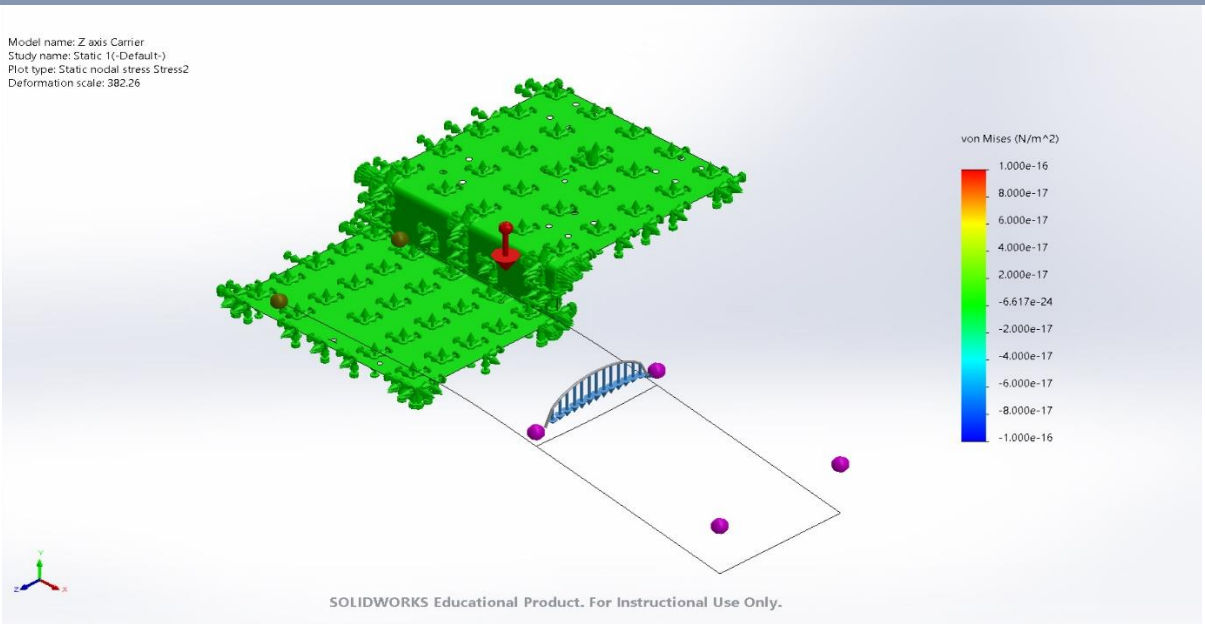
Name	Type
Displacement1{1}	Deformed shape



Z axis Carrier-Static 1-Displacement-Displacement1{1}

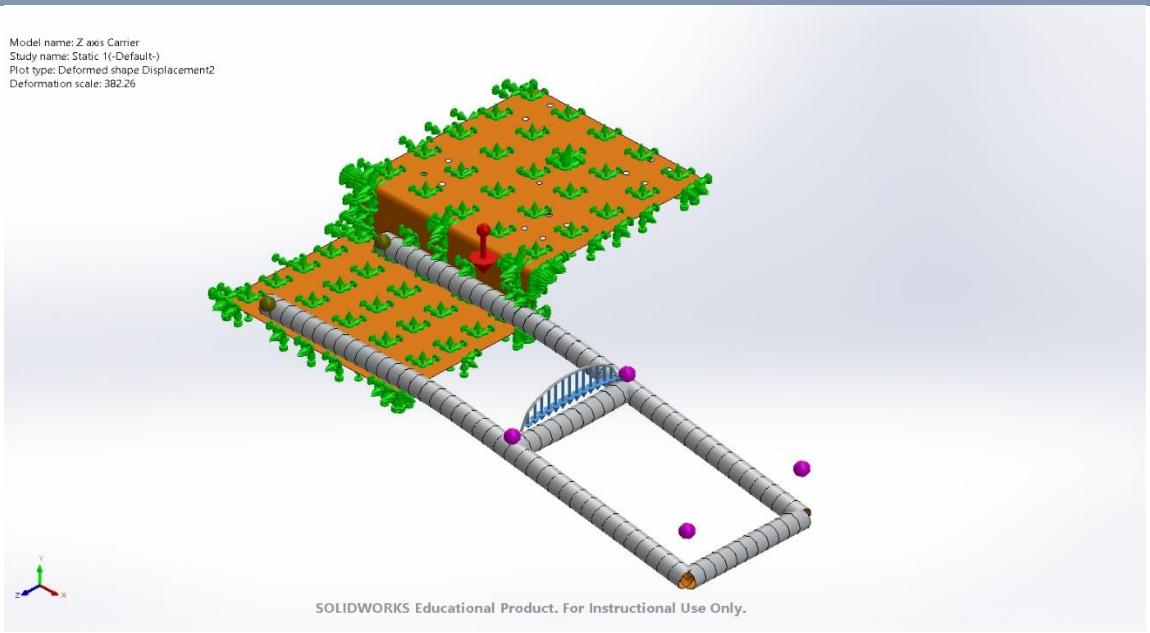
Name	Type	Min	Max
Stress2	VON: von Mises Stress	0.000e+00N/m^2 Node: 1	0.000e+00N/m^2 Node: 1

Name	Type	Min	Max



Z axis Carrier-Static 1-Stress-Stress2

Name	Type
Displacement2	Deformed shape



Z axis Carrier-Static 1-Displacement-Displacement2

Static Analysis Summary

The designed Z- Axis motor has capacity to easily lift and actuate for a payload of 10kg, from the Static Analysis we understand that the structure and design can lift and carry the payload of 5kg with any major deformation in any part. From the above figures we come to a conclusion that the payload capacity of more than 7kg can cause minor deformations in the aluminum graded beams and might disturb the functioning of the assembly. So it is advised and studied that a safe payload of 5kg is the capacity of the Z-Axis Carrier.

3.1.2. Electrical

The placement of electric components has been made in AutoCAD software as depicted in Figure 7 following IEEE standard of industrial guidelines with separating AC (220V) wiring to left and DC (48v) wires to the right. Wiring regulations often define a maximum fuse current rating of (10A) for these circuits. Overcurrent protection devices are essential in electrical systems to limit property damage and threats to human life. This standard provides test criteria to determine the suitability of heating devices and fittings that are used for commercial applications. The standard also includes detailed recommendations for the design, installation, and maintenance of electrical resistance heat tracing in these applications.

AutoCAD and Solidworks Electrical Wiring Diagrams

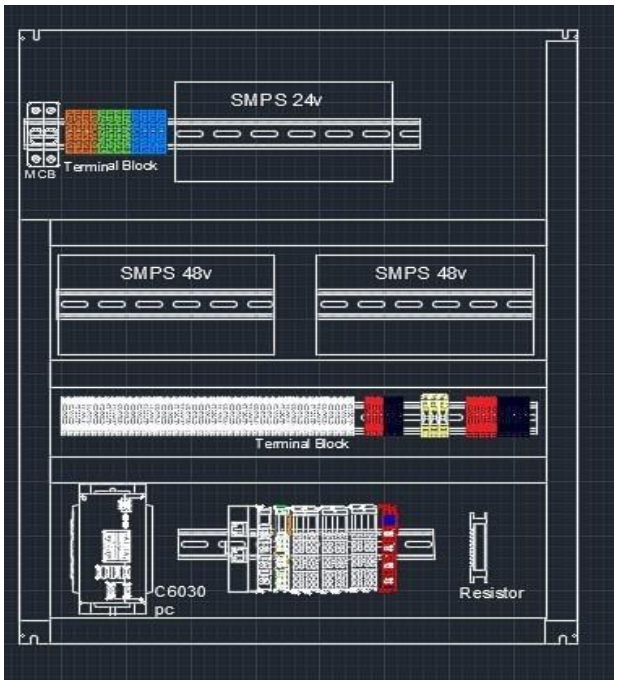


Figure 7 Control Panel Design AUTOCAD

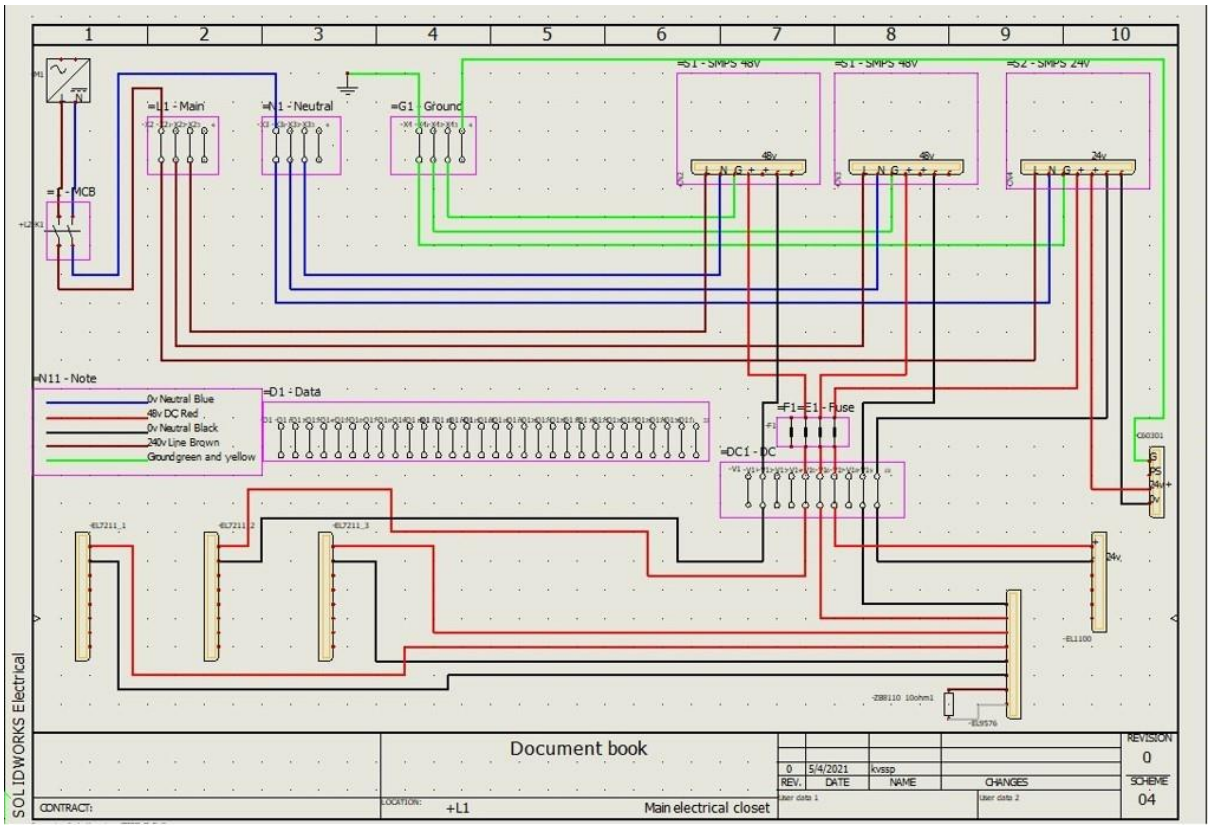


Figure 8 Wire Diagram of Electrical Components

3.2. Fabrication

Fabrication of our approach to the problem statement had many challenges as well as learnings for developing a functional and rugged Automated Storage and Retrieval system. Fabricating of the designed solution involved many machine operations such as Cutting of Aluminum beams, Laser Cutting of Sheet Metals, grindings, deburring, bore drill, tapping operations, fastener Application, etc.

These are some of the processes that are implied for fabricating and assembling various parts for the machine. The operations that are carried are done under the guidance of machine operation experts and proper safety measures are taken before the operations.

3.3. Software Architecture

An automated storage and retrieval system (ASRS) is a high-rise system which consists of computer-controlled methods for automatically placing and retrieving loads from specific storage locations. Thus, reduces human intervention and avoids human error. C6030 Beckhoff IPC is used to control the hardware system with the structured text programming done with Beckhoff Twincat 3.0 software, it is used to configure and control motors.

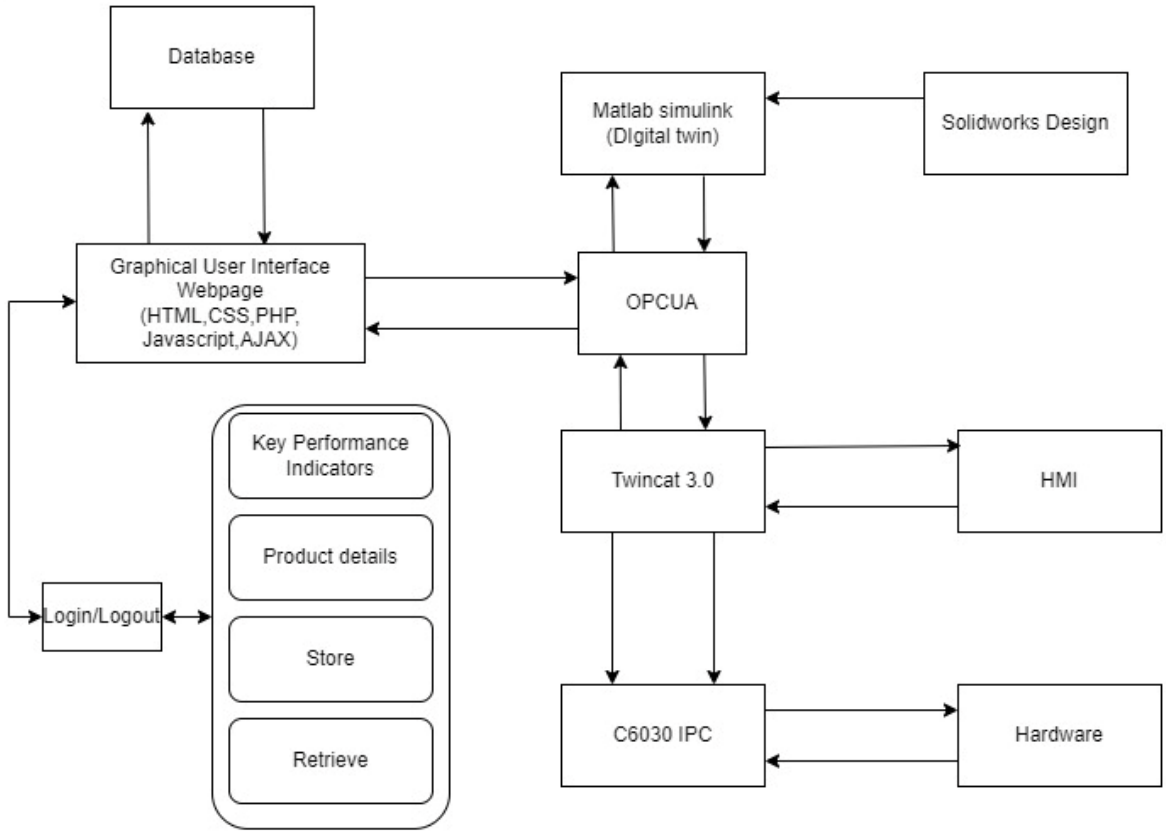


Figure 9 Software Architecture of ASRS

We have created an HMI to control the whole ASRS for storage and retrieval mechanisms. OPCUA network is being used to access and control the system for far distance and it is also used for digital twin under local ethernet. A Solidworks model is been imported to MATLAB-Simulink and code is been written to access the variables from TwinCAT to MATLAB for digital representation and controlling of ASRS.OPCUA network is been linked to the webpage interface where we can monitor the Key performance indicators and product details and can control the storage and retrieval operations from this webpage interface. The software architecture of ASRS is depicted in Figure 9.

3.4. Hardware Architecture

Hardware architecture refers to the identification of a system's physical components and their interrelationships as shown in Figure 10. This is also called hardware design model, that allows hardware designers to understand how their components fit into a system architecture and provides to software component designers important information needed for software development and integration.

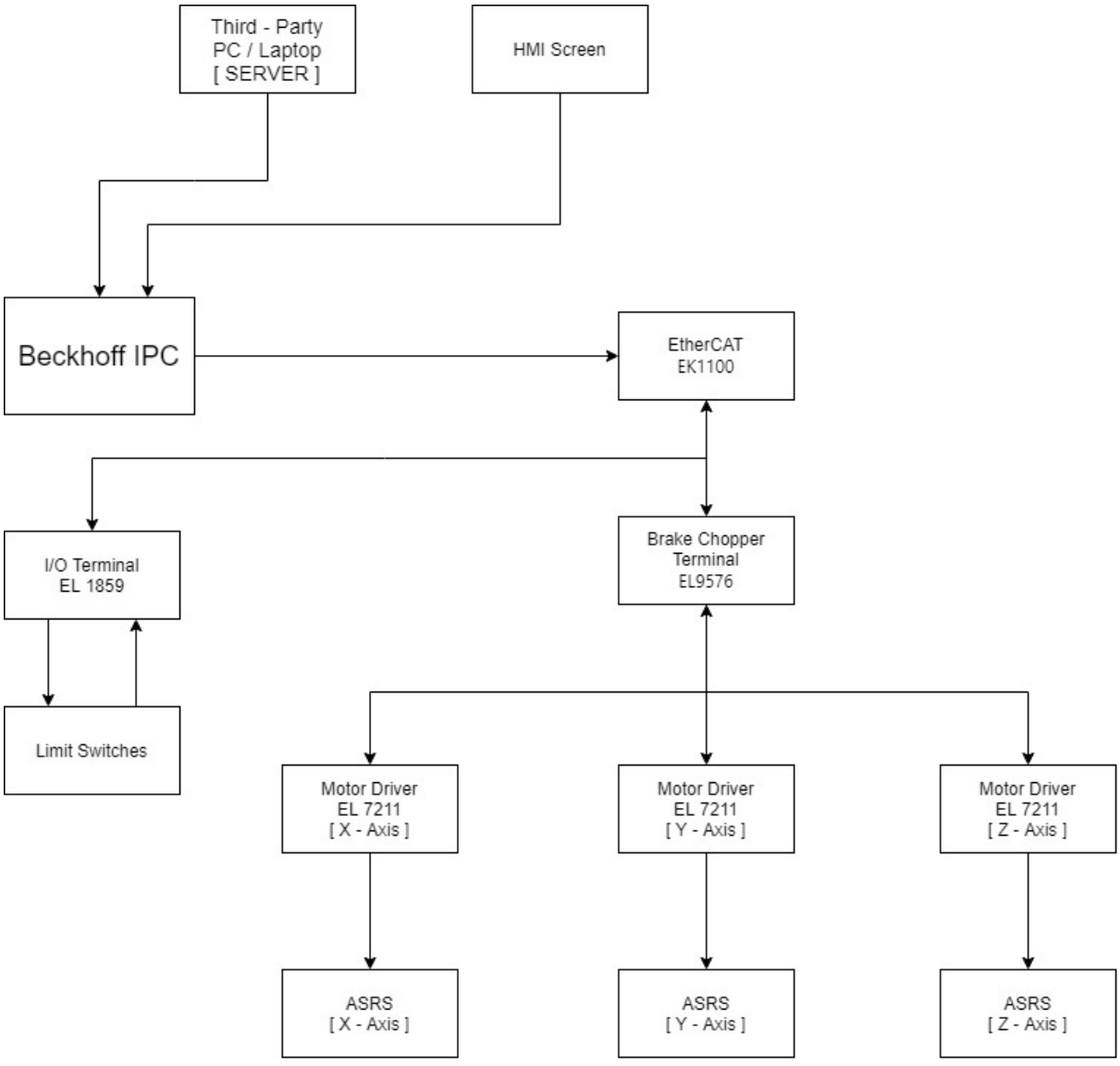


Figure 10 Hardware Architecture of ASRS

3.5. Use Case Diagram

In the Unified Modelling Language (UML), a use case diagram can summarize the details of your system's users (also known as actors) and their interactions with the system. An effective use case diagram can help in team discussion and represent scenarios in which the system or application interacts with people, organizations, or external systems, Goals that your system or application helps those entities (known as actors) achieve, the scope of your system. Use Case diagram for ASRS is depicted below in Figure 11.

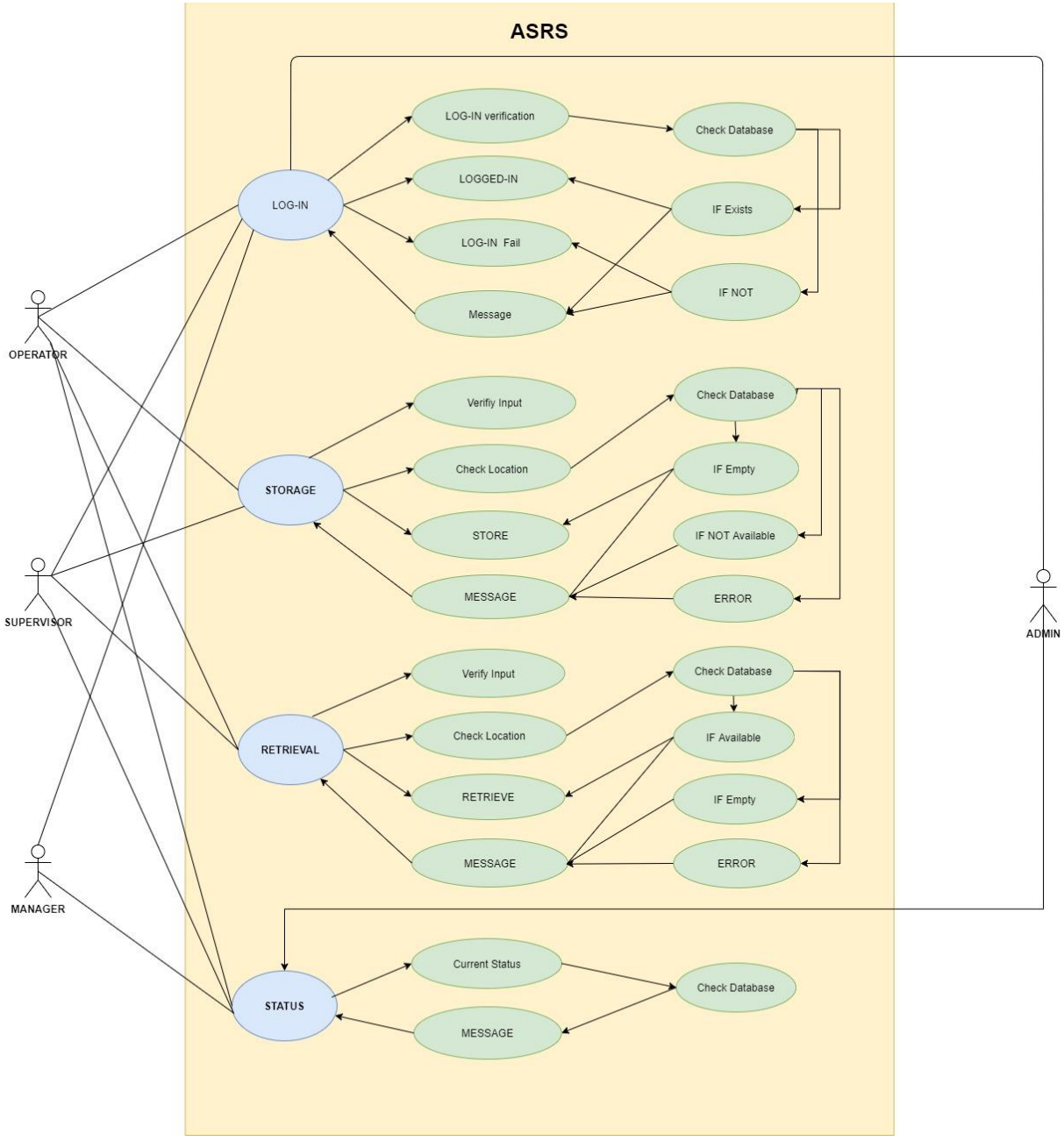


Figure 11 Use Case Diagram of ASRS

3.6. ER – diagram

An Entity Relationship (ER) Diagram is a type of flowchart that illustrates how entities such as people, objects or concepts relate to each other within a system. ER Diagrams are most often used to design or debug relational databases in the fields of software engineering, business information systems, education and research. ER diagram for ASRS is depicted in Figure 12.

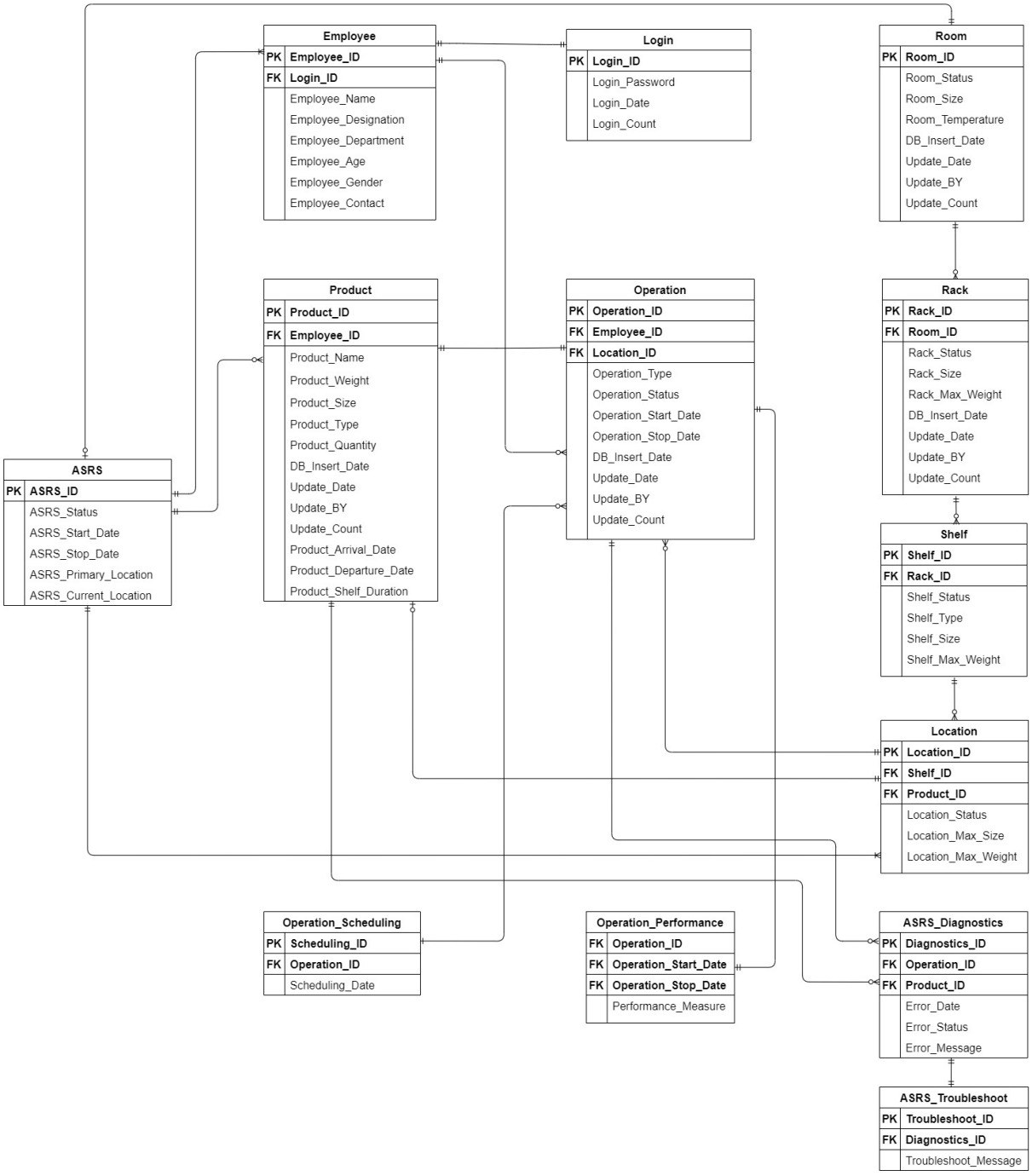


Figure 12 ER Diagram of ASRS

Chapter 4:

Methodology

To solve any engineering related problems, we need to follow certain procedures or methodology which further helps in better understanding of the problem and leads to solution which can be modified and updated according to different needs and purposes.

The best methodologies that solve any engineering related problem with whole new perspectives are Agile Methodology and Engineering Design.

Agile Methodology is a process which promotes continuous iteration of development and testing throughout the software development lifecycle of the project. The development of the model and testing of the model goes hand in hand in this methodology as shown in Figure *13*.

The Agile Methodology follows the following steps

1. Requirement's definition and Analysis of concepts
2. Planning of sprints
3. Collaborative design development
4. Creation and implementation
5. Review and Monitor.

Figure 13 Agile Methodology

Source: https://www.nvisia.com/insights/agile-methodology

The engineering design process (ED) is a process which has series of steps that engineers follow to come up with a solution to any given need statement or problem. This process is followed when the product involves designing, building and testing as shown in Figure 14.

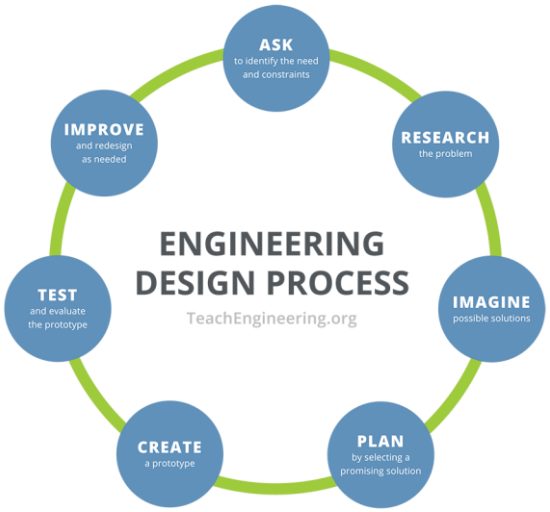


Figure 14 Engineering Design Process Flow

The V-model is verification and validation model as displayed in Figure 15. It is based on the association of a testing phase for each corresponding development stage. Development of each step directly associated with the testing phase. The next phase starts only after completion of the previous phase i.e., for each development activity, there is a testing activity corresponding to it.

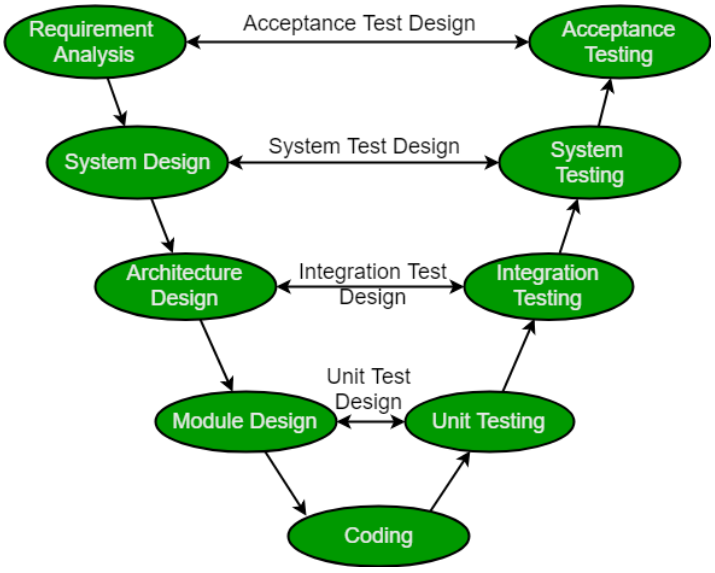
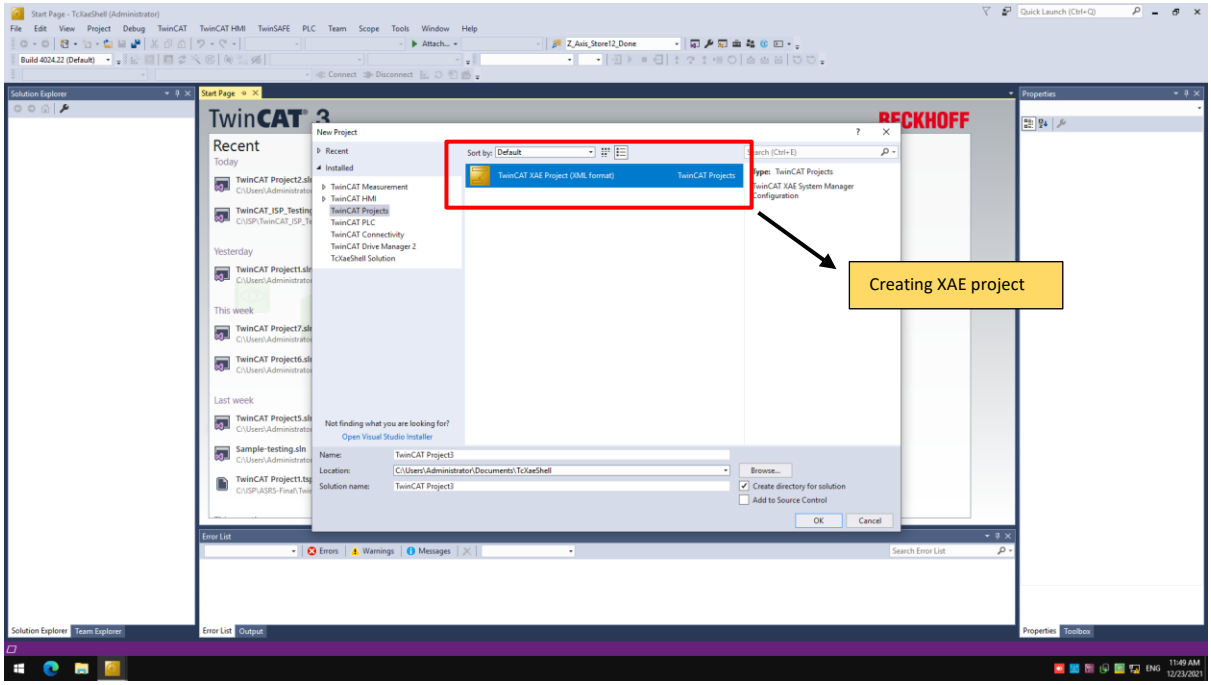


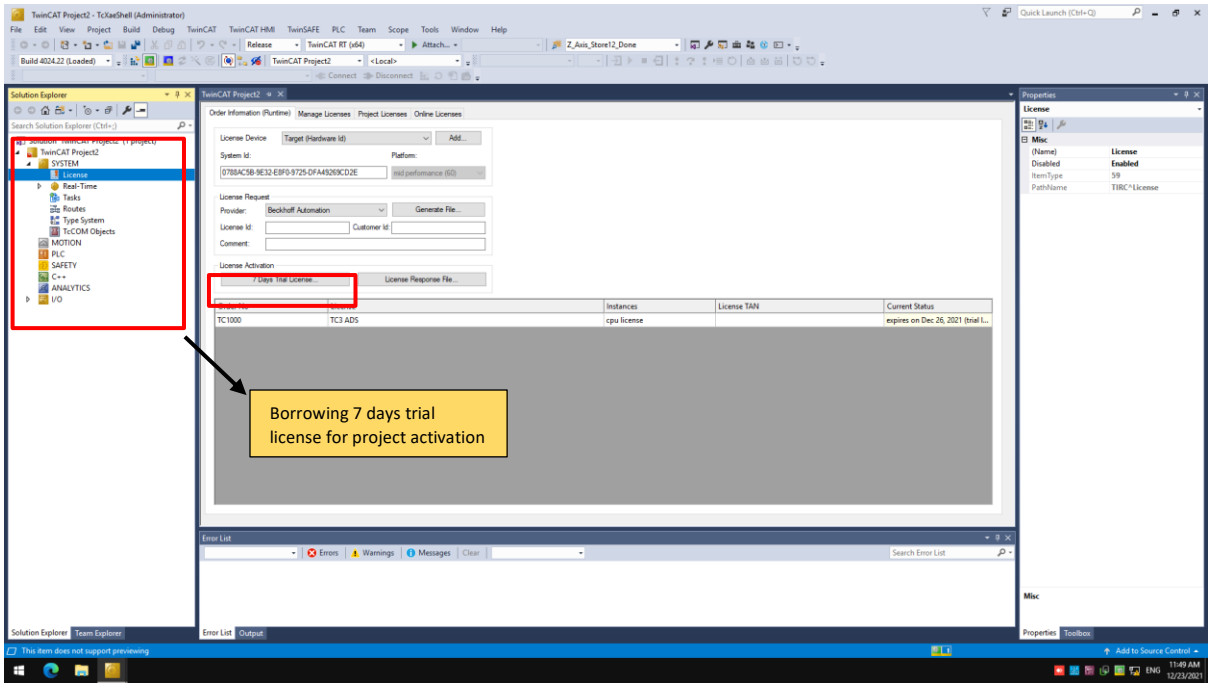
Figure 15 V-Model

4.1. TwinCAT

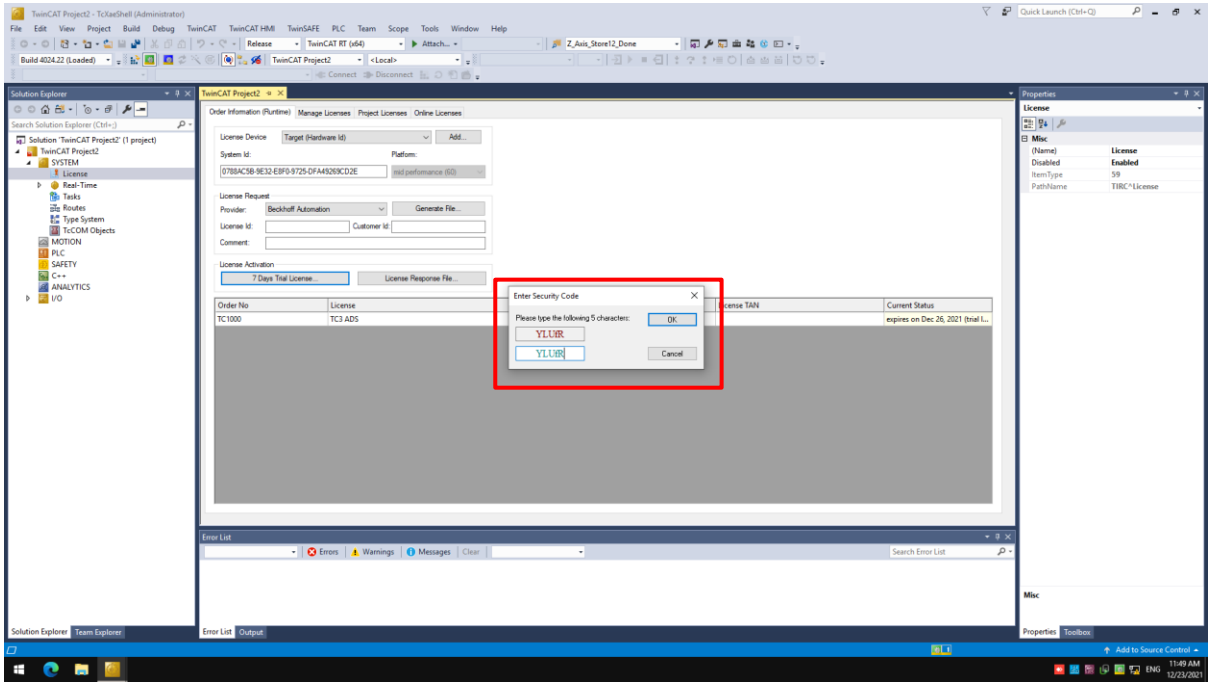
The TwinCAT (The Windows Control and Automation Technology) automation suite forms the core of the control system. The TwinCAT software system turns almost any PC-based system into a real-time control with multiple PLC, NC, CNC and/or robotics runtime systems.

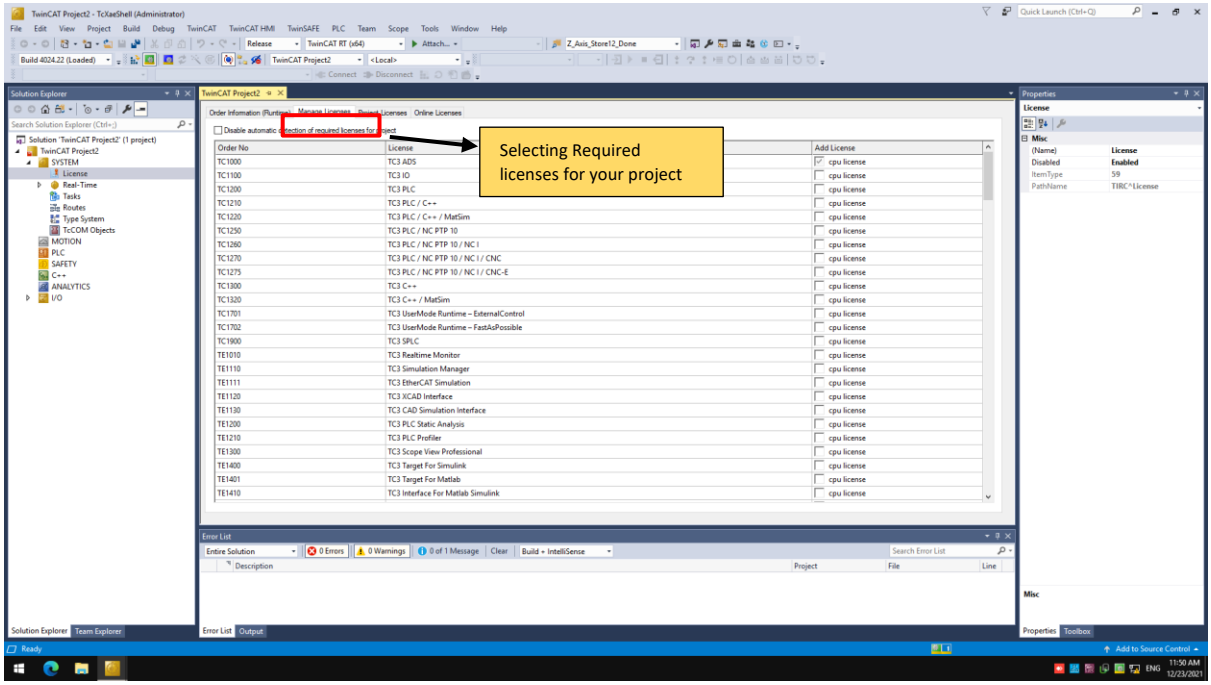
4.1.1 Creating Twincat Project



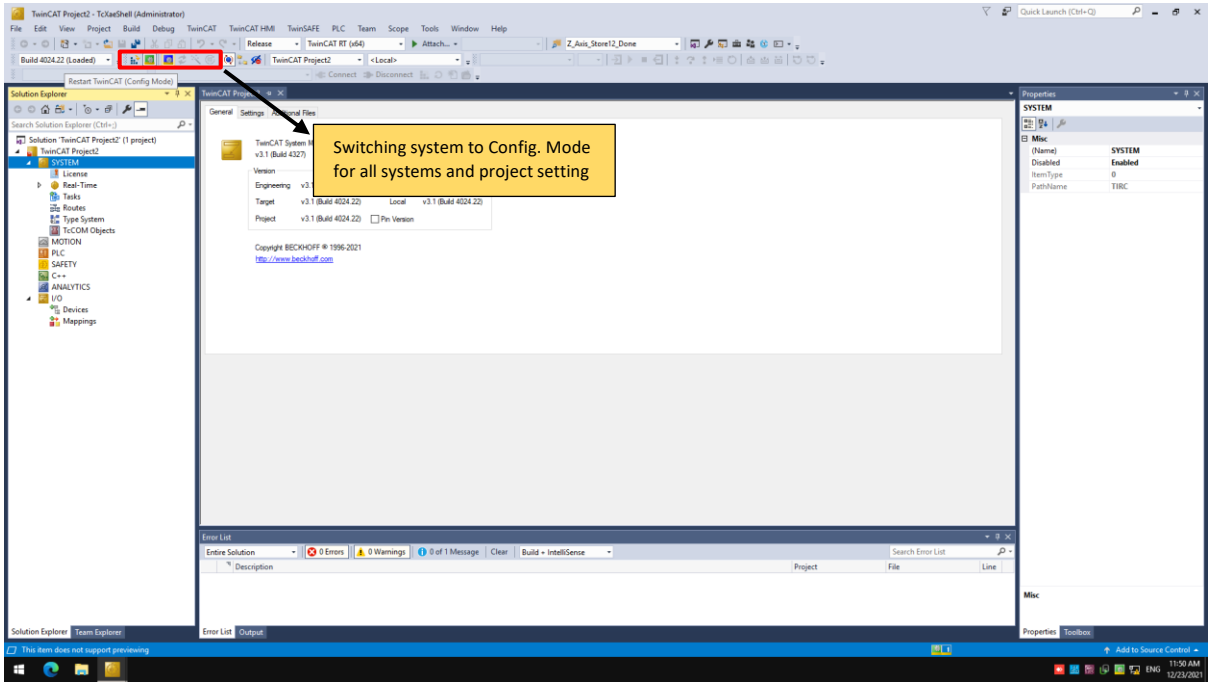


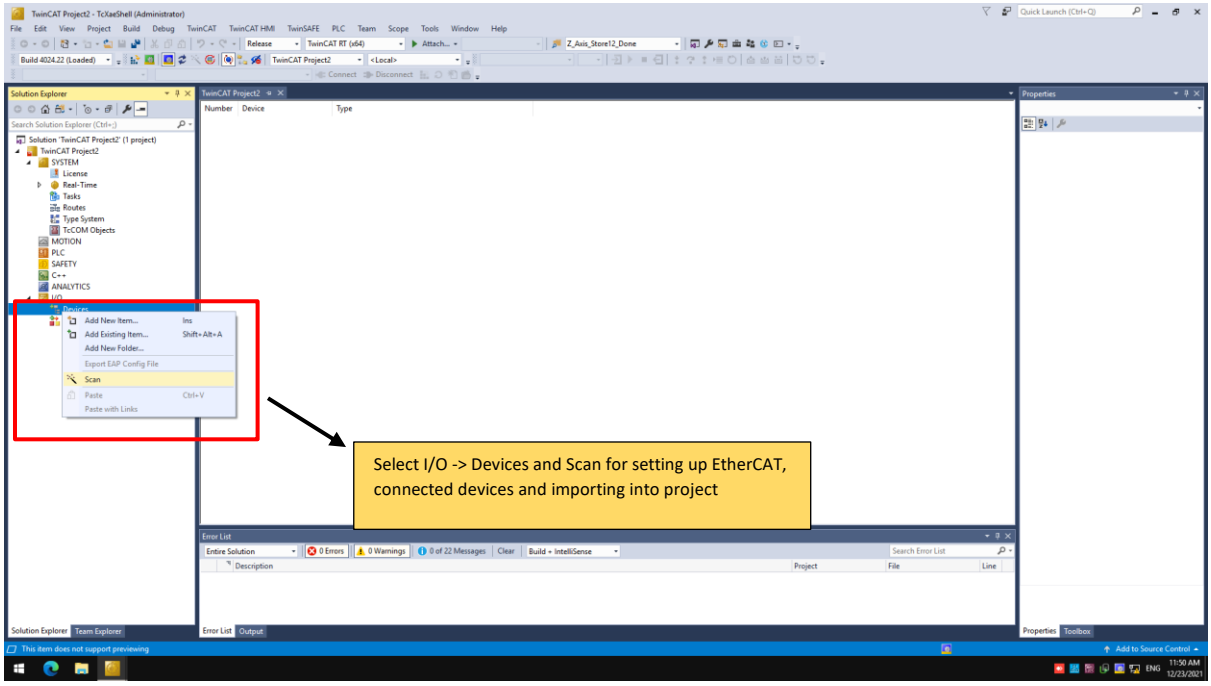
4.1.2 Borrowing License for Project

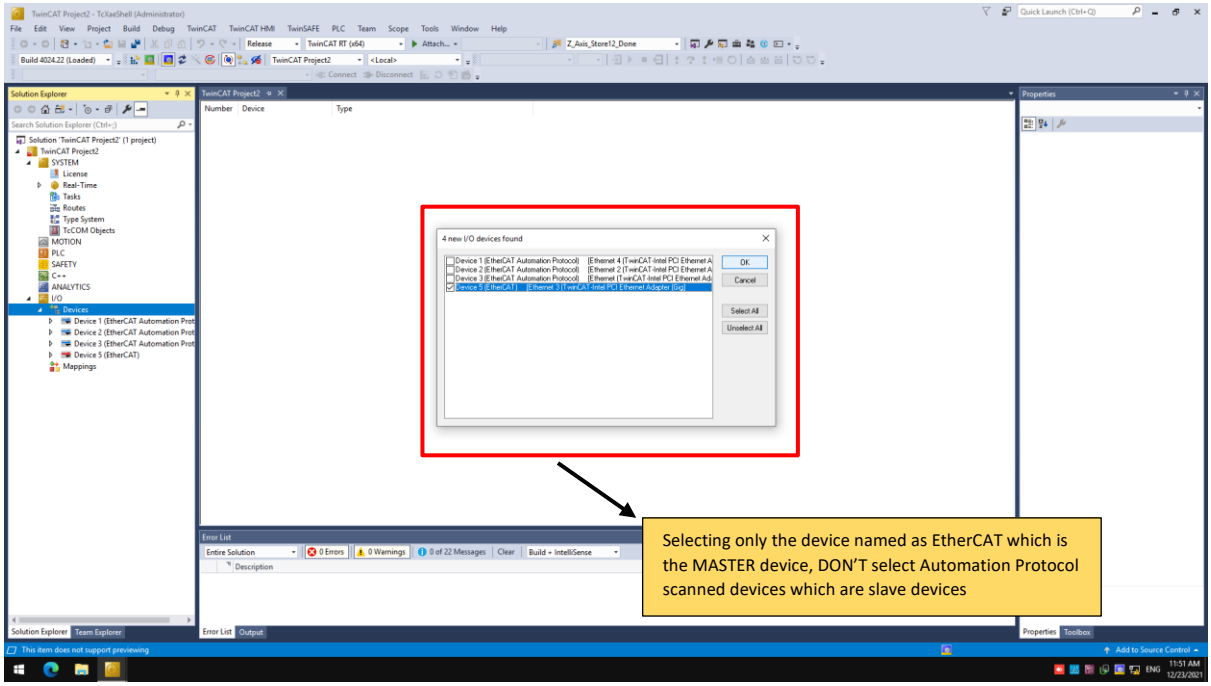


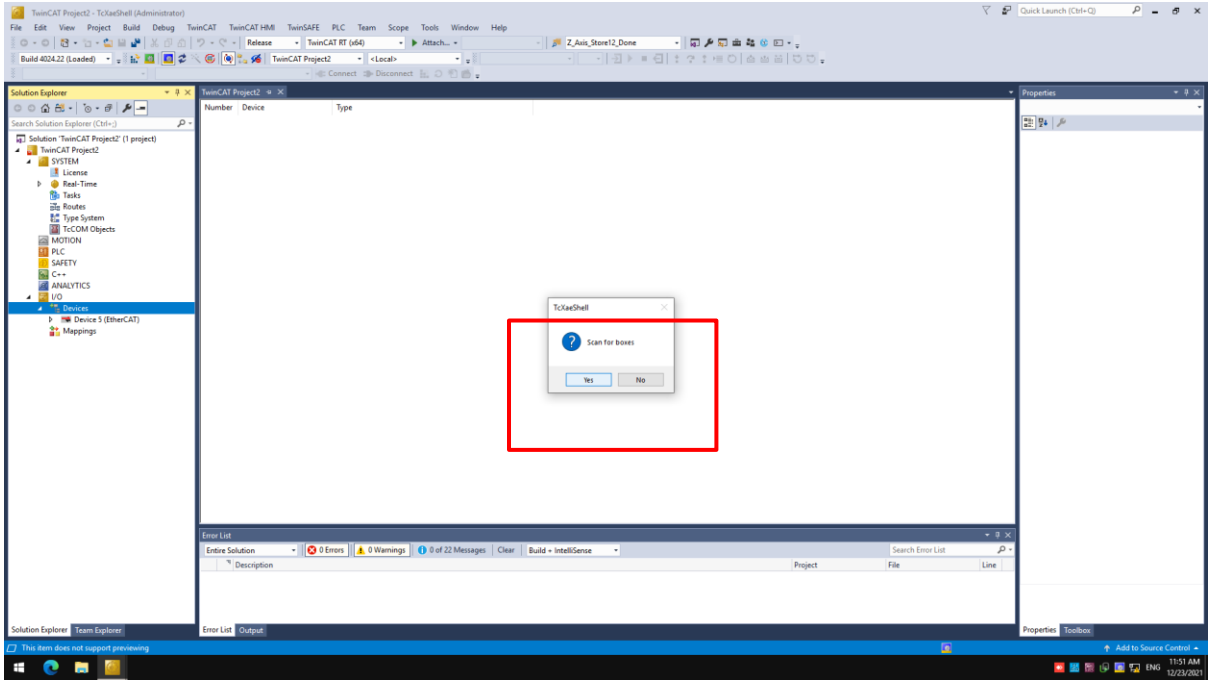


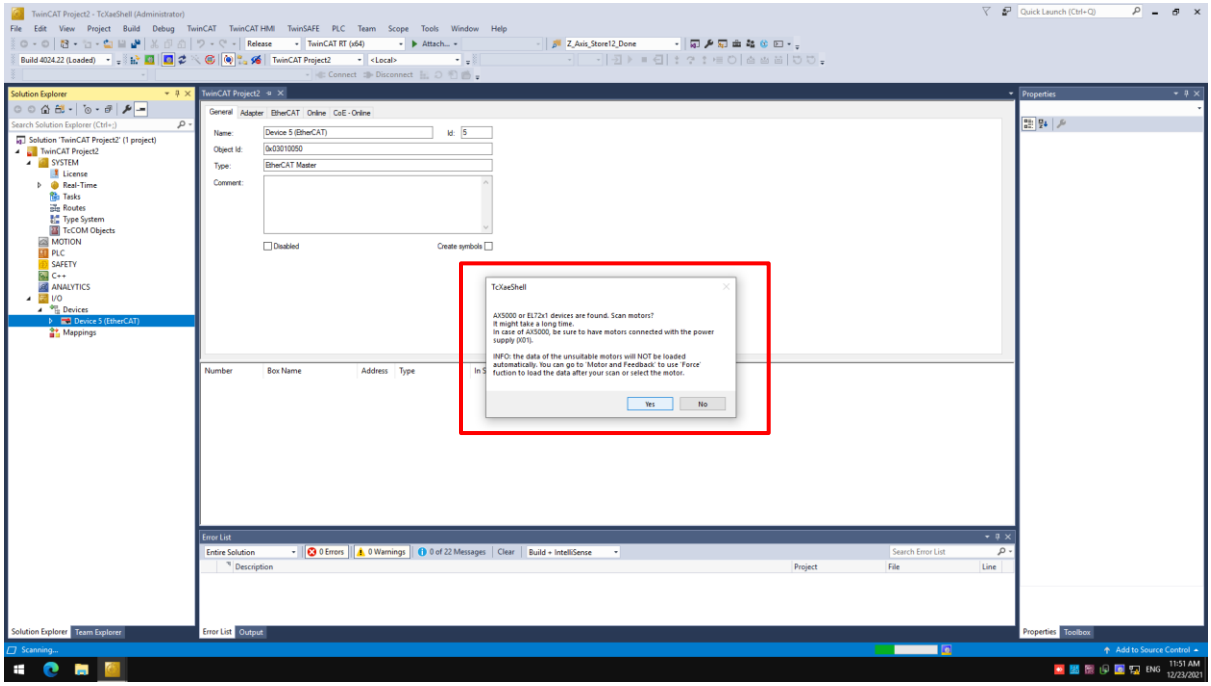
4.1.3 Initial Project Setup and Scanning of Beckhoff Hardware

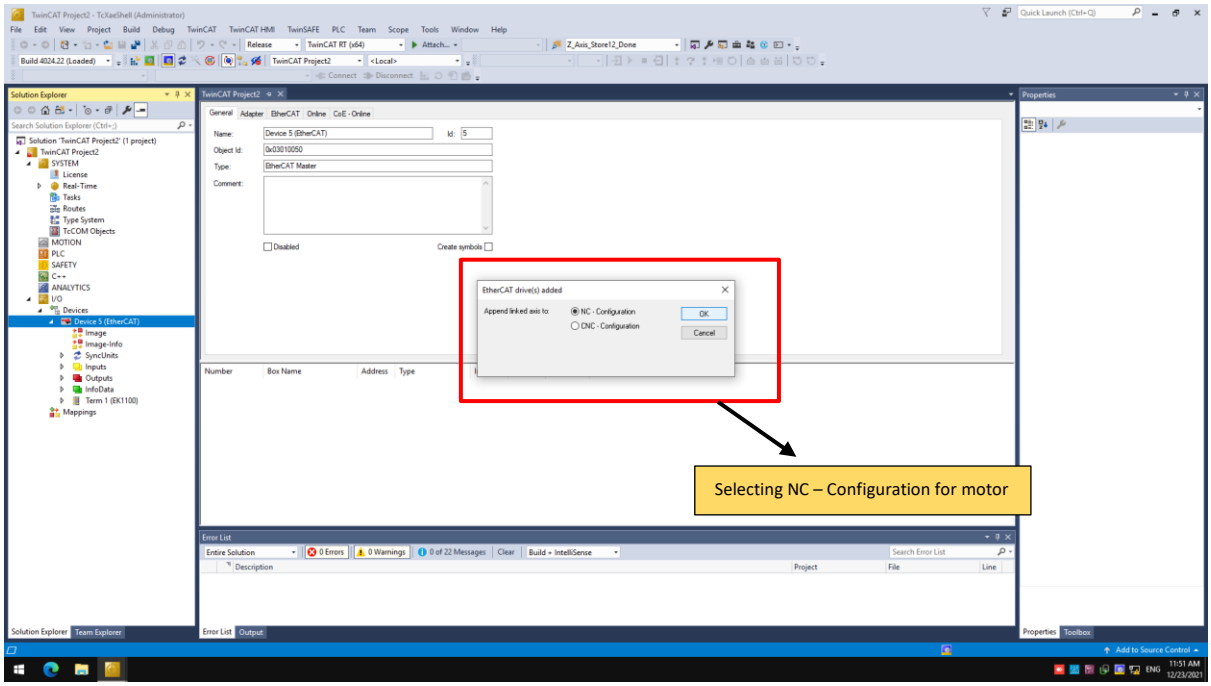


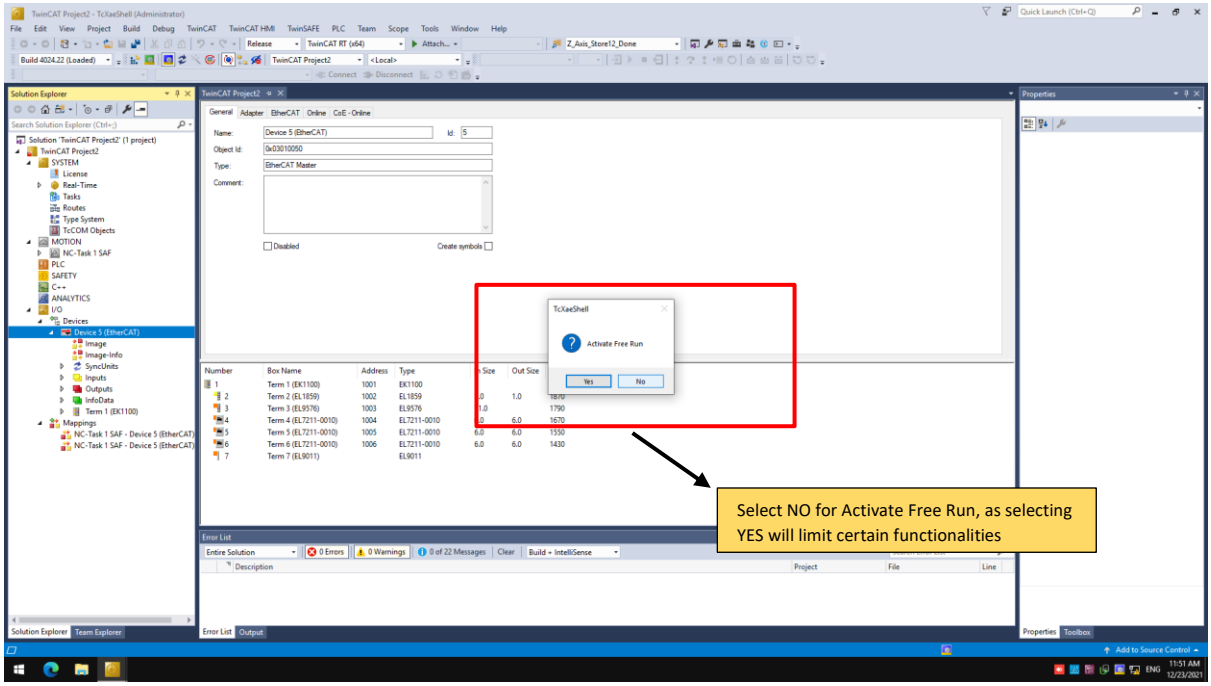


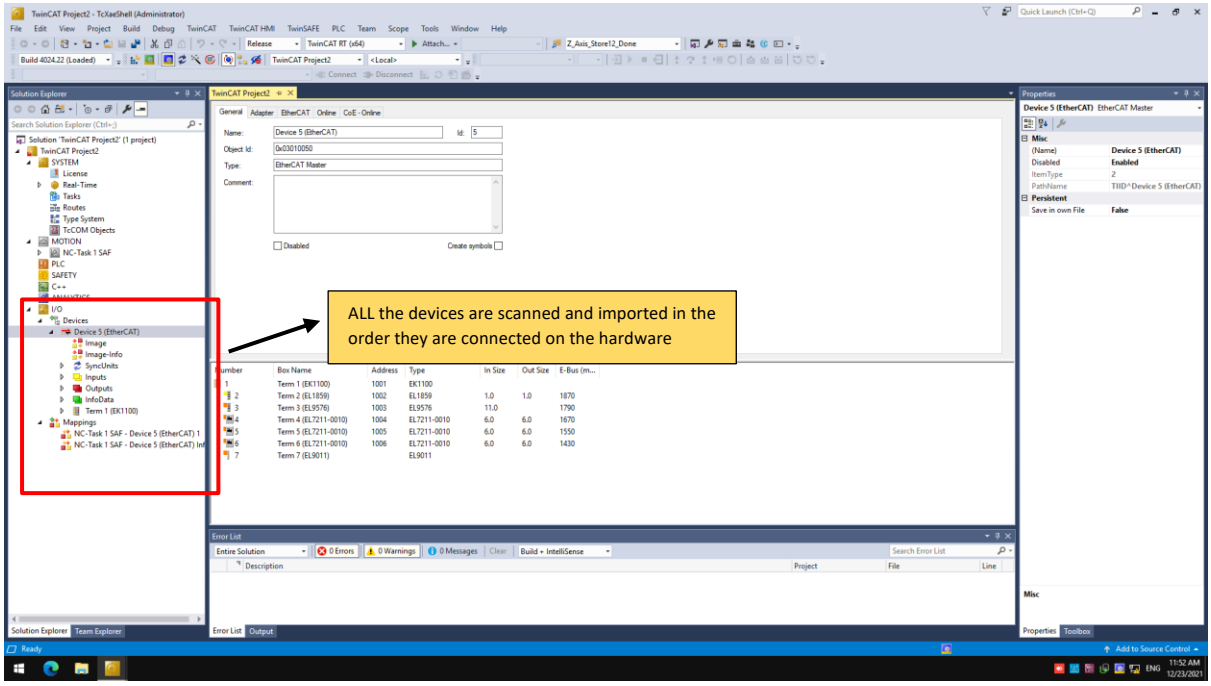

4 new I/O devices found
OK
Cancel
Select All
Unselect All
Selecting only the device named as EtherCAT which is the MASTER device, DON'T select Automation Protocol scanned devices which are slave devices


