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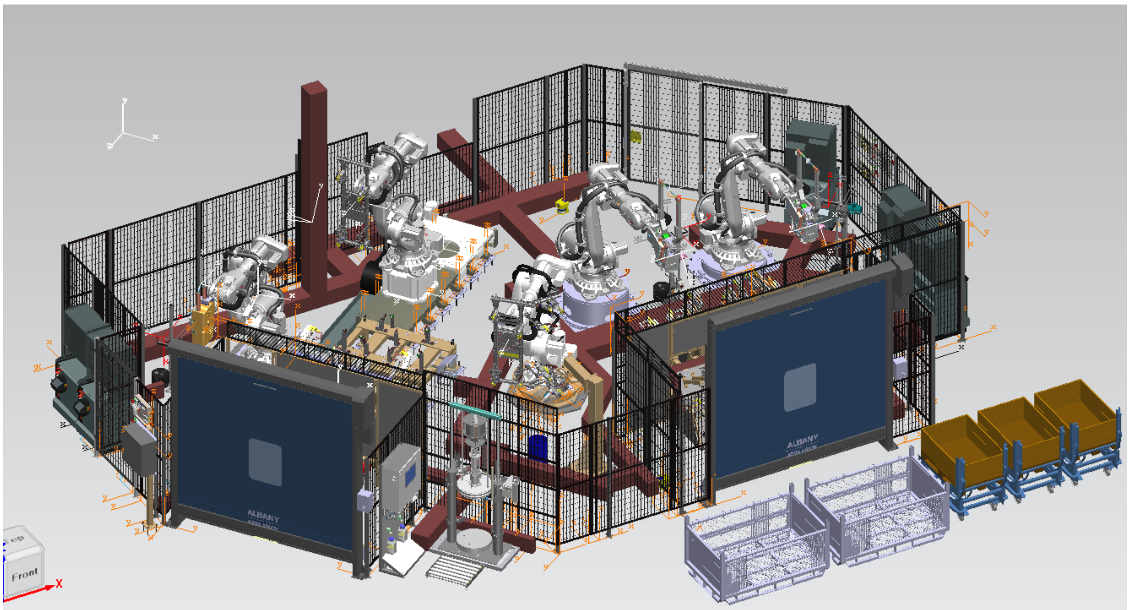

Software in Loop Virtual Commissioning at Volvo Cars Torslanda

Master's thesis in Production Engineering

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Abstract

With Industry 4.0 looming large, factories have never felt so much pressure to keep up with the growing competitiveness to be digitally competent. Production systems are in the limelight like never before to produce products and deliver them to the market as early as possible. A critical amount of time is spent on physical commissioning when a new station or a line is introduced. To reduce this, Virtual Commissioning can be performed where the entire station can be commissioned virtually and checked for its correctness even before stepping foot into the factory.

In this thesis, a firm step has been taken towards standardizing the procedure of Virtual Commissioning. The station studied in this thesis is a spot welding station comprising of five ABB robots, two fixtures and turntables. The software used in this thesis are Siemens Process Simulate, TIA portal and PLCSIM Advanced. A software in the loop(SiL) Virtual Commissioning has been performed on the station and steps followed to achieve Virtual Commissioning have been documented. Apart from creating a step by step procedure, standards have been introduced in the naming of objects in Process Simulate and the procedure of resetting safety has been standardized.

Apart from commissioning the station virtually, Siemens package has been benchmarked with WinMod software. The working of sequence planner, a software developed by Chalmers university has been illustrated in this thesis work.

Keywords: Process Simulate, TIA portal, PLC verification, WinMod, sequence planner, simulation, robot programming, commissioning

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We would also like to thank our supervisor Per Nyqvist and Examiner Björn Johansson at Chalmers University for their extensive support in the project. They have been very supportive in providing general guidance on how to carry out and structure the project as well as guiding us to move in the right direction regarding whom to contact about different subjects. This has made sure that the report reached a certain academic level.

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Santhosh Ganesan, Gothenburg, 09/2019
Visveswaran Dharmaraj, Gothenburg, 09/2019

List of abbreviations

CPU	Central Processing Unit
CEE	Cyclic Event Evaluator
HiL	Hardware in Loop
HMI	Human Machine Interface
MES	Manufacturing Execution Systems
MRES	Manual RESet
NX	Next Generation
OPC UA	Open Platforms Communication Unified Architecture
PLC	Programmable Logical Controller
PLCSIM	Programmable Logical Controller Simulation
PLM	Product Lifecycle Management
PS	Process Simulate
RCS	Robot Control System
SCADA	Supervisory Control and Data Acquisition
SiL	Software in the Loop
TIA	Totally Integrated Automation
VC	Virtual Commissioning

Contents

List of Figures

1
Introduction

This section presents the background of this project and why it was initiated. Purpose, research questions to be answered in this thesis and limitations are also introduced.

1.1 Background

The growing need for digitalization of factories to complete a production process in a fast and smart way has led to using concepts like Virtual Commissioning. In the current competitive market, the time to release a product plays a major role and shorter launch time will increase the possibility of success of a product. For a shorter launch time, the different phases of a manufacturing process right from design to physical installation in the plant need to be optimized in such a way that they take the least amount of time. One of the key phases in a manufacturing process is validation and verification of PLCs which is usually a tedious job.

From the concept phase, the product has to reach the production phase as soon as possible. Different model mixes and variants add up to this challenge. This is where the concept of Virtual Commissioning plays a major role. When a new line is a setup, the physical commissioning of a station may have lot of errors while setting up and the cost of error correction is very high. When the physical commissioning is done during the summer shutdown of the factory, the entire process must be completed error-free and in a fast-paced manner. This is where Virtual Commissioning plays a big role as all major errors can be visualized and rectified in the digital model and so lesser time can be spent in physical commissioning.

Virtual Commissioning involves the development of a 3D model of a factory that is connected to a PLC logic through a hardware or software CPU. The PLC program can be verified by running the PLC in conjunction with the simulation model. The kinematics is added to the components in the virtual model and then logic resources are defined so that these smart components can be controlled by the signals from the PLC. Volvo Car Corporation has a long history in trying to be the forerunner in the Virtual Manufacturing domain. They have started using Catia for designing way back in 1984 and started using off-line programming from 1993 and ever since they have advanced by every possible aspect in the digital manufacturing domain. They have been trying to implement Virtual Commissioning with many different software since 2014 and although they have attained good success in it, they couldn't implement this Virtual Commissioning on a larger scale.

1.2 Purpose

The purpose of our thesis is to support the standardization of the Virtual Commissioning process at Volvo Car Corporation, Torslanda by documenting the steps we have followed. The study should be focused on cluster 60 cars production line at the production unit at Torslanda factory. The problems encountered during the process and the actions taken to solve the problems are going to be used to create a theoretical framework of the VC procedure. The Virtual Commissioning procedure is carried out with the tools and resources available at Volvo Cars and Siemens products will be used to achieve Virtual Commissioning of the station. According to Älegård et al. it is possible to save 10 to 30 percent of commissioning time and increase the quality of engineering solutions using Virtual Commissioning [1].

Apart from Siemens Package, there are also other software which are used for Virtual Commissioning in the automotive industry. WinMod is one such software that has a strong base in the German car industry and it will be benchmarked with Siemens software in this thesis. The PLC program for the station has been programmed manually and Sequence Planner, a software developed by Chalmers University which is mainly used for automatic generation of PLC codes will be analyzed for use in Virtual Commissioning at Volvo Cars.

1.3 Software used in the project

- Tecnomatix Siemens Process Simulate v14.1.
- Tecnomatix Siemens Process Designer v14.1.
- Siemens Totally Integrated Automation (TIA) Portal v15.
- Siemens WinCC Runtime advanced.
- Siemens PLCSIM Advanced V2.0 SP1.
- Sequence Planner.

1.4 Research questions

- What are the major challenges faced today in Virtual Commissioning?
- How can Virtual Commissioning be applied on a factory level rather than on a station level?
- Is it possible to standardize the Virtual Commissioning process?
- Which software platforms are suitable for usage at Volvo Cars?

1.5 Delimitations

- Time constraints - the total time of the project is 6 months and so the project is tuned to be completed within this time frame.

- Safety parameters will not be considered in this thesis as it is a bigger area and so some extensive time should be dedicated to it.
- Implementation of VC will not be done on a station which is under development. The project is performed on an already existing station.

2
Theoretical Framework

The literature study aims to figure out the basic knowledge of Virtual Commissioning, problems faced in VC, data collection methods and knowledge about various software used in this thesis. The literature study was carried out throughout the thesis work and research papers from Chalmers library and google scholar were used in formulating the background of this thesis work.

2.1 Literature study

The literature study was aimed at studying the previous work in the Virtual Commissioning expertise. Since there were many different software methods that can be used for achieving Virtual Commissioning, there was a lot of previous work that was done in this domain. So, our focus was to understand the process behind it and some of the problems which they faced during it. The results from the literature study were used as a base for our thesis work.

The main problem in VC implementation is the lack of integration between the virtual model and the PLC. The virtual model which should be used for VC should be designed keeping in mind the perspective of VC, i.e., it should be as accurate as possible, if not it will be a difficult task to redesign the model to suit the accuracy demanded by VC [2]. VC enables tests with realistic time delays and intercommunication between hardware. Since it is a time-consuming process to create virtual models as accurate as possible for all the stations, surfaces or parts which are not prone to collision or which are static can be neglected or can be merged together as single units. In simpler terms, the important elements within a model can be concentrated and the unimportant elements can be safely neglected. The virtual model is connected to the PLC and it is controlled by the PLC signals. The mapping of the relevant signals from the PLC to the virtual model is a tedious process and so a macro can be generated for it [2]. VC is increasingly used for training operators. Many parameters such as safety and ergonomics can be tested virtually before testing it physically. In Hardware In the Loop (HiL) VC, the connection is established between Process Simulate and TIA portal using the SIMBA box and simulation unit. Some of the common problems faced during achieving this HiL VC were that TIA portal would slow down after the connection is established and it will slow down the entire operation. So, the simulation unit has to be closed after the connection was established [3].

The major drawback of OPC connection is that there is no mechanism that synchronizes the industrial control system and this could lead to unreliable results from the simulation [2]. Currently, there are two ways of connecting industrial control systems and PLC / RRS and OPC. RRS is a standardized interface between a simulation tool and a representation of a robotic system, while OPC is a more general approach for communication with PLCs and other control equipment. However, one of the main problems faced in OPC is freewheeling which is defined as the asynchronous execution of the PLC and the simulation tool. Henrik et al. propose a method to tackle this asynchronization – the PLCs used must support IEC-61131-3 programming language and should be able to communicate to a regular computer through OPC connection [3].

One of the authors has argued that there are some prerequisites to be fulfilled for a successful VC implementation. A detailed layout of the station or the entire plant under study should be available so that an overview is visualized and also a realistic 3D simulation of all the devices and robots within the scope of the project. Then, the sequence of operations should be defined clearly and in a robust way. The input and output between the virtual model and the PLC should then be mapped correctly. For better working, the hardware configuration of the PLC and its auxiliary equipment should be clearly determined [4]. Another author has also argued that extensive 3D simulation models including geometrics, kinematics and electronics should be available in the first place [5]. When the virtual model is as accurate and detailed as possible, it becomes easier for the VC engineer on the longer run. Minsuk et al. suggest that the design procedures for the mechanical and electrical aspects of the virtual model should be performed concurrently to save time [6].

