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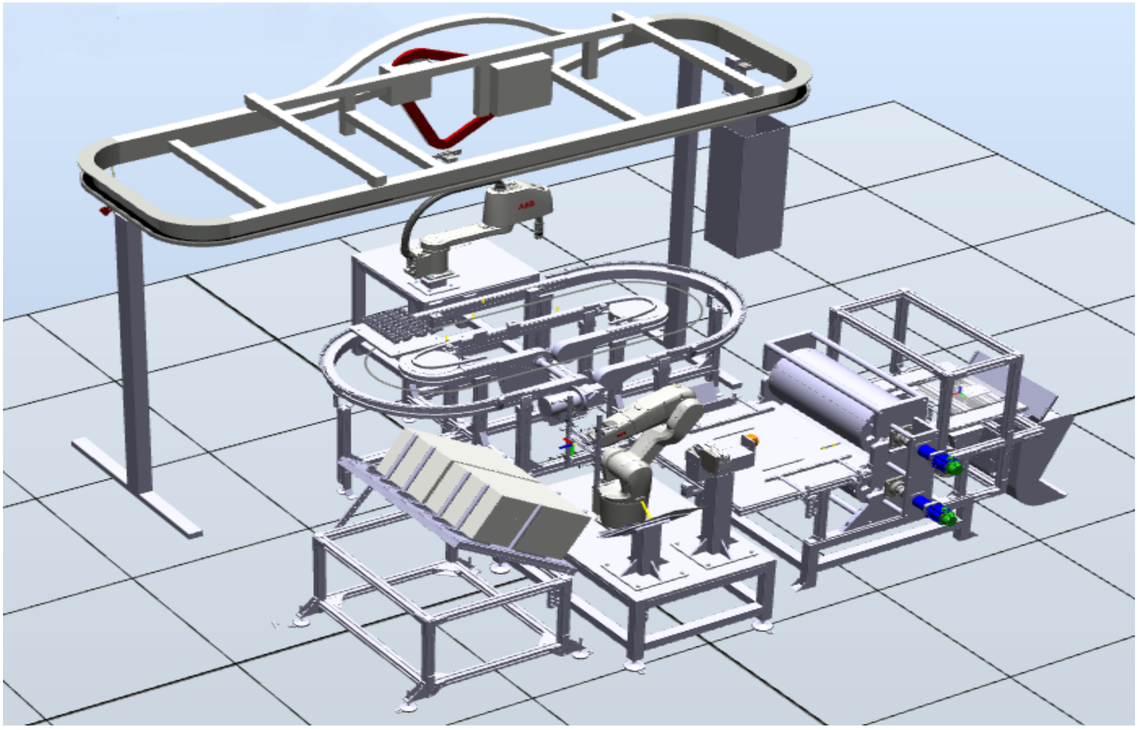

# Virtual Commissioning and construction of a digital twin for Smarta Fabriker

*Bachelor of Science thesis in the Bachelor Degree Programme, Mechanical Engineering.*

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Marianne Jakob and Patrik Nilsson, Gothenburg, May 2018.

# Abstract

A digital twin is a virtual copy of the physical factory, with the purpose to create a digital copy that looks and behaves exactly like the original physical factory. This thesis is being done for ABB in collaboration with project Smarta Fabriker. This report presents the problems that are often disregarded when creating a digital twin, by trying to create a digital twin and discuss the difficulties that arise.

This thesis is a continuation of previous thesis projects within Smarta Fabriker, since the project that had been done did not match correctly with the physical factory. Therefore, the tasks were to correct the existing virtual model with help from the point cloud scan of the physical factory and connect the Supervisory Control And Data Acquisition system with the adjusted virtual model to include the superior system.

The study together with the results showed that when constructing the overlap between the adjusted virtual model and the point cloud scan, differences in geometry occur resulting in a situation with a model with differences. Thus we have a situation where we have to choose between accepting the differences or adjusting the parts in the virtual factory in a CAD software. For the superior system, time was spent debugging to get the systems to communicate with each other, this part of the work was not completed. The problem here was in the host computer's security system where a software blocked the communication, resulting in low interoperability between the systems.

The conclusion when creating a digital twin is that it is complex and time consuming, the amount of work to run the digital twin just as in reality can not be underestimated. Just as in a real automation project, all parts must be fully functional and this requires a broad and cross functional knowledge and a structured way of working.

A recommendation for further work would be to work in a method like network planning to achieve the best possible result.

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# Abbreviations

| | |
|---|---|
| AVM | Adjusted Virtual Model, the virtual model that has been constructed by Marianne and Patrik. |
| eLIPS | A type of SCADA system constructed by Prevas. |
| EVM | Existing Virtual Model, the virtual model that has been constructed by a previous project group. |
| OPC | Open Platform Communications. |
| PLC | Programmable Logic Controller |
| SCADA | Supervisory Control And Data Acquisition |
| VC | Virtual Commissioning. |
| Virtual machine | Virtual computer. |
| VR | Virtual Reality |
| QR | Quick Response |

# 1 Introduction

This section introduces the background and purpose, research questions and delimitations.

## 1.1 Background

Today, the market is constantly changing as each country pursues to increase its competitiveness. It is clearly stated in Germany where Industry 4.0 came to. The aim of the strategy is to develop a factory where everything is connected, which reminiscent of IoT (Internet of Things). By constantly having information about each product in the production line the factory can now organize itself efficiently. It is now possible to recognize where and how products are moving (1).

The thesis is being done for Project Smarta Fabriker which is a project initiated by GTC (Göteborg Tekniska College) and is a collaboration with ABB. The purpose of the Smarta Fabriker project is to increase the attractiveness of technology and careers in industrial companies, and to disseminate knowledge about industrial digitization (2). ABB is a multinational group in the fields of energy transfer and robotics (3). The work will be performed at ABB Robotics in Mölndal.

The factory produces VR (Virtual Reality) glasses made of cardboard. The customer places an order in the Smarta Fabrikers app and a QR (Quick Response) code will be obtained. The code is then scanned at a station where the robot takes a cardboard sheet that is moved to a printer where it receives a name chosen by the customer. The cardboard sheet is then punched out and the part is finished. A pair of lenses drop down to the customer through a machine and the customer can now follow instructions for folding the VR glasses.

A thesis has been done previously for Smarta Fabriker, where the aim was to simulate the digital twin of the factory that would be built. However, the physical factory differs from the EVM (Existing Virtual Model). The previous thesis has only addressed the EVM at the cell level, which means that no SCADA (Supervisory Control and Data Acquisition) system has been implemented (4).

VC (Virtual Commissioning) is a process that enables a comprehensive evaluation of production systems before physical commissioning. That means using an accurate and realistic 3D simulation to validate the features of the production equipment control system prior to actual implementation (5).

## 1.2 Purpose

The purpose is to create a digital twin of the existing virtual model made by previous thesis at Smarta Fabriker, to inform about the problems that may arise in the construction of the digital twin.

## 1.3 Research questions

What are the problems while constructing a digital twin?

Why is it difficult to get systems from different manufacturers to work well together? I.e. why is interoperability low?

## 1.4 Delimitations

In this project the following delimitations had to be made since the project is being done on part time, 16 weeks.

- Nothing is physically being built since the thesis only deal with the virtual environment.
- For simulations of the factory only RobotStudio 6.06 and Automation Builder are used.
- All scanning of point cloud is done by an external group.

# 2 Theoretical framework

This section of the thesis introduces the theory behind Industry 4.0, interoperability and project theory. The software that is being used are also presented.