TcXaeShell
Scan for boxes
Yes
No

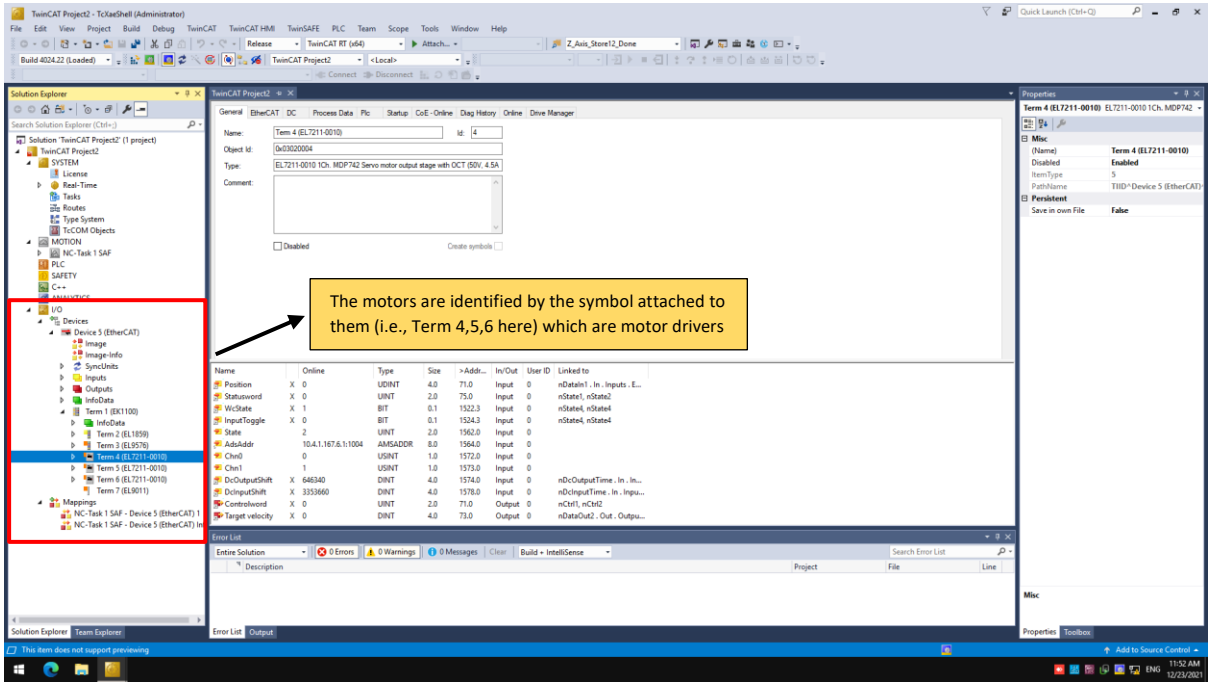

TcXaeShell
AX5000 or EL72x1 devices are found. Scan motors?
It might take a long time.
In case of AX5000, be sure to have motors connected with the power supply (W/).
INFO: the data of the unsuitable motors will NOT be loaded automatically. You can go to 'Motor and Feedback' to use 'Force' fuction to load the data after your scan or select the motor.
Yes
No

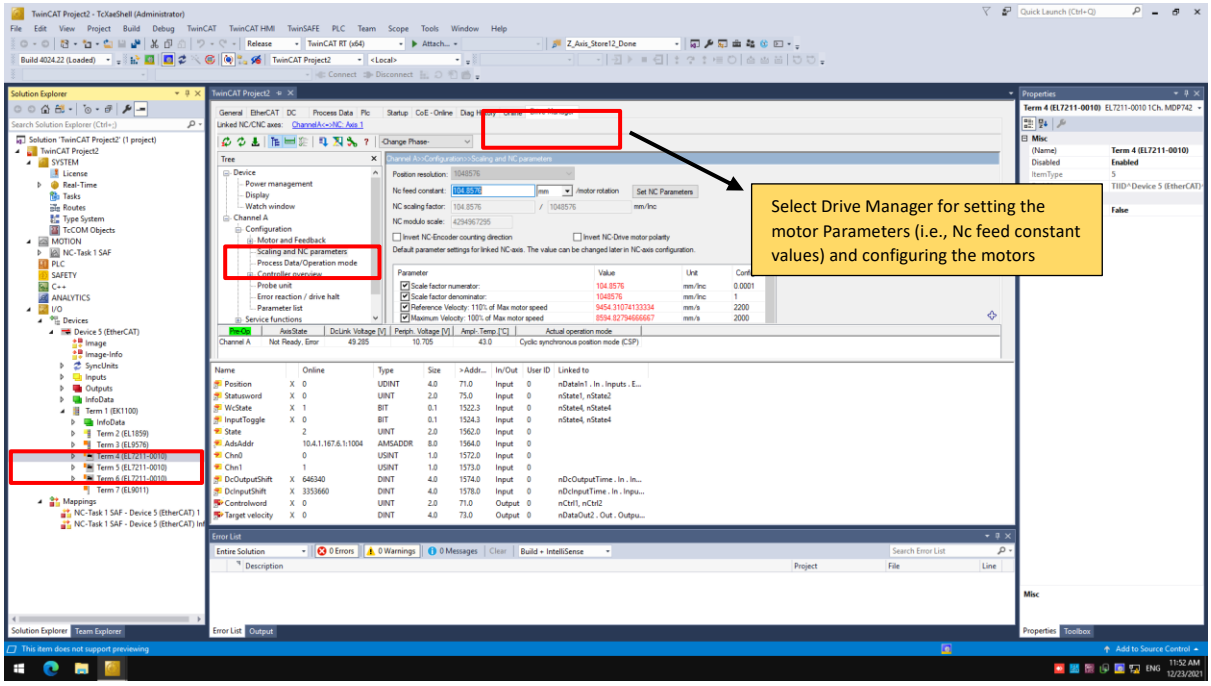

EtherCAT drive(s) added
Append linked axis to:
NC - Configuration
CNC - Configuration
OK
Cancel
Selecting NC – Configuration for motor

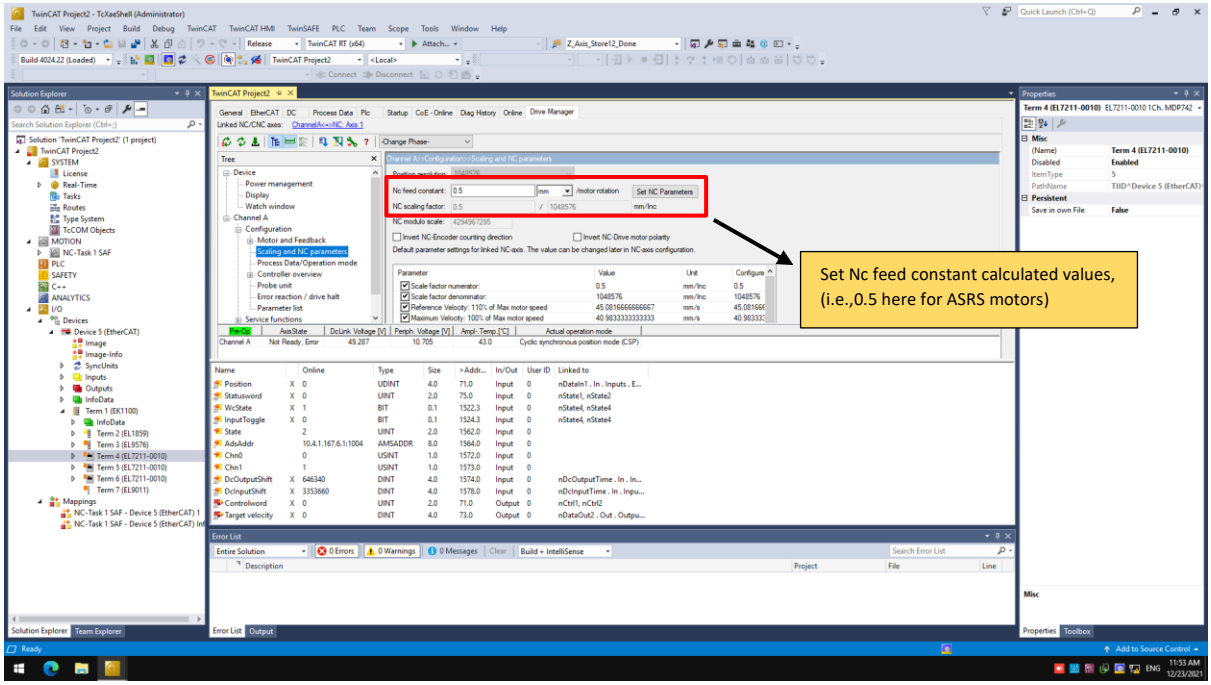

Select NO for Activate Free Run, as selecting YES will limit certain functionalities

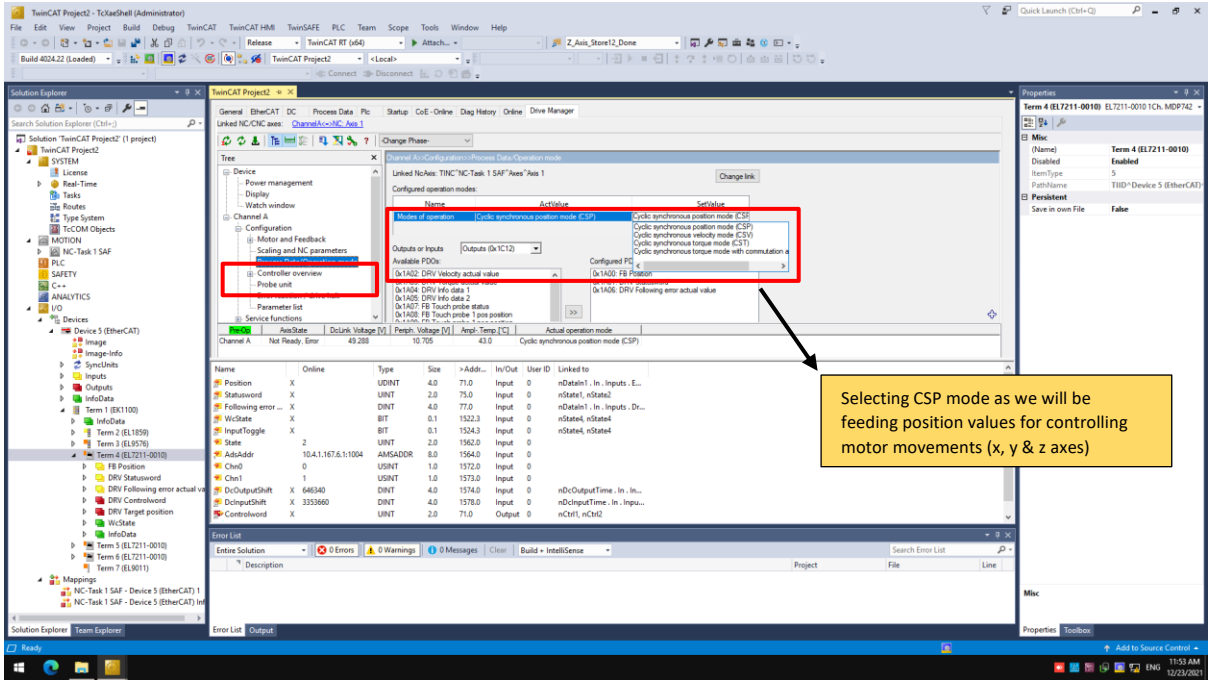

ALL the devices are scanned and imported in the order they are connected on the hardware

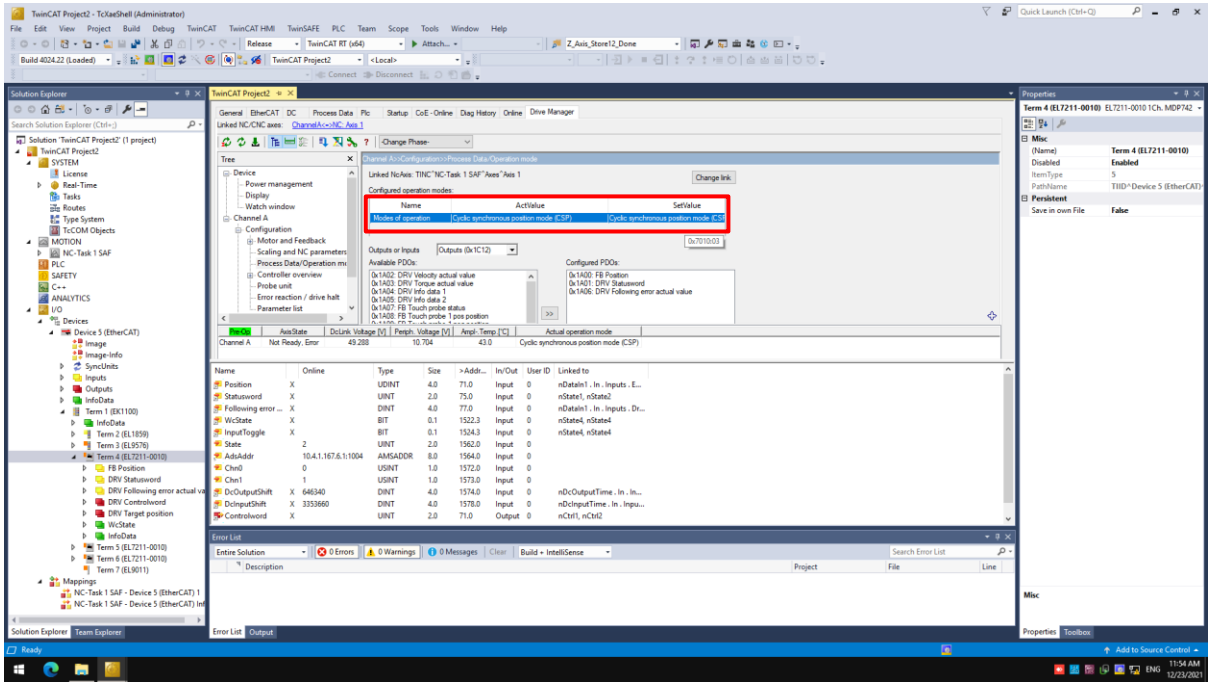
4.1.4 Motor Parameters Configuration

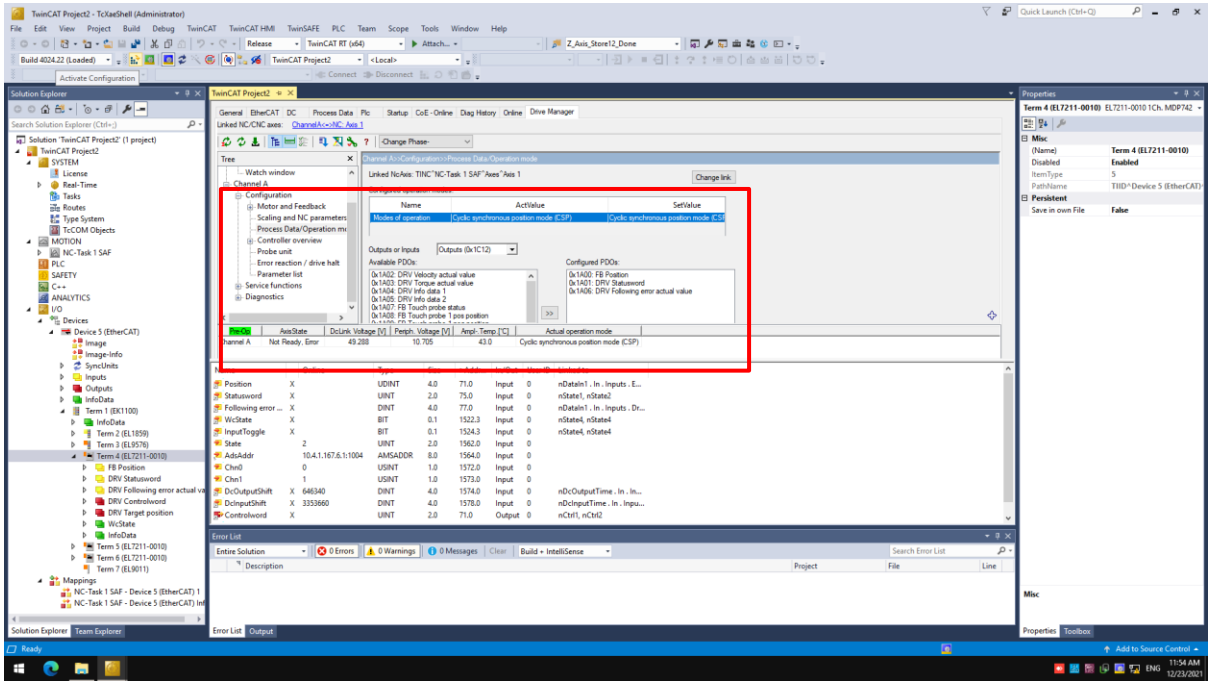




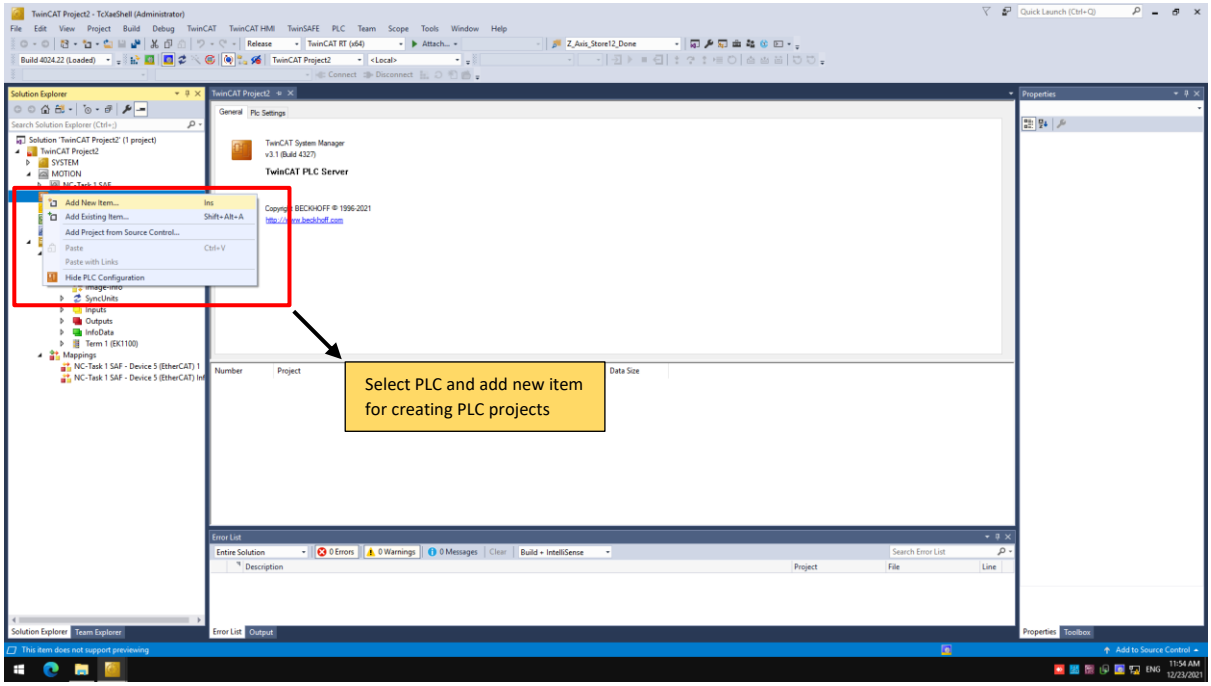

Set Nc feed constant calculated values, (i.e.,0.5 here for ASRS motors)

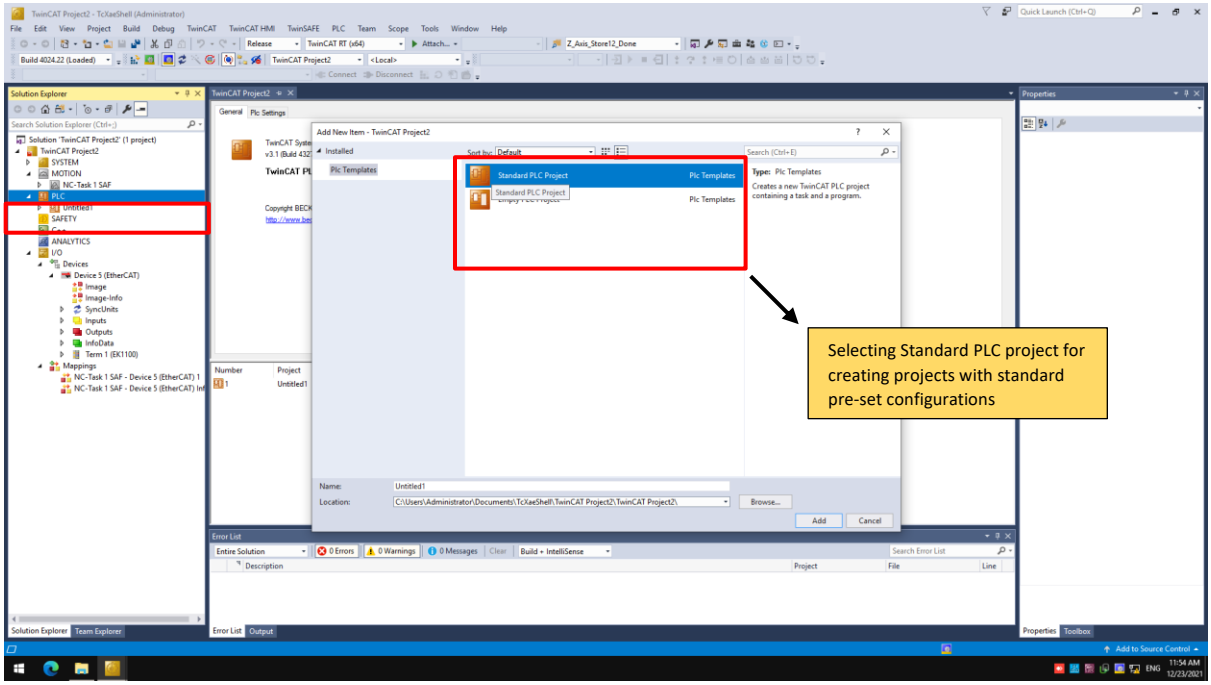

Selecting CSP mode as we will be feeding position values for controlling motor movements (x, y & z axes)

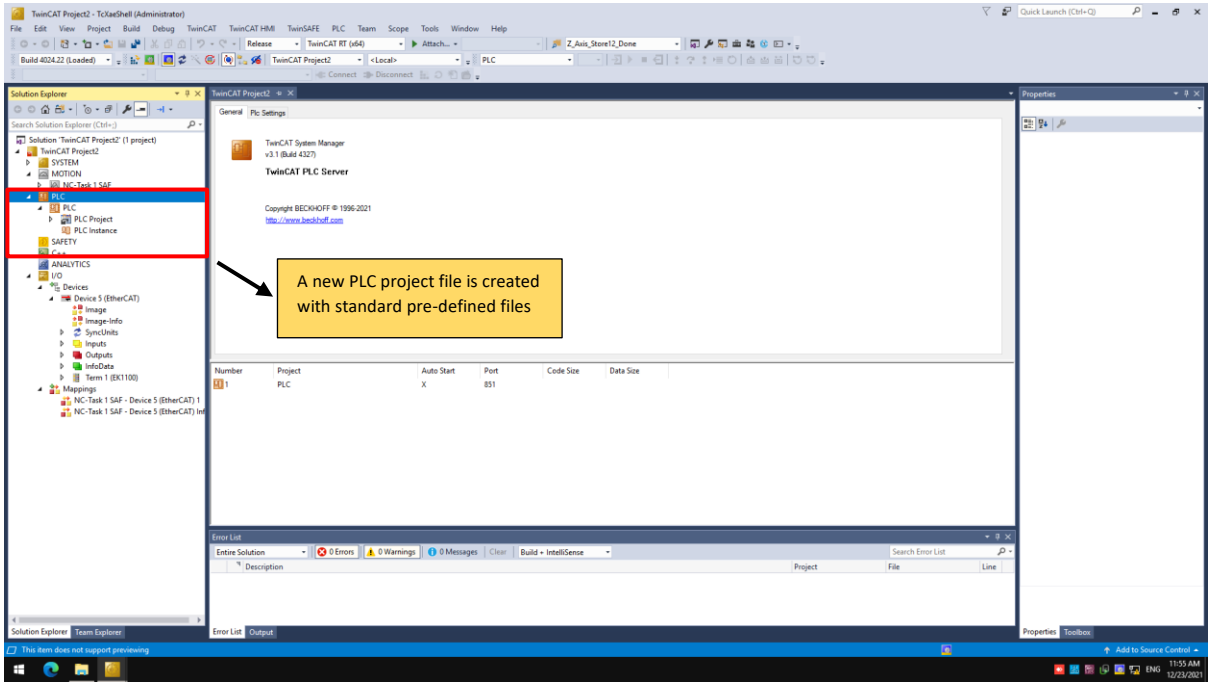


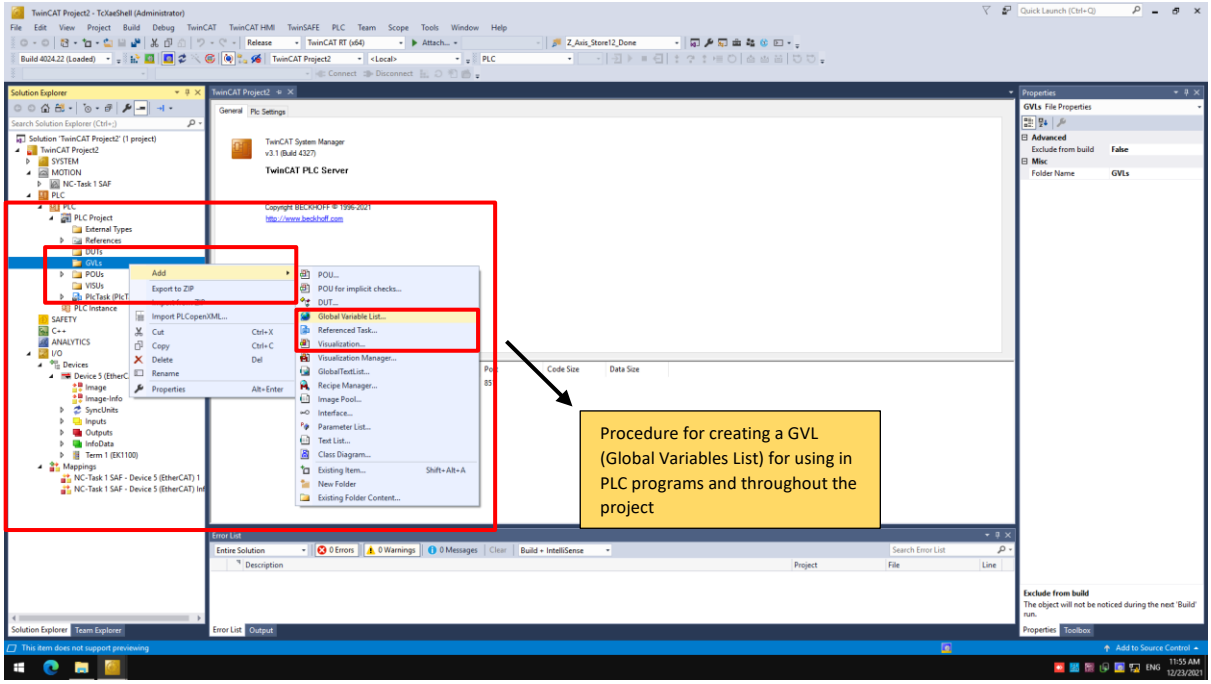


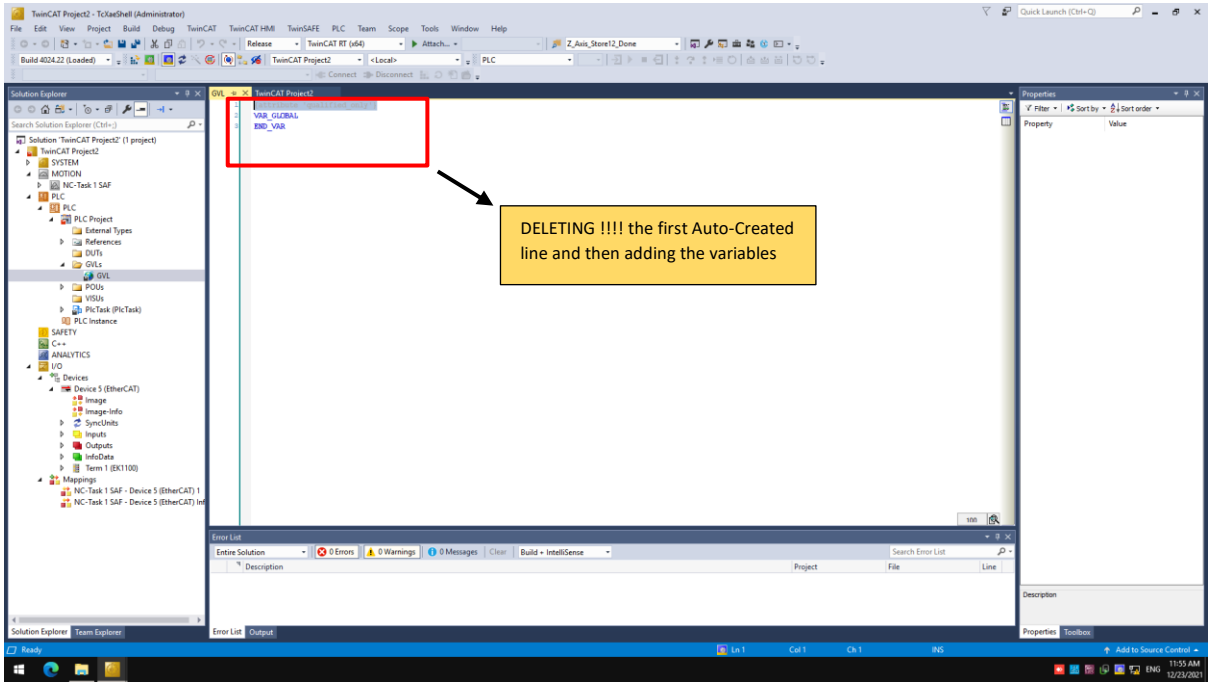
4.1.5 Creating PLC project and programs

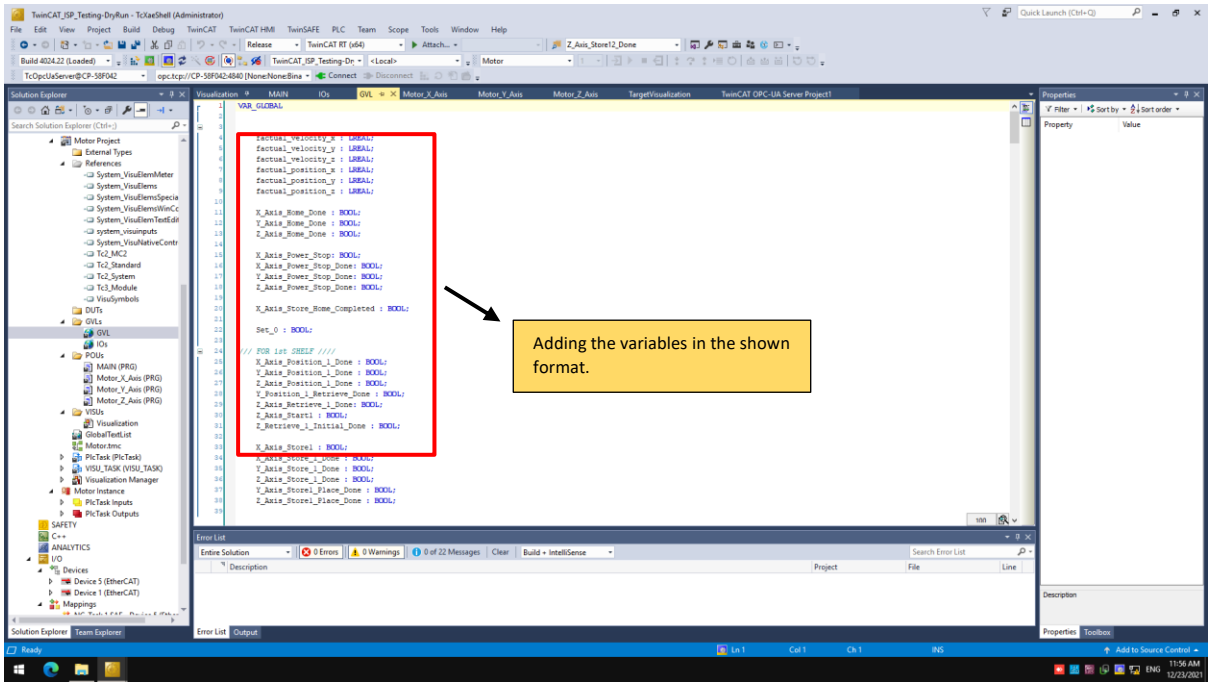




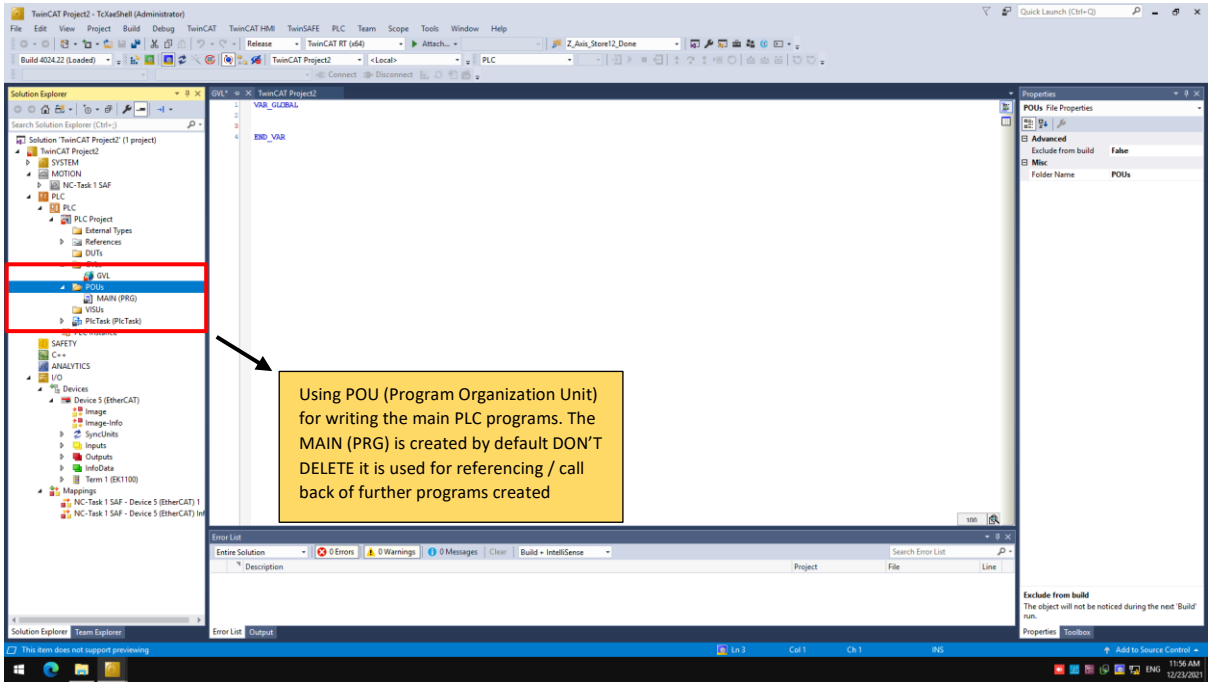

A new PLC project file is created with standard pre-defined files

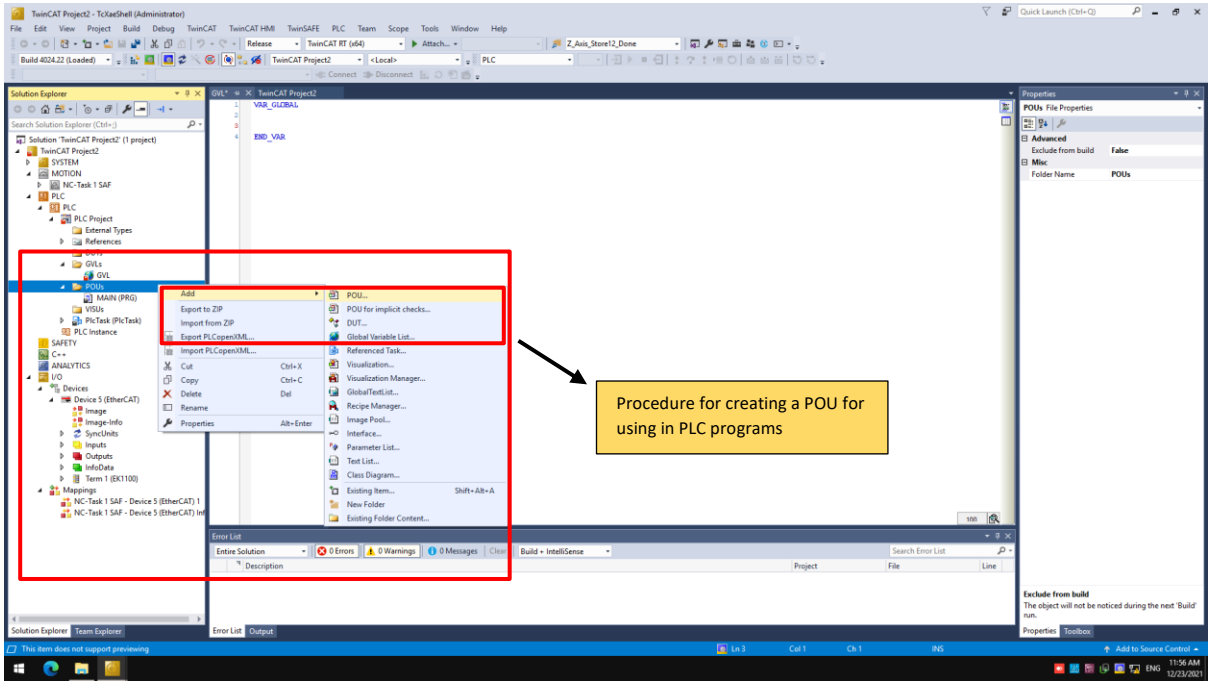

Procedure for creating a GVL (Global Variables List) for using in PLC programs and throughout the project

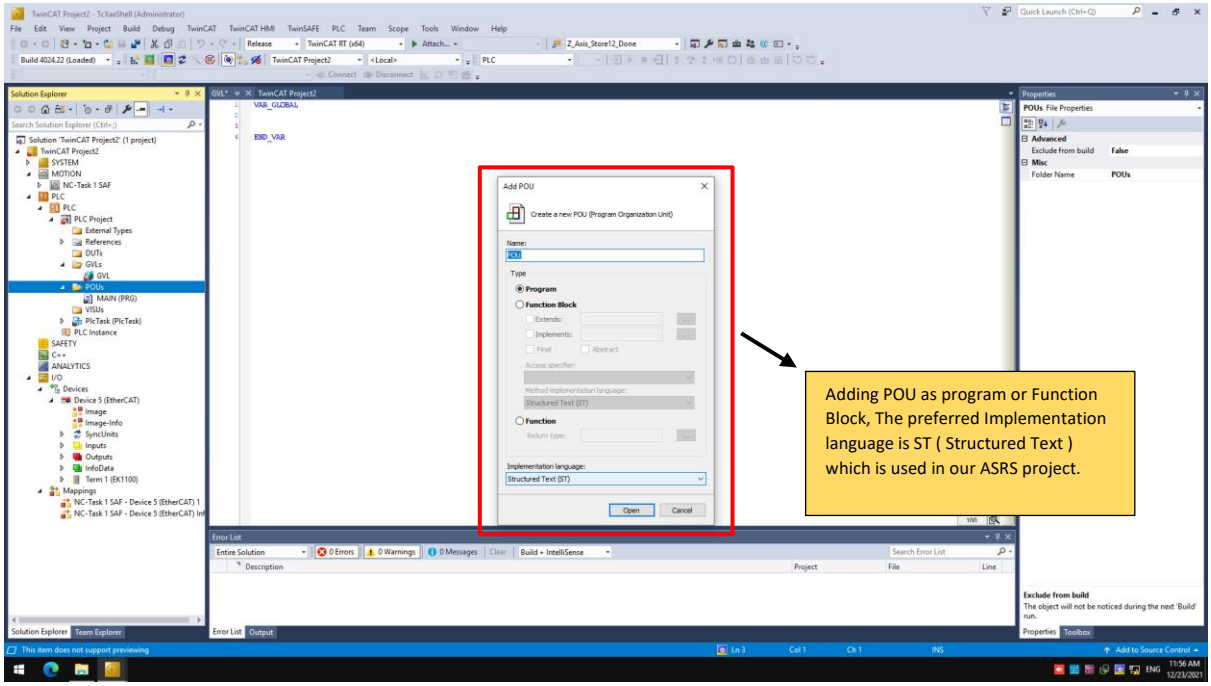

VAR_GLOBAL
END_VAR
DELETING !!!! the first Auto-Created line and then adding the variables

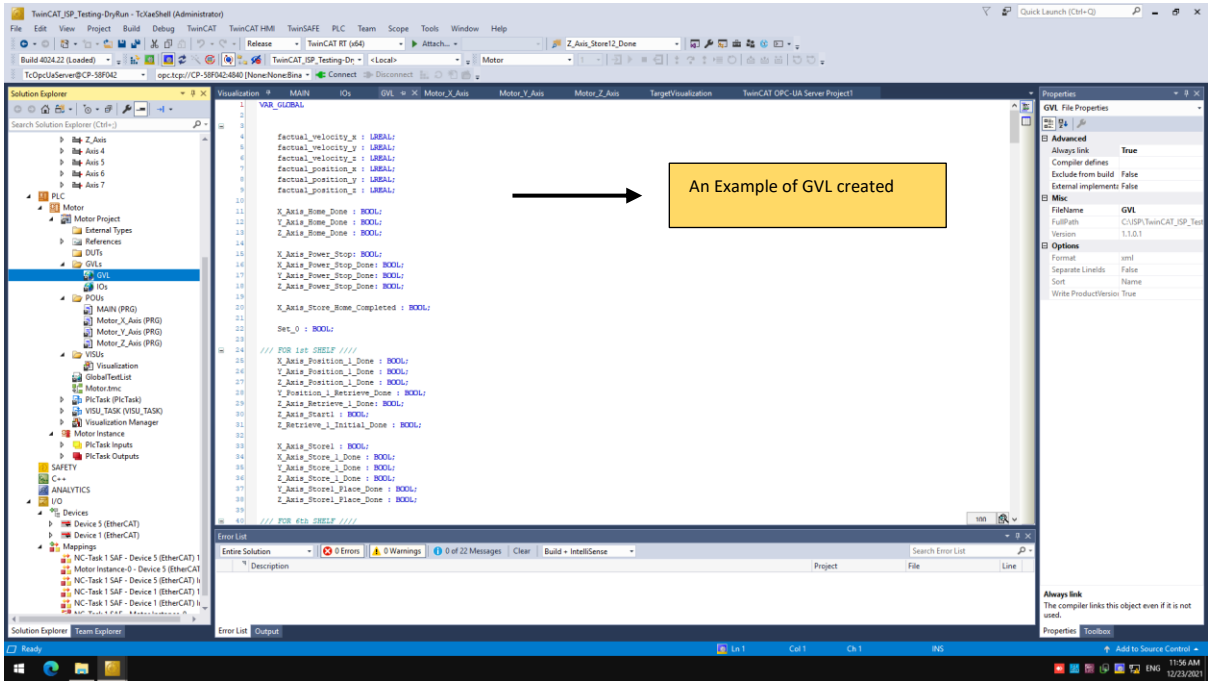

VAR_GLOBAL
Adding the variables in the shown format.

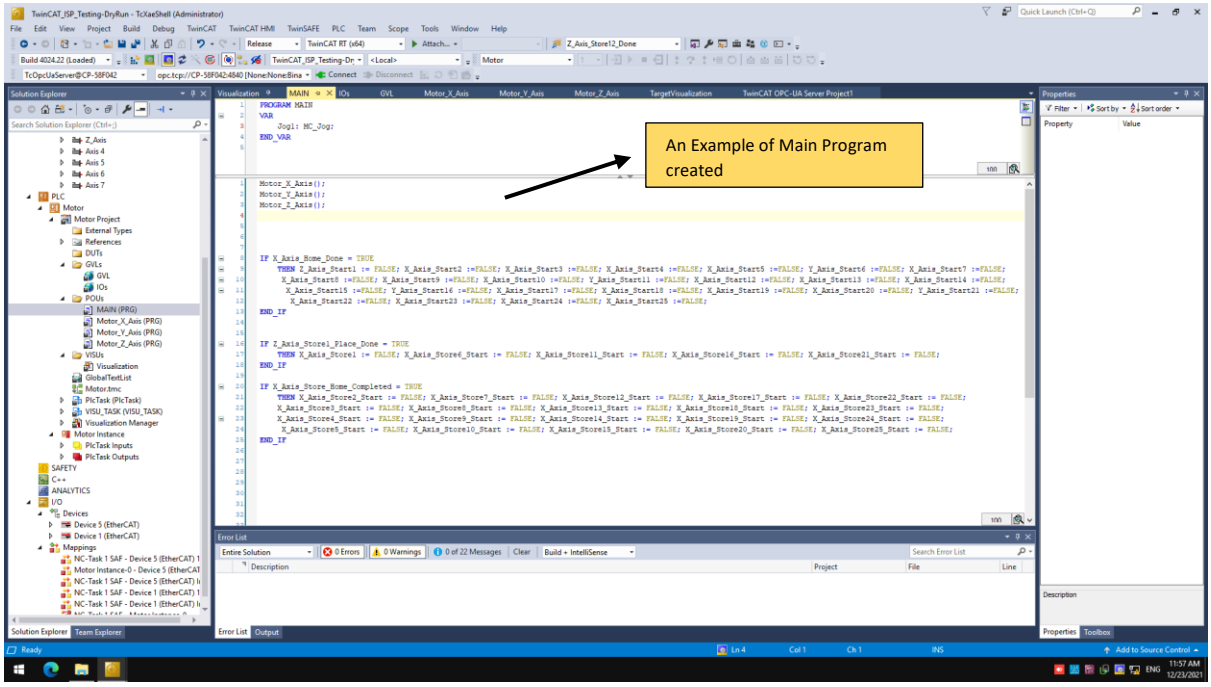
4.1.5.1 Creating program files and implementation procedures

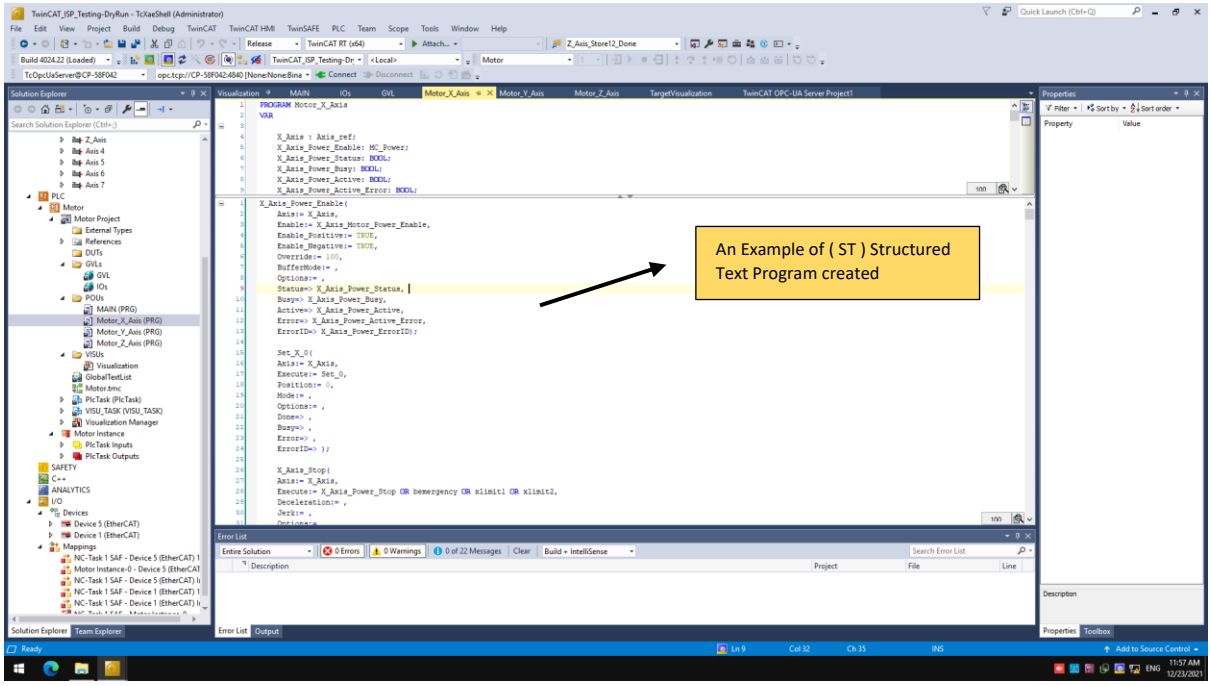




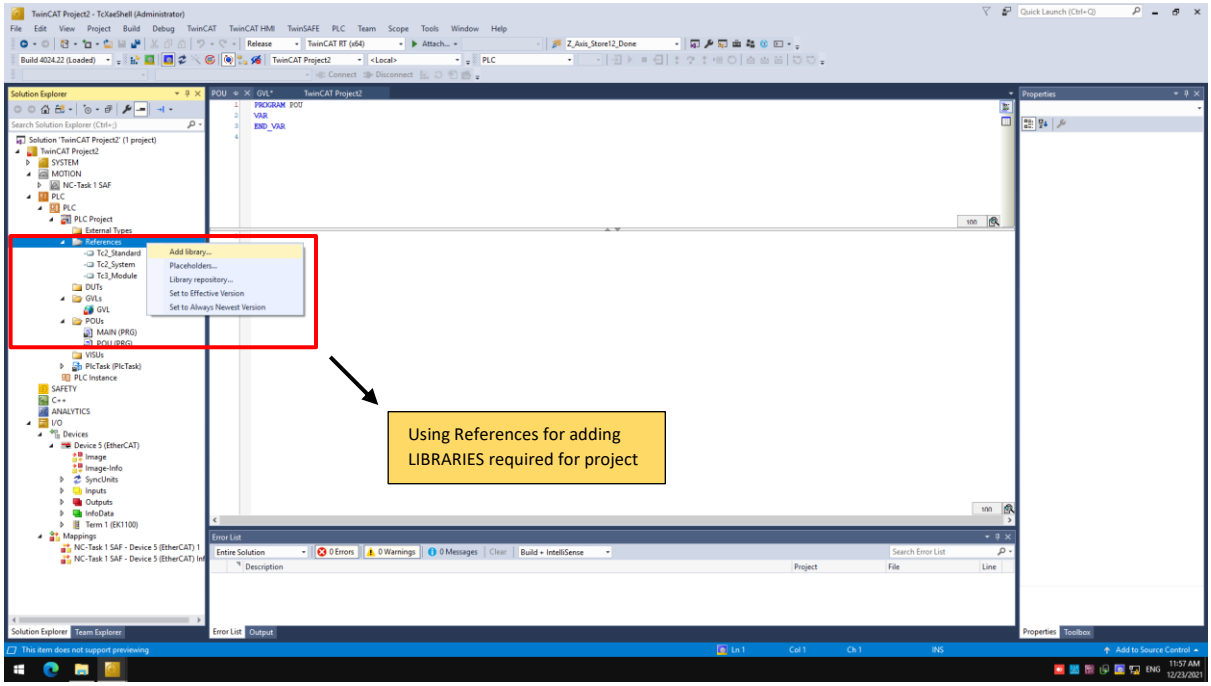

Add POU
Create a new POU (Program Organization Unit)
Name:
Type
Program
Function Block
Function
Implementation language:
Structured Text (ST)
Open
Cancel
Adding POU as program or Function Block, The preferred Implementation language is ST (Structured Text) which is used in our ASRS project.

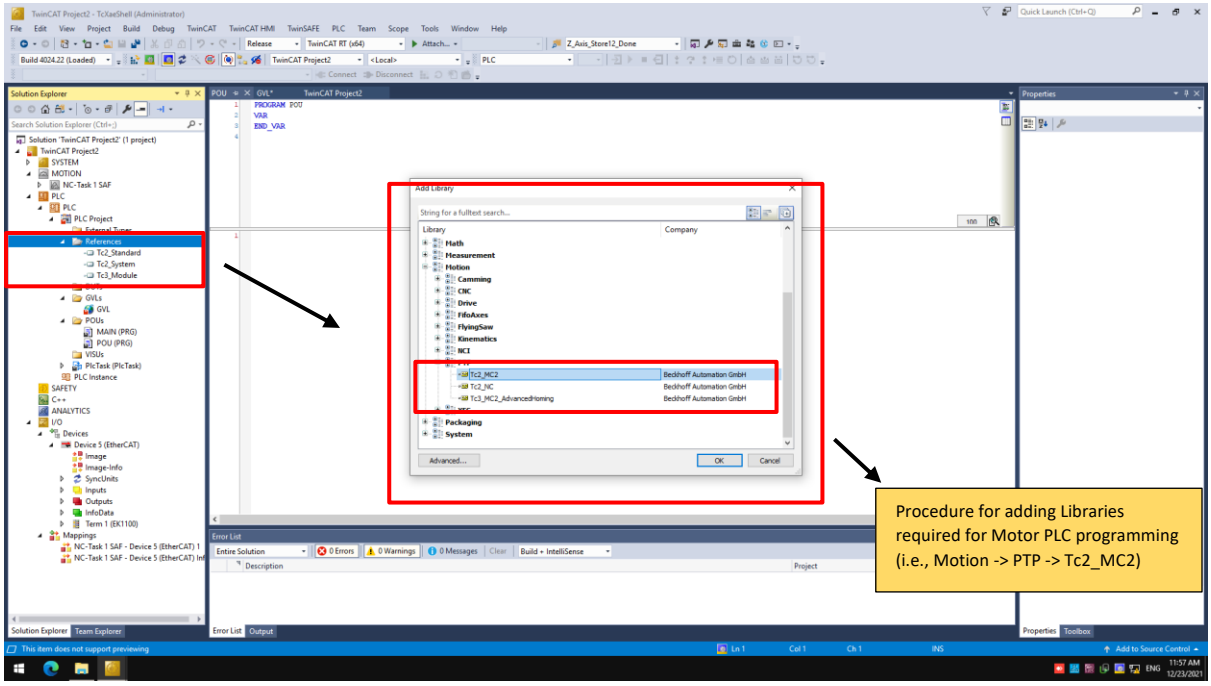

VAR_GLOBAL
factual_velocity_x : LREAL;
factual_velocity_y : LREAL;
factual_velocity_z : LREAL;
factual_position_x : LREAL;
factual_position_y : LREAL;
factual_position_z : LREAL;
X_Axis_Home_Done : BOOL;
Y_Axis_Home_Done : BOOL;
Z_Axis_Home_Done : BOOL;
X_Axis_Power_Stop: BOOL;
X_Axis_Power_Stop_Done: BOOL;
Y_Axis_Power_Stop_Done: BOOL;
Z_Axis_Power_Stop_Done: BOOL;
X_Axis_Store_Home_Completed : BOOL;
Set_0 : BOOL;
/// FOR 1st SHELF ////
X_Axis_Position_1_Done : BOOL;
Y_Axis_Position_1_Done : BOOL;
Z_Axis_Position_1_Done : BOOL;
Y_Position_1_Retrieve_Done : BOOL;
Z_Axis_Retrieve_1_Done: BOOL;
Z_Axis_Start1 : BOOL;
Z_Retrieve_1_Initial_Done : BOOL;
X_Axis_Store1 : BOOL;
X_Axis_Store_1_Done : BOOL;
Y_Axis_Store_1_Done : BOOL;
Z_Axis_Store_1_Done : BOOL;
Y_Axis_Store1_Place_Done : BOOL;
Z_Axis_Store1_Place_Done : BOOL;
/// FOR 6th SHELF ////
An Example of GVL created

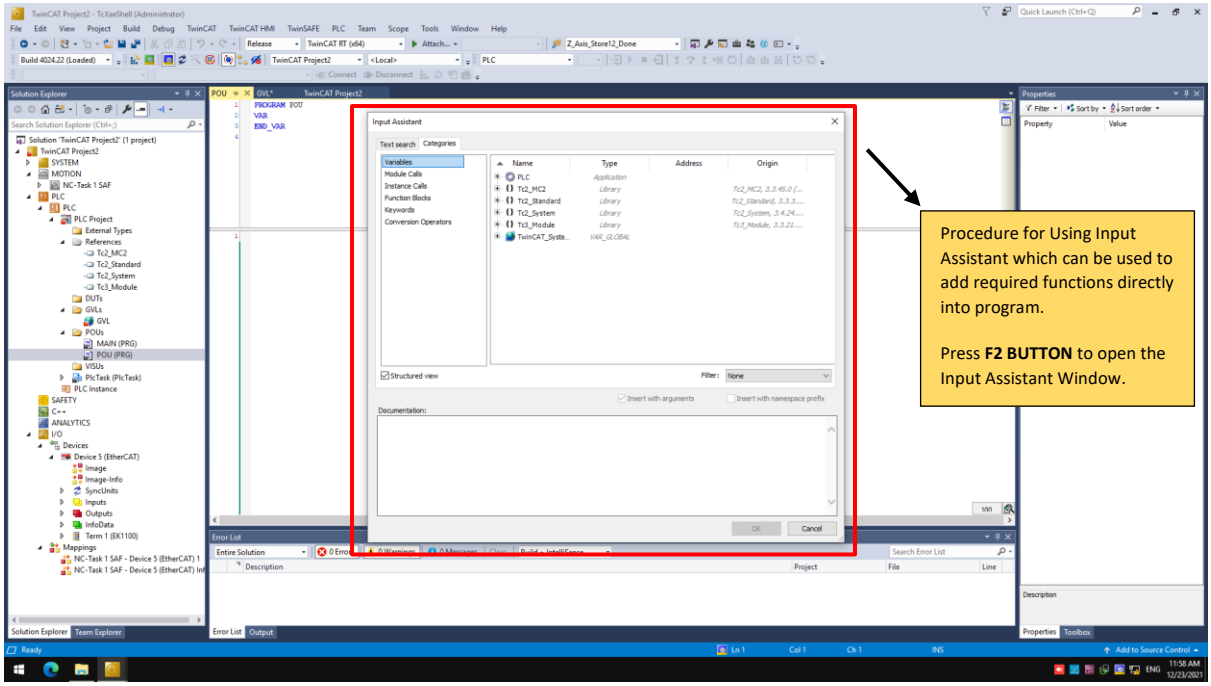

An Example of Main Program created

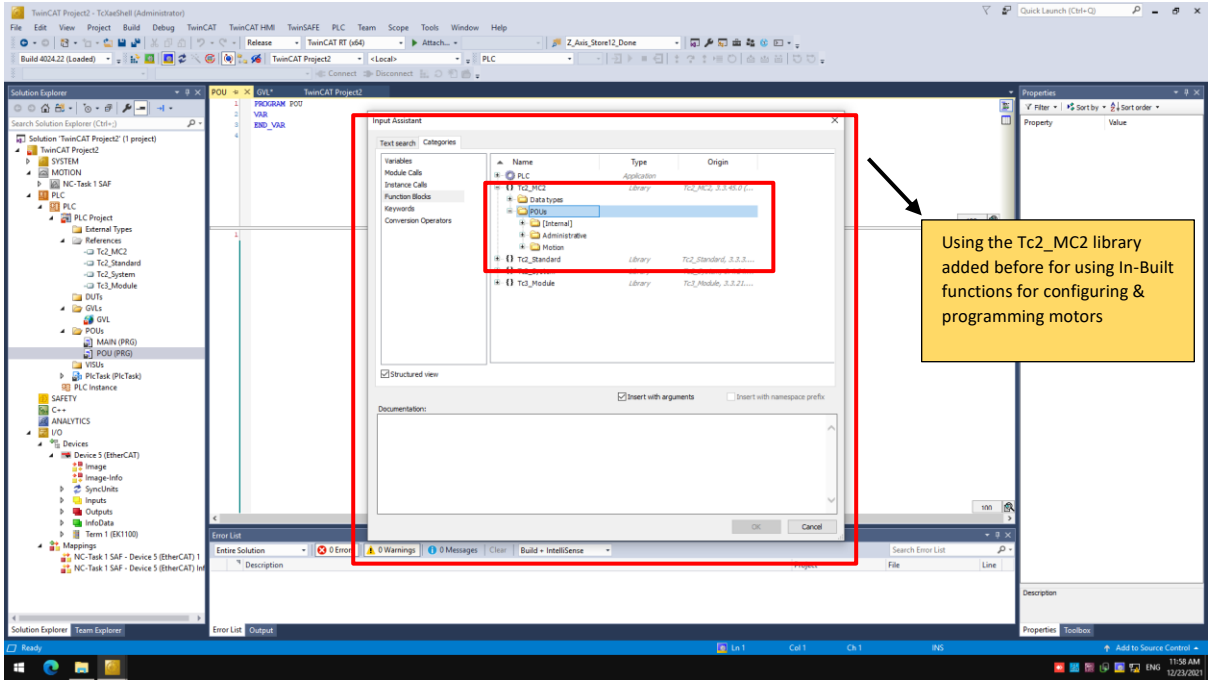

An Example of (ST) Structured Text Program created

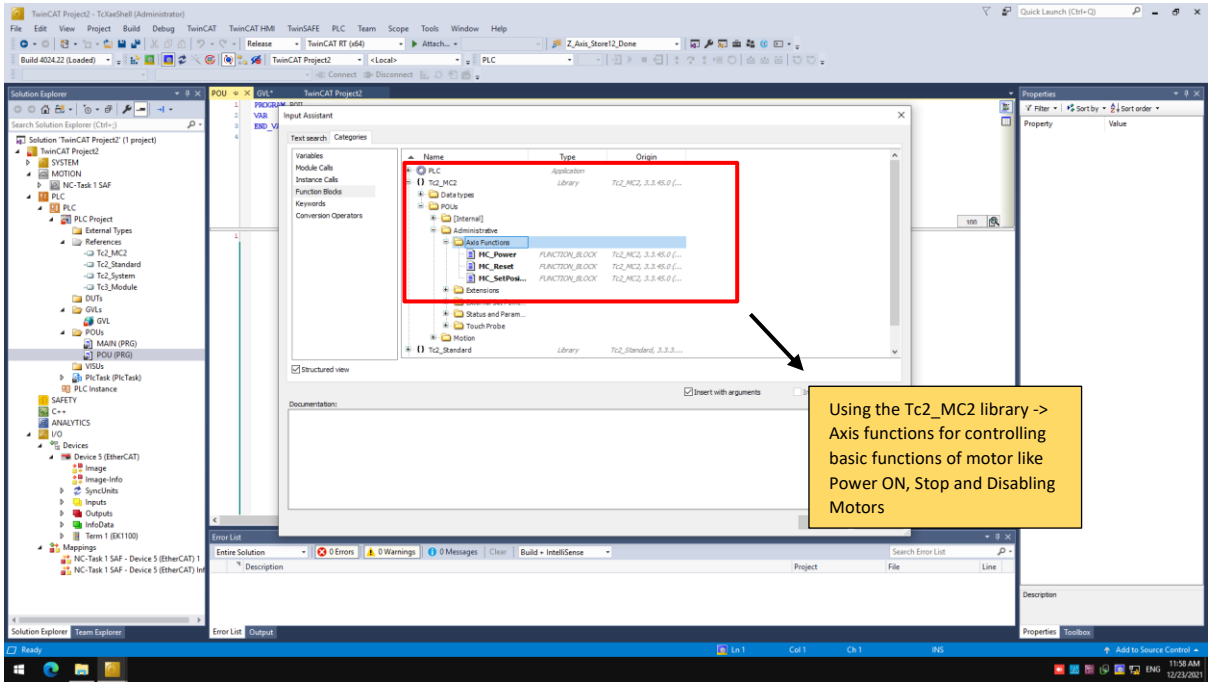
4.1.5.2 Adding Libraries and using In-built functions

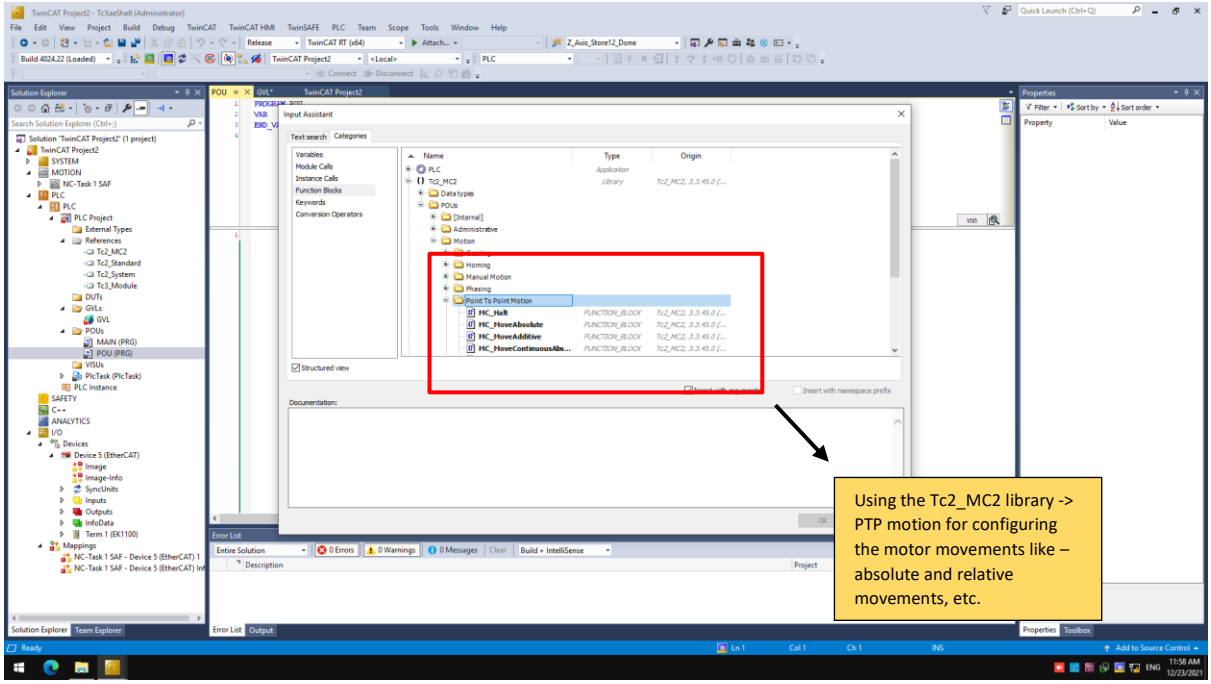


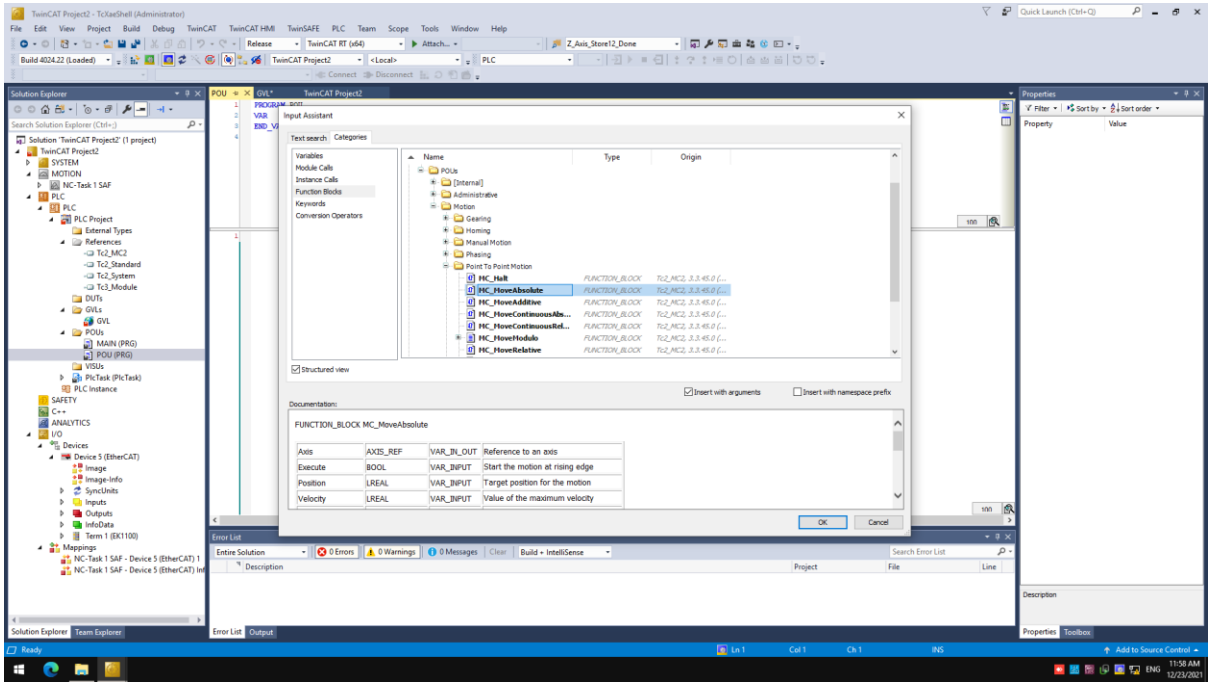


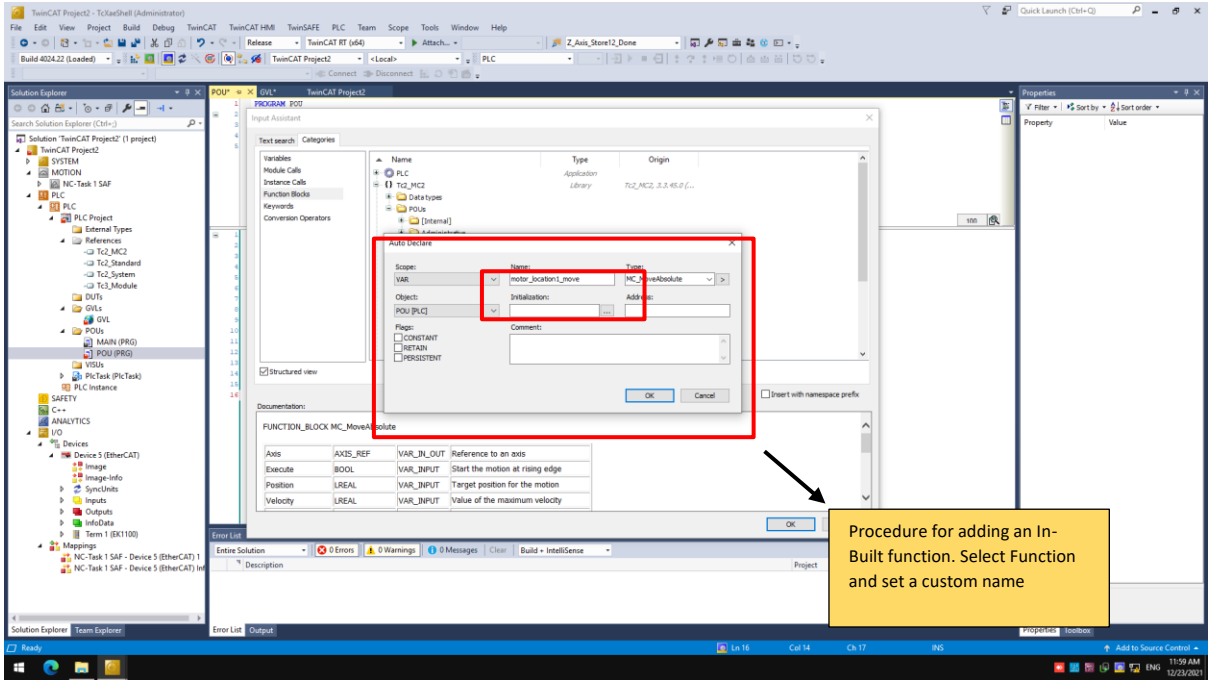

Procedure for Using Input Assistant which can be used to add required functions directly into program.
Press F2 BUTTON to open the Input Assistant Window.

