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People's Democratic Republic of Algeria
Ministry of Higher Education and Scientific Research
University M'Hamed BOUGARA-Boumerdes

Faculty of Hydrocarbons and Chemistry

Final Year Thesis in Order to Obtain the Degree of

MASTER

In **Industrial Processes Automation**

Presented by

Oussama Bendahmane

Branche: Hydrocarbons
Major: Industrial Processes Automation: Automatic Control

Theme

Automation and Supervision of Sea Water Demineralisation Station of Ras Djinet Power Plant – Steam Turbine

Jury Members:

Kifouche	Rezki	MAA	UMBB	President
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Supervisor Favorable Opinion
Full Name: Karim Beddek
Signature:

Juries President Favorable Opinion
Full Name: Rezki Kifouche
Signature:

Stamp and Signature

Abstract

The work presented in this thesis involves utilising the programmable logic controller of Siemens, the SIMATIC S7-1500 and the Totally Integrated Automation (TIA) Portal V14 software to develop a program that reduces human dependency, enhances safety measures, and improves the reliability of the demineralisation station processes at the Ras Djinet power plant. Additionally, the project includes establishing supervision of the station through a human-machine interface (HMI).

Key Words: Programable logic controller, Demineralisation, SIMATIC S7-1500, Totally Integrated Automation (TIA) Portal V14, Human machine interface (HMI).

Résumé

Le travail présenté dans cette thèse implique l'utilisation d’automate programmable de Siemens, le SIMATIC S7-1500, et du logiciel Totally Integrated Automation (TIA) Portal V14 pour développer un programme qui réduit la dépendance humaine, améliore les mesures de sécurité et renforce la fiabilité des processus de la station de déminéralisation de la centrale de Ras Djinet. De plus, le projet comprend la mise en place de la supervision de la station par une interface homme-machine (HMI).

Mots-clés: Automate programmable, Déminéralisation, SIMATIC S7-1500, Totally Integrated Automation (TIA) Portal V14, Interface homme-machine (IHM).

ملخص

العمل الذي قدم في هذه الرسالة ينطوي على استخدام وحدة التحكم المنطقية القابلة للبرمجة من Siemens ، SIMATIC S7-1500 ، وبرنامج Totally Integrated Automation (TIA) Portal V14 لتطوير برنامج يقلل من الاعتماد على الإنسان ، ويعزز تدابير السلامة ، ويحسن موثوقية عمليات محطة إزالة المعادن في محطة رأس جنات الكهربائية. بالإضافة إلى ذلك ، يتضمن المشروع إنشاء وحدة إشراف على المحطة من خلال واجهة إنسان - آلة (HMI).

الكلمات المفتاحية: وحدة تحكم منطقية قابلة للبرمجة ، إزالة المعادن ، SIMATIC S7-1500 ، Totally Integrated Automation (TIA) Portal V14 ، واجهة إنسان - آلة.(HMI)

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Dedications

This hamble work is dedicated:

To my mother, your endless love, patience, and sacrifices have laid the foundation for my success. Your constant encouragement and belief in my potential have inspired me to reach for the stars. Your prayers have been my constant companions during the life ups and downs.

To my father, your constant support and wisdom have been invaluable. Your strength, dedication, and confidence in my abilities have motivated me to persevere and excel during all the stages of my life.

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List of Acronyms

AC: Alternative Current

AI: Analog Input

ALU: Arithmetic Logic Unit

AO: Analog Output

CPU: Central Processing Unit

DB: Data Block

DC: Direct Current

DI: Digital Input

DO: Digital Output

FBD: Function Block Diagram

FB: Function Block

FC: Function

HMI: Human Machine Interface

HP: High Pressure

IL: Instruction List

LAD: Ladder Diagram

LP: Low Pressure

MP: Medium Pressure

OB: Organisation Block

PLC: Programmable Logic Controller

PROFIBUS: Process Field Bus

PROFINET: Process Field Network

PS: Power Supply

SFC: Sequential Function Chart

SIMATIC: Siemens Automatic

ST: Structured Text

TFT: Thing Film Transistor

TIA: Totally Integrated Automation

WinCC: Windows Control Centre

General Introduction

General Introduction

Since the dawn of civilization, humans have continually sought ways to improve their lives. Early innovations focused on basic survival needs, such as the development of tools for hunting and farming. As societies evolved, the quest for better living conditions drove the invention of more complex technologies. The discovery and harnessing of energy sources marked a significant leap in this journey, fundamentally transforming human life.

Electricity, in particular, has played a crucial role in enhancing our daily lives. Its introduction revolutionized industries, healthcare, communication, and household conveniences, making it indispensable. Today, electricity powers almost every aspect of modern life, from lighting our homes to enabling advanced technological innovations.

Electricity is generated from various sources, each contributing uniquely to the energy grid. Traditional sources include coal, natural gas, and oil, while renewable sources like wind, solar, and hydroelectric power are increasingly prevalent.

In our case, we completed our final year project at the Algerian Electricity Production Company (SPE), a subsidiary of the SONELGAZ group, within the Cap-Djinet Steam Thermal Power Plant. This power plant plays a crucial role in the national electricity production network, providing a useful power output of 704 MW through its four generation units. The plant operates by transforming seawater from its liquid phase into hot steam to power the four units. Before the seawater is converted into steam, it undergoes a treatment phase due to its physicochemical characteristics: high conductivity from significant salinity, dissolved oxygen, etc. In the water-steam cycle, this steam contacts metallic surfaces of varying compositions, such as turbines, superheaters, and condensers, which are highly sensitive to water quality and require protection. One of the treatment steps is demineralisation, which is the focus of our work.

The demineralisation process involves mixed bed filters where chemical reactions produce demineralised water ready for storage and use. These filters, however, become saturated after a period of operation and require regeneration. Post-regeneration, the water discharged from this process does not go directly to the sea; it first passes through a neutralisation pit to adjust its acidity and pH to meet environmental standards before being discharged.

The major issue we identified was the use of manual control in managing processes like filtration, regeneration, and neutralisation. Manual control often poses accident risks for personnel and fails to ensure the efficiency of processes, leading to time and financial losses as well as environmental damage. In addition to that, we noticed a lake of some safety measurement such as emergency shutdown, valves limits switches use and pumps and air boosters failure feedback signals.

Our project aimed to study the detailed functioning of the demineralization station and replace the existing manual control with a high-performance Programmable Logic Controller (PLC) system (Step7 - 1500), incorporating functional and safety improvements. Additionally, we aimed to implement a supervisory system using WinCC RT Professional software to enhance system reliability, performance, and operational efficiency.

Our work is divided into five chapters:

- **Chapter I:** Introduces the Cap-Djinet power plant, emphasizing the water-steam cycle's operational principle.
- **Chapter II:** Details the demineralisation station, its equipment, and the functioning principles of filtration, regeneration, and neutralisation processes.
- **Chapter III:** Discusses the generalities of PLCs and the hardware configuration chosen for our automated solution.
- **Chapter IV:** Focuses on programming, specifically using TIA Portal V14, and highlights examples of our program.
- **Chapter V:** Concludes with the realisation of a supervisory system, explained in detail.

The culmination of our thesis presents a general conclusion.

Chapter I

Ras Djinet Power Plant Overview

I.1. Introduction

In this chapter, we delve into the comprehensive process of generating electrical energy at the Cap Djinet power plant. We provide an in-depth exploration of the substations, circuits, and instruments integral to this procedure, elucidating their respective functions and significance. Through this detailed examination, we aim to offer a comprehensive understanding of the intricacies involved in the production of electrical energy at the plant.

I.2. Historical Background

The Ras Djinet thermal power plant was built by an Austro-German group, SIEMENS-SOP, which was responsible for studies, supervision of assembly and control of the project, and by a Spanish company, DRAGADOS, which was entrusted with the construction of the sea water intake.

The main Algerian companies involved in the construction of the power station are: GENIE SIDER, ENCC, ETTERKIB, INERGA, SNLB, PROSIDER, ENATUB, SNIC, GTP, SONATRAM and SOGEP.

As the main contracts were signed in 1980, groundworks started in 1981 and assembly work began in 1984.

A. The main operations are carried out according to the following schedule:

- Civil engineering works: **1984- 1985.**
- Mechanical installation: **1984- 1986.**
- Electrical installation: **1984- 1986**.

B. The production units were commissioned as follows:

- Group 1 in December **1985.**
- Group 2 in April **1986.**
- Group 3 in September **1986.**
- Group 4 in December **1986.**

The Ras Djinet power station, with a capacity of 672 MW (704 at full load), was commissioned in 1986. It consists of 4 steam-thermal monoblocs, each with an output of 176 MW. The first electricity was supplied to the grid on 17 June 1986.

I.3. Location

The Ras-Djinet thermal power plant is located on the eastern coast of Algiers, near the town of Ras-Djinet in the state of Boumerdes. With a surface area of 35 hectares, it is 25 km from the centre of the state and 75 km from Algiers. (Figure I.1)

Figure I.1: Satellite View of the Ras Djinet Power Plant

I.3.1 Choice of Site

The choice of site was based on the following criteria:

- Proximity to the sea.
- Proximity to major consumers, particularly in the Rouiba - Reghaia industrial zone.
- Potential for expansion.
- Favourable subsoil conditions requiring no deep foundations.

I.3.2 Metrological Data

The location of the plant is exposed to a Mediterranean climate, characterised by a high degree of humidity in both summer and winter. The area is exposed to water spray and has no protection against the wind.

The location is considered dusty. Average environmental conditions are as follows:

- Maximum temperature **45°C**
- Minimum temperature **0°C**
- Average project temperature **20°C**
- Air humidity **55% - 80%**
- Average rainfall **750 mm**

I.4. Operation of the Ras Djinet Thermal Power Plant

In the "water-steam" transformation cycle, seawater, after being treated by the desalination and demineralisation units, will be sent to the buffer tank and then to the condenser. The water leaving the condenser passes through the LP heater to reach the feed tank (110°C). The feed tank supplies the boiler through the feed pumps, sending the water at 160 bars of pressure to the boiler tank, passing through the HP heater at a temperature of 240°C, then through a control valve that regulates the water level up to 350°C.

The water from the tank passes through the lower collectors of the evaporator. The saturated steam (a mixture of water and steam) rises in the membrane wall-heated risers to the upper collectors, then returns to the tank at 350°C and 160 bars, where the steam is separated from the water in cyclones. The water will be reused in the evaporation circuit while the steam will pass through superheater No. 1, then to superheater No. 2, and finally to superheater No. 3. The steam exiting superheater No. 3, known as dry steam, has a temperature of 540°C and a pressure of 160 bars, and then enters the HP body which contains 4 steam inlets.

At the outlet of the HP body, the steam expands at a temperature of 350°C and a pressure of 38 bars, to increase its temperature again to avoid premature condensation. It passes through the reheat heaters 1 and 2, then successively through the MP and LP bodies of the turbine to reach the condenser at 0.1 bars, and is then recovered through the circulation of cold water from the sea. (Figure I.2)

