Peter the Great St. Petersburg Polytechnic University
Institute of Computer Sciences and Technologies
School of Cyber-Physical Systems and Control

# Course Project

Developing MES system

Discipline   High-level Design of Information and Control Systems

Students

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# Contents

# 1. Introduction and Aim:

This project tries to implement a Manufacturing Execution System (MES) for the FESTO chemical Line, which currently is set up in the laboratory of Cyber-Physical Department in our University. What is MES?

A MES system is a computerized system that tracks and monitors all the elements involved in the transformation of raw materials to the final product and documents these information in order to have full reports of all elements involved in the process.
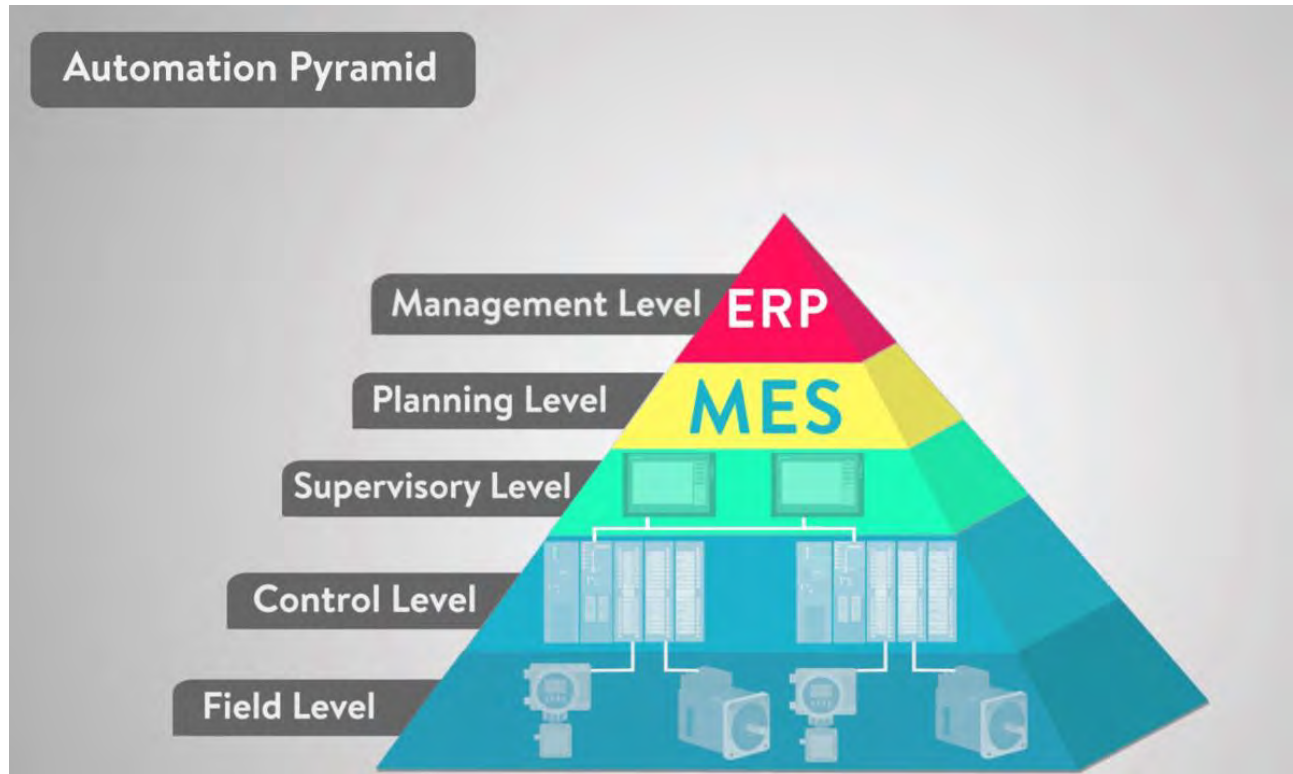


Manufacturing Execution System (MES) are becoming an essential tool for operating Small and medium-sized enterprises (SME). With the rapid increase in technology, it is almost guaranteed that paper based operating systems that documents all assets of these enterprises will be replaced by more efficient and reliable smart MES [1]. MES system can help us to make decisions for the future in order to optimize our process to achieve better results.

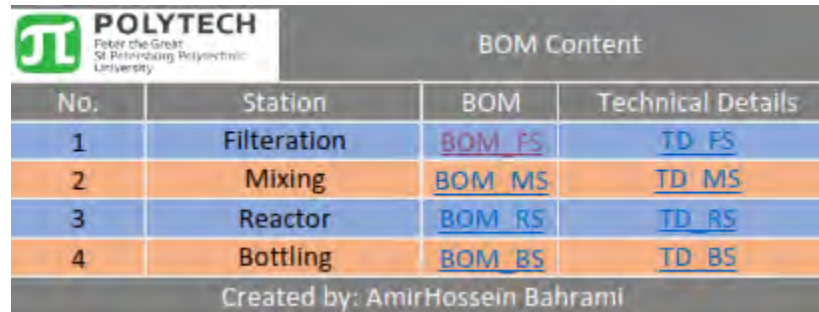# 2. Task to solve in order to achieve our goal:
- Write the PLC programs.
- Create UML Diagrams
- Create MES Program (We tried to use Master SCADA)

In the Project Section, we could not overcome most of our problems because of the pandemic situation. For our project to be complete we have to be in the laboratories to work with the production line directly. The following sections are presented for this project.

## 2.1 BOM

First, we have to see what our system consists of. This is important in the sense that we have to create our price list for our equipment, our spare parts and generally it is necessary for our financial analysis and for the next steps in creating our MES.

Our automation system consists of 4 different stations. The list is shown in figure 2.1:

| POLYTECH Peter the Great St. Petersburg Polytechnic University | BOM Content | | |
|---|---|---|---|
| No. | Station | BOM | Technical Details |
| 1 | Filteration | BOM_FS | TD_FS |
| 2 | Mixing | BOM_MS | TD_MS |
| 3 | Reactor | BOM_RS | TD_RS |
| 4 | Bottling | BOM_BS | TD_BS |
| Created by: AmirHossein Bahrami | | | |

Figure 2.1 Station List

Next we have to see what parts create our stations. The lists are shown in figures 2.2 - 2.8 as well as a schematic of each station for more guidance.

| Part Groups | Part Name | Quantity |
|---|---|---|
| | **Filteration Station** | |
| **Sensors** | Float switch for container level | 2 |
| | Capacitive proximity sensor | 4 |
| | Pressure sensor (analogue) incl. display (2) | 1 |
| | Pressure gauge (mechanical) | 1 |
| **Actuators** | Waste water, pump downstream PA station (12) | 1 |
| | Stirrer (8) | 1 |
| | 3-way ball valve with pneumatic drive (11) | 1 |
| | Gate valve with pneumatic drive (6) | 1 |
| | Butterfly valve with pneumatic drive (5) | 1 |
| | Pressure regulator (analogue) (3) | 1 |
| **Connecting components** | Connection board (7) | 1 |
| | Touch panel with mounting bracket (1) | 1 |
| | Measuring transducer for motor actuation – pump downstream station | 1 |
| | Comparator | 1 |
| **Control units** | Open/closed-loop control unit | 1 |
| | PLC industrial closed-loop controller (optional) | 1 |
| **Passive elements** | Piping | 1 |
| | Pure water tank (10) | 1 |
| | Waste water tank (9) | 1 |
| | Filter (4) | 1 |
| | Cable ducts | 1 |
| | Profiles | 1 |
| | Profile plate with cabinet frame (19''/ER/A4) | 1 |
| | Carriage | 1 |
| | PLC industrial closed-loop controller (optional) | 1 |