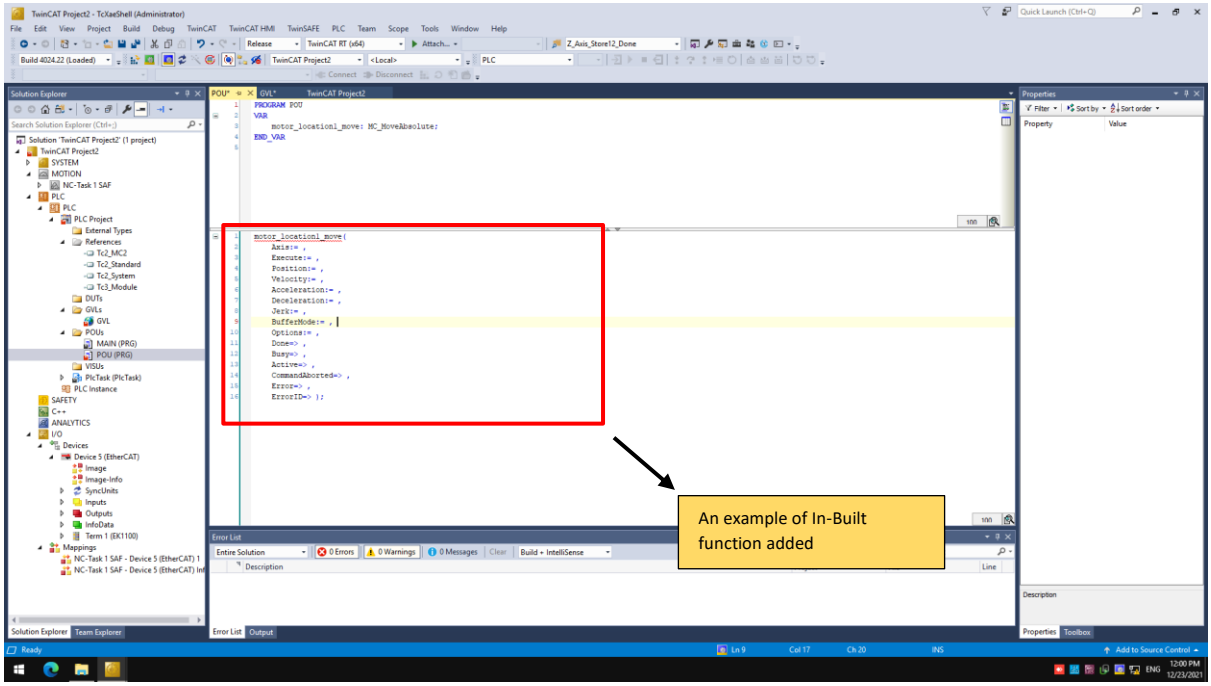

Using the Tc2_MC2 library added before for using In-Built functions for configuring & programming motors

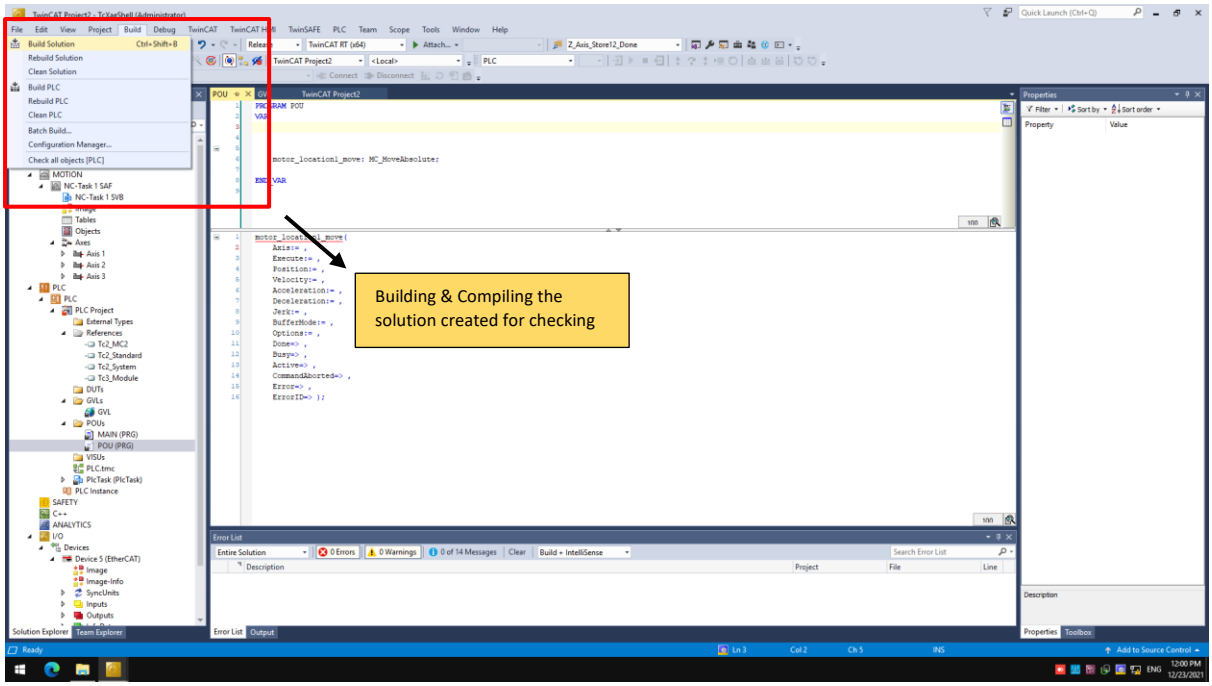

Using the Tc2_MC2 library -> Axis functions for controlling basic functions of motor like Power ON, Stop and Disabling Motors

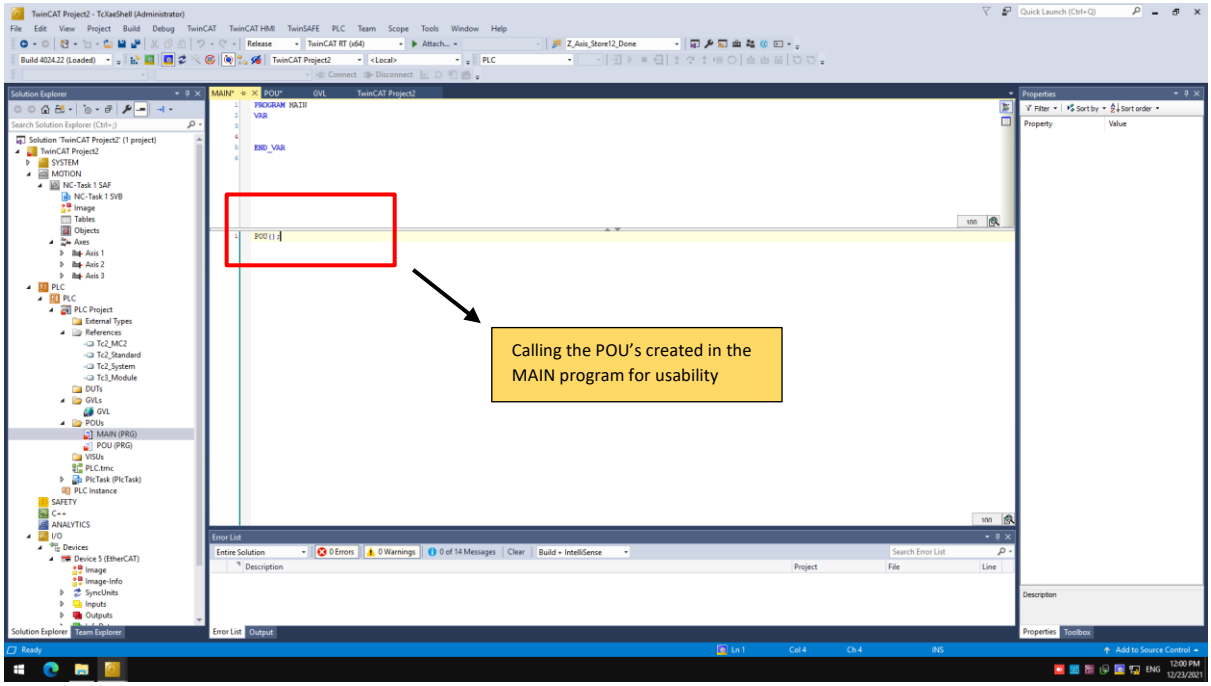

Using the Tc2_MC2 library -> PTP motion for configuring the motor movements like – absolute and relative movements, etc.

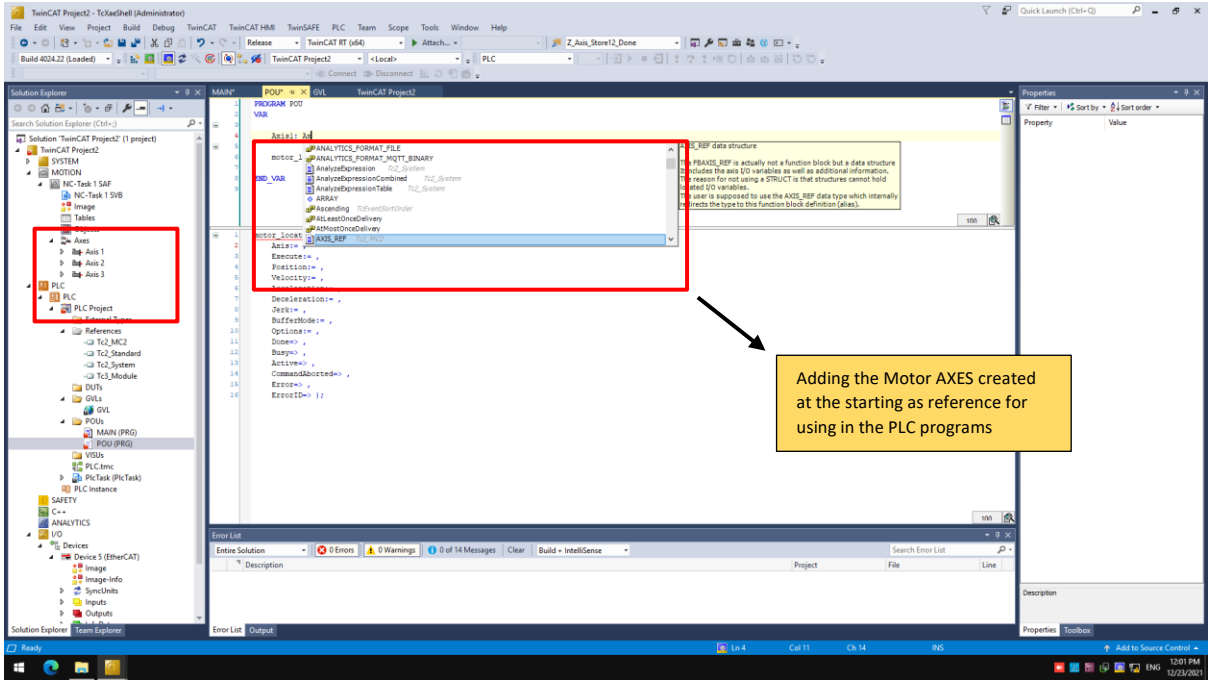


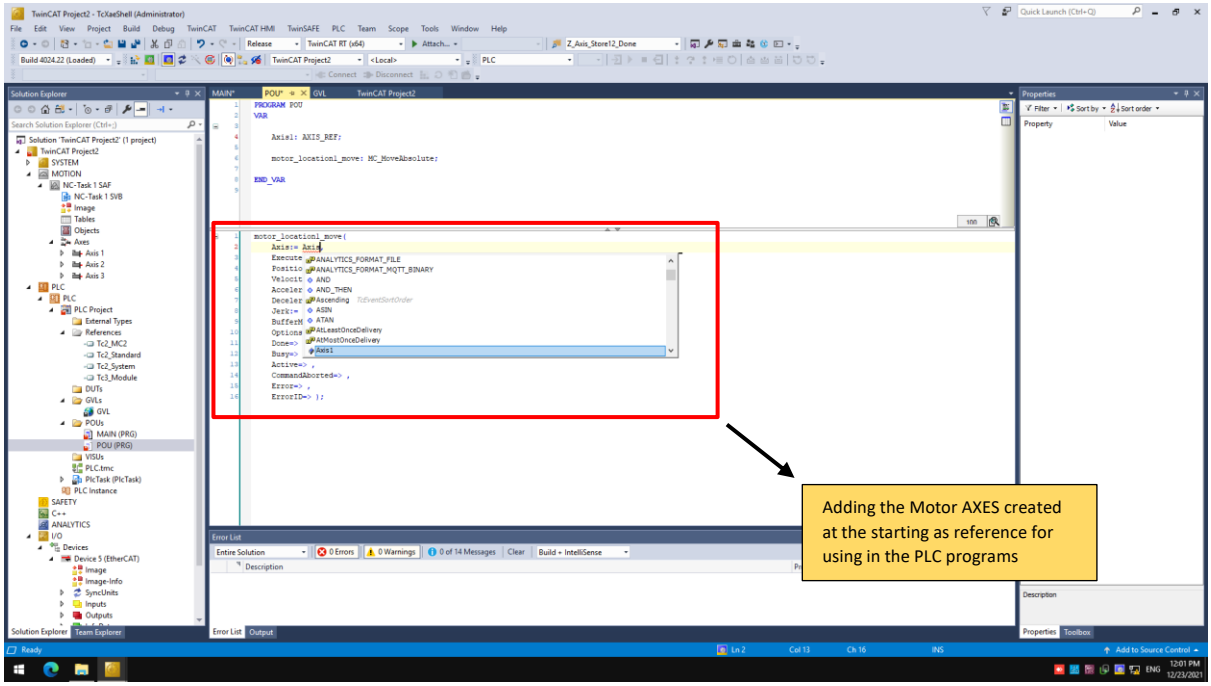

Procedure for adding an In-Built function. Select Function and set a custom name

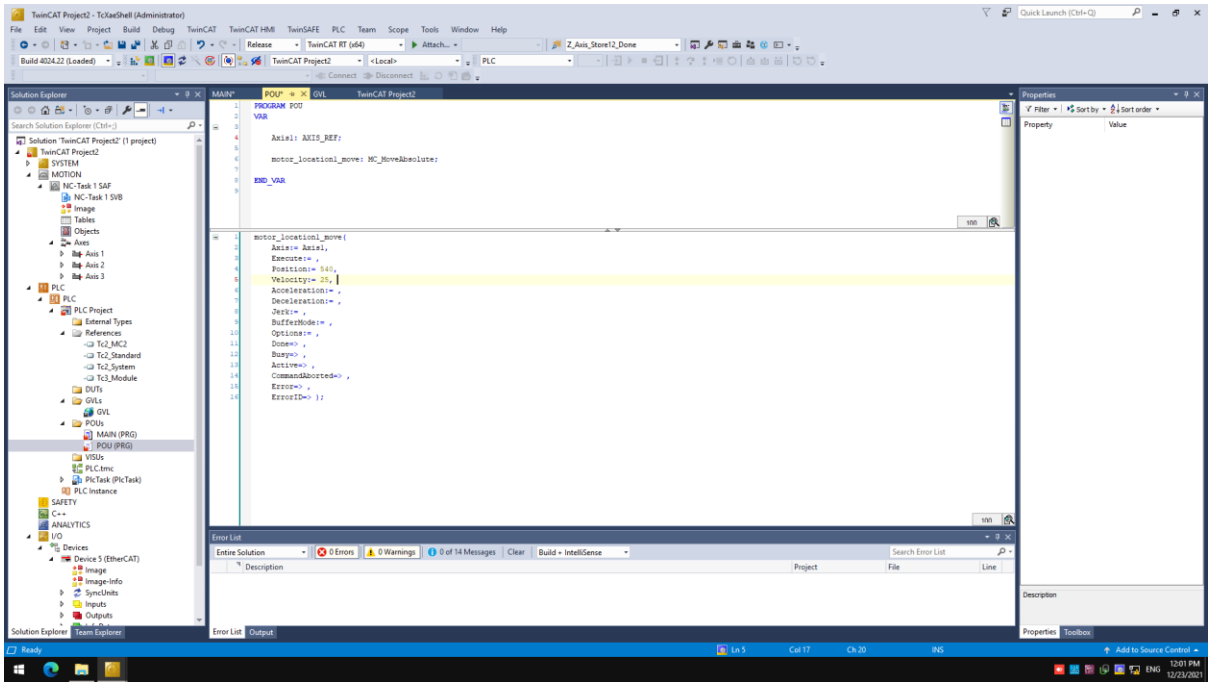

An example of In-Built function added


Building & Compiling the solution created for checking

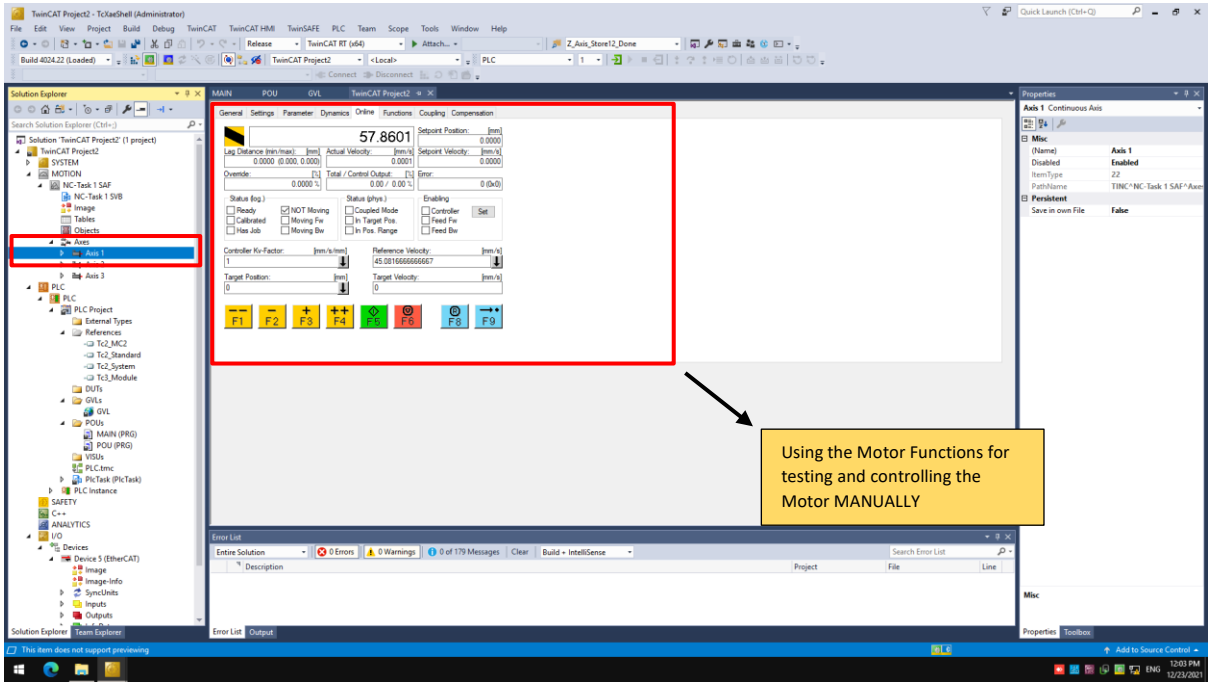

Calling the POU's created in the MAIN program for usability

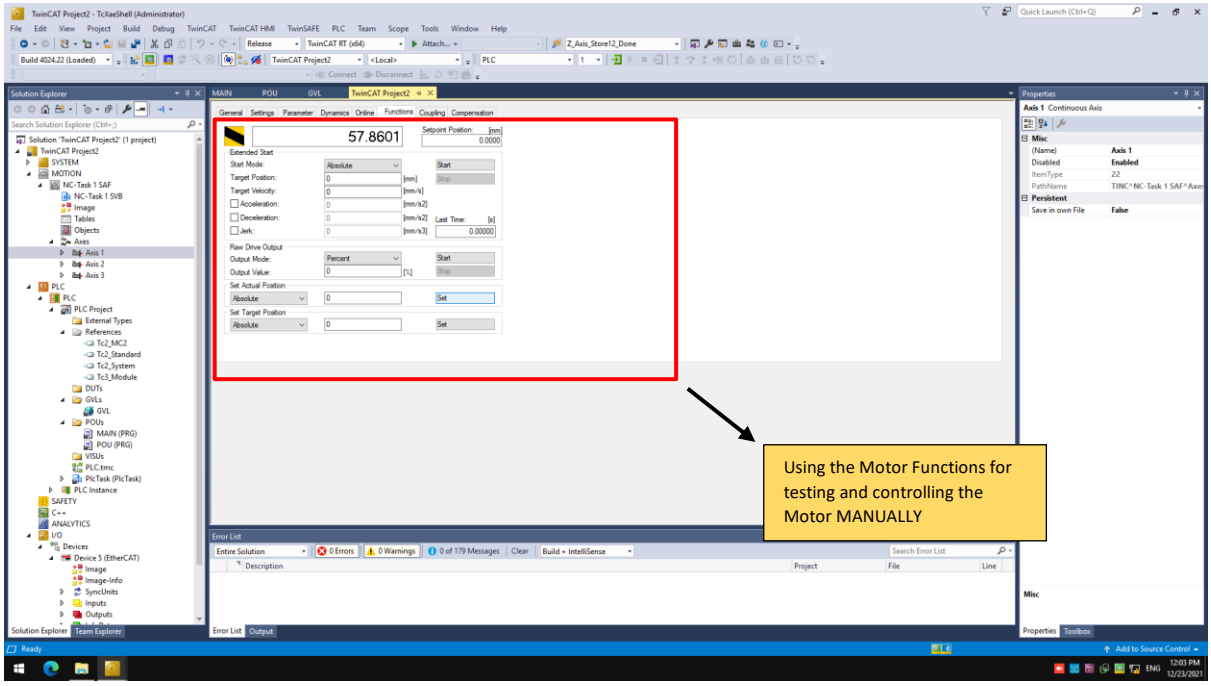

Adding the Motor AXES created at the starting as reference for using in the PLC programs

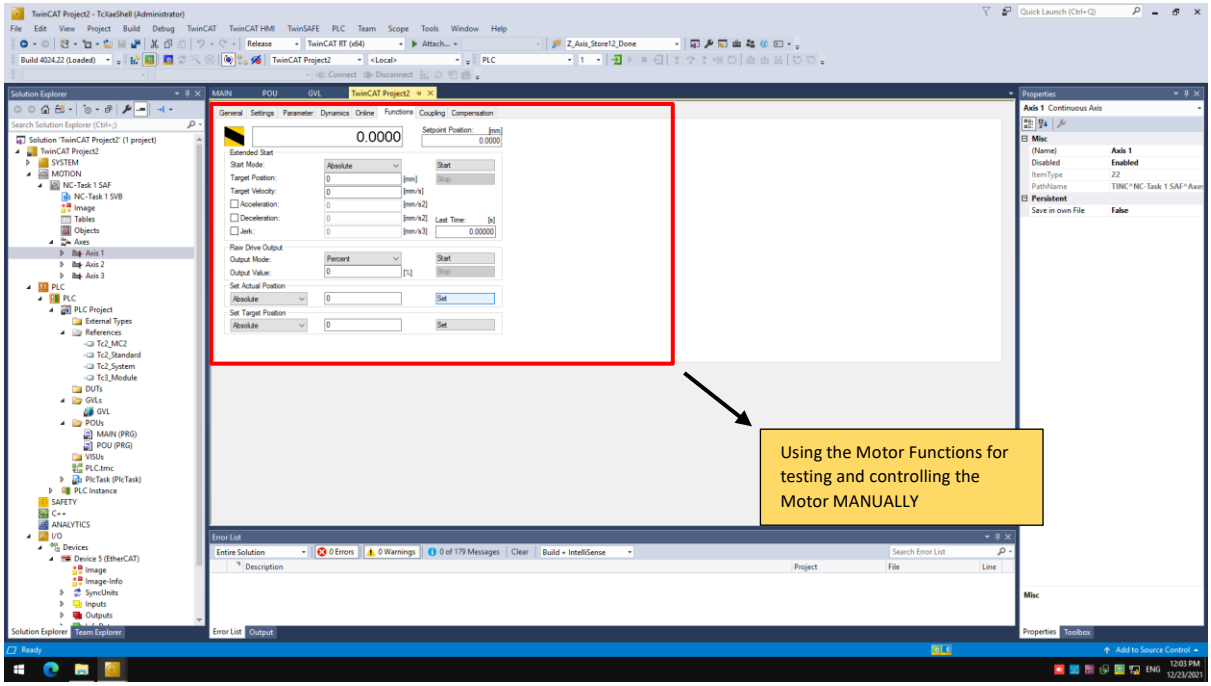

Adding the Motor AXES created at the starting as reference for using in the PLC programs

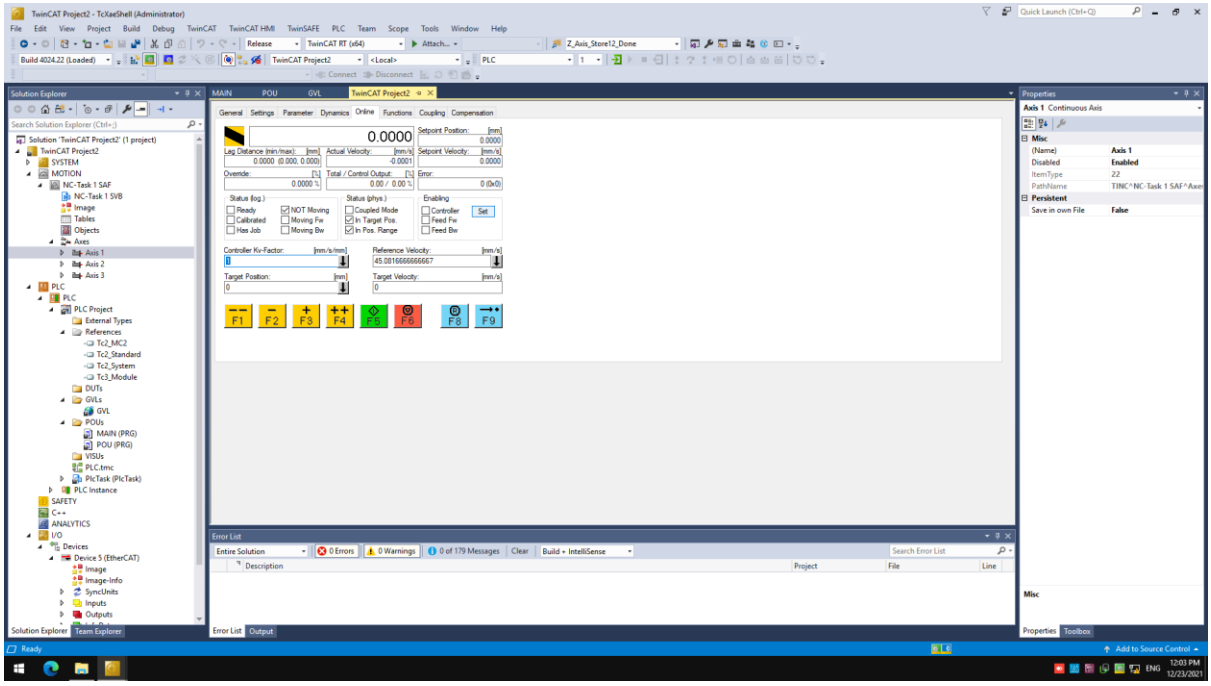


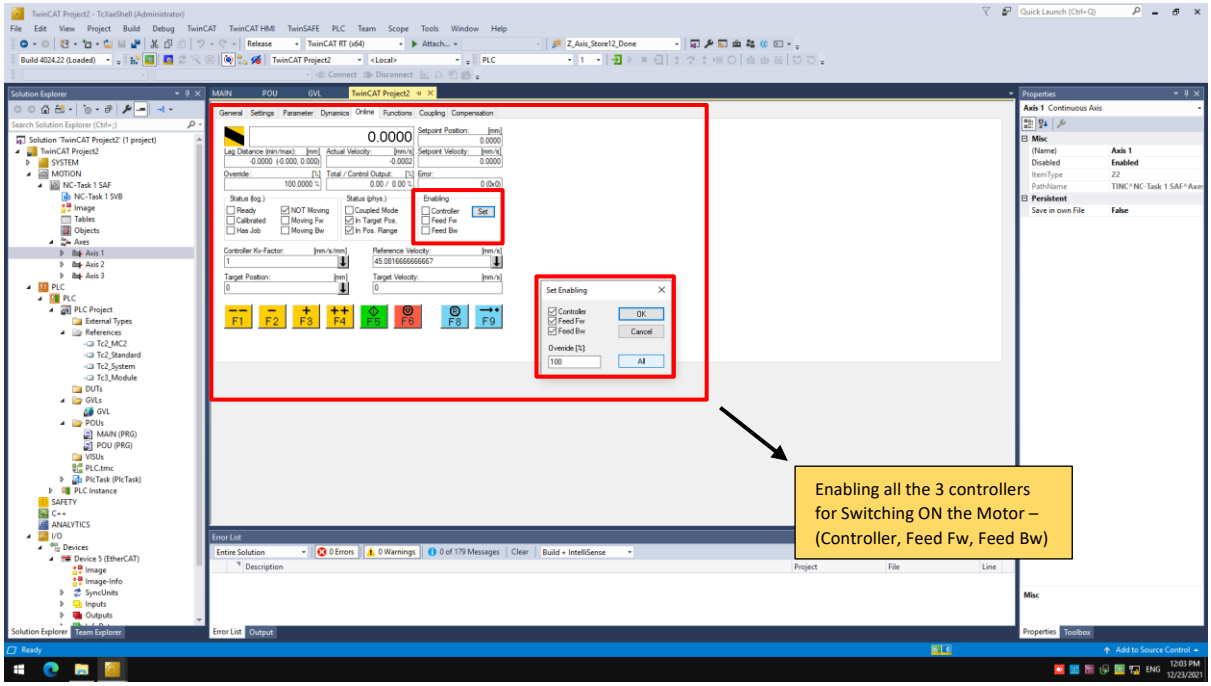
4.1.6 Controlling and testing Motors through TwinCAT interface

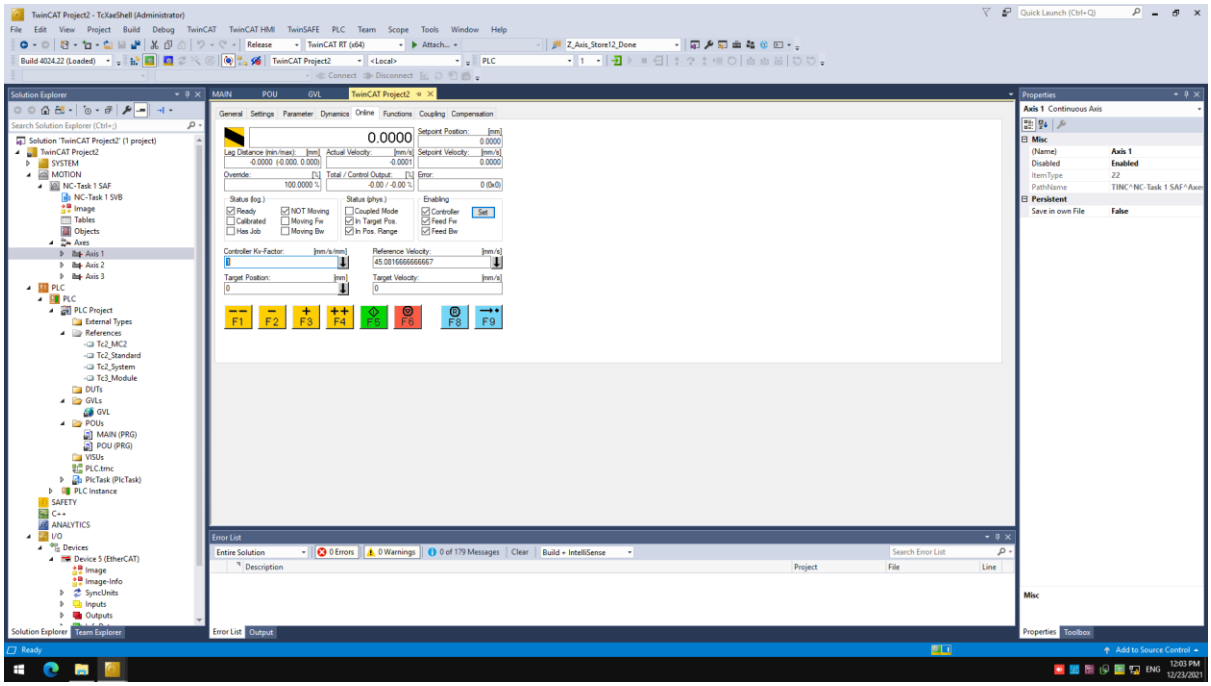


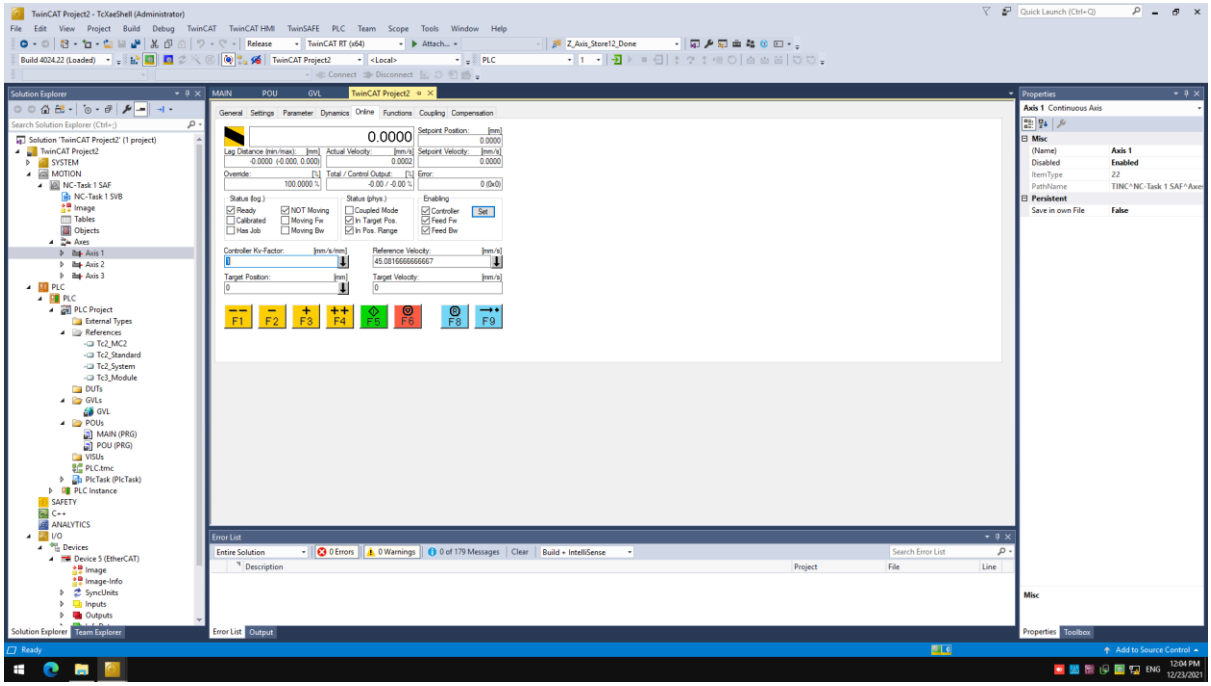


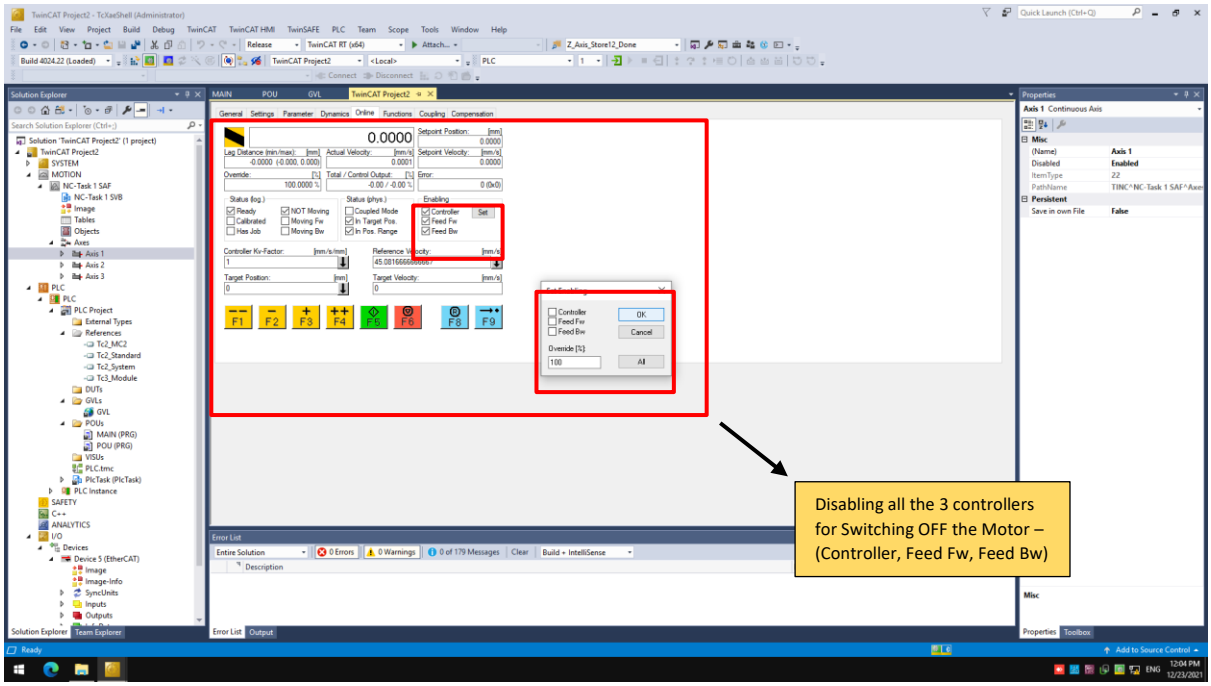

Using the Motor Functions for testing and controlling the Motor MANUALLY

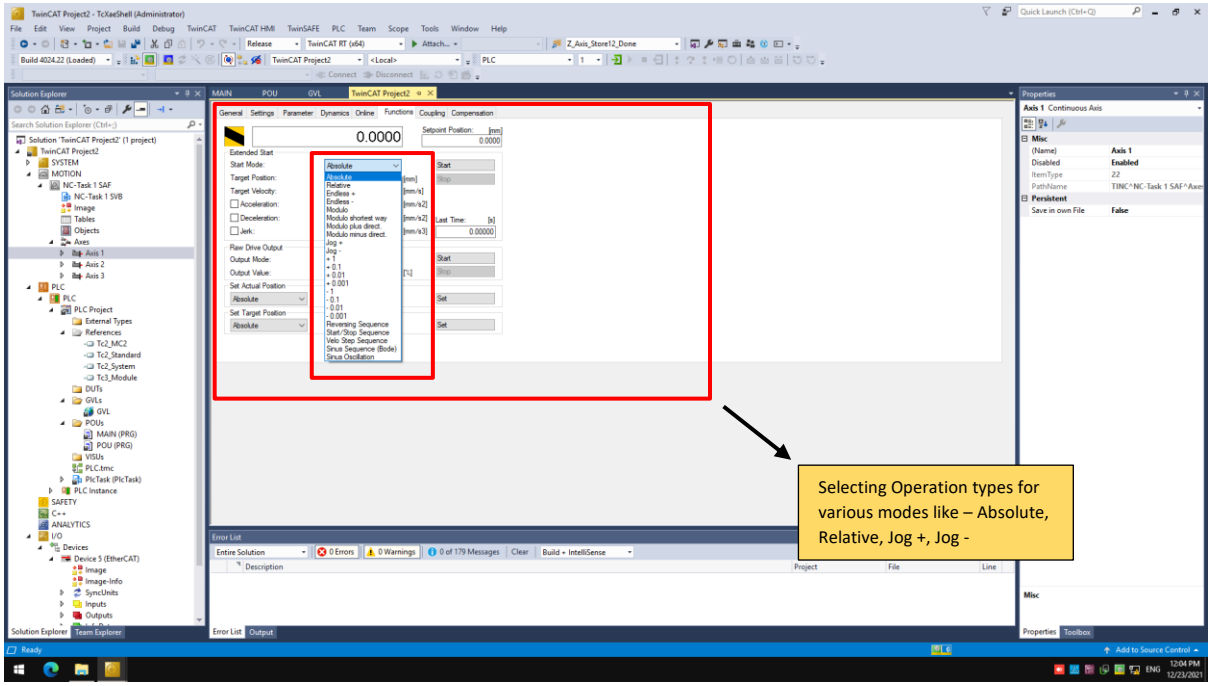


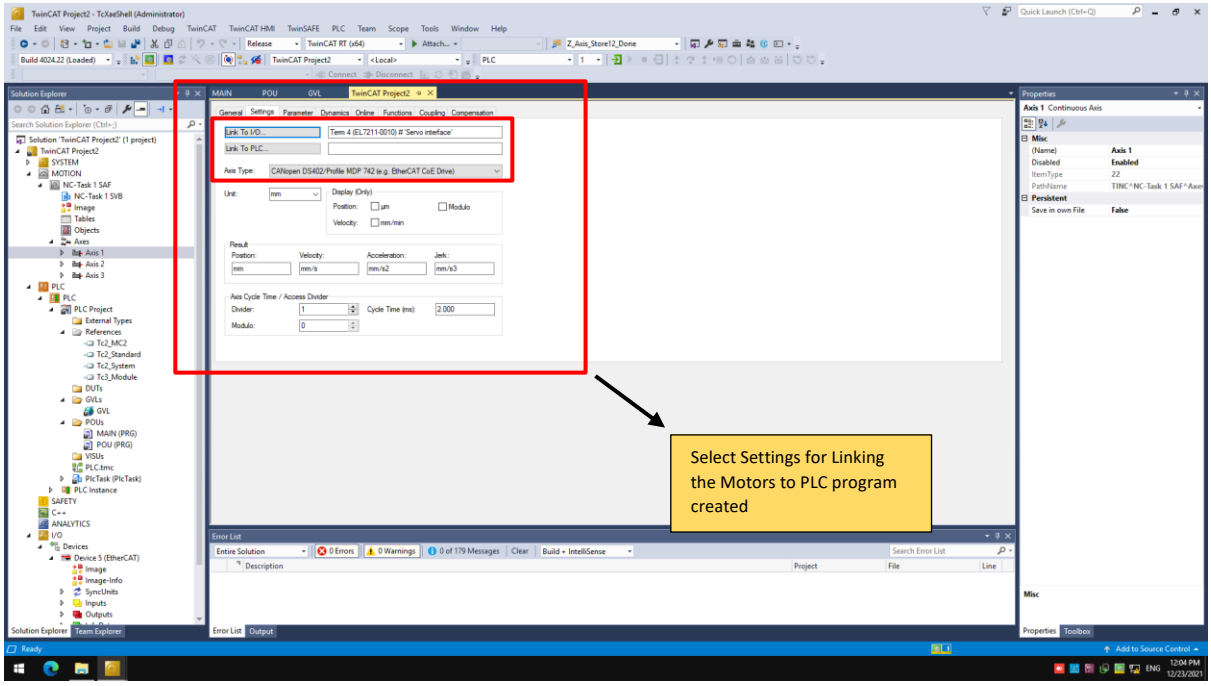

Enabling all the 3 controllers for Switching ON the Motor – (Controller, Feed Fw, Feed Bw)



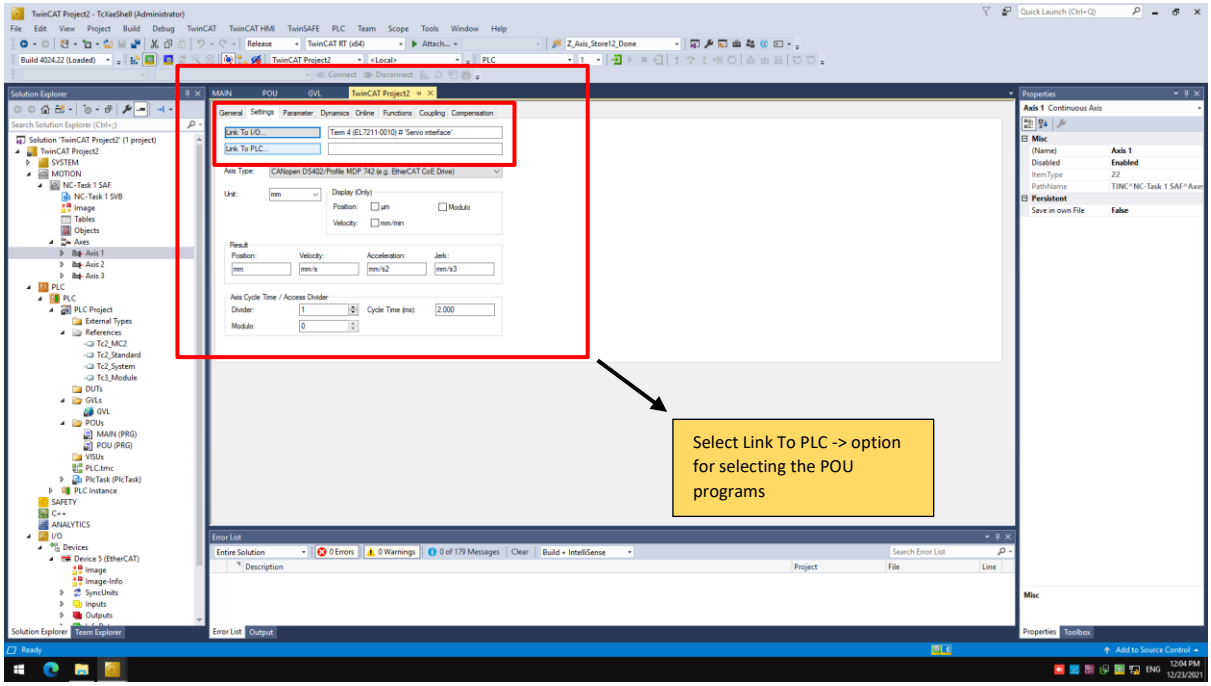


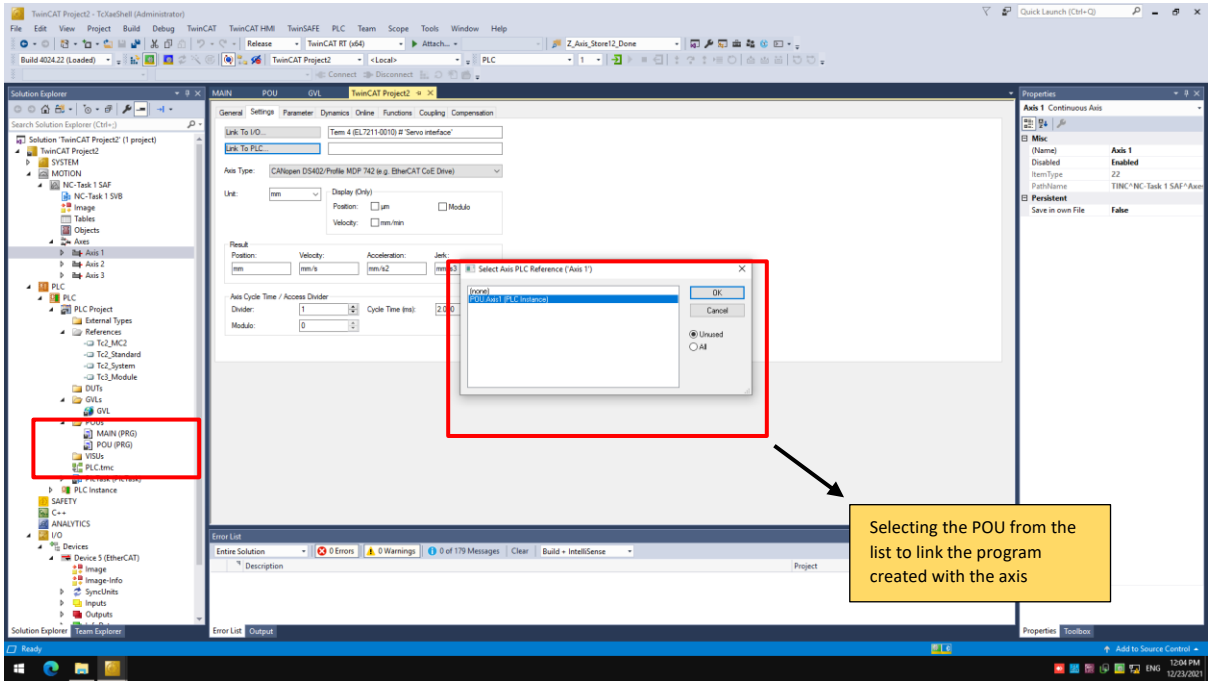

Disabling all the 3 controllers for Switching OFF the Motor – (Controller, Feed Fw, Feed Bw)


Selecting Operation types for various modes like – Absolute, Relative, Jog +, Jog -