## 2.1 Industry 4.0

During the last centuries, the society has undergone various stages of technological evolution. Each of them has been important to the increase in productivity in the world. Industry 4.0 is the fourth industrial revolution, first mentioned during the Hannover Messe, in Germany 2011. Digitalization is the main purpose within Industry 4.0. When digitized it is possible to simulate the whole production process without running the physical factory. In the physical factory, every single part including the machines are connected to each other via smart sensors (using for example IoT). The main goal connecting things to each other using IoT is to let them communicate with each other and with the operator in the factory. Industry 4.0 increases the ability to decision-making which helps to optimize the factory. It will also increase the productivity because the factory will produce the exact amount of products in the right time span resulting in less waste and out of date products (1).

## 2.2 Digital twin

The digital twin is the virtual copy of the physical factory. The purpose of the digital twin is to create a digital copy that looks and behaves exactly like the original physical factory. The digital twin can be run simultaneously with the physical factory. Via the digital twin, one can collect data from the factory that can be used for future improvements. When designing a digital twin, these factors in the following figure are important to be able to achieve the final goal (6).

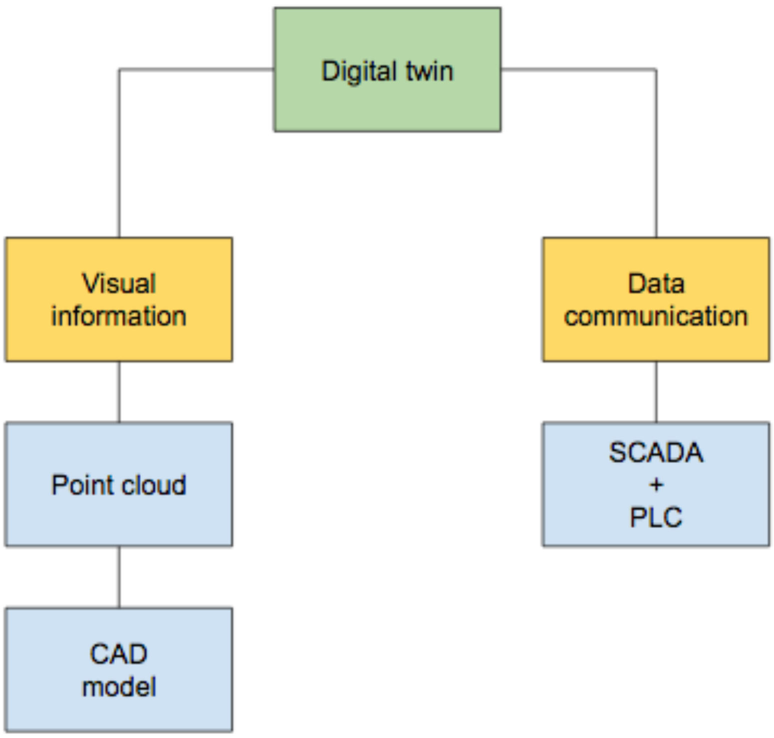


*Figure 1. Structure of the digital twin.*

## 2.3 Virtual Commissioning

The aim with VC is to shorten the lead time from when the factory is planned to when it is up and running (7). One crucial point is that the physical model behaves in the same way as the digital. It is important to construct the digital model before building the physical one, because the digital model would allow to see if things will interfere with each other and therefore prevent distractions. This results in saving time and capital. To perform a VC a connection between the model and the PLC (Programmable Logic Controller) must be done, and that's when the I/O signal list can be defined and imported to the Virtual Model. Lastly, an emulation platform is being used to test and validate the PLC, by running simulations in the Virtual Model (8).

## 2.4 Point cloud

Point cloud is a three-dimensional coordinate system using lots of points to build up the system via three-dimensional scanning of the object. The point cloud gives a reference guide of where the objects are located relative to each other in the digital model (9).

## 2.5 SCADA

SCADA is the superior system for automated processes. Via SCADA, it is possible to monitor and control physical processes. SCADA is based on a hierarchical structure that contains three different levels. The SCADA architecture starts with the I/O-level, which is the level where the product connects to the electrical and the mechanical devices. The next level is based on the PLC. The PLC execute the logical and sequential control of the connections to the machines the final level is where the monitoring of the system occurs, it is here the communication with the SCADA system appears (10).

## 2.6 PLC

PLC is a control system that controls the connected devices using logical and sequential signals. It works by the computer which storage it in the internal memory. Lastly it executes the specified program code to get a result (11).

## 2.7 Interoperability

Interoperability is the ability of two or more systems to communicate and interact with each other. In order to achieve a high level of interoperability, it is important that the systems are integrated with each other. However, it is important to notice that a too high integration level in the companies' own systems can result in low flexibility when communication with other companies' systems is needed, which may cause lower interoperability. Through standardization of the communication and the software it is possible to improve interoperability.

Within interoperability, there are four different levels.

1. Organisational interoperability is about overall processes where the purpose is to fulfill several agreed results where several organizations interact.
2. Semantic interoperability is about how both humans and technology have a common understanding of how the exchange of information should work correctly.
3. Syntactical interoperability is about the structure and content of information.

4. Technical interoperability is about the ability to transfer and exchange information at the basic level, for example, I/O-signals (12).

## 2.8 RobotStudio

RobotStudio is a software from ABB used to program in offline mode. The software is used for simulation and to control how the robots behave and work. Because the programming and simulation are done on the computer, robots can be simulated in advance without shutting down the physical factory, i.e. resulting in less downtime (13).

## 2.9 Automation Builder

Automation Builder from ABB is a software used to integrate PLCs and robots to one model resulting in a whole picture of the factory. Primary focus within Automation Builder is to simulate the environment of the factory and see how it behaves. This gives the operator the ability to optimize through the programs function of debugging and configuration (14).

## 2.10 CloudCompare

CloudCompare is a free processing software for 3D point cloud. It was created in a collaboration between Telecom ParisTech and the R&D division of EFD. The program provides basic tools for manual editing and rendering point clouds. It also offers methods such as distance computation between cloud to cloud or cloud to CAD component (15).

## 2.11 Project theory

A project means a task that has, for example, a goal that is delimited and takes place within a certain time span and with resources determined in advance. A project contains different actors with different responsibilities. Every person in a project has a responsibility that must be completed in order for the task to be finished. On some occasions problems occurs, it is the project leader's responsibility to ensure that they are solved (16).

### 2.11.1 The Deming cycle

When working on projects the Deming cycle provides an advantage, since it is a structured approach that ensures the quality of the project.

1. Plan - identify important parameters and plan the solutions.
2. Do - make a stable process and collect data, to perform the solution.
3. Check - assess whether the change was an improvement.
4. Act - introduce changes as new standards (17).

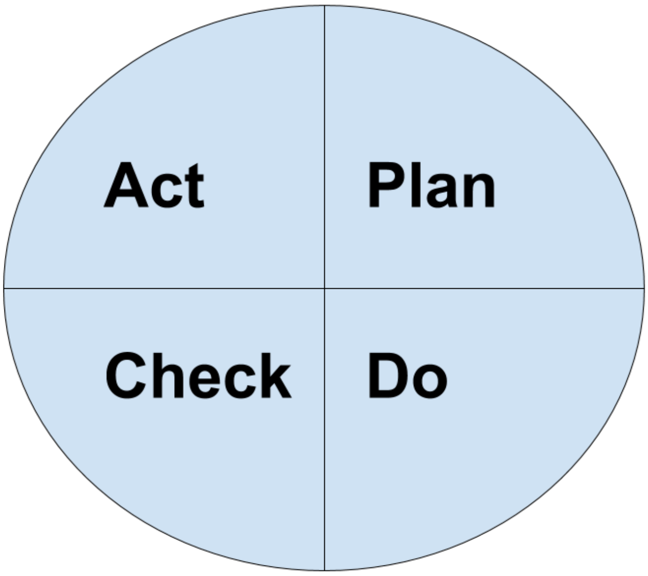


*Figure 2. Deming cycle.*

### 2.11.2 Project handover and network planning

A project can also be a continuation of previous work. For projects such as these, it is important to achieve the requirements for project handover. Network planning is a method used in projects where a logical schedule describes the dependency of activities between each other. These dependencies are called connections. When using red lines between the activities, the previous activity must be completed correctly in order to be able to start and preform the next activity in the schedule. When using green lines between the activities, the next activity can be started before the previous one is completed (17).