POLYTECH — Peter the Great St Petersburg Polytechnic University — BOM Chart

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Figure 2.2 Filtration BOM
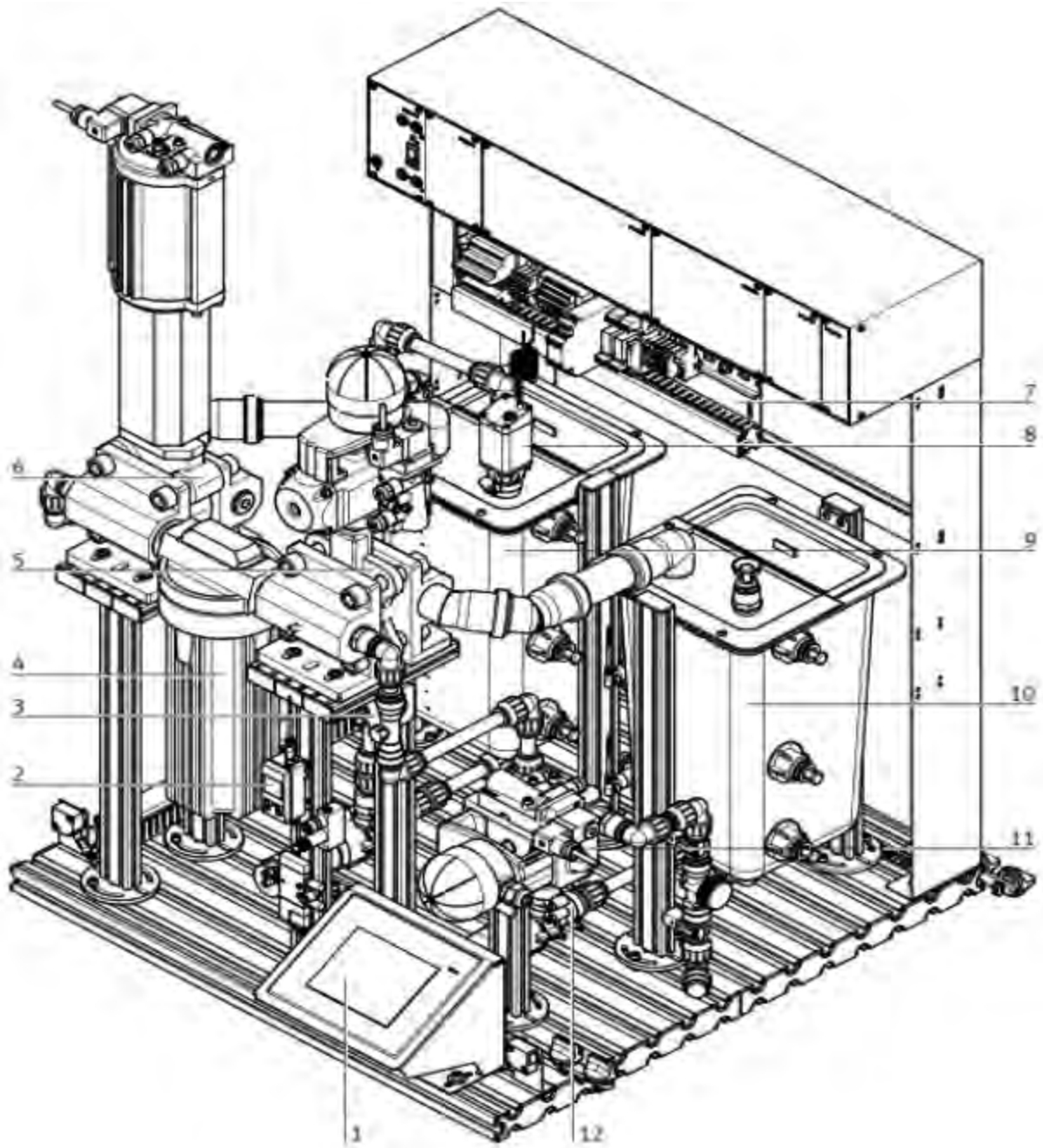
Figure 2.3 Filtration Station

| Part Groups | Part Name | Quantity |
|---|---|---|
| | | |
| **Sensors** | Float switch for container level | 4 |
| | Capacitive proximity sensor (3) | 6 |
| | Flow sensor – float (mechanical) (7) | 1 |
| | Flow sensor – impeller (electrical) (8) | 1 |
| **Actuators** | Proportioning pump, pump of downstream PA station (9) | 1 |
| | 2-way ball valve with pneumatic drive (2) | 1 |
| **Connecting components** | Connection board/Measuring transducer frequency/voltage (5) | 1 |
| | Touch panel with mounting bracket (1) | 1 |
| **Control units** | Open/closed-loop control unit | 1 |
| | PLC industrial closed-loop controller (optional) | 1 |
| **Passive elements** | Piping | 1 |
| | Main tank (6) | 1 |
| | Metering tank (4) | 3 |
| | Piping | 1 |
| | Profiles | 1 |
| | Profile plate with cabinet frame (19''/ER/A4) | 1 |
| | Carriage | 1 |

BOM Chart

Mixing Station

POLYTECH
Peter the Great
St Petersburg Polytechnic
University

| Created By | AmirHossein Bahrami | Verified by | AmirHossein Bahrami |

Figure 2.4 Mixing BOM
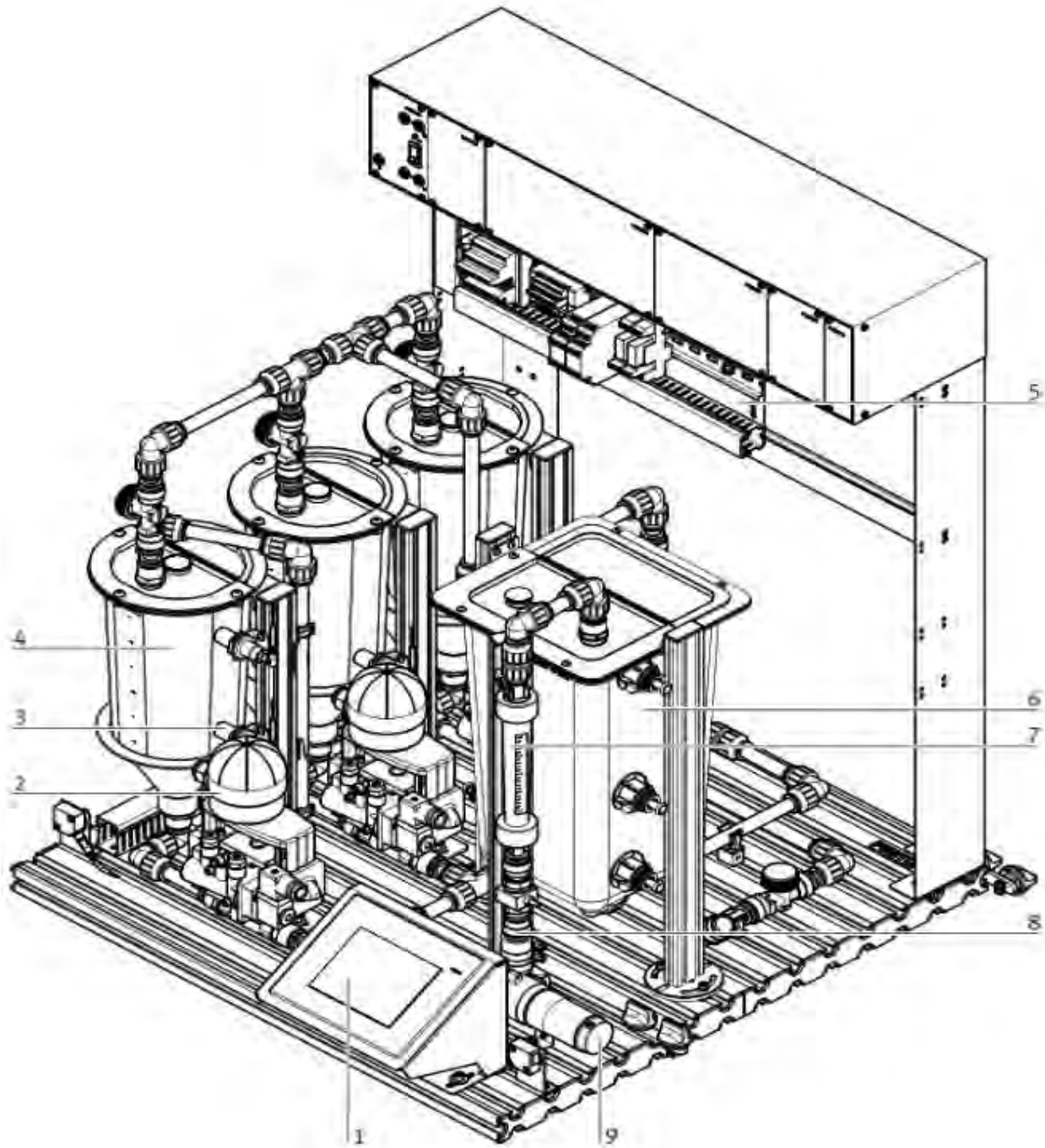
Figure 2.4 Mixing Station