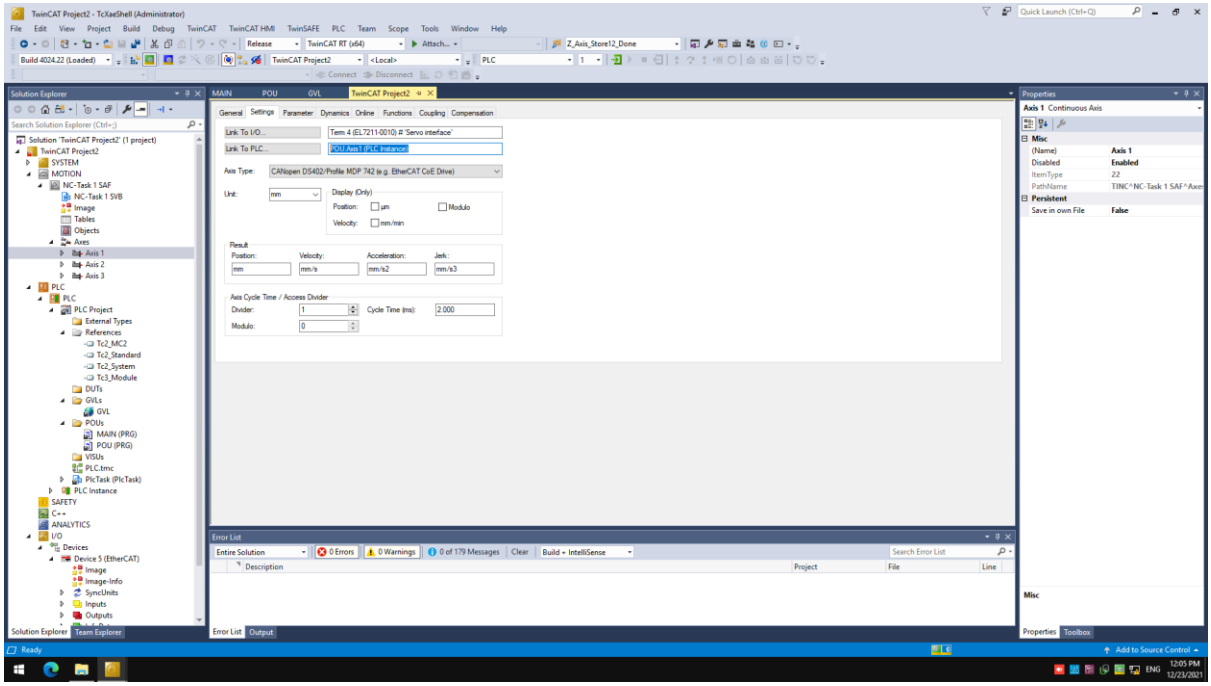

Select Settings for Linking the Motors to PLC program created

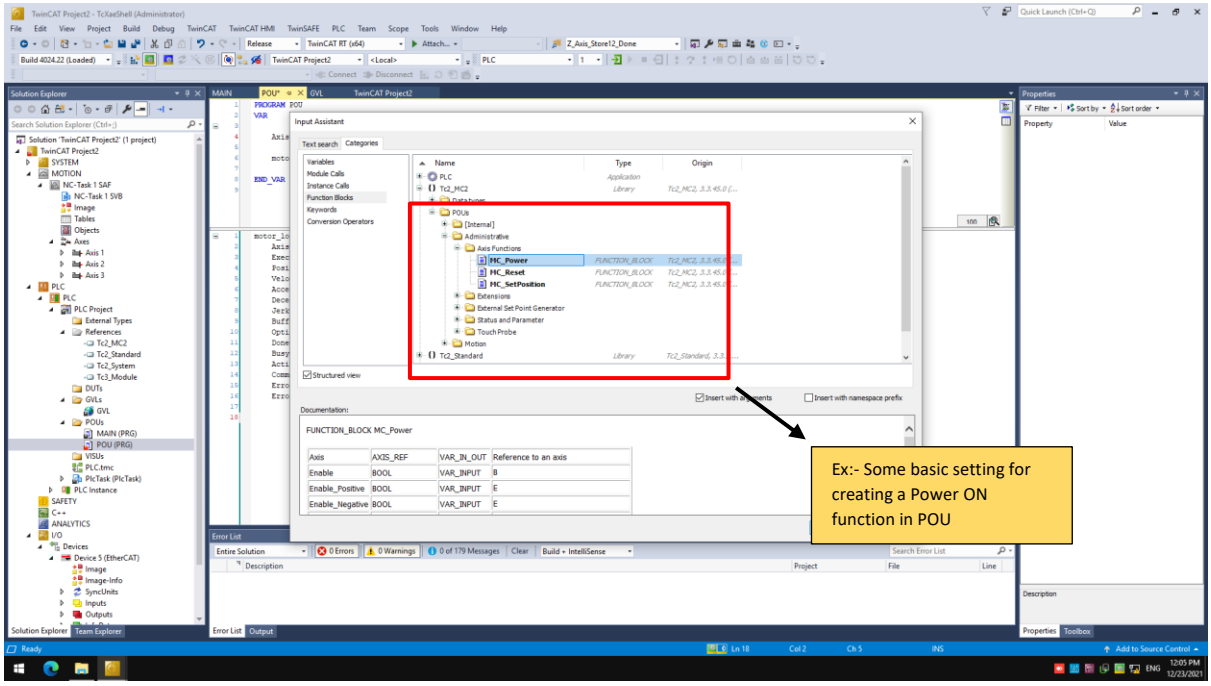
4.1.7 Linking Motors with PLC program

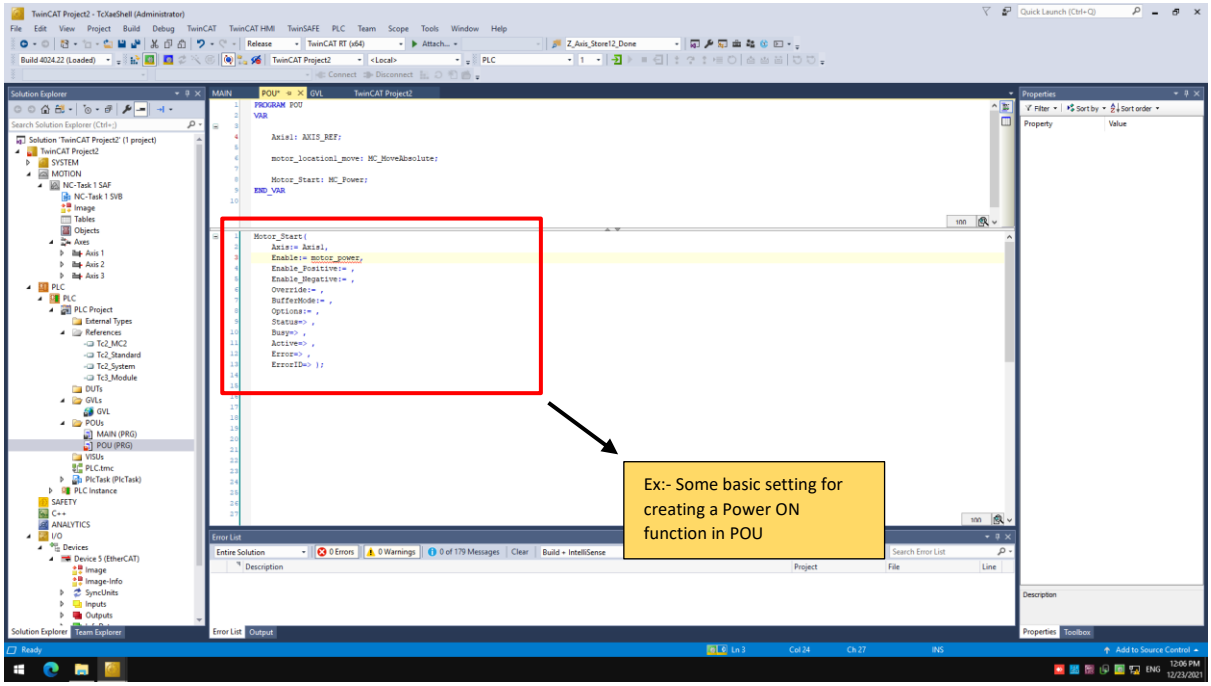


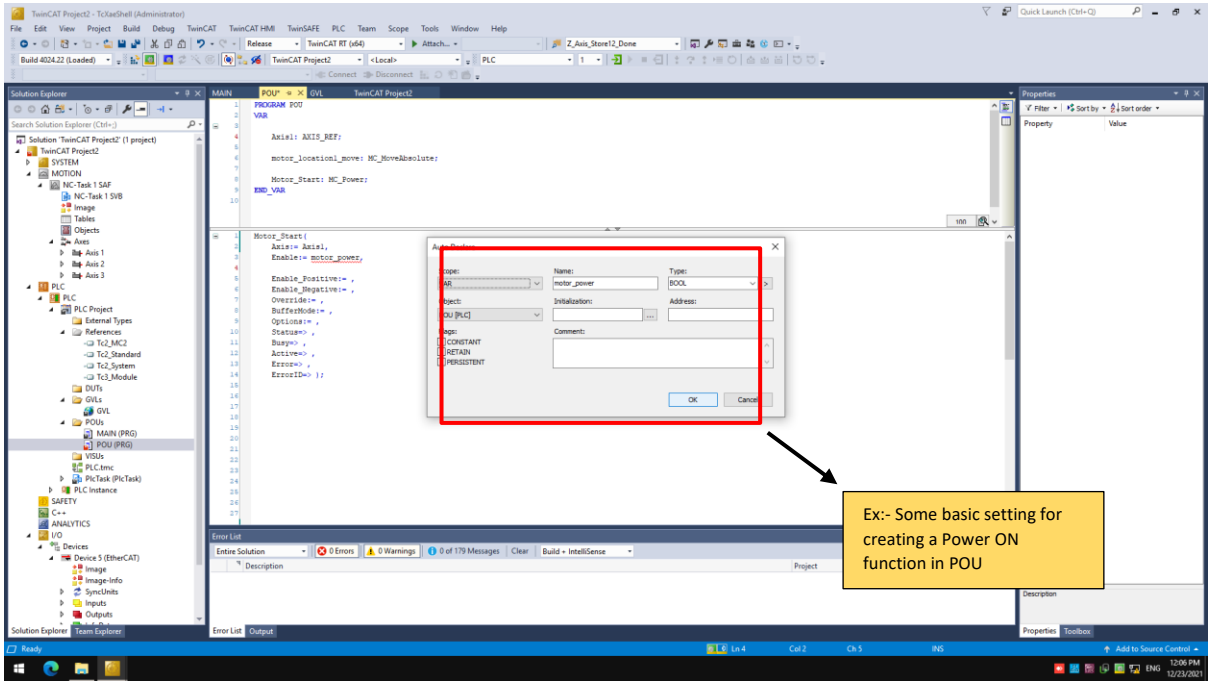


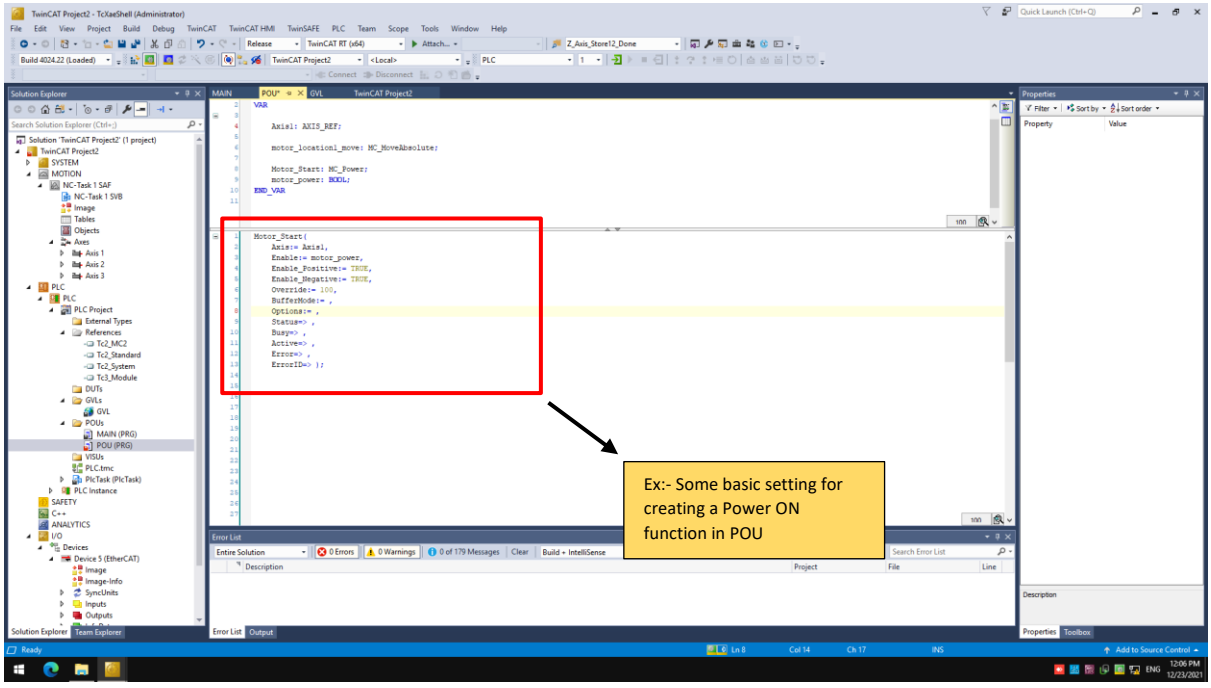
4.1.7.1 Example motor functions

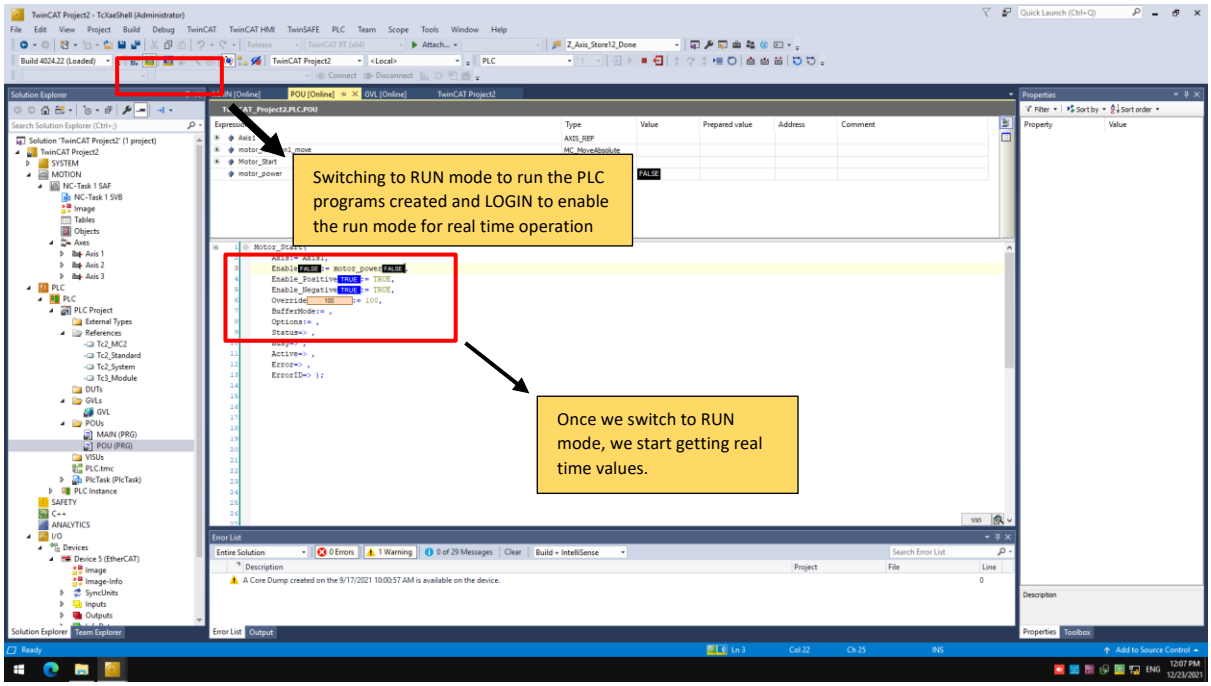


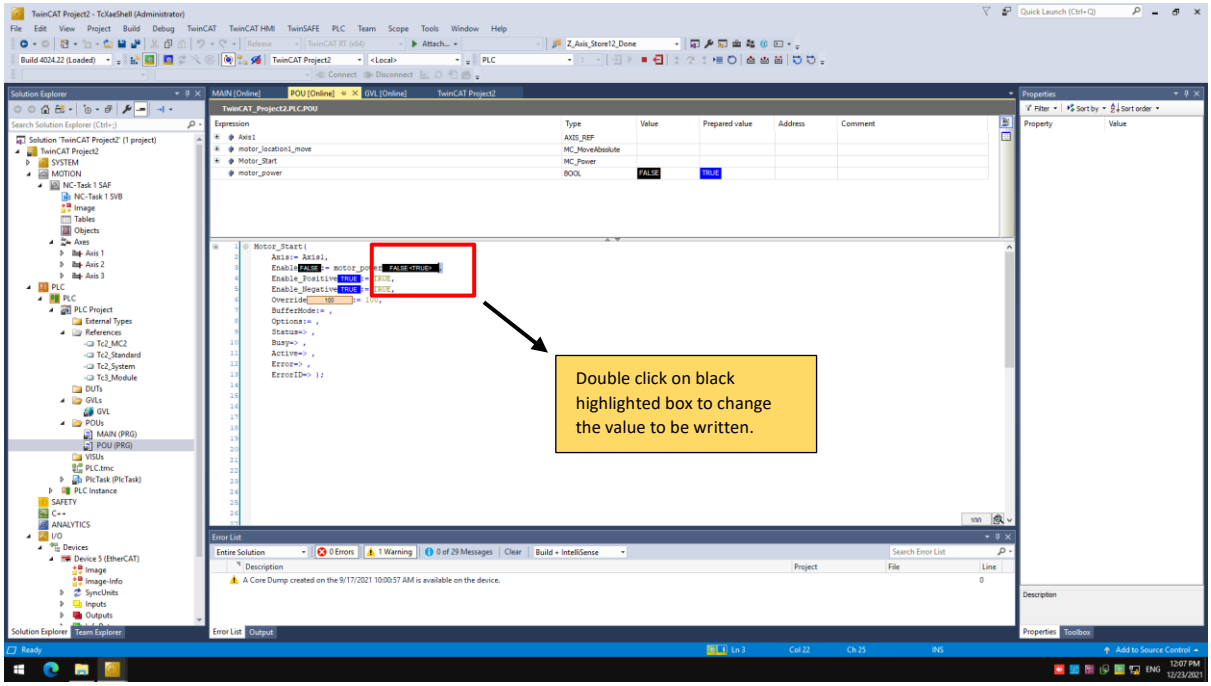


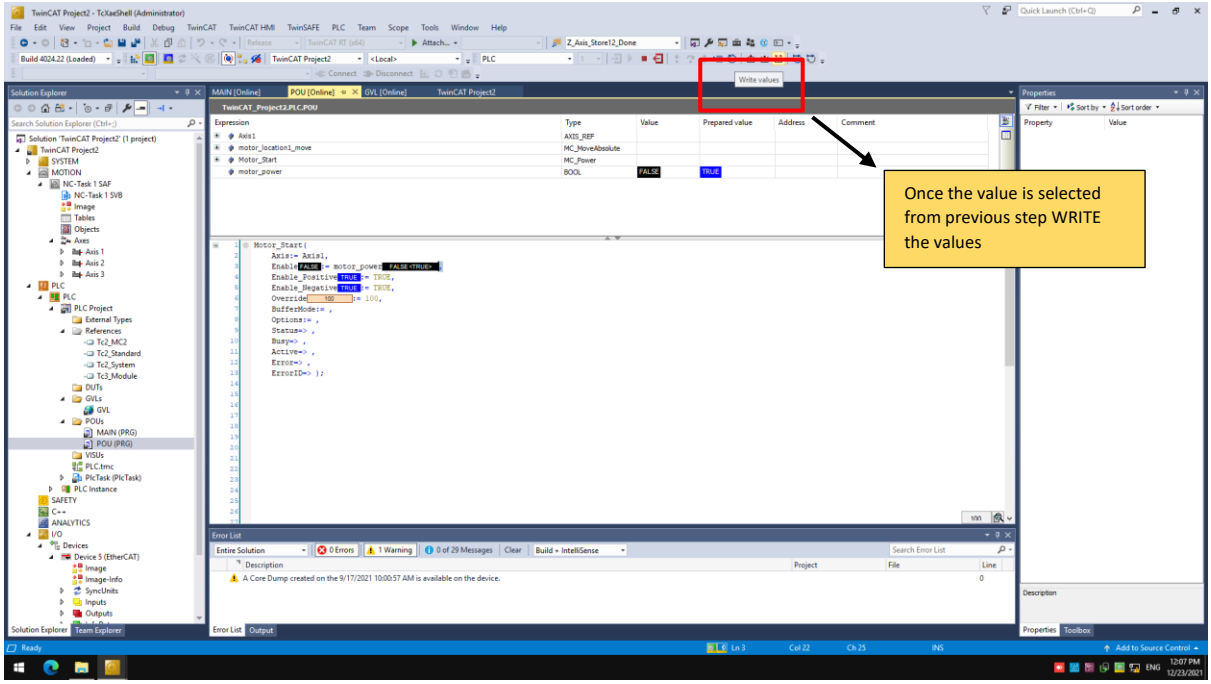

Ex:- Some basic setting for creating a Power ON function in POU

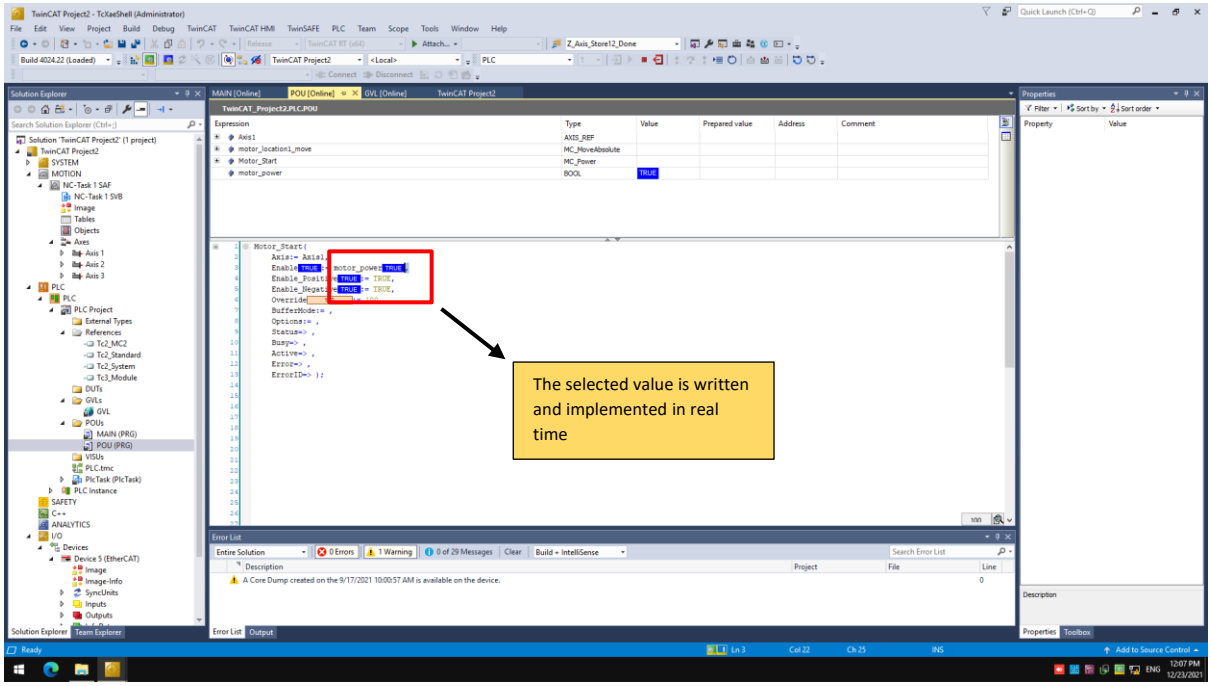

Ex:- Some basic setting for creating a Power ON function in POU

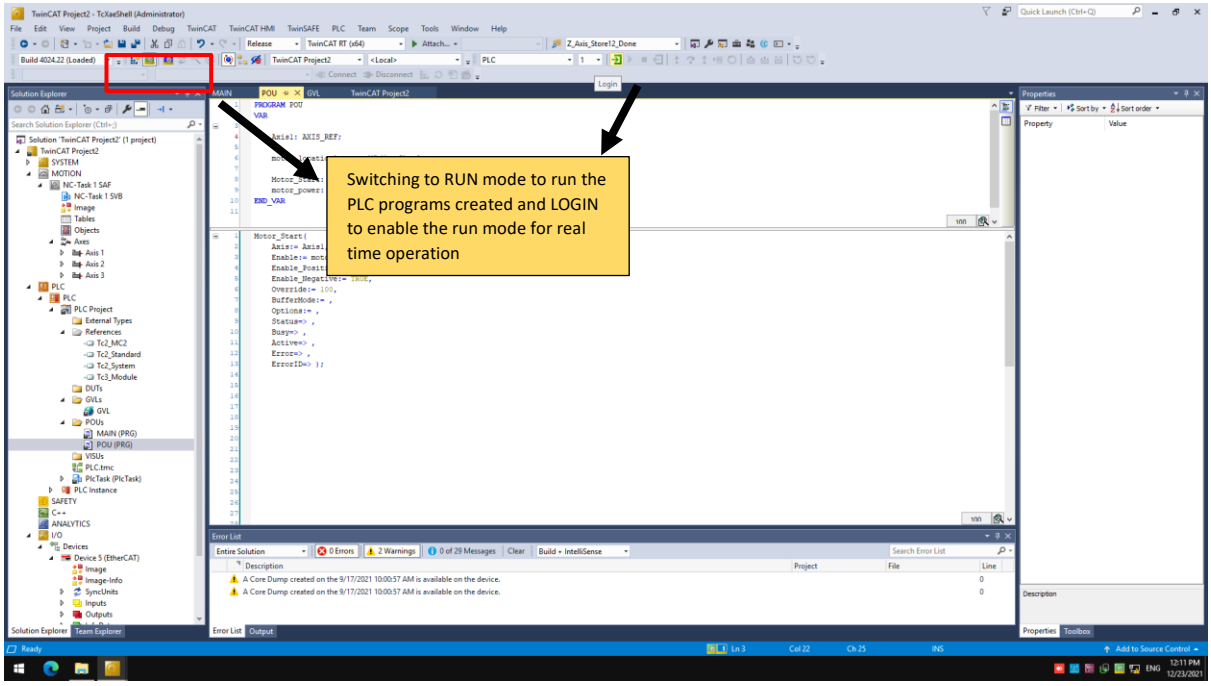

Ex:- Some basic setting for creating a Power ON function in POU


Switching to RUN mode to run the PLC programs created and LOGIN to enable the run mode for real time operation
Once we switch to RUN mode, we start getting real time values.

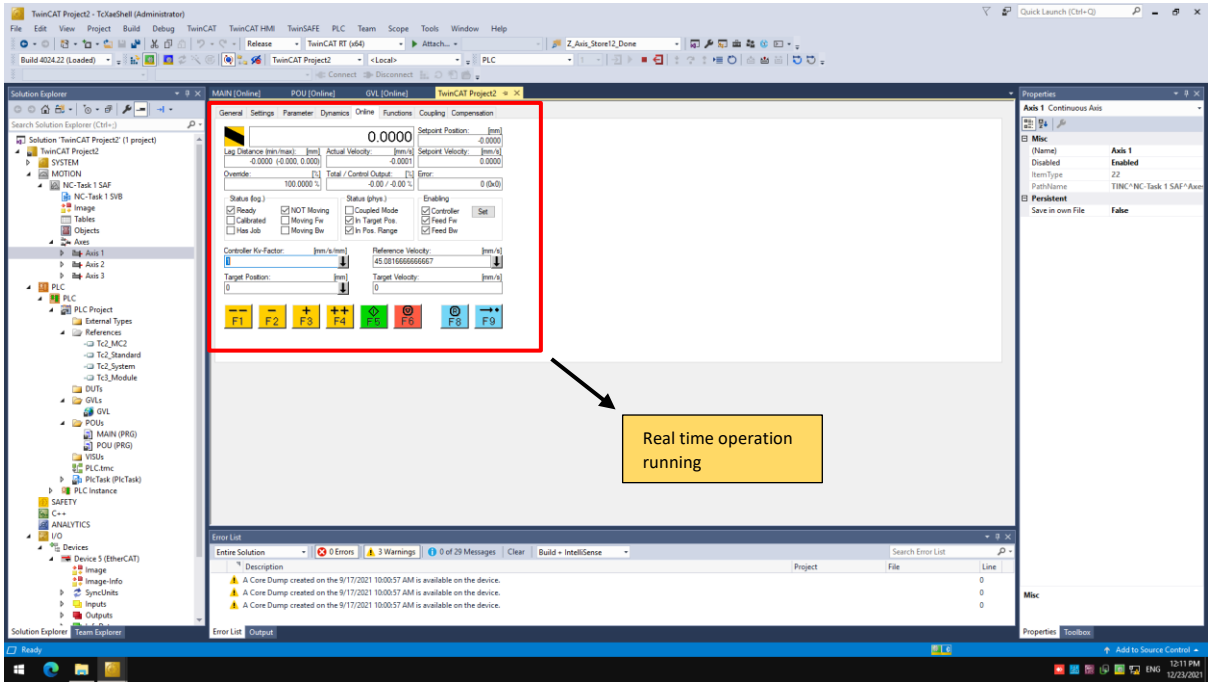

Double click on black highlighted box to change the value to be written.

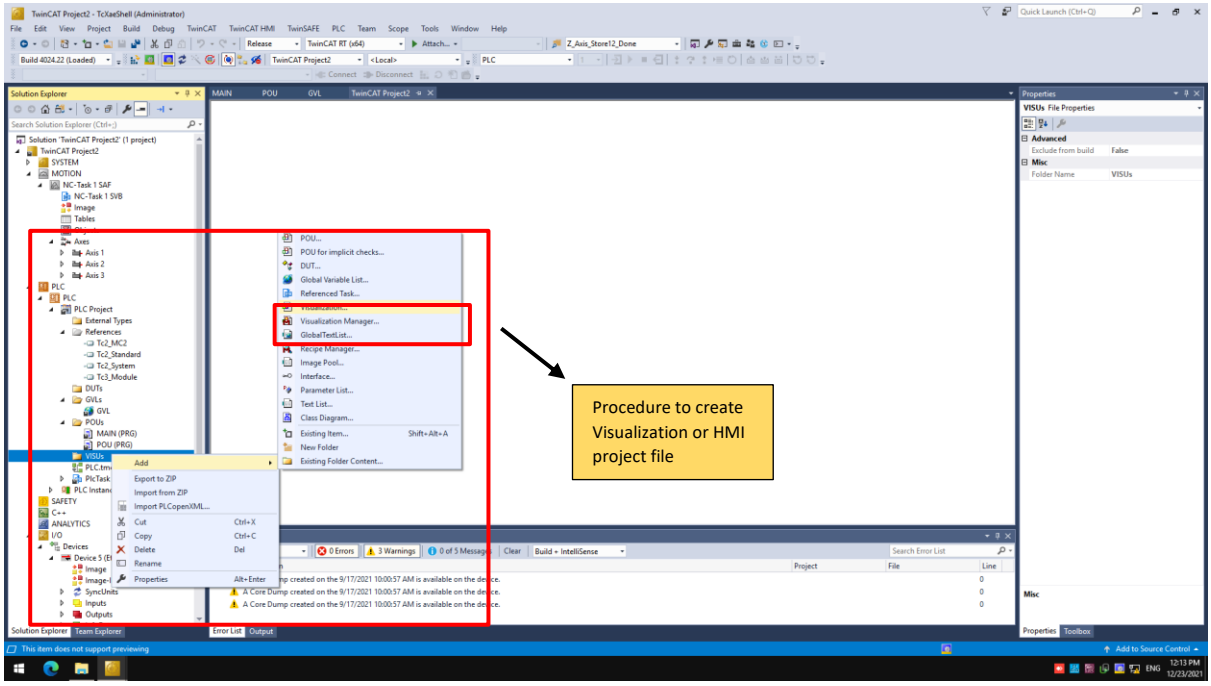

Once the value is selected from previous step WRITE the values

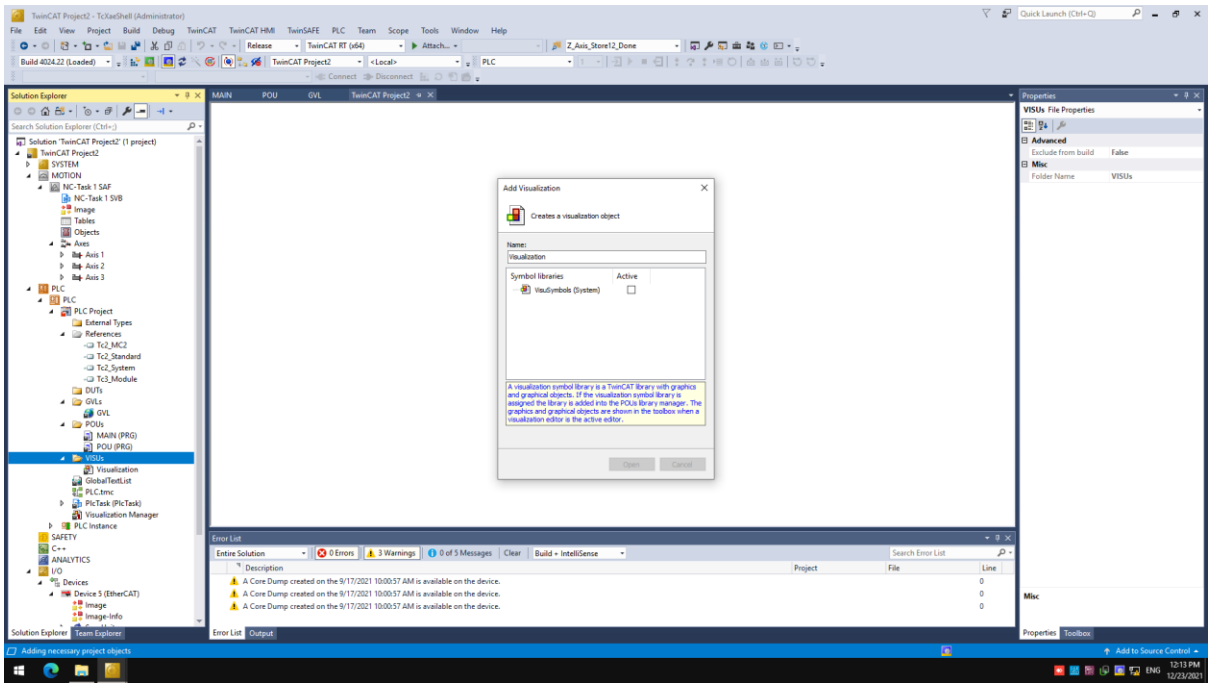

The selected value is written and implemented in real time

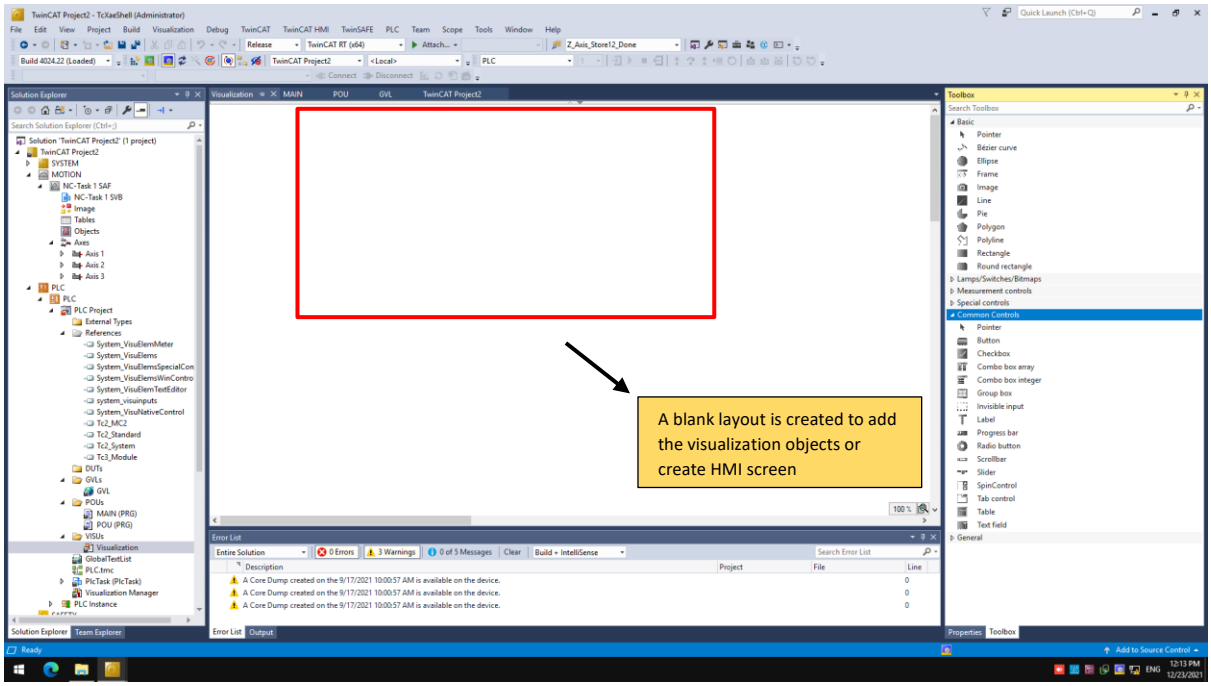

Switching to RUN mode to run the PLC programs created and LOGIN to enable the run mode for real time operation

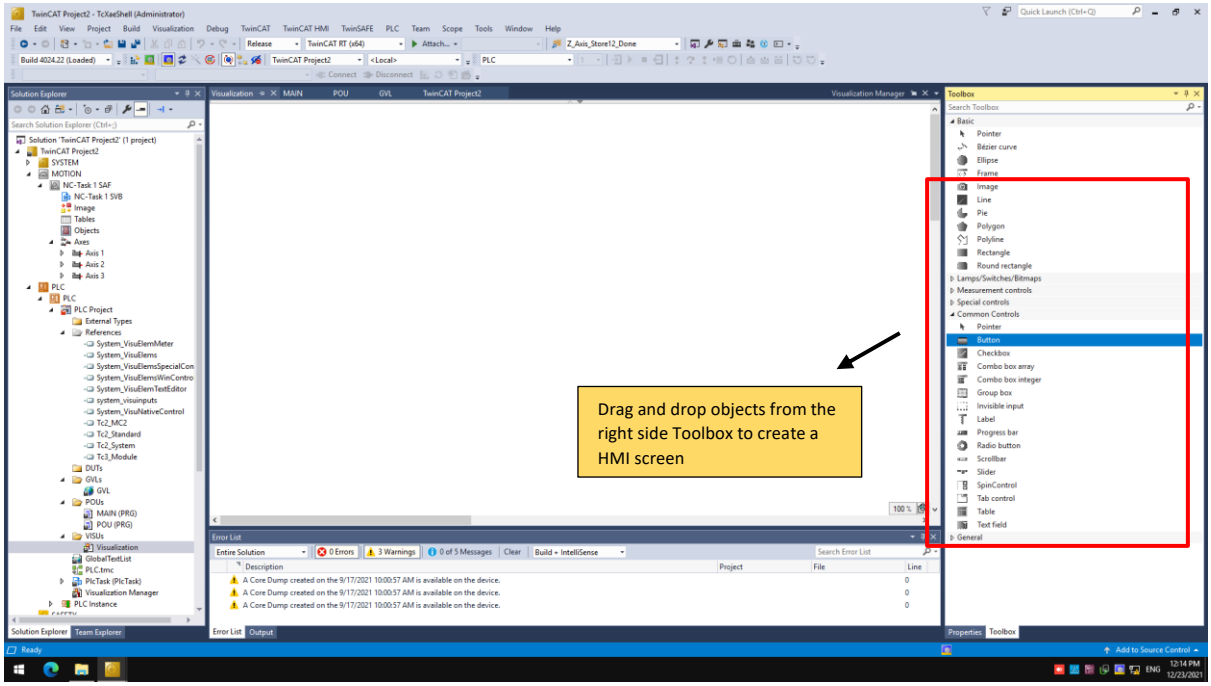
4.1.8 Creating Visualisation or HMI screen

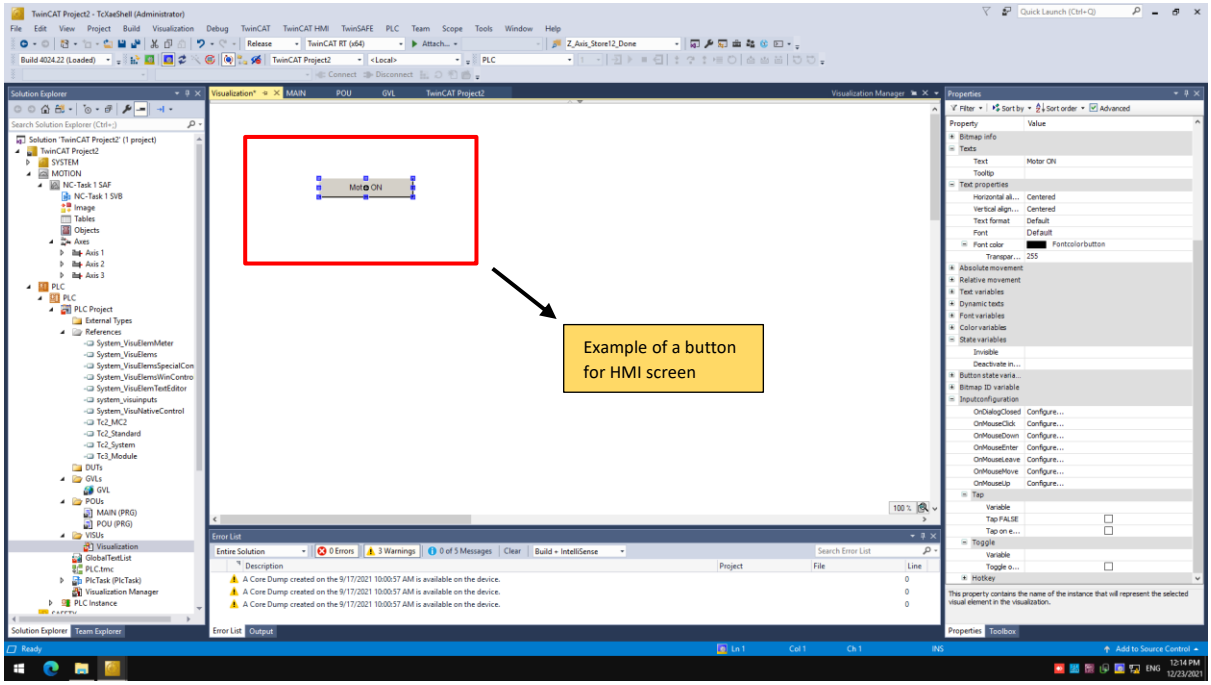


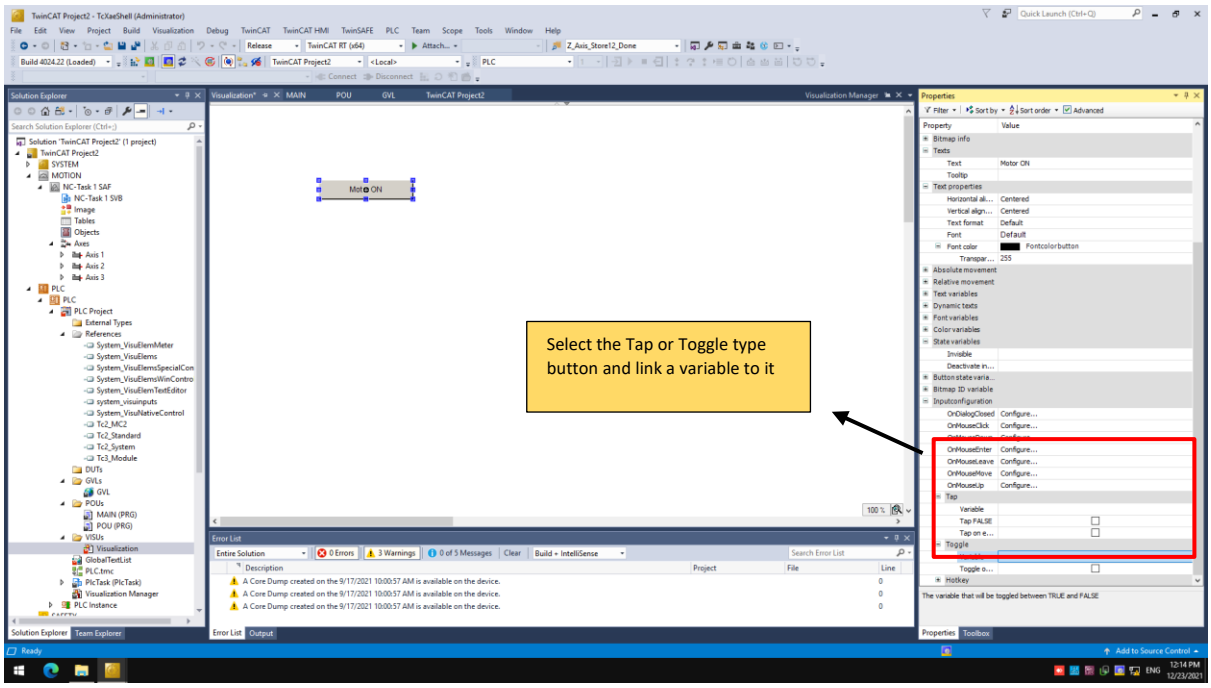


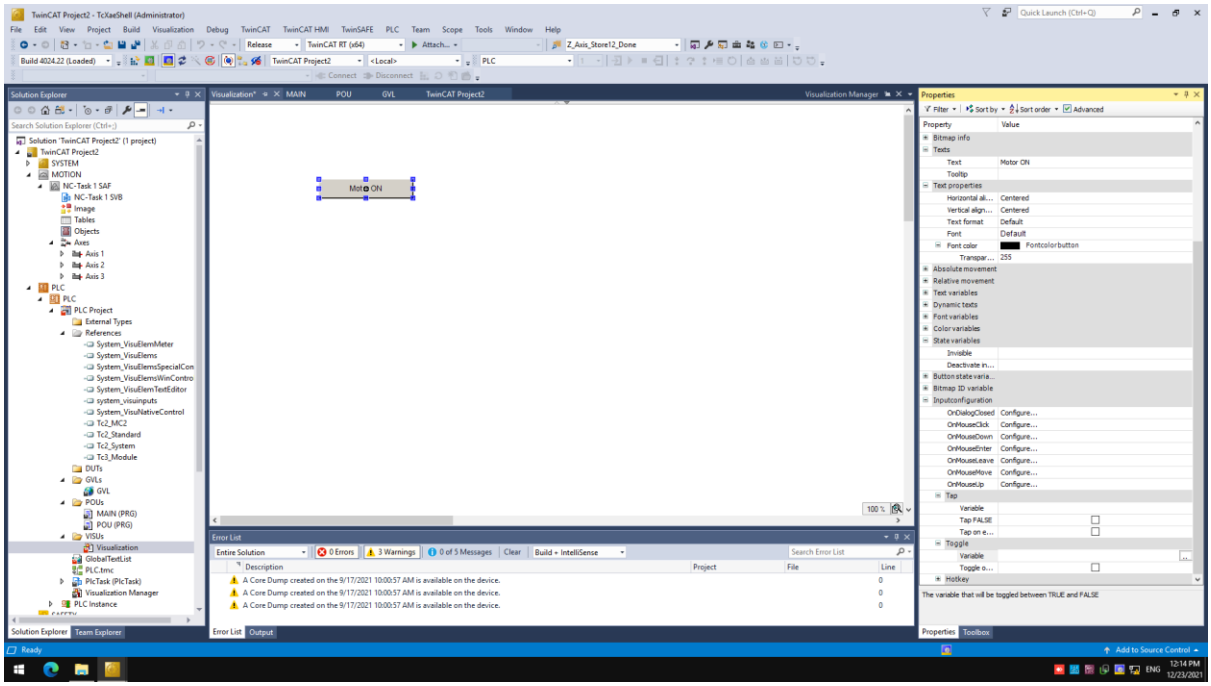

Add Visualization
Creates a visualization object
Name:
Visualization
Symbol libraries
Active
VisuSymbols (System)

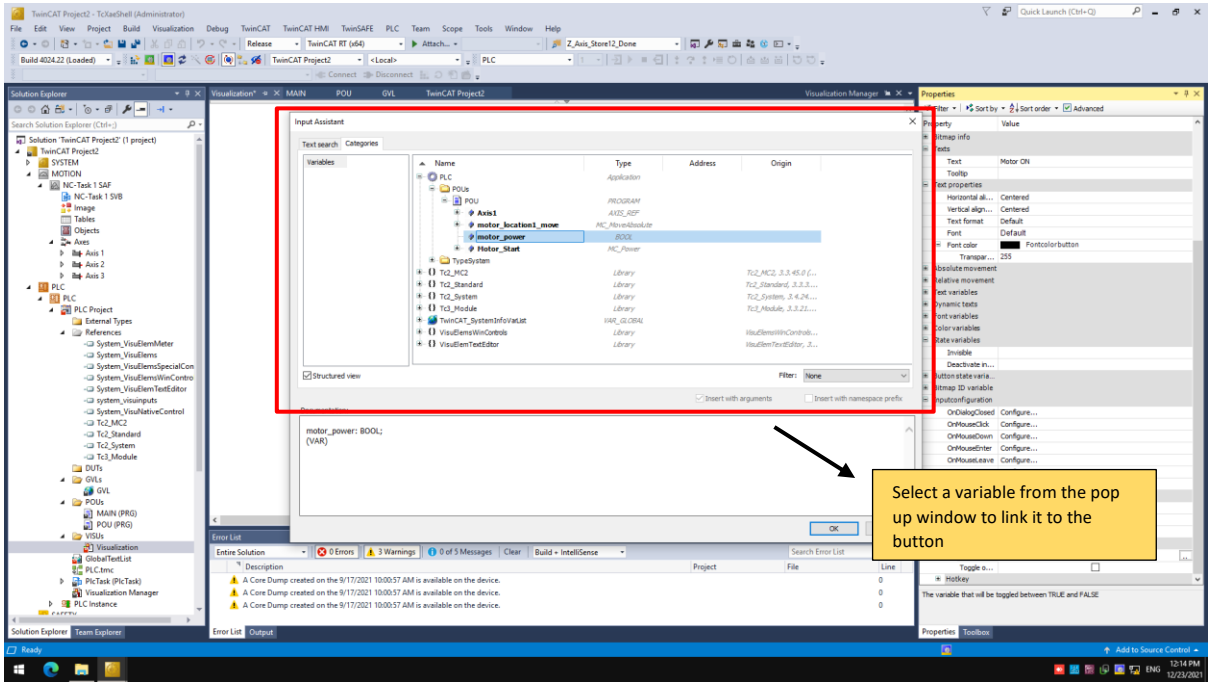

A blank layout is created to add the visualization objects or create HMI screen

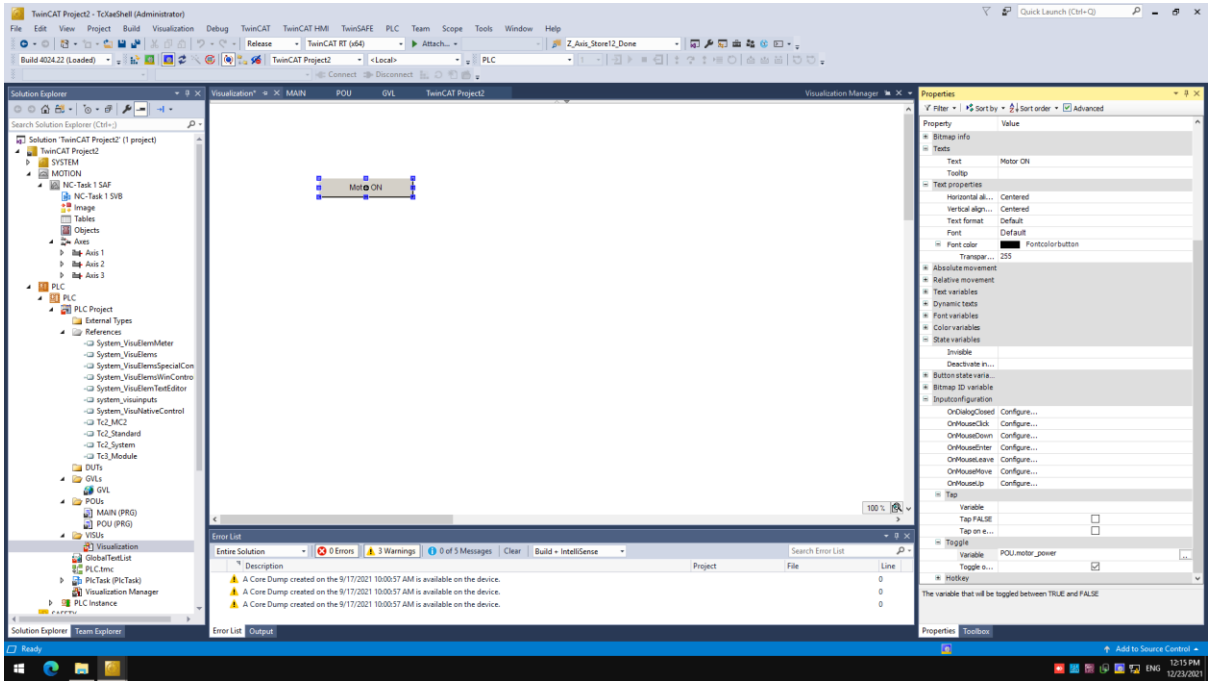

Drag and drop objects from the right side Toolbox to create a HMI screen


Motor ON
Example of a button for HMI screen

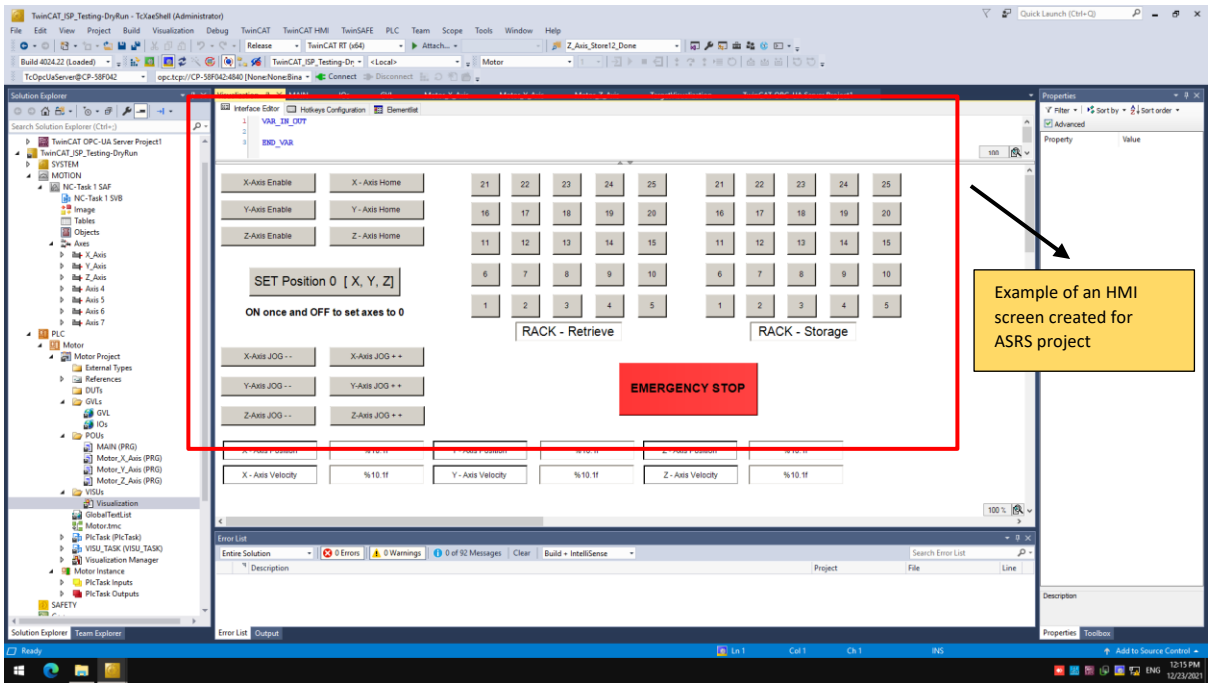

Select the Tap or Toggle type button and link a variable to it

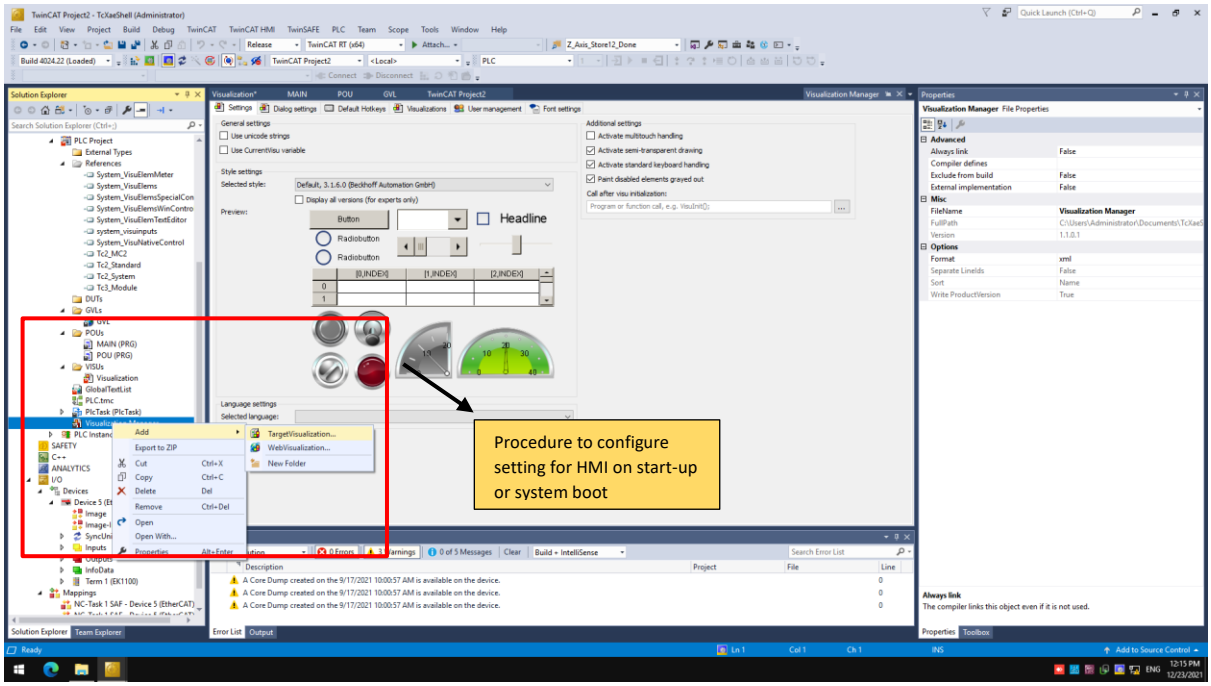


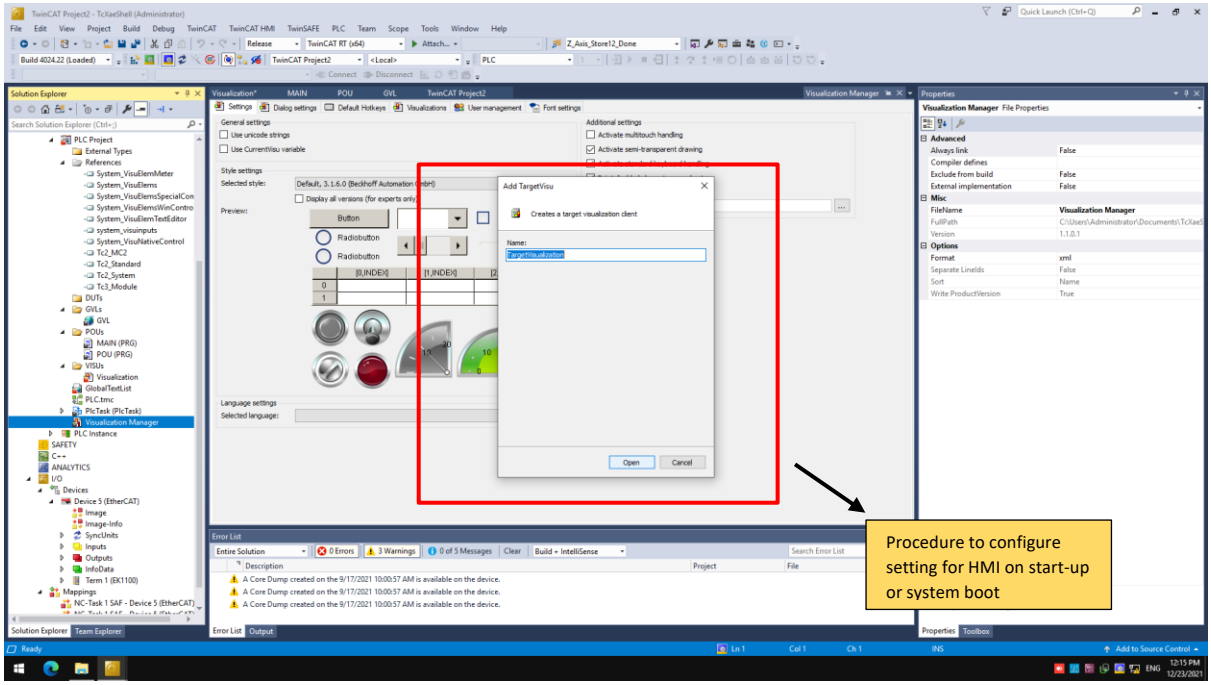

Select a variable from the pop up window to link it to the button

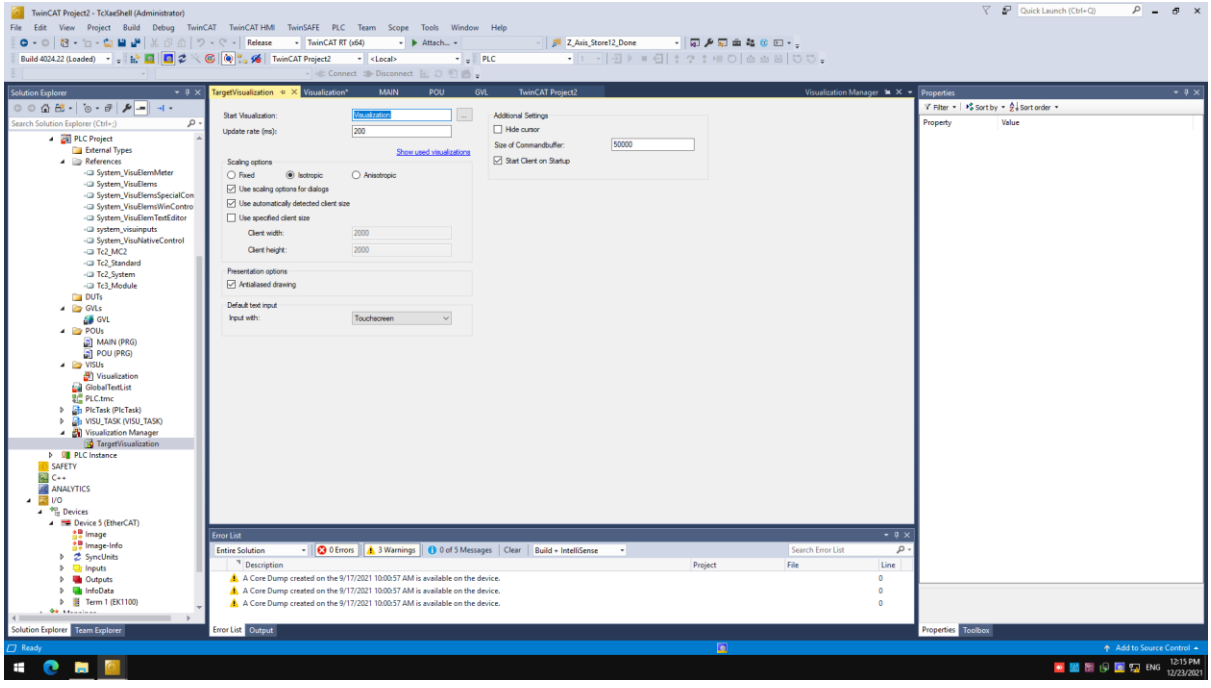


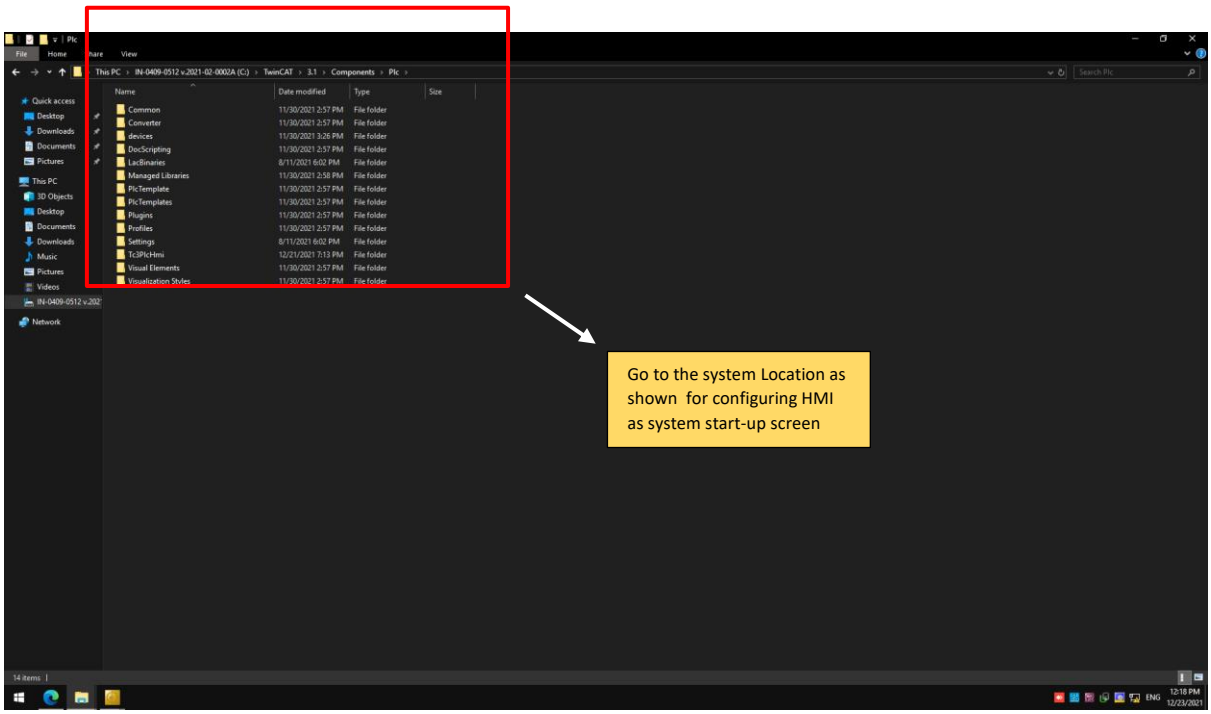
4.1.8.1 HMI settings and system configuration for boot up

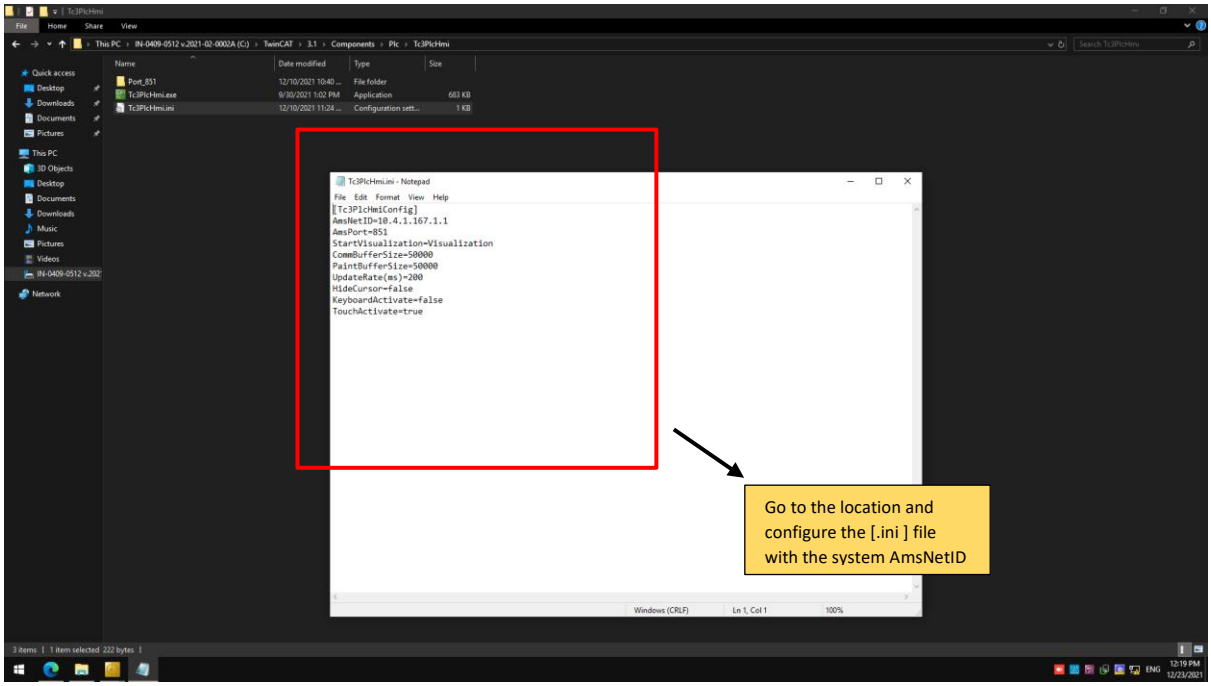




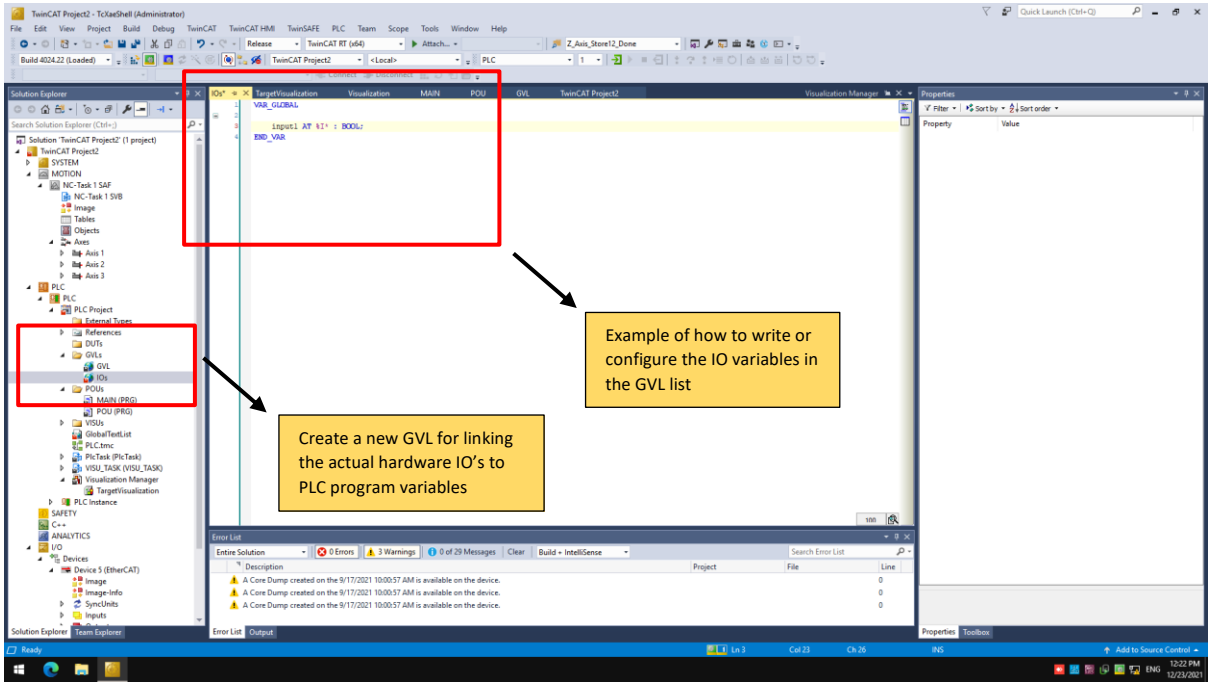

Add TargetVisu
Creates a target visualization client
Name:
TargetVisualization
Open
Cancel
Procedure to configure setting for HMI on start-up or system boot