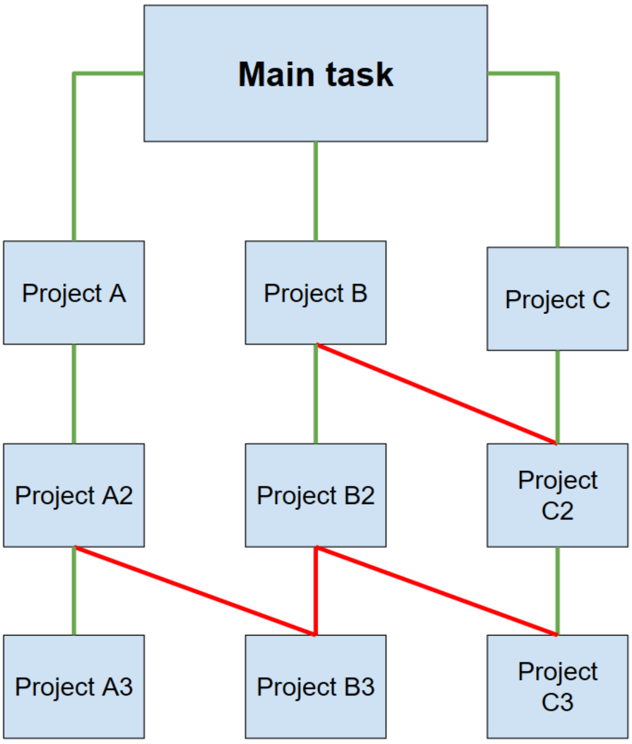


*Figure 3. Network planning.*

# 3 Description of the Smart factory process

The Smart factory produces cardboard VR glasses and today it consists of two different production lines. The former produces and delivers the cardboard while the latter delivers the plastic lenses. The idea is then to build it up manually by instruction.

## 3.1 Production line 1: process of cardboard glasses

This section introduces Production line 1, how it is built up and how it works.

### 3.1.1 Cardboard storage, ABB IRB 1200-robot, printer and scanner

The first step to be able to start the production is to download the app Smart factory to a smartphone, which include the QR code that is going to be scanned in the scanner which is located on then cage around the factory. Once the code is scanned, the ABB IRB 1200-robot picks up a cardboard sheet from the storage units with help of the suction cup tool that the robot has. For the sheet to end in the same way each time, a station is required where the robot places the sheet in a fixture and ensures the orientation of the sheet in the subsequent operations. The robot then moves the sheet with a linear movement to the printer where the printer prints the QR code from the app and a print of text decided in advance by the customer, just to have an information carrier through the whole process. Therefore, the codes are checked out to be correct by the scanner before the sheet is passed on to the next process. If the scanner cannot read the QR code the sheet is scrapped and the customer orders a new product.

### 3.1.2 Input and stamp

The next step starts with the robot transferring the sheet to the inlet of a rolling stamp. The robot moves away from the inlet when the ultrasound sensor lets the PLC know that a sheet has arrived. This will activate the sensor and by the actuator the sheet will be pushed into the rolling stamp that consist of a tool that punches out the contour of the glasses. Both cylinders act as a stamp and a transporter, that is, the rotation of the stamp cylinders will move the sheet forward to the next process in the production line.

### 3.1.3 Output and delivery of cardboard sheet

The last process in production line 1 is to transport the sheet towards the delivery by a conveyor. At the start of the conveyor there is another ultrasound sensor. This sensor is used to let the PLC know that the sheet has arrived and that's how the transporter is activated. There are also one sensor telling the PLC that the sheet has arrived to the actuator at the end of the conveyor. As soon as the conveyor is turned off the actuator flips the cardboard sheet into a delivery box where the customer may pick it up.

## 3.2 Production line 2: process of the delivery of plastic glasses lenses

In this section Production line 2 is presented, how it is built up and how it works.

### 3.2.1 Flexlink conveyor system

Flexlink is the company that delivers the conveyor system for the delivery of lenses to the customer. The conveyor is constructed as an ellipse and contains five pallets moving around, with containing 50 lenses each which is positioned in three rows. To be able to stop the conveyor system, a PLC is implemented which is used to stop the pallets twice at specific positions. The former stop is placed at the position where the robot will pick up a lens from the box. The latter stop is placed with an offset before the pick-up position so that the subsequent pallets will not collide with the pallet the robot picks from. At the picking position an inductive sensor and a fixing device is placed, to indicate that the pallet is in the correct position and as a check before fixing the pallet. To prevent unwanted movements from the conveyor the fixation device raises the palette a few millimetres from the conveyor belt and fixes it. Now when the palette is fixated the robot is allowed to pick a lens.

Aligned with the two stops that are implemented there are two inductive sensors for programming the Flexlink system. These sensors are used to trigger when to stop the pallets and to count the pallets that have passed a stop. The process works by picking a lens from a box on the conveyor and then moving the pallets a whole turn until the same box returns to the picking station again. When the box is empty, the process of selecting a lens from the next box repeats. This is done until all the boxes on the conveyor are empty and that’s when a manual re-filling is needed.

### 3.2.2 SCARA robot, Eton conveyor system and delivery

The process in production line 2 consists of a SCARA robot and a lens fixture that is standing on the same table. Through an actuator and a transport system delivered by Eton, the lens fixture moves up and down with the help of sensors. In this way the lens can be picked up by the Eton conveyor and transferred to delivery. When the palette with the lenses is in the correct position and an order has been placed, the SCARA robot will receive a signal and then pick a lens from the box. The SCARA robot uses an electrical clamping tool to pick the lens which is then placed on the lens fixture on the robot-table.
The actuator will be lifted up to the Eton transport system. When the lens is in place and the robot has moved to its home position. By this movement, the lens is now carried by the carriers hanging down from the conveyor. For the carrier to be able to transport the lens to the delivery in a safe position the Eton system has to receive a start signal from the PLC. The customer needs to scan the QR code that’s on the sheet and place the hands in the delivery station to receive the lenses, which is possible by the sensor that activates and tells the Eton system to drop the lens. The last step in the factory is an assembly station where the glasses will be manually assembled by the customer.

# 4 Methodology

Chapter 4 introduces how this project has been conducted to fulfill the aim of this thesis. Here is the planning behind the project presented, how the construction of the digital twin was performed and how the connection between the SCADA system and the AVM was done.

## 4.1 Project planning

During the start-up of the project, the group met with other students, doing their thesis in collaboration with Smarta Fabriker. Information was given about the other projects and a general picture of the aim with Smarta Fabriker was given by Johan Bengtsson, project manager. As this project to a high extent is independent from the other projects, it will not be necessary to collaborate with other groups during the project. Planning within the group will be done weekly via Google Calendar and to follow up what has actually been done during the week a note sheet in Google docs will be filled in. For long term planning, a Gantt chart will be used (Appendix A).

## 4.2 Data collection

In the beginning of this thesis, information from earlier work and what has been done was gathered to get background information.

### 4.2.1 Underhåll 2018

During March, Underhåll 2018 at Svenska Mässan was held. The aim of the visit was to see the Smart Factory in progress and observe how it worked. To get an overview of the factory, photos were taken and information about the physical factories superior system was gathered.

### 4.2.2 Meetings Prevas

To gather information about the superior system (eLIPS) and how to implement the connection between the subordinate system, meetings with Prevas was held. Prevas has designed the superior system to the physical factory and they helped with the general coding of the integration of the SCADA system for the AVM (Adjusted Virtual Model).