2.1.1 Types of Virtual Commissioning

The main concept behind VC is the digitalization of every device from the plant so that it works in the same way as the real one. The current technologies allow us to digitalize Robots and other field devices and emulate them with the PLCs. There are different methods in which Virtual Commissioning can be done or in particular it is called Virtual Commissioning configurations [7]. The various popularly used VC configurations are:

1. Software in the Loop:
   Here the 3D program, PLCs and the CPU are all software-based. No real devices are used. This configuration is relatively cheap and fast to deploy. The model will be controlled by an emulated PLC. But since no real-time devices are used safety- related issues in the real plant may be omitted.

2. Hardware in the Loop:
   In this configuration the 3D model is run in conjunction with a Hardware PLC and CPU. The connection is based on 3D model, a hardware PLC from a manufacturer such as Siemens and they are connected together with the help of a hardware CPU. Advantage of this kind of setup is that the results are

very much closer to that obtained in the plant as real time devices are used. But there are disadvantages such as high cost of the equipment used and when changes are needed in any of the components used then it is difficult i.e. they are not as flexible as SiL.

3. Hybrid Simulation:

   Makes use of a 3D model of the plant with virtual robots controllers (RCS - they are developed by the robot manufacturer) and connects the simulation to a real PLC. In this way we can run the code on the exact model of the PLC with the hardware configuration that is going to be used, and any changes that are being made to the plant design can be easily adapted into the 3D model. Also, field devices such as encoders and motor drivers can be included in the hardware configuration by using equipment such as simulation unit.

2.2 Tecnomatix Process Simulate

Tecnomatix Process Simulate (PS) (opening window of the software is shown in Figure 2.1) is a digital manufacturing solution for virtually verifying manufacturing processes. It provides an advanced 3D environment which is capable of emulating the behaviour of manufacturing processes in a realistic manner and also to optimise cycle times and process sequences. It facilitates simulation of assembly processes, human operations and kinematics of parts. Many different manufacturing processes such as welding, gluing, human operations and other robot operations can be simulated and verified using PS. Some of the main factors which can be verified using PS are - most efficient assembly sequence, collision checks and identifying the shortest cycle time. It can also be used to design an ergonomically safe process for human workers. The PS model can be coupled with a PLC and it can be used to virtually verify the PLC codes before being physically commissioned. The CAD parts can be imported into PS and then the kinematics can be defined for each unit according to their movement. PS allows to check the whole model or parts of the model independently. The advantage of using PS is the possibility of simulating several manufacturing scenarios that are otherwise very hazardous or costly to be physically tested. PS also provides signal mapping from external PLC source. There is also an option of using modules (CEE mode) to simulate the process if the PLC is not available [8].

Figure 2.1: Opening screen of Siemens Process Simulate [9]

At Volvo Cars, signal operations are used by the robots to communicate with the PLC. Logic blocks contain entries, exits and logical functions. Entries are signals from the robots to the external PLC and exits are signals from external PLC back to the robot logic blocks can be imported into a new study or project, logic blocks can be used again and again. Sensors used in Volvo Car Corporation are proximity sensors and joint value sensors. Joint value sensors are used to make sure that a kinematic device is in a specified given state. No graphical representation in the model or joint value sensor. For a sensor to work properly, it must be used as a transition condition in the sequence editor.

2.3 Siemens Totally Integrated Automation portal

TIA portal provides the user digitalized automation services from planning to operation. The TIA tools increase productivity, energy management functions, broader flexibility and shortens time to market. TIA portal is a part of Digital Enterprise Suite and along with PLM and MES guides a factory towards Industrie 4.0. TIA portal includes software like STEP 7, WinCC, SINAMICS Start Drive and SIMOCODE ES. In this thesis, WinCC software is directly used and SINAMICS drive is a prerequisite for TIA portal. SIMATIC Step 7 is widely used in programming of PLCs. Step 7 supports ladder diagram, functional block diagram and ST (Structured Text) languages for programming PLCs [10]. STEP 7 not only allows programming but also used for device and network configuration, diagnostics and online monitoring of PLC programming and visualization for WinCC. The major advantages of using STEP 7 as mentioned by Siemens is reduced engineering times, fast commissioning, short downtimes and investment security.

For machine-level visualization SIMATIC WinCC is present as a part of TIA portal and it provides efficient visualization and engineering of the Human Machine Interface. SIMATIC WinCC is divided into Basic, Professional, Comfort and Advanced. WinCC provides solutions from basic panels and SCADA applications. In this thesis, WinCC Advanced is used. For industrials PCs WinCC Advanced is normally used. The other versions have applications from basic panels to SCADA panels. WinCC actually contains features for visualization via windows, alarms, logging of alarms, documentation of process data, language support for multilingual projects, open communication and user administration. WinCC allows the user to directly start or stop a process directly in automatic and manual mode without even touching the actual HMI present in a station. This feature helps the user to test the conditions before commissioning [11].

TIA portal includes SINAMICS Startdrive to integrate SINAMICS drives into automation. SINAMICS is the frequency converter for any drive task. The drive task can be done in low voltage, medium voltage and DC voltage range. All drive components, motors and controllers can be matched and integrated into automation systems. SINAMICS drive will prepare the project for digitalization. A wide range of diverse applications can be implemented thanks to the extensive SINAMICS drive portfolio in Startdrive: This includes the implementation of speed-controlled axes such as pumps, fans, mixers, conveyor belts, etc. via positioning axes – all the way to high-end motion control applications such as handling systems, stacker cranes and packaging machines. It is irrelevant whether these motion functions are implemented in the controller or in the drive. Figure 2.2 shows the various functionalities of TIA portal.

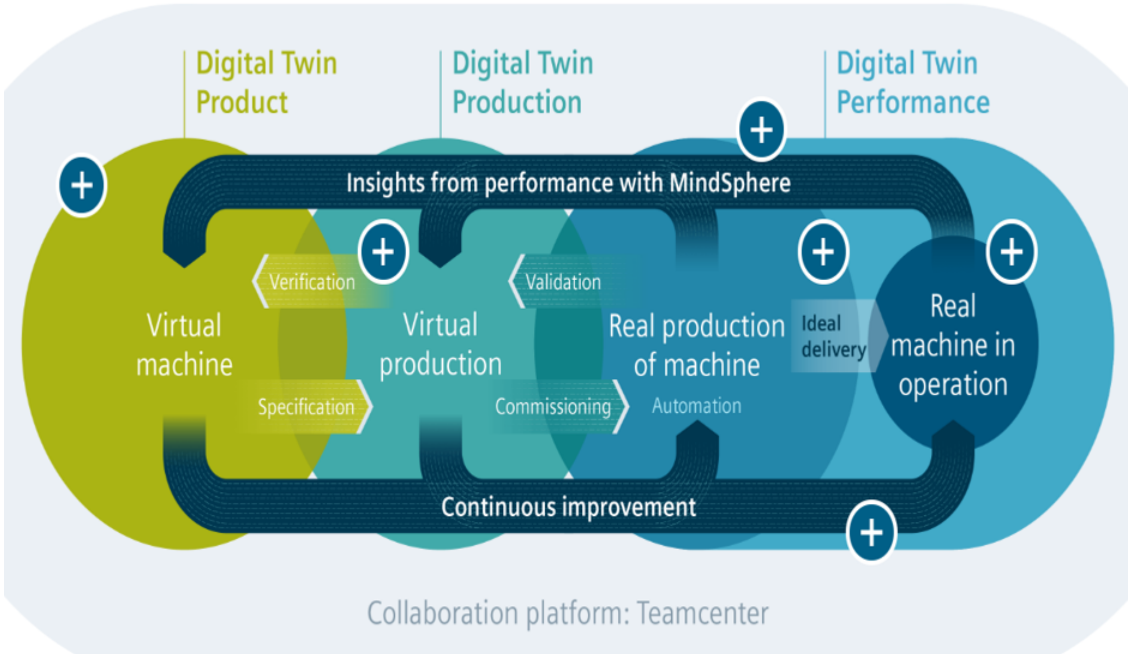


Figure 2.2: Various functionalities of Siemens TIA portal [12]

2.4 Siemens PLCSIM Advanced 2.0

PLCSIM Advanced is the CPU that connects TIA portal and Siemens Process Simulate. It allows simulation of functions during configuration and engineering with TIA portal without actually connecting to the physical S7 1500 hardware. Since no hardware is needed, it helps in early fault detection and validation of functions. Since the HMI can be connected to the simulation setup, it will be similar to working in a real environment. In this thesis, PLCSIM Advanced 2.0 SP 1 has been used. PLCSIM Advanced is flexible as it can be used in combination with simulation software like Process Simulate and not just the SIMIT Tool.

The controller functions include Webserver, OPC UA, Traces, S7 Communication and Process diagnostics. PLCSIM Advanced can be considered as a Virtual Controller and can be connected to simulation software such as SIMIT or NX applications. In contrast to PLCSIM, PLCSIM Advanced can be installed independently of TIA portal and ethernet adapter “PLCSIM Virtual Ethernet Adapter” offers extended communication paths even beyond computer limits. The functionality is simple that if a CPU instance is started from the Control Panel (See Figure 2.3) the PLC CPU starts instantly. Steps on how to start a CPU is explained in the upcoming sections. The functionality of the buttons named 1 to 13 in Figure 2.3 is mentioned below [13].

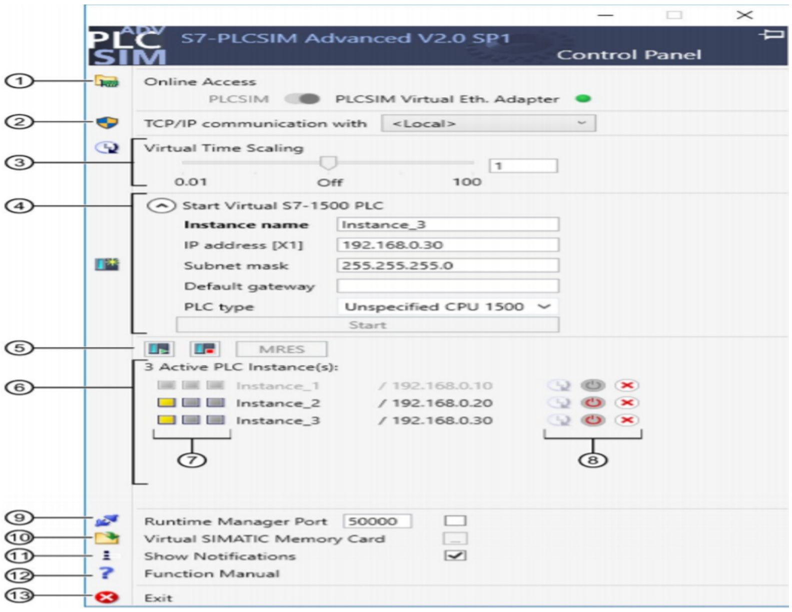


Figure 2.3: PLCSIM Advanced control panel [14]

1. Online access selecting the communication interface - PLCSIM: Softbus, local - PLCSIM Virtual Eth. Adapter: TCP/IP, local or distributed
2. TCP/IP communication selecting the network adapter for distributed communication - <Local>: local communication - <Network card>: Distributed communication via the set network card
3. Virtual time slider for setting the scaling factor
4. Start Virtual S7-1500 PLC - Instance Name: Name of the instance; min. 3, max. 64 characters.
5. PLC type: Selection of the CPU type to be simulated Start: Create and start the instance. Additionally, when selecting the PLCSIM Virtual Eth. Adapters: - IP address - Subnet mask - Standard gateway
6. Instance list The "RUN", "STOP" and "MRES" buttons for the operating mode and reset. The list shows the local instances of the CPUs.
7. LED displays The meaning of the LED is displayed when you move the mouse pointer over it.
8. Instance start, stop and delete functions
9. Runtime Manager Port- Opens a port on the local PC
10. Virtual SIMATIC Memory Card - Opens the location of the virtual memory card. Click on the following symbol to define the storage location.
11. Displaying messages - Here you deactivate the S7-PLCSIM Advanced messages in the Windows taskbar for the duration of operation.
12. Function Manual - Here you open the function manual S7-PLCSIM Advanced in the standard PDF viewer.
13. Exit - switches off all instances and closes the control panel.