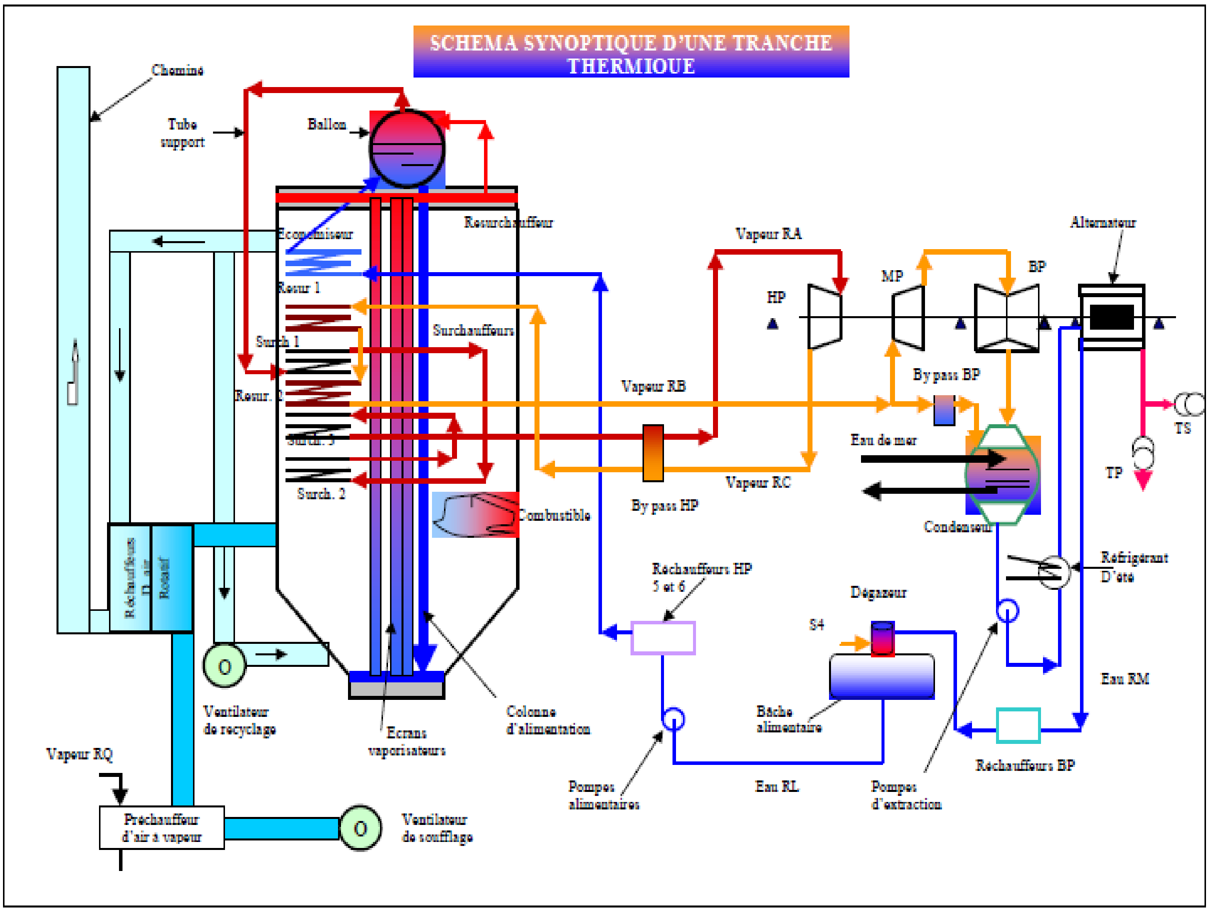


Figure I.2: Synoptic Diagram of a Thermal Unit

I.5. Stations and Components of the Power Plant

The Ras Djinet power station consists of four generating units (turbo-alternator groups), each capable of producing 176 MW, with common auxiliary facilities for all four groups. These facilities are essential for the Ras Djinet station to operate smoothly and maintain continuous production

I.5.1 Seawater Filtration and Pumping Station

The Ras Djinet power plant operates on a water-steam transformation cycle, requiring water as a crucial resource to generate the high-power output expected from the Cap-Djinet plant (up to 704 MW). Additionally, the plant requires significant amounts of cooling water to dissipate residual heat, necessitating approximately 30 m3/s. This cooling water is sourced from the pumping station.

The seawater pumping and filtration station is situated at a depth of approximately 7 meters in the Mediterranean Sea. The water intake, positioned 900 meters from the coast, is connected to the pumping station through three concrete pipes with a diameter of 2.70 meters.

The pumping station is divided into four (04) filtration channels, each equipped with a screen and a filtering drum. The materials trapped by the screen and those trapped by the filtering drum are conveyed by a discharge channel into the waste collection basket. The main circulation pumps are installed at the end of the filtration channels. The draw-off chambers are located between these channels.

The two outer chambers are used to feed the desalination plant via the transfer pumps, and each includes a feed pump for the chlorination station. A fire extinguishing pump is installed in the middle chamber.

The reheated water (after heat exchange at the condensers) is discharged via a common discharge channel for the four (04) units.

I.5.2 Desalination Station

The plant requires around 1,100 m3 of desalinated water per day. It comprises four (4) units operating on the principle of expansion distillation in 18 stages. Each unit produces 500 m3 of desalinated water per day, stored in two tanks with a capacity of 2,700 m3 each. Each unit can operate independently, but three units are generally used, with the fourth serving as a reserve. In exceptional situations, all four units can operate simultaneously. (Figure I.3)

Figure I.3: Desalination Station

I.5.3 Demineralisation Station

Before being used in the steam water cycle, the desalinated water undergoes further treatment in two demineralisation lines, each with a capacity of 40m3/h and using mixed cationic and anionic resin filters. The demineralised water is then stored in two tanks, each capable of holding 1,500 m3. (Figure I.4)

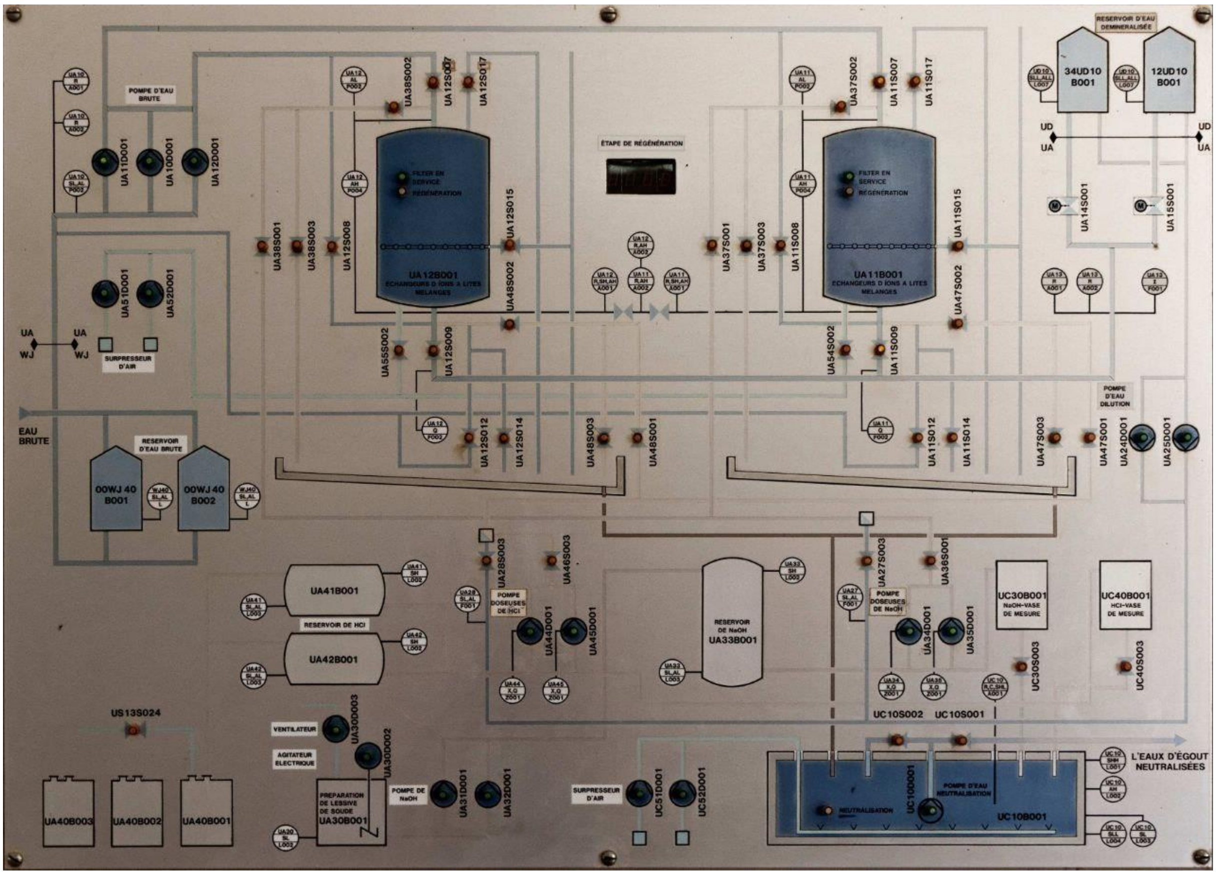


Figure I.4: Demineralisation Station

I.5.4 Hydrogen Production Station

To cool the plant's four alternators, hydrogen is produced using a gas installation that includes an electrolyser (Figure I.5) supplied with water (electrolyte) and subjected to an electric current. The alternative current (AC) mains supply is first reduced to a lower voltage by a step-down transformer, then converted to direct current (DC) before being fed to the electrolyser.

The process generates hydrogen and oxygen in a 1:2 ratio. The oxygen is released into the atmosphere, while the hydrogen is compressed and stored.

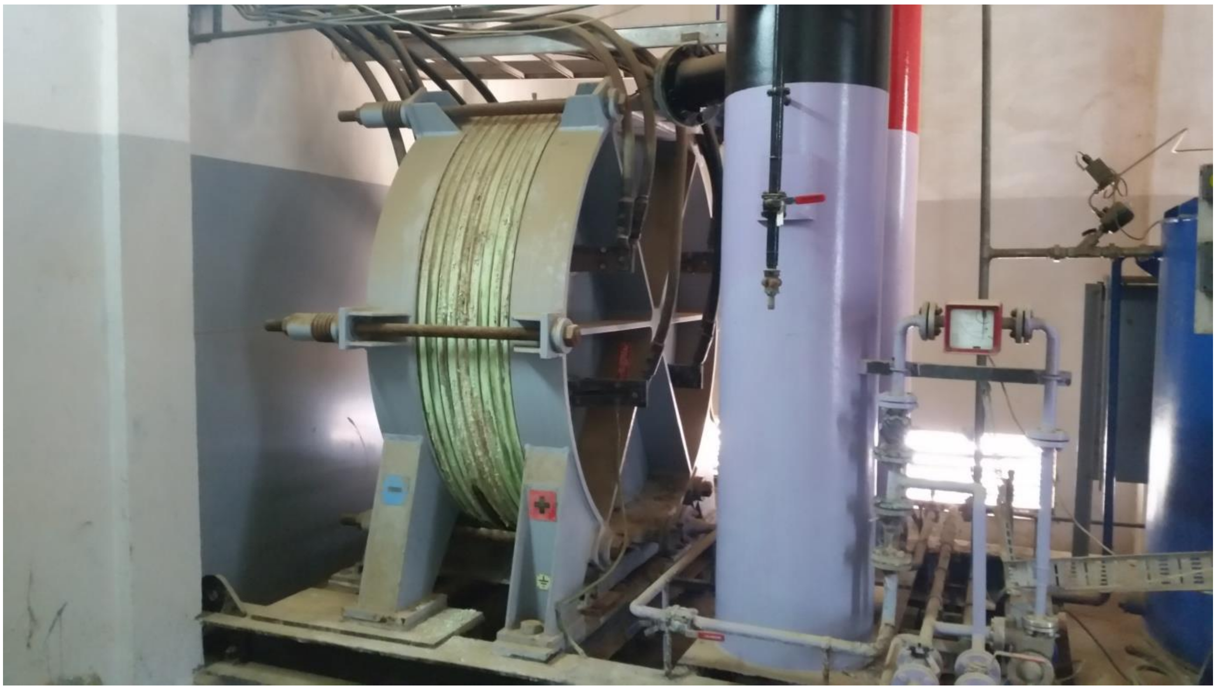


Figure I.5: Electrolyser

I.5.5 Fuel System

The Cap-Djinet power station can use either natural gas or fuel oil for fuel. Natural gas is usually the main choice, with fuel oil as a backup.

I.5.5.1 Gas Pressure Reducing Station

The gas pressure reduction station's purpose is to supply the power plant's boilers with gas at a moderate pressure.

The gas pressure reduction station receives gas at high pressure, typically 20, 30, 50, up to 60 bars, and reduces it to a moderate 5-6 bars before supplying it to the power plant's boilers.

I.5.5.2 Fuel Transfer Circuit

The transfer circuit consists of multiple supply lines, each featuring several pumps. Each pump is equipped with a suction filter and a discharge non-return valve, along with a set of isolation valves.

I.5.5.3 Fuel Oil System (Backup)

Fuel oil serves as an emergency fuel at the power station. It is transported by truck from the refineries and stored in two 10,000 m3 tanks. The fuel oil is distributed to boilers and other consumers using the same method as gas.

I.5.5.4 Boiler

The boiler is a crucial component of the thermal circuit, responsible for converting feedwater into high-pressure, high-temperature steam. The Ras-Djinet boiler is of the natural circulation type.

Boiler Characteristics

- Spray capacity: **540 t/h.**
- Feed water temperature: **246°C.**
- Operating pressure: **160 bar.**
- Steam flow rate: **523 t/h.**
- Smoke outlet temperature: **118°c.**
- Furnace temperature: **900°c.**

I.5.6 Water System

I.5.6.1 Economizer

The economizer is a vital component of the boiler system, serving as a heat exchanger. It recovers heat from the combustion gases and transfers it to the feed water, which has already been preheated. This process increases the feed water's temperature before it returns to the boiler tank. During the boiler's startup, the economizer receives cold water through a large surface area of approximately 2080 m2 of serpentine piping. This arrangement, located at the end of the combustion gas path, helps to heat the water destined for the boiler tank.

I.5.6.2 Boiler Tank

This is a tank placed above the combustion chamber, which contains water in liquid form from the economizer feeding the vaporising screen tubes and water in vapor form from the screen tubes feeding the superheaters.