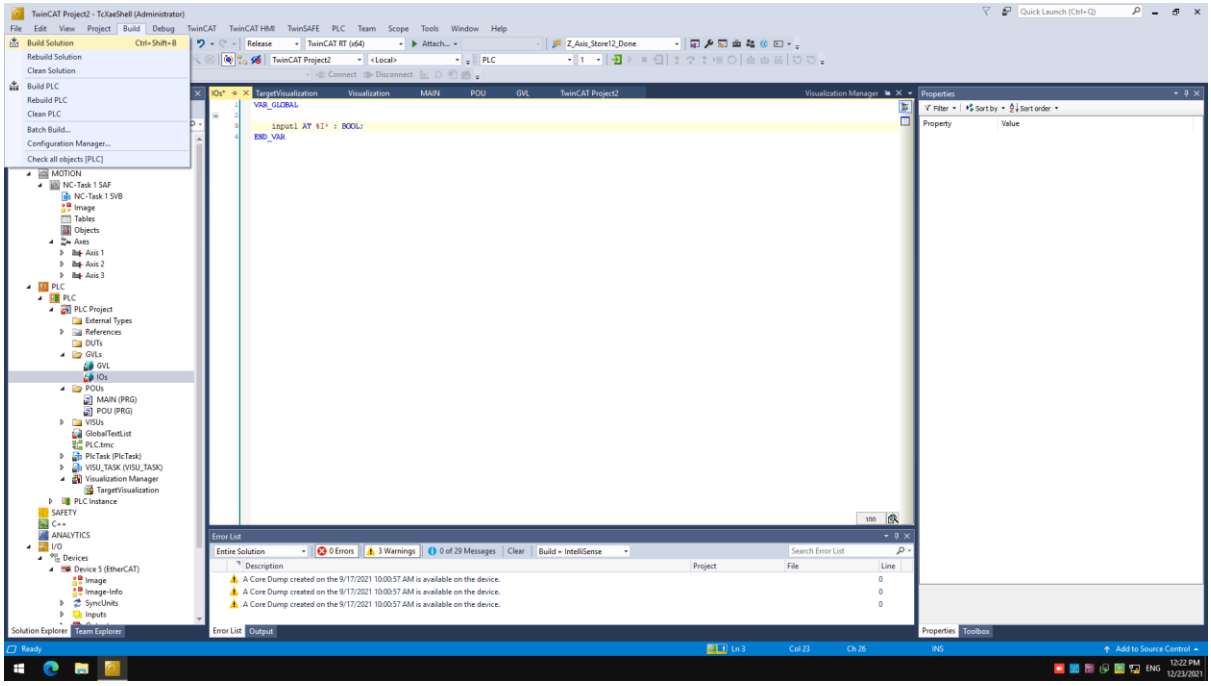


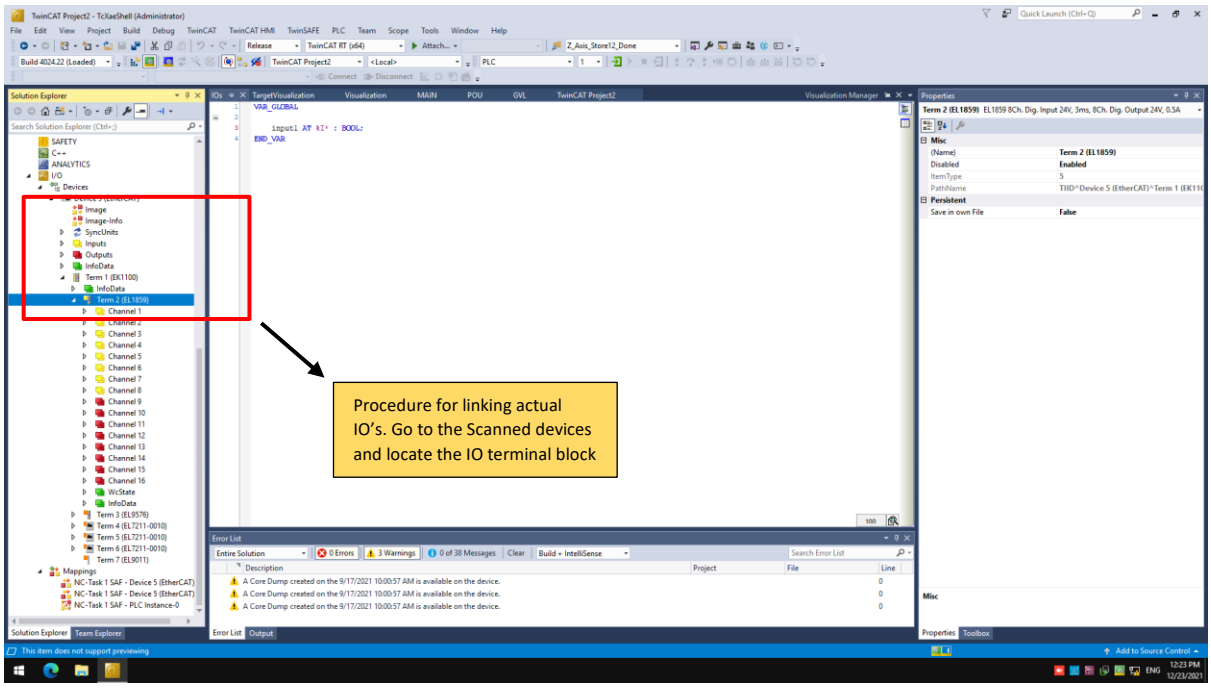

Go to the system Location as shown for configuring HMI as system start-up screen

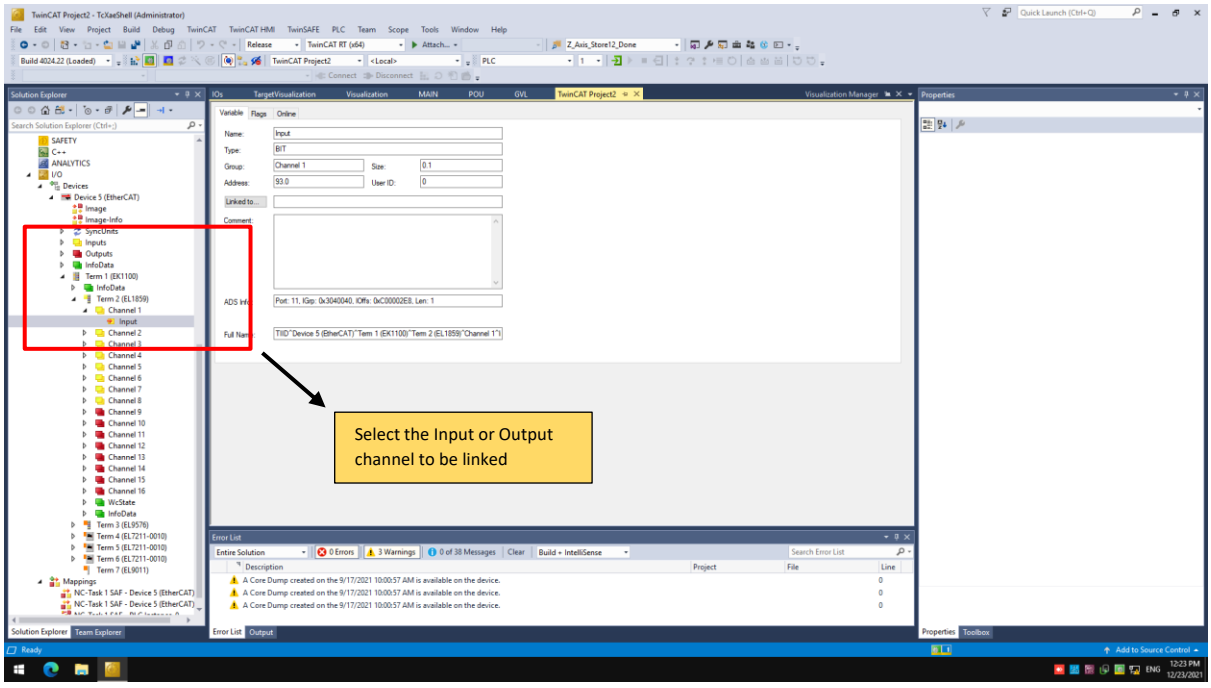

Tc3PlcHmi.ini - Notepad
[Tc3PlcHmiConfig]
AmsNetID=10.4.1.167.1.1
AmsPort=851
StartVisualization=Visualization
CommBufferSize=50000
PaintBufferSize=500000
UpdateRate(ms)=200
HideCursor=false
KeyboardActivate=false
TouchActivate=true
Go to the location and configure the [.ini] file with the system AmsNetID

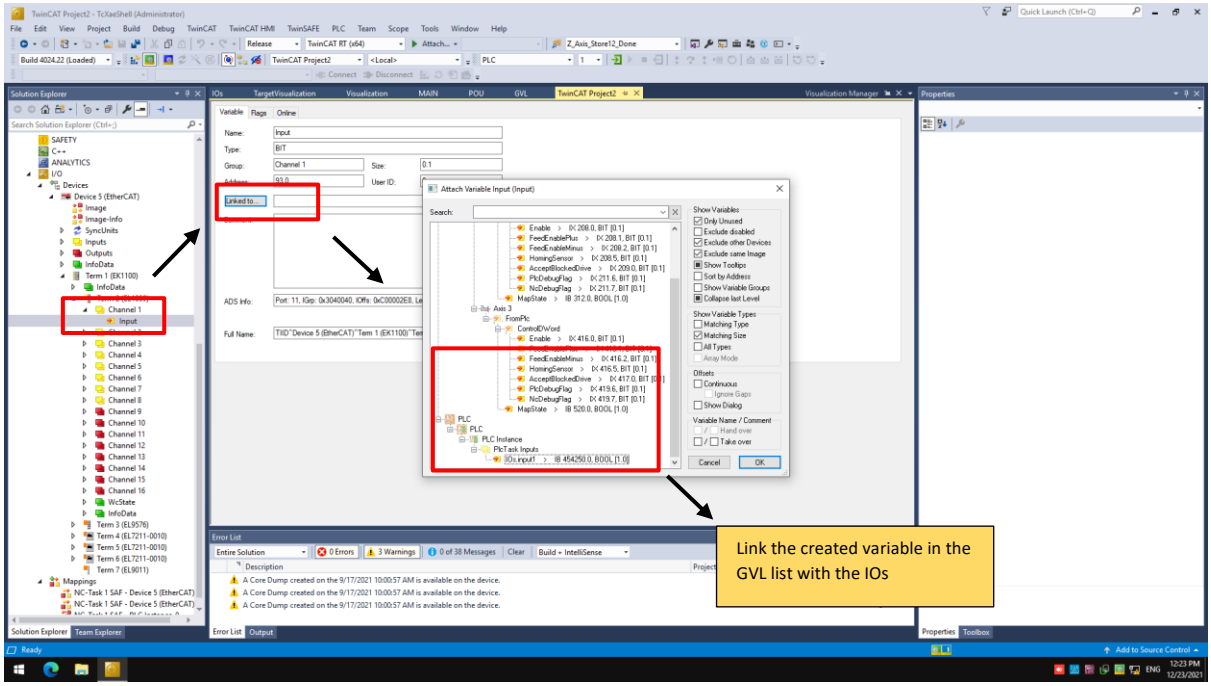
4.1.9 Examples Hardware IO's linking with PLC program

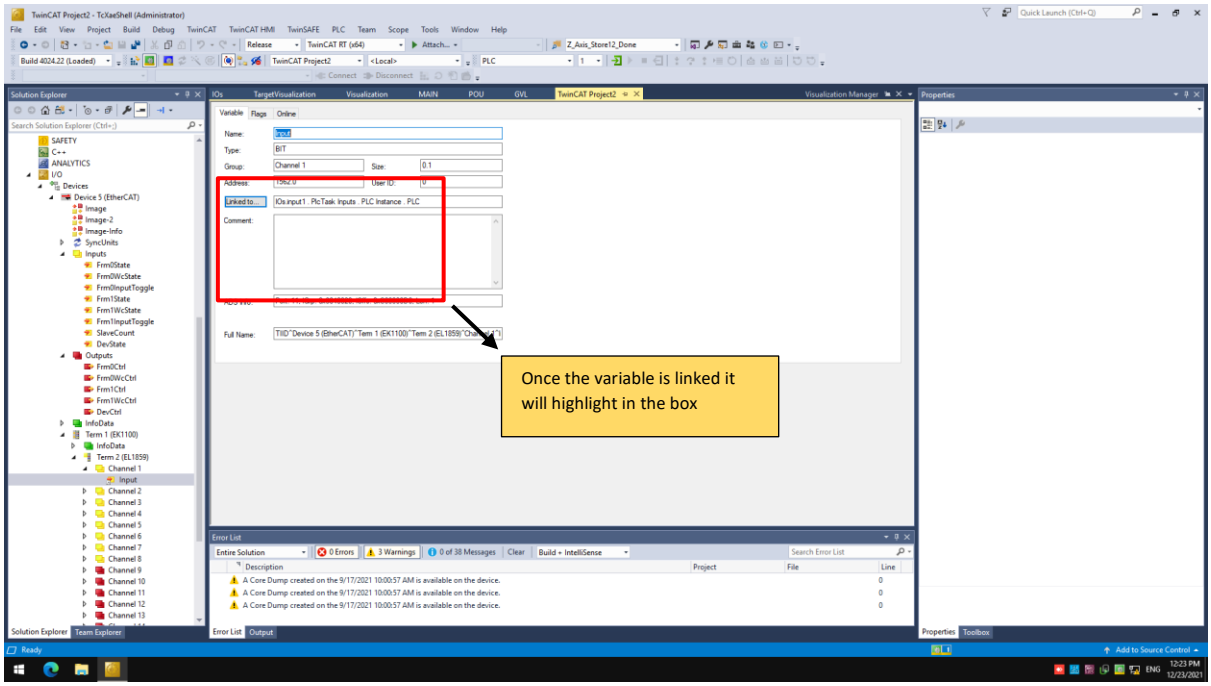




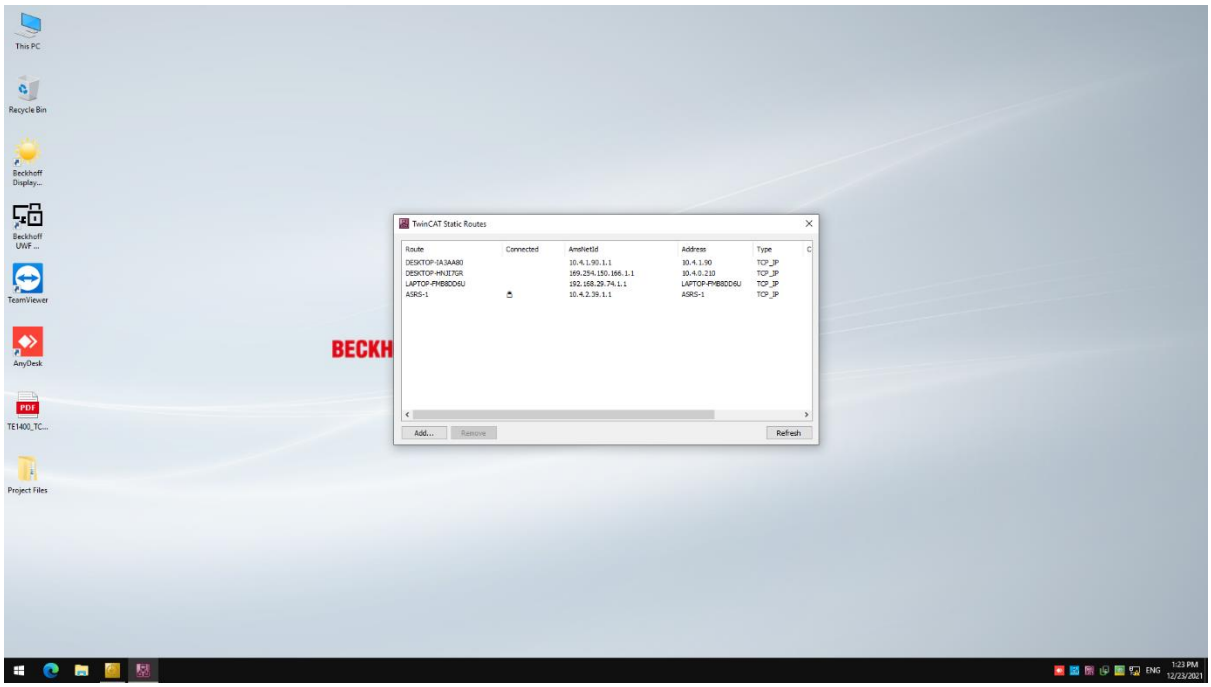

Procedure for linking actual IO's. Go to the Scanned devices and locate the IO terminal block

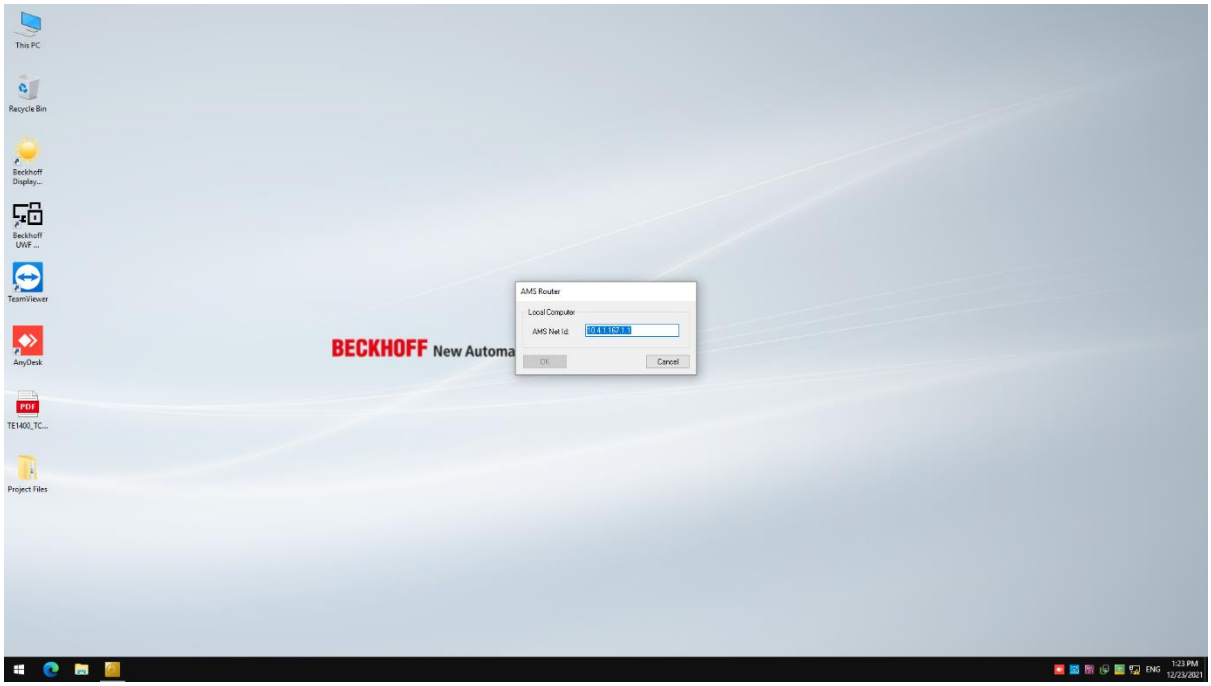

Select the Input or Output channel to be linked

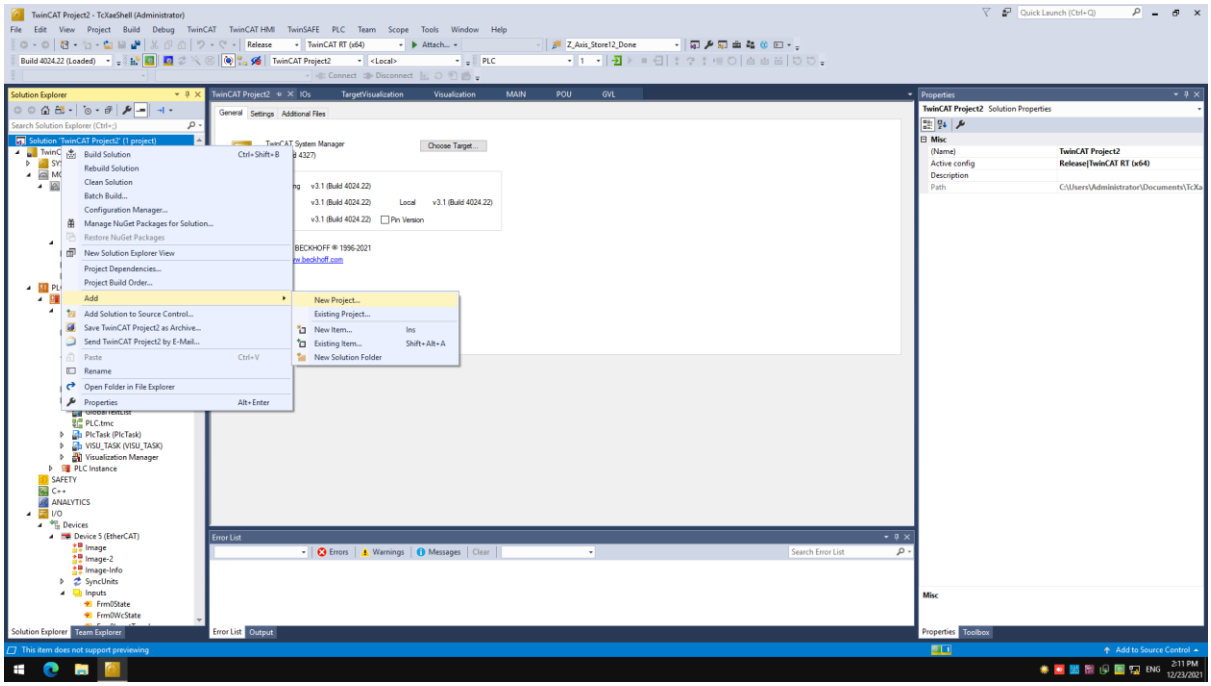

Link the created variable in the GVL list with the IOs

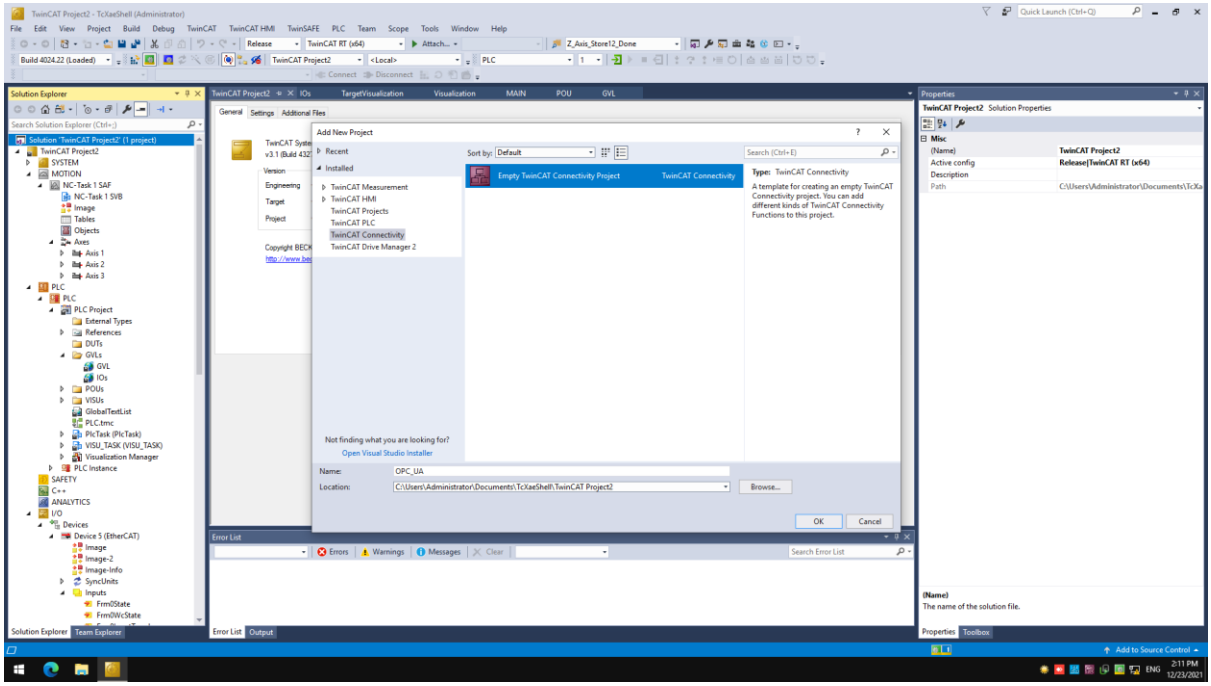

Once the variable is linked it will highlight in the box

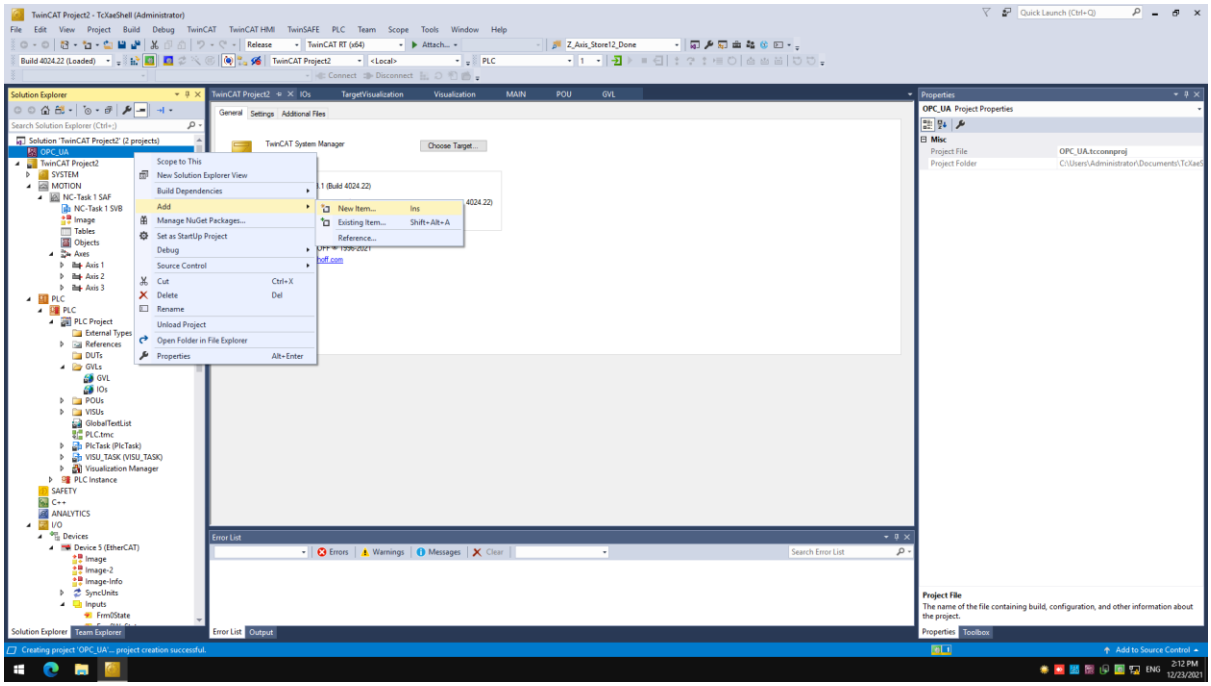
4.2 Creating OPC UA server and configuration: -

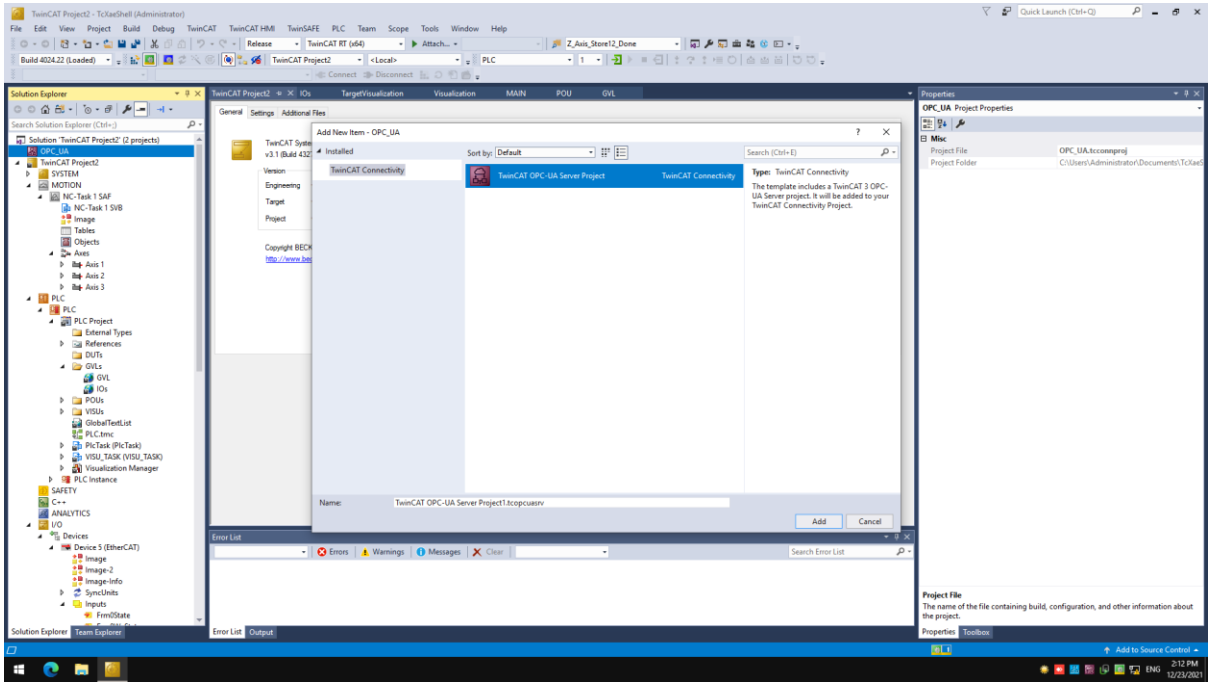


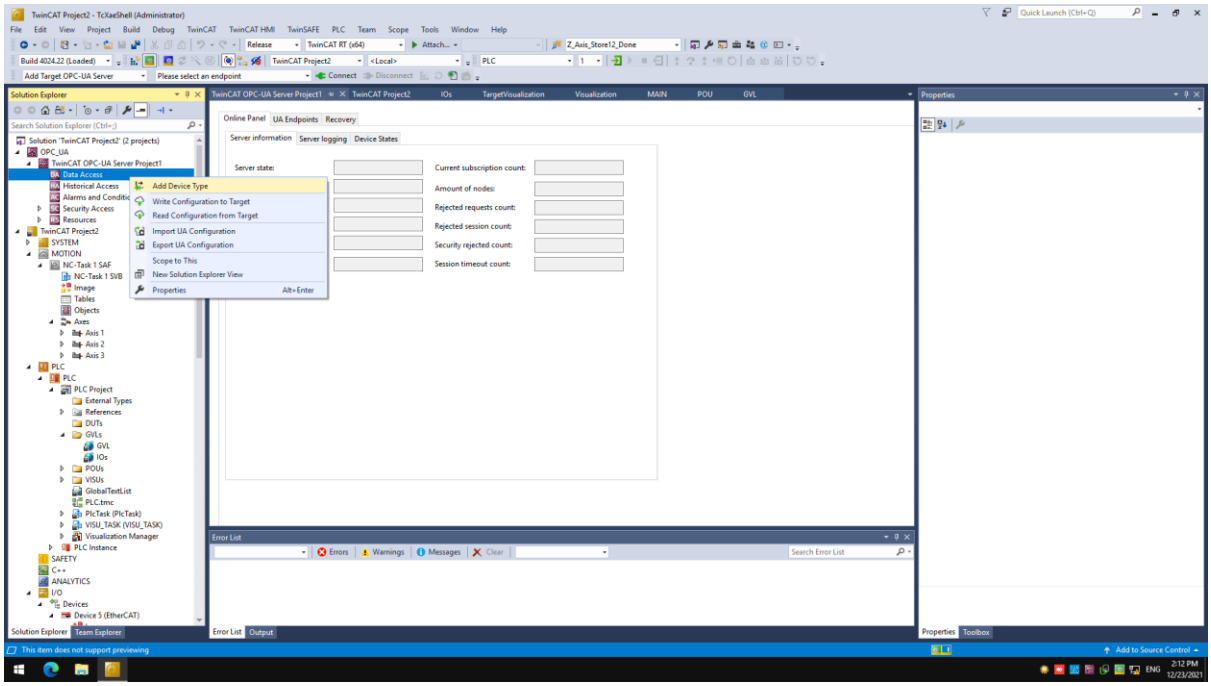

This PC
Recycle Bin
Beckhoff Display...
Beckhoff UWF...
TeamViewer
AnyDesk
TE1400_TC...
Project Files
BECKHOFF New Automa
AMS Router
Local Computer
AMS Net Id:
OK
Cancel

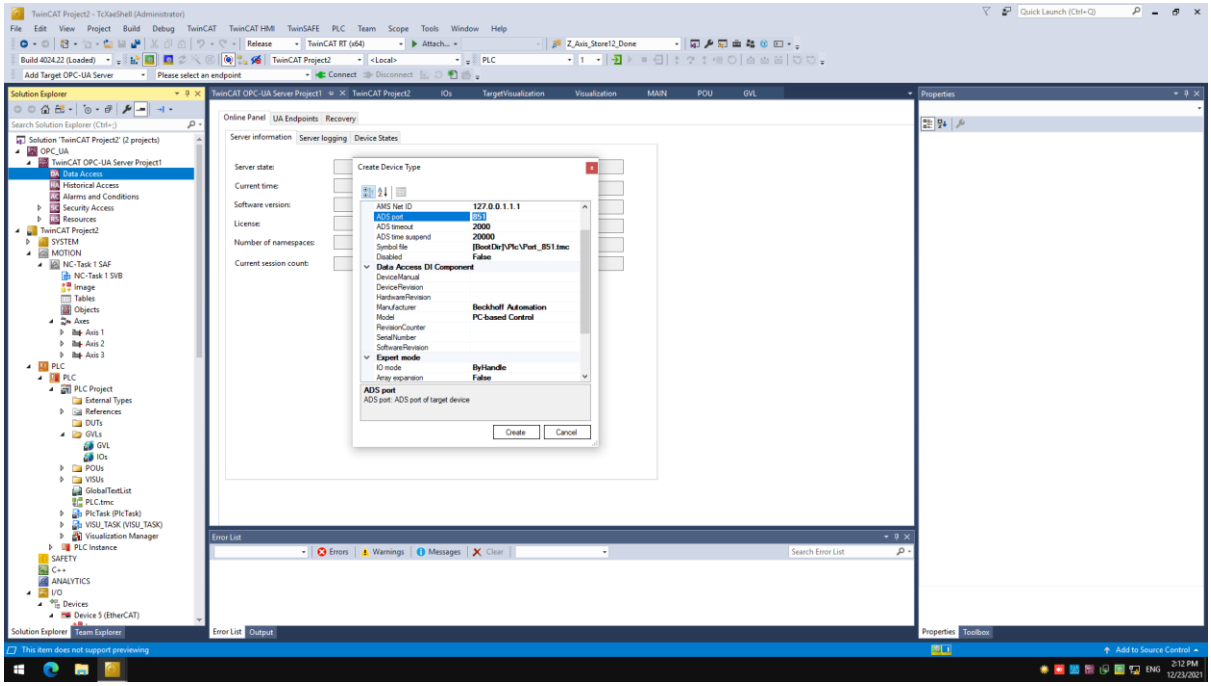

TwinCAT Project2 - TcXaeShell (Administrator)
Solution Explorer
Build Solution
Rebuild Solution
Clean Solution
Batch Build...
Configuration Manager...
Manage NuGet Packages for Solution...
Restore NuGet Packages
New Solution Explorer View
Project Dependencies...
Project Build Order...
Add
Add Solution to Source Control...
Save TwinCAT Project2 as Archive...
Send TwinCAT Project2 by E-Mail...
Paste
Rename
Open Folder in File Explorer
Properties
New Project...
Existing Project...
New Item...
Existing Item...
New Solution Folder
Error List
Properties

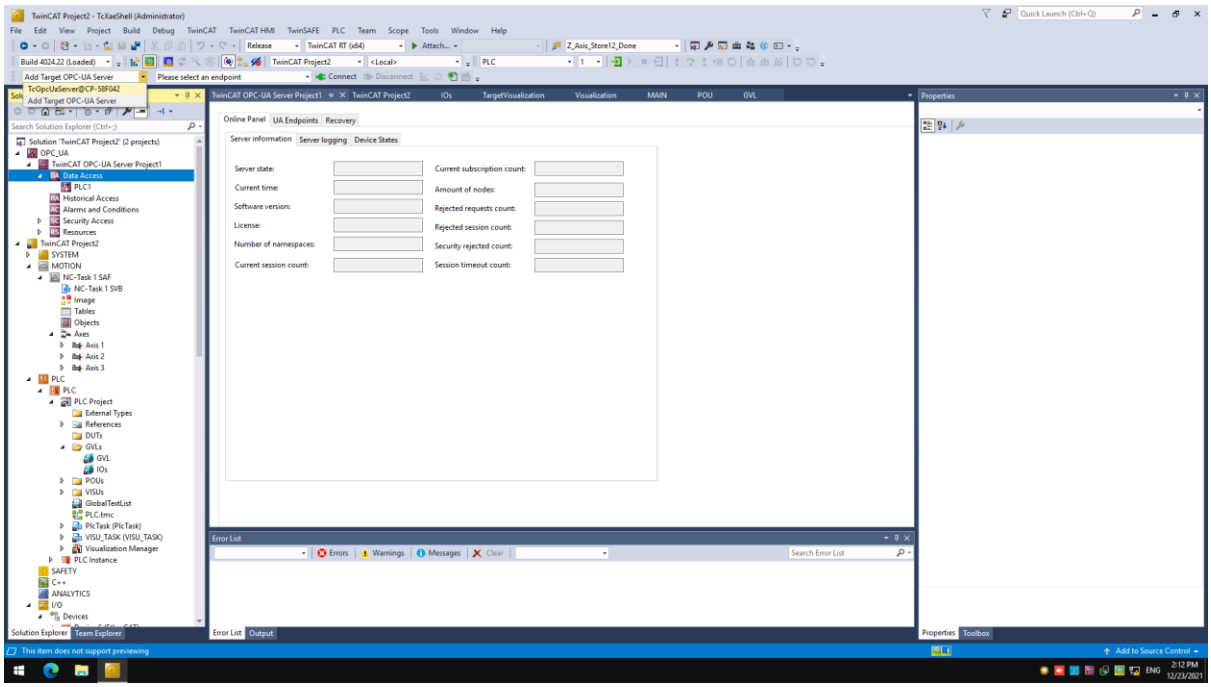

Add New Project
Empty TwinCAT Connectivity Project
TwinCAT Connectivity
Name: OPC_UA
Location: C:\Users\Administrator\Documents\TcXaeShell\TwinCAT Project2
OK
Cancel

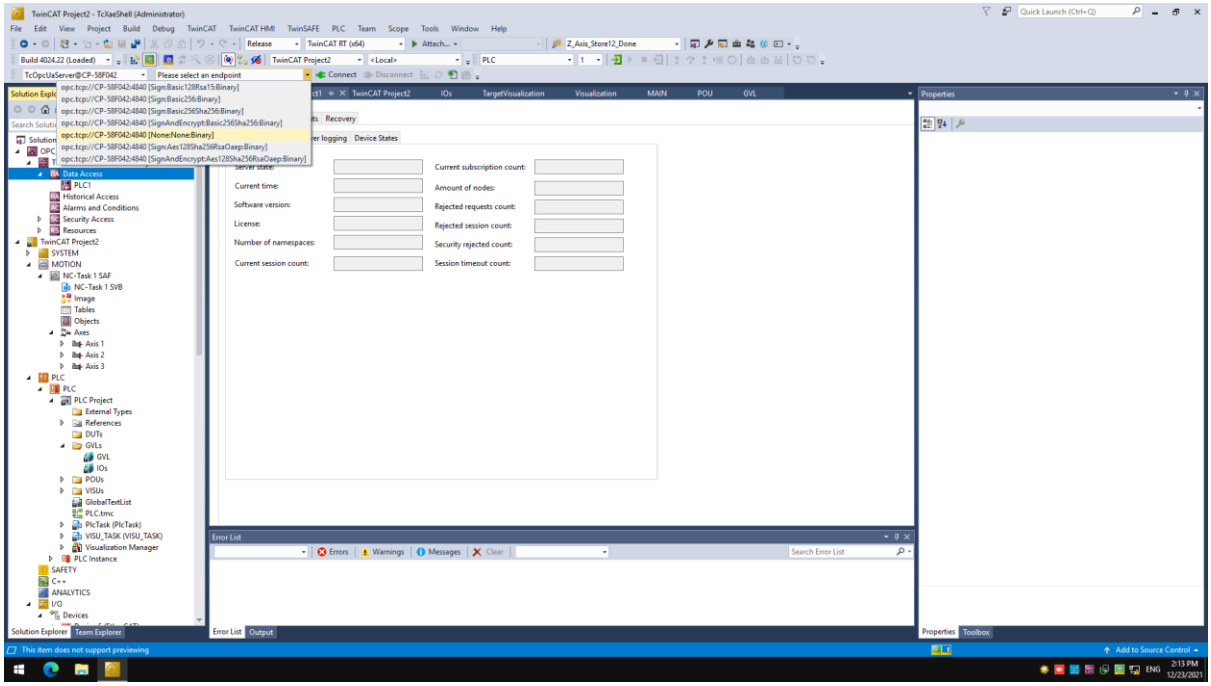

Scope to This
New Solution Explorer View
Build Dependencies
Add
Manage NuGet Packages...
Set as StartUp Project
Debug
Source Control
Cut Ctrl+X
Delete Del
Rename
Unload Project
Open Folder in File Explorer
Properties Alt+Enter
New Item... Ins
Existing Item... Shift+Alt+A
Reference...
Creating project 'OPC_UA'... project creation successful.

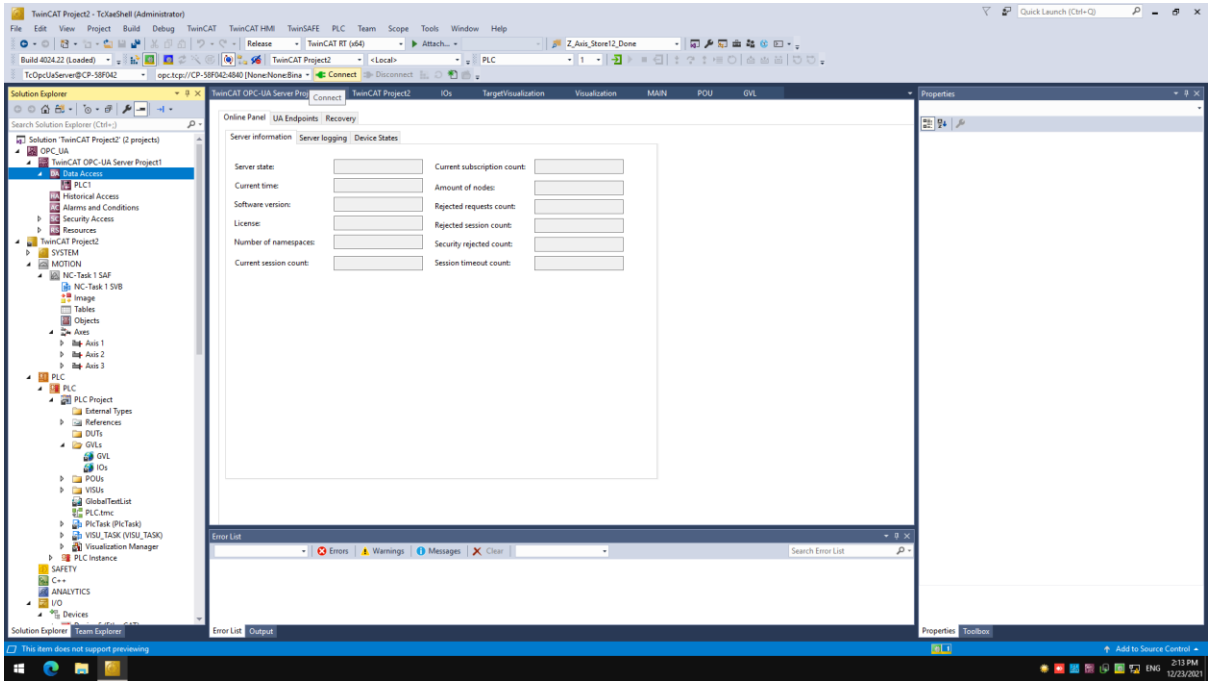


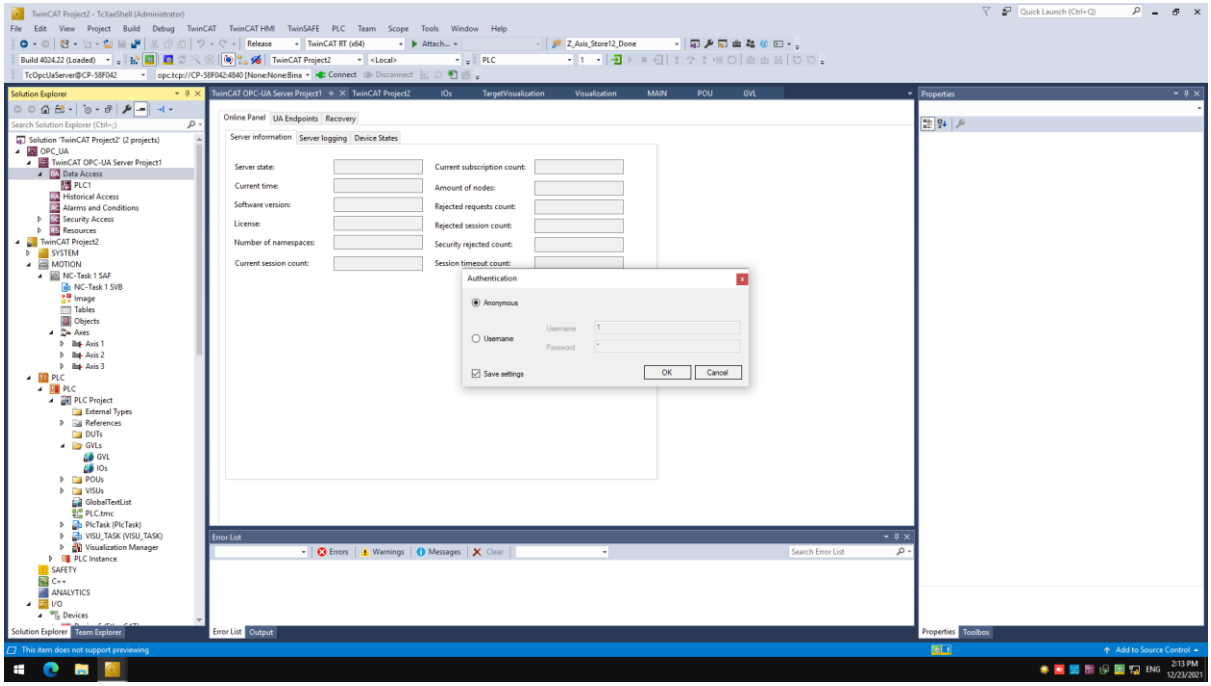


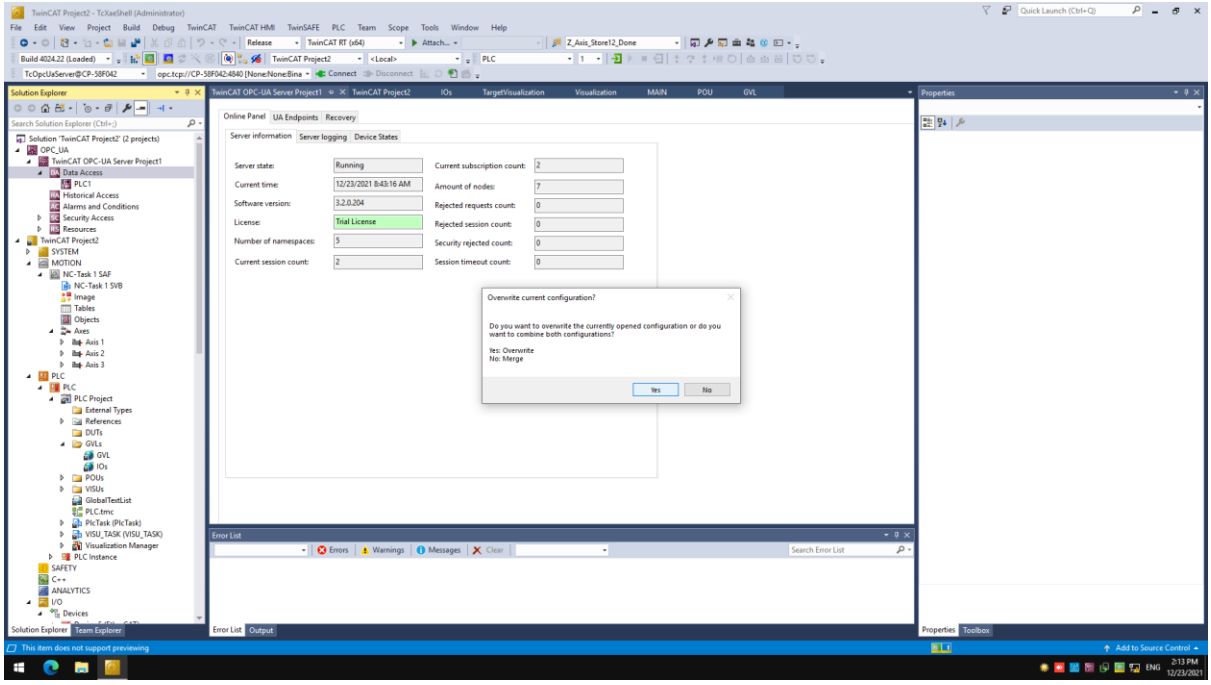

Create Device Type
AMS Net ID
127.0.0.1.1.1
ADS port
851
ADS timeout
2000
ADS time suspend
20000
Symbol file
[BootDir]\Plc\Port_851.tmc
Disabled
False
Data Access DI Component
DeviceManual
DeviceRevision
HardwareRevision
Manufacturer
Beckhoff Automation
Model
PC-based Control
RevisionCounter
SerialNumber
SoftwareRevision
Expert mode
IO mode
ByHandle
Array expansion
False
ADS port
ADS port: ADS port of target device
Create
Cancel

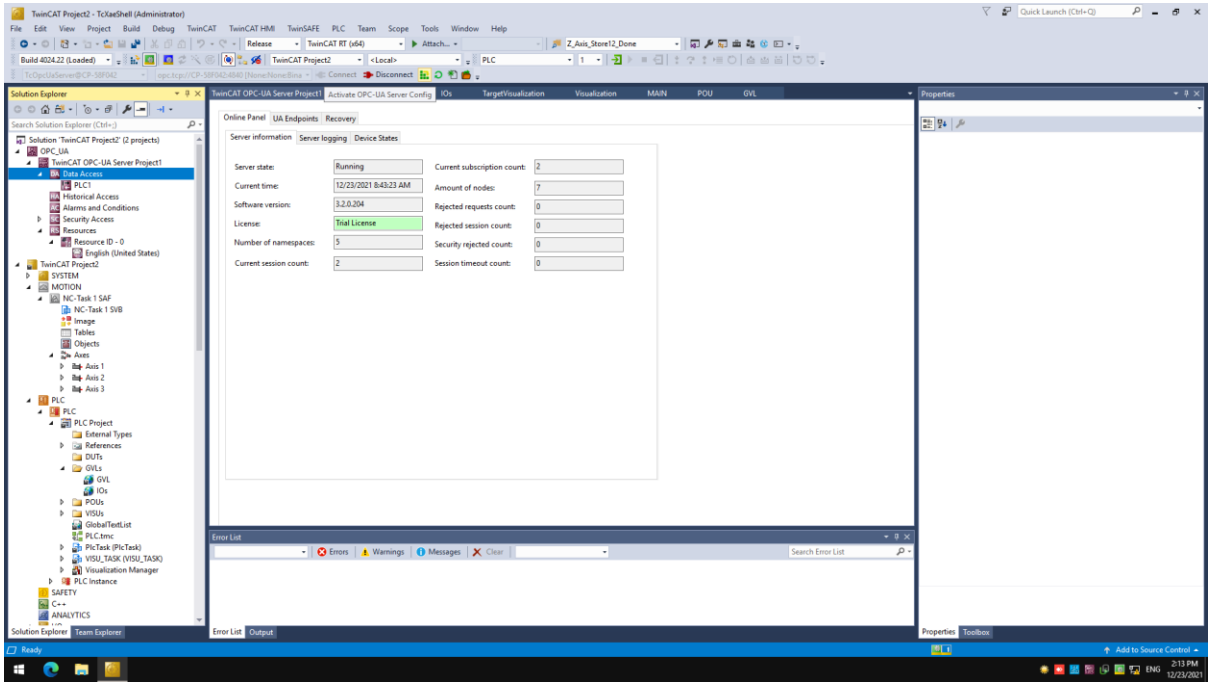


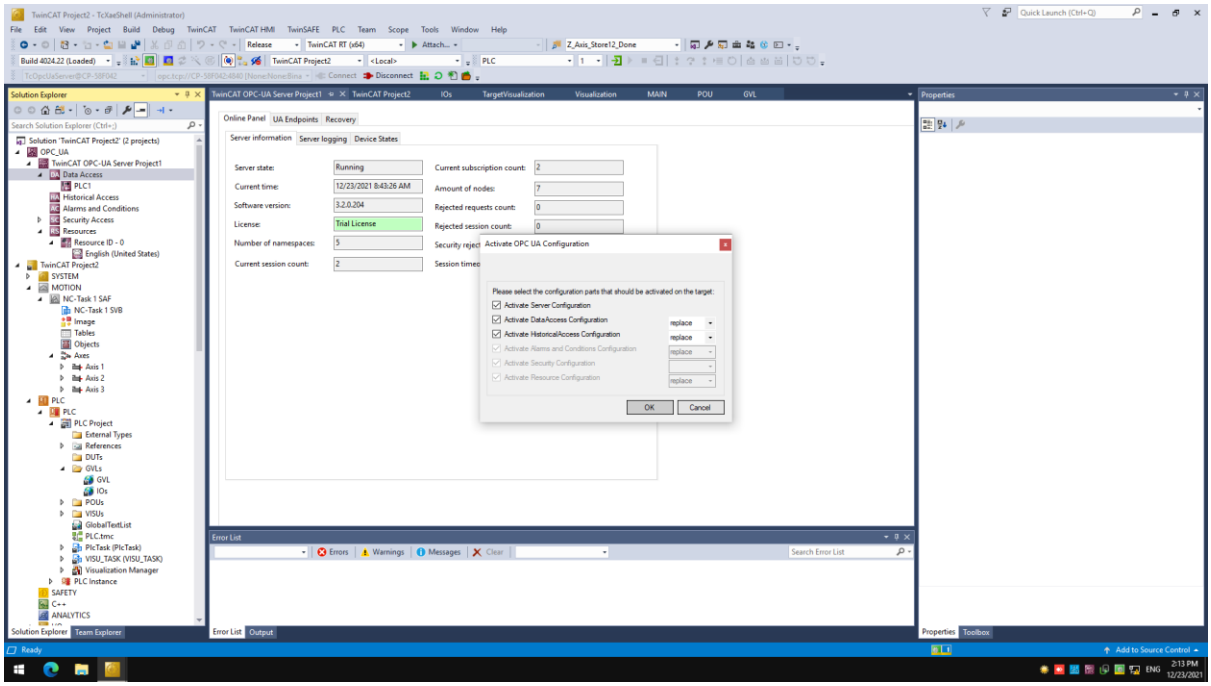

TwinCAT Project2 - TcXaeShell (Administrator)
Please select an endpoint
Connect
Disconnect
Server information
Server logging
Device States
Current subscription count:
Amount of nodes:
Rejected requests count:
Rejected session count:
Security rejected count:
Session timeout count:
Server state:
Current time:
Software version:
License:
Number of namespaces:
Current session count:
Error List
Errors
Warnings
Messages
Solution Explorer
Properties
Toolbox

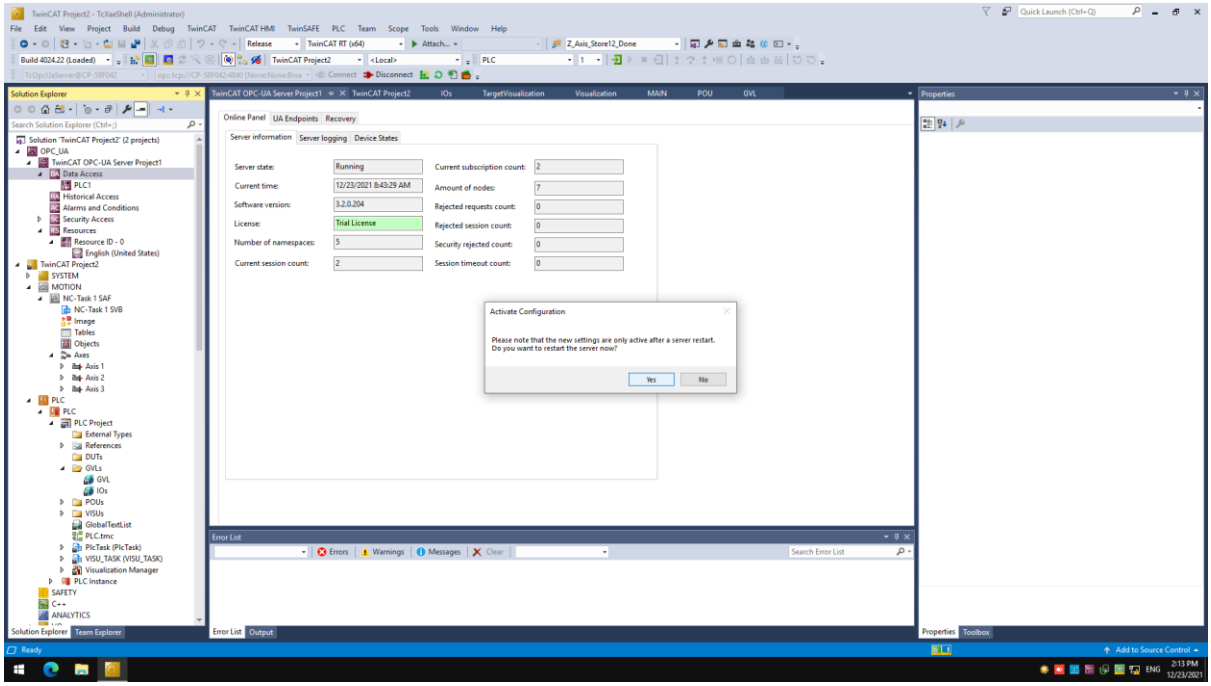

TwinCAT Project2 - TcXaeShell (Administrator)
TwinCAT OPC-UA Server Pro
Connect
Online Panel
UA Endpoints
Recovery
Server information
Server logging
Device States
Current subscription count:
Amount of nodes:
Rejected requests count:
Rejected session count:
Security rejected count:
Session timeout count:
Server state:
Current time:
Software version:
License:
Number of namespaces:
Current session count:
Error List
Errors
Warnings
Messages
Solution Explorer
Properties
Toolbox

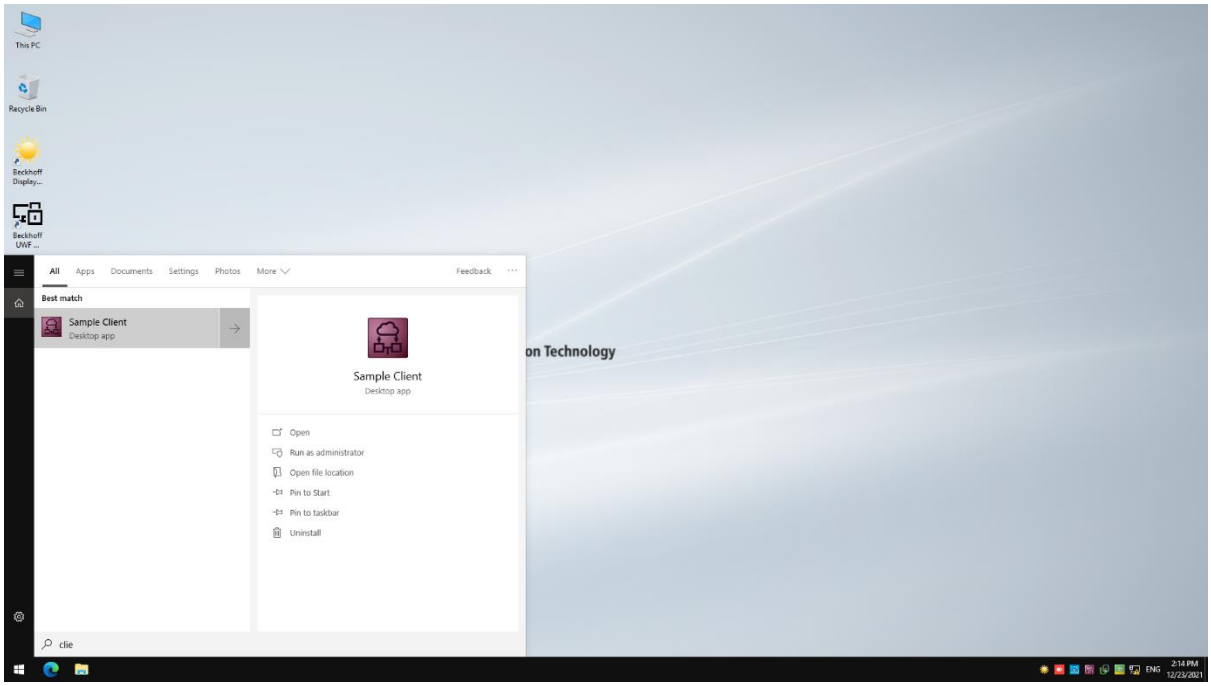

Authentication
Anonymous
Username
Save settings
OK
Cancel

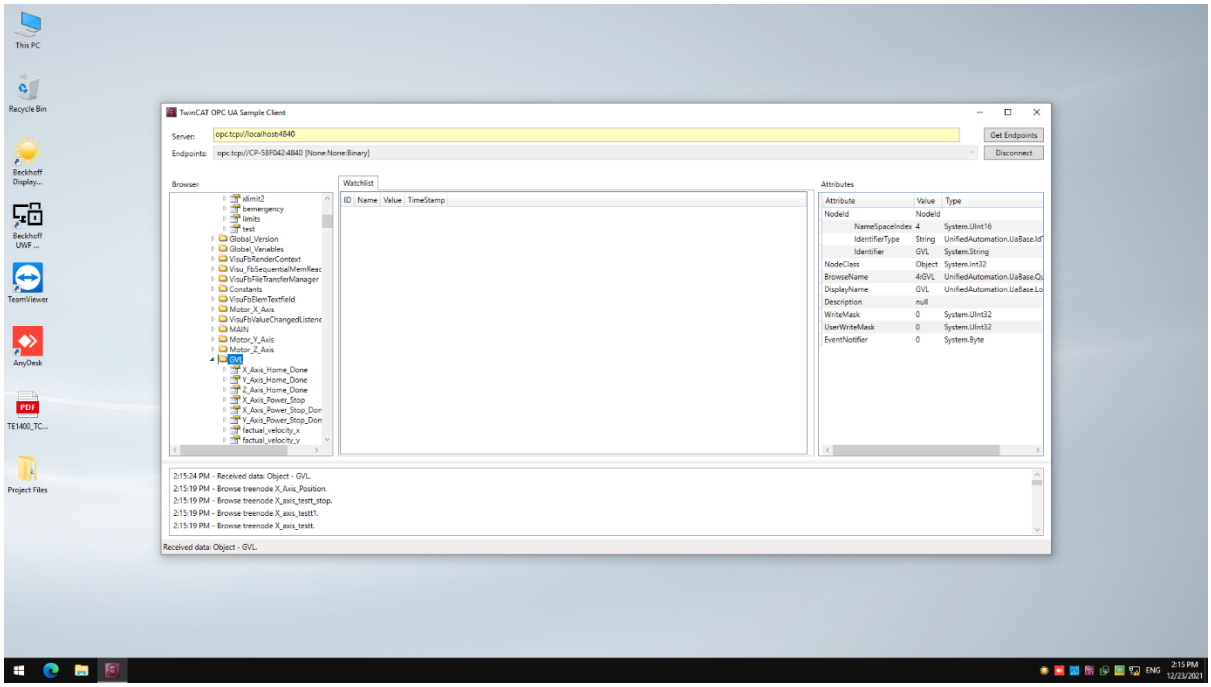

Overwrite current configuration?
Do you want to overwrite the currently opened configuration or do you want to combine both configurations?
Yes: Overwrite
No: Merge
Yes
No

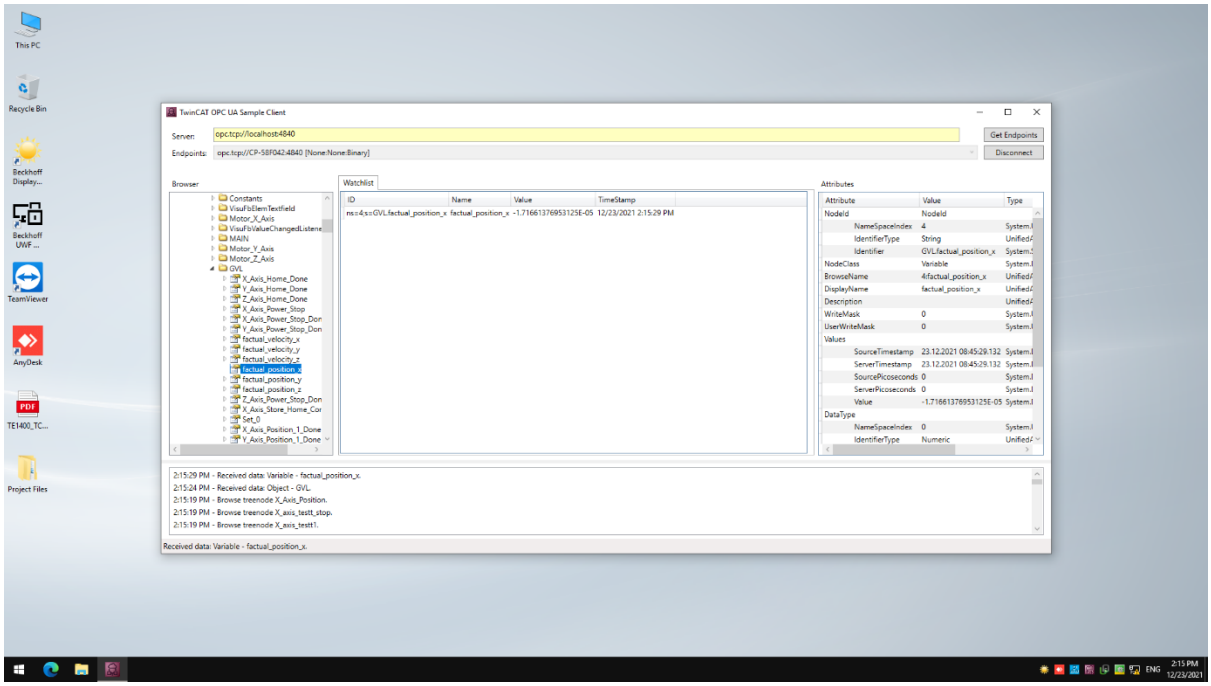



Activate OPC UA Configuration
Please select the configuration parts that should be activated on the target:
Activate Server Configuration
Activate DataAccess Configuration
Activate HistoricalAccess Configuration
Activate Alarms and Conditions Configuration
Activate Security Configuration
Activate Resource Configuration
OK
Cancel


Activate Configuration
Please note that the new settings are only active after a server restart.
Do you want to restart the server now?
Yes
No

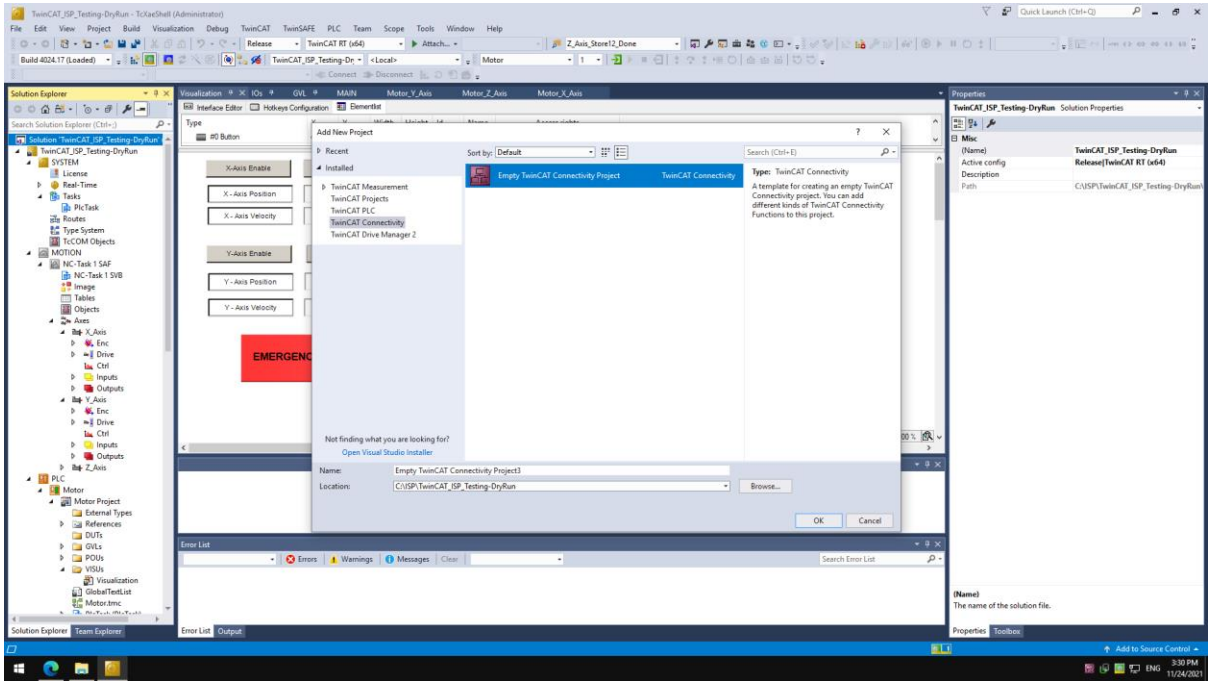

Sample Client
Desktop app
Open
Run as administrator
Open file location
Pin to Start
Pin to taskbar
Uninstall

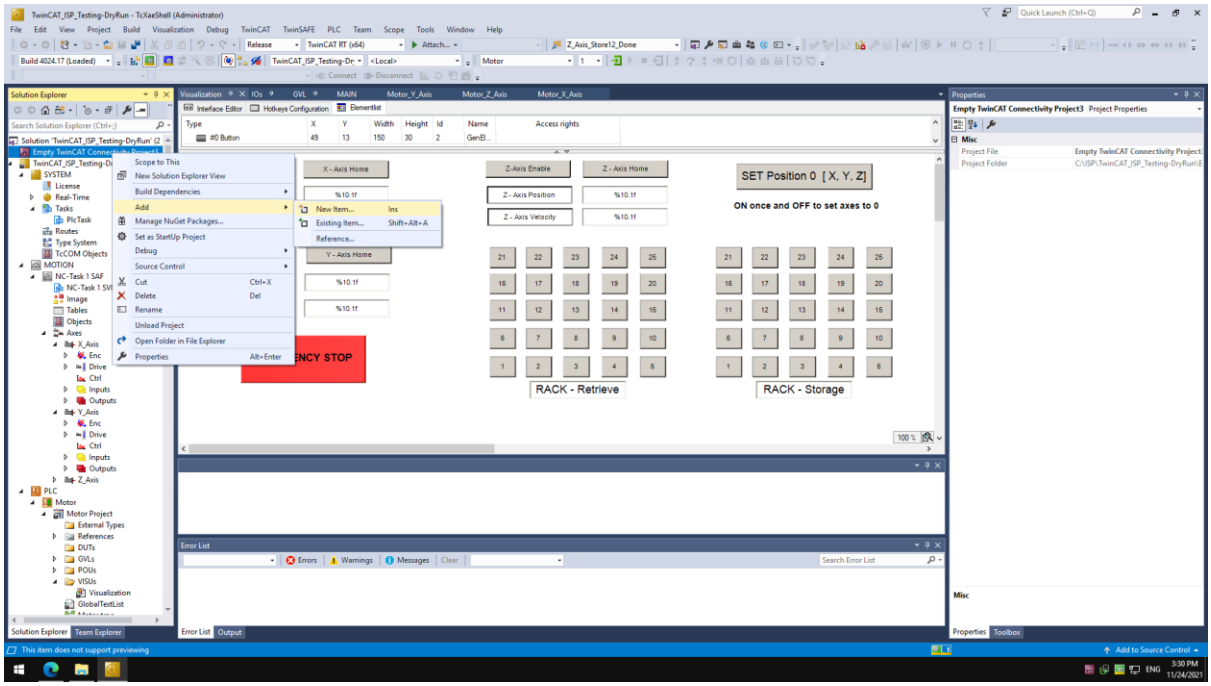

TwinCAT OPC UA Sample Client
Server:
opc.tcp://localhost:4840
Endpoints:
Get Endpoints
Disconnect
Browser
Watchlist
Attributes
Received data: Object - GVL.