| Part Groups | Part Name | Quantity |
|---|---|---|
| | **Reactor Station** | |
| **Sensors** | Float switch for container level | 1 |
| | Capacitive proximity sensor | 2 |
| | Temperature sensor (3) | 1 |
| **Actuators** | Cooling pump (8), pump of PA downstream station | 1 |
| | Heating unit, including pulse width actuation 0 - 10 V (2) | 1 |
| **Connecting components** | Touch panel with mounting bracket (1) | 1 |
| | Connection board (5) | 1 |
| | 24 V power pack (6) | 1 |
| | Measuring transducer °C/voltage | 1 |
| | Comparator (7) | 1 |
| **Control units** | Open/closed-loop control unit | 1 |
| | PLC with internal closed-loop controller (optional) | 1 |
| | External industrial closed-loop controller | 1 |
| **Passive elements** | Piping Tank | 1 |
| | (4) Cable | 1 |
| | ducts | 1 |
| | Profiles | 1 |
| | Profile plate with cabinet frame (19''/ER/A4) | 1 |
| | Carriage | 1 |
| Created By | AmirHossein Bahrami | Verified by | AmirHossein Bahrami |

Figure 2.5 Reactor BOM
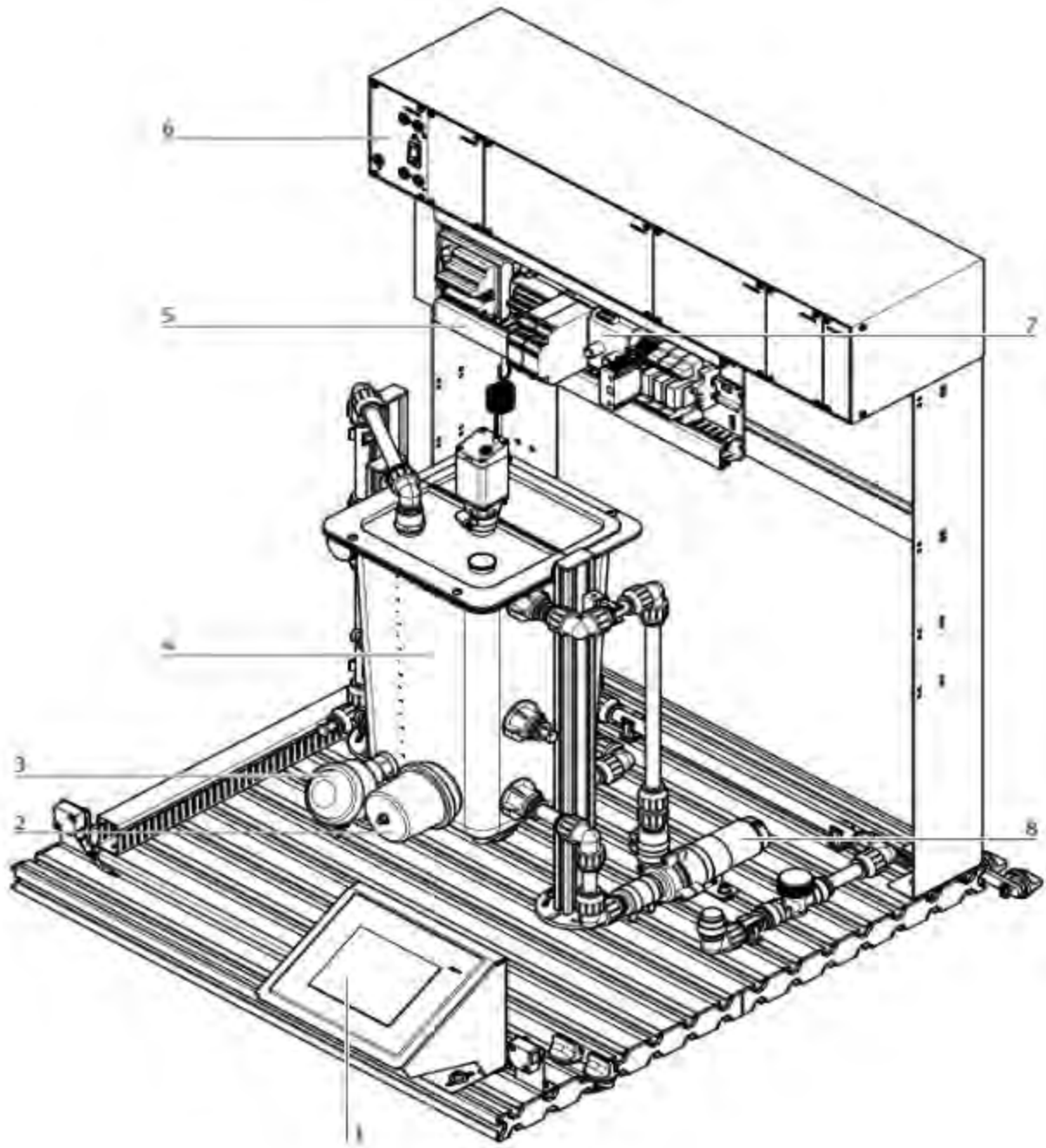
Figure 2.6 Reactor Station

| Part Groups | Part Name | Quantity |
|---|---|---|
| **POLYTECH** Peter the Great St Petersburg Polytechnic University | **BOM Chart** | |
| | **Bottling Station** | |
| Sensors | float switch for bottle level (5) | 2 |
| | capacitive proximity sensor | 2 |
| | Acoustic sensor (6) | 1 |
| | diffuse sensor | 3 |
| | Through-beam sensor | 1 |
| Actuators | Pump (9) | 1 |
| | 2/2-way dosing valve (8) | 1 |
| | Pneumatic feed separator (10) | 1 |
| | Conveyor belt, 2 partial sections complete (2) | 1 |
| Connecting components | Connection board (4) with comparator | 1 |
| | Touch panel with mounting bracket (1) | 1 |
| | Motor actuation | 1 |
| Control units | Open/closed-loop control unit | 1 |
| | PLC industrial closed-loop controller (optional) | 1 |
| Passive elements | Piping | 1 |
| | Main tank (3) | 1 |
| | Metering tank (7) | 1 |
| | Cable ducts | 1 |
| | Profiles | 1 |
| | Profile plate with cabinet frame (19''/ER/A4) | 1 |
| | Carriage | 1 |
| Created By | AmirHossein Bahrami         Verified by      AmirHossein Bahrami | |