2.4.1 Virtual SIMATIC memory card

S7 PLCSIM Advanced stores the user program, the hardware configuration and the data of a loaded instance of a virtual controller in a virtual SIMATIC memory card. Each instance has a virtual SIMATIC memory card, which is created under a unique instance name of the virtual controller.

If you use S7-PLCSIM Advanced to start a virtual controller with an instance name for which a virtual SIMATIC memory card already exists, the controller is started with the user program and hardware configuration contained in it. The storage location of the virtual SIMATIC memory card can be opened or changed via the control panel of S7-PLCSIM Advanced.

2.5 WinMod

Mewes and Partner GmBH was founded in 1991 and located in Henningsdorf near Berlin.WinMod is the windows based modeling of communications, devices, machines and plants controlled by automation systems. From today's perspective, the digitization of the systems needs to be controlled. WinMod helps in realizing the automation system in virtual world.[14]

The modular WinMod system (See Figure 2.4) platform creates WinMod Systems for virtualization, Virtual Commissioning (VC) and more.WinMod system helps in connecting the virtual system to the physical system through emulated field bus technology, simulation systems such as robot simulation and different technologies in the plant. The WinMod system platform for Virtual Commissioning was developed in the 2002. WinMod uses virtual controllers to emulate the real time scenario from the factory floor [15].

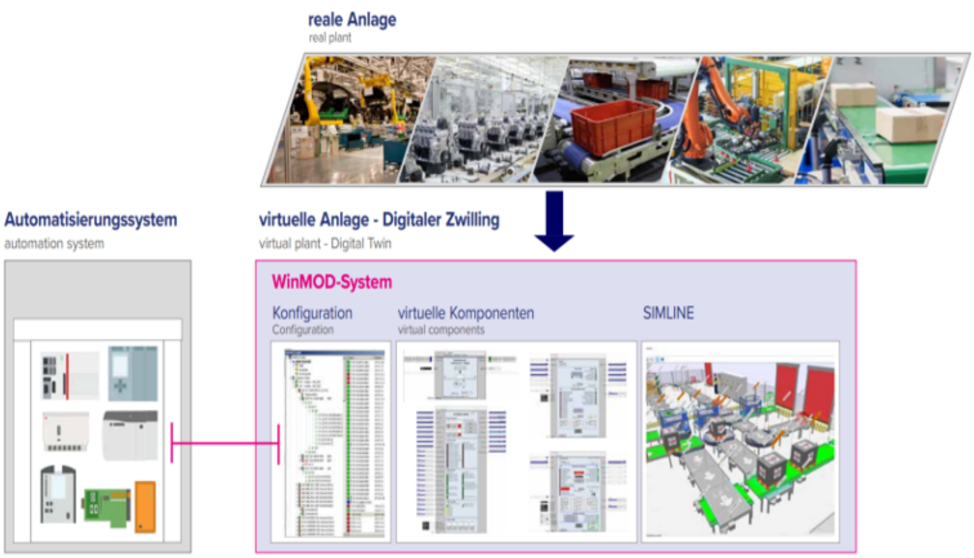


Figure 2.4: WinMod system [15]

WinMod system creates the virtual model of a station as a digital twin. The behaviour of the system is simulated in the software by mapping signals from PLC. The WinMod configuration (See Fig) connects virtual model with the automation systems. WinMod configuration can be used in Software in the Loop and Hardware in the Loop solutions. WinMod SIMLINE software simulates the material flow in a 3D environment. WinMod system consists of libraries that contain virtual components that can be exported directly into the virtual model. Simple switching devices, frequency converters or hydraulic cylinders are available in the libraries which helps visualizing physical components accurately.

WinMod has the capability to connect across platforms using WinMod configuration feature (See Figure 2.5) . It can be used in conjunction with software like Siemens Process Simulate, Robot Studio and EKS Intec. Before using WinMod with other software, consultancy from WinMod team is required in selecting the appropriate configuration. The configuration system will help transmitting signals from one automation software to another. In this way the advantages of WinMod and other automation system software can be utilised completely. The WinMod configuration software allows task-specific, very complex and large scale WinMod projects to be realized with this feature.

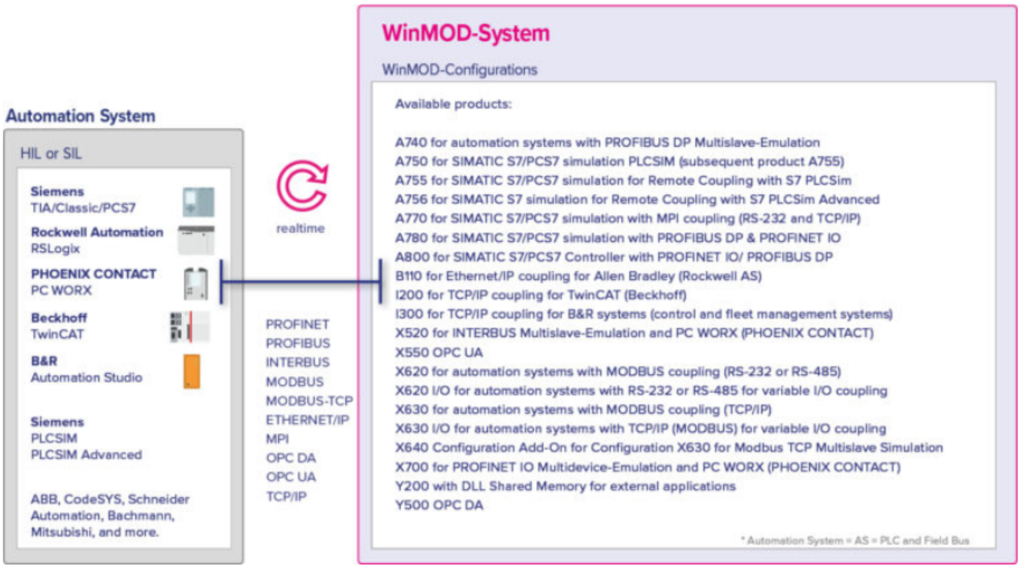


Figure 2.5: Connection between WinMod system and automation system [15]

2.6 Sequence Planner

Sequence Planner (SP), is a modeling and analysis tool of process sequences in an automation system, developed by professionals at Chalmers University of Technology. It is a software for smart sequencing, coordination and optimization of production systems. The tool is developed in java, scala and functional programming and can be used as a high-level control system by getting input from formal representations of the relation between product properties and process operations. The information which is obtained can then be translated into a formal graphical language for hierarchical operations and sequences of operations (SOPs). Initially, SP was developed in assisting the creation of PLC codes. Over the years, several features such as cycle time optimization, formal verification, energy optimization etc. were added. SP is developed as a microservice architecture, where the services interact with each other through messages. By using visualization and synthesis algorithms, the challenging task to model complex systems is simplified in SP [16].

The main use of SP is to optimise the robot sequences in a virtual manufacturing tool. SP is used as an enabling technology for integrating formal verification, optimization and supervisory control theory methods into industrial use. The working is briefly described as follows. The virtual model should be ready with all the kinematics and signals defined. Then an OPC UA connection is established between the virtual model and SP which will enable the communication between them. Signals to start operation in the virtual manufacturing tool are available to SP. By setting up an OPC server that brings these signals and SP together, SP can control the functioning of these operations. Though SP can't be as accurate as PLC codes, it will come handy when the PLC codes are not available [17].

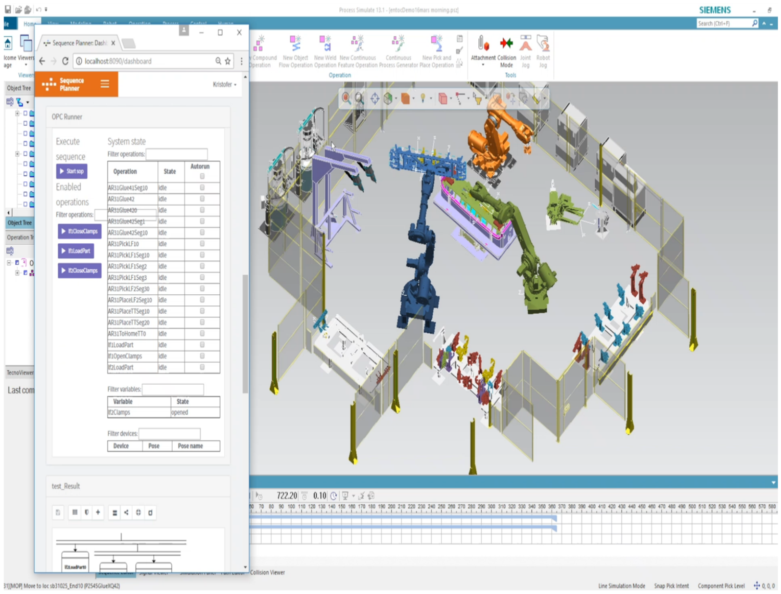


Figure 2.6: Sequence Planner software in operation [17]

2.7 Data collection - qualitative interviews

Interviews were conducted with various experts in the field of Virtual Commissioning. The interviewees include professors from Chalmers University, engineers from various companies such as Volvo Cars, Summ Systems and ÅF. The interview questions are listed in Appendix A. The summary of the various responses received is mentioned below.

The general view on Virtual Commissioning is that it is one of the important milestones in the journey towards Industry 4.0. VC will have positive impact on the profits of the company since it will reduce the time to market considerably. Since VC requires the expertise of simulation, design and controls, finding the right personnel and putting them together in a single team is a practical problem faced by industries today. VC will have a positive cost impact on the longer run. Although implementing VC will require considerable investment, it will help in reaping benefits in the near future. One of the engineers from Volvo cars insisted that when the factory is shut down for maintenance during summer, it becomes extremely difficult to complete the work on time as mistakes happen with installing and verification of PLC programs when testing physically on the machines. Hence Volvo Cars see this as an improvement area when the programs can be tested before onsite installation and testing. It will reduce considerable time in the physical commissioning phase which will ultimately reduce the direct costs. And the time saved can be used in some productive work which will increase the productivity of the factory, thereby increasing profits. Once a standardized procedure is used for implementing VC, it can help the entire development process at different stages.

There are many different tools available for implementing VC. Particularly, Germany is more advanced in Virtual Commissioning and they use software like WinMod for it. But since the Siemens package of Process Simulate and Totally Integrated Automation (TIA) portal are widely available within Volvo Cars Corporation, it is wise to use it for VC implementation. And also, there will not be compatibility issues between the software since it is from the same supplier. Only the license for PLCSIM Advanced should be acquired. OPC UA seems to be the efficient communication setup for Software in the Loop Virtual Commissioning. Even though there are some synchronization issues in OPC UA, it is way better than the other forms of communication.

The toughest phase in achieving VC will be the virtual model creation phase. This is because the current virtual models which are being used are not fully customized to be used for VC. VC requires more detailing to the level of signals and sensors, so it takes more time to create such a detailed model. Efforts are being taken throughout the organisation to upgrade the current virtual model creation method to adapt to VC. There should be a proven and approved standard which will serve as a guide for the designers in case of confusion. Also, there are no standard methods available at Volvo Cars Corporation for VC as of now. Different departments have worked on this but not collectively. It will be very good if there is a separate team for this in the future which will take care of maintaining a standard procedure for VC. People have started to believe that VC is mandatory for an organisation to be thriving on the longer run and there can't be a better time than this to start looking at VC for a full-scale implementation.