### 4.2.3 Literature

To get an overview of the Smarta Fabriker project and what has been done at an earlier stage, theses and reports was read in the area. In order to collect information about a digital twin and gather further knowledge in the area, a research was made on the concepts, allowing the project group to start work.

## 4.3 Construction of the digital twin

This part describes how the process of constructing the digital twin was conducted. By dividing it into several parts to first describe the EVM and then the construction of the AVM.

### 4.3.1 Simulation of the Existing Virtual Model

To get a current situation analysis over the EVM and its functionalities including the virtual PLC and program code, a model was downloaded via the cloud. In the next step, the model was loaded into RobotStudio and the program code from CodeSys was loaded into the virtual PLC. To get the EVM started, the PLC and RobotStudio were required to connect to each other.

### 4.3.2 The difference between the point cloud model and the Existing Virtual Model

Measurement of the difference between the Smart Factory and EVM was made to compare the possible improvements that will occur when the factory parts are moved.

The point cloud scanning over the Smart Factory robot cell that was built has been done at an earlier stage so the data files have been downloaded from a cloud service and then imported into CloudCompare using .xyz file format.

In order to get an overlap, it was required that the EVM CAD file was loaded into CloudCompare and converted to a point cloud, to be able to match the reference points between the point clouds. Three reference points were chosen for an identical geometry between the clouds. In this way a transformation matrix of the EVM point clouds was formed. After that EVM's point cloud were returned to the original CAD figure and the point clouds matrix was copied and replaced EVM's matrix. It was then possible to move the CAD figure so the EVM overlapped with the Smart Factory.

### 4.3.3 Adjustment of the Existing Virtual Model in RobotStudio

In order to get the EVM to match the point cloud scanning of the Smart Factory, it was necessary to adjust the position of the factory parts that did not match. The Flexlink conveyor system and the table with the SCARA robot were rotated in the EVM in order to match the physical Smart Factory. The rotation was made from the lens fixture coordinate system, since it was important for the carriers and the lens fixture to match exactly in the z-axis.

Then it was necessary to adjust the position of Production line 2. Since it was not possible to get any drawings of the Smart Factory, it was necessary to measure the point cloud scanning and thus measure how much the EVM would be adjusted in RobotStudio. When the measurements were made, an offset of the Production line 2 was done in order to get an overlap.

### 4.3.4 The difference between the point cloud model and the Adjusted Virtual Model

In order to see how well the AVM corresponds with the point cloud scan, a comparison was required in CloudCompare. The adjusted solid was exported in .STL format from RobotStudio to CloudCompare where the transformation matrix for the EVM was used to overlap. This was possible because Production line 1 had not been adjusted and was therefore identical with the Smart Factory.

### 4.3.5 Simulation of the Adjusted Virtual Model

The simulation of the AVM was performed in the same way as the EVM. All program codes used by the EVM were copied and used for the AVM. This was possible because the rotation was made around the lens fixture and the carriers coordinate system, which meant that no PLC or RAPID code needed to be changed.

## 4.4 The SCADA system and the connection between the Adjusted Virtual Model

This section describes how the SCADA system should communicate with the AVM and how it is built up. In the figure below, it is described how the connection between the systems should be.

### 4.4.1 Education of the SCADA system from Prevas

The project group met Prevas to get to know how their eLLips system is structured and to understand how interoperability of the virtual machine and the host computer works.

The SCADA system and the OPC server (Kepserver) are the software that comes from Prevas, which will communicate with the PLC from ABB. eLIPS submits commands and reads the values in the PLC to trigger production. The scanner and the printer communicate with Scannercom and Printercom, which will make the entire process happen automatically and no manual input of variables will be required.

In the yellow box the PLC, the scanner and the printer are the physical components and they can also be virtual components in the VC project. In the red box the Scannercom and the Printercom are the systems that belongs to the superior system eLIPS.

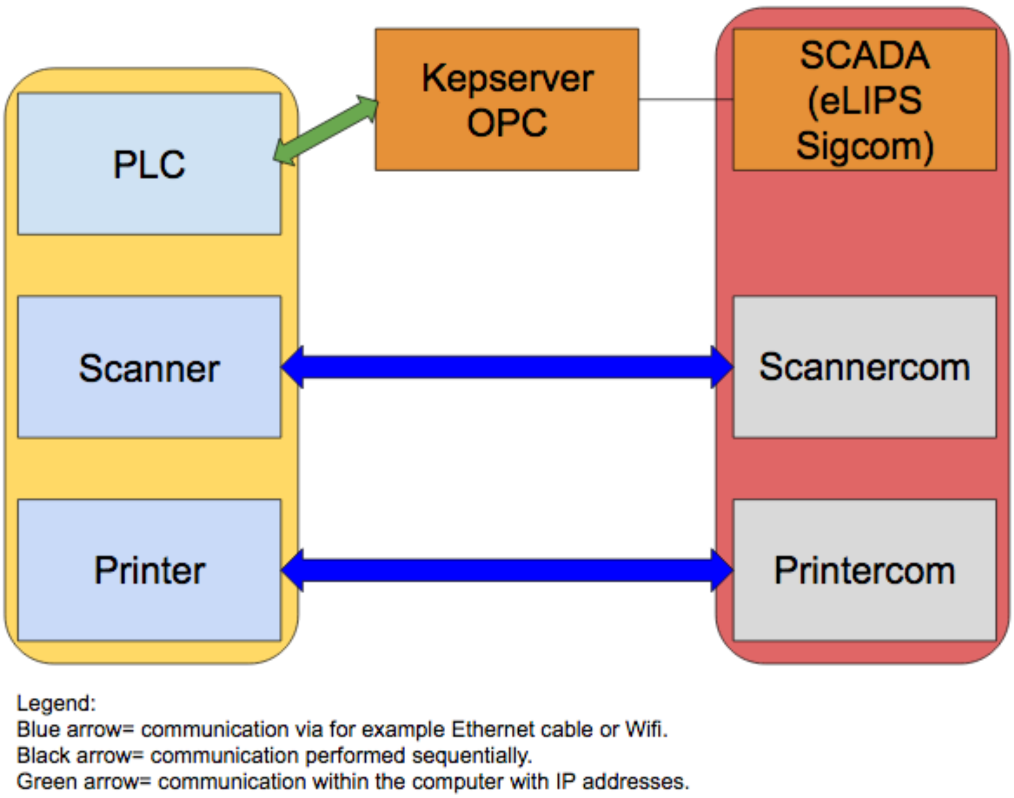


*Figure 4. Construction of the SCADA system.*

### 4.4.2 Implementation of the SCADA system from Prevas

The software and the operating system of the existing factory's SCADA system were uploaded to a virtual machine. The virtual machine was run on the same computer as the PLC. Then a connection between the OPC server and the PLC was required, with help from ABB´s in house support it was possible to try out the connection. To create a local area network in order for the virtual machine and the computer to communicate, it was required that the IP address of the PLC was known to the OPC server.

# 5 Results

This chapter presents the results in the thesis.

## 5.1 Construction of the digital twin

This part describes the result of the digital twin, by dividing it into several parts.

### 5.1.1 Simulation of the Existing Virtual Model

The model was not possible to simulate correctly. Production line 1 works as it should, while at Production line 2 problems arise when the Eton systems carrier does not stop exactly over the lens fixture. The fact that the carrier does not stay in the correct position causes the sensor to not realize that the carrier is ready to pick up a lens from the lens fixture. Therefore, also the SCARA robot does not move any lens to the lens fixture, which causes that the lens fixture does not raise up to the Eton systems carrier.