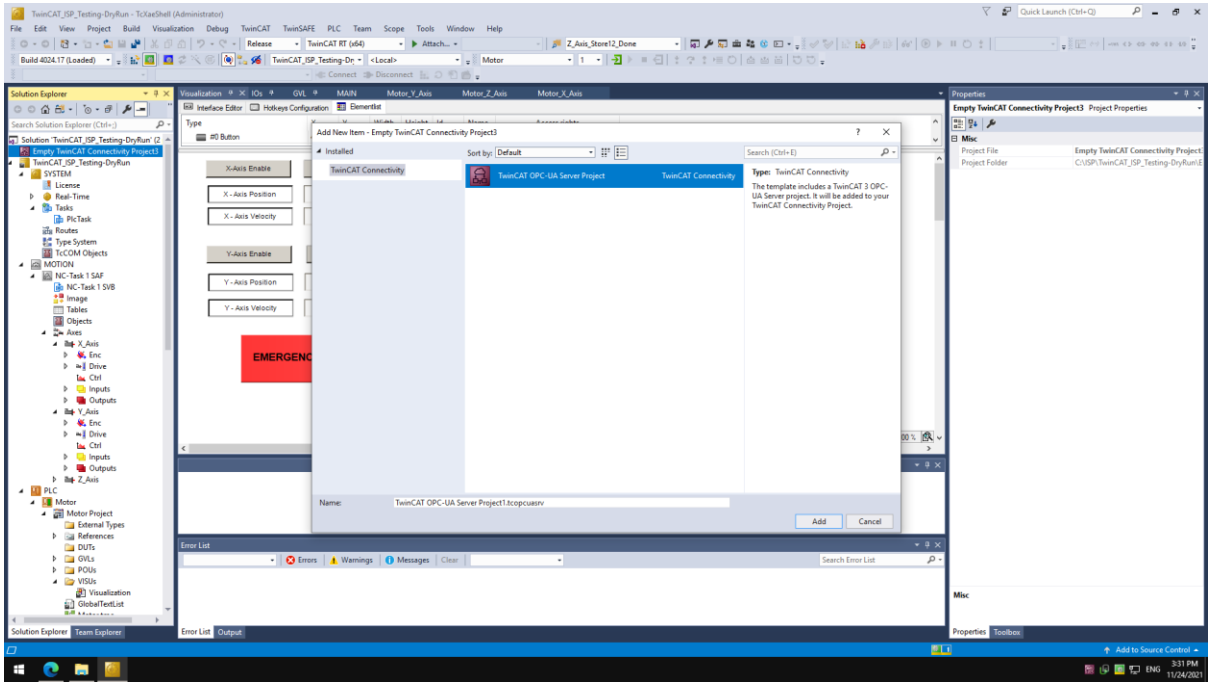

TwinCAT OPC UA Sample Client
Server:
opc.tcp://localhost:4840
Endpoints:
Get Endpoints
Disconnect
Browser
Watchlist
Attributes
Received data: Variable - factual_position_x.

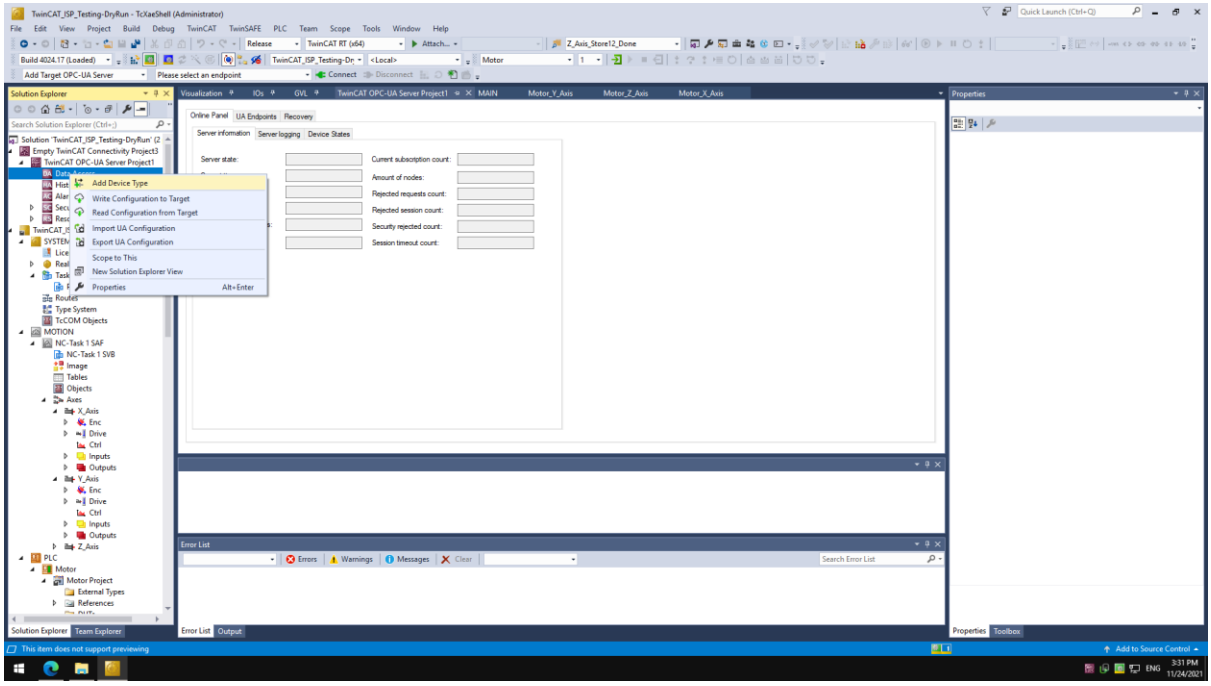
4.3 Digital Twin (MATLAB)

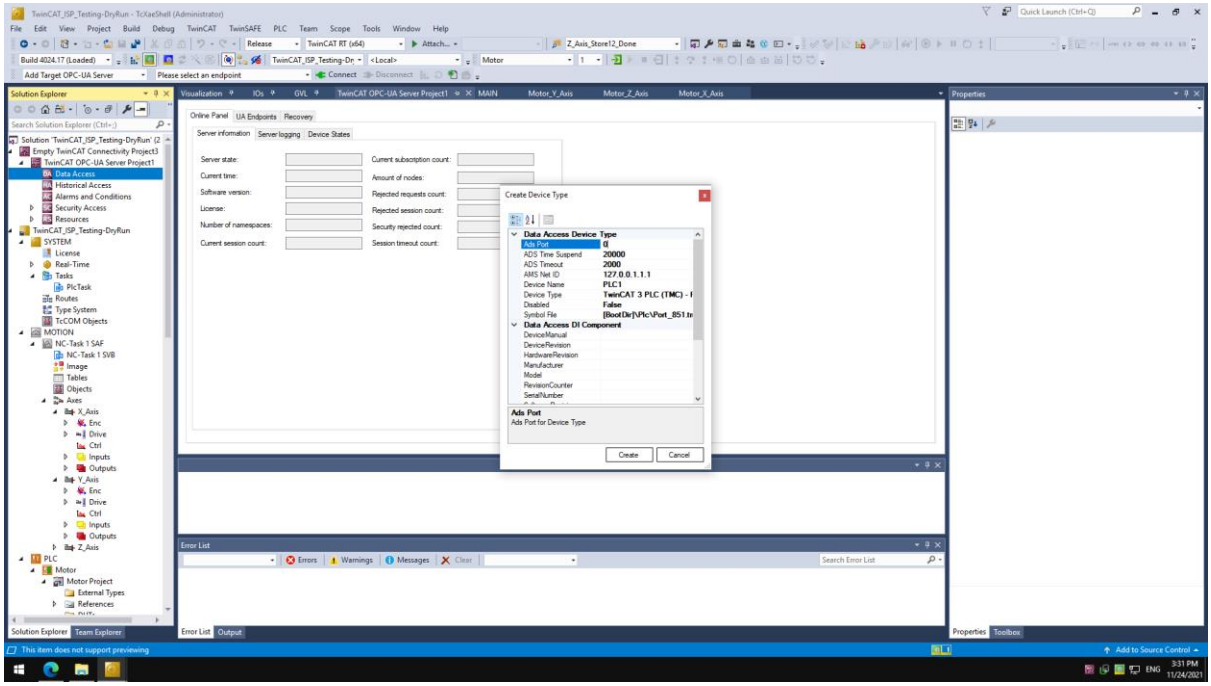
Digital Twin is the real time simulation model of the actual machine or robot setup. These digital twins are very useful in real time analysis and monitoring of the machine without actually being physically present and also helps in analysis of various critical machine parameters. (TwinCAT OPC Server setup): - OPC servers are open platform communication setup to get the real time data from the TwinCAT automation setup. These data from the OPC servers can be used to design any third-party applications with the TwinCAT environment.

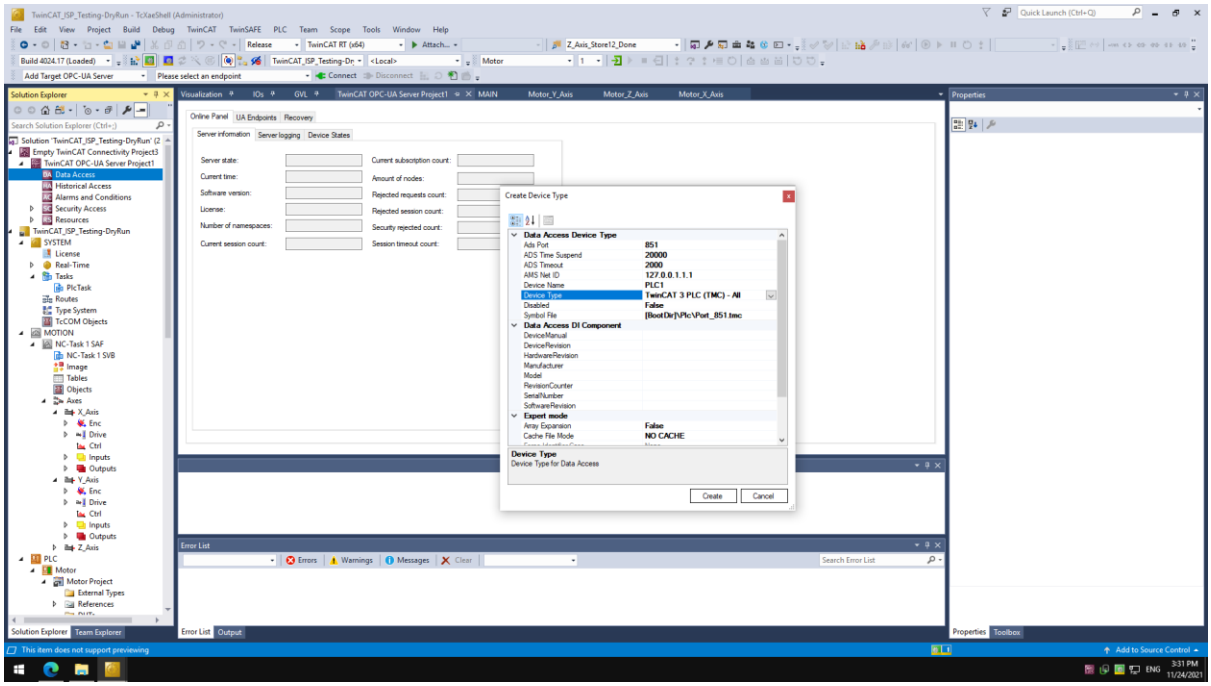


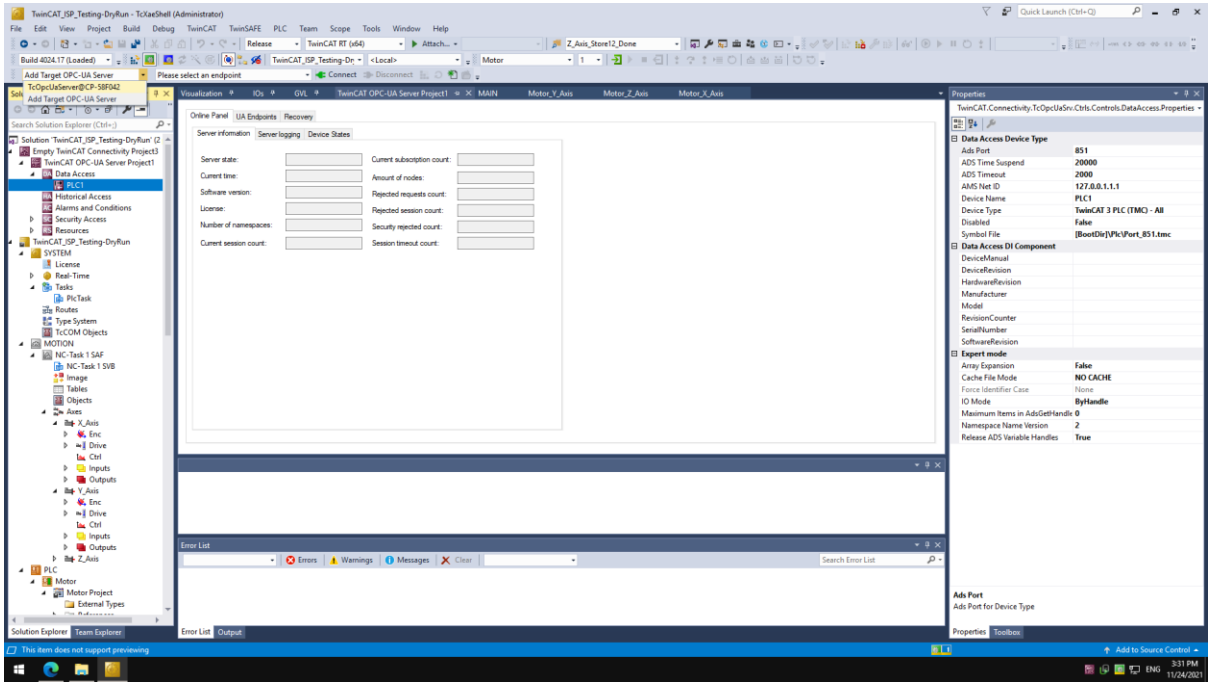


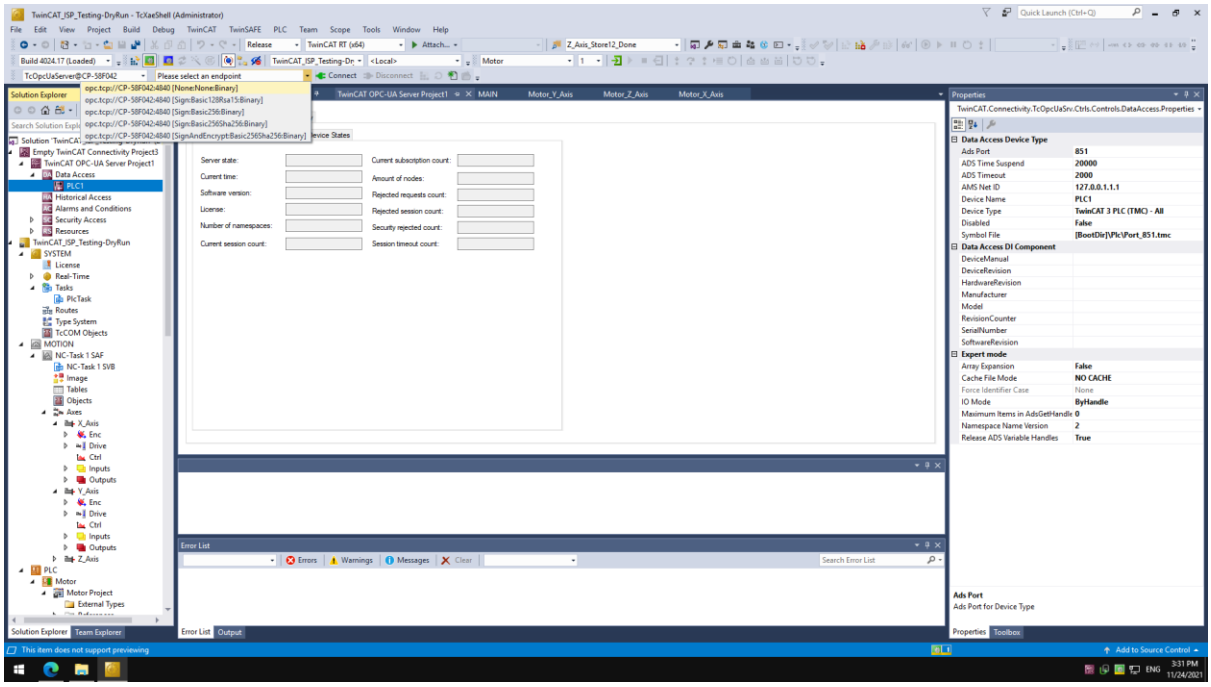

Add New Item - Empty TwinCAT Connectivity Project3
TwinCAT OPC-UA Server Project
TwinCAT Connectivity
Add
Cancel

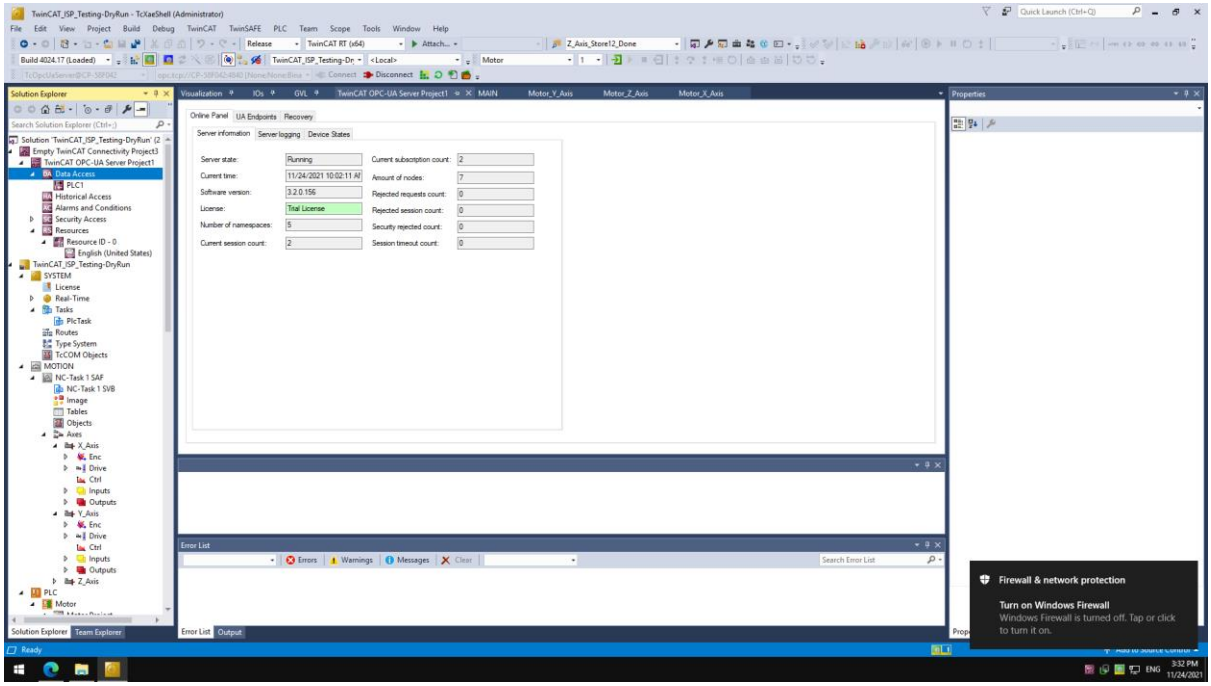

Add Device Type
Write Configuration to Target
Read Configuration from Target
Import UA Configuration
Export UA Configuration
Scope to This
New Solution Explorer View
Properties
Alt+Enter

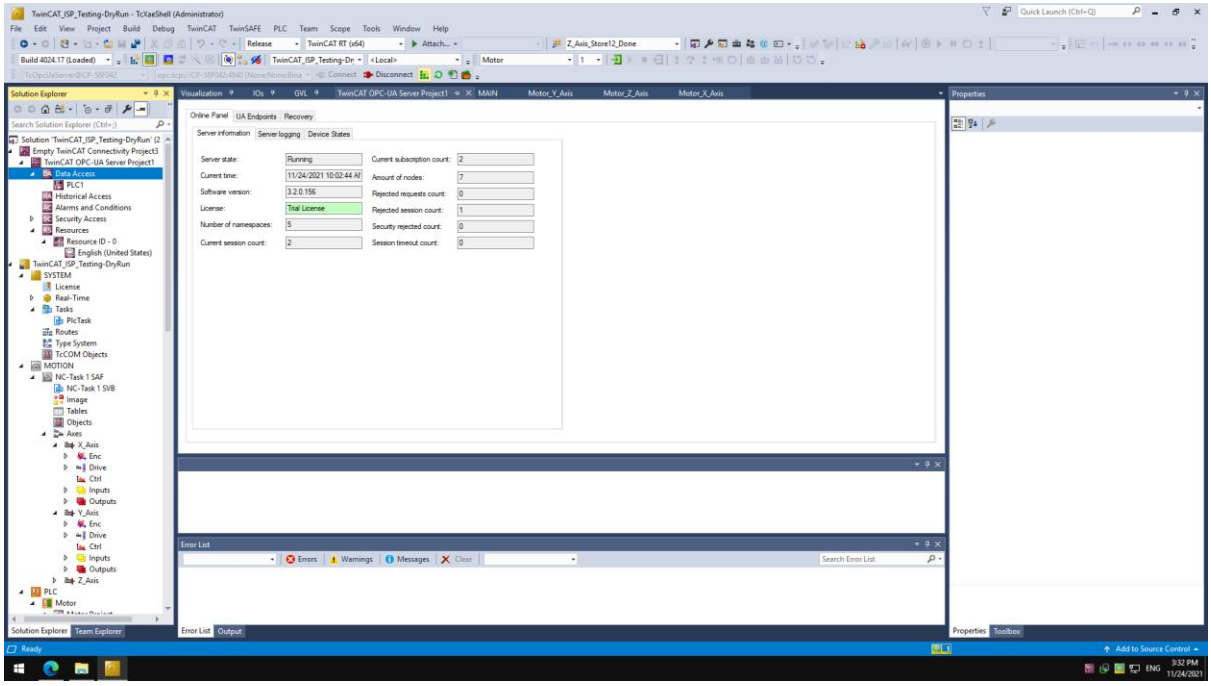

Create Device Type
Data Access Device Type
Ads Port
ADS Time Suspend
ADS Timeout
AMS Net ID
Device Name
Device Type
Disabled
Symbol File
Data Access DI Component
Ads Port
Ads Port for Device Type
Create
Cancel


Create Device Type
Data Access Device Type
Ads Port
ADS Time Suspend
ADS Timeout
AMS Net ID
Device Name
Device Type
Disabled
Symbol File
Data Access DI Component
Expert mode
Device Type
Device Type for Data Access
Create
Cancel



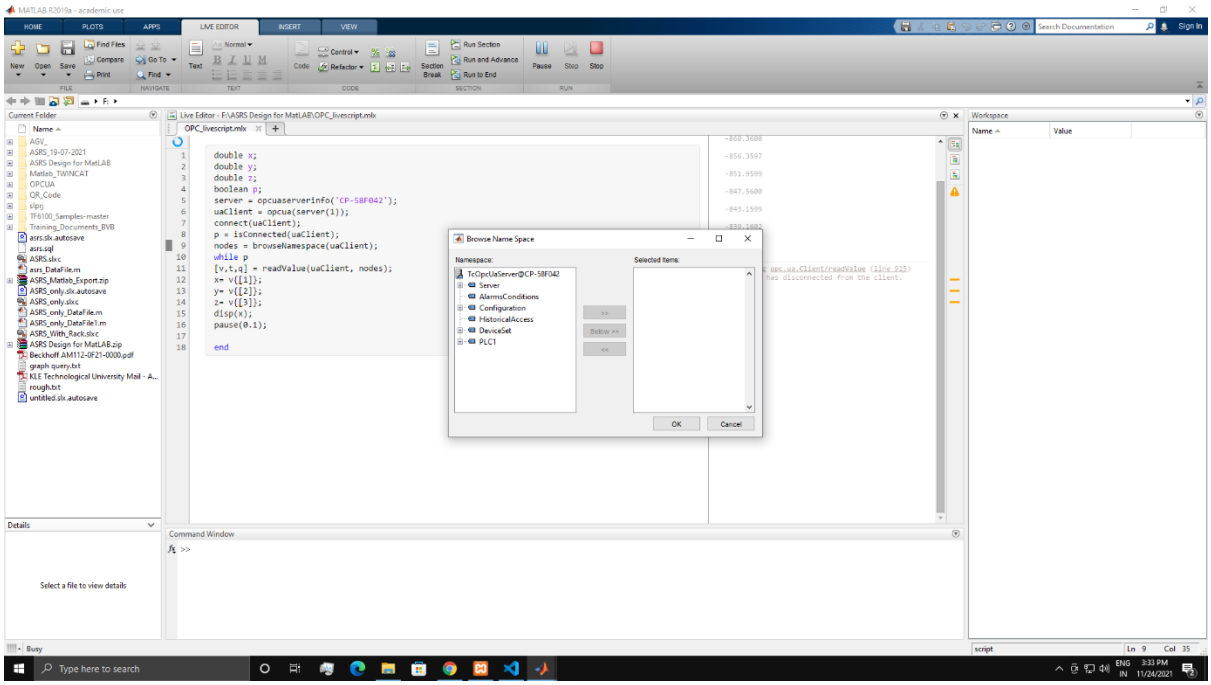


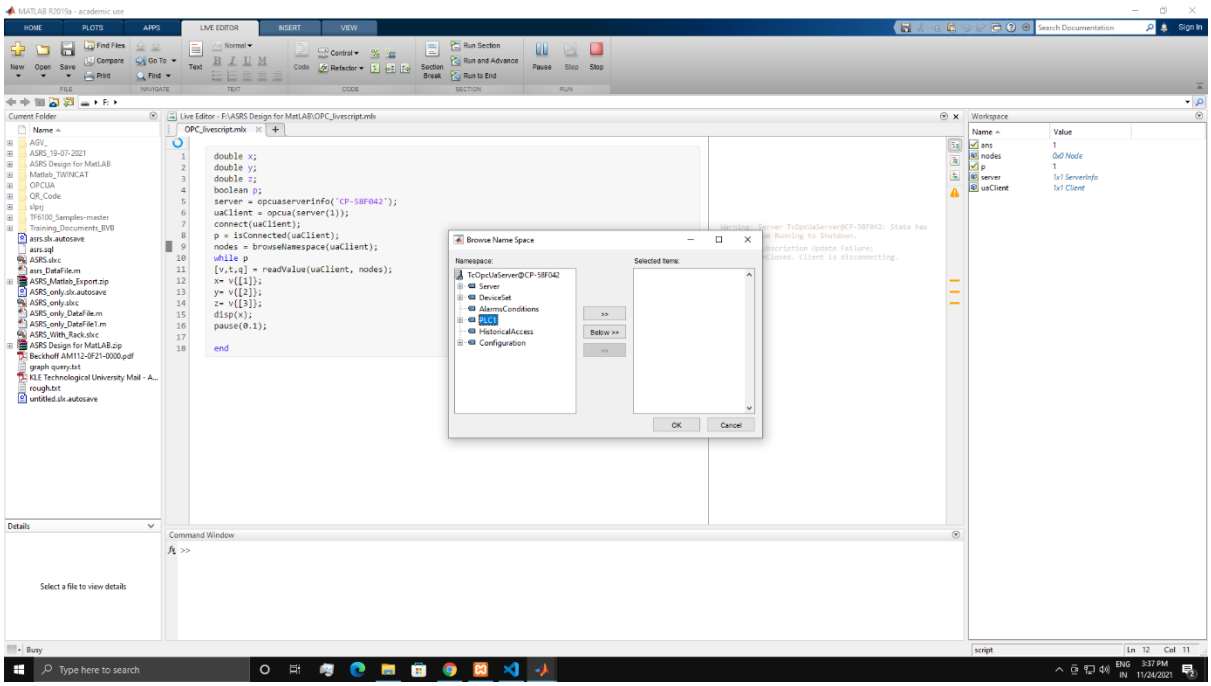

Firewall & network protection
Turn on Windows Firewall
Windows Firewall is turned off. Tap or click to turn it on.

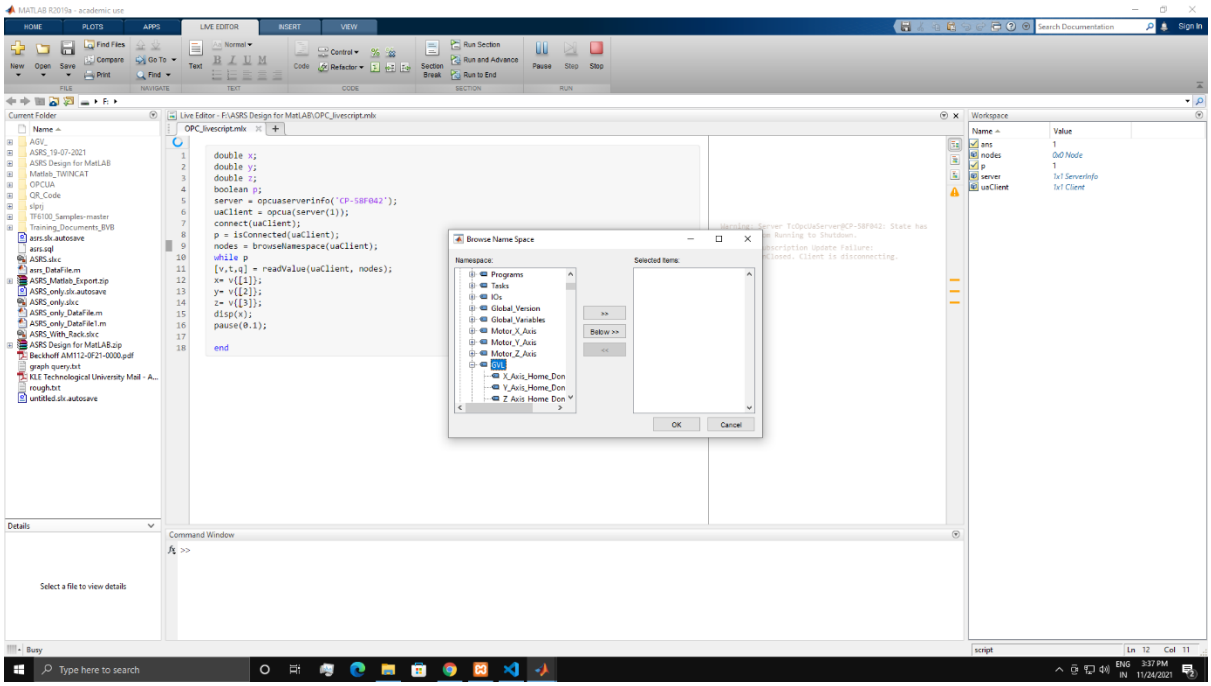


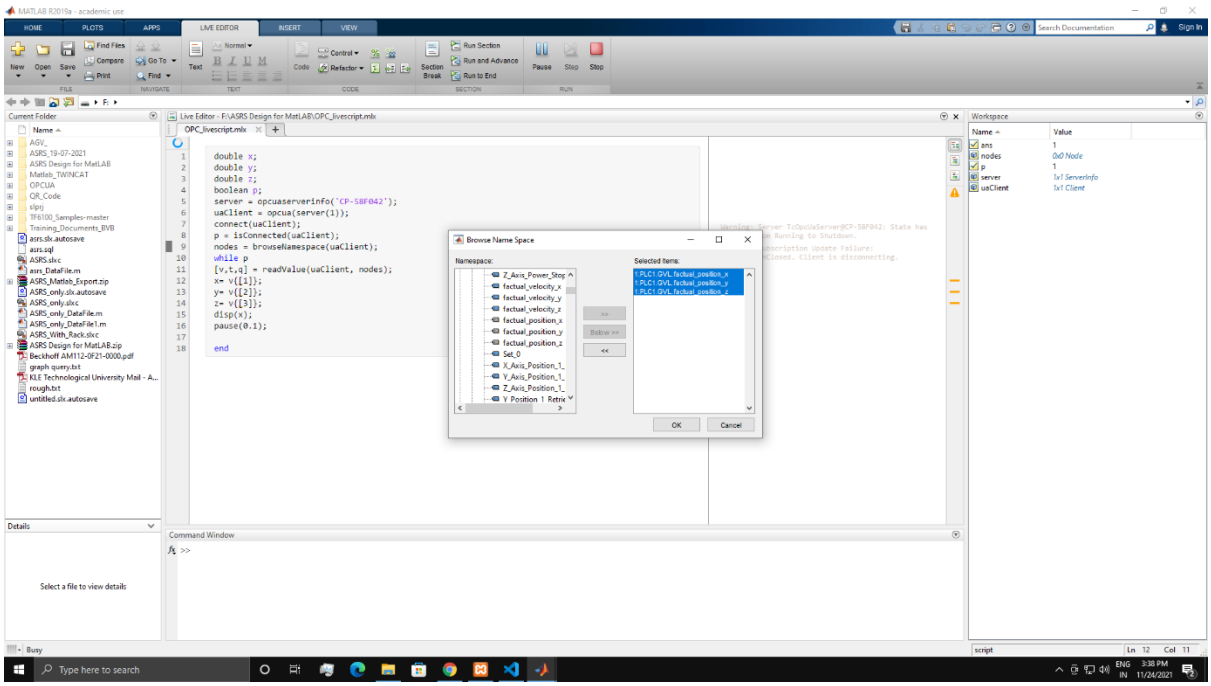
4.3.1 MATLAB setup: -

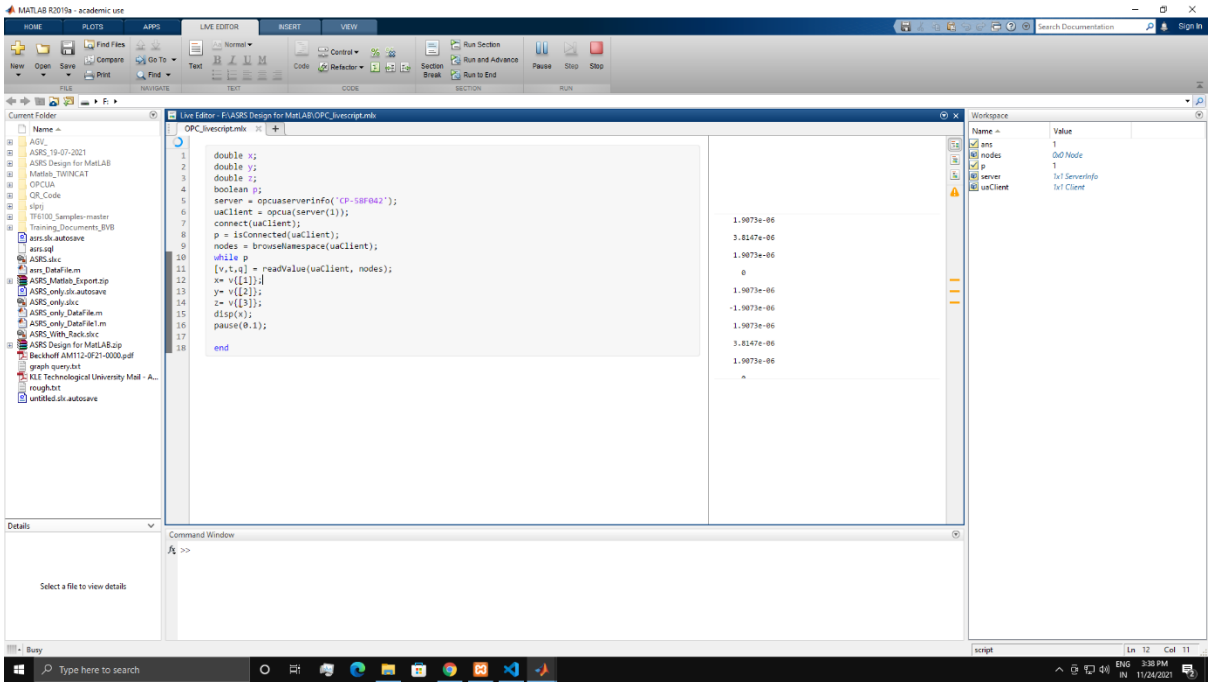
The following steps must be followed to setup the MATLAB or configure the settings to start receiving real time data from the OPC Server established to run the digital twin.

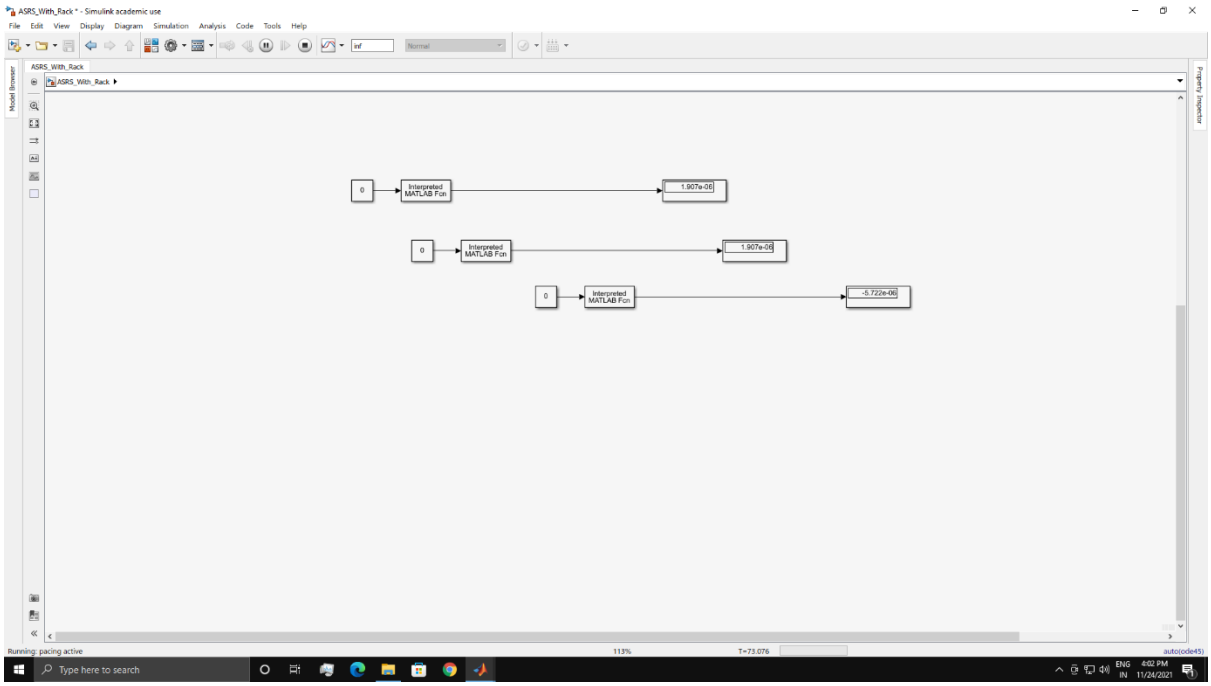





Browse Name Space
Namespace:
Selected Items:
OK
Cancel


Browse Name Space
Namespace:
Selected Items:
OK
Cancel


MATLAB R2019a - academic use
OPC_livescript.mlx
double x;
double y;
double z;
boolean p;
server = opcuaserverinfo('CP-5BF042');
uaClient = opcua(server(1));
connect(uaClient);
p = isConnected(uaClient);
nodes = browseNamespace(uaClient);
while p
[v,t,q] = readValue(uaClient, nodes);
x= v([1]);
y= v([2]);
z= v([3]);
disp(x);
pause(0.1);
end
Command Window


ASRS_With_Rack * - Simulink academic use
ASRS_With_Rack
Interpreted MATLAB Fcn
1.907e-06
Interpreted MATLAB Fcn
1.907e-06
Interpreted MATLAB Fcn
-5.722e-06

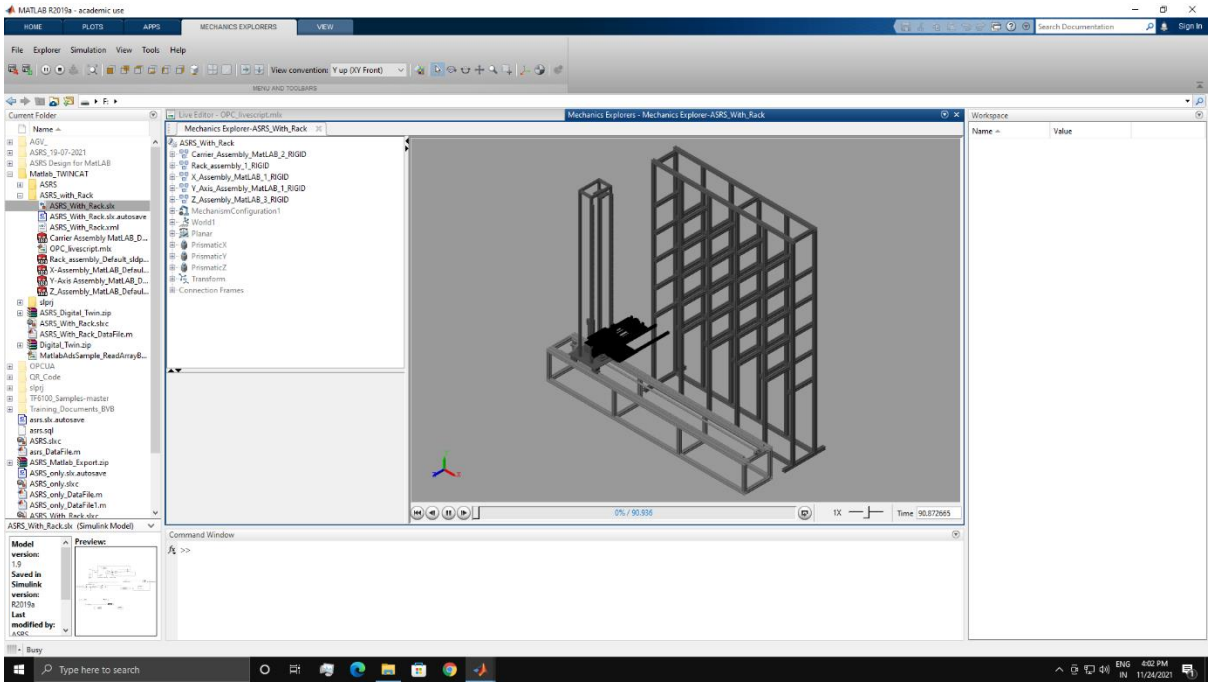
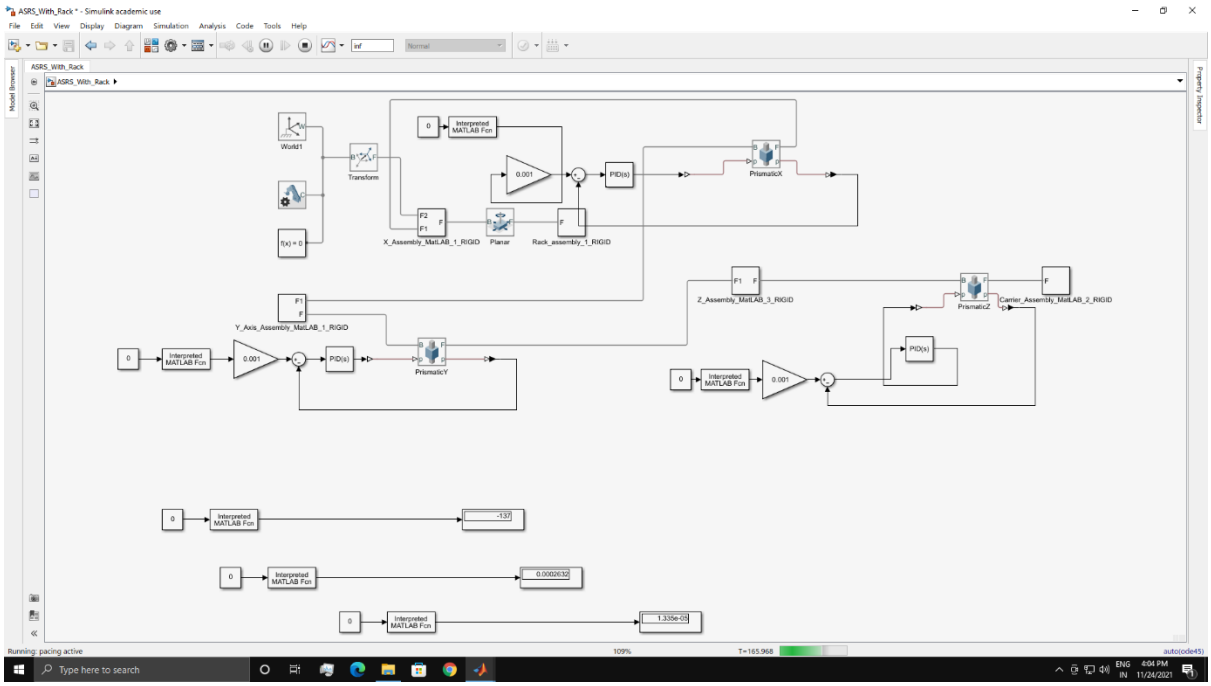


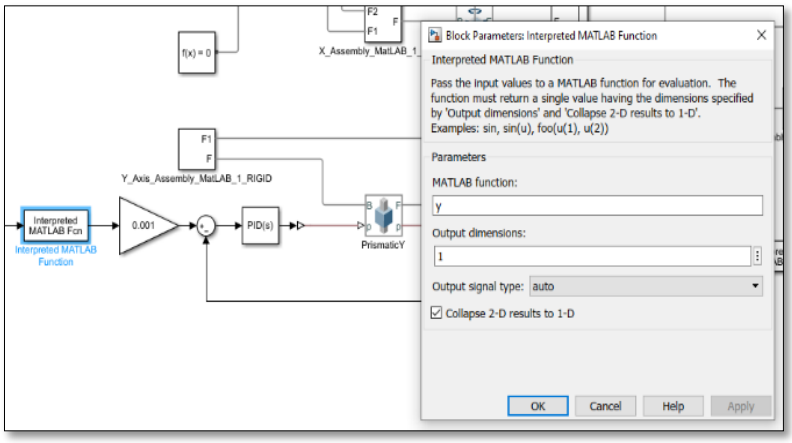
Figure 16 Digital Twin MATLAB Simulink



After the Solidworks model is exported to MATLAB using the Solidworks-Matlab extension, the .slx file is opened in Simulink. This file consists of the Simulink block diagram which is the code or function codes as blocks connected to different blocks, which combined give us a working model.

Here, various blocks like constants, joints, gains, PID controllers, solid files, and etcetera are present which cover various domains like arithmetic, logical, trigonometry, mechanics to kinematics, etc.

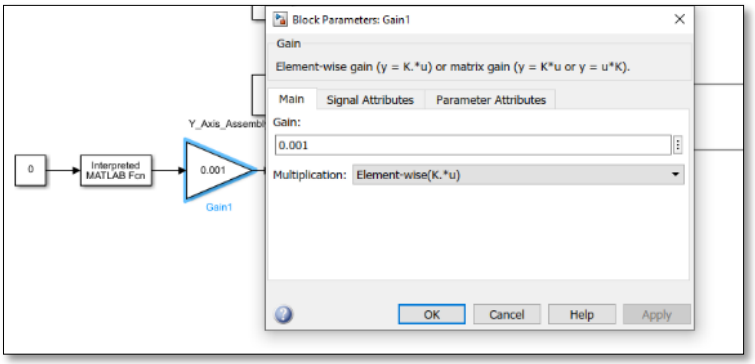
Below listed are the required blocks, their definitions and their use to achieve a fully functional Digital Twin:



Integrated MATLAB function:

This block is used in order to access a MATLAB workspace variable into Simulink environment. Here, the integrated MATLAB function is used to access 'y' variable which is generated in the workspace after receiving the variables from the OPC server.

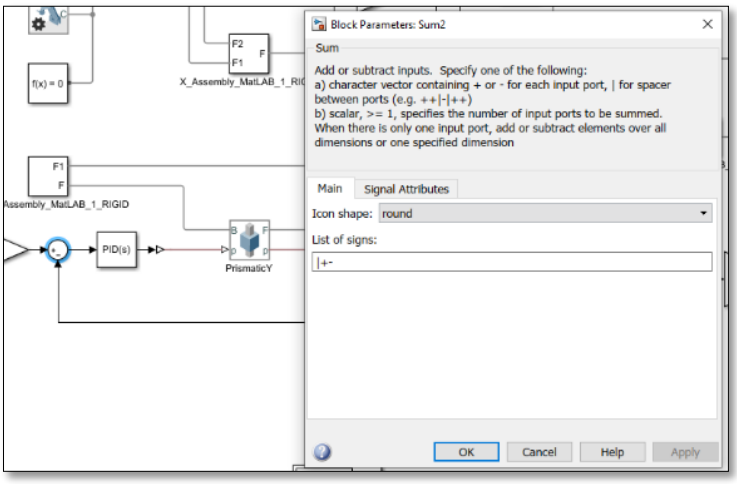
This received variable are the factual position of x, y and z axes. Variables with the same name are created in the workspace and then are accessed into the Simulink model for the Digital twin. This variable has integer values which show the position in mms.



Gain:

The gain block is used as a multiplier to the input. It basically multiplies the input with the given gain and generates output.

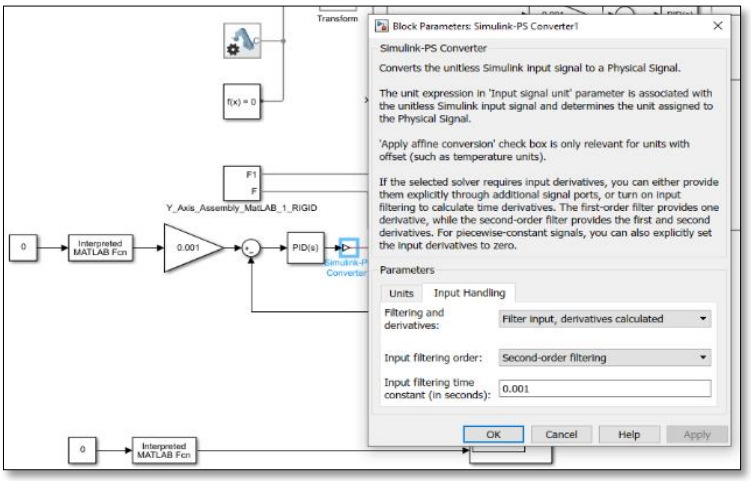
Here, 0.001 is used for gain as the input is factual position in mm which needs to be converted to mtrs as the joints need the position in mtrs.



Summing block:

Similar to the gain block, the summing block, takes two input values and adds them up and outputs the sum of those variables. When the block is expanded, the list of signs, consists a pipeline followed by the sign of the values.

Here, the signs are |+- because the feedback loop is always taken in with a negative sign while the forward loop is positive.

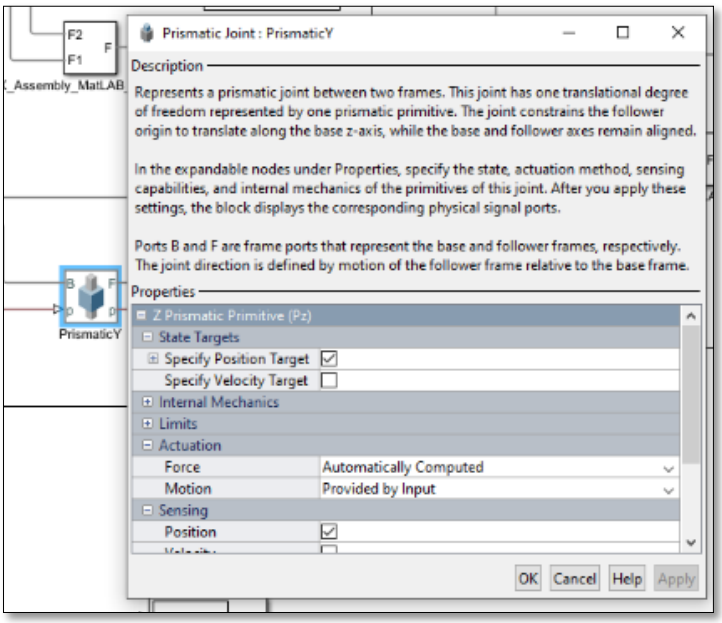


Simulink- PS (convertor):

The Simulink-PS convertor is used whenever the Simulink values are to be converted to Physical Signals to be accessed by the joints.

The filtering and derivatives is toggled to “Filter input, derivatives calculated” , the input filtering order to “Second order filtering” and Input filtering time constant to 0.001.

This will make the inputs the second order derivatives and will be sampled every 0.001 seconds giving more precise digital twin.



Prismatic joint:

The prismatic joint is used whenever translation is to be performed. The motion takes place along the Z axis.

When the block is expanded, there are various options which are to be changed for proper adaption for the digital twin. The state targets is the input which is being taken. Here, the specify position target is checked, as the input being given is the factual position in mms.

Here, the motion is being provided by input from us as we have the factual position from the OPC server while the force is automatically computed.

Sensing is the outputs being taken out from the joint block. Here, only the position is required as the output, as it is feeding the value back to the summing block for the feedback loop.

Settings required before simulating the Digital Twin:

- The simulation time should be changed to “inf” i.e. infinity from the definite time.
- The pacing for the simulation is better if turned on.
  - Menu bar → Simulation → Pacing →Check box.
- The python script to connect MATLAB to the OPCUA server should be run after the Simulink simulation is run. The vice versa is not possible.
- Select “Y up (XY front)” in view convention in the simulation explorer page.
- Isometric view show cases most of the features of the system. (better if selected)
- Always add all the folders and subfolders to the path before trying to run the .slx file. Else the simulation crashes or gives errors.

4.4 User Interface

A web-based user interface has been developed to control and manipulate the ASRS from any remote location with user friendly interface which also provides adding into or getting information from the database.

4.4.1. Web Based

Various markup and programming languages used are:

HTML: Used for structuring and presenting content on the World Wide Web.

JavaScript: a programming language that conforms to the ECMAScript specification. JavaScript is high-level, often just-in-time compiled and multiparadigm. It has dynamic typing, prototype-based object-orientation and first-class functions.

CSS: style sheet language used for describing the presentation of a document written in a mark-up language such as HTML.

PHP: general-purpose scripting language geared towards web development.

Ajax: a set of web development techniques that uses various web technologies on the client-side to create asynchronous web applications.

Bootstrap: CSS framework directed at responsive, mobile-first front-end web development.

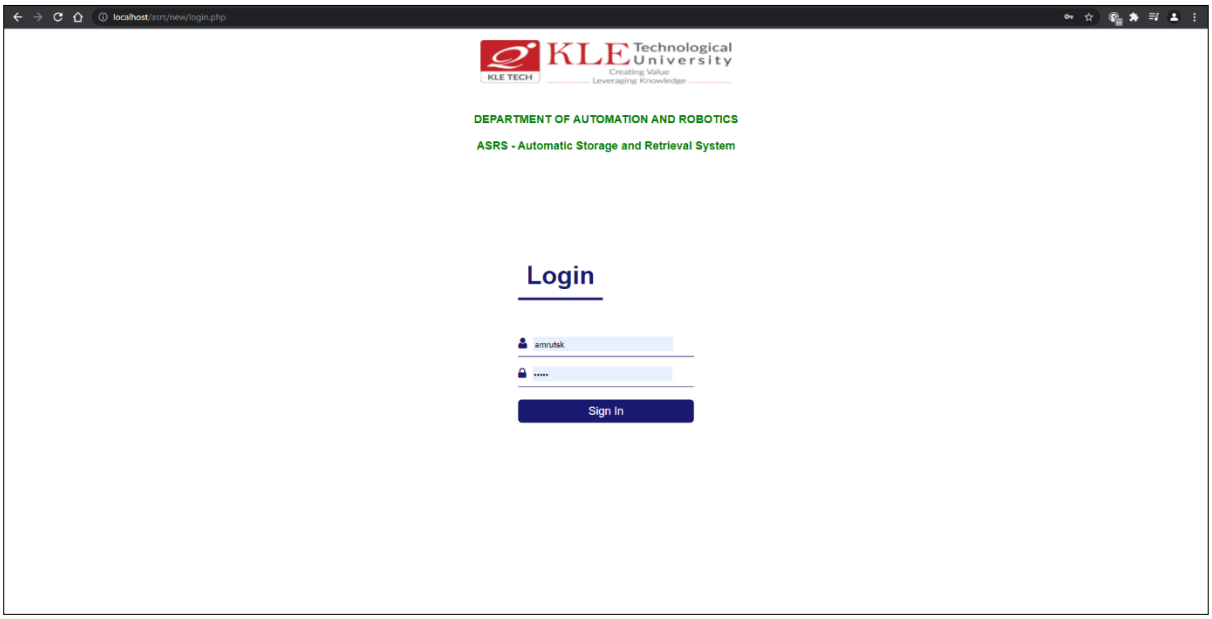


Figure 17 Web-Based U.I Login Page

Login page:

The login page is for allowance of only the registered users into the interface.