According to the interviews, the main aim of Virtual Commissioning is to check the PLC codes before being physically tested in the factory. Since PLC is the one which is controlling the entire station, it is better to test it virtually once so that there are no hazards during the physical commissioning phase. VC can be able to help developers to test adverse scenario which will be a costly exercise in the realistic world to do. Many parameters such as safety, collision detection, reachability etc. can be realistically checked in VC before physical commissioning phase. And there are currently no proven methods that can test a PLC so effectively. The codes can be proofread and checked for errors manually.

When asked about mass implementation of Virtual Commissioning, the response is that there should be an organisation wide consensus on the positive effects of doing VC. Different departments like design, simulation and control logic departments should be involved in this implementation. These three departments should appoint dedicated personnel for VC and a cross functional team should be formed. The top management has to be convinced of the benefits this implementation will bring, so that they give complete support. Resistance might come from experienced workers who will doubt the usefulness of this method. Efforts should be taken to educate these workers of the importance of VC before mass implementation. A standard operating procedure (SOP) should be formulated and used as a guide for implementation so that there is no confusion and also uniformity is maintained throughout the organisation. A standard can be created to list similar items/processes within the virtual model so that they can be stored in the library and can be used later. This will reduce the redundant tasks considerably. The 2D drawings created should involve the specifications for VC. This will allow the designers to focus on the factors for VC in the nascent stages of design itself

3

Virtual Commissioning and setup

This chapter explains the station background and pre-work that has to be done in PS, TIA and PLCSIM Advanced to implement Virtual Commissioning.

3.1 Station background

The station under study is a spot-welding station for rear floor panel front of cluster 60 collections. There are 5 ABB robots employed in this station – 2 spot welding robots, 1 robot for pick place and gluing operation and 2 robots exclusively for pick and place operation. The parts to be welded are loaded onto the fixture positioned in the turntable manually by the operator. The PLC which is used to control this station is Siemens PLC S7 1500. There are two roller gates and there are SICK scanners present to detect the closing of the roller gates.

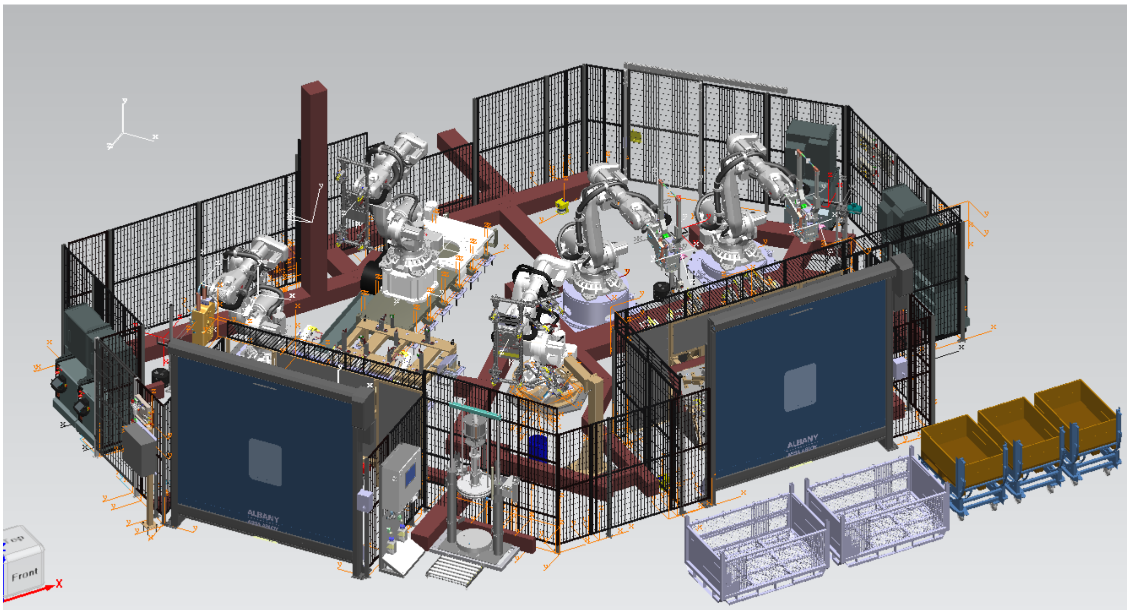


Figure 3.1: Station 136021 at CL 60 production line at Volvo Torslanda [18]

3.2 Virtual Commissioning setup

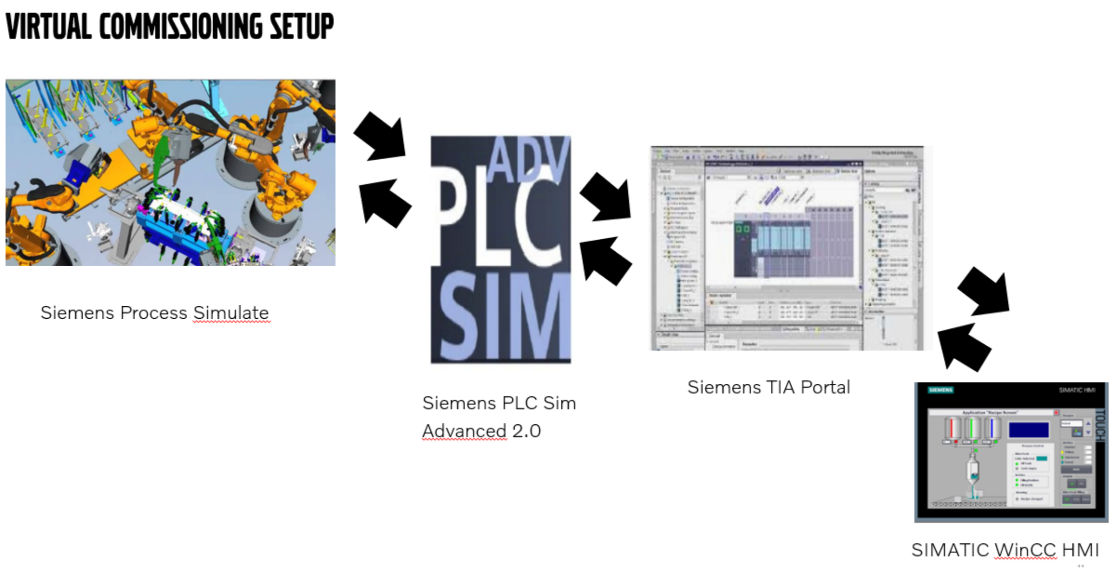


Figure 3.2: Virtual Commissioning setup used in this thesis

Software in Loop (SiL) Virtual Commissioning approach is implemented at the station. The Figure 3.2 shows the setup used in this thesis. The simulation of the station is developed and implemented using Siemens Process Simulate software and the CPU software used is Siemens PLCSIM Advanced. Siemens TIA portal is the PLC programming and control software and the entire process is visualized using WinCC Runtime advanced. All these software communicate with each other as shown in Figure 3.2. Siemens PLCSIM Advanced is the software that receives and sends information from Process Simulate to TIA portal and vice versa.

3.3 System prerequisites for Virtual Commissioning

3.3.1 Hardware requirements

1. Min 8 GB RAM core i3
2. HardDisk space min 256 GB
3. Level 100 user for Windows 7 or admin-level requirement for Windows 10'
4. Level 100 requirement for machine

3.3.2 Software requirements

1. Full license for TIA portal
2. 21-day trial license or full license for PLCSIM Advanced 2.0 SP1
3. PS in eMS server or standalone server

3.3.3 Documentation

1. PNEU Drawings
2. Assembly instructions

3.4 Pre-work in Process Simulate

Process Simulate is the simulation tool used to visualize the virtual model of the station. The kinematics for the fixtures and sensor behaviors are modified in PS. The signals from TIA portal are mapped to the resources by adding them to the logic blocks of the resources.

Signals used in Process Simulate could be categorized as input or output signals. Input signals are used for triggering an event in Process Simulate and output signals are signals coming from TIA portal [19]. The signals in TIA portal have to be mapped with the resources in Process Simulate and these signals are connected to the kinematics of the resources. All the signals from the PLC Project are exported from TIA portal. The specific signals for each resource will not be mentioned in this report as it is confidential but an example is provided below. For example, if the roller gate is named 021IG01 in Process Simulate, the signals in TIA portal corresponding to roller gate is named 021IG01xxxx where xxxx corresponds to different signals.

The signals for the resources are added in the logical block in Process Simulate. PLC communicates with PS through these signals.

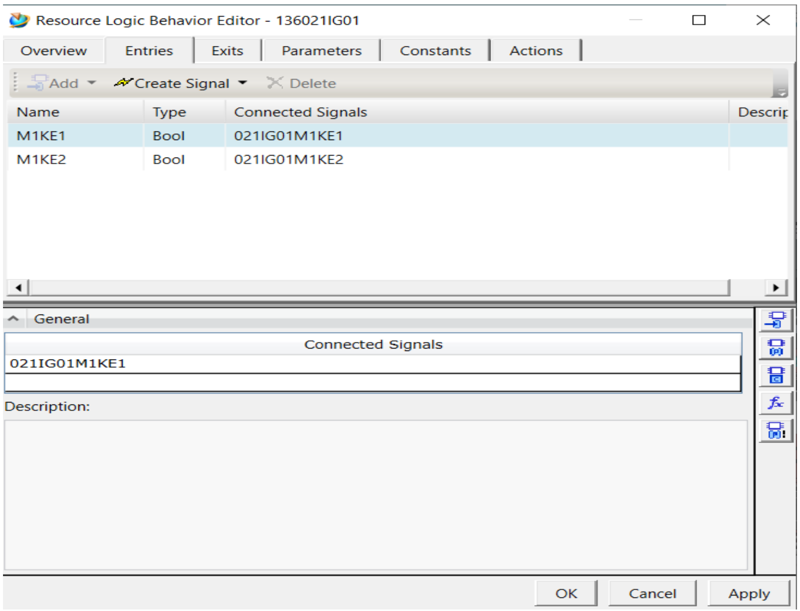


Figure 3.3: Mapping signals with the resources

As mentioned above, the signals are mapped to the kinematics of the resources. Hence kinematics are added to the resources in Process Simulate to enact the real-time behavior. The figure 3.4 shows the joints and positions of the resources. Each joint can be assigned a position and value of the position depends on the joint and it is usually between 0 and 180 degrees.

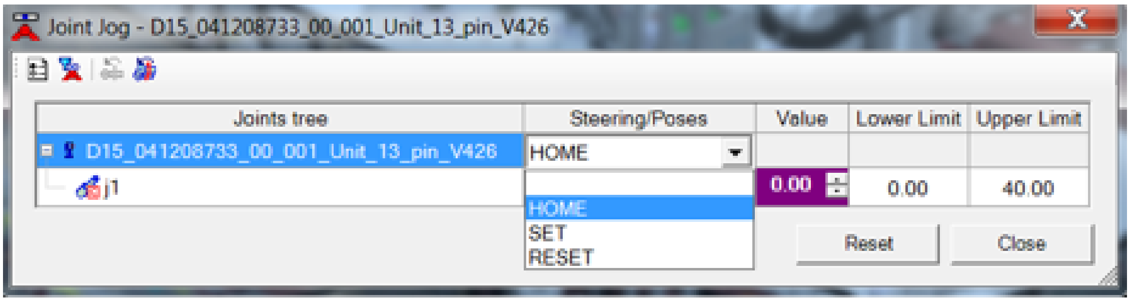
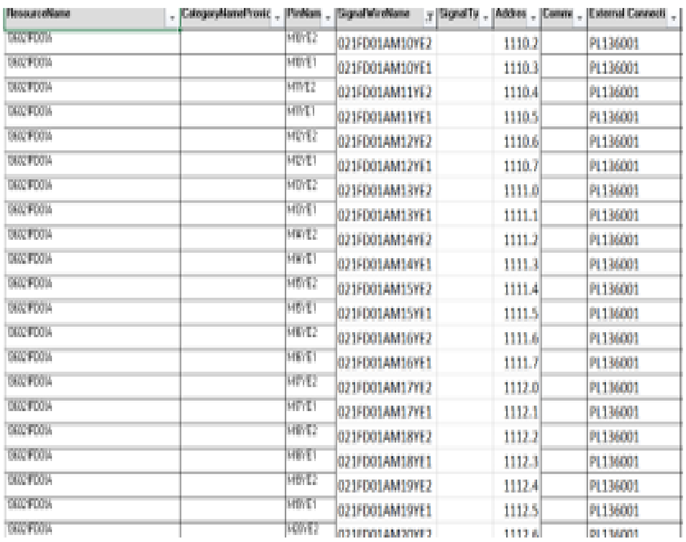


Figure 3.4: Adding kinematics to the resources

The downloaded signals from TIA portal look as in figure 3.5.