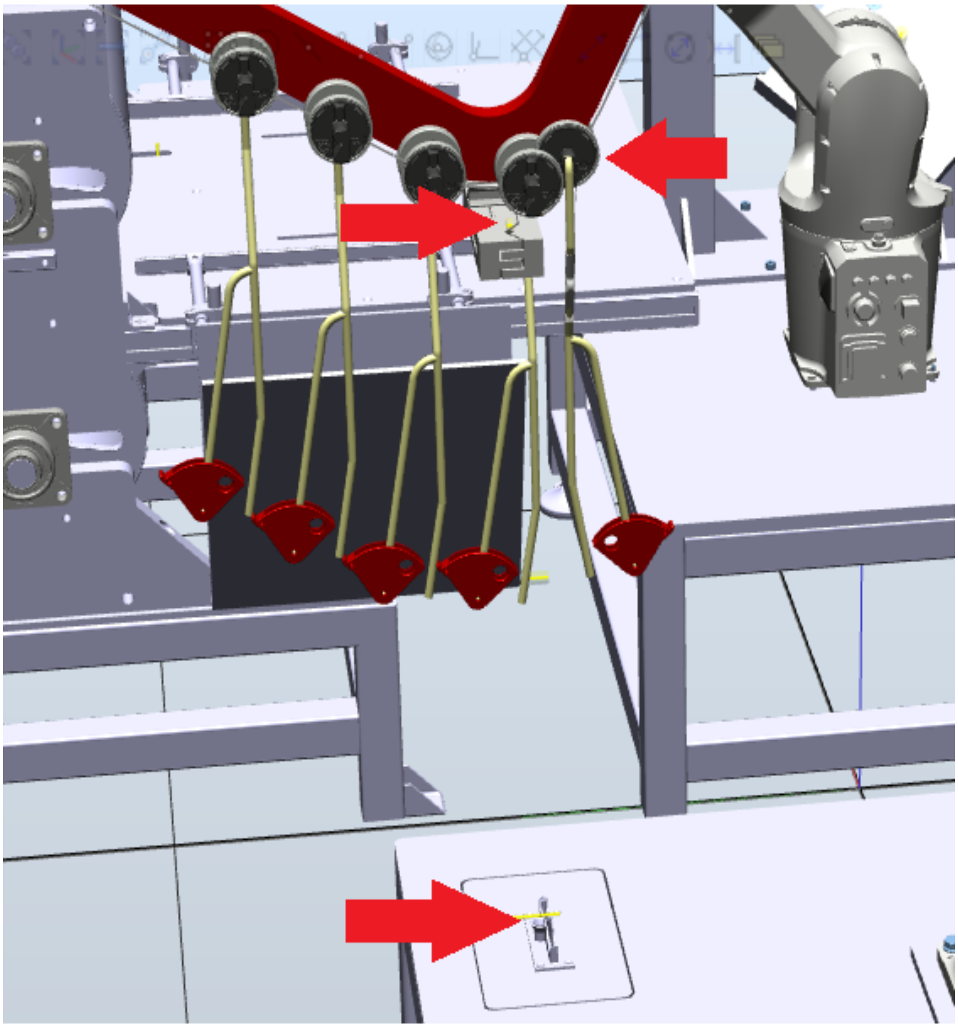

*Figure 5. The carrier and the lens fixture.*

### 5.1.2 The difference between the point cloud model and the Existing Virtual Model

Below are the results in form of a picture with the above view from the CloudCompare software, were the Flexlink system is not rotated. The green colour in the image is the model imported from RobotStudio while the rest is the factory based on the point cloud scan.

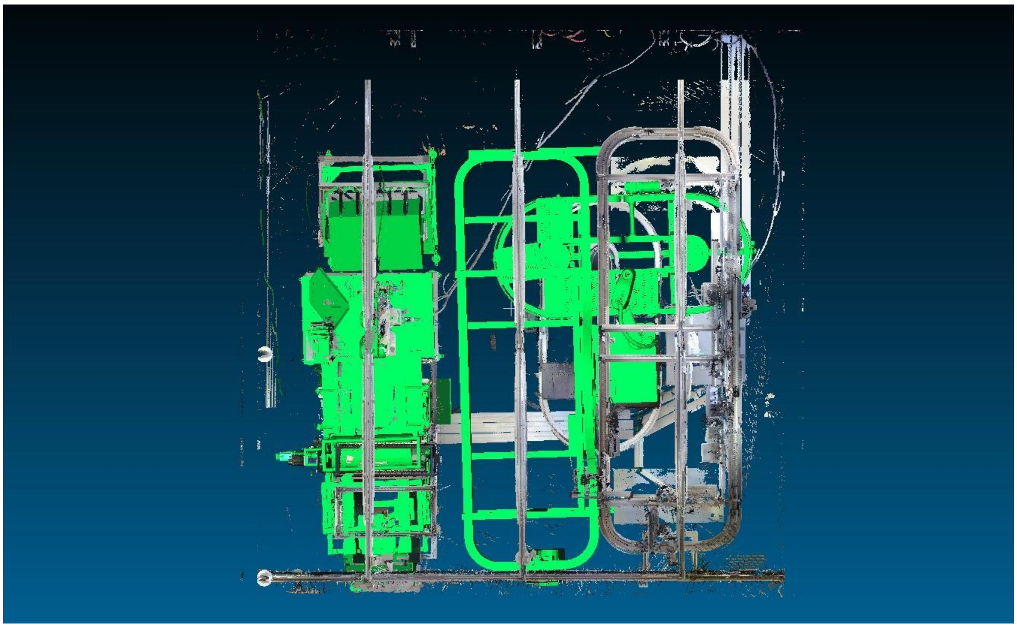

*Figure 6. Overlap between the point cloud scan and the EVM.*

## 5.1.3 Adjustment of the Existing Virtual Model in RobotStudio

The view below shows the factory in RobotStudio when the Flexlink system has been rotated and an offset on Production line 2 has been made.

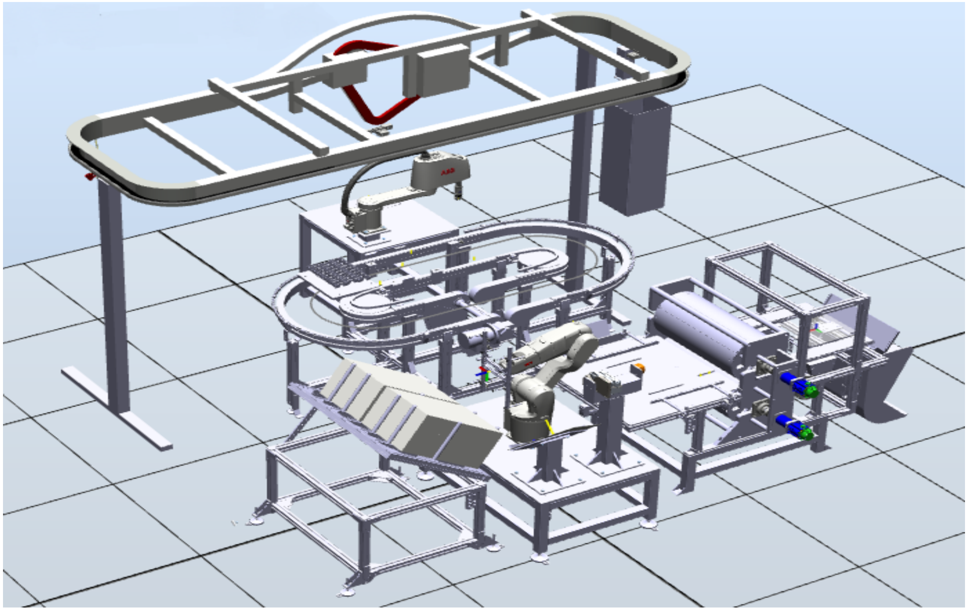

*Figure 7. The final robotcell (AVM).*

## 5.1.4 The difference between the point cloud model and the Adjusted Virtual Model

Below are the results in form of a picture with the above view from the CloudCompare software, were the Flexlink system is rotated.

*Figure 8. Overlap between the point cloud and the AVM.*

### 5.1.5 Simulation of the Adjusted Virtual Model

The simulation of Production line 1 works correctly, but due to the problem in Production line 2 with the sensor of the Eton system, the AVM has not been possible to perform simulation fully.