The registered users, employees here, should enter their credentials in order to access the site, ASRS and the database itself.

The page uses all the above-mentioned languages and is responsive. If the user successfully logs in, he/she gets access to the whole site. If the user is unable to log in successfully, a pop-up appears suggesting to retry logging in.

Once the person logs out of the site, it redirects to the same page and has to login again. This keeps in mind the security of the system so that no other individual can misuse the site.

Figure 18 Web-Based U.I Home Page

Home page:

After logging in, the user redirects to the home page, where some visual aid is provided, such as bar graphs and histogram, which show the hourly empty-occupied locations of the day and daily storage-retrieves respectively.

The sidebar allows user to switch between different pages.

The graphs visible are developed in JavaScript. Chartjs provides a simple and efficient way of representing the data visually using JS and HTML5 as various graphs and charts.

The data for the graphs is accessed from the database using PHP and then processed in JS as an array with a little formatting and then fed into the chart input data to get the proper visualization.

Various features like, hovering over the bar, color shifting is provided to the user using Chartjs.

The sizing and formatting is done using CSS.

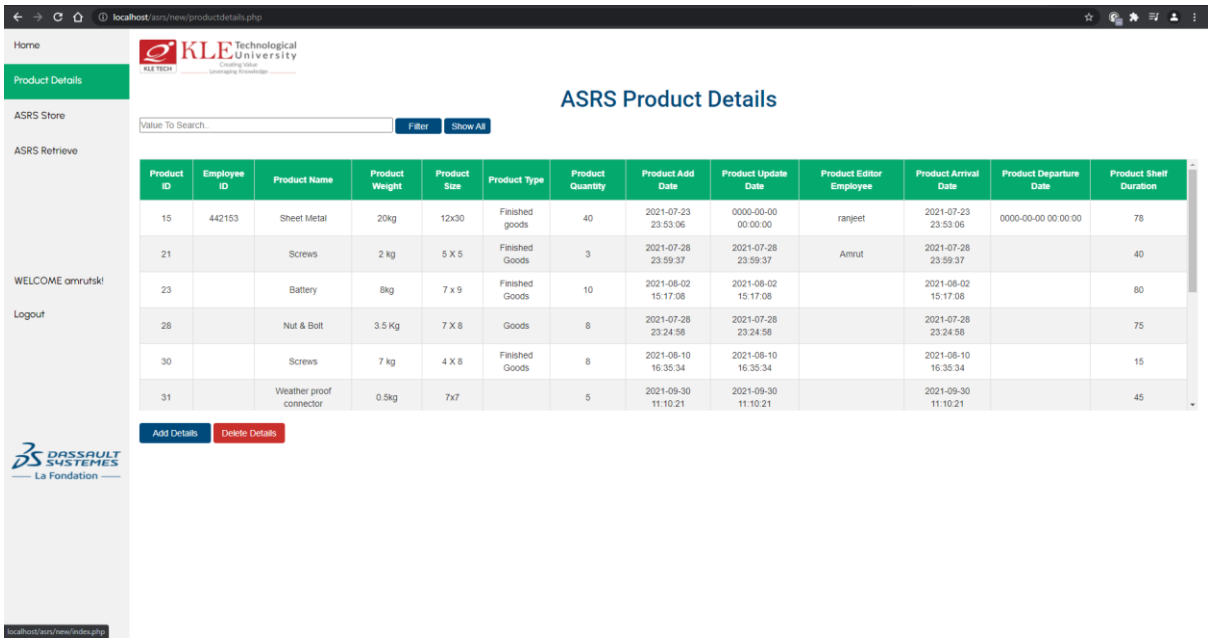


Figure 19 Web-Based U.I Product Details Page

Product details page:

The product details page consists of a table which displays the details of the various products present in the database.

The search bar helps in searching the table of products with any of the desired parameter. The filter button searches the products which satisfy the search value and the Show All button reloads the whole table.

The table is scrollable so that the person can scroll down for further product details.

There are even two buttons to **ADD** a product and **DELETE** a product.

This page uses Bootstrap5 majorly for all these features and style. The formatting is done in HTML5 and style in CSS.

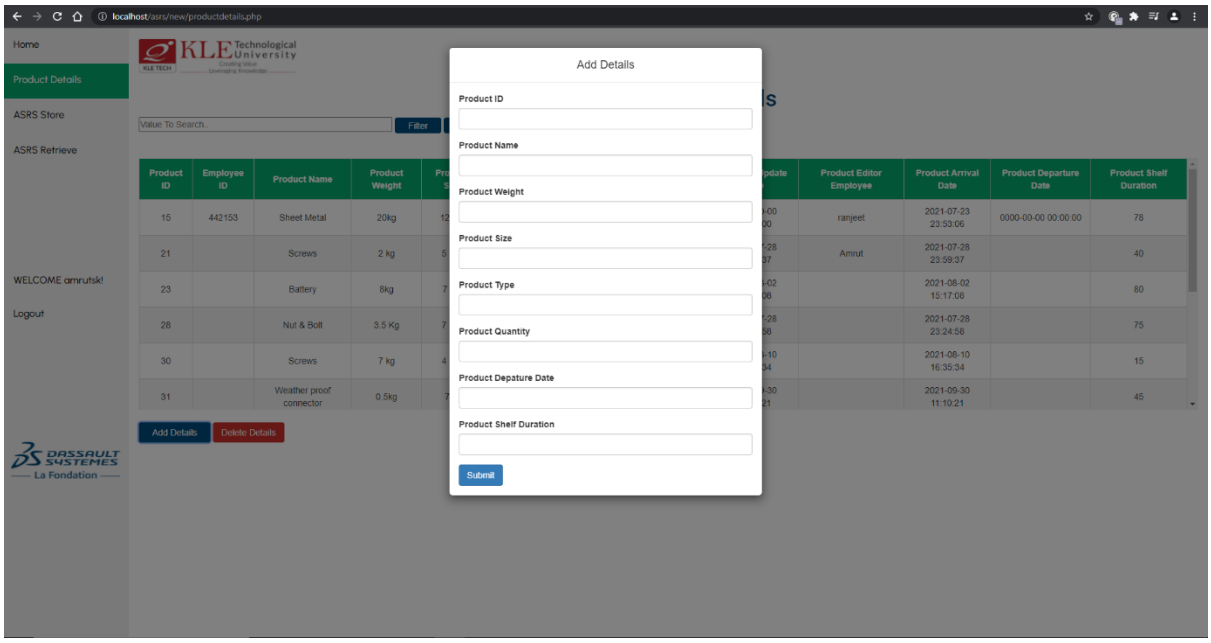


Figure 20 Web-Based U.I Product Entry Page

Add Product/Delete Product:

When the buttons is pressed, a pop-up form is obtained, where the user can enter the product details.

The product ID being the primary key of the products table, if the user enters a same Product ID, it shows up a warning.

If none warnings and errors are generated, the product detail is added in the table.

Similarly, the delete product button pops up a form which asks for the product ID to be deleted and deletes the product from the table in the site and also from the database.

Bootstrap5 is used for the pop-up form, its styling and various features like, clicking outside the form closes the form.

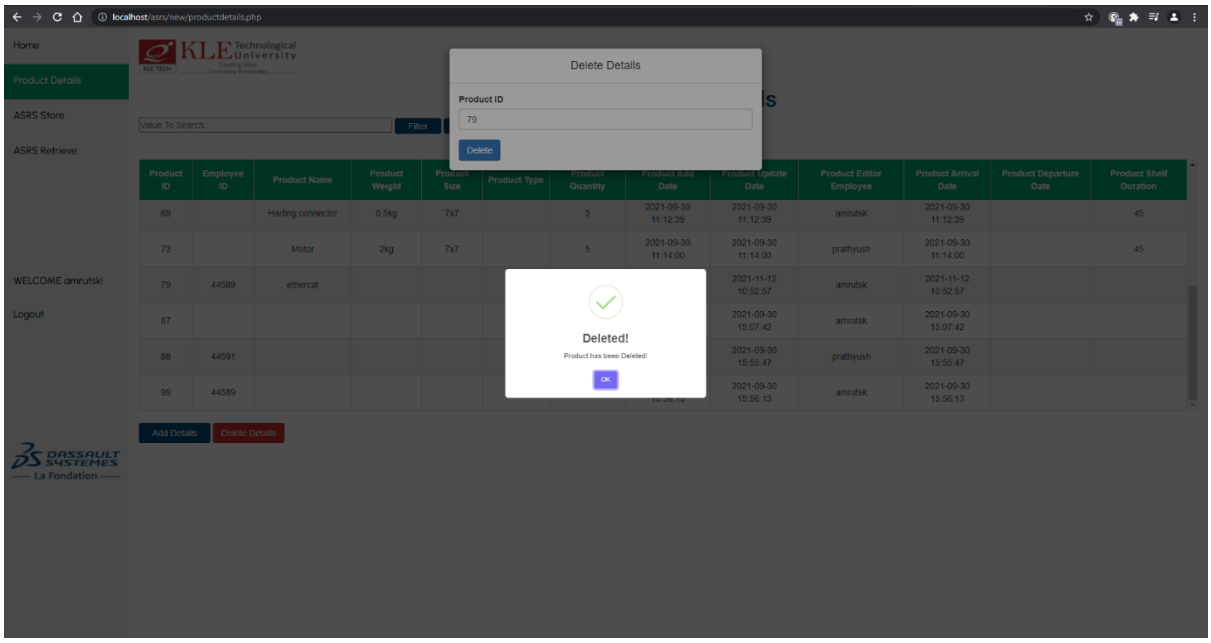


Figure 21 Web-Based U.I Screenshot - 1

Success/Failure feedback:

After successful addition or deletion of the product, an animated pop-up appears which is been developed using Ajax framework.

Ajax helps in developing web applications or widgets which refresh itself without the whole page being refreshed.

Further application of Ajax is been planned in the site.

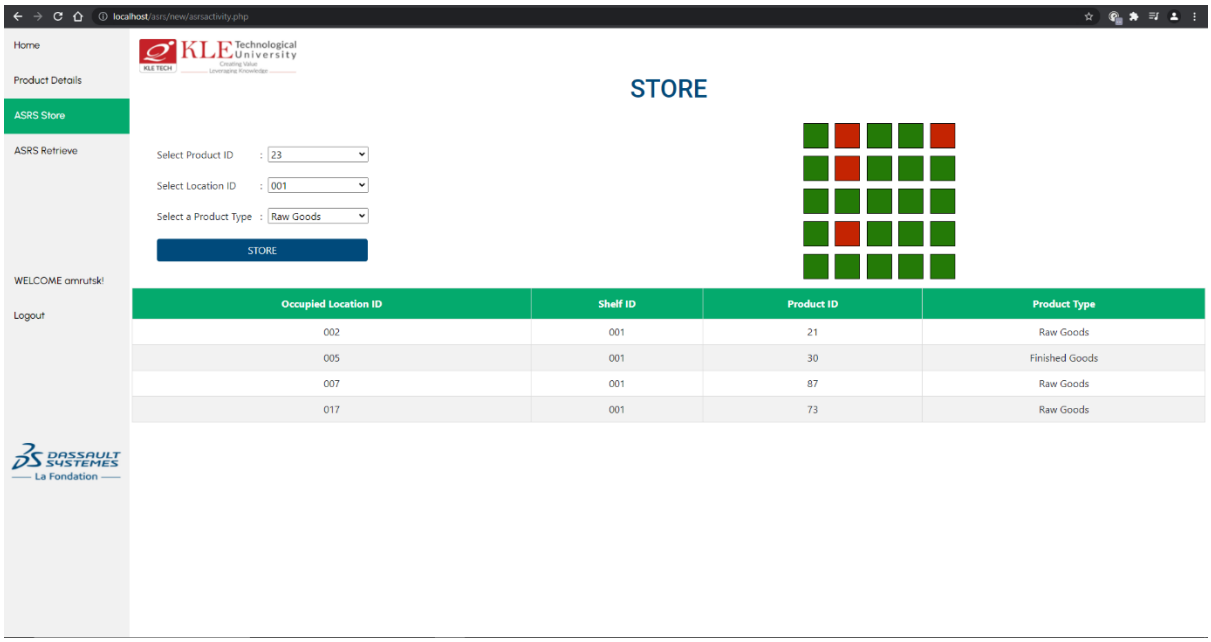


Figure 22 Web-Based U.I STORE Page

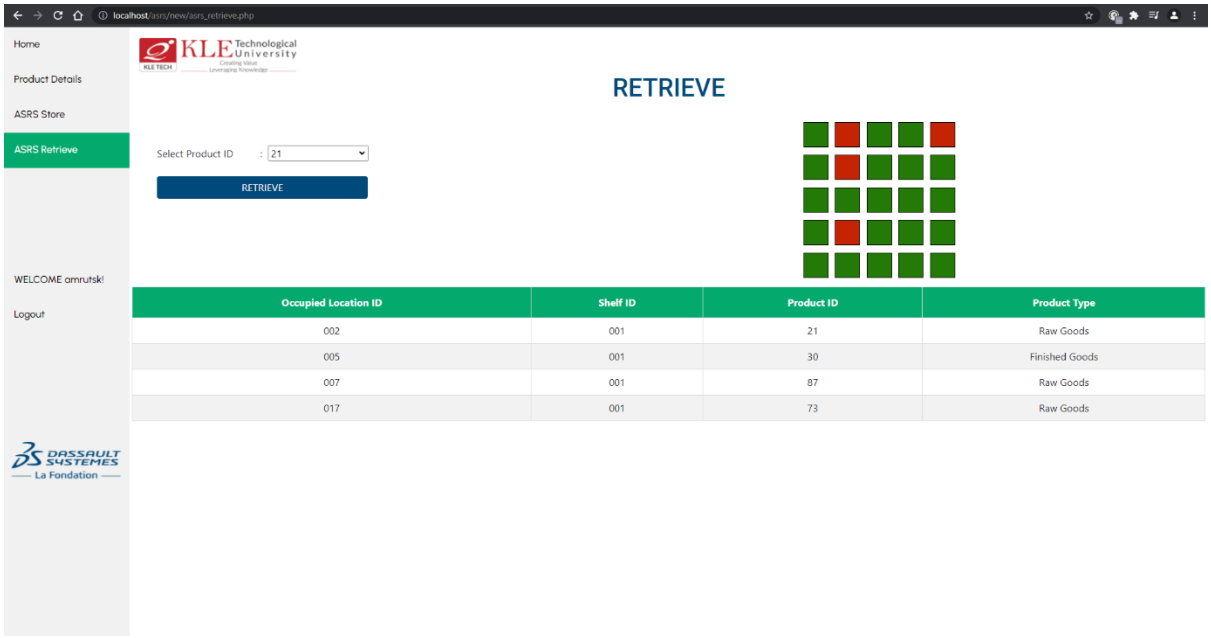


Figure 23 Web-Based U.I Retrieve Page

Store and Retrieve page:

The store and retrieve pages allow the user to either store a product from the product details table into the rack locations.

The dropdowns show the storable/retrievable products in these respective pages. The store and retrieve buttons update the table with the particular operations.

The 25 boxes show whether the locations are empty or stored. Green represents an empty location while the Red ones show that the location is occupied with a product which is developed in JS and the details is received from the database using PHP.

4.5 Database

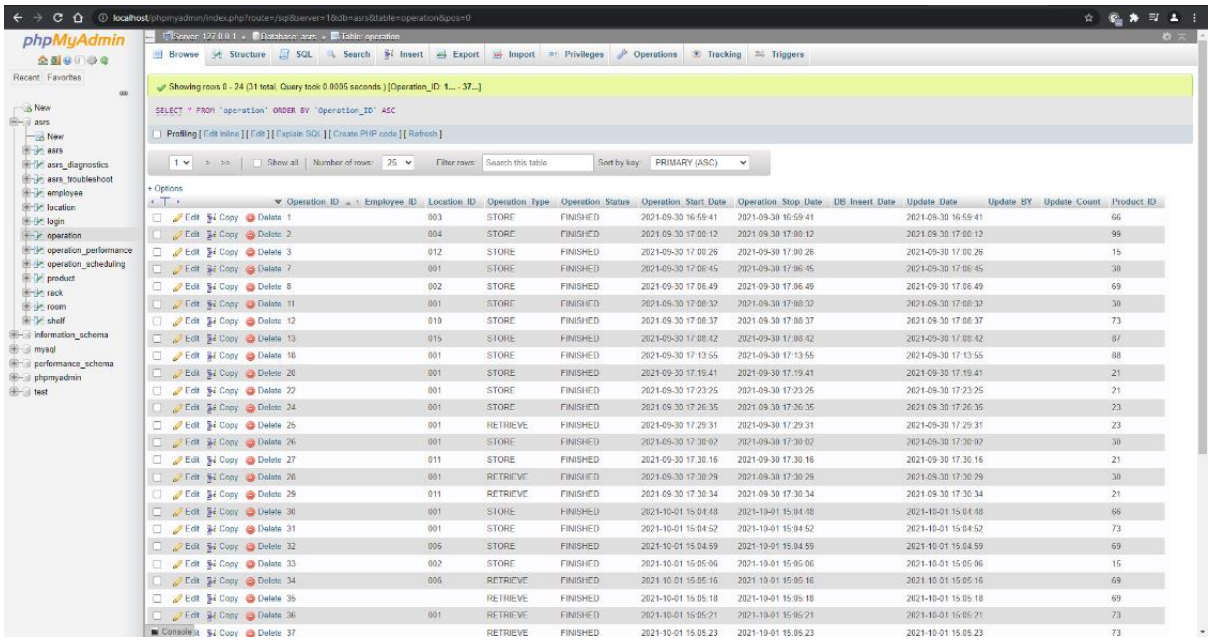


Figure 24 Database Screenshot - 1

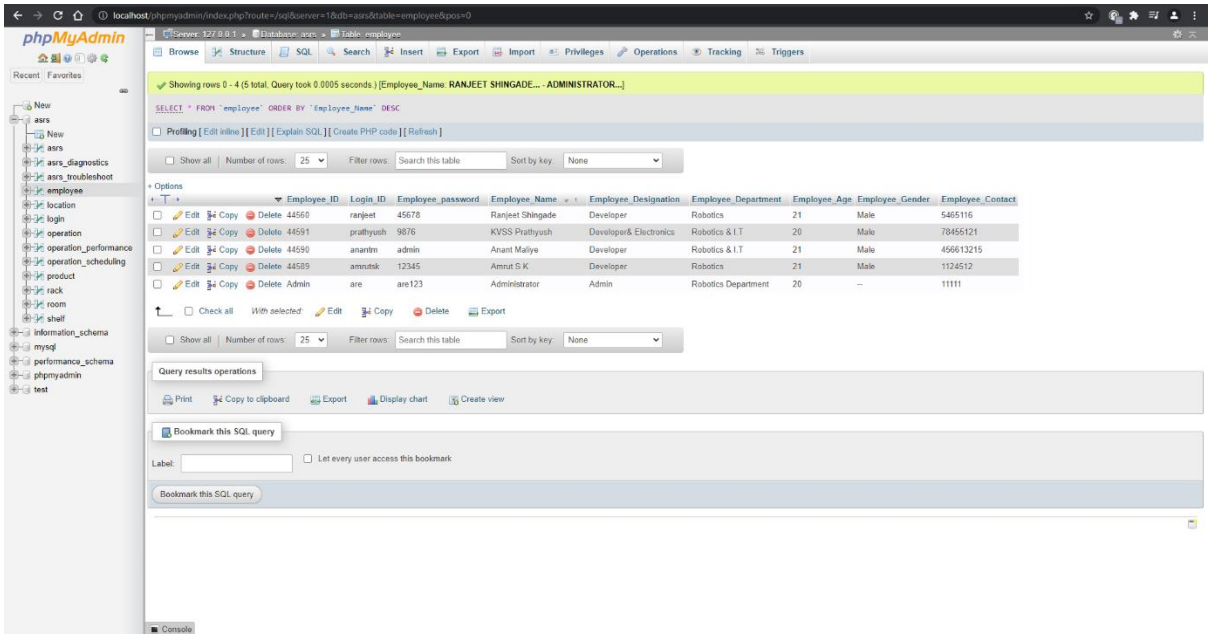


Figure 25 Database Screenshot - 2

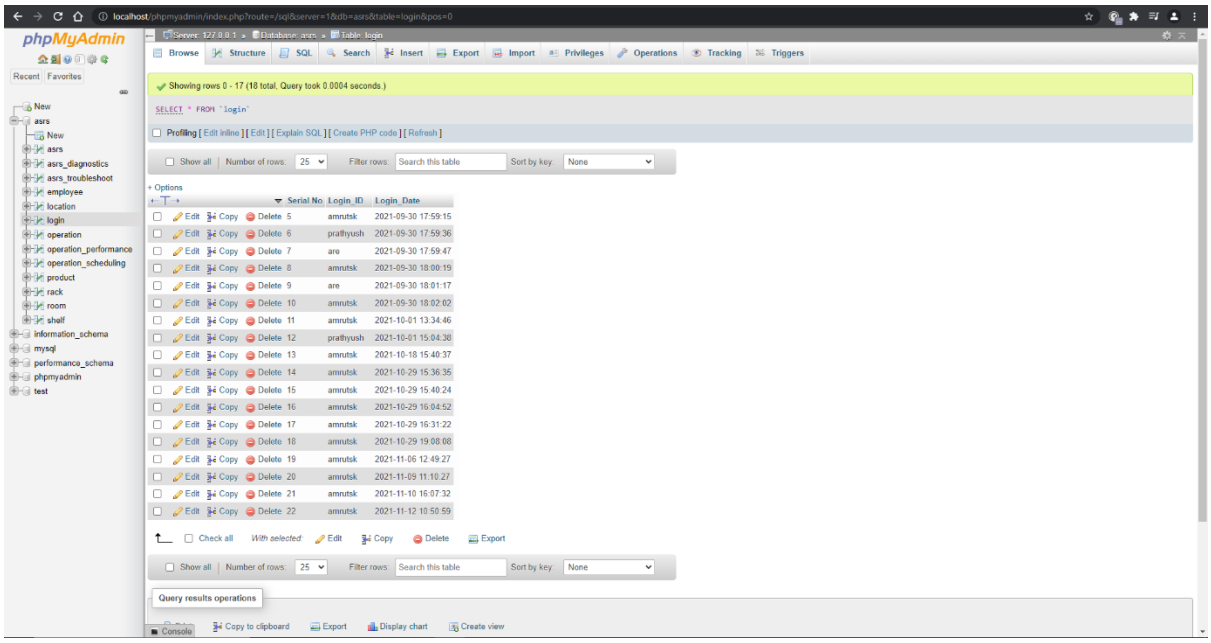


Figure 26 Database Screenshot - 3

The database is been created in MYSQL with PHP as the interface between database and the front-end.

SQL queries were written to create the schema and the tables. The tables are manipulated directly from the site, like insertion and deletion to the tables.

Tables were created as got from the ER diagram.

Tables like:

ASRS

ASRS_Diagnostics

ASRS_Troubleshoot

Employee

Location

Login

Operation

Operation performance

Operation Scheduling

Product

Rack

Room

Shelf

The primary keys and foreign keys have been assigned to the parameters to keep track of the table using it.

Every detail of the ASRS will be stored in the database without any data loss so that a track can be kept on the system.

Ex: who logged in when, how many times, what product was added when, what product was stored at what location and so on.

Chapter 5:

Results

Verification and Validation: -

Verification is the process for determining whether or not a product fulfils the requirements or specifications established for it. Validation is the assessment of a planned or delivered system to meet the client's operational need in the most realistic environment achievable. Verification is the critical feedback element that confirms the specifications were satisfied. Validation is confirmation that the user's needs will be or are satisfied in the final material solution. It cannot be overemphasized that Verification and Validation and Test and Evaluation are not separate stages or phases, but integrated activities within of the process.

For the verification and validation process we have designed few test cases for the ASRS :-

1. Automatic Storage and Retrieval

   This test case was taken into account for completely automated storage and retrieval procedures of the ASRS.

   One – cycle time for Min. location [RETREIVAL] = 1min: 57 sec

   One – cycle time for Max. location [RETREIVAL] = 2min: 21 sec

   One – cycle time for Min. location [STORAGE] = 26 sec

   One – cycle time for Max. location [STORAGE] = 1min: 23 sec

   Database update time lag = < 1 sec

2. Manual Storage and Retrieval

   This test case was taken into account for completely manual storage and retrieval procedures of the ASRS with the help of HMI designed in Twincat and Web based User Interface.

   One – cycle time for Min. location [RETREIVAL] = 1min: 57 sec

   One – cycle time for Max. location [RETREIVAL] = 2min: 21 sec

   One – cycle time for Min. location [STORAGE] = 26 sec

   One – cycle time for Max. location [STORAGE] = 1min: 23 sec

   Database update time lag = < 1sec

   UI and actuation lag = < 1sec

3. OPC server connectivity and Database Update

   This test case was taken into account to verify and validate the updating of the Backend established Database for proper registration of the values into database upon completion of one cycle of defined case and connectivity between between ASRS – TwinCAT and UI and MySQL database with the help of OPC – UA server which has been established.
   Parameters to be checked: -

   - Successful updating of Database with Storage location allocated.
   - Successful updating of Database for Retrieving the object order received.

4. Testing a whole Automation cycle with integrated conveyor

   This test case was taken into account for testing a complete automation process designed which involved an integrated conveyor system and taking a payload or box and automatically allocating a storage location.

   One Complete cycle time = 2min: 15 sec

   Time taken for retrieving empty storage location from database = < 1 sec

   Database update time lag upon completion of cycle = < 1sec

5. Integration of ASRS system with Digital Twin [MATLAB]

   This test case was taken into account for testing the digital twin designed in MATLAB with the integration of real time operation of ASRS with the help of TwinCAT OPC – UA server established for connectivity.

   Time delay between actual run and digital twin simulation = 2 – 3 sec

Chapter 6:

Conclusion

This report summarizes our attempt at designing an Automated Storage and Retrieval System. The most optimum design and methodologies have been presented here. Results were also compared with material selection table and software analysis. This can be further used to make working models of what is now on paper. Variations in the design as per requirement can be done, with proper implementation of mechanical and electronic components, variety of automation can be achieved, which can be as complex, versatile and flexible as required. This model can serve as a reference for various applications, some of which are automatic car parking system, automatic baggage handling for loading/unloading at airports, inventory and raw material management in large industries, automated parcel sorting in postal services, books management in huge libraries, etc.

The protype developed here presents the maximum possible achievable parameters defined for the ASRS developed. The speed of the ASRS achieved here is not apar with the industrial machines due to the economic constraints, as we have proposed a prototype version of ASRS here. But the designed is developed in such a modular way that this design can be easily implemented in industries also with very minor hardware upgrades to achieve speed and accuracy. The challenges we faced in this project in this initial phase was to integrate two separate sub-systems i.e., a conveyor-based delta robot sorting system with the ASRS but with proper planning of the industrial setup or automation scenario we were able to achieve this. Through this implementation of the automation scenario, we understood the importance of proper planning and setup of various industrial robots or sub systems to achieve an optimum and efficient industrial automation environment setup. The proper planning of the industrial automation scenario helps in future integration of multiple sub-systems or addition of automation machines and robots into the existing automation setup easily or with minor changes. This project has helped us in gaining knowledge on Industrial automation process and development of industrial environments for solving customers problems.

Chapter 7:

Future Scope

The proposed prototype is preliminary model of industry level automatic storage and retrieval system. Several new and innovative features can be added to the present version to make it stand out from the existing solutions.

Below listed are few of such features:

- The UI can be developed in such a way, for the user to schedule various store and retrieval processes at particular time without collision of commands
- The digital twin can be integrated with the site developed for the ASRS and displayed there, real-time, using GStreamer libraries; reducing the number of screens required for monitoring the complete system.
- A QR code can be assigned to each box and a QR code scanner (camera) can be installed on the system to track the box in real time and act as the feedback for the whole system.
- The prompt in the ASRS store and retrieve pages can be developed as a console for the user to add commands in (Assembly level language) and to display the debug, directly to and from the TwinCat platform.
- The scope data of the motors can directly be taken into the digital twin, and a model for predictive maintenance can be developed.
- The data of the operations undertaken by the system can be used to learn the trends of the incoming and outgoing products, like their shelf life, their frequency and the locations they can be stored for greater efficiency of the system.
- Guideways can be installed on the conveyor system, the z-axis or the racks itself, to always keep the boxes in proper orientation and avoiding the system from collapsing onto each other.
- The site can be tweaked in order to provide each user with different versions of the site, say operator, supervisor or manager, with limited set of their functions, so that no other person can misuse or mishandle the ASRS.
- Various conveyor systems can be integrated together with the pick and place robot to send and receive the goods from various stations and showcase the execution of the Industry 4.0

Appendix 1

Twincat Scope Graphs:

The TwinCAT 3 Scope View is a software oscilloscope for the graphic representation of signal curves in different chart types. These could be, for example, YT, XY, bar or digital charts. The Scope View Professional extends the Scope View Base version supplied with TwinCAT 3 XAE by additional functionalities. The field of application refers to processes that are to be tracked and monitored over a longer period of time.

Here we have measured the velocity vs time graphs for storage and retrieval from certain locations defined below: -

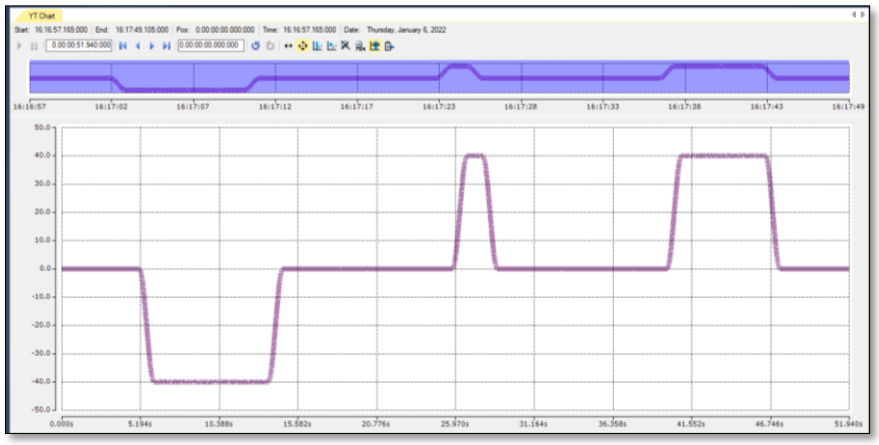


Figure 27 Y Axis Store 6th Location

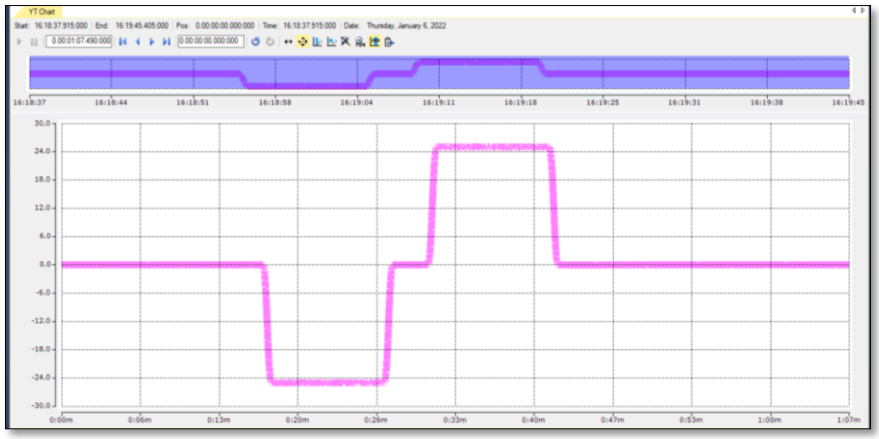


Figure 28 Z Axis Store 7th Location

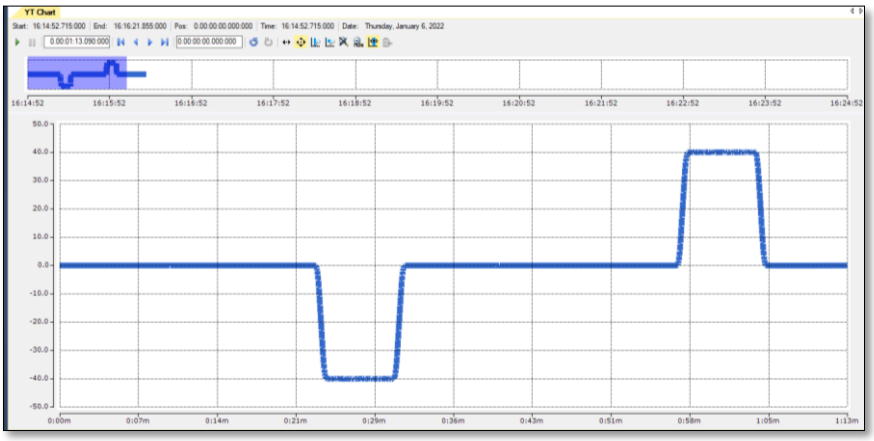


Figure 29 X Axis Store 2nd Location

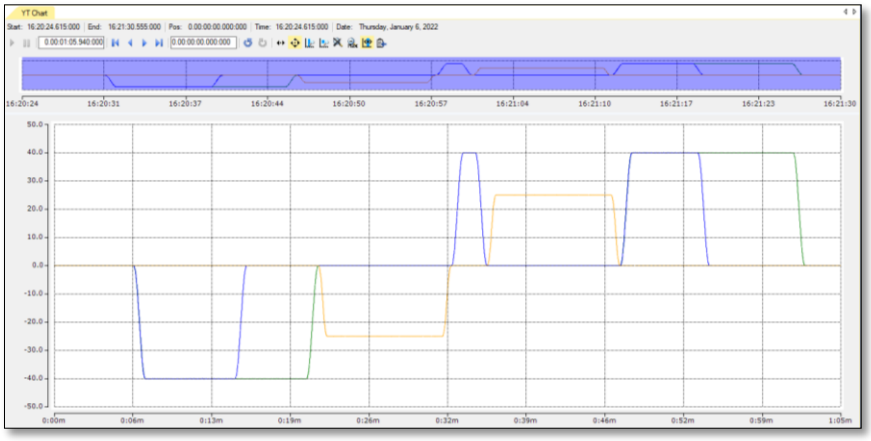


Figure 30 XYZ Storage 8th Location

Components Used with Their Specifications (Electrical)

1. C6030-0070 / 000131560 / Ultra Compact Control Cabinet IPC:

Figure 31 Beckhoff IPC

The Industrial PC sector from Beckhoff offers superior hardware solutions for every requirement. Whether Panel PCs, PCs, Control Panels or Embedded PCs. Learn more about the advantages of IPC technology from Beckhoff. It has Intel® Celeron® G4900 3.1 GHz, 2 cores (TC3: 50) processor. It has compact motherboard for 8th/9th generation Intel® Celeron®, Pentium®, Core™ i3/i5/i7.

2. EK1100 / Ether CAT Coupler for E-Bus-terminal (ELxxxx)

Figure 32 Beckhoff EtherCAT

The EK1100 EtherCAT Coupler is the link between the EtherCAT protocol at fieldbus level and the EtherCAT Terminals. The coupler converts the passing telegrams from Ethernet 100BASE-TX to E-bus signal representation. A station consists of a coupler and any number of EtherCAT Terminals that are automatically detected and individually displayed in the process image.

Special features:

- Connection technology: 2 x RJ45 socket
- Connection lengths: up to 100 m
- Number of EtherCAT Terminals in the overall system: up to 65,535

3. EL1859 / 8-channel digital input and output terminal

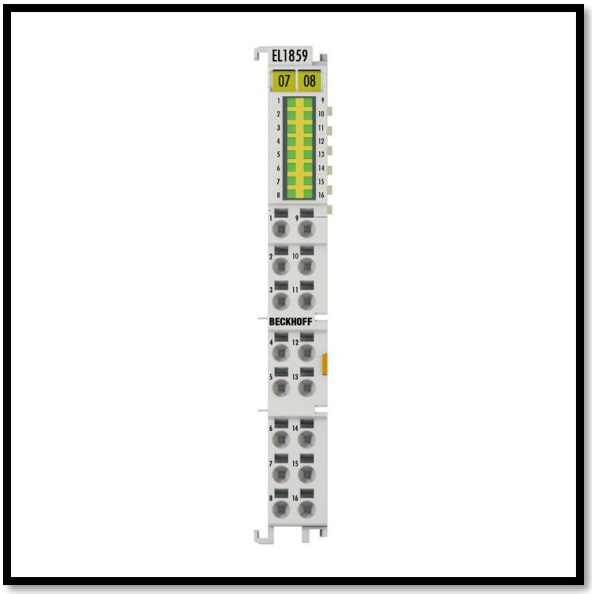


Figure 33 I/O Terminal 8 Channel

The digital EL1859 EtherCAT Terminal combines eight digital inputs and eight digital outputs on a single device. The signal state of the channels is indicated by LEDs. The reference ground for all inputs is the 0 V DC power contact; the outputs are fed via the 24 V power contact.

4. EL9576 / Brake chopper terminal

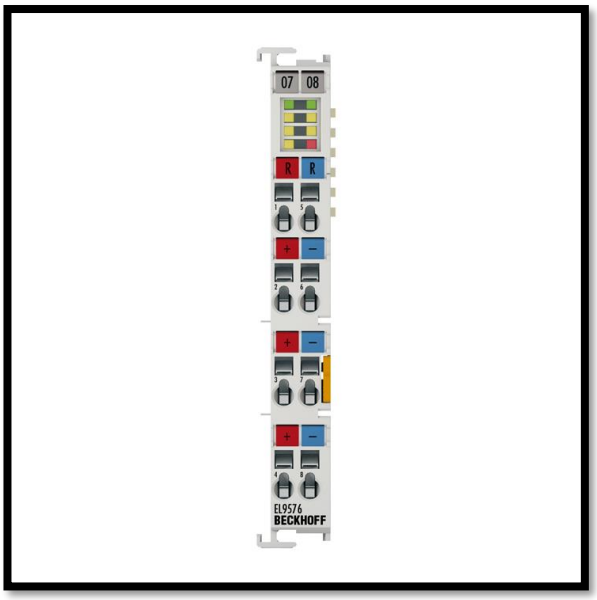


Figure 34 Brake Chopper Terminal

The EL9576 EtherCAT Terminal contains high-performance capacitors for stabilising supply voltages. The EL9576 can be used in conjunction with the EL70x1 stepper motor terminals, the EL73x2 DC motor terminals and the EL72x1 servomotor terminals. Low internal resistance and high-pulsed current capability enable good buffering in parallel with a power supply unit.

5. EL7211-0010 / Servomotor terminal with OCT integrated

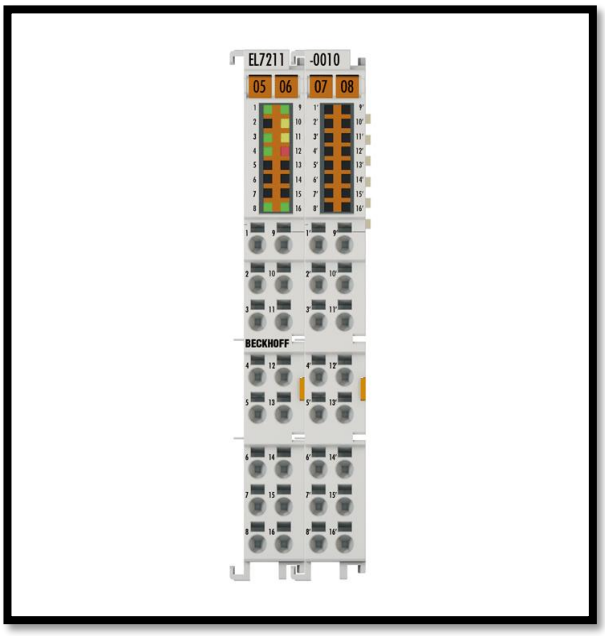


Figure 35 Servomotor Terminal with OCT

The EL7211-0010 servomotor EtherCAT Terminal with integrated One Cable Technology (OCT) offers high servo performance in a very compact design for motors from the AM8100 up to 4.5 A (Irms). The One Cable Technology combines a motor cable and an absolute feedback system in a single cable.

6. ZB8110 / External ballast resistor 10 Ohm, 100 W

Figure 36 External Ballast Resistor

During the acceleration phase, a motor needs energy supply, whereas during braking a motor can be used as a generator, feeding energy back into the DC-Link, which raises the voltage in the DC-Link. If the voltage exceeds the adjustable threshold value, a braking resistor is activated.

The external ZB8110 braking resistor is available as an accessory to the EL9576 brake chopper terminal or the KL9570 buffer capacitor terminal. It regulates the DC-Link voltage as soon as more braking power is needed. It has a maximum continuous rating of 100 W. The ZB8110 is connected directly to the EL9576 or KL9570. A mounting plate is included in the scope of supply for each braking resistor.

7. AM8112-0F21-0000 / 000009147

Figure 37 Beckhoff Motors

The AM8112 low-voltage servomotor is suitable for highly dynamic drive solutions in compact design in the voltage range of < 50 V DC. The standstill torque of the motor depends on the winding and is in the range of < 1.5 Nm. It is available with the OCT feedback system (absolute encoder). The low-voltage servomotor with flange code F1 (40 mm) and motor length 2 has a shaft diameter b = 8 h7 and a free shaft end of d = 25 mm.

Motor Sizing

X-Axis:

Load and linear guide

Total mass of loads and table	m =	15	[kg]
Friction coefficient of the guide	μ =	0.5	

Ball/Lead screw specifications

Diameter	D_B =	16	[mm]
Total length	L_B =	1984	[mm]
Lead (pitch)	P_B =	10	[mm/rev]
Efficiency	η =	85	[%]
Materia - Stainless-steel 304	ρ =	8000	[kg/m 3]
Breakaway torque of the screw	T_B =	0.42	[N·m]

External force

F_A	=	35	[N]

Transmission belt and pulleys or gears

	Primary pulley (gear)	Secondary pulley (gear)
pitch circle diameter (PCD)	D_{p1} = 16 [mm]	D_{p2} = 16 [mm]
thickness	L_{p1} = 25 [mm]	L_{p2} = 25 [mm]
material	ρ = 7900 [kg/m 3] Steel	ρ = 7900 [kg/m 3]
Steel		

Mechanism Placement

Mechanism angle	α	=	180	[°]

Other requirement(s)

Is it necessary to hold the load even after the power supply is turned off? → YES
Is it necessary to hold the load after the motor is stopped, but not necessary to hold after the power supply is turned off? → NO

Operating conditions

Fixed speed operation	Operating speed	V_1 =	20	[mm/s]
	Acceleration / deceleration time	t_1 =	1	[s]

Stopping accuracy

Stopping accuracy $\Delta l = 1$ [mm]

Safety factor

Safety factor $S{\cdot}F = 1.5$

Load Inertia

$J_W = m \times ((P_B \times 10^{-3}) / 2\pi)^2$

$= 15 \times ((10 \times 10^{-3}) / (2 \times 3.14))^2 = 3.7995e\text{-}5$ [kg·m ^{2}]

$J_S = (\pi / 32)\, \rho\, (L_B \times 10^{-3})\, (D_B \times 10^{-3})^4$

$= (3.14 / 32) \times 8000 \times (1984 \times 10^{-3}) \times (16 \times 10^{-3})^4 = 1.0212e\text{-}4$ [kg·m ^{2}]

$J_{Dp1} = (\pi / 32)\, \rho\, (L_{p1} \times 10^{-3})\, (D_{p1} \times 10^{-3})^4$

$= (3.14 / 32) \times 7900 \times (25 \times 10^{-3}) \times (16 \times 10^{-3})^4 = 1.2707e\text{-}6$ [kg·m ^{2}]

$J_{DP2} = (\pi / 32)\, \rho\, (L_{p2} \times 10^{-3})\, (D_{p2} \times 10^{-3})^4$

$= (3.14 / 32) \times 7900 \times (25 \times 10^{-3}) \times (16 \times 10^{-3})^4 = 1.2707e\text{-}6$ [kg·m ^{2}]

$J_L = (J_W + J_S + J_{Dp2})\, (D_{p1} / D_{p2})^2 + J_{Dp1}$

$= (3.7995e\text{-}5 + 1.0212e\text{-}4 + 1.2707e\text{-}6) \times (16/16)^2 + 1.2707e\text{-}6$

$= 1.4266e\text{-}4$ [kg·m ^{2}]

Required Speed

$V_m = V_1\, (60 / P_B)\, (D_{p2} / D_{p1})$

$= 20 \times (60 / 10) \times (16/16) = 120$ [r/min]

Required Torque

$T = (T_a + T_L)$ (Safety Factor)

$= (1.7925e\text{-}3 + 0.4148) \times 1.5$

$= 0.6249$ [N·m]

Acceleration Torque

$T_a = J_L\, (V_m / (9.55 \times t_1))$

$= 1.4266e\text{-}4 \times (120 / (9.55 \times 1))$

$= 1.7925e\text{-}3$ [N·m]

Load Torque

$F = F_A + (m \times 9.8)(\sin\alpha + \mu\cos\alpha)$

$= 35 + (15 \times 9.8)(\sin 180 + 0.5 \times \cos 180) = -38.50\ [N]$

$T_L = ((((F \times P_B \times 10^{-3}) / 2\pi) \times 1.1) + T_B)(D_{p1} / D_{p2})(1 / (\eta \times 0.01))$

$= ((((-38.50 \times 10 \times 10^{-3}) / (2 \times 3.14)) \times 1.1) + 0.42) \times (16 / 16) \times (1 / (85 \times 0.01)) = 0.4148\ [N{\cdot}m]$

Y- Axis:

Load and linear guide

Total mass of loads and table	m	= 10	[kg]
Friction coefficient of the guide	μ	= 0.5	

Ball/Lead screw specifications

Diameter	D_B	= 16	[mm]
Total length	L_B	= 1475	[mm]
Lead (pitch)	P_B	= 10	[mm/rev]
Efficiency	η	= 85	[%]
Materia - Stainless-steel 304	ρ	= 7900	[kg/m 3]
Breakaway torque of the screw	T_B	= 0.42	[N·m]

External force

F_A	=	0	[N]

Transmission belt and pulleys or gears

	Primary pulley (gear)	Secondary pulley (gear)
pitch circle diameter (PCD) D_{p1}	= 16 [mm]	D_{p2} = 16 [mm]
thickness L_{p1}	= 25 [mm]	L_{p2} = 25 [mm]
material	ρ = 7900 [kg/m 3] Steel	ρ = 7900 [kg/m 3] Steel

Mechanism Placement

Mechanism angle	α	= 0	[°]

Other requirement(s)

Is it necessary to hold the load even after the power supply is turned off? → YES
Is it necessary to hold the load after the motor is stopped, but not necessary to hold after the power supply is turned off? → NO

Operating conditions

Fixed speed operation	Operating speed	V_1 =	20	[mm/s]
	Acceleration / deceleration time	t_1 =	1	[s]

Stopping accuracy

Stopping accuracy	Δl =	1	[mm]

Safety factor

Safety factor $S{\cdot}F = 1.5$

Load Inertia

$J_W = m \times ((P_B \times 10^{-3}) / 2\pi)^2$

$= 10 \times ((10 \times 10^{-3}) / (2 \times 3.14))^2 = 2.5330e\text{-}5 \ [kg{\cdot}m^2]$

$J_S = (\pi / 32)\, \rho\, (L_B \times 10^{-3})\, (D_B \times 10^{-3})^4$

$= (3.14 / 32) \times 7900 \times (1475 \times 10^{-3}) \times (16 \times 10^{-3})^4 = 7.4972e\text{-}5 \ [kg{\cdot}m^2]$

$J_{Dp1} = (\pi / 32)\, \rho\, (L_{p1} \times 10^{-3})\, (D_{p1} \times 10^{-3})^4$

$= (3.14 / 32) \times 7900 \times (25 \times 10^{-3}) \times (16 \times 10^{-3})^4 = 1.2707e\text{-}6 \ [kg{\cdot}m^2]$

$J_{DP2} = (\pi / 32)\, \rho\, (L_{p2} \times 10^{-3})\, (D_{p2} \times 10^{-3})^4$

$= (3.14 / 32) \times 7900 \times (25 \times 10^{-3}) \times (16 \times 10^{-3})^4 = 1.2707e\text{-}6 \ [kg{\cdot}m^2]$

$J_L = (J_W + J_S + J_{Dp2})\, (D_{p1} / D_{p2})^2 + J_{Dp1}$

$= (2.5330e\text{-}5 + 7.4972\ e\text{-}4 + 1.2707e\text{-}6) \times (16/16)^2 + 1.2707e\text{-}6$

$= 1.0284e\text{-}4 \ [kg{\cdot}m^2]$

Required Speed

$V_m = V_1 (60 / P_B) (D_{p2} / D_{p1})$

$= 20 \times (60 / 10) \times (16/16) = 120$ [r/min]

Required Torque

$T = (T_a + T_L)$ (Safety Factor)

$= (1.2923e\text{-}3 + 0.5950) \times 1.5$

$= 0.8945$ [N·m]

Acceleration Torque

$T_a = J_L (V_m / (9.55 \times t_1))$

$= 1.0284e\text{-}4 \times (120 / (9.55 \times 1))$

$= 1.2923e\text{-}3$ [N·m]

Load Torque

$F = F_A + (m \times 9.8) (\sin\alpha + \mu\cos\alpha)$

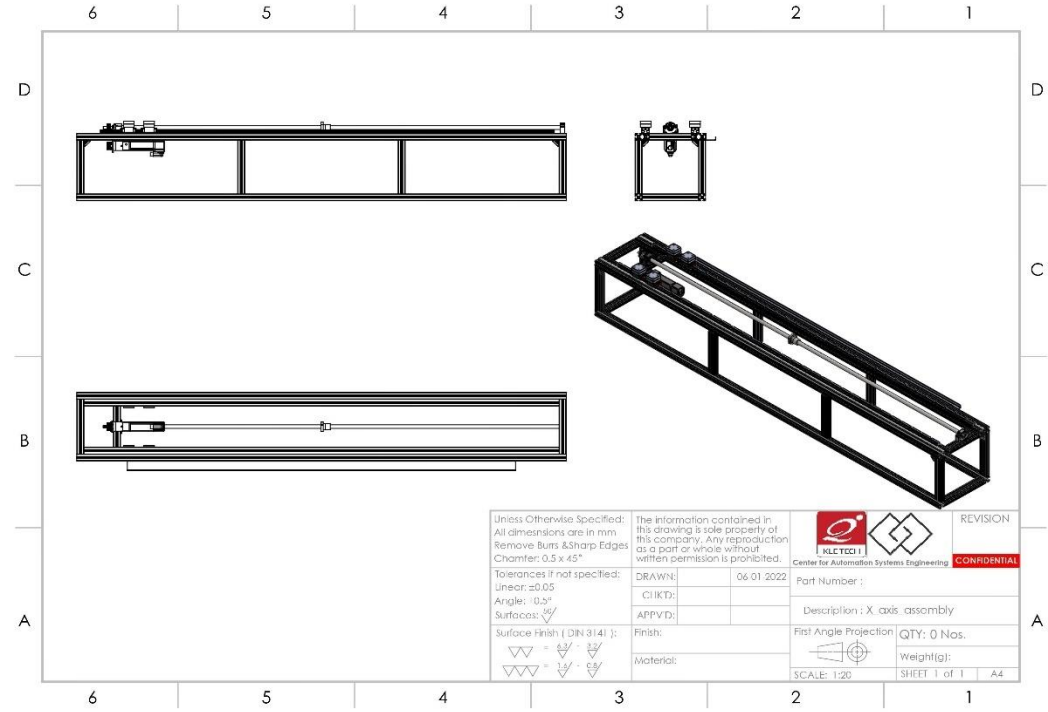
$= 0 + (10 \times 9.8) (\sin 0 + 0.5 \times \cos 0) = 49$ [N]

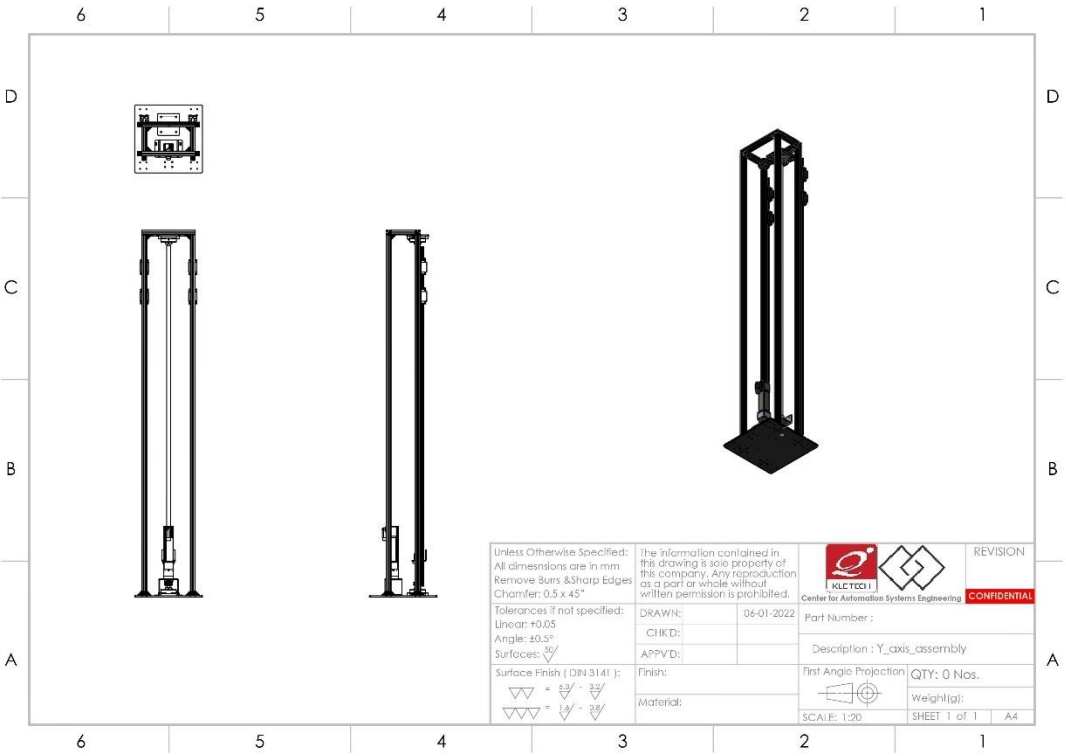
$T_L = (((F \times P_B \times 10^{-3}) / 2\pi) \times 1.1) + T_B) (D_{p1} / D_{p2}) (1 / (\eta \times 0.01))$

$= ((((49 \times 10 \times 10^{-3}) / (2 \times 3.14)) \times 1.1) + 0.42) \times (16 / 16) \times (1 / (85 \times 0.01))$

$= 0.5950$ [N·m]

DRAWINGS


Unless Otherwise Specified:
All dimesnsions are in mm
Remove Burrs &Sharp Edges
Chamfer: 0.5 x 45°
Tolerances if not specified:
Linear: ±0.05
Angle: ±0.5°
Surfaces:
Surface Finish (DIN 3141):
The information contained in this drawing is sole property of this company. Any reproduction as a part or whole without written permission is prohibited.
DRAWN: 06.01.2022
CHKD:
APPVD:
Finish:
Material:
KLE TECH
Center for Automation Systems Engineering
REVISION
CONFIDENTIAL
Part Number :
Description : X_axis_assembly
First Angle Projection
QTY: 0 Nos.
Weight(g):
SCALE: 1:20
SHEET 1 of 1
A4


Unless Otherwise Specified:
All dimesnsions are in mm
Remove Burrs &Sharp Edges
Chamfer: 0.5 x 45°
Tolerances if not specified:
Linear: ±0.05
Angle: ±0.5°
Surfaces:
Surface Finish (DIN 3141):
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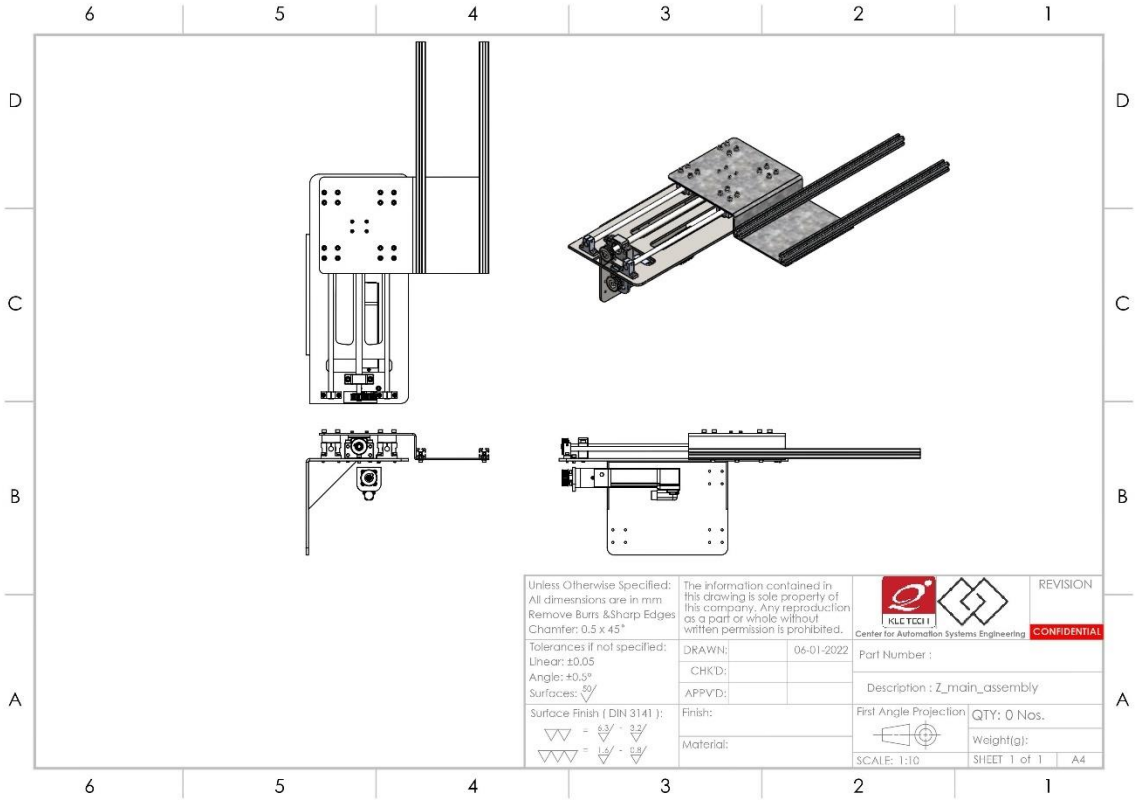
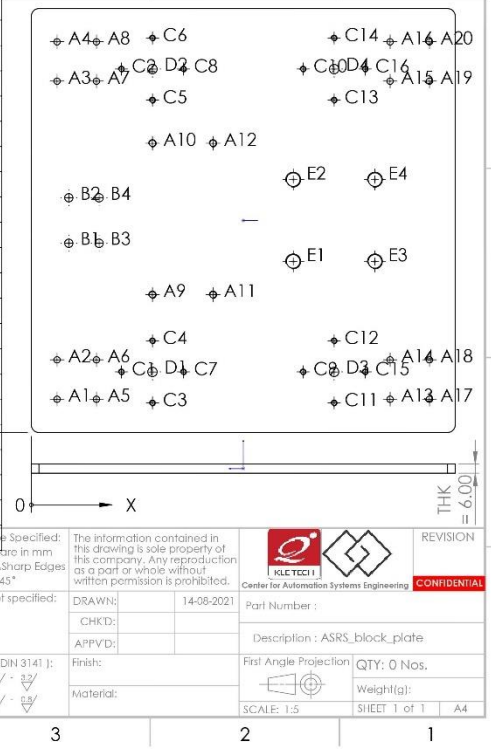
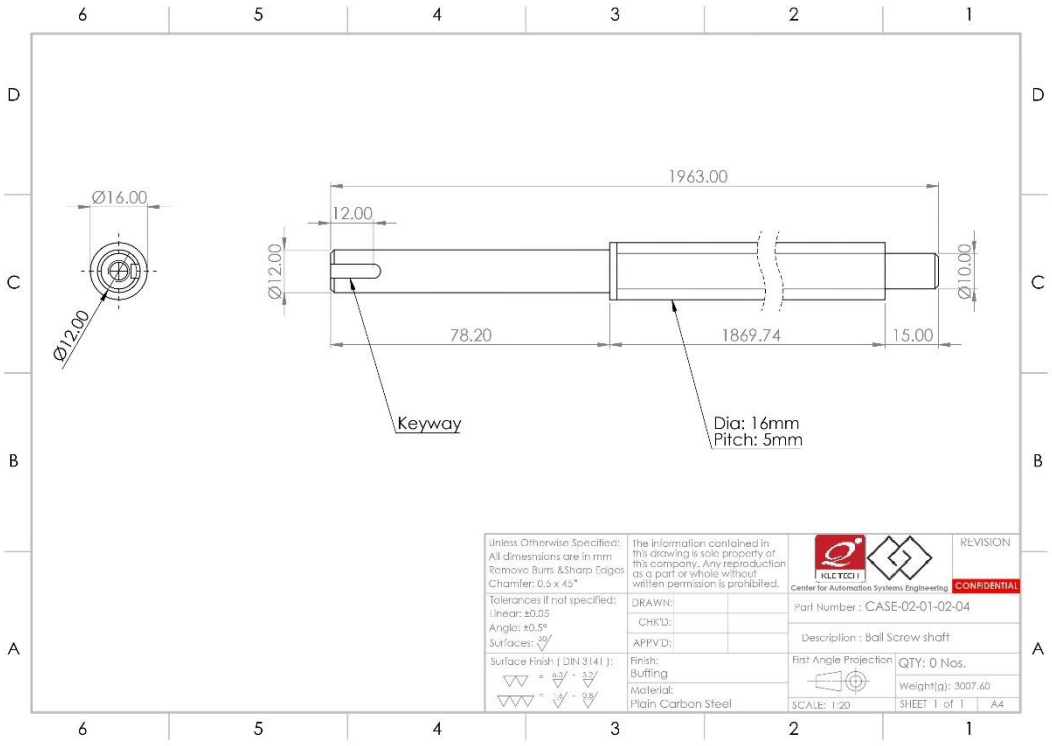
DRAWN: 06-01-2022
CHKD:
APPVD:
Finish:
Material:
KLE TECH
Center for Automation Systems Engineering
REVISION
CONFIDENTIAL
Part Number :
Description : Y_axis_assembly
First Angle Projection
QTY: 0 Nos.
Weight(g):
SCALE: 1:20
SHEET 1 of 1
A4



TAG	XLOC	YLOC	SIZE	TAG	XLOC	YLOC	SIZE
A1	17	22	∅4.20 THRU	C4	80	60.50	∅3.20 THRU
A2	17	48	∅4.20 THRU	C5	80	219.50	∅3.20 THRU
A3	17	232	∅4.20 THRU	C6	80	260.50	∅3.20 THRU
A4	17	258	∅4.20 THRU	C7	100.50	40	∅3.20 THRU
A5	43	22	∅4.20 THRU	C8	100.50	240	∅3.20 THRU
A6	43	48	∅4.20 THRU	C9	179.50	40	∅3.20 THRU
A7	43	232	∅4.20 THRU	C10	179.50	240	∅3.20 THRU
A8	43	258	∅4.20 THRU	C11	200	19.50	∅3.20 THRU
A9	80	91	∅4.20 THRU	C12	200	60.50	∅3.20 THRU
A10	80	191	∅4.20 THRU	C13	200	219.50	∅3.20 THRU
A11	120	91	∅4.20 THRU	C14	200	260.50	∅3.20 THRU
A12	120	191	∅4.20 THRU	C15	220.50	40	∅3.20 THRU
A13	237	22	∅4.20 THRU	C16	220.50	240	∅3.20 THRU
A14	237	48	∅4.20 THRU	D1	80	40	∅6.20 THRU
A15	237	232	∅4.20 THRU	D2	80	240	∅6.20 THRU
A16	237	258	∅4.20 THRU	D3	200	40	∅6.20 THRU
A17	263	22	∅4.20 THRU	D4	200	240	∅6.20 THRU
A18	263	48	∅4.20 THRU	E1	173	113	∅9.00 THRU
A19	263	232	∅4.20 THRU	E2	173	167	∅9.00 THRU
A20	263	258	∅4.20 THRU	E3	227	113	∅9.00 THRU
B1	24.75	125	∅5.50 THRU	E4	227	167	∅9.00 THRU
B2	24.75	155	∅5.50 THRU				
B3	44.75	125	∅5.50 THRU				
B4	44.75	155	∅5.50 THRU				
C1	59.50	40	∅3.20 THRU				
C2	59.50	240	∅3.20 THRU				
C3	80	19.50	∅3.20 THRU				