ResourceName	CategoryNameProvic	PinNam	SignalWireName	SignalTy	Addres	Comm	External Connecti
[illegible]		[illegible]	021FD01AM10YE2		1110.2		PL136001
[illegible]		[illegible]	021FD01AM10YE1		1110.3		PL136001
[illegible]		[illegible]	021FD01AM11YE2		1110.4		PL136001
[illegible]		[illegible]	021FD01AM11YE1		1110.5		PL136001
[illegible]		[illegible]	021FD01AM12YE2		1110.6		PL136001
[illegible]		[illegible]	021FD01AM12YE1		1110.7		PL136001
[illegible]		[illegible]	021FD01AM13YE2		1111.0		PL136001
[illegible]		[illegible]	021FD01AM13YE1		1111.1		PL136001
[illegible]		[illegible]	021FD01AM14YE2		1111.2		PL136001
[illegible]		[illegible]	021FD01AM14YE1		1111.3		PL136001
[illegible]		[illegible]	021FD01AM15YE2		1111.4		PL136001
[illegible]		[illegible]	021FD01AM15YE1		1111.5		PL136001
[illegible]		[illegible]	021FD01AM16YE2		1111.6		PL136001
[illegible]		[illegible]	021FD01AM16YE1		1111.7		PL136001
[illegible]		[illegible]	021FD01AM17YE2		1112.0		PL136001
[illegible]		[illegible]	021FD01AM17YE1		1112.1		PL136001
[illegible]		[illegible]	021FD01AM18YE2		1112.2		PL136001
[illegible]		[illegible]	021FD01AM18YE1		1112.3		PL136001
[illegible]		[illegible]	021FD01AM19YE2		1112.4		PL136001
[illegible]		[illegible]	021FD01AM19YE1		1112.5		PL136001
[illegible]		[illegible]	[illegible]		[illegible]		[illegible]

Figure 3.5: PLC signals from TIA portal

Apart from mapping signals from PLC, sensors should also be placed on the respective resources in order to detect objects. The sensors should be placed similar to the physical location in the factory. As mentioned above in section 3.3.3, assembly instructions can be used to find the exact locations of the sensors. Looking at the assembly instructions is a better way to find the location of the sensors instead of looking at the factory floor as lot of time can be saved if assembly instructions are available. Figure 3.6 shows how a sensor should be placed on the resources. The sensors should be placed in the resources in such a way that the sensor detection line (red line) should be pointing out in z-axis.

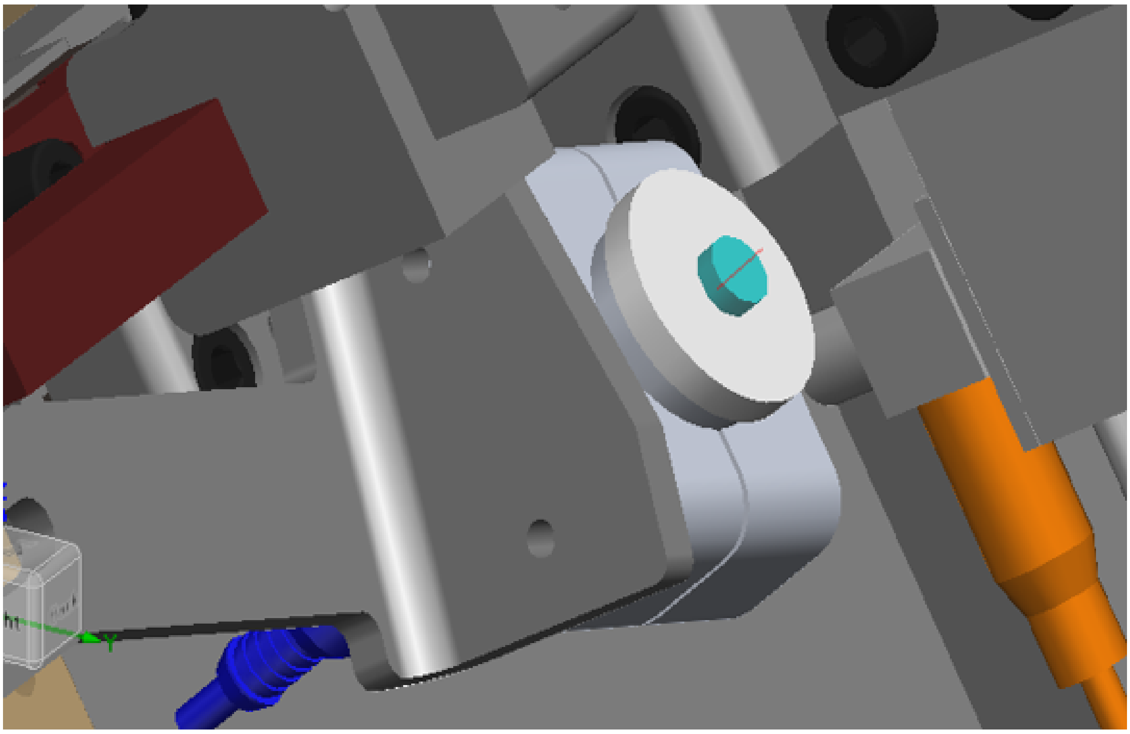


Figure 3.6: Sensor placement on the resource

The final step is to connect PS with PLCSIM Advanced. Figure 3.7 shows the dialog box available in Process Simulate to connect to PLCSIM Advanced. This dialog box can be found under file - options. The same name used as an instance name in PLCSIM Advanced should be used here and the software should not show any error while connecting. If there is an error, it means the instance is not running in PLCSIM Advanced or the naming is wrong.

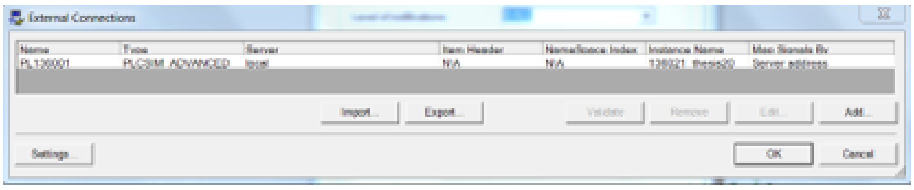


Figure 3.7: Connecting PS to PLCSIM Advanced

3.5 Pre-work in TIA portal

TIA portal is used to program and simulate PLC. Before running the station, the PLC program has to be downloaded to the PLC CPU. The step is simple and it can be downloaded just by right-clicking on the PLC name and clicking download configuration (See Figure 3.8). When downloading the PLC program, the TIA portal checks for available PLC CPUs and connects TIA portal and PLCSIM Advanced. TIA portal does not directly communicate with Process Simulate but rather communicates using the PLC CPU. Any change made in the PLC program during simulation will not be updated automatically, rather when a change is made on the PLC program it needs to be compiled and downloaded again. The compilation option in TIA portal checks for errors in the PLC program and only if all the errors are rectified the program is downloaded to the CPU.

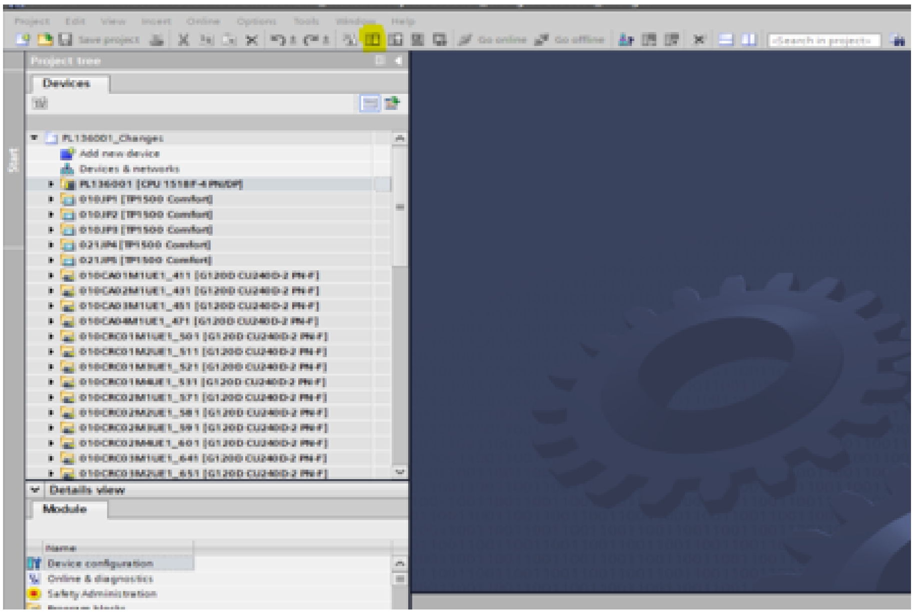


Figure 3.8: Downloading the CPU configuration from TIA portal

The station can be visualized and controlled using Siemens WinCC runtime advanced HMI in TIA portal. HMIs at Volvo Cars are named with the station name followed by JPx. The HMI for this station is 021JP4 and can be started by selecting the HMI in the description tree and pressing the simulation option on the top pane. See Figure 3.9 for the loaded HMI of the station.

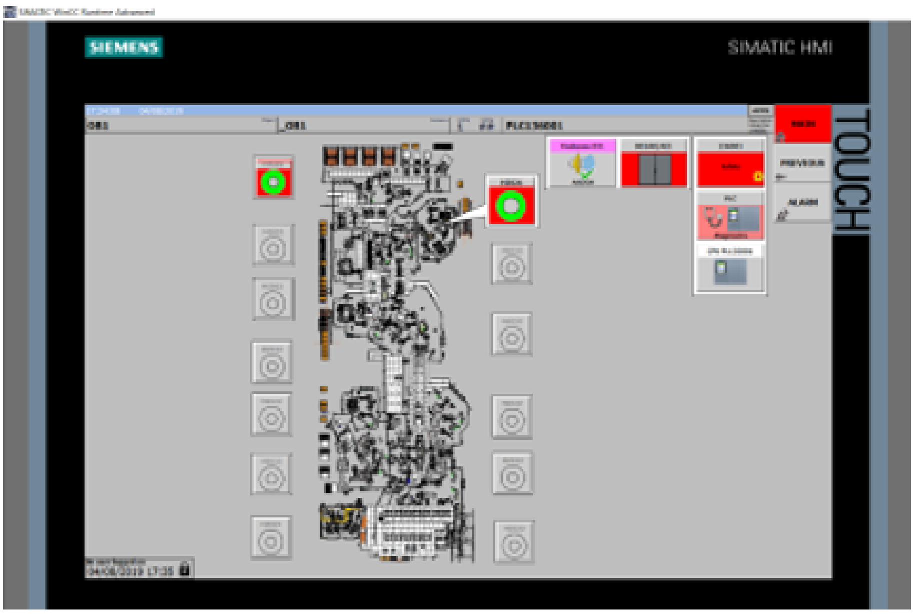


Figure 3.9: HMI screen of the station

3.5.1 Safety resetting HMI

Safety resetting of HMI is the major step that needs to be performed in order to start the station. The PLC program contains certain safety I/O and these are needed in order to confirm the safety of the station. In the physical station, the safety resetting is done by the operator. In order to emulate the real-world scenario, various inputs and outputs should be triggered by Process Simulate in order to simulate the station. Before safety resetting, all the resources icons will be in red colour meaning safety of the station is yet to be checked and reset. (See Figure 3.10).