## 5.2 The SCADA system and the connection between the Adjusted Virtual Model

During the attempt to achieve communication between the systems, the PLC did not connect with the SCADA system from Prevas. This was due to McAfee software. This was detected by debugging and logging in Wireshark for both the virtual machine and the host computer. As soon as a connection request was sent, it was rejected and the OPC server received no response from the PLC. With this result it was possible to say that the implementation of the SCADA system was not possible, and the outcome was that the interoperability was low. Accordingly, one can say that the system is integrated only up to level 4 and 3.

# 6 Discussion

The whole simulation of the EVM could not be performed correctly from the start. It was also discovered that the transfer from the previous project did not work correctly. An example of this is that in the first trials of the simulation of the EVM, it was discovered that there was a problem with the instruction manual and thus it did not match how it would work. Time was spent on troubleshooting and correcting the manual (Appendix B). It was necessary that the factory could be simulated without any problems so that the rotation of the table and the simulation could be performed. Because this did not work and we had a schedule to relate to, new activities were being started, that were dependent on previous unfinished activities.

The point cloud scan that was used was cleared, so that it would look like the model in RobotStudio. An example of this is the floor of the model in the point cloud scan.
In connection with this, it is likely that it is not only the floor in the point cloud that was removed, but also a little of the contents of the robot cell. When the comparison in CloudCompare was made, the RobotStudio model and the point cloud scan were not in the same starting position, for example, the SCARA robot was located in different locations in the point cloud scan and in RobotStudio. These sources of error result in a less accurate overlap.

The parts that was used in RobotStudio did not fully match geometrically with the physical factory. This resulted in a situation where one could not find parts that matched with the physical factory in the point cloud so the only thing to do to solve this situation would be to reconstruct the parts in a CAD software.

When we tried to simulate the AVM, it did not work well. This is because when the rotation was made around the coordinate system in the lens fixture, this part of the simulation in the EVM did not work correctly. As a result, tags and program code did not remain there, since they were not there from start. We have found that if the EVM had worked correctly from the start, then the whole AVM would have worked well, since those parts that did not work in EVM also did not work in the AVM.

The work on the SCADA system was not fully completed. Time was spent trying to find out how the systems should be linked together. Several different manufacturers' products were used, but it is not because of this the interoperability was low. Instead, this depends on the McAfee software on the computer. We tried to shut down the software but this was not possible, which was probably caused by ABB's security system. The figure below shows the structure of communication between the systems and what it would have looked like if it had worked.

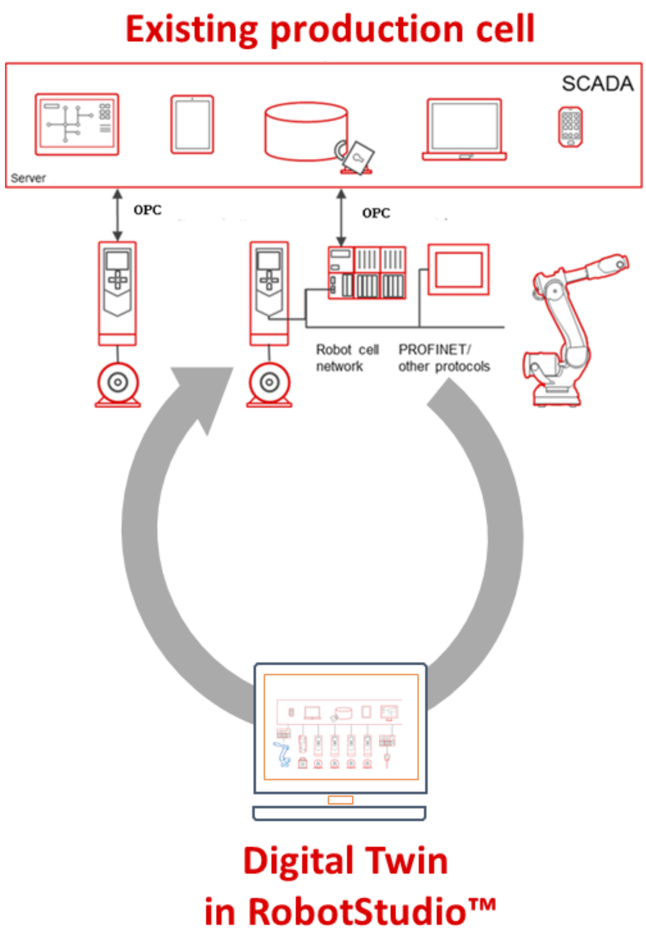


*Figure 9. The communication between the AVM and the SCADA system.*

At the simulation of the AVM, it was shown at the end of the results the importance of network planning and of ensuring that previous activity is met before starting the next task to get the correct result and fulfill the goal of the project. It is also important to use the Deming cycle and work by first Plan, Do, Check and Act to make sure that it is a good structure and a good quality in the project. In the project, it is clear that it is not working well when we choose to ignore the fact that the simulation of EVM is not working from the start. During the project we discovered how important it is to work with the Deming cycle and network planning to achieve best possible result. In the network planning schedule below, it is described how the work actually should be done.

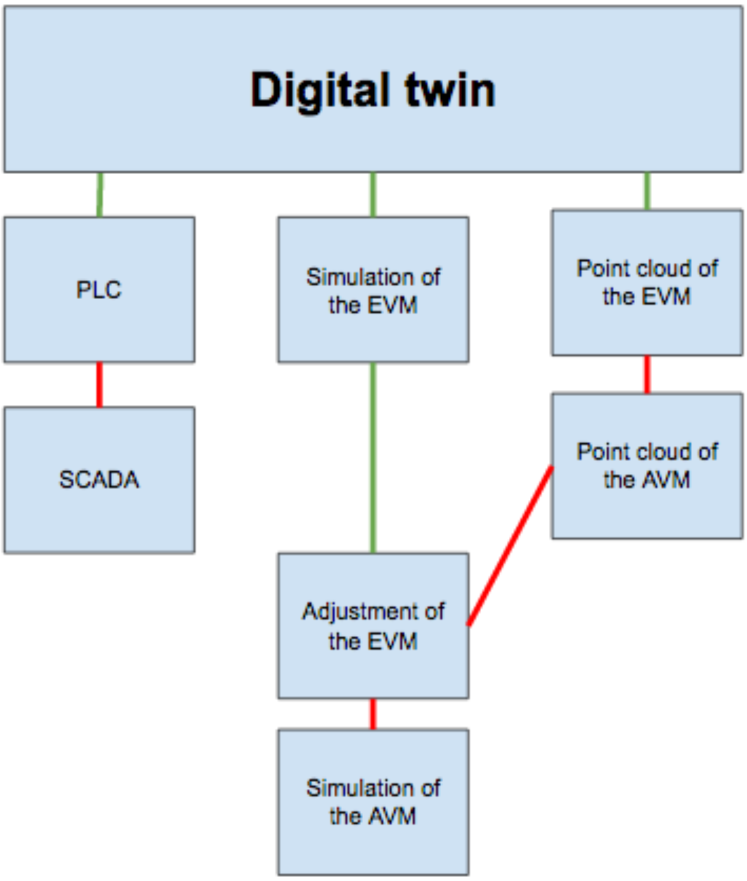


*Figure 10. Network planning of our project.*

Thus, it can be concluded that if this schedule was fully followed and that all the project handover that was handed to us was functioning properly, time would not be spent on troubleshooting and the structure in the project would have been better.

When using network planning, there is a risk with this way of working and it is that you work in a bureaucratic way where you get stuck in a bad circle. It is important to get the help you need when needed so you do not get stuck in the project.

# 7 Conclusion

In the beginning of this report two questions were formulated which this project was set up to answer. This chapter will answer these questions and present the outcome of the questions.