Figure 2.7 Bottling BOM

Figure 2.8 Bottling Station
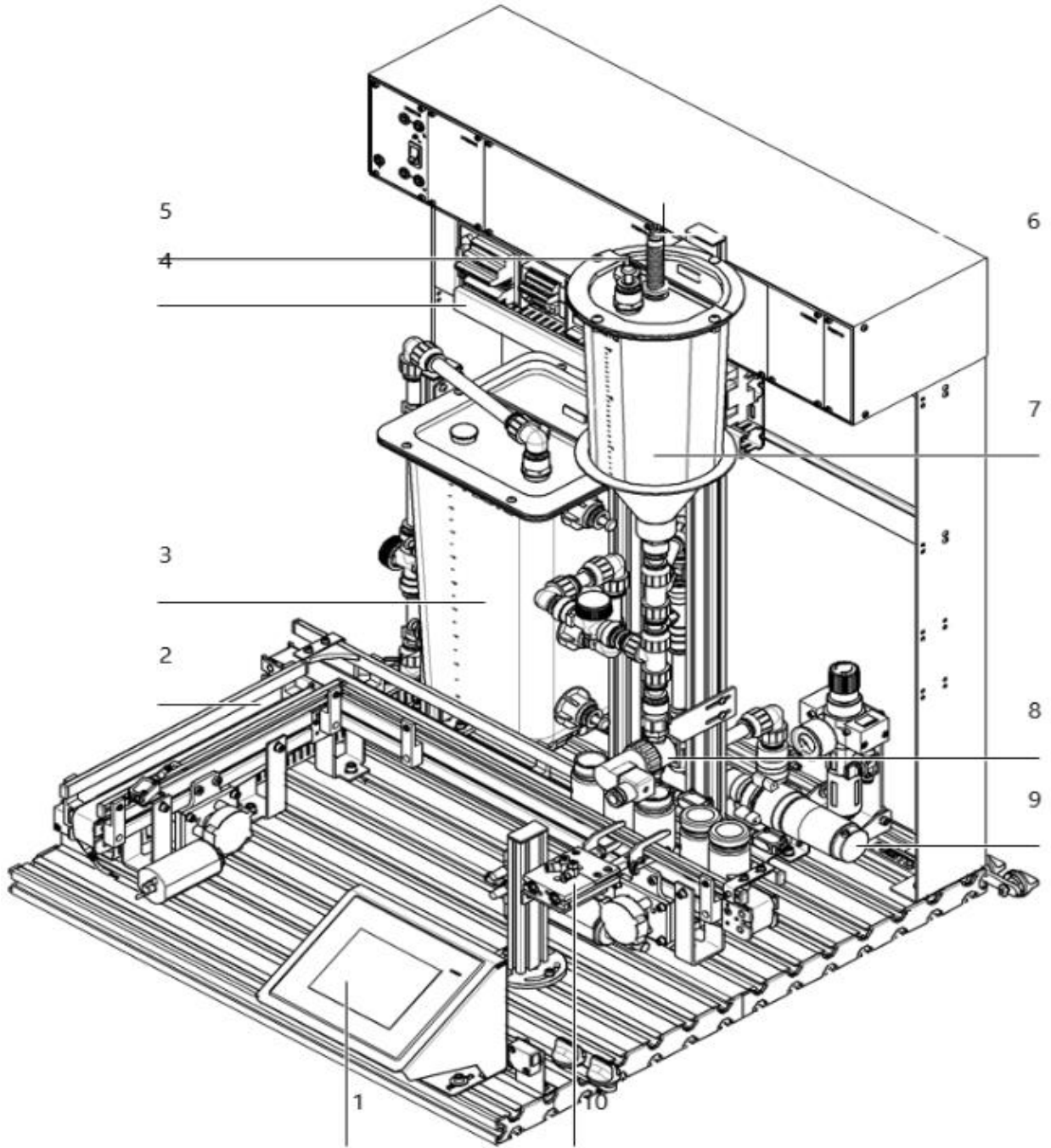
Next the Technical Details of these Parts needed for our station are demonstrated in the table 2.1 – 2.4. These Details will help us to find the best model of the equipment needed for our system and will help us to not go over budget.

| Parameters | | Value |
|---|---|---|
| Max. operating pressure in piping | | 0.5 bar (50 kPa ) |
| Power supply for station | | 24 V DC/4.5 A |
| Profile plate | | 700 x 700 x 32 mm |
| Pump flow rate | | 0 – 6 l/min |
| Pure water tank | | 10 l max. |
| Waste water tank | | 10 l max. |
| Flexible piping system | | DN15 ($\emptyset_a$ 15 mm) |
| Digital inputs | | 8 |
| Digital outputs | | 6 |
| Analogue inputs | | 1 |
| Analogue outputs | | 1 (2) |
| Signal range of signalling elements | Proportional pressure regulator | 0...10 V |
| | Pumps (0...24 V DC) with motor actuation (digital) | On/Off |
| | Stirrer (0...24 V DC) with gear unit Analogue actuation of stirrer also possible | On/Off |
| | | (Control voltage 24 V DC) |
| | | 0 – 10 V DC |
| Signal range of signalling elements | Electrical pressure sensor | Measuring range 0 – 10 bar |
| | | 0 – 10 V DC |
| Filter, max. flow rate | | 13.04 l/min |

Table 2.1 Filtration Details

| Parameters | Value |
|---|---|
| Max. operating pressure in piping | 0.5 bar (50 kPa) |
| Power supply for station | 24 V DC/4.5 A |
| Profile plate | 700 x 700 x 32 mm |
| Pump flow rate | 0 - 6 l/min |
| Metering tank | 3 l max. |
| Main tank | 10 l max. |
| Flexible piping system | DN15 ($\emptyset_a$ 15mm) |
| Digital inputs | 8 |
| Digital outputs | 6 |
| Analogue inputs | 1 |
| Analogue outputs | 1 (2) |
| Number of containers | 4 |

| | | |
|---|---|---|
| **Signal range of final signalling elements** | Pump (0 - 24V DC) with | On/Off |
| | Motor actuation (digital) | 0 - 10 V |
| | | (control voltage 24 VDC) |
| **Signal range of final signalling elements** | Flow sensor impeller, electrical | Measuring range 0.3 - 9 l/min |
| | | 40 - 1200 Hz converted 0 - 10 V |

Table 2.2 Mixing Details

| Parameters | | Value |
|---|---|---|
| **Max. Operating pressure in piping** | | 50 kPa (0.5 bar) |
| **Power supply for station** | | 24 V DC/4.5 A |
| **Profile plate** | | 700 x 700 x 32 mm |
| **Pump flow rate** | | 0 - 6 l/min |
| **Container volume** | | 10 l max. |
| **Flexible piping system** | | DN15 ($\varnothing_a$ 15 mm) |
| **Digital inputs** | | 4 |
| **Digital outputs** | | 5 |
| **Analogue inputs** | | 1 |
| **Analogue outputs** | | 1 (2) |
| **Number of containers** | | 1 |
| **Signal range of final control elements** | Heating unit (capacity 0 - | 0 - 10 V |
| | 1000 W) | (control voltage 24 V DC) |
| | 230 V AC | |
| | Pumps (0 - 24 V DC) | On/Off |
| | | 0 - 10 V |
| | | (control voltage 24 V DC) |
| | Stirrer (0 - 24 V DC) with gear unit | On/Off |
| | | (control voltage 24 V DC) |
| | Analogue actuation of the stirrer is also possible. | 0 - 10 V |

| | |
|---|---|
| **Operating range of temperature control system** | 0° C - +60° C |
| **Measuring range of temperature control sensor** | -50° C - 150° C |
| **Signal of sensor for temperature control system** | Resistor PT100 |

Table 2.3 Reactor Details

| Parameters | | Value |
|---|---|---|
| Max. operating pressure in piping | | 0.5 bar (50 kPa) |
| Power supply for station | | 24 V DC / 4.5 A |
| Profile plate | | 700 x 700 x 32 mm |
| Pump flow rate | | $0 - 6$ l/min |
| Metering tank | | 3 l max. |
| Main tank | | 10 l max. |
| Flexible piping system | | DN15 ($\emptyset_a$ 15mm) |
| Digital inputs | | 8 |
| Digital outputs | | 6 |
| Analogue inputs | | 1 |
| Analogue outputs | | 1 (2) |
| Number of bottles | | 2 |
| | | |
| Signal range of control elements | Pump (0 - 24 VDC) with motor actuation g (digital) | On/Off |
| | | |
| | | 0 - 10 V |
| | | (Control voltage 24 VDC) |
| Signal range of signalling elements | Acoustic sensor (analogue), electrical | Measuring range 500 - 150 mm |
| | | 0 - 10 VDC |

Table 2.4 Bottling Details

## 2.2 IDEF0

The IDEF0 Functional Modeling method is designed to model the decisions, actions, and activities of an organization or system. So, we can have a better understanding of what we have to do and what resources we need.