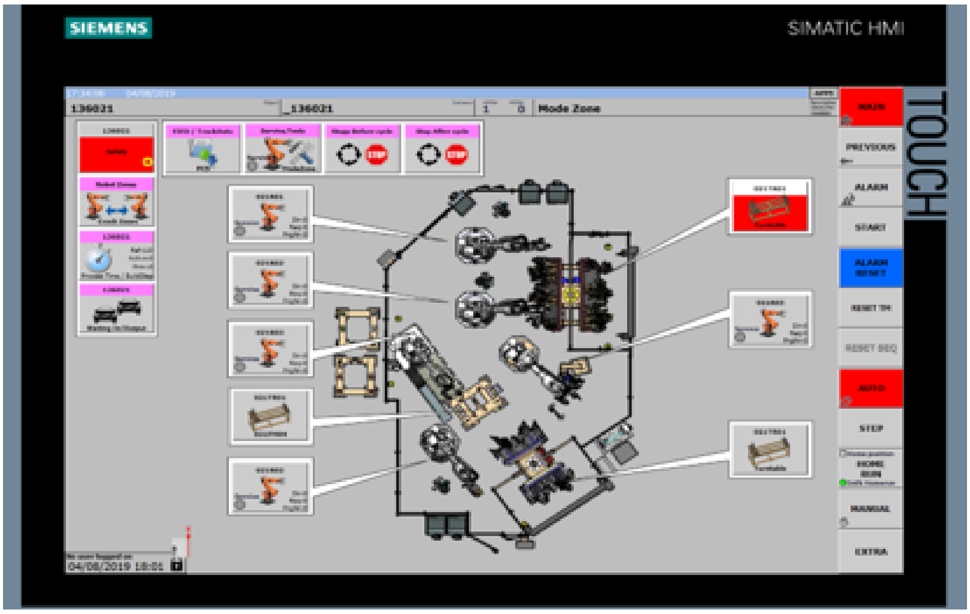


Figure 3.10: HMI screen before safety resetting of the station.

Once the safety resetting of the station is complete, Auto button in the HMI will turn green and the resources will turn grey from red, meaning that the station can be started in Auto mode. In order to safety reset, various signals are to be triggered from Process Simulate. This process is one of the time-consuming process and effort has been taken to standardize this process. Some resources are to be safety reset from TIA portal and some resources from Process Simulate. The standardization of this process has been mentioned in section 4.2.

Once the safety resetting signal of a resource is triggered from Process Simulate or after safety resetting from TIA portal, general safety reset signals of the station should be set to true. These are signals which are common to the station and need to be true in order to complete the process of safety resetting. See Figure 3.11 for general safety reset signals of 136021 station. After safety resetting all the resources, the HMI should look like Figure 3.13.

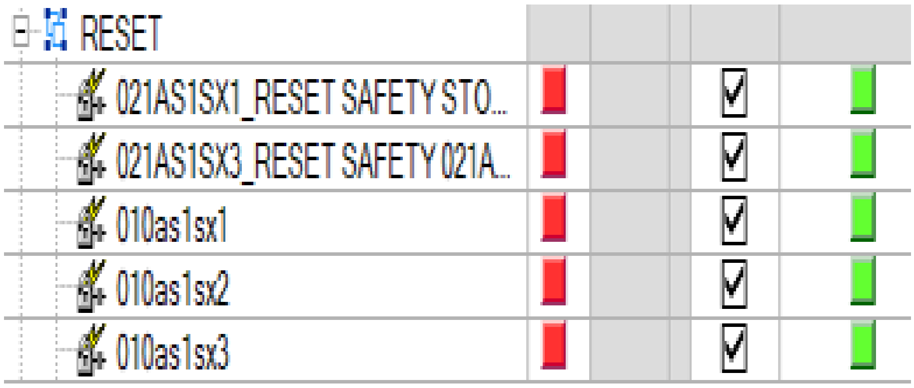


Figure 3.11: General safety reset signals for 136021 station.

3.6 Starting PLC CPU

Starting the CPU in PLCSIM Advanced is a very simple task and the CPU is started by starting an instance (see Figure 3.12). A unique instance name is provided by the user and PLC type used in the thesis is CPU 1500. Pressing the start button will start an instance. When an instance is started, status of the CPU will be in yellow which means connection from PS and TIA portal is yet to be established. Process Simulate, TIA portal and PLCSIM Advanced are connected using the instance name mentioned in PLCSIM Advanced. Once TIA portal contents are downloaded to the CPU, instance colour will change to green. (See Figure 3.12).

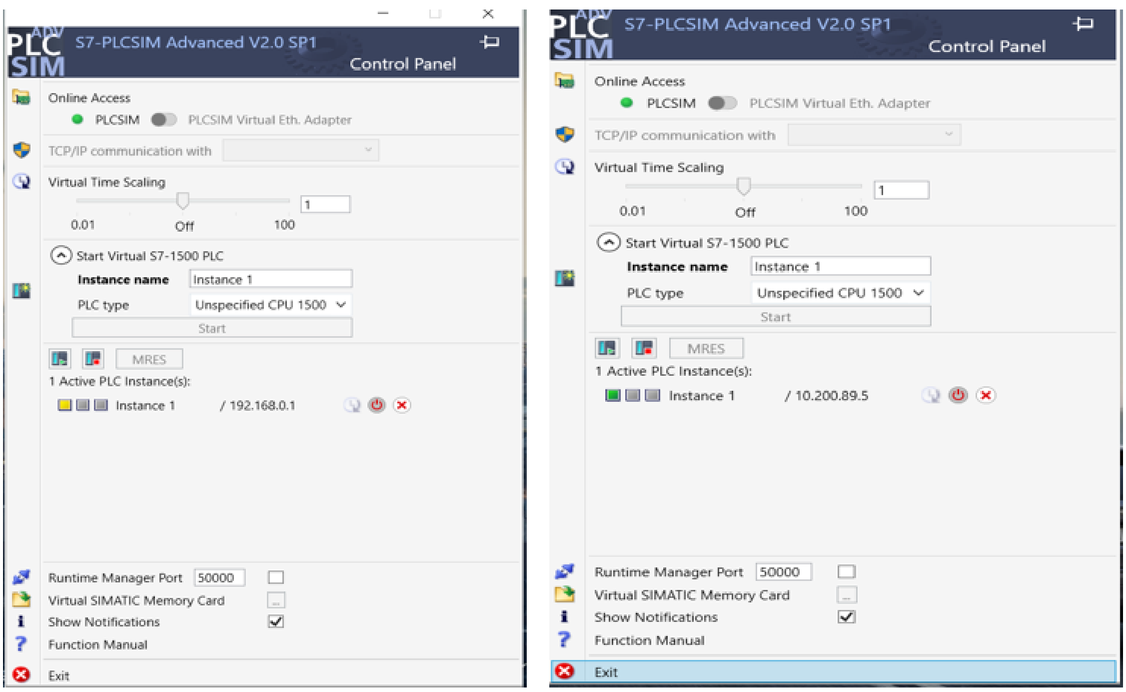


Figure 3.12: Starting an instance in PLCSIM Advanced

3.7 Working methodology

The communication between the software applications are confirmed when the PLC CPU status in PLCSIM Advanced turns green. Once the safety resetting of the station is completed, the HMI turns green and the Auto button in HMI will turn steady green. Once the Auto button is pressed, the station is in a position to run in automatic Mode. The station is started by pressing the Auto button (see Figure 3.13).

The PLC signals are sent to Process Simulate through PLCSIM Advanced. The PLC program will send the corresponding signals to PLCSIM Advanced which are connected to the resources in PS. For example, if the signal 021FD01ASG7 signal is sent from TIA portal, PLCSIM Advanced will send the same signal to Process Simulate and PS will trigger the signal. The above mentioned signal is used for opening the valve 7 in fixture 136021FD01A. Hence when PLCSIM Advanced communicates the above signal to Process Simulate, valve 7 is opened. Similarly all the actions are performed in Process Simulate.

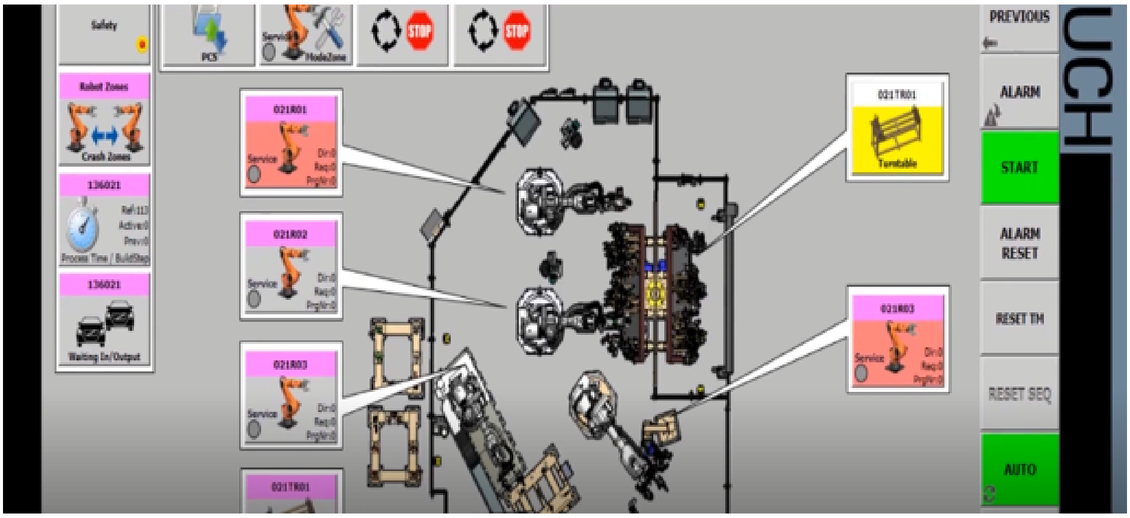


Figure 3.13: Running the station in AUTO mode

4 Standardization

This chapter explains the various steps taken in order to standardize the processes in Virtual Commissioning. The areas identified which can be standardized are naming standards, safety reset standards and step by step procedure for implementing Virtual Commissioning.

4.1 Naming standards

In the Process Simulate virtual model, we could see that there was a lack of standardization in the naming of the components in line with performing VC. That's why we are proposing a new design standard – "Design for Virtual Commissioning", so that the designers while designing the virtual model will keep the VC attributes in mind from the start. The signal names from the PLC which are connected to the respective components in the virtual model are getting more significance for a VC compatible model. After connecting all the signals from the PLC with the components in the virtual model and running the station virtually, if some problem arises in any one of the signals, it is currently very difficult to maneuver through the object tree to find which signal is creating the problem. So, we suggest to add the signal name to the resources name in the object tree so that it is easy to spot signals. The below figure 4.1 illustrates our suggestion.