*What are the problems while constructing a digital twin?*

Constructing a digital twin is a big project that is time-consuming with many people involved. It is necessary to study the previous work and understand what has been done and how to proceed with this. It was discovered that it took longer than expected to read about the subject and troubleshoot functionalities.

When inserting the models from RobotStudio into the point cloud, differences in geometries were discovered. These errors cause a worse overlap to the point cloud and reduce the accuracy in the construction of the digital twin.

*Why is it difficult to get systems from different manufacturers to work well together? I.e. why is interoperability low?*

Implementation of the SCADA system was perceived as complex, since we lack sufficient knowledge for this subject. As mentioned before, several different manufacturers' products were used, but it is not the reason why the interoperability was low in our situation. Sometimes it is difficult to get systems from different manufacturers to work well together since companies want to have a high integration level with their own products. Automatically it causes a situation where the interoperability and flexibility gets lower with communication with other companies’ systems, which causes problems with connection between the systems.

# 8 Recommendations for further research

It is important that at the beginning of the project, the project members meet with the previous project members so that it is possible to review the basics of their working methods and how they have thought and structured the work. Therefore, the project group recommend to have mandatory start-up meetings which previous year's examiners attend and that contact information is exchanged for any questions that may arise during the project.
It is also important to review the folder structure of the computer to easily find the correct files that the project group is looking for. Materials that are irrelevant or not working should be removed immediately. The folders should be structured in such a way that a maximum of five clicks in different subfolders is needed to find the correct file, and the maps should also be logically organized. This is to facilitate the workflow for the current and the next project group.

Regarding the model in RobotStudio, the advice here would be to use something like BIM (Building Information Modelling) and the advantage of this is that the parts from BIM are real ones, i.e. they exist on the market and can easily be manufactured by the producer. The advantage of this is that it is possible to save time and to avoid differences in geometry that can occur when moving the CAD figure in to RobotStudio (18).

As for the SCADA system, the project group realized that it was not possible to run it on the host computer and other possibilities were discussed. One solution could be to run the PLC on the virtual machine instead. The PLC could not be moved to the Virtual machine without installing Automation Builder and we realized it would be time-consuming to do this so late in the project. Another option would be to run the system on a different computer than the host computer, but it was not possible due to the fact that all the programs had to be reinstalled.

A suggestion for further research is to focus on CLM (Closed Loop Manufacturing). CLM is a closed process for manufacturing and inspection. The purpose of a closed process is that inspection is used in the manufacturing. With continuous input of production data in this case in the digital twin, patterns can be continuously improved. The aim of CLM is to reduce the costs that occur due to defects while improving the quality and accuracy of production (19).

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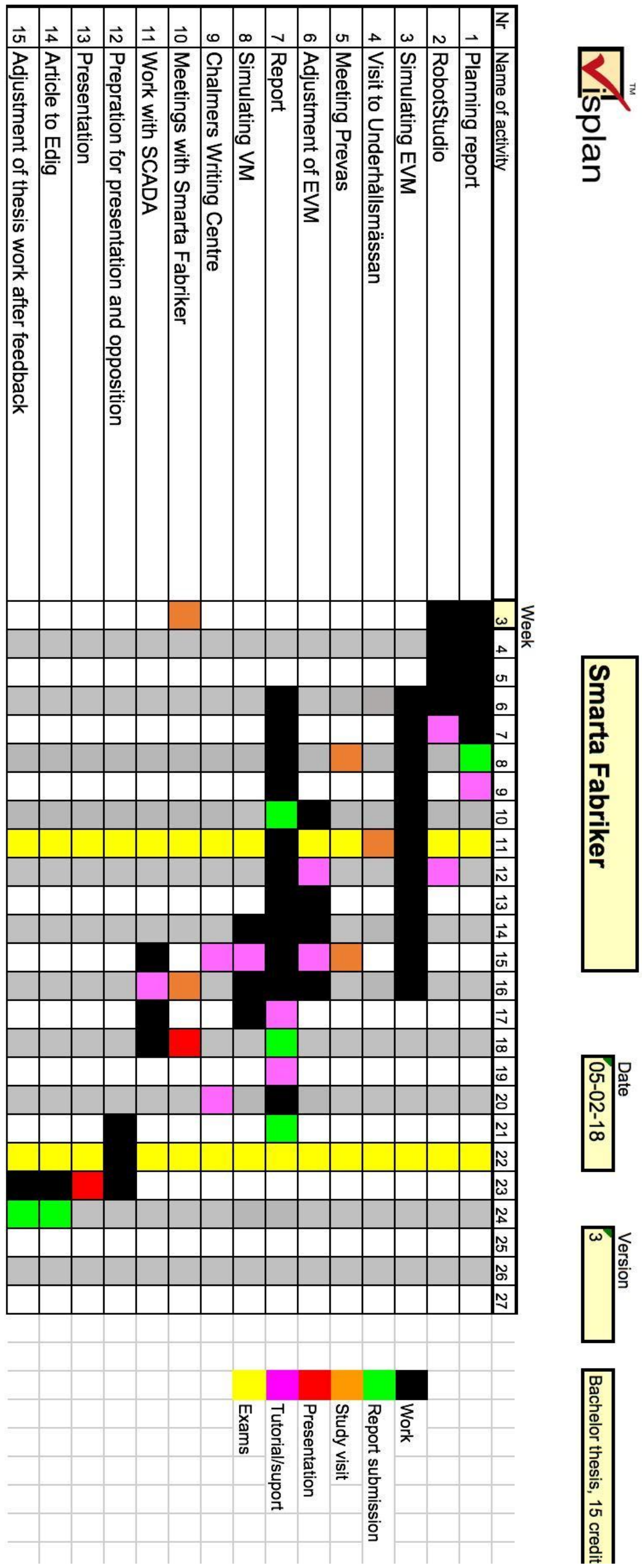
# Appendix

## Appendix A -Gannt chart



Appendix B- Instruction manual

(The green marking are changes that we made)

Guide Smarta fabriker simulering:
1)
Öppna: ...\AutomationBuilder Smarta Fabriker körbar\PLC\VAC500.bat genom att dubbelklicka, för att öppna den virtuella PLCn

Öppna: ...\AutomationBuilder Smarta Fabriker körbar\Codesys\PLC_program_0523\Application2.PRO
i codesys för att öppna programmet

Öppna:
...\AutomationBuilder Smarta Fabriker körbar\Robotstudio\Stations\Smarta_fabriker_final.rrstn i robotstudio för att öppna modellen

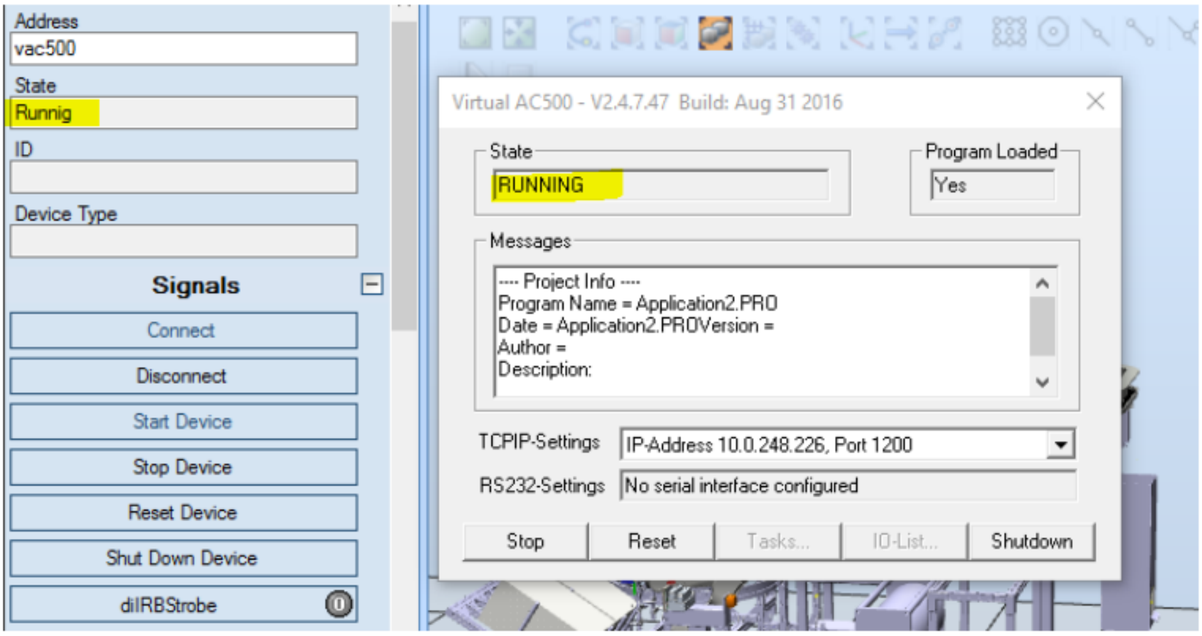
Codesys:
2) se till att Simulation mode är avkryssat under ”online”