Ø16.00
Ø12.00
1963.00
12.00
Ø12.00
Ø10.00
78.20
1869.74
15.00
Keyway
Dia: 16mm
Pitch: 5mm
Unless Otherwise Specified:
All dimensions are in mm
Remove Burrs &Sharp Edges
Chamfer: 0.5 x 45°
Tolerances if not specified:
Linear: ±0.05
Angle: ±0.5°
Surfaces:
Surface Finish (DIN 3141):
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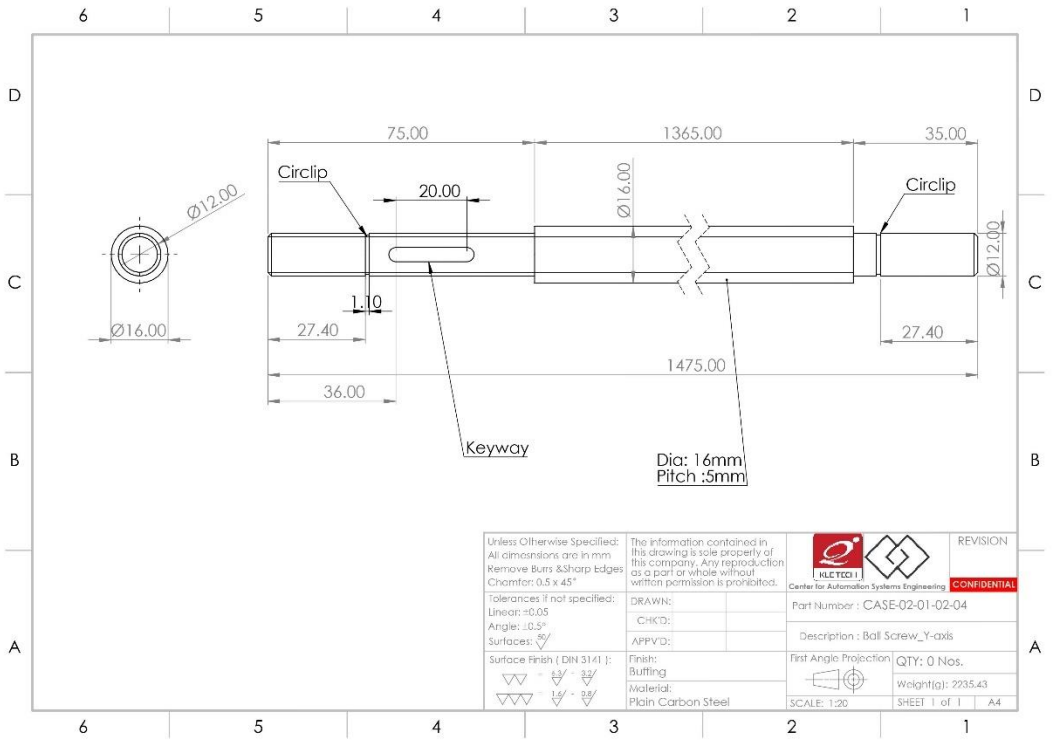
DRAWN:
CHK'D:
APPV'D:
Finish:
Buffing
Material:
Plain Carbon Steel
KLE TECH
Center for Automation Systems Engineering
REVISION
CONFIDENTIAL
Part Number : CASE-02-01-02-04
Description : Ball Screw shaft
First Angle Projection
QTY: 0 Nos.
Weight(g): 3007.60
SCALE: 1:20
SHEET 1 of 1
A4


75.00
1365.00
35.00
Circlip
20.00
Ø16.00
Circlip
Ø12.00
Ø12.00
1.10
27.40
27.40
Ø16.00
1475.00
36.00
Keyway
Dia: 16mm
Pitch :5mm
Unless Otherwise Specified:
All dimensions are in mm
Remove Burrs &Sharp Edges
Chamfer: 0.5 x 45°
Tolerances if not specified:
Linear: ±0.05
Angle: ±0.5°
Surfaces:
Surface Finish (DIN 3141):
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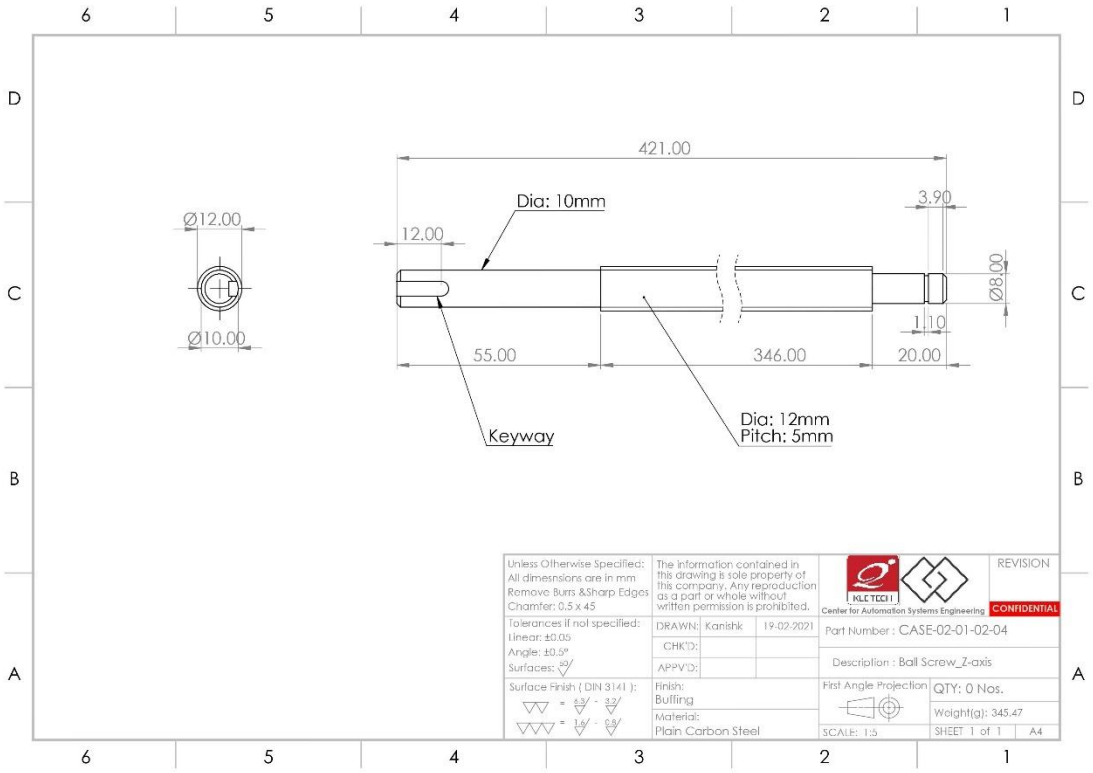
DRAWN:
CHK'D:
APPV'D:
Finish:
Buffing
Material:
Plain Carbon Steel
KLE TECH
Center for Automation Systems Engineering
REVISION
CONFIDENTIAL
Part Number : CASE-02-01-02-04
Description : Ball Screw_Y-axis
First Angle Projection
QTY: 0 Nos.
Weight(g): 2235.43
SCALE: 1:20
SHEET 1 of 1
A4


421.00
Dia: 10mm
3.90
Ø12.00
12.00
Ø8.00
1.10
Ø10.00
55.00
346.00
20.00
Keyway
Dia: 12mm
Pitch: 5mm
Unless Otherwise Specified:
All dimensions are in mm
Remove Burrs &Sharp Edges
Chamfer: 0.5 x 45
Tolerances if not specified:
Linear: ±0.05
Angle: ±0.5°
Surfaces:
Surface Finish (DIN 3141):
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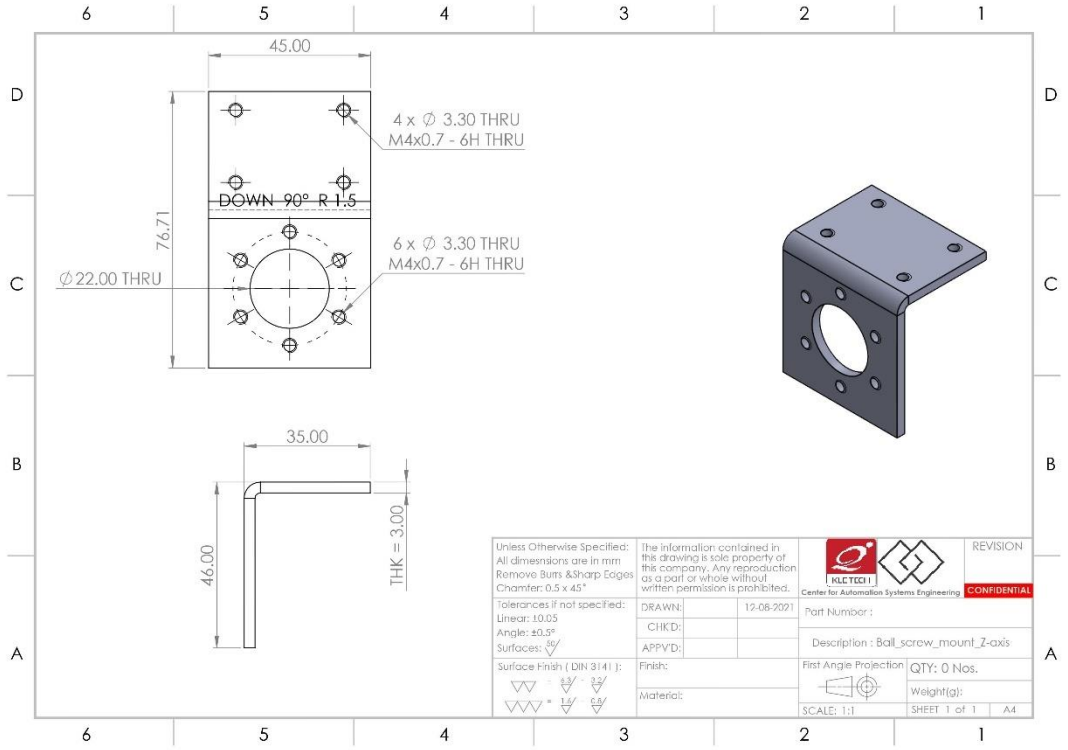
DRAWN: Kanishk 19-02-2021
CHK'D:
APPV'D:
Finish: Buffing
Material: Plain Carbon Steel
KLE TECH
Center for Automation Systems Engineering
REVISION
CONFIDENTIAL
Part Number : CASE-02-01-02-04
Description : Ball Screw_Z-axis
First Angle Projection
QTY: 0 Nos.
Weight(g): 345.47
SCALE: 1:5
SHEET 1 of 1
A4


45.00
4 x ∅ 3.30 THRU
M4x0.7 - 6H THRU
DOWN 90° R 1.5
76.71
6 x ∅ 3.30 THRU
M4x0.7 - 6H THRU
∅22.00 THRU
35.00
46.00
THK = 3.00
Unless Otherwise Specified:
All dimensions are in mm
Remove Burrs &Sharp Edges
Chamfer: 0.5 x 45°
Tolerances if not specified:
Linear: ±0.05
Angle: ±0.5°
Surfaces:
Surface Finish (DIN 3141):
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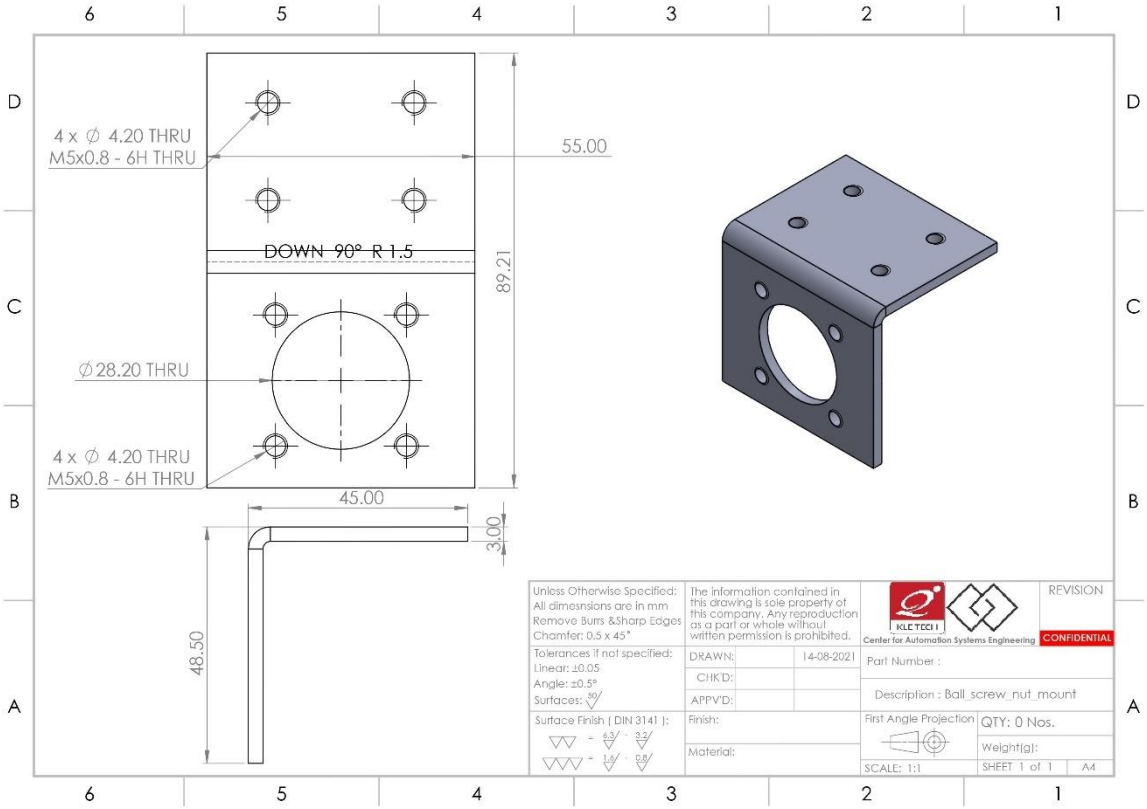
DRAWN: 12-08-2021
CHK'D:
APPV'D:
Finish:
Material:
KLE TECH
Center for Automation Systems Engineering
REVISION
CONFIDENTIAL
Part Number :
Description : Ball_screw_mount_Z-axis
First Angle Projection
QTY: 0 Nos.
Weight(g):
SCALE: 1:1
SHEET 1 of 1
A4


4 x ∅ 4.20 THRU
M5x0.8 - 6H THRU
55.00
DOWN 90° R 1.5
89.21
∅28.20 THRU
4 x ∅ 4.20 THRU
M5x0.8 - 6H THRU
45.00
3.00
48.50
Unless Otherwise Specified:
All dimensions are in mm
Remove Burrs &Sharp Edges
Chamfer: 0.5 x 45°
Tolerances if not specified:
Linear: ±0.05
Angle: ±0.5°
Surfaces:
Surface Finish (DIN 3141):
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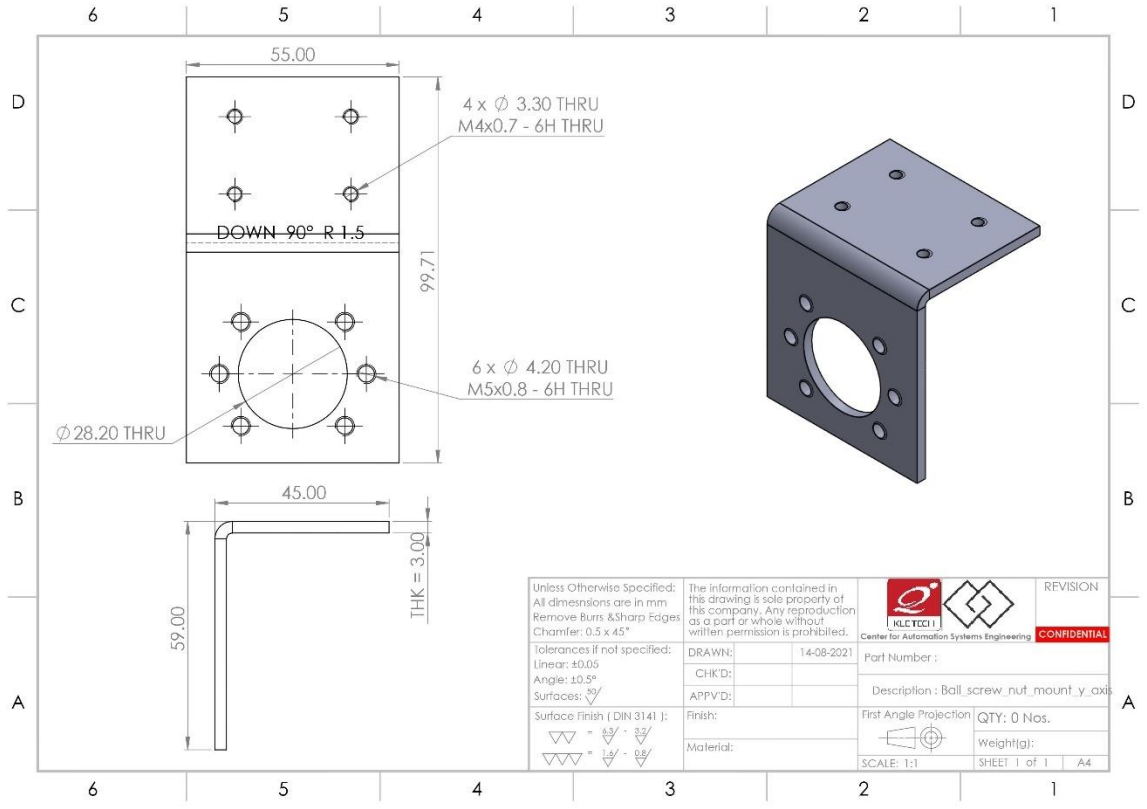
DRAWN:
14-08-2021
CHK'D:
APPV'D:
Finish:
Material:
KLE TECH
Center for Automation Systems Engineering
CONFIDENTIAL
REVISION
Part Number :
Description : Ball_screw_nut_mount
First Angle Projection
QTY: 0 Nos.
Weight(g):
SCALE: 1:1
SHEET 1 of 1
A4


55.00
4 x ∅ 3.30 THRU
M4x0.7 - 6H THRU
DOWN 90° R 1.5
99.71
6 x ∅ 4.20 THRU
M5x0.8 - 6H THRU
∅28.20 THRU
45.00
THK = 3.00
59.00
Unless Otherwise Specified:
All dimensions are in mm
Remove Burrs &Sharp Edges
Chamfer: 0.5 x 45°
Tolerances if not specified:
Linear: ±0.05
Angle: ±0.5°
Surfaces:
Surface Finish (DIN 3141):
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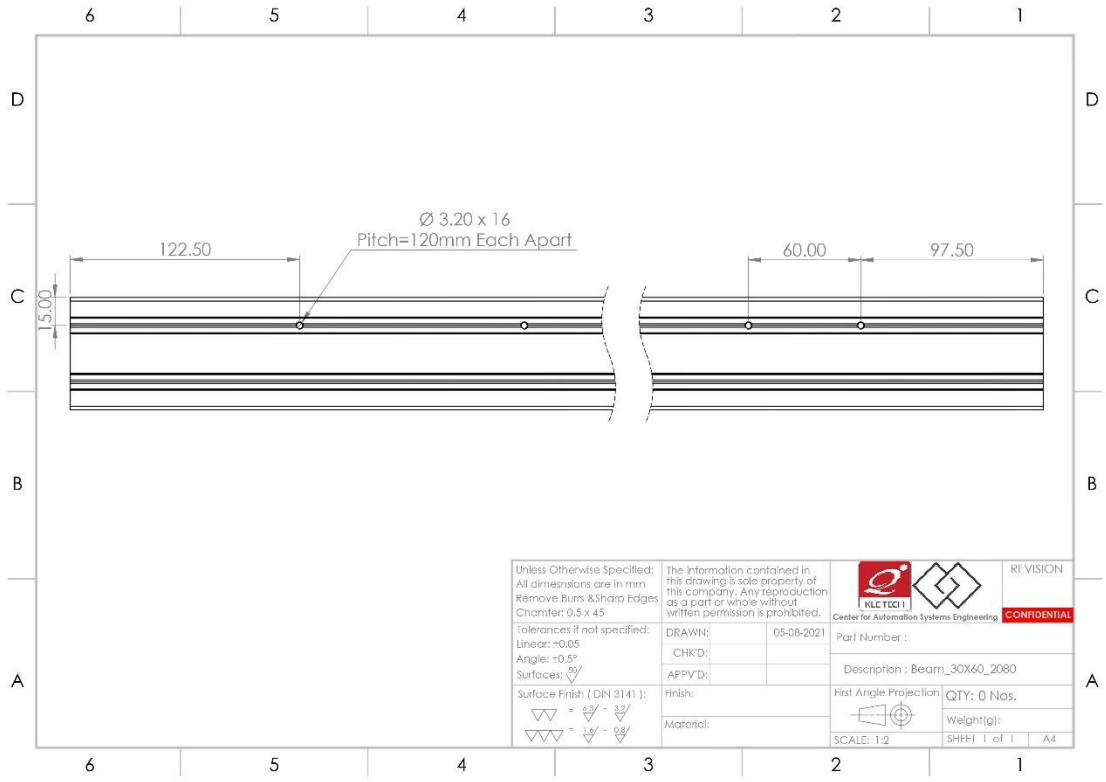
DRAWN:
14-08-2021
CHK'D:
APPV'D:
Finish:
Material:
KLE TECH
Center for Automation Systems Engineering
CONFIDENTIAL
REVISION
Part Number :
Description : Ball_screw_nut_mount_y_axis
First Angle Projection
QTY: 0 Nos.
Weight(g):
SCALE: 1:1
SHEET 1 of 1
A4


Ø 3.20 x 16
Pitch=120mm Each Apart
122.50
60.00
97.50
15.00
Unless Otherwise Specified:
All dimensions are in mm
Remove Burrs &Sharp Edges
Chamfer: 0.5 x 45
Tolerances if not specified:
Linear: ±0.05
Angle: ±0.5°
Surfaces:
Surface Finish (DIN 3141):
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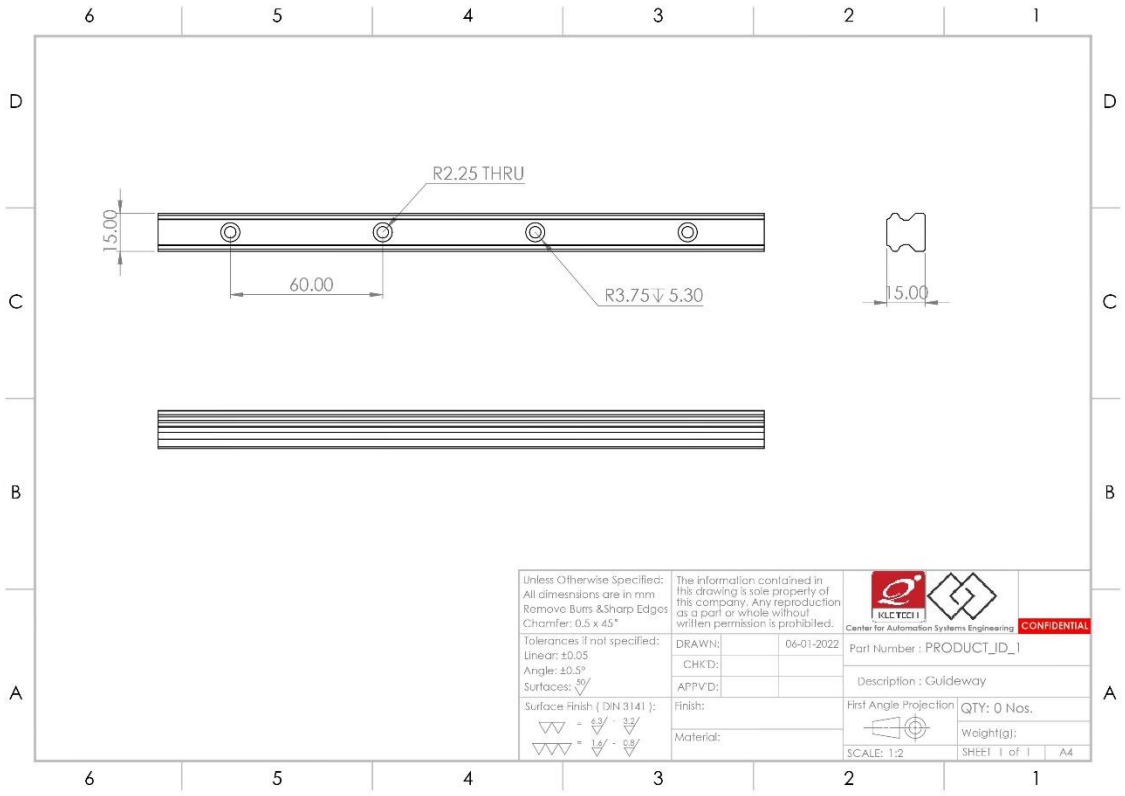
DRAWN: 05-08-2021
CHK'D:
APPV'D:
Finish:
Material:
KLE TECH
Center for Automation Systems Engineering
REVISION
CONFIDENTIAL
Part Number :
Description : Beam_30X60_2080
First Angle Projection
QTY: 0 Nos.
Weight(g):
SCALE: 1:2
SHEET 1 of 1
A4


R2.25 THRU
15.00
60.00
R3.75
5.30
15.00
Unless Otherwise Specified:
All dimensions are in mm
Remove Burrs &Sharp Edges
Chamfer: 0.5 x 45°
Tolerances if not specified:
Linear: ±0.05
Angle: ±0.5°
Surfaces:
Surface Finish (DIN 3141):
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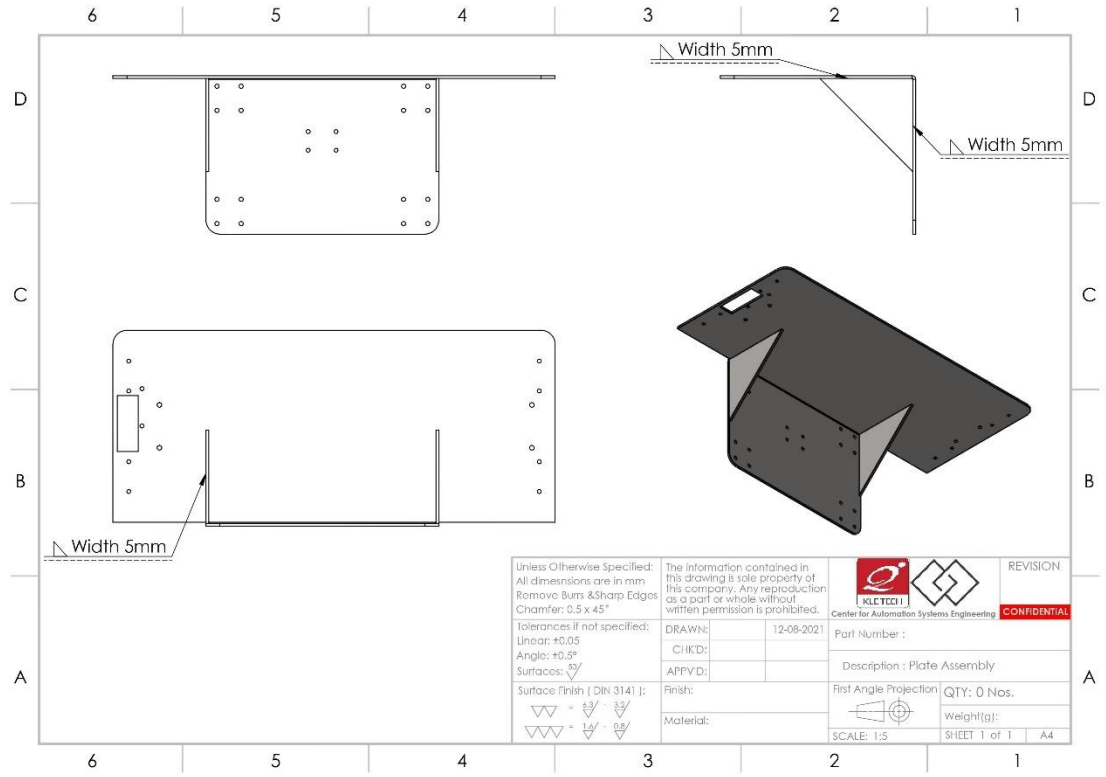
DRAWN: 06-01-2022
CHK'D:
APPV'D:
Finish:
Material:
KLE TECH
Center for Automation Systems Engineering
CONFIDENTIAL
Part Number : PRODUCT_ID_1
Description : Guideway
First Angle Projection
QTY: 0 Nos.
Weight(g):
SCALE: 1:2
SHEET 1 of 1
A4


Width 5mm
Width 5mm
Width 5mm
Unless Otherwise Specified:
All dimensions are in mm
Remove Burrs &Sharp Edges
Chamfer: 0.5 x 45°
Tolerances if not specified:
Linear: ±0.05
Angle: ±0.5°
Surfaces:
Surface Finish (DIN 3141):
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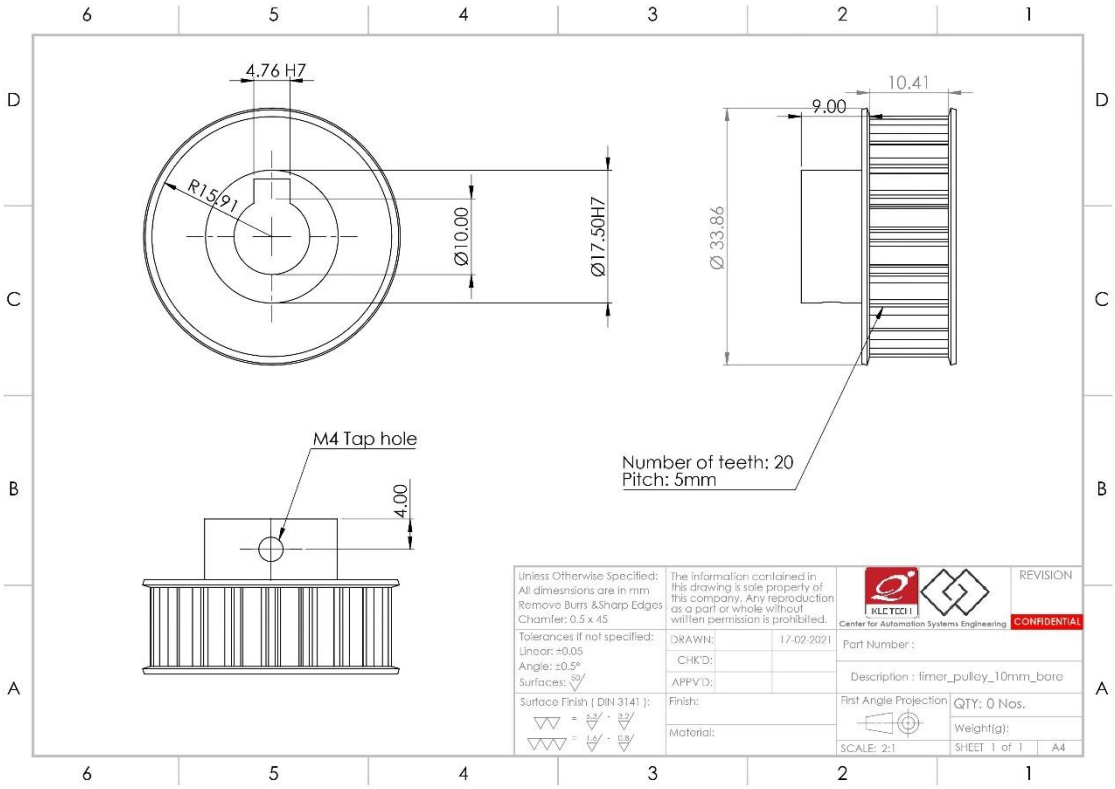
DRAWN:
12-08-2021
CHK'D:
APPV'D:
Finish:
Material:
KLE TECH
Center for Automation Systems Engineering
REVISION
CONFIDENTIAL
Part Number :
Description : Plate Assembly
First Angle Projection
QTY: 0 Nos.
Weight(g):
SCALE: 1:5
SHEET 1 of 1
A4


4.76 H7
R15.91
Ø10.00
Ø17.50H7
10.41
9.00
Ø 33.86
M4 Tap hole
4.00
Number of teeth: 20
Pitch: 5mm
Unless Otherwise Specified:
All dimensions are in mm
Remove Burrs &Sharp Edges
Chamfer: 0.5 x 45
Tolerances if not specified:
Linear: ±0.05
Angle: ±0.5°
Surfaces:
Surface Finish (DIN 3141):
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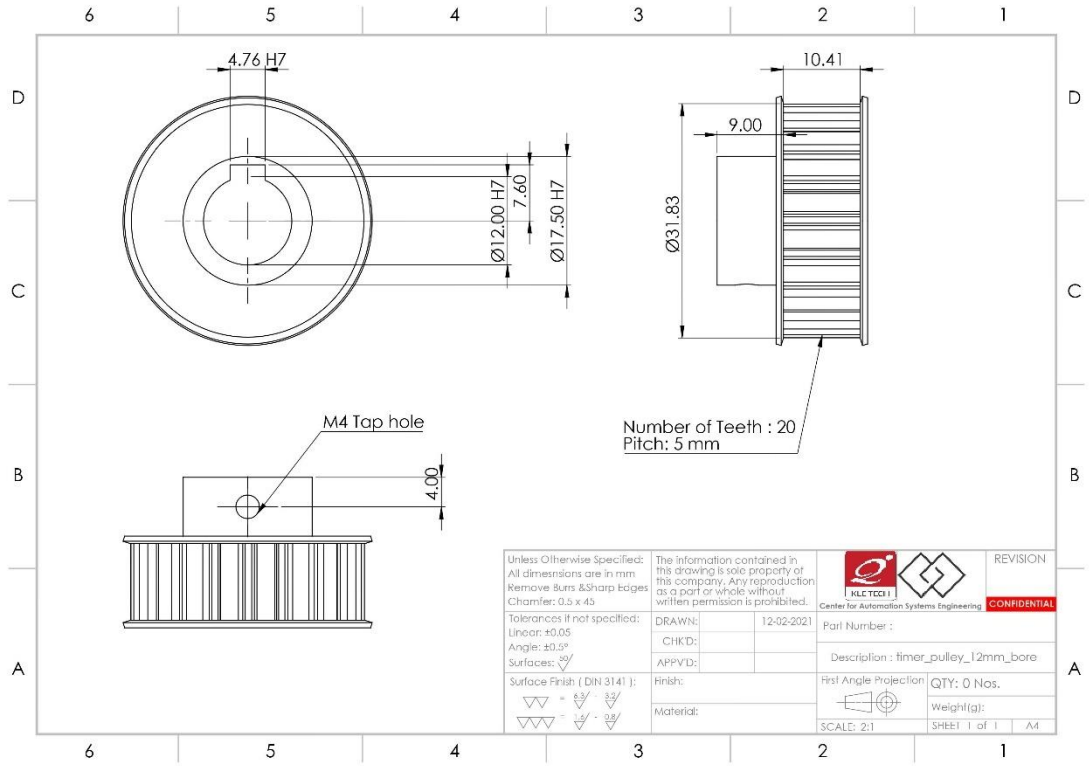
DRAWN:
17-02-2021
CHK'D:
APPV'D:
Finish:
Material:
KLE TECH
Center for Automation Systems Engineering
REVISION
CONFIDENTIAL
Part Number :
Description : timer_pulley_10mm_bore
First Angle Projection
QTY: 0 Nos.
Weight(g):
SCALE: 2:1
SHEET 1 of 1
A4


4.76 H7
10.41
9.00
Ø12.00 H7
7.60
Ø17.50 H7
Ø31.83
M4 Tap hole
4.00
Number of Teeth : 20
Pitch: 5 mm
Unless Otherwise Specified:
All dimensions are in mm
Remove Burrs &Sharp Edges
Chamfer: 0.5 x 45
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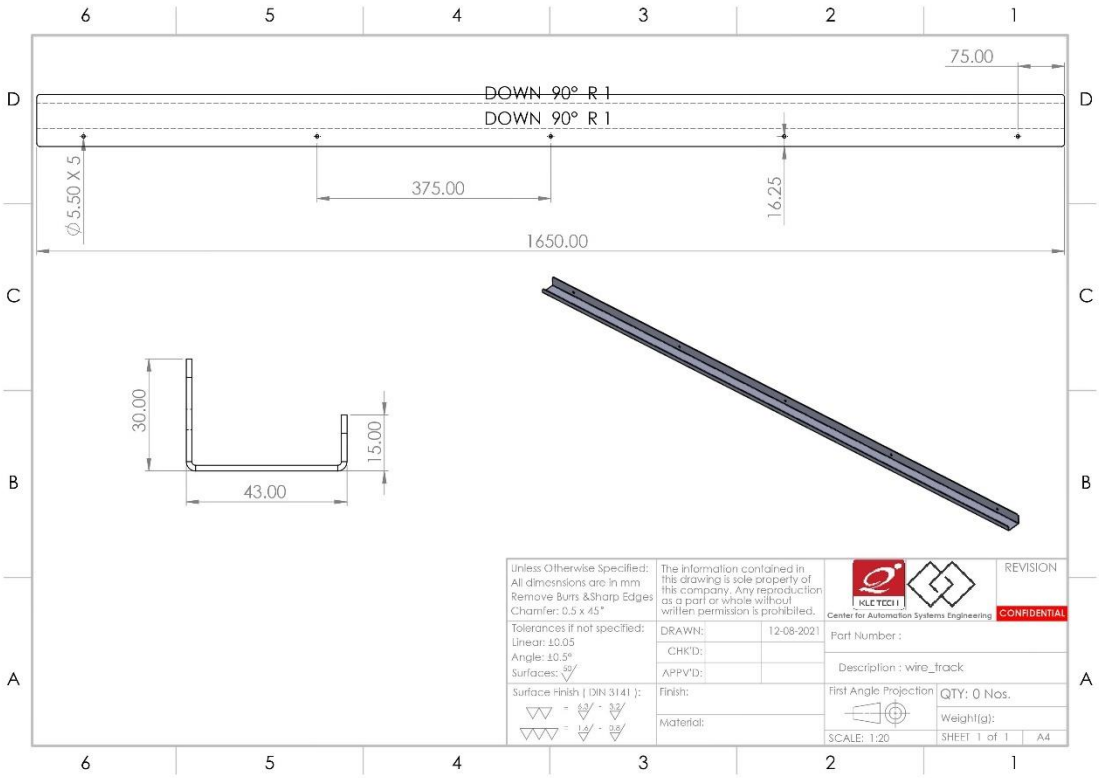
REVISION
CONFIDENTIAL
Tolerances if not specified:
Linear: ±0.05
Angle: ±0.5°
DRAWN: 12-02-2021
CHK'D:
APPV'D:
Part Number :
Description : timer_pulley_12mm_bore
Surface Finish (DIN 3141):
Finish:
Material:
First Angle Projection
QTY: 0 Nos.
Weight(g):
SCALE: 2:1
SHEET 1 of 1
A4


75.00
DOWN 90° R 1
DOWN 90° R 1
Ø5.50 X 5
375.00
16.25
1650.00
30.00
15.00
43.00
Unless Otherwise Specified:
All dimensions are in mm
Remove Burrs &Sharp Edges
Chamfer: 0.5 x 45°
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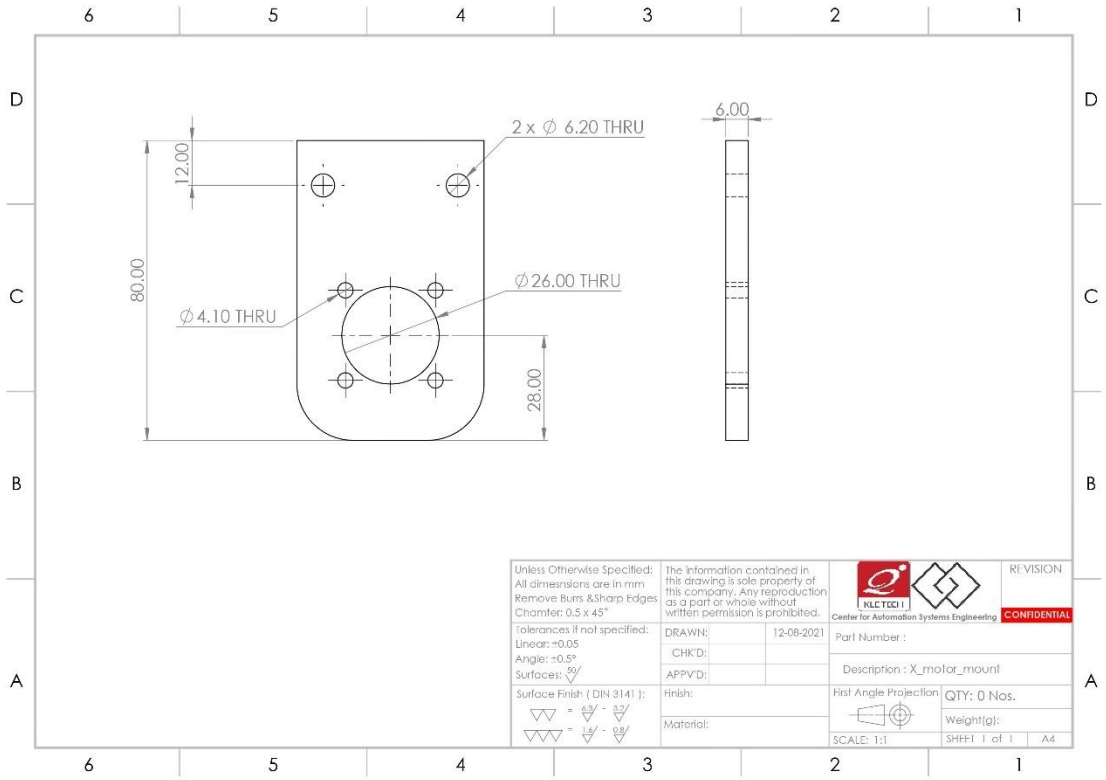
REVISION
CONFIDENTIAL
Tolerances if not specified:
Linear: ±0.05
Angle: ±0.5°
DRAWN: 12-08-2021
CHK'D:
APPV'D:
Part Number :
Description : wire_frack
Surface Finish (DIN 3141):
Finish:
Material:
First Angle Projection
QTY: 0 Nos.
Weight(g):
SCALE: 1:20
SHEET 1 of 1
A4


2 x ∅ 6.20 THRU
6.00
12.00
80.00
∅4.10 THRU
∅26.00 THRU
28.00
Unless Otherwise Specified:
All dimensions are in mm
Remove Burrs &Sharp Edges
Chamfer: 0.5 x 45°
Tolerances if not specified:
Linear: ±0.05
Angle: ±0.5°
Surfaces:
Surface Finish (DIN 3141):
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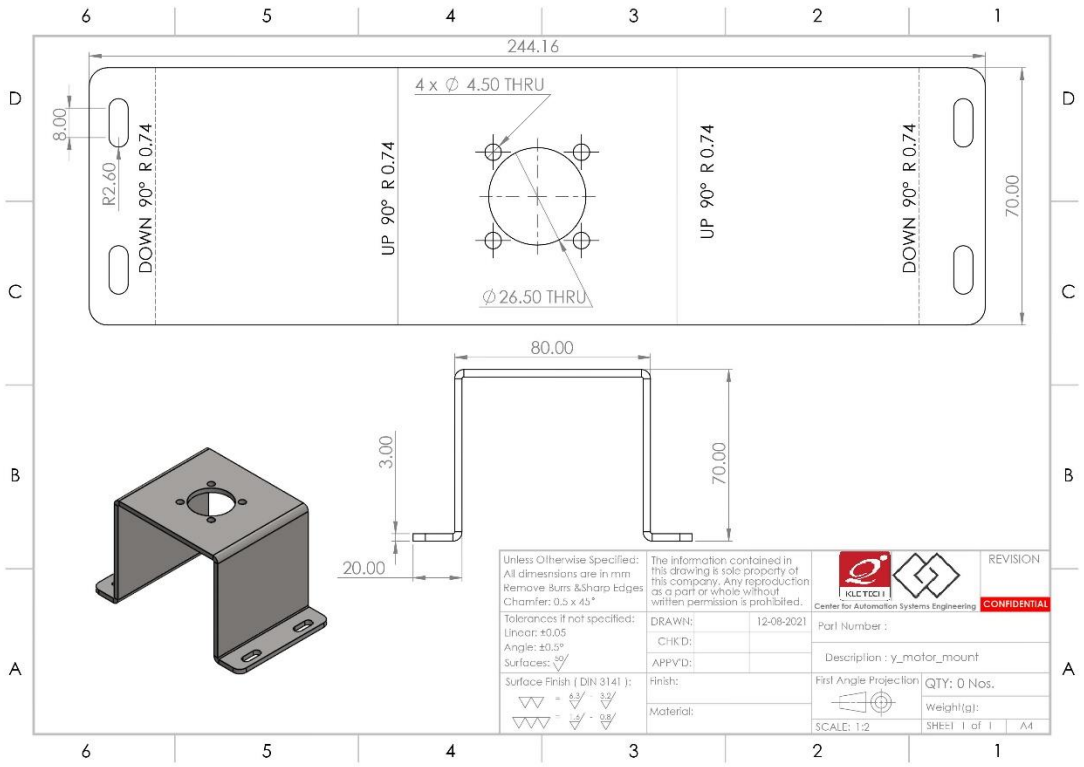
DRAWN:
12-08-2021
CHK'D:
APPV'D:
Finish:
Material:
KLE TECH
Center for Automation Systems Engineering
REVISION
CONFIDENTIAL
Part Number :
Description : X_motor_mount
First Angle Projection
QTY: 0 Nos.
Weight(g):
SCALE: 1:1
SHEET 1 of 1
A4


244.16
4 x ∅ 4.50 THRU
8.00
R2.60
DOWN 90° R 0.74
UP 90° R 0.74
UP 90° R 0.74
DOWN 90° R 0.74
70.00
∅26.50 THRU
80.00
3.00
70.00
20.00
Unless Otherwise Specified:
All dimensions are in mm
Remove Burrs &Sharp Edges
Chamfer: 0.5 x 45°
Tolerances if not specified:
Linear: ±0.05
Angle: ±0.5°
Surfaces:
Surface Finish (DIN 3141):
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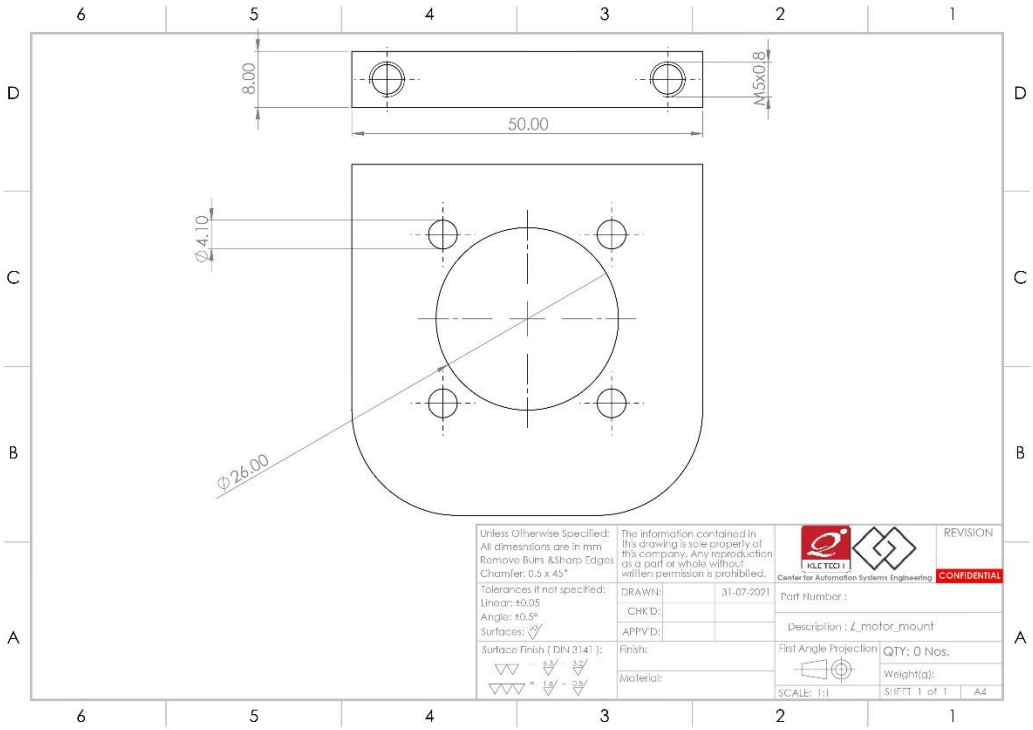
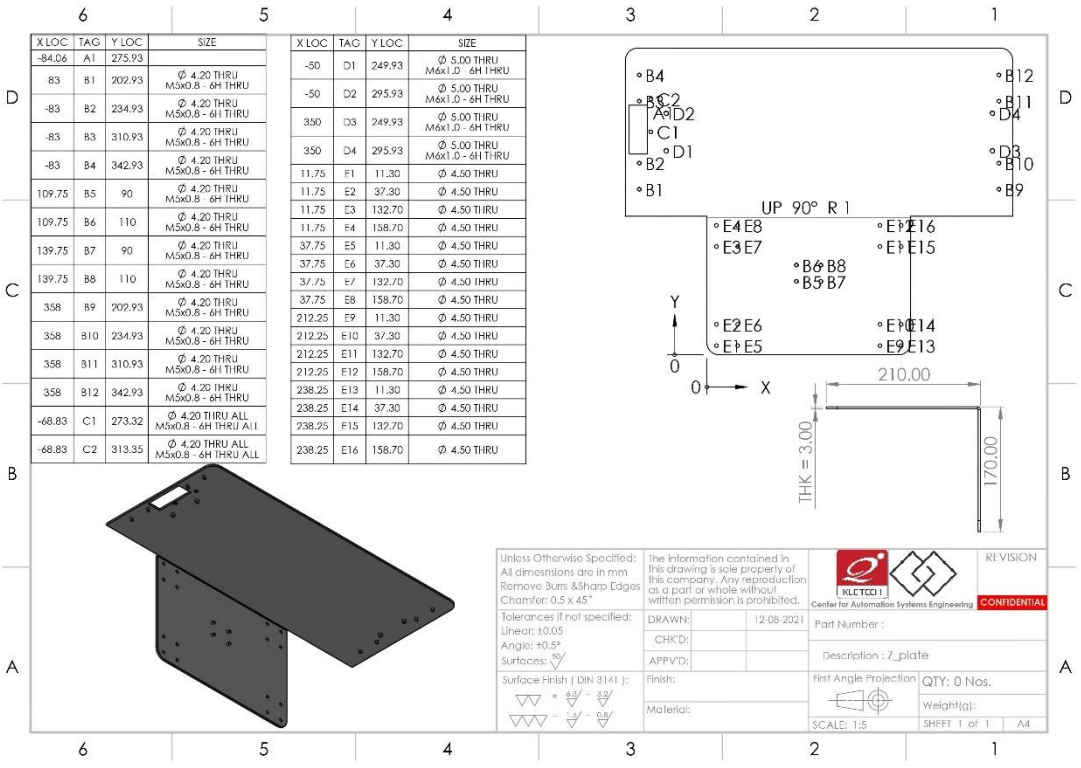
DRAWN:
12-08-2021
CHK'D:
APPV'D:
Finish:
Material:
KLE TECH
Center for Automation Systems Engineering
REVISION
CONFIDENTIAL
Part Number :
Description : y_motor_mount
First Angle Projection
QTY: 0 Nos.
Weight(g):
SCALE: 1:2
SHEET 1 of 1
A4



X LOC	TAG	Y LOC	SIZE
-84.06	A1	275.93	
-83	B1	202.93	Ø 4.20 THRU M5x0.8 - 6H THRU
-83	B2	234.93	Ø 4.20 THRU M5x0.8 - 6H THRU
-83	B3	310.93	Ø 4.20 THRU M5x0.8 - 6H THRU
-83	B4	342.93	Ø 4.20 THRU M5x0.8 - 6H THRU
109.75	B5	90	Ø 4.20 THRU M5x0.8 - 6H THRU
109.75	B6	110	Ø 4.20 THRU M5x0.8 - 6H THRU
139.75	B7	90	Ø 4.20 THRU M5x0.8 - 6H THRU
139.75	B8	110	Ø 4.20 THRU M5x0.8 - 6H THRU
358	B9	202.93	Ø 4.20 THRU M5x0.8 - 6H THRU
358	B10	234.93	Ø 4.20 THRU M5x0.8 - 6H THRU
358	B11	310.93	Ø 4.20 THRU M5x0.8 - 6H THRU
358	B12	342.93	Ø 4.20 THRU M5x0.8 - 6H THRU
-68.83	C1	273.32	Ø 4.20 THRU ALL M5x0.8 - 6H THRU ALL
-68.83	C2	313.35	Ø 4.20 THRU ALL M5x0.8 - 6H THRU ALL

X LOC	TAG	Y LOC	SIZE
-50	D1	249.93	Ø 5.00 THRU M6x1.0 - 6H THRU
-50	D2	295.93	Ø 5.00 THRU M6x1.0 - 6H THRU
350	D3	249.93	Ø 5.00 THRU M6x1.0 - 6H THRU
350	D4	295.93	Ø 5.00 THRU M6x1.0 - 6H THRU
11.75	E1	11.30	Ø 4.50 THRU
11.75	E2	37.30	Ø 4.50 THRU
11.75	E3	132.70	Ø 4.50 THRU
11.75	E4	158.70	Ø 4.50 THRU
37.75	E5	11.30	Ø 4.50 THRU
37.75	E6	37.30	Ø 4.50 THRU
37.75	E7	132.70	Ø 4.50 THRU
37.75	E8	158.70	Ø 4.50 THRU
212.25	E9	11.30	Ø 4.50 THRU
212.25	E10	37.30	Ø 4.50 THRU
212.25	E11	132.70	Ø 4.50 THRU
212.25	E12	158.70	Ø 4.50 THRU
238.25	E13	11.30	Ø 4.50 THRU
238.25	E14	37.30	Ø 4.50 THRU
238.25	E15	132.70	Ø 4.50 THRU
238.25	E16	158.70	Ø 4.50 THRU



GALLERY

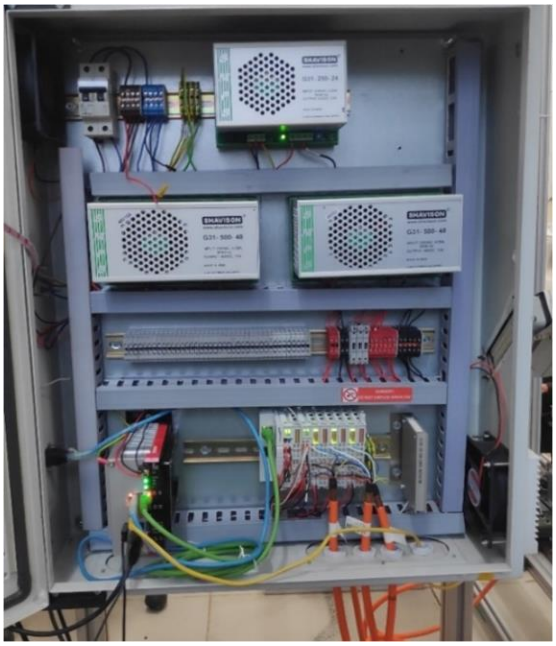


Figure 38 Control Panel Cabinet

Figure 39 ASRS Assembly

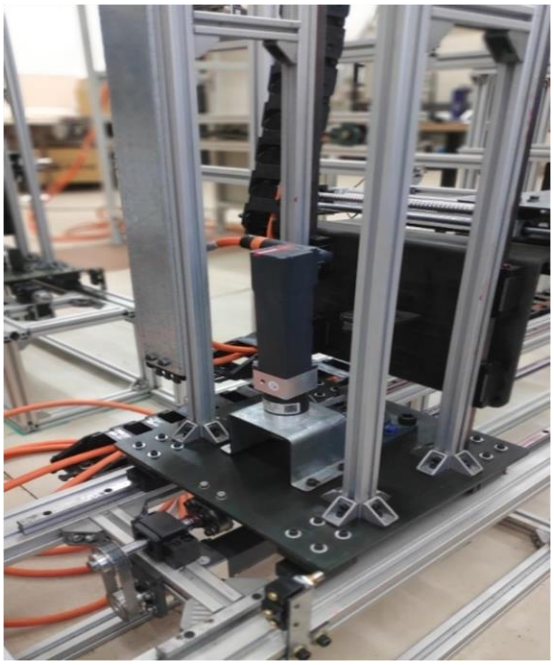


Figure 40 X – Axis of ASRS

Figure 41 Y – Axis of ASRS

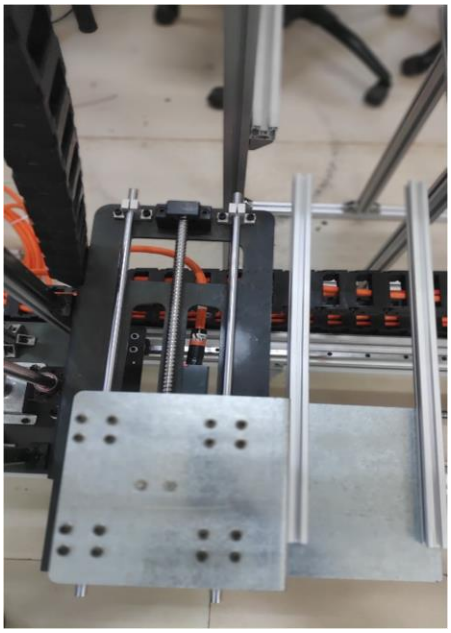


Figure 42 Z - Axis of ASRS

Appendix 2

Bill Of Materials (Mechanical)

SL.NO	PRODUCT DESCRIPTION	SPECIFICATION	QTY.	UNITS	PART NO.
Ball Screw					
1	Ball Screw	16mm diameter, Pitch = 5mm Length= 1710mm (x-axis)	2	pc	--
		16mm diameter, Pitch = 5mm Length= 1453mm (y-axis)	2	pc	--
		12mm diameter, Pitch = 5mm Length= 455mm (z-axis)	2	pc	--
Ball Screw Nut					
2	Nut	16mm diameter (x-axis)	2	pc	--
		16mm diameter (y-axis)	2	pc	--
		12mm diameter (z-axis)	2	pc	--
Bearings					
3	Linear Bearing	12mm ID, 24mm OD	8	pcs	61901
	4 bolt flange Bearing	15mm ID	4	pcs	FY12
	Linear Rail Shaft Support	8mm diameter	4	pcs	SK8
	Linear Bearing	8mm Inner diameter	4	pcs	SC8UU
	LM Bearing LM 10UU	10mm Inner diameter	8	pcs	--
	Ball screw end supporter	10mm diameter (z-axis)	4	pcs	BF12
		12mm diameter (x-axis)	2	pcs	BF12
		12mm diameter (x-axis)	2	pcs	BK12
LM Guideway Block					
4	Guide Block	Width=25mm (x and y-axis)	16	pcs	HGH15CAZ0C
5	LM Guides	Width=15mm, Length=1400mm (y-axis)	4	pcs	HGR25R1800C
	Guideway	Width=25mm, Length=1800mm (x-axis)	4	pcs	HGR15R1400C
Structures					
6	Structures Aluminium extrusions (Bosch)	**30x30**	--	feet	--
		X axis 240mm	8	pcs	--
		235mm	16	pcs	--
		2080mm	4	pcs	--
		180mm	6	pcs	--
		Rack 200mm	4	pcs	--
		430mm	4	pcs	--

		1430mm	4	pcs	--
		2000mm	24	pcs	--
		1490mm	4	pcs	--
		260mm	100	pcs	--
		20x20	--	feet	--
		Y axis 1490mm	8	pcs	--
		100mm	12	pcs	--
		220mm	4	pcs	--
		Z axis 490mm	4	pcs	--
		112mm	4	pcs	--
		60x30			--
		x axis 2080mm	4	pcs	--
Timing Belt - Pulley					
7	Pulley	Teeth=20, width=10mm, ID=12mm (x-axis & y-axis)	4	pcs	--
		Teeth=20, width=10mm, ID=10mm (x-axis & y-axis)	4	pcs	--
		Teeth=20, width=10mm, ID=10mm(z-axis)	4	pcs	--
8	Timing Belt	loop length=200mm, width=10mm(y-axis)	2	pcs	--
		loop length=315mm, width=10mm(x-axis)	2	pcs	--
		loop length=315mm, width=10mm(z-axis)	2	pcs	--
Sheet Metal					
9	MS sheet metal	**X-axis**			
		Thickness = 6mm, length x breadth=800x800mm	1	pcs	--
		Y & Z-axis			--
		Thickness = 5mm, length x breadth=1000x1000mm	1	pcs	--
	GI sheet metal	**X, Y & Z axis**			
		Thickness = 3mm, length x breadth=1000x2000mm	1	pcs	--
Fasteners, Nuts and Washers					
10	Allen Bolt	M3x8	20	pcs	--
		M3x12	10	pcs	--
		M4x10	20	pcs	--
		M4X12	30	pcs	--
		M4x20	30	pcs	--
		M4x25	30	pcs	--

		M4x30	30	pcs	--
		M4x35	150	pcs	--
		M5x12	20	pcs	--
		M5x16	10	pcs	--
		M5x20	10	pcs	--
		M5x45	40	pcs	--
		M6x30	10	pcs	--
		M6x40	10	pcs	--
11	Spring Washers	M3	30	pcs	--
		M4	290	pcs	--
		M5	80	pcs	--
		M6	20	pcs	--
12	Washers	M3	30	pcs	--
		M4	290	pcs	--
		M5	80	pcs	--
		M6	20	pcs	--
13	T nut and bolt and washers	M6	880	pcs	--
		M4	200	pcs	--
14	Gussets	20x20	100	pcs	--
		30x30	440	pcs	--
Guide Rod					
15	z-axis	460mm	2	pcs	--
		510mm	2	pcs	--
Track chain					
16	x-axis	1200mm	2	pcs	--
	y-axis	1200mm	2	pcs	--
Shaft end support					
17	z-axis	Shaft end support	8	pcs	SK10

Bill Of Materials (Electrical)

ITEM. NO	PART NUMBER	QTY.	VENDOR
1	Shavison G31-250-24	1	SHAVISON ELECTRONICS PVT. LTD.
2	Shavison G31-500-48	2	
3	Meanwell 24v SMPS	1	MEAN WELL Enterprises Co
4	Meanwell 48v SMPS	2	
5	MCB 2p	2	Prajay Electrotech, Hubli
6	Terminal blocks	{4L ,4N, 4G, 24v(6p,4n),48v(2p, 2n), Data blocks(30)}x2	
7	Indicator	2	
8	Toggle on/off Power Switch	2	
9	Emergency Switch	2	
10	Ethernet port	2	
11	Exhaust Fans	4	
12	Harting Connector (32pins)	2	
13	Weather proof connector	2	
14	Fuse 10A	6	
15	Wire duct and Dendrill	2 set	
16	Limit switch – 15A, 250VAC [ID15GQ-B]	12	

BECKOFF Electrical Components			
17	C6030-0070 (IPC)	1	Beckhoff Automation
18	EL1859 8 channel digital I/O terminal	2	
19	EL9576 Brake chopper terminal	2	
20	EL7211-0010 Servo motor terminal	6	
21	El9011 Bus end cap	2	
22	ZB8110 External ballast Resistor (10R, 100W, 600Vac)	2	
23	AM8112-0F21-0000 Motor	6	
24	ZK1090-9191-0000 Ethernet patch Cable	2	
25	Ek1100 EtherCAT terminal for E-bus terminal	2	
26	ZK4704-0421-2050 Motor power cable	6	

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