## Diagram 1 (Top)

KPI(s):
PLC Running : K1
5bar<Air Pressure<6bar : K2
Network Setup : K3

K1 K2 K3

Input(s) :
Storage Materials : I1
Number of Bottles : I2

I1
I2
I3

**MES System**

A0

O1
O2
O3
O4

Output(s):
Storage Materials : O1
Number of OK parts from each station : O2
Number of defected parts from each station : O3
Defects in each station : O4
Defects Happening in future : O5

R2 R3 R4

Resource(s):
: R1
Electricity : R2
PLC Programing (STEP7) : R3
WinCC Flexible : R4

NODE: | TITLE: | MES System | NO.:

---

## Diagram 2 (Bottom)

Setup
According to
Problem

Station's Mechanical
Parts from Part List

**Setting Up Stations Mechanicals**

A1   1

Tools

Program
Should Work
Manually and
Automatically

**Writing PLC Programs**

A2   2

Knowledge of
FBD, Ladder,
Sequence
Programing

Input Table

**Writing WinCCFlexible Program for the TouchPanels**

A3   3

Touch Panels

Tag Defining

Knowledge
of WinCC
Programing

Bottling OK
Mixture OK
Filtration OK

**Getting the Number of OK Parts**

A4   4

Counter
Sensor

DataBase

Bottling Not OK
Mixture Not OK
Filtration Not OK

**Getting Number of NOT OK Parts**

A5   5

OK, NOK Parts

DataBase

Counter
Sensor

NODE: A0 | TITLE: | Monitoring Produced Parts | NO.:

## Diagram 1 (NODE A0)

Each I/O should
have a name
assigned to it

List of I/O address →

**List of Variables**

A6

6

Defining the
tags (I/O) for
Master SCADA

**List of Tags**

A7

7

Each PLC should
have an IP
address defined

Network Setup

**IP Adress of PLCs
and Network**

A8

8

**Creating MES
System with
Master SCADA**

A9

9

→ MES →

Master SCADA
Software

| NODE: | A0 | TITLE: | Network Link Stablishment | NO.: |
|---|---|---|---|---|

## Diagram 2 (NODE A9)

→ Purpose of the MES →

**Graphical Window
Interface
Definition**

A10

10

Required
Design
standard

**Object Definition**

A11

11

What Needs
to be
monitored

**Libraries**

A12

12

→ Monitoring System →

| NODE: | A9 | TITLE: | Master SCADA | NO.: |
|---|---|---|---|---|

## 2.3 Sequence Diagram

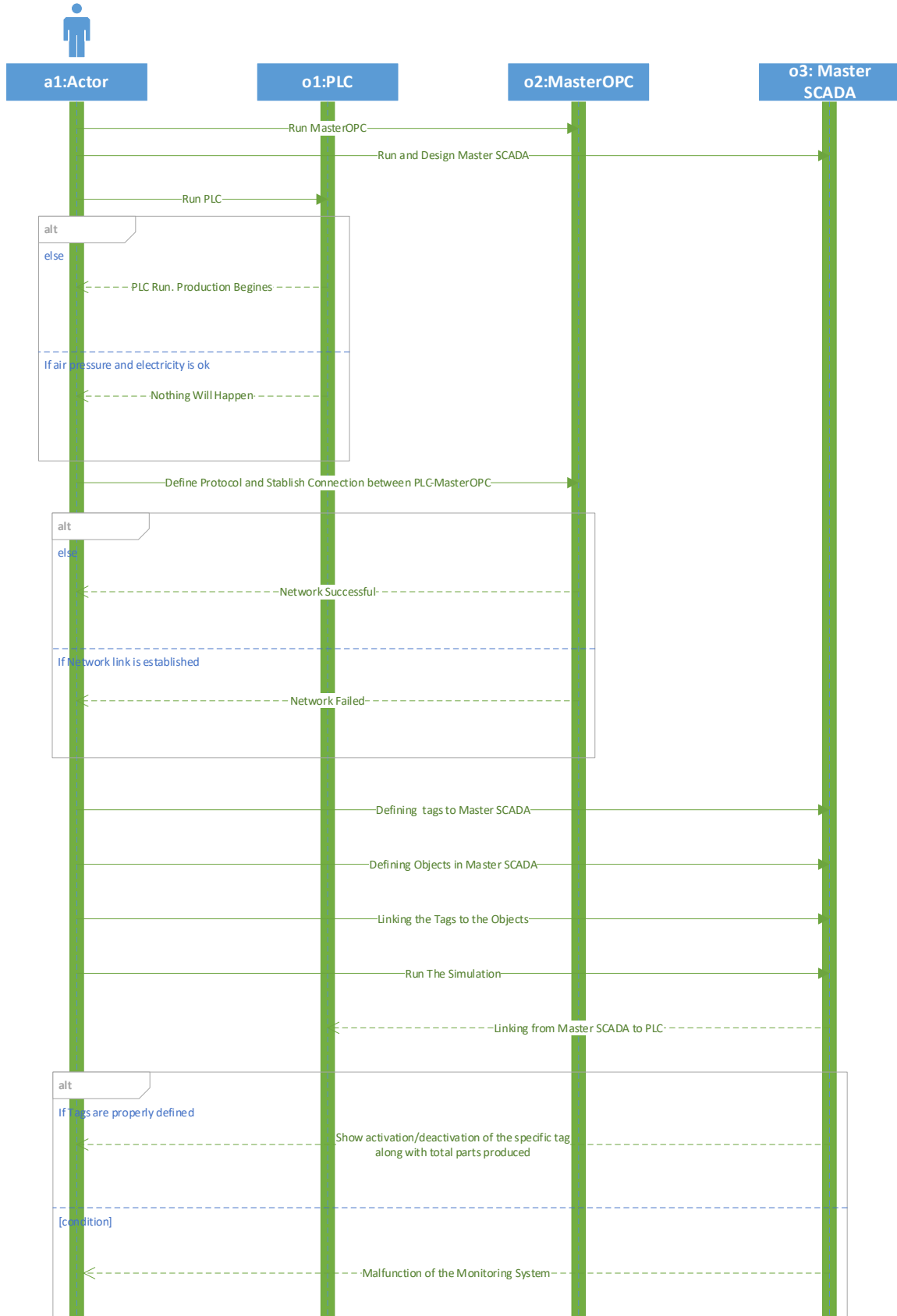A sequence diagram shows object interactions arranged in time sequence. It depicts the objects and classes involved in the scenario and the sequence of messages exchanged between the objects needed to carry out the functionality of the scenario.