3) Klicka på Online -> Login för att ladda över programmet på den virtuella PLCn

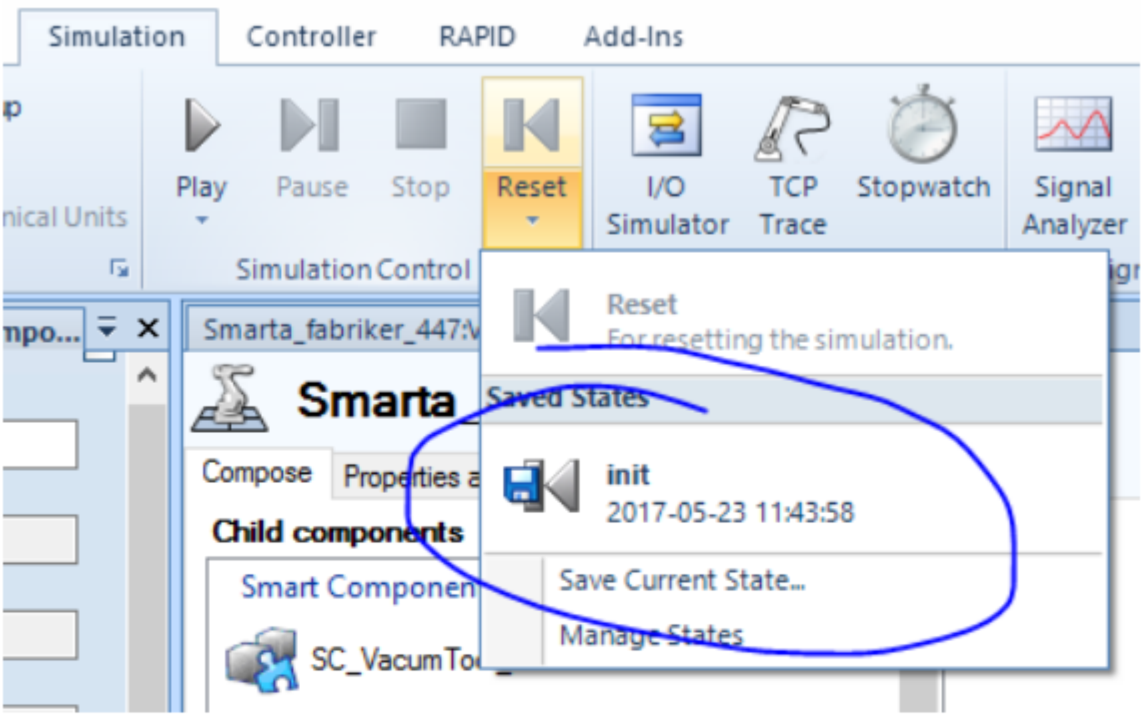
RobotStudio:
4)högerklicka: ConnectivitySmartComponent_2_2 och välj ”properties”

5) skriv något valfritt i ”Address”->klicka apply->Skriv VAC500 i ”Address” -> klicka apply-> klicka connect

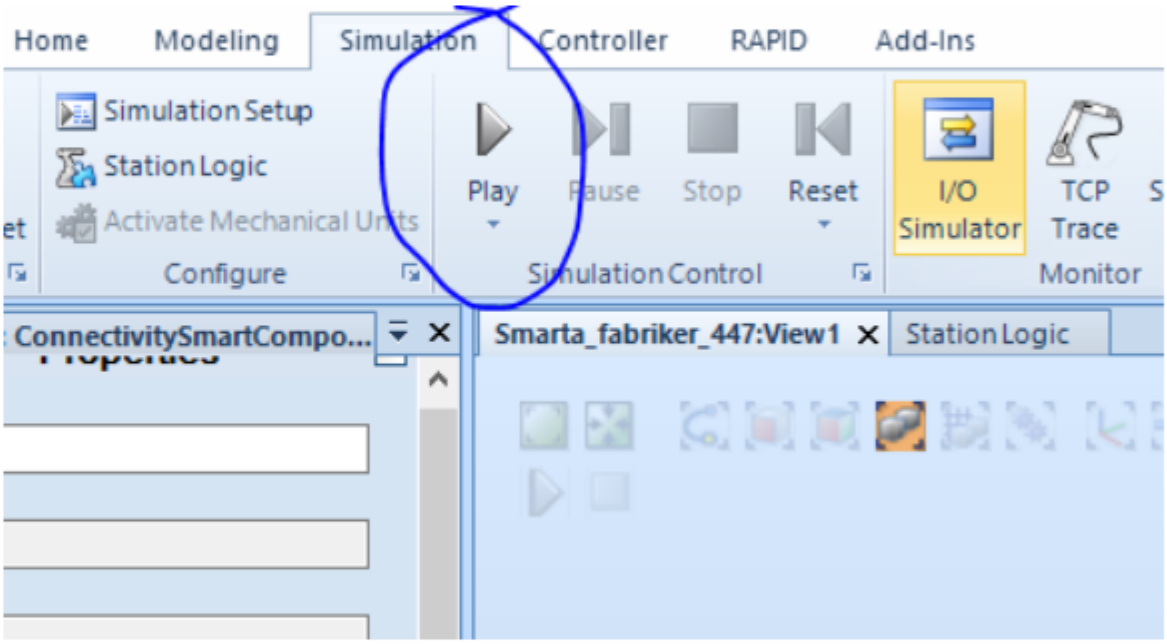
6) Klicka ”start device” och kolla så att State=”running” i robotstudio och den virtuella PLCn



7) Se till att initial state är rätt genom att i simulation-taben klicka
reset ->Saved  states   -> init




8) Klicka "play"



Codesys:

*Tvinga ett värde gör ni genom att dubbelklicka på variabeln ni vill ändra och skriv in det önskade värdet. Därefter klickar ok och sen CTRL+F7 så laddas det nya värdet in i PLCn.*

9) i filen PLC_PRG: tvinga Stn1_Product till 1,2 eller 3
Tvinga Stn1_Command till 1

10) I filen PrintAndRead: tvinga Stn1_ResultCMD till 2 för att simulera att QR-koderna godkänns och 3 för att simulera QR-koder icke kodkända(går ändra medans man simulerar)

11) I filen ServoAuto: tvinga ”auto” till TRUE för att valsarna ska kunna snurra i simuleringen samt att trycka på F7.

RobotStudio:

12) I 3D-vyn, högerklicka på lådan där linserna levereras till kund

13) Toggla Modify -> detectable by sensors två gånger så att den går från på -> av ->på(annars kommer inte linserna kunna levereras till kund som det är nu)

OBS! tänk på att resetta PLC och ”initial state” i robotstudio efter varje simulering