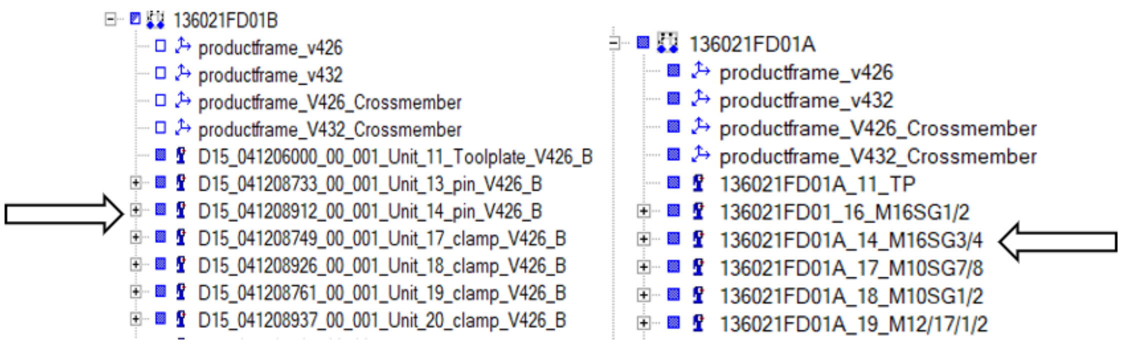


Figure 4.1: Proposed naming standard

The resources in the virtual model should also be named in accordance with the VC standards. To illustrate this better, see the image below (Figure 4.2), where the name of the albany door is marked. It does not have any similarities with the PLC tags and it becomes very difficult to map the signals from PLC. So, we have suggested to change the name which will then become easier to refer and to map.

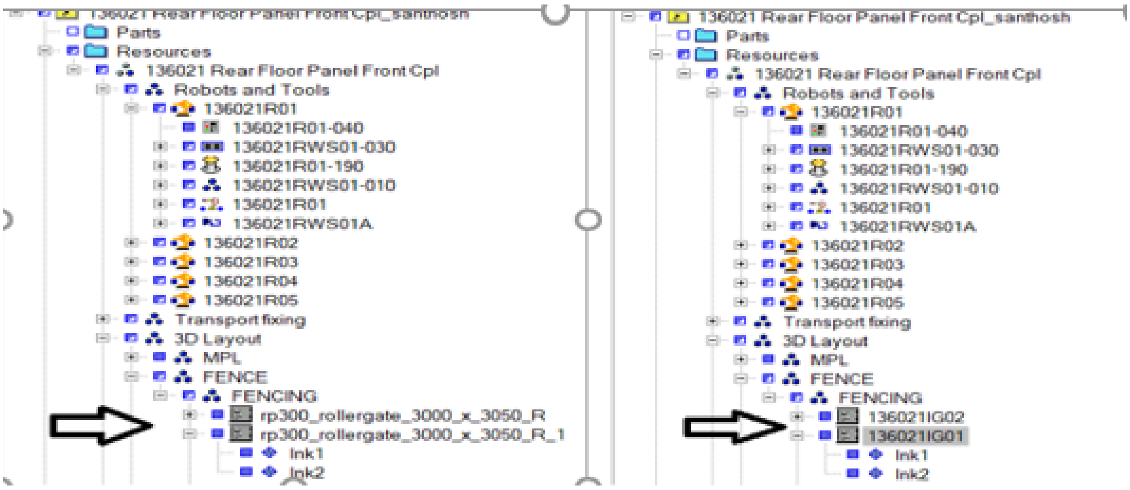


Figure 4.2: Proposed naming standard for various resources

4.2 Safety reset standards

The resetting of safety in the TIA portal for the entire station is one of the most time-consuming process in VC. So, it is ideal that there is a standardized procedure available for it. Since this process requires PLC knowledge, we advise the persons involving in implementing VC to acquire good level of knowledge in PLC programming before starting this procedure. We have bifurcated the safety reset standards into 3 types as below.

- For safety mode zone – the safety should be reset from the TIA portal.
- For Robots – the safety can be reset from the Process Simulate by bringing the robots to the home position manually or by forcing signals.
- For turntables and gates – the safety can be reset from Process Simulate by forcing relevant safety signals.

4.3 Step by step procedure

One of the main aims of our thesis was to standardize the procedure of Virtual Commissioning so that it can be used as a standard for future full-scale implementation. As discussed before, there wasn't a widely available procedure for VC implementation using Siemens package. In view of this, a manual for step by step implementation of the VC procedure was created. Cognitive aspects were considered while designing this manual - the illustrations or pictures are located sideways to the text so that it is easy for the reader to go through the text and see the illustration in the same line of sight (See the appendix for a snippet of standardization manual). Effort was taken in having as little text as possible and to explain it clearly using pictures. Manuals for the work in both Process Simulate and TIA portal were

created.
During the course of our master thesis, many issues related to software and procedures were encountered. All the problems we have faced were properly documented and the root cause of the problem were found. A list of all the problems faced with possible solutions to it are documented as mentioned in Figure 4.3.

4.3.1 Problems faced and possible solutions

S.No	Problem description	Reason for the problem	Possible Solution
1	When downloading the PLC program from the TIA portal to the device, the downloading is stuck and the downloading is not completed at all	When creating an instance in PLC SIM Advanced, it gets stored in a folder under "My Documents". If the storage space is less and if there are more instances created, the new instances cannot be stored in that folder due to storage	Make sure there are enough storage space available in the folder where the instances are getting stored.
2	When pressing "End Modeling" after making some changes to a component, an error message appears which says that the changes cannot be saved because the component is used by	If the same station is used by more than one person at the same time by checking out different parts of the station, this problem appears.	Make sure that the entire station is checked out by you only. If not, an empty robcad study can be created and the component which needs to be edited can be dragged and dropped from the equip library and the changes can be made.
3	When mapping signals for two fixtures with the same source, the signals get mapped to only one fixture and the other fixture doesn't have any signals	Since both the fixtures have the same source, when it is used in the station, both have the same names for their components and sub parts	Distinguish both the fixtures by having different names for the components and sub parts. For example, for the second fixture, a suffix can be added to differentiate it from the second fixture
4	Spending more time in resetting safety in the HMI.	There is no standardised procedure for resetting the safety of the entire station. Many signals have to be forced and unforced in Process Simulate in succession on a trial and error basis for resetting. For some, the PLC logic has to be modified in the TIA portal to reset the safety. This will consume a lot of time if the user does not have complete	We have formulated a standard procedure for resetting the safety. This can help for future works in resetting the safety easily.
5	User authorisation level creates problems in installation of the necessary software	If the system does not have level 100 authorisation as per Volvo standards, there will be some installation problems and it requires the IT support.	Acquiring level 100 authorisation for both user and system before starting with the VC work
6	Problem in downloading PLC program to the device	When the download to device button is pressed, some times there will be an error which says "Error downloading to	Delete the current instance and create a new instance in PLC SIM Advanced.
7	More time spent in placing the sensors correctly	When the part which is to be welded is big and complex, more sensors are required to position the part correctly in the fixture. These sensors should be placed in an accurate position in the fixture so that it senses the part correctly. More time will be lost in placing these sensors when there is no	We solved this problem by referring to the work instructions manual for the station workers. In that a step by step procedure of where the parts and sub parts should be loaded in the fixture is given. So the sensors are placed accordingly referring to the position of the part in the manual.
8	Unable to play simulation in the Line Sim mode	When the Line operation is not set as current operation, the simulation cannot be played in the sequence editor	Make sure that the Line Operation node is set as current operation

Figure 4.3: Problems faced and possible solutions

5

Benchmarking Siemens package with WinMod

This section explains the advantages of WinMod over Siemens and a suggestion on whether WinMod can be used at Volvo Cars based on the experience gained during the thesis period.

5.1 Advantages of WinMod over Siemens package

1. Platform to connect to all simulation software such as PS Modules available for different processes such as BiW, Painting, Assembly etc.
2. Less cost compared to Siemens package
3. It has the capability to connect to robotstudio to study the robot behavior
4. When the simulation is playing in WinMod, the communication between PLC software and WinMod simulation displays various signals acting on an object (see Figure 5.1). This feature is unique to WinMod and it is now available in other Virtual Commissioning software.

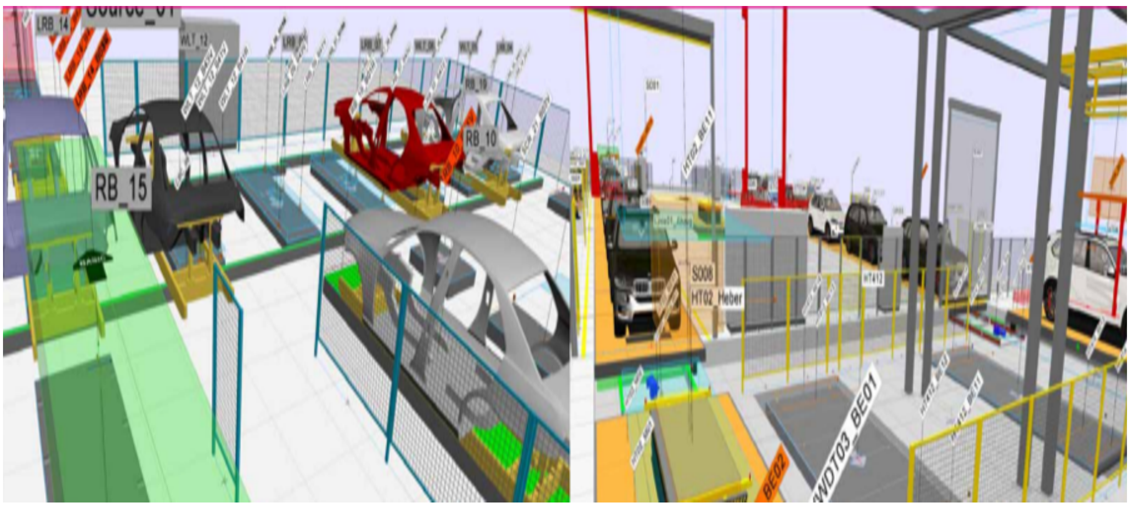


Figure 5.1: Signals activated by the PLC are shown in the simulation

5.2 WinMod at Volvo Cars ?

1. Since Siemens packages are used for simulation and PLC programming, using WinMod is not recommended as it will increase costs.
2. PS Simulation models can be converted to WinMod models but the accuracy of the models are yet to be asserted
3. Our recommendation would be to use Siemens platform for Virtual Commissioning as the available resources can be easily used for VC
4. But painting is a potential area where WinMod can be used as they have specialized modules.

6
Results and Discussion

This thesis has set a Virtual Commissioning methodology for Software in Loop using Siemens Process Simulate, Siemens TIA portal and Siemens PLCSIM Advanced. Apart from creating the methodology, a study on Sequence Planner and WinMod was performed to find the feasibility of their use in Volvo Cars. The objective and purpose of the thesis is fulfilled with the development of the VC methodology and implementation of VC in the production cell.

Question 1: What are the major challenges faced today in Virtual Commissioning?

The major challenge faced today in successfully implementing Virtual Commissioning is the lack of coordination between the design, simulation and controls department. Since all these three expertise are equally important, it is vital that a common platform is provided for them where they can interact on a daily basis and develop this implementation process. The other major challenge faced is that there are myriads of software available for simulation, PLC control and design in the market and so there can't be a universal standard which will cover all kinds of software. So, every company which is willing to implement Virtual Commissioning has to put effort in creating their own standard and adhering to it.

Question 2: How can Virtual Commissioning be applied on a factory level rather than on a station level?