**a1:Actor** — **o1:PLC** — **o2:MasterOPC** — **o3: Master SCADA**

Run MasterOPC

Run and Design Master SCADA

Run PLC

**alt**

else

PLC Run. Production Begines

If air pressure and electricity is ok

Nothing Will Happen

Define Protocol and Stablish Connection between PLC-MasterOPC

**alt**

else

Network Successful

If Network link is established

Network Failed

Defining tags to Master SCADA

Defining Objects in Master SCADA

Linking the Tags to the Objects

Run The Simulation

Linking from Master SCADA to PLC

**alt**

If Tags are properly defined

Show activation/deactivation of the specific tag along with total parts produced

[condition]

Malfunction of the Monitoring System

## 2.4    Use case Diagram



Use case diagram is used to define the main functionality and the interaction of the user with the various components of the MES system for the production line of a chemical plant.

As we can see from the diagram, Master SCADA is used to collect, archive, display data, as well as to control various technological processes. The system allows to program controllers with an open architecture. Thus, Master SCADA allows to create a single integrated automation project (SCADA system + PLC). The basic functionality includes: Programming the PLC, OPC, Process monitoring and collection of data regarding various operation parameters like number of OK/ Not OK parts, maintenance schedules, defects, raw material. The data is represented in the necessary formats and is accessible to the various levels of management according to their clearance and also to the floor operator. Human machine interface is used for the representation of the data in human understandable format.

The various steps in the operation of the plant are Filtration, Mixing, Reacting and Filling the bottles.

The first step is the filtration of the raw material. The filtration station combines a closed-loop control system with digital and analogue sensors and actuators. The pressure control system is operated via a PLC and closed-loop controller. A liquid to be filtered is supplied to the filter from the waste water tank via a pump. The filtered water reaches the pure water tank via a butterfly valve. From there, it can then be pumped to a downstream station via a pump or back again into the waste water tank. During this rinsing process, the filter is first of all completely filled with liquid and the particles are then removed from the filter by means of compressed air. The liquid containing the released dirt particles is then once again returned to the waste water tank.

The second step is mixing the components. The mixing station consists of a controlled system with digital and analogue sensors and actuators. The controlled flow system is operated via a PLC and closed-loop controller. The process is executed according to the selection of a mixing quantity (0 - 10l) and a recipe. Depending on the recipe selected, the mixture is transported from three metering tanks into the main tank via the proportioning pump. The ready mixture can subsequently be pumped to a downstream station via a pump.

The third step is Reacting the components. The reactor station consists of a controlled system with digital and analogue sensors and actuators. The temperature control system is operated via a PLC and closed loop controller. The process runs according to three selectable recipes and consists of the heating and stirring of a liquid. Depending on the recipe selected, the liquid is cooled by a cooling circuit. The ready mixture can be fed towards a downstream station by means of a pump.

The fourth and the final step is bottling of the product. The bottling station combines a closed-loop control system with digital and analogue sensors and actuators. The level control system is operated via a PLC and closed-loop controller. The empty bottles are supplied to the bottling station via two conveyor belts. Once the recipe has been selected, either a specific number of bottles are filled with the liquid from the metering tank or, if in continuous operation, any number of bottles.

The engineer is the skilled human resource responsible for building the system like developing the master SCADA simulation, Construction, wiring and commissioning of the hardware. The operator is responsible for daily activities and monitoring the operation of the plant like selection of the batch size, recipe etc. as instructed to him.

The monitoring task in the operator's scope includes monitoring the raw material, shortages and various sensor data values and warning signs for the safe operation of the system.

The engineer has an important task to develop the codes for the PLC controllers for the operation units if the system mentioned above. This includes preparing the mathematical model, parameterization, optimization and analysis of control process and control circuits.
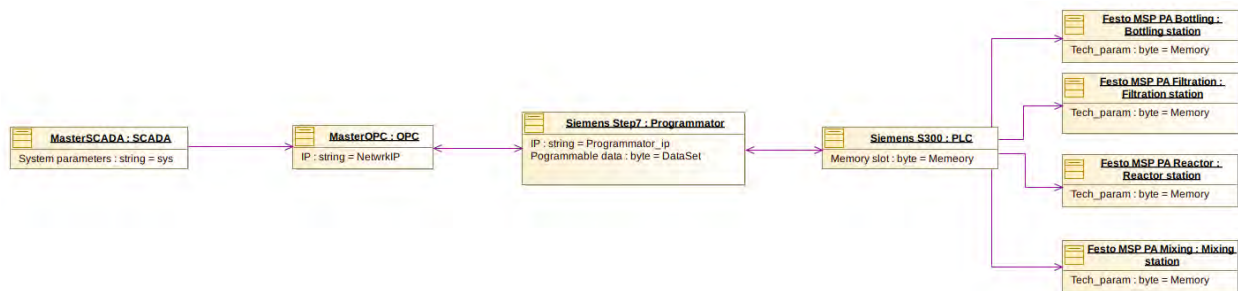
## 2.5   Class Diagram and Object Diagram:

**Filtration station**
+ Tech_param : byte

**Mixing station**
+ Tech_param : byte

**Reactor station**
+ Tech_param : byte

**Bottling station**
+ Tech_param : byte

+ PROFIBUS    0..1

**OPC**
+ IP : string
+ Connect()
+ Send Data()
+ Recieve Data()

**SCADA**
+ System parameters : string

+ sCADA API    0..1    0..1

**Programmator**
+ IP : string
+ Pogrammable data : byte
+ Read()
+ Write()
+ Debug()

+ USB    0..1    0..1

**PLC**
+ Memory slot : byte

+ MPI    0..1    0..1
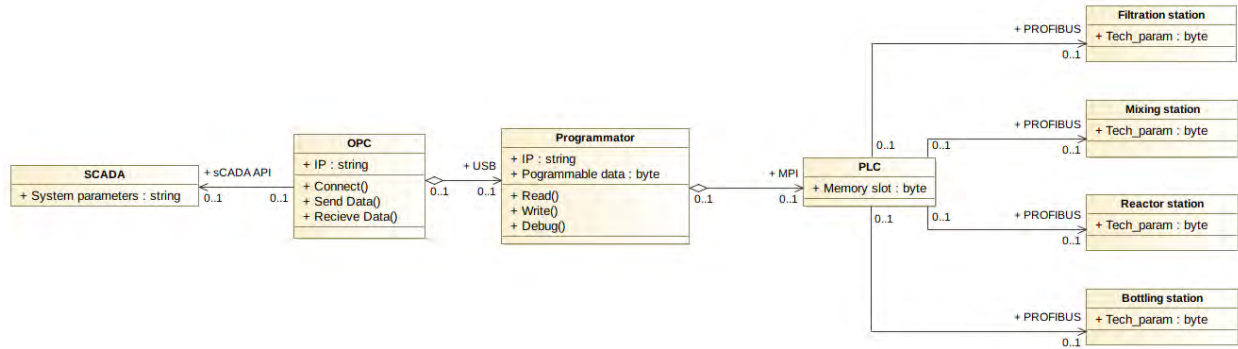
In engineering, a **class diagram** in the Unified Modeling Language (UML) is a type of static structure diagram that describes the structure of a system by showing the system's classes, their attributes, operations (or methods), and the relationships among objects.

In our case class diagram consists of 8 classes:

- SCADA class
- OPC class
- Programmator class
- PLC class
- Filtration station class
- Mixing station class
- Reactor station class
- Bottling station class

Each class connects witch each other through special interface, some of them are physical like USB or PROFIBUS, some of them just software like sCADA Api or MPI.