After heating, a water-steam mixture rises towards the tank. In the tank, the steam and water are separated by cyclone separators.

Boiler Tank Characteristics

- Operating pressure: **160 bars.**
- Temperature: **347.5°c**
- Water volume: **26.9 m3**

I.5.6.3 Downpipes and Screen Pipes

The downpipes connect the bottom of the tank to the lower part of the vaporizing screens, letting water flow down naturally. In the screens, water is heated by radiation and partly turned into vapor. The vaporizer tubes are sealed tightly and make up the second heating surface after the economizer.

Downpipes and Screen Pipes Characteristics

- Heating surface: **1980 m2**
- Stamp: **172 bars.**
- Operating pressure: **160 bars.**
- Water volume: **37 m3.**
- Number of downpipes: **4**

I.5.7 Steam System

I.5.7.1 Superheaters

Three superheaters are arranged in separate parallel lines, with two desuperheaters following the first and second superheaters. These desuperheaters help protect the latter from excessive temperatures and maintain a consistent outlet temperature in the boiler. Steam from the boiler tank passes through the superheaters to enhance the installation's efficiency. The flow rate of superheated steam is 523.9 tonnes per hour.

I.5.7.2 Resuperheater

Following the initial expansion in the high-pressure turbine casing, steam flows through the resuperheater tubes where its temperature increases again, while the expansion pressure stays constant. The steam is then directed to the second section of the turbine, consisting of the medium-pressure and low-pressure casings. The flow rate of resuperheated steam is 467.9 tonnes per hour.

I.5.7.3 Desuperheaters

These droplets are supplied with water from the feed pump, which helps stabilize the temperature of the steam at the outlet. They are positioned between the superheaters and the reheaters.

I.5.8 Air and Smoke System

This system is designed to supply combustion air, heat it through heat recovery, and recycle a portion of the flue gases. It consists of:

I.5.8.1 Combustion Air Fans

These fans are responsible for delivering the necessary air for combustion (natural gas or fuel oil) to the steam generator.

I.5.8.2 Rotary Air Preheater

The rotary air preheater is used to heat the combustion air by recovering heat from the flue gases.

I.5.8.3 Flue Gas Recirculation Fans

Each unit is equipped with two flue gas recirculation fans. They draw a portion of the combustion gases from the boiler outlet (before the rotary air preheater) and inject them into the lower part of the combustion chamber. This system improves efficiency, especially at low loads.

I.5.9 Burner System

The steam generator is equipped with eight (8) burners, running on natural gas and light fuel oil. These burners are arranged in four stages on the front of the boiler. They include various types, such as gas and fuel oil burners, as well as ignition burners.

I.5.10 Combustion Chamber (Firebox)

This is the central component of the boiler, where combustion and heat exchange processes occur to produce steam.

I.5.11 Chimney

The chimney of the steam generator is tall to prevent combustion gas from being drawn back down and to disperse the gases into the atmosphere effectively.

I.5.12 Water System

The water system consists of all components from the turbine's exhaust to the economizer's inlet, and includes the following parts:

I.5.12.1 Condenser

This heat exchanger condenses the steam from the turbine's low-pressure section, which has already been used to generate electricity.

I.5.12.2 Extraction Pumps

These pumps move the main condensate from the condenser to the feed tank, passing through the low-pressure heaters, summer coolers, and hydrogen coolers.

I.5.12.3 Low Pressure /High Pressure Heaters

These heaters preheat the extraction water or feedwater.

I.5.12.4 Degasser

The degasser removes oxygen, carbon monoxide, and carbon dioxide from the extraction water at the feed tank inlet to prevent corrosion.

I.5.12.5 Feed Tank

The feed tank acts as a heater and conditions the pressure at the feed pump intake. It is a cylindrical tank combined with a degasser. It receives water from the extraction pumps, which passes through a number of heaters. (Figure I.6)

It also receives steam from the draw-off (S4) which comes from the MP (medium pressure) body. The water heats up to the saturation temperature corresponding to the extraction pressure, condensing the steam taken from the turbine.

Figure I.6: The Feed Tank

I.5.12.6 Feed Pumps

This system, including pumps, motors, and couplers, supplies water to the boiler from the feed tank. Each production unit has three identical feed pumps, with two in operation during normal conditions, each providing 50% of the required water flow, while the third serves as a backup.

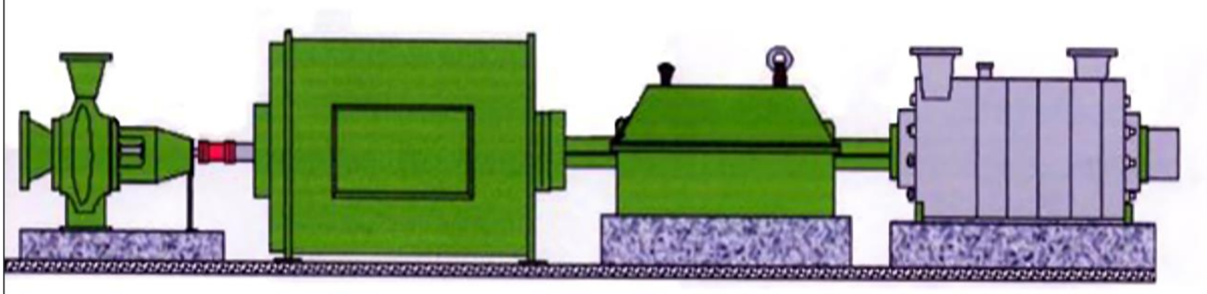


Figure I.7: Illustration of a Feed Pump

I.5.13 Turbine

The turbine is a crucial component that converts the thermal energy of steam into mechanical energy. It is a device that allows a fluid to expand, capturing its energy in mechanical form. This machine is vital in power plants as it transforms the thermal energy from steam into a rotating motion of the shaft, which in turn drives the alternator.

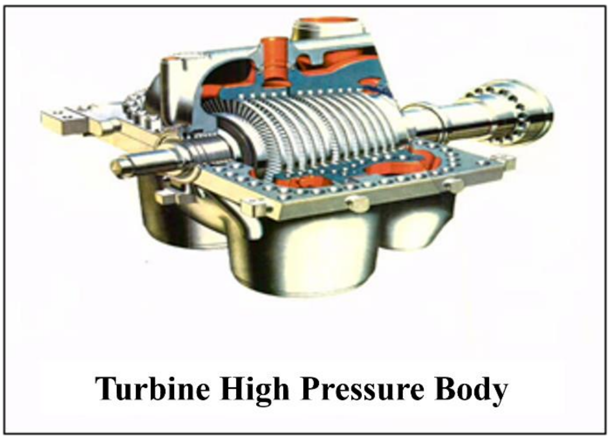
This particular turbine is a single-shaft machine, consisting of separate bodies for High Pressure (HP), Medium Pressure (MP), and Low Pressure (BP). It features six bleeders that supply three Low Pressure reheaters, two High Pressure reheaters, and the feed tank. The rotors of the turbine and alternator are rigidly connected.

Turbine Characteristics

- Length: **16.125 m**.
- Width: **13 m.**
- Weight: **500,103 kg**.
- Rotation speed: **3000 rpm.**
- Power: **176 MW** (full load).

A. HP body: this is a single flow body with an S6 outlet which feeds the high-pressure heaters (HP6).

- Body inlet: Pressure: **138 bar.**
  Temperature: **540°C.**
- Body outlet: Pressure: **40 bar.**
  Temperature: **357°C.**



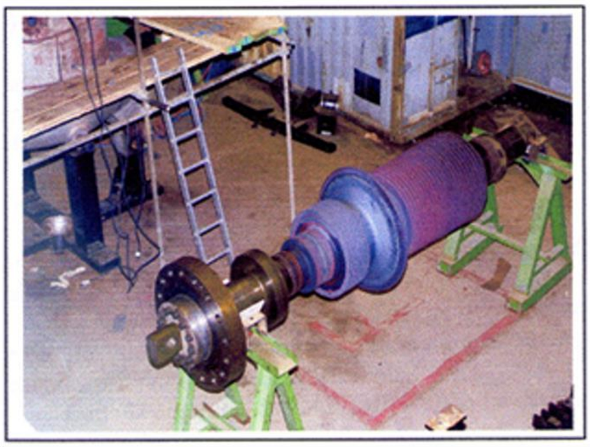


Figure I.8: Turbine High Pressure Body

B. MP body: double flow with two tapings S5 and S4.

- Body inlet: Pressure: **35.9 bar.**
  Temperature: **535°C.**
- Body outlet Pressure: **5.52 bar.**
  Temperature: **282°C.**
- Decanter S5 feeds the high-pressure heater (HP5) at a temperature of 423°C and a pressure of 16.5 bar.
- Tap S4 feeds the feed tank with a temperature of 282°C and a pressure of 5.5 bars.

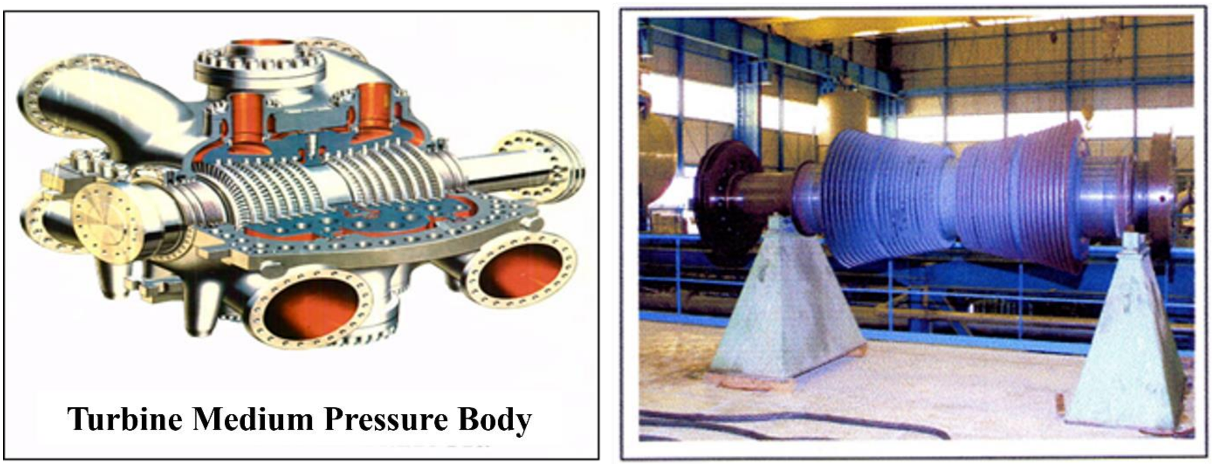


Figure I.9: Turbine Medium Pressure Body

C. **LP body:** this is a double-flow body with three draw-offs. The inlet to this body is connected directly to the inlet to the MP body by a pipe.

- Tap (S3): feeds the 3rd reheater (BP) with a temperature of 173°C and a pressure of 1.77 bar.
- Draught (S2): feeds the 2nd reheater (BP) with a temperature of 89°C, and a pressure of 0.65 bar.
- Withdrawal (S1): feeds the 1st reheater (BP) with a temperature of 56°C, and a pressure of 0.15 bar.

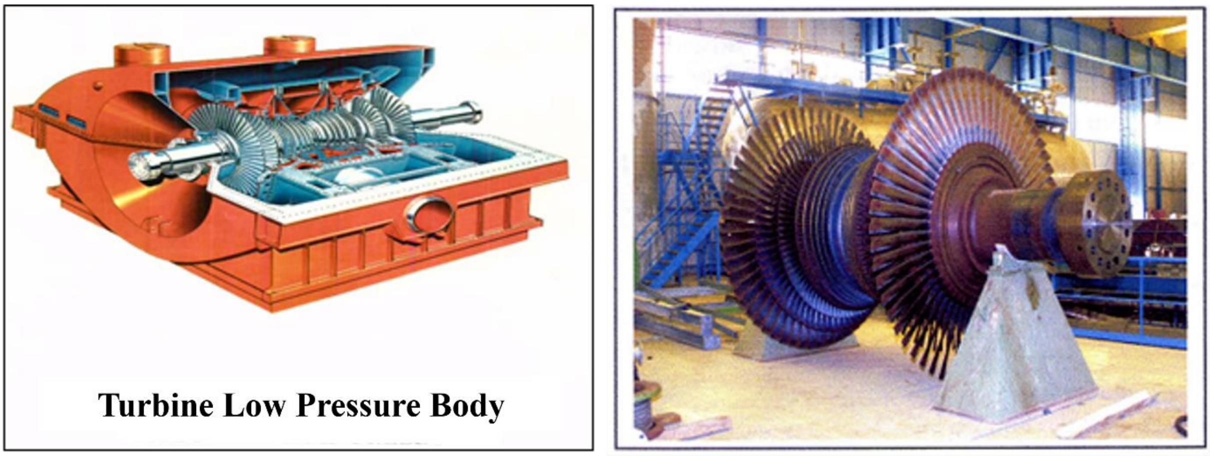


Figure I.10: Turbine Low Pressure Body

I.5.14 Alternator

It converts the mechanical energy produced by the turbine shaft into electrical energy (Figure I.11). It is a smooth pole alternator and the electrical current generated is a three-phase alternating current with the following characteristics:

- Maximum power output: **176 MW.**
- Voltage: **15.5 KV.**
- Frequency **50 Hz.**
- Current intensity **8195 A.**

Figure I.11: The Alternator

I.5.14.1 Excitation System:

The alternator excitation unit comprises:

- A permanent magnet pilot exciter
- A three-phase main exciter
- A rotating diode wheel
- A voltage regulation cabinet (JK)

I.6. Conclusion

Throughout this chapter, we've deepened our understanding of the intricate stages and transformations necessary for electricity generation, alongside the pivotal roles played by each component in these complex processes. We've also highlighted the significance of auxiliary systems in the production cycle and underscored the critical nature of treated water and its treatment process for seamless plant operation. Moving forward, our focus will shift to the demineralisation plant, where we will delve into its definition and explore the diverse processes it employs.