In the current trend in the industry, research is going on to apply Virtual Commissioning on a plant level. In this thesis, the research question was asked to various interviewees and they were also confident that Virtual Commissioning will be applied on a plant level. The main problem here will be the coordination between various departments. This is a major challenge faced even today when implementing Virtual Commissioning on a station level. Management support and like-minded thinking of all the employees towards VC will be the key challenges in implementing VC on a plant level.

Question 3: Is it possible to standardize the Virtual Commissioning process?

The answer to this research question is quite tricky as there are multiple ways to achieve Virtual Commissioning. But in the case of this thesis, since Siemens platform is only used, standardization of the procedure is possible. A big step towards making the process of VC standard has been accomplished in this thesis. Various problems faced during the process has been documented and this has enhanced the quality of standardization. Standardization has been implemented not only in step by step procedure but also in the naming and resetting safety in TIA portal. Resetting safety is one of the most time consuming work in VC and the standardization will help in reducing the time spent on safety resetting.

Question 4: which software platforms are suitable for usage at Volvo Cars?

Currently, Siemens platform is used for Discrete Event Simulation(DES) and PLC programming at Volvo Cars. All the departments that work with DES and PLC use only Siemens products. In the study made in the above sections, it can be seen that there are advantages when using WinMod and Sequence Planner but the biggest disadvantage is loss of money and time. When Volvo Cars decides to purchase WinMod software for Virtual Commissioning it still needs TIA portal for PLC programming. Hence it is just an increase in licensing cost for WinMod on top of license cost for TIA portal. Even when there is a saving in time, this solution can be adopted. Time is again wasted in converting Process Simulate files to WinMod files and there is a loss in quality when such a change is made.

7
Conclusion

This master thesis illustrated the importance of Virtual Commissioning in a production line. Initially there was no framework on the steps that has to be taken to perform Virtual Commissioning on a station at Volvo Cars. But now a firm step have been taken towards standardizing and creating a step by step procedure. The guidelines provided in the thesis in the form of step by step document as attached in the Appendix will act as the base to perform Virtual Commissioning on any station. Since the problems faced during the thesis have been documented and also the solutions provided will help the user to overcome problems if stuck at any step.

An introduction to Sequence Planner and its usage has been explained in the thesis. The advantages and limitations of Sequence Planner has been explained and it is suggested to use sequence planner in future applications at Volvo Cars in order to save time in PLC Programming.

The benchmarking of WinMod software with Siemens package available at Volvo Cars shows that, purchasing of WinMod software will only increase costs and work even though there are better features than Siemens package. With the available resources, Volvo Cars is now in a position to implement Virtual Commissioning at a larger scale. This thesis along with the expertise of Simulation and PLC Engineers will help Volvo Cars decrease the gap in the product to market time.

7.1 Future work

The future of production lies with Virtual Commissioning. Based on the study made the following recommendations are suggested to Volvo Cars.

1. Implementation of Sequence Planner to automatically create PLC codes.
2. Setting up a cross functional team for Virtual Commissioning involving design, PLC and robot simulation engineers.
3. Exploring Virtual Commissioning in virtual Reality(VR)- by using VR, the factory conditions can be better visualized and tested. The usage of VR is ever-expanding and it can be a good value addition to the Virtual Commissioning process.

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A

Appendix 1 - Interview questions

The following questions were asked to various professionals in the area of Virtual Commissioning. The questions were created after the detailed literature study related to Virtual Commissioning.

1. What is your general view on Virtual Commissioning?
2. Do you think VC will reduce cost?
3. According to you which is a good tool for VC?
4. Since VC contains different phases, which do you think is the toughest and requires more attention by VC developers?
5. Do you think PLC is the biggest area which needs attention in VC?
6. Do you suggest any efficient way in which PLC can be tested before running it in a VC software?
7. How do you think will be the efficiency of the communication using OPC UA?
8. For mass implementation of VC what do you think is required?
9. As far as you know, do you think there any standard methodologies for VC?
10. With VC, the impetus on creating an accurate virtual model is more than before, but this is a time consuming process. How do you think we can reduce the time spent on virtual modeling?

The answers from one of the interviews is listed below. All the professionals working in Virtual Commissioning almost had a similar view of how the industry is moving forward in the field of Virtual Commissioning.

1. What is your general view on Virtual Commissioning?

   Virtual Commissioning is one of the important milestones in the journey towards Industry 4.0. Virtual Commissioning will have a tremendous positive impact on the profits of the company since it will reduce the time to market abundantly. Since there is a varied expertise in the fields of simulation, design and control code is required, finding the right personnel for implementing VC is difficult.

2. Do you think VC will reduce cost?

   Yes. Even though implementing VC will require considerable investment, it will be beneficial in the longer run. It will reduce considerable time in the physical commissioning phase which will ultimately reduce the overhead costs by a good margin. Once a standardized procedure is used for implementing VC, it can help the entire development process at different stages.

3. According to you which is a good tool for VC ?

   Germany is more advanced in Virtual Commissioning and they use different software like WinMod for it. But since Siemens products are widely used in our organization, it is wise to use Siemens products for VC. And since the products are from the same supplier, compatibility issues will not be faced. Even though there are some minor issues with Process Simulate, the way forward should be Siemens products.

4. Since VC contains different phases, which do you think is the toughest and requires more attention by VC developers ?

   The toughest phase will be the virtual model creation phase. This is because the current virtual models which are being used are not fully customised to be used for VC. VC requires more detailing to the level of signals and sensors, so it takes more time to create such a detailed model. Efforts are being taken throughout the organisation to upgrade the current virtual model creation method to adapt to VC. There should be a proven and approved standard which will serve as a guide for the designers in case of confusion.

5. Do you think PLC is the biggest area which needs attention in VC ?

   Yes, the main aim of Virtual Commissioning is to check the PLC codes before being physically tested in the factory. Since PLC is the one which is controlling the entire station, it is better to test it virtually once so that there are no hazards during the physical commissioning phase. VC can be able to help developers to test adverse scenario which will be a costly exercise in the realistic world to do.

6. Do you suggest any efficient way in which PLC can be tested before running it in a VC software ?

   There are currently no proven methods that can test a PLC so effectively. The codes can be proofread and checked for errors manually. Other than that, VC seems to be the only way in which the PLC can be effectively tested.

7. How do you think will be the efficiency of the communication using OPC UA ?

   OPC UA seem to be the efficient communication setup for Software in the Loop Virtual Commissioning. Even though there are some synchronisation issues in OPC UA, it is way better than the other forms of communication.

8. For mass implementation of VC what do you think is required ?

   There should be an organisation wide consensus on the positive effects of doing VC. Different departments like design, simulation and control logic departments should be on the same page in this implementation. These three departments should appoint dedicated personnel for VC and a cross functional team should be formed. The top management has to be convinced of the benefits this implementation will bring, so that they give complete support. The biggest form of resistance might come from experienced workers who will doubt the usefulness of this method. Efforts should be taken to educate these workers of the importance of VC before mass implementation. A Standard Operating Procedure (SOP) should be formulated and used as a guide for implementation so that there is no confusion and uniformity is maintained throughout the organisation.

9. As far as you know, do you think there any standard methodologies for VC ?

   There are no standard methods available at Volvo for VC as of now. Different departments have worked on this intermittently but not collectively. It will be very good if there is a separate team for this in the future which will take care of maintaining a standard procedure for VC. People have started to believe that VC is mandatory for an organisation to be thriving on the longer run and there can't be any better time than this to start looking at VC for a full-scale implementation.

10. With VC, the impetus on creating an accurate virtual model is more than before, but this is a time consuming process. How do you think we can reduce the time spent on virtual modelling?

    A standard can be created to list similar items/processes within the virtual model so that they can be stored in the library and can be used later. This will reduce the redundant tasks by a huge margin. The 2D drawings created should involve the specifications for VC. This will allow the designers to focus on the factors for VC in the nascent stages of design itself.

B

Appendix 2 - Step by step procedure for Virtual Commissioning

The following section shows step by step procedure that has been designed in order to perform Virtual Commissioning. The entire document is not uploaded due to confidentiality agreements with Volvo Cars, but a snippet of the document is attached. There are separate documents designed for the procedure to be followed in Process Simulate, TIA portal and PLCSIM Advanced.

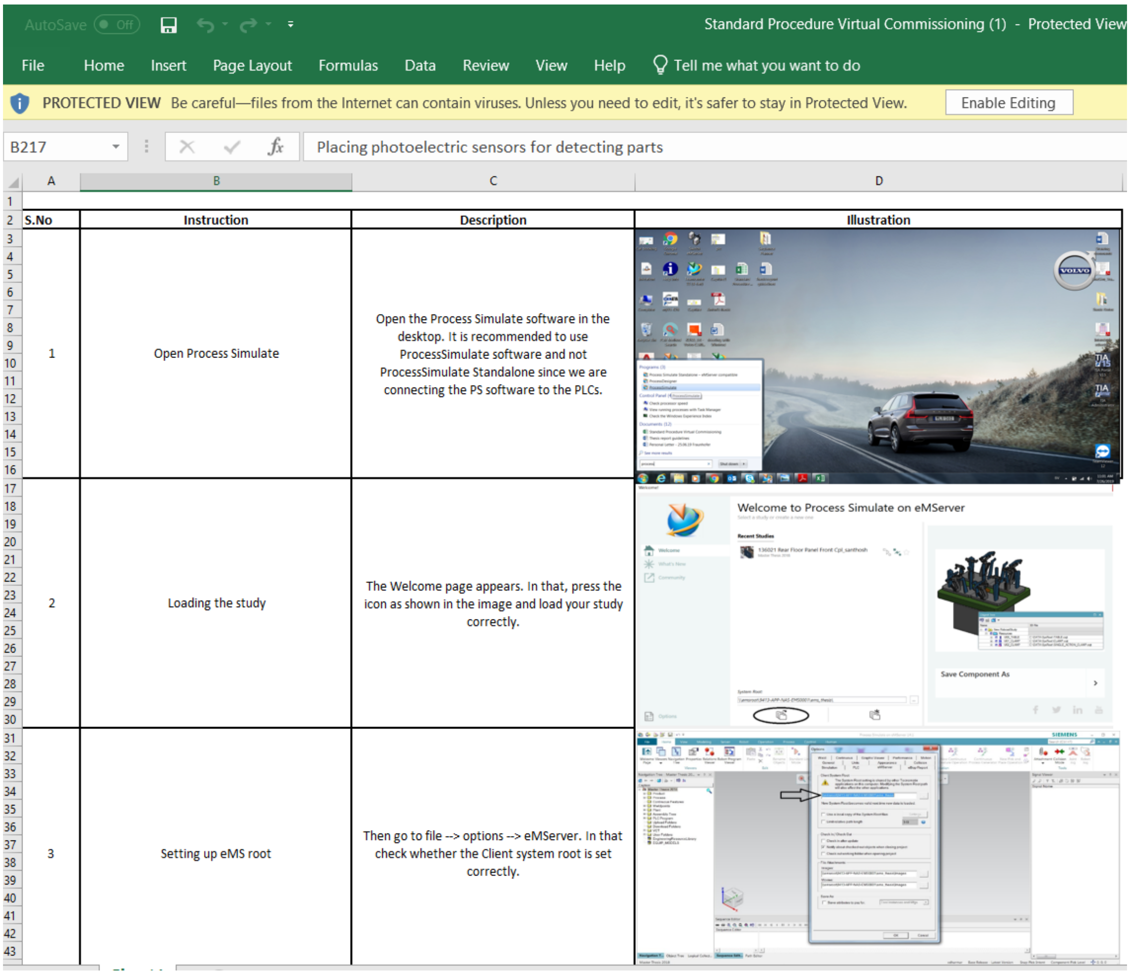

Figure B.1: Step by step procedure