**Festo MSP PA Bottling : Bottling station**
Tech_param : byte = Memory

**Festo MSP PA Filtration : Filtration station**
Tech_param : byte = Memory

**Festo MSP PA Reactor : Reactor station**
Tech_param : byte = Memory

**Festo MSP PA Mixing : Mixing station**
Tech_param : byte = Memory

**MasterSCADA : SCADA**
System parameters : string = sys

**MasterOPC : OPC**
IP : string = NetwrkIP

**Siemens Step7 : Programmator**
IP : string = Programmator_ip
Pogrammable data : byte = DataSet

**Siemens S300 : PLC**
Memory slot : byte = Memeory

An **object diagram** in the Unified Modeling Language (UML), is a diagram that shows a complete or partial view of the structure of a modeled system at a specific time.

This object diagram is completely repeats our class diagram and show our system specification.

It consist of:

- MasterSCADA:SCADA
- MasterOPC:OPC
- Siemens Step7:Programmator
- Siemens S300:PLC
- FESTO MPS PA Bottling:Bottling station
- FESTO MPS PA Filtration:Filtration station

- FESTO MPS PA Reactor:Reactor station
- FESTO MPS PA Mixing:Mixing station

## 2.6   Activity Diagram

The Activity Diagram „Overview" gives the user an overview of the whole termination of the production line and the monitoring. It starts with powering up the system, followed by a check of prerequisites that are needed for the production line to work. If the prerequisites are not fulfilled an error message is published, the system waits for a specific time and then starts again until all prerequisites are fulfilled.

After the powerup different activities are happing simultaneously. Starting from left to right we first have the filtration, mixing, reacting and bottling processes that are explained in every station diagram in detail. In the middle we have a safety check to make sure that no tank is overflowing. If any of the float switches has contact, all pumps stop working and an error message is published.

On the right we have the monitoring process. It is separated into the different stations for better understanding and always running in a loop to keep the sensor information up to date. We limited the diagrams to the sensor information of the tanks and did not add the information of the valves and pumps, because they don't have separate sensors to check whether they are running or not so we can just use the control signals to monitor them.

Most of the tanks have three sensors integrated. Two capacitive proximity sensors (CP-sensors)  that can be manually attached to the tank. If they are actuated, the Liquid level in the tank is at the position of the sensor. If one CP-Sensor is mounted nearly the top and one nearly the bottom of the tank we can conclude whether a tank is full or empty, but no values in between. The third Sensor is the already mentioned float switch, that stops the pumps when the maximum capacity of the tank is reached. In the following this tank setup will be referred to as a standard tank setup.

In the filtration station are two tanks with each three sensors (standard tank setup). Based on the water levels they publish messaged whether they are full or not.

In the mixing station we have three tanks for the component liquids and one mixing tank. The first component tank and the mixing tank have standard tank setup. The first component tank is connected to the filtration station and can be filled from there automatically. The other two component tanks have only on CP-Sensor to send a signal, when they are empty so that they can be refilled manually. In this station we decided to add the valves of the different tanks in the monitoring, because they are relevant to monitor the correct following of the recipes.

In the reactor station is one tank with standard setup. It is connected to the mixing station and can be filled automatically. The liquid in the tank can be stirred, heated or cooled. It is monitored, which step is happening at the moment. There is also a thermometer installed to monitor the temperature inside the tank.

In the bottling station is one main tank that is connected to the reactor station and has a standard setup. A metering tank is installed as well with an acoustic sensor to monitor the level inside and conclude an exact amount of liquid to be filled into the bottles.

### 2.6.1 Filtration

The process starts with checking if the pure water tank is full. If the tank is filled, the water can either be directly pumped to the next station or can be used to clean the filter of the station. If the tank is empty it is checked whether the wastewater tank is full. If it is full the filtration process can start and keeps going until either the wastewater tank is empty and needs more water to filter or the pure water tank is full so one can decide whether to pump the pure water to the next station or flush the filter.

### 2.6.2 Mixing

The process has two simultaneous terminations taking place. One is to make sure that the component tanks are not empty and stops the process, if one of them is empty. The other is the mixing. It starts with checking if the component tanks are empty and request liquids if so. Then it checks if the mixing tank is full. If yes, the mixture can be pumped to the following station. If not, the mixture process can start. The amount of liquid is measured by the time that passes with the open valve and the running pump. The time is specified in the recipes. The first valve opens, the pump and the timer start. The second valve opens and the first one closes simultaneously and the timer starts again. Same with the second and third valve until the mixture is finished and can be pumped to the next station.

### 2.6.3 Reactor

First needs to be checked, if the tank is filled. If not, liquid is requested from mixing station. If yes, the reactor process can start according to the recipe and liquid can be stirred, heated or cooled until it is finished.
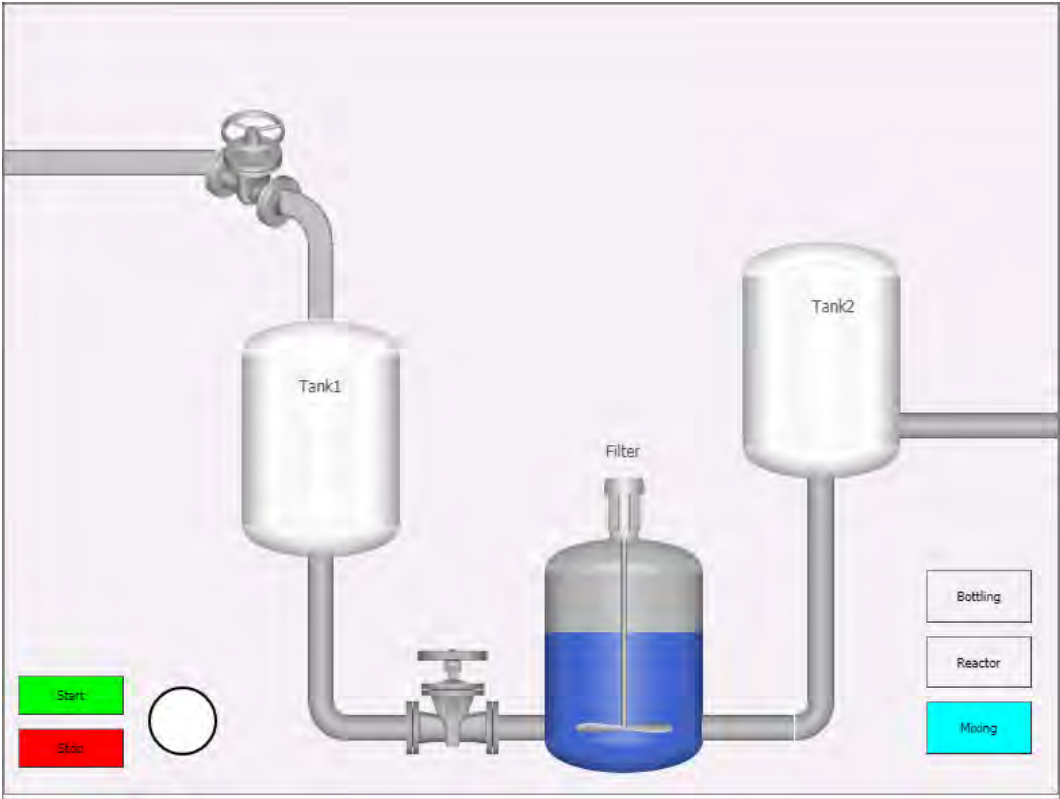
### 2.6.4 Bottling

First is checked if enough liquid is in the main tank. If not, liquid is requested from reactor station. Then the metering tank is checked, because if not empty the first bottle does not have the requested mixture and should be disposed.