Chapter II

Demineralisation Station Overview

II.1. Introduction

This chapter covers the demineralisation station, an essential facility in water treatment that produces treated water for power generation and cooling operations. We will explore the principles of demineralisation and the various instruments and equipment used to demineralise water at the Ras Djinet power plant.

II.2. General Concepts

II.2.1 Demineralisation

Water demineralisation involves the elimination of almost all inorganic salts through ion exchange. During this process, a strong acid cation resin in its hydronium form converts dissolved salts into acids, while a strong base anion resin in its hydroxide form eliminates these acids.

II.2.2 Demineralisation Equations

The equations involved in demineralisation, specifically in the context of water treatment using ion exchange processes, include:

- Cation Exchange Reaction:
  $R\text{-}H + Na^+ \rightarrow R\text{-}Na + H^+$
- Anion Exchange Reaction:
  $R\text{-}OH + Cl^- \rightarrow R\text{-}Cl + OH^-$

These equations represent the fundamental ion exchange reactions that occur during the demineralization process. Cations like calcium, magnesium, and sodium are removed by hydrogen ions (H^+) in the cation exchange, while anions such as sulphates and chlorides are removed by hydroxyd ions (OH^-) in the anion exchange.

II.2.3 Regeneration

The regeneration process in ion exchange involves restoring the functionality of exhausted ion-exchange resins by removing the ions that have been picked up during the service run.

II.2.4 Regeneration Equations

- Cation Exchange Regeneration:
  $R\text{-}Na + H^+ \rightarrow R\text{-}H + Na^+$

- Anion Exchange Regeneration:
  $R\text{-}Cl + OH^- \rightarrow R\text{-}OH + Cl^-$

These equations represent the reversible ion exchange reactions that occur during the regeneration process.

During the service run, the resin exchanges its hydrogen (H^+) or hydroxide (OH^-) ions with the cations or anions in the feed solution, respectively. To regenerate the resin, a highly concentrated solution of the counter-ions (Na^+ for cation exchange, Cl^- for anion exchange) is introduced. This forces the reaction to reverse, displacing the adsorbed ions and restoring the resin to its original ionic form (R-H or R-OH).

The regeneration process is crucial to restore the ion exchange capacity of the exhausted resin so it can be reused for further demineralisation cycles.

II.2.5 Neutralisation

Neutralisation is a process used to adjust the pH of wastewater to a neutral level (around pH 7) before discharging it into the environment or sending it for further treatment.

The process involves adding acids or bases directly to the wastewater flow. Common chemicals used include:

- Bases: sodium hydroxide (NaOH), lime milk ($Ca(OH)_2$), magnesium hydroxide
- Acids: sulfuric acid (H_2SO_4), hydrochloric acid (HCl), carbon dioxide (CO_2)

II.3. Mixed-bed Demineralisation Unit

The process of water demineralisation using a mixed-bed involves using special cation and anion exchange resins to remove dissolved ions from water, replacing them with different ions of the same charge. This process results in the production of high-purity water with extremely low levels of dissolved solids and ions.

The demineralisation station at the Ras Djinet power plant treats the water used to supply its four boilers. It uses distillate from seawater desalination units, with a maximum salt content of 20 mg/l in the form of NaCl and a maximum temperature of 40°C. The plant is equipped with two mixed-bed filters (Figure II.1), each capable of treating 40 m^3/h, generally operating in alternating mode, with one used for demineralisation and the other kept in reserve. The demineralised water is stored in two tanks, each with a volume of 1,500 m^3, and must meet the quality requirements for high pressure steam boiler make-up water.

Figure II.1: Mixed Bed Filters

II.4. Purpose of the Unit

The goal of demineralisation is to generate purified water with an electrical conductivity below 0.1 µS/cm and a silicic acid (SiO_2) content below 0.02 mg/L. The two mixed-bed demineralisation filters each have a capacity of 40 m^3/h, totalling 80 m^3/h. The purified water is first stored in 1500 m^3 tanks before being transferred to a buffer tank to supply the boiler and a small quantity for drinking water consumption.

II.5. Components of the Demineralisation Station

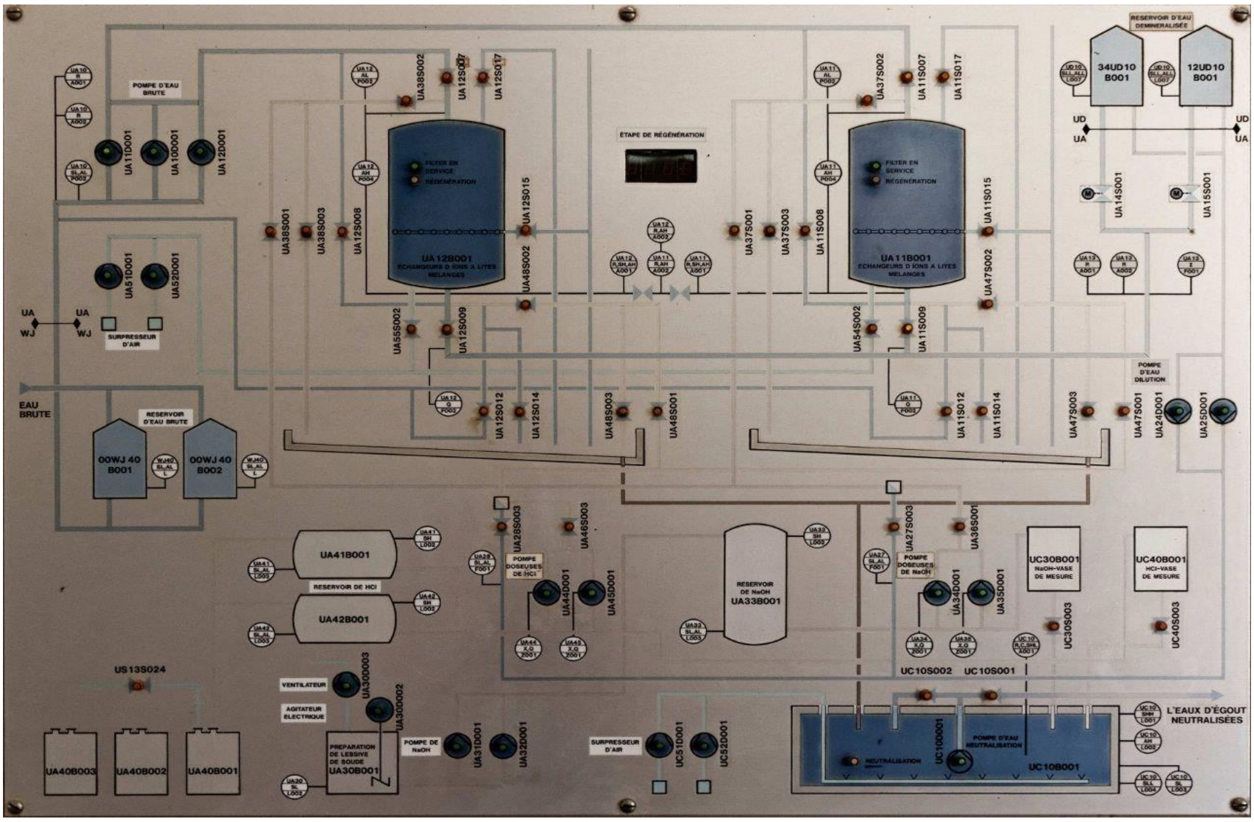


Figure II.2: Demineralisation Station Illustration

The demineralisation station is equipped with various instruments and components to ensure its efficiency and reliability. These components include:

II.5.1. Equipment

Table II. 1: Demineralisation Station Equipments

Equipment	Quantity	Alpha-Numeric Symbol
Mixed Bed Filter	2	UA11B001
		UA12B001
HCl Reservoir	2	UA41B001
		UA41B002
NaOH Reservoir	1	UA33B001
NaOH Preparation Reservoir	1	UA30B001
Neutralisation Pit	1	UC10B001
Neutralisation HCl Reservoir	1	UC40B001
Neutralisation NaOH Reservoir	1	UC30B001

II.5.2. Sensors:

A sensor is a device or component that detects variations or events in its environment and transmits this data to other electronic systems, often a computer processor. It converts the physical changes into a numeric signal that can be observed, interpreted or analysed.

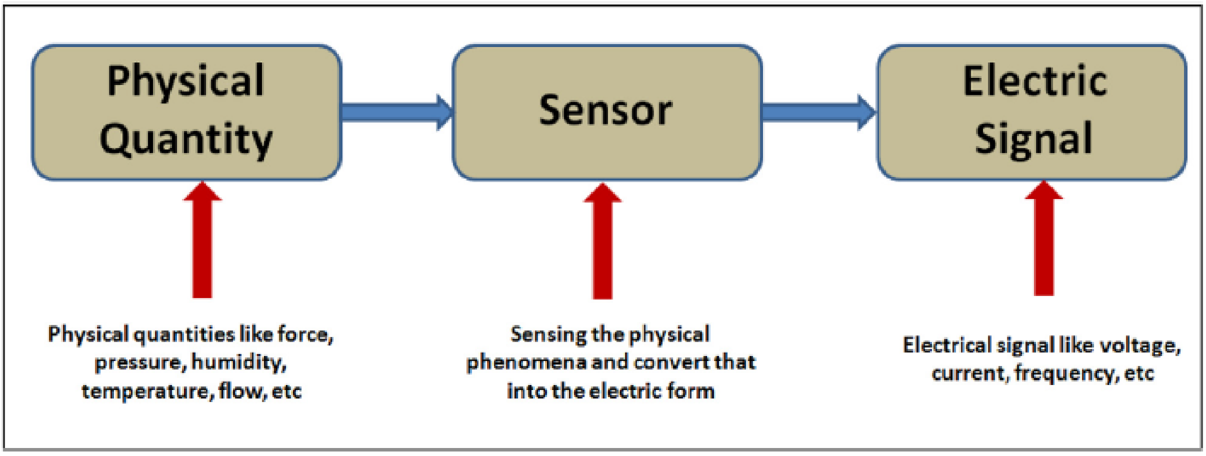


Figure II.3: Illustration on Sensors Working

The sensors used in the demineralisation station can be divided into two groups based on their output signal:

- **Analog Sensors** work by processing analogue information, which represents quantities that change continuously over time and can take on an infinite range of values. The signals produced by these sensors, standardised as currents, are generally from 4 to 20 mA.
- **Digital Sensors** operate on a binary principle, are designed to process simple, easily interpretable logical information. These sensors generate signals with two possible states: 0 or 1. The output signals, standardised in voltage, are either 0V or 5V, where 0V indicates a false state (0) and 5V a false state (1).

II.5.2.1. Conductivity Sensor

A conductivity meter is a device that measures the conductivity of a solution. It consists of an electronic box that displays the conductivity value and a cell that takes the measurement. To avoid polarisation of the electrodes, the measurement is made using alternating current.

The conductivity meter measures the electrical voltage at the terminals of the cell immersed in the solution to be measured, as well as the intensity of the current flowing through it.

The cells used for measurement consist of two parallel conductive plates of cross-section ‘S’, separated by a distance ‘L’. A parameter called the cell constant ‘K’, which depends on the cell, is used to convert conductance ‘G’ into conductivity ‘σ’.

Figure II.4: Conductivity Sensor

II.5.2.2. Flow Sensor

The flowmeter is an instrument that uses magnetic transmission and is specially designed to measure liquids circulating in pipes. It works by measuring the flow rate of a fluid passing through the valve at sufficient speed. The valve, mounted either horizontally or vertically, then rotates around its axis until it reaches a balance of force between the thrust of the fluid and the return force of the internal spring. The angular position of this equilibrium point is the measure of the flow rate.

Using a permanent ring magnet at the end of the valve shaft, the position is transmitted contactlessly to the indicator needle and other electrical options via a follower magnet in the housing

Figure II.5: Flow Meter

II.5.2.3. Pressure Sensor

The device, known as an electric contact manometer, is specifically crafted to measure fluid pressures within the range of 0.6 to 4Kbar. Depending on the position of the pointer on the scale, the contacts of the device can either open or close an electrical control circuit. Importantly, the pointer moves freely across the entire range without the need for prior adjustment. Additionally, the setpoint indicator can be adjusted using a removable adjustment key located in the sight glass. It is crucial to note that these instruments not only indicate pressure but also serve as devices for starting or stopping pumps and machines. They are triggered when the pressure exceeds the minimum or maximum thresholds.

Figure II.6: Pressure Tube Gauge with Electrical Contact

II.5.2.4. Level Sensors

The station employs two types of level sensors:

- **Bypass Level Indicator - BNA**

The BNA device is a liquid level measurement and control system that operates on the principle of a magnetic float. It measures the liquid level in open or closed tanks, using coloured balls for precise and easy reading. The float of the device moves based on the amount of liquid in the tank until it reaches a balance between the buoyancy force A and the weight of the float Gs.

The BNA Controller features advanced functionalities such as closed-loop control and positioning control to ensure accurate measurement and effective control of the liquid level. The BNA device is designed to be easy to install and configure, and it is compatible with different types of tanks. It is also robust and durable, thanks to the use of high-quality materials. Overall, the BNA device is a reliable solution for liquid level measurement and control applications in the industry.

Figure II.7: Bypass Level Indicator

- **Hydrostatic Level Sensor**

Hydrostatic level sensors measure the hydrostatic pressure of a liquid to determine the level in a tank. They are installed at the bottom of tanks and can be used in corrosive or hazardous environments. This sensor is used in the neutralisation process.

II.5.2.5. PH Sensors

The pH meter is a device that measures the pH of a solution. Its operating principle is based on the relationship between the concentration of H3O+ ions and the electrochemical potential difference formed in the glass electrode. In general, this electrode is called a 'combined' electrode because it consists of two separate electrodes: one with a constant, known potential, and the other whose potential varies as a function of pH. The pH corresponding to zero potential between these two electrodes is 7. The pH value can therefore be determined by correlation, as the potential difference between the two electrodes changes proportionally to the pH of the solution.

Figure II.8: PH meter

Table II.2: Demineralisation Station Sensors

Physical Quantity	Sensor Alpha-Numeric Symbol	Sensing environment	Output Type
Conductivity	UA10A001	Raw Water Flow Line	Analogue
	UA11A001	Filter UA11B001 Water Output	
	UA12A001	Filter UA12B001 Water Output	
	UA13A001	Storage Tanks Flow Line	
Level	WJ40L001(02)	Raw Water Tanks	Digital
	UA41L002	HCl Reservoir UA41B001	
	UA41L003		
	UA42L002	HCl Reservoir UA42B001	
	UA42L003		
	UA33L002	NaOH Reservoir UA33B001	
	UA33L003		
	UC10L001	Neutralisation Pit	
	UC10L002		
	UC10L003		
	UC10L004		
	UD10L007	Water Storage Tanks	
Pressure	UA10P002	Raw Water Flow Line	Digital
	UA11P002	Filter UA11B001	
	UA12P002	Filter UA12B001	
Differential Pressure	UA11P004	Filter UA11B001	Digital
	UA12P004	Filter UA12B001	
Flow	UA11F002	Filter UA11B001 Water Output	Analogue
	UA12F002	Filter UA12B001 Water Output	
	UA13F001	Storage Tanks Flow Line	
	UA27F001	HCl Dilution Water	
	UA27F001	NaOH Dilution Water	

PH	UA10A002	Raw Water Flow Line	Analogue
	UC10A001	Neutralisation Pit	
	UA13A002	Storage Tanks Flow Line	
Liquide Quantity	UA34Z001	NaOH Quantity through Dosing Pump UA34D001	Analogue
	UA35Z001	NaOH Quantity through Dosing Pump UA35D001	
	UA44Z001	HCl Quantity through Dosing Pump UA44D001	
	UA45Z001	HCl Quantity through Dosing Pump UA45D001	

II.5.3. Pre-actuator

The Station uses switches of different types to control the actuators.

II.5.3.1. Three Position Switches

- **OFF/AUTO/MANUAL Switch**

A type of switch that has three distinct positions: OFF, AUTO, and MANUAL. This switch allows for the selection of different modes of operation for a device or system. When the switch is in the OFF position, the device is turned off and no operation is possible. In the AUTO position, the device operates automatically based on pre-programmed settings or external inputs. In the MANUAL position, the device can be controlled directly by the user. This type is used to control pumps and air boosters.

- **OFF/FILTRATION/REGENERATION Switch**

used to define the function of the two filters UA11B001 and UA12B001. When the switch is in OFF position, the filter is out of service. When in FILTRATION position, the filter is in filtration process and when it is in REGENERATION position, the filter is in the regeneration process.

II.5.3.2. Momentary Switch

A momentary switch, or momentary contact switch, is a device that, when pressed or turned to the "on" position, temporarily makes contact to start another device, then returns to its original state. The device continues to operate because the switch activates a relay or latching circuit that maintains the operation until it is explicitly turned off. This type of switch is used to initiate the neutralization process.

II.5.4. Actuators

II.5.4.1. Valves

A valve is a device that controls the flow of a liquid, gas, or other material through a passage, pipe, inlet, outlet, etc. It is a mechanical device that opens and closes to regulate the flow by opening, closing, or partially obstructing a passageway.

The station uses only pneumatic, all-or-nothing (TOR) valves, which regulate fluid flow with two distinct states: open or closed. These valves operate discontinuously, represented by values "0" or "1" (or 0% and 100%), meaning they can be either fully open or fully closed based on the application's needs.

these valves are also equipped with limit switches which confirm that the valve is fully open or closed.

Figure II.9: Pneumatic Valve

II.5.4.2. Pumps

A pump is a device that moves fluids, such as liquids or gases, by mechanical action. Pumps can be used to raise, transfer, deliver, or compress fluids. They work by creating a pressure difference, which causes the fluid to flow from an area of lower pressure to an area of higher pressure. All the Pumps are equipped with a feedback signal in case the pump fails to work.

Several types of pumps are used in demineralisation stations:

- **Centrifugal pumps:** This element is part of the energy transmission chain and is used to control the circulation of pressurised fluids. It is activated by a mechanical, electrical or pneumatic control signal, which allows it to select the direction of fluid flow or to interrupt circulation completely.
- **Volumetric pumps:** Positive displacement pumps are designed to draw an incompressible volume of liquid from the suction side in a given time and direct it to the discharge side. There are two main types of positive displacement pump: rotary pumps, which set the pumped flow rate as a function of displacement and speed of rotation, and reciprocating pumps, which use alternating movement of a piston or diaphragm to set the flow rate as a function of displacement and stroke. There are also pumps that combine the properties of the two previous types.

Table II.3: Demineralisation Station Pumps

Pump Alpha-Numeric Symbol	Function
UA11D001	Raw water circulation (Main)
UA12D001	Raw water circulation (Main)
UA10D001	Raw water circulation (Back-up)
UA24D001	Dilution water circulation (Main)
UA25D001	Dilution water circulation (Back-up)
UA34D001	NaOH Dosing (Main)
UA35D001	NaOH Dosing (Back-up)
UA31D001	NaOH reservoir refiling (Main)

UA32D001	NaOH reservoir refiling (Back-up)
UA44D001	HCl Dosing (Main)
UA45D001	HCl Dosing (Back-up)
UC10D001	Neutralisation pit mixing and draining

II.5.4.3. Air Boosters

These devices are used to mix the contents of the filters or the neutralisation pit by injecting pressurized air. Like the pumps, all air boosters are equipped with a feedback signal in case the device fails to work

Table II.4: Demineralisation Station Air Boosters

Air Booster Alpha-Numeric Symbol	Function
UA51D001	Mixed bed filters content mixing (Main)
UA52D001	Mixed bed filters content mixing (Back-up)
UC51D001	Neutralisation pit content mixing (Main)
UC52D001	Neutralisation pit content mixing (Back-up)

II.6. Operation of the various processes in the station

II.6.1. Demineralisation Process

The mixed-bed demineralisation (or filtration) system consists of two filters, each with a capacity of 40m3/h, operating alternately.

The water is filtered by passing through cationic and anionic resins in each filter. The cationic resins bind ions such as Na^{+}, Ca^{2+} and Mg^{2+}, and exchange H^{+} ions in return. Similarly, the anionic resins bind ions such as Cl^{-}, $SO4^{-}$ and $NO3^{-}$ and exchange OH^{-} ions.

The process begins with drawing water from tanks 00WJ40B001 and 00WJ40B002 using pump UA11(12)D001 (or UA10D001). The drawn water is directed to the mixed-bed filters UA11B001 or UA12B001 through valve UA11S007 (for UA11B001) or

UA12S007 (for UA12B001) and forced to recirculate into the filter again through valve UA11S012 (for UA11B001) or UA12S012 (for UA12B001) by lowering the recirculation setpoint to 0 µS/cm. This recirculation is necessary to remix the resins inside the filter that have separated due to time and weight differences. (Figure II.10)

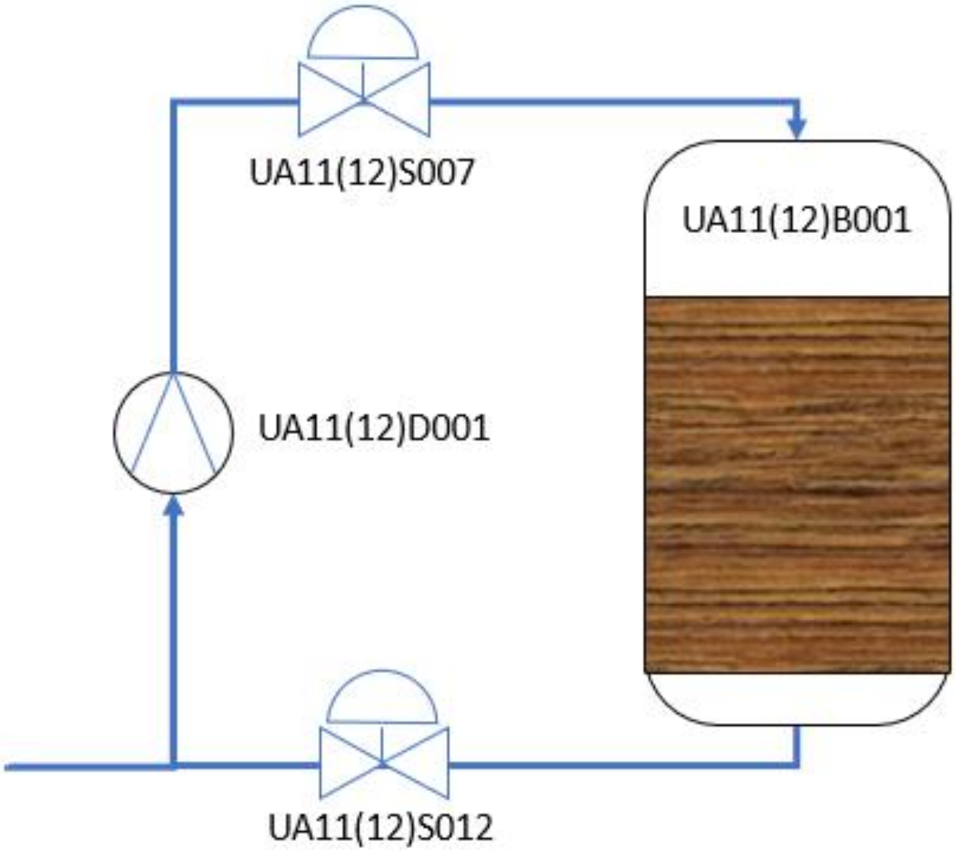


Figure II.10: Pre-service Step

After a few minutes, if the conductivity at the filter output stabilizes at a value lower than 0.1 µS/cm, the setpoint is raised again to 0.1 µS/cm, and the filter enters service mode. If the conductivity does not stabilize at a value less than 0.1 µS/cm within 60 minutes, it indicates that the filter cannot go into service or the last regeneration failed.

If the filter enters service mode, the demineralized water is then sent to storage tanks 34UD10001 and 12UD10B001 via valve UA11S009 (or UA12S009 for filter UA12B001). (Figure II.2)

If the conductivity of the water exceeds 0.1 µS/cm at the outlet of the mixed-bed filters, it means the resins are saturated with Na^+ and Cl^-, and it is necessary to regenerate the system by closing valve UA11S007 (or UA12S007 for filter UA12B001). Once the resins are saturated, the filter proceeds to the regeneration process.

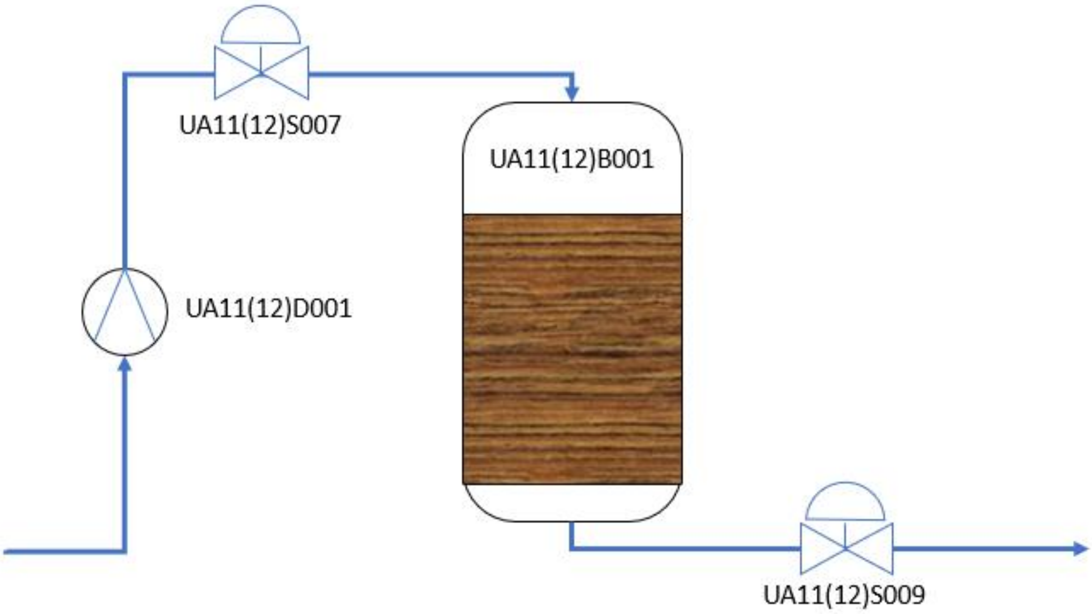


Figure II.11: Filtration Step

II.6.2. Regeneration Process

As previously mentioned, the regeneration process aims to restore the functionality of spent ion-exchange resins by removing the accumulated ions from the service run. This is achieved through the use of two (2) 5% diluted solutions: hydrochloric acid (HCl) and sodium hydroxide (NaOH).

The following indicators help determine if regeneration is necessary:

1. If the conductivity at the outlet of the mixed beds is greater than 0.1 µS/cm.
2. If the pressure difference between the inlet and outlet of the mixed beds is greater than 1.5 bar.
3. If the Silica $SiO_2 > 0.02$mg/L
4. After continuous operation for 4 weeks.

Although these indicators indicate the necessity of regeneration, the factor that we rely on it is the high conductivity in the output of the filter.

Regeneration proceeds in 9 steps, as set out below:

Step 1: backwashing and resin separation

The initial step is the separation of the resins. Raw water is introduced from the bottom, leading to backwashing and separation. Valves S008 and S017 are opened, and the respective raw water pump is turned on, allowing the water to flow out from the top (Figure II.12). Because of the specific weight differences, the denser cationic resins settle at the bottom of the tank, while the lighter anionic resins remain at the top. This process takes 37 minutes.

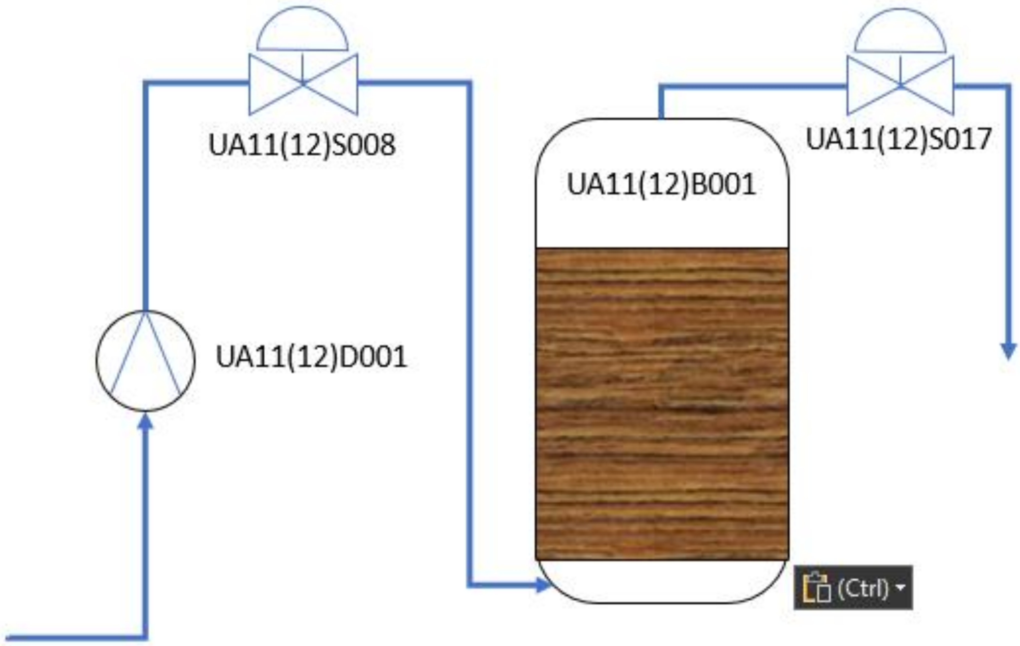


Figure II.12: Backwashing and Resin Separation

Step 2: Pause

To allow the resins to precipitate completely, the raw water pumping is stopped and valve S008 is closed. A 7-minute pause follows, during which drain valve S017 remains open. (Figure II.13)

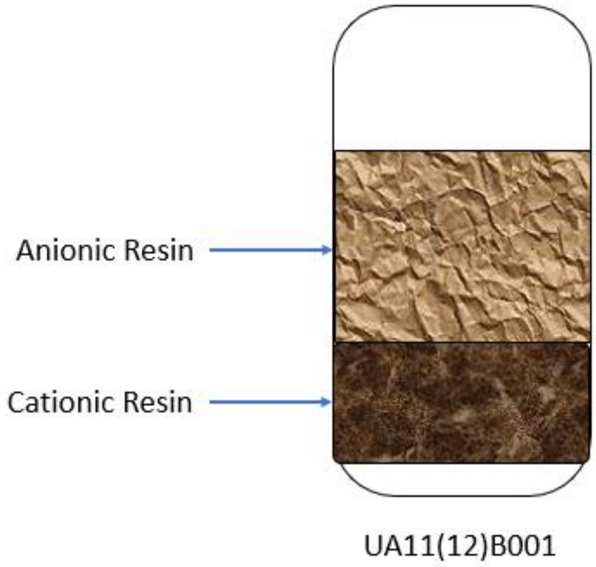


Figure II.13: Pause

Step 3a+4a: Filling with Hydrochloric Acid

The 30% hydrochloric acid (HCl) in the UA41B001 and UA42B001 storage tanks is first diluted with water to a 5% solution using the UA44D001 or UA45D001 dosing pumps.

If the flow of the dilution water is too low, an alarm is triggered by a limit switch, causing the UA44D001 or UA45D001 dosing pump to stop while the UA28S003 valve remains open.

The diluted HCl solution passes through the cationic resin layer from bottom to top and does not flow through the distribution pipe. Valves UA11S015 (UA12S015), UA47S001 (UA48S001), and UA11S002 (UA12S002) are open. The quantity of dilution water is set using flowmeter UA28 (I, AC) F001, as well as valve UA28S003.

Once the acid amount pre-configured in the counter UA44Z001 or UA45Z001 has been introduced, the HCl dosing pumps stop automatically. The dilution water pump remains in service to wash the resins and remove the HCl and the UA46S003 valve is closed. Acid washing begins, lasting approximately 80 minutes. Subsequently, valves UA28S003, UA47S001, and UA48S001 are closed, and valves UA47S003 and UA48S003 are opened.

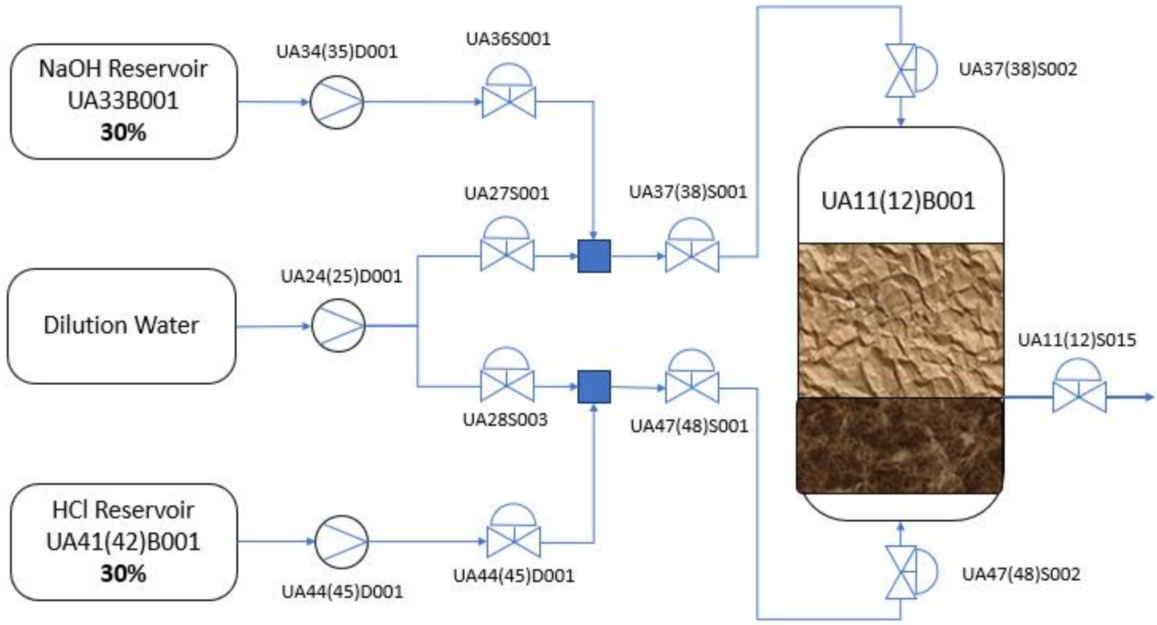


Figure II.14: HCl and NaOH Dosing

Step 3a+4a: Filling with caustic soda

The 30% caustic soda, or sodium hydroxide (NaOH) contained in the UA33B001 storage tank is first diluted with water to obtain a 5% solution using the UA44D001 or UA45D001 dosing pumps.

If the dilution water flow rate is too low, an alarm is triggered by a limit switch, causing the UA44D001 or UA45D001 dosing pump to stop while the UA27S003 valve remains open.

The diluted NaOH solution passes through the anion resin layer from top to bottom and does not flow into the dispensing pipe. Valves UA11S015 (UA12S015), UA37S001 (UA38S001) and UA47S002 (UA48S002) are open. The amount of dilution water is adjusted using the UA27F001 flow meter and the UA27S003 valve.

Once the quantity of NaOH pre-configured in meter UA34Z001 or UA35Z001 has been introduced, the caustic soda dosing pumps stop automatically. The dilution water pump remains in operation to wash the resins and remove the NaOH, and valve UA36S001 is closed. The soda wash begins and lasts about 80 minutes. Then valves UA27S003, UA37S001 and UA38S001 are closed and valves UA37S003 and UA38S003 are opened.

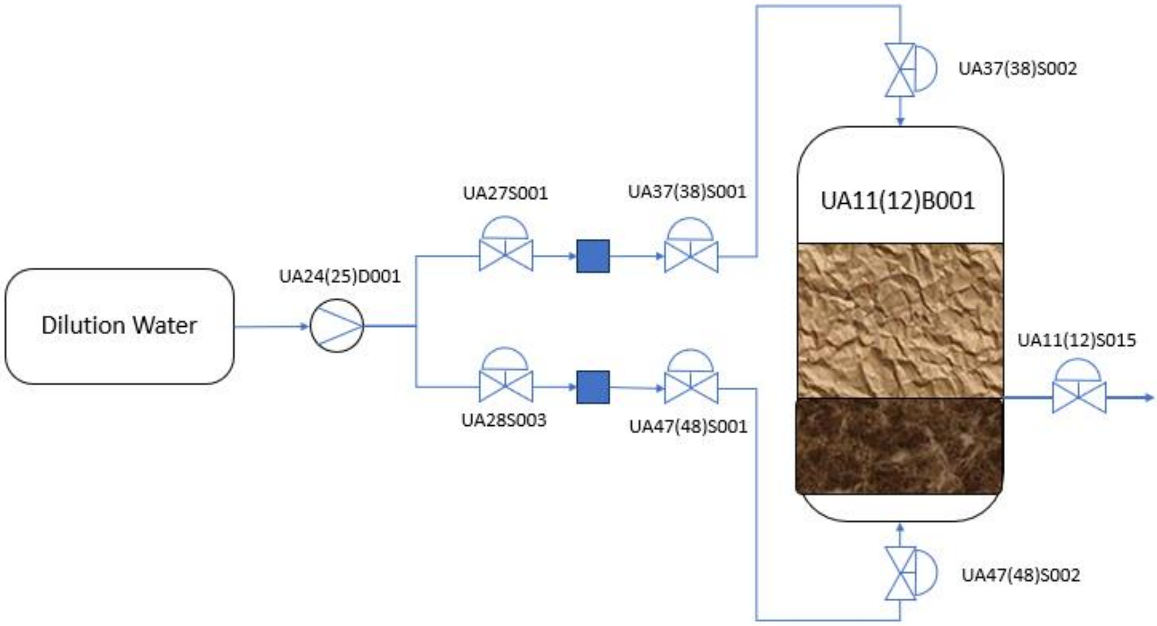


Figure II.15: HCl and NaOH Washing

Step 5: Pause

The UA11(12)S015 valve, along with the safety valves for acid and detergent, stay open, while the rest are closed. This pause for stabilization lasts 30 seconds.

Step 6: Water level lowering

The water level in the mixed bed should drop and stabilize at 10 cm above the resins (Figure II.16). This process takes 30 minutes.

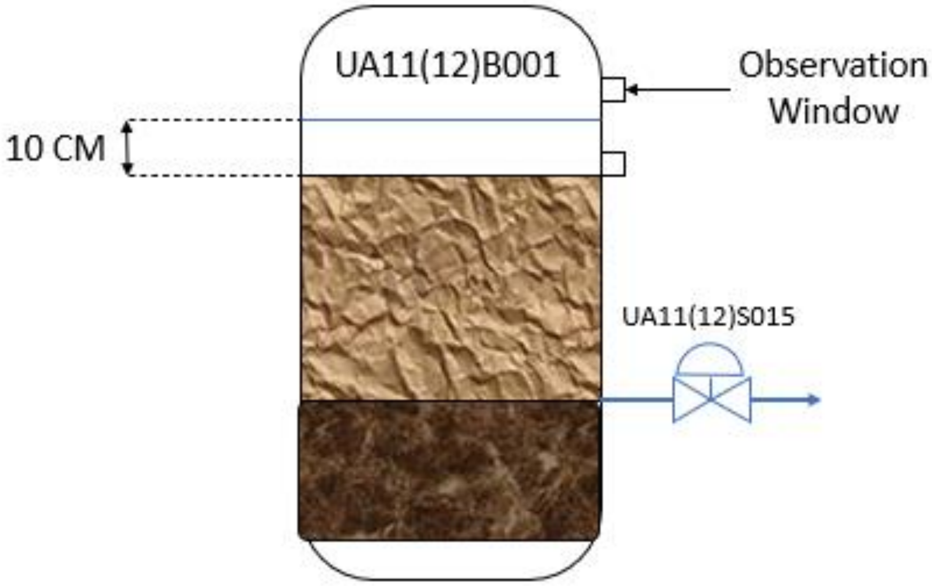


Figure II.16: Water Level Lowering

Step 7: Reconstituting the resin mixture

The separate cationic and anionic resins are thoroughly mixed by compressed air. The UA51 D001 and UA52 D001 are in operation, with valves UA54 (55) S002 and UA11 (12) S017 open (Figure II.17). The mixture of cationic and anionic resins can be observed in the indicator glass. This operation takes about 10 minutes.

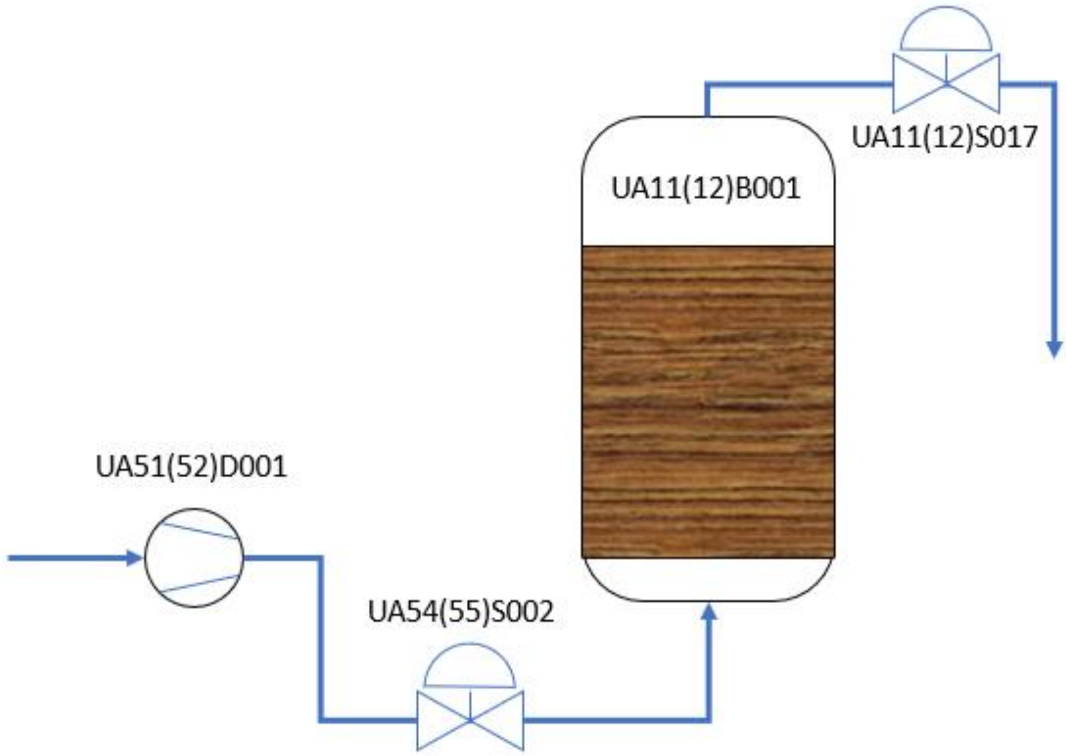


Figure II.17: Resins Mixing

Step 8: Refilling

This operation involves filling the empty space in the mixed bed reservoir until water emerges from the highest point (Figure II.18). It takes 5 minutes.

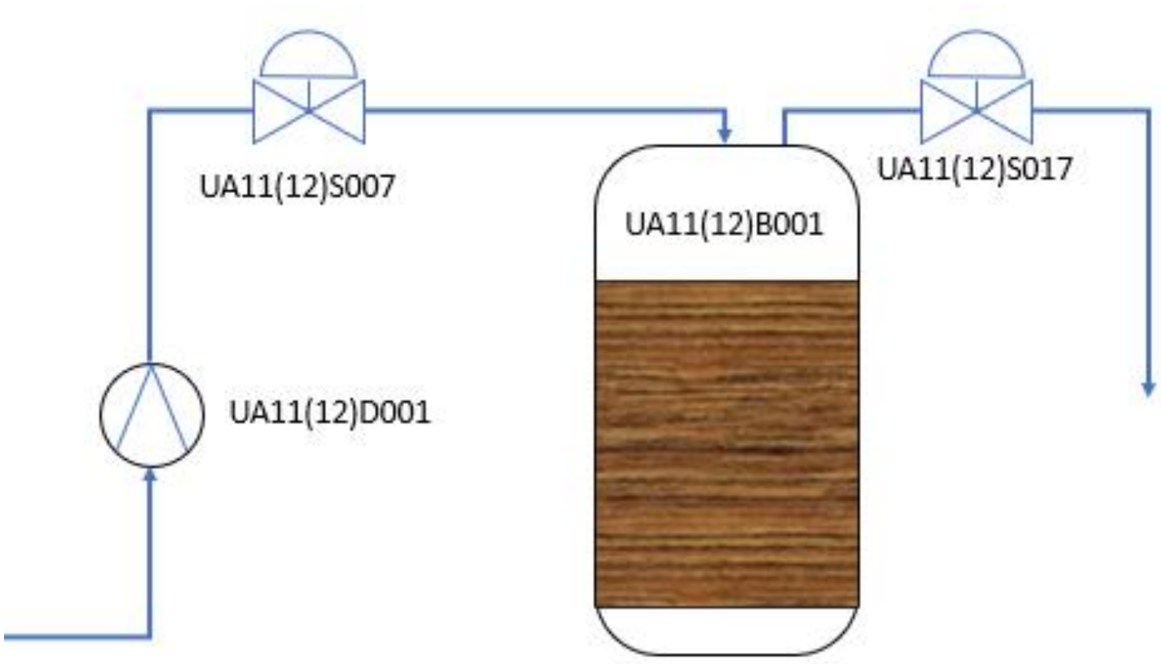


Figure II.18: Filter Refilling

Step 9+10: Running-in

This step involves testing the efficiency of the regeneration process. Raw water is pumped into the regenerated filter, and the conductivity of the water is measured.

If the conductivity exceeds 10 µS/cm, valve S014 opens, and the water is discharged. If the conductivity is below 10 µS/cm, valve S012 opens, and the water recirculates into the filter.

The conductivity is monitored for 120 minutes. If the conductivity does not stabilize below 0.1 µS/cm within this period, an alarm will trigger, indicating a regeneration issue. Possible causes include poor resin separation or inadequate washing with HCl and NaOH, requiring further investigation.

If after 120 minutes the conductivity is less than 0.1 µS/cm, the filter switches to filtration mode for 24 hours. Valve S009 opens, redirecting the filtered water into the storage tanks.

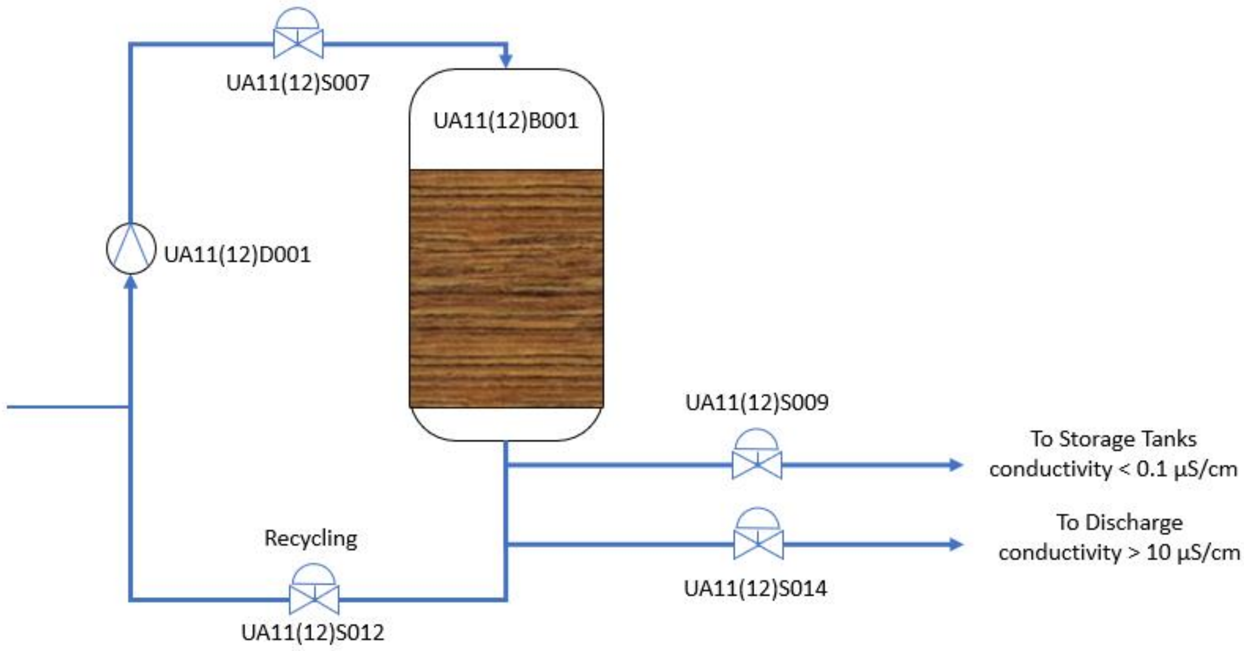


Figure II.19: Filter Running-in

II.6.3. Neutralisation

This stage consists of neutralising the chemicals used to regenerate the mixed beds, such as HCL acid and caustic soda. As acid and caustic soda are highly corrosive and aggressive chemicals, they can cause damage to the discharge installation (deterioration of pipes) and pollute the environment. For this reason, when discharging, the pH must be between 6.5 and 7.5

The high-level sensor triggers an alarm in the control room for manual start-up. If neutralisation is not initiated and a very high-level alarm occurs, neutralisation starts automatically. The UC10S002 valve opens, the UC10S001 valve closes, and the recirculation pump UC10D001 starts operating along with the air boosters UC51(52)D001 before any injection, ensuring a homogeneous mixture and accurate pH measurement.

After 20 minutes, if the pH is below 6.5, NaOH is injected. If the pH is above 7.5, HCl is injected. When the pH value stabilizes between 6.5 and 7.5, the UC10S002 valve closes, and the UC10S001 valve opens, directing the water into the sea. (Figure II.20)

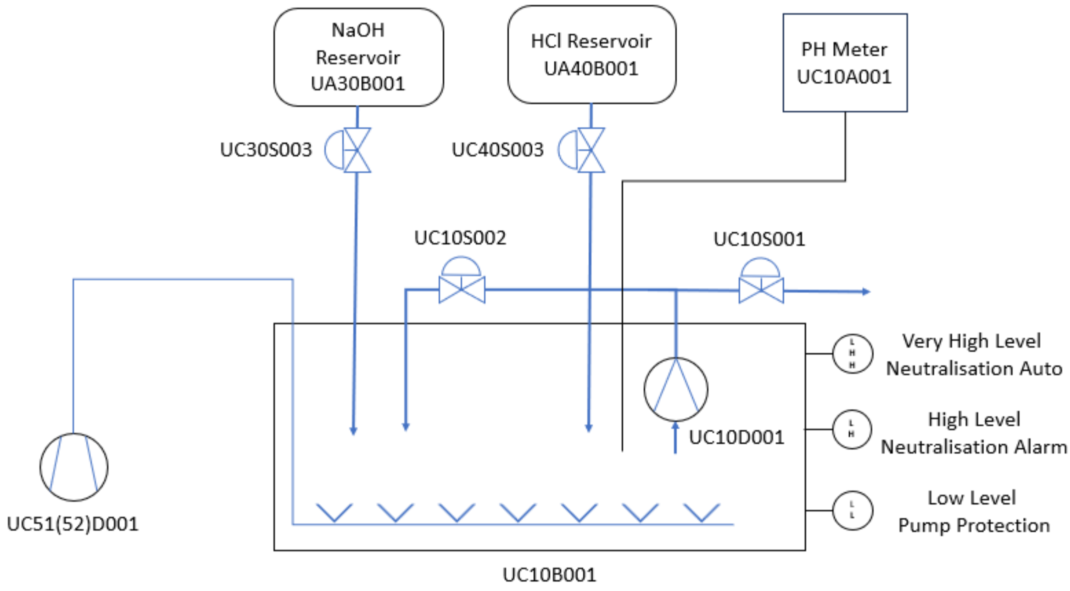


Figure II. 20: Neutralisation Operation

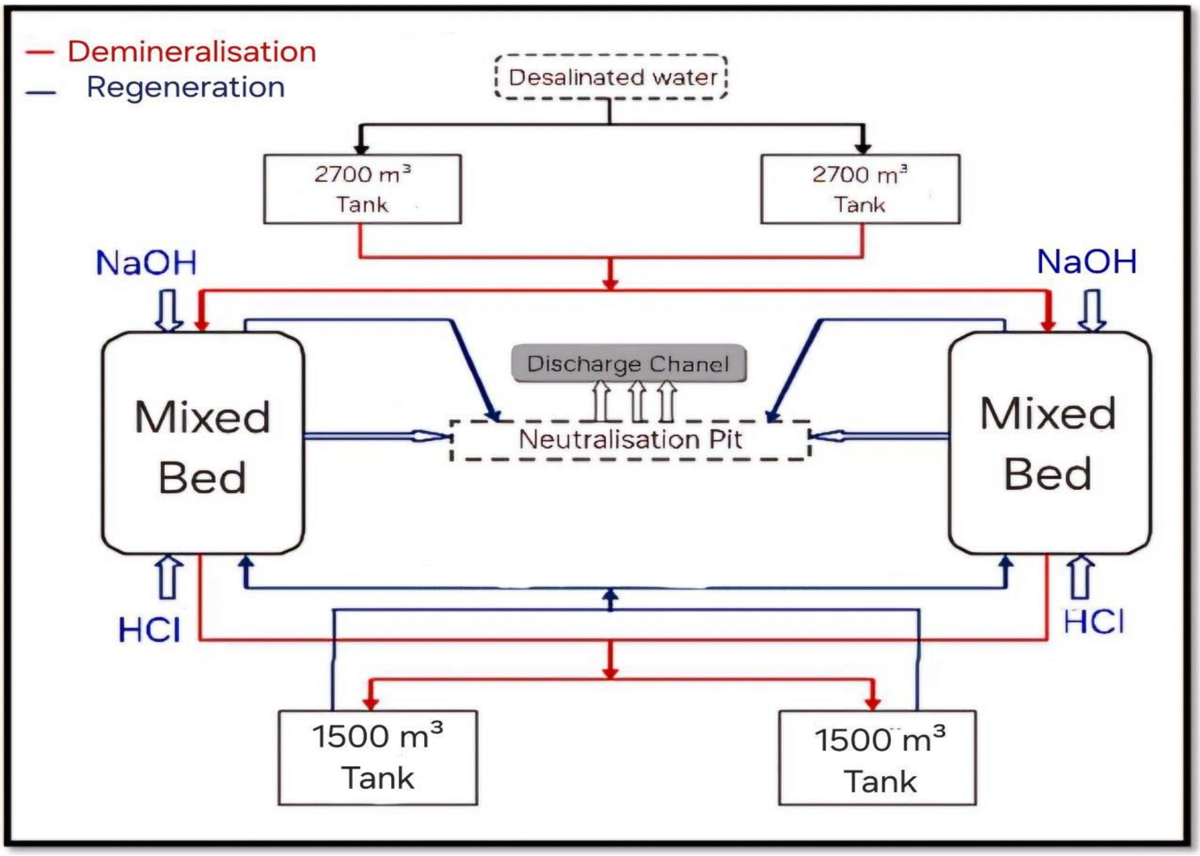


Figure II.21: Simplified Diagram of Demineralisation Station

II.7. Conclusion

In this chapter, we covered the general principles of the demineralisation station and the various types of equipment involved in the process. We explored their functions and operational principles. Additionally, we examined all the processes that occur in the station, detailing each step from filtration to regeneration and neutralisation.

Chapter III

Automation Hardware

III.1. Introduction

In this chapter, we will delve into Programmable Logic Controllers (PLCs), discussing their definition, roles, and operational mechanisms. We will explore the programming languages and software used with PLCs, providing a comprehensive overview of these crucial components in industrial automation.

Additionally, we will discuss the process of selecting a PLC and configuring its hardware for our specific solution, highlighting key considerations and factors that influenced our decision-making.

III.2. Programmable Logic Controllers

III.2.1. Definition

A programmable logic controller (PLC) is a specialized microprocessor-based controller that utilizes programmable memory to store instructions. It performs functions such as logic, sequencing, timing, counting, and arithmetic to control machines and processes.

III.2.2. PLC Hardware

A typical Programmable Logic Controller (PLC) system comprises several essential functional components. These components work together to ensure the proper functioning of the PLC system (Figure III.1).

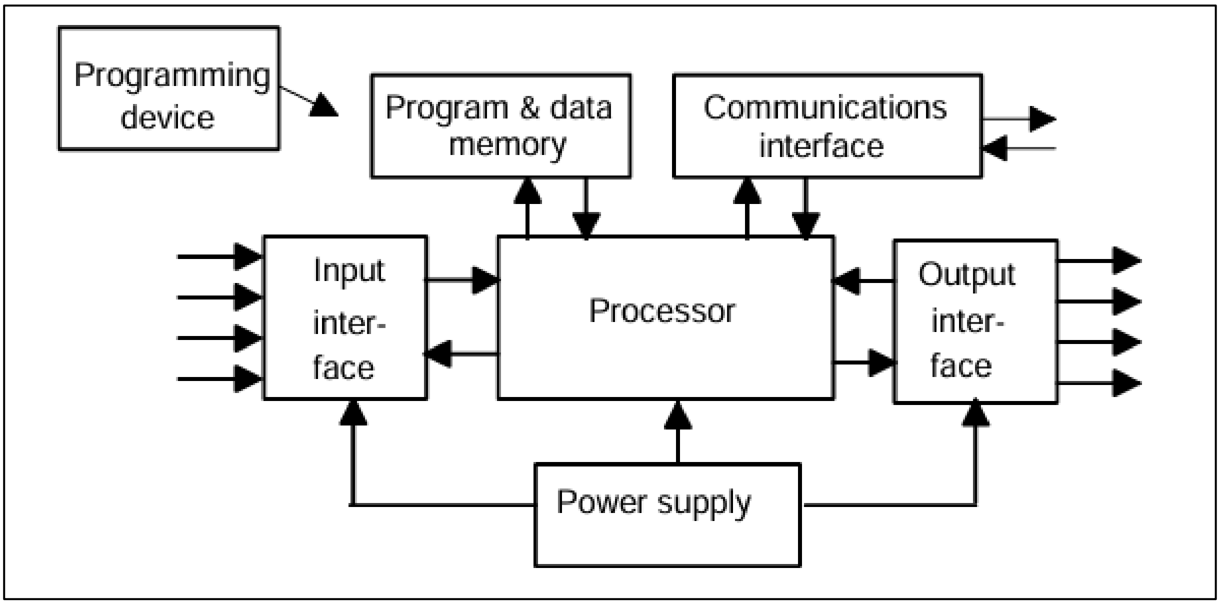


Figure III.1: Basic Configuration of a PLC System

- **The processor unit** or central processing unit (CPU), contains the microprocessor, which interprets input signals and executes control actions based on the program stored in its memory. It communicates decisions as action signals to the outputs.
- **The power supply unit** converts mains AC voltage to the low DC voltage necessary for the processor and the circuits in the input and output interface modules.
- **The programming device** used to enter the required program into the processor's memory. The program is developed in the device and then transferred to the memory unit of the PLC.
- **The memory unit** stores the program used for the control actions executed by the microprocessor, as well as data from inputs for processing and outputs for outputting.
- **The input and output sections** enable the processor to receive information from and communicate information to external devices. Inputs can come from switches, photoelectric cells, temperature sensors, flow sensors, and more. Outputs can be directed to devices such as motor starter coils or solenoid valves etc.

  Input and output devices can be classified into digital, or analogue categories. Digital devices provide signals that are either off or on. Digital devices generate a sequence of on-off signals, while analogue devices produce signals proportional to the measured variable.
- **The communications interface** facilitates the receiving and transmitting of data over communication networks to and from other remote PLCs. It handles tasks such as device verification, data acquisition, synchronization between user applications, and connection management.

III.2.3. PLCs Internal Structure

- **The CPU:** its internal architecture varies depending on the microprocessor. Generally, it includes an arithmetic and logic unit (ALU) responsible for data manipulation, performing arithmetic and logic operations. The microprocessor also contains registers, a type of memory, used to store information essential for program execution. Additionally, a control unit manages the timing of operations.

- **The buses:** in a PLC, buses are the communication pathways within the system, transmitting information in binary form, represented by groups of bits where each bit is a binary digit (1 or 0) indicating an on/off state. A word refers to a group of bits representing specific information, such as an 8-bit word like 00100110. Each bit in a word is transmitted simultaneously along its own parallel wire. The system typically includes four buses:
  - **Data Bus:** The data bus transports the data used in CPU processing. For example, an 8-bit microprocessor has an internal data bus that can manage 8-bit numbers, allowing it to perform operations and produce results as 8-bit values.
  - **Address Bus:** carries memory location addresses, ensuring that each word in memory has a unique address for access. The address bus specifies which address the CPU needs to access, allowing it to read or write data at that location. An address bus with 8 lines can handle 256 distinct addresses ($2^8 = 256$), while 16 address lines allow for 65,536 addresses.
  - **Control Bus:** transmits signals used by the CPU for control, such as instructing memory devices to receive data from input or output sources and carrying timing signals to synchronize actions.
  - **System Bus:** facilitates communication between input/output ports and the input/output unit.

- **The Memory:** There are several memory elements in a PLC system:
  - **Random-Access Memory (RAM):** It is used for the user's program and serves as storage for data, encompassing details on input and output device statuses, timer and counter values, and other internal device information. This segment of RAM is commonly known as a data or register table. Specific parts of this memory are designated for input and output addresses along with