To start the bottling the main tank is checked if full and if not liquid is requested from previous station, then if bottles are in line to be filled. Both have an error count to ensure that the system does not get stuck and shuts down automatically if no more bottles or liquid can be filled or bottled.
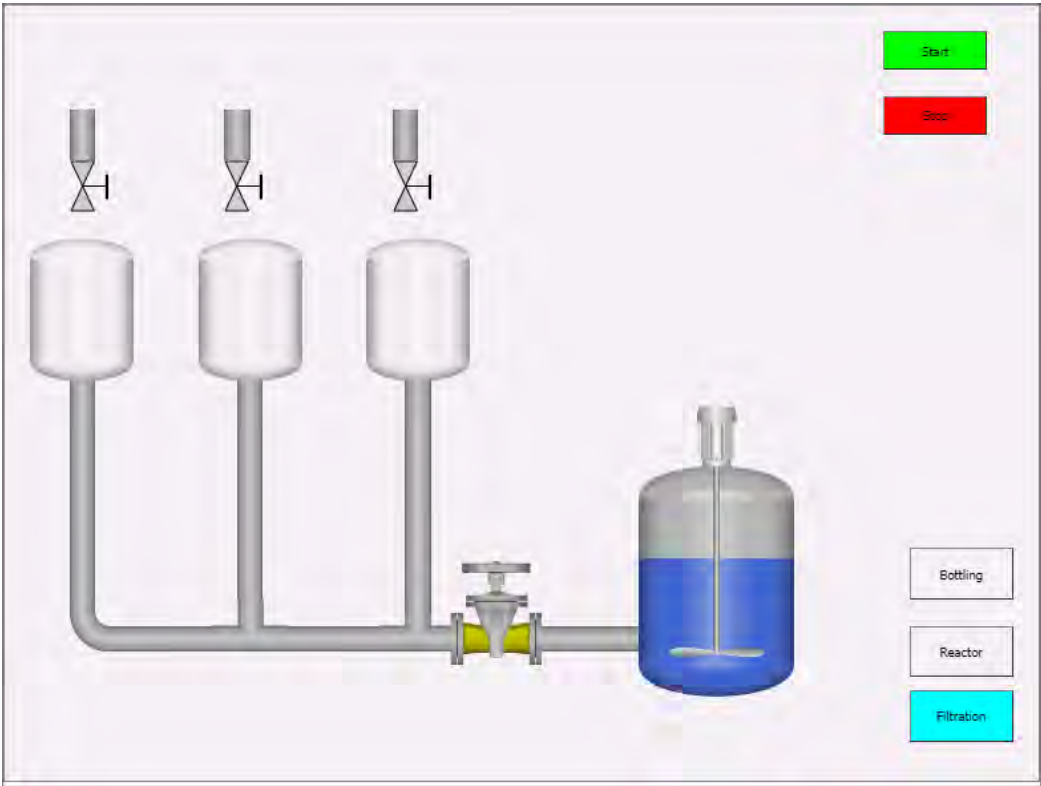
Then two simultaneous processes start. The liquid is pumped in the metering tank until the limit is reached while the first conveyer belt is started and the bottles are separated and placed under the metering tank. The bottle is filled and moved away by the second conveyer belt. The bottle count goes one up if the requested number of bottles is reached, the process terminates. Otherwise it keeps running until either bottles or liquid runs out.
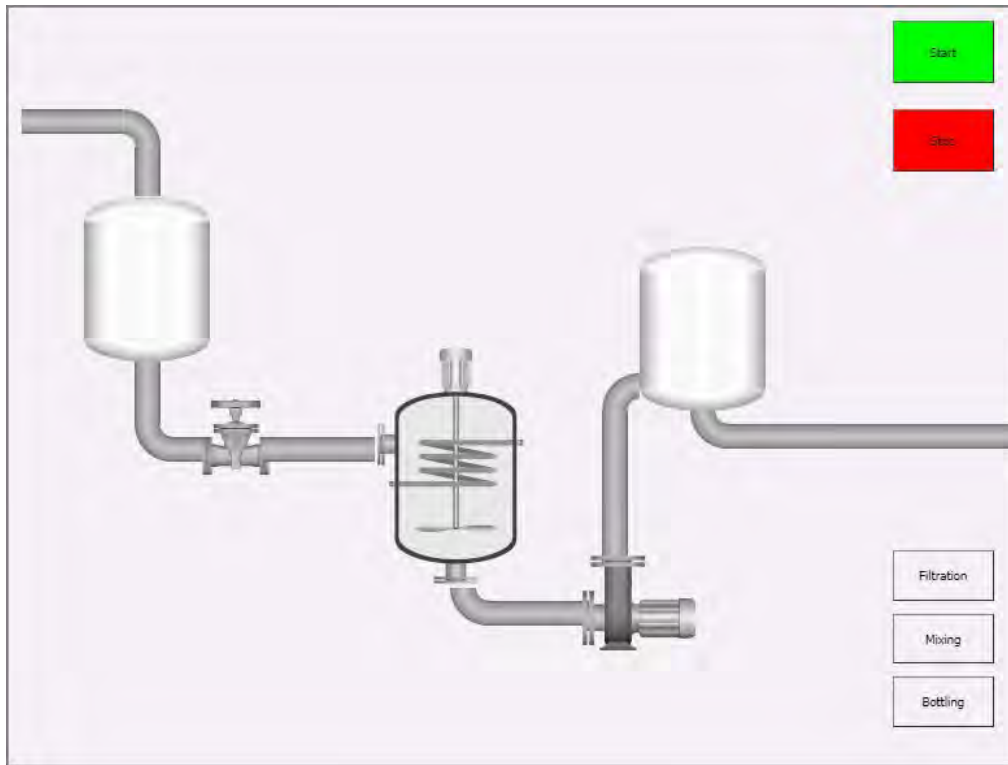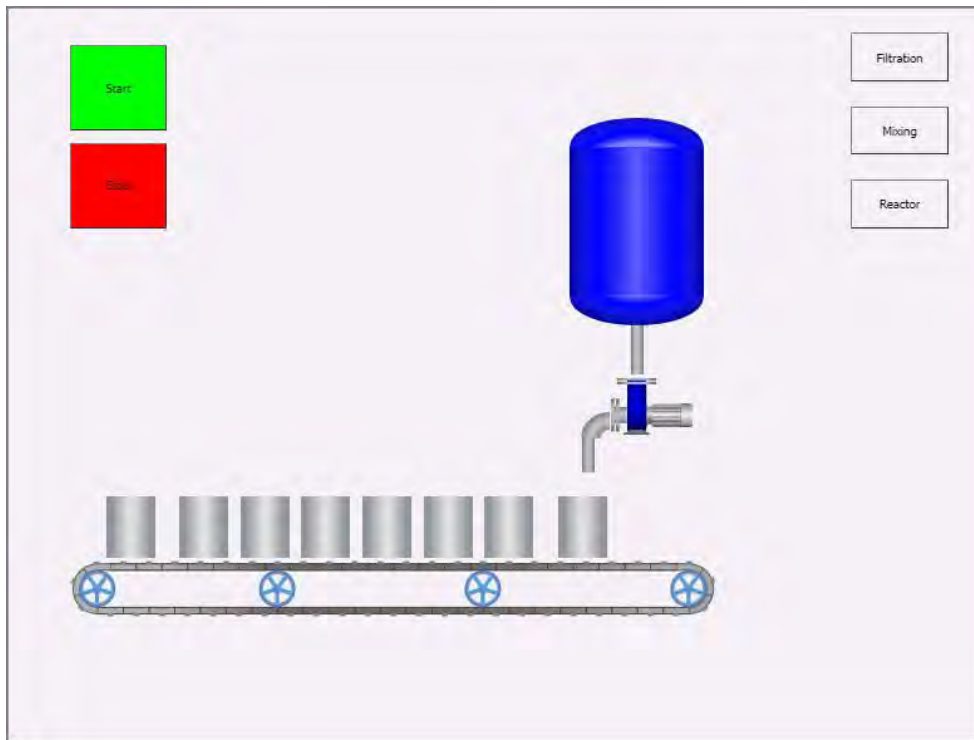
## 2.7    Demonstration of the MES system



Filtration

Mixing



Reactor



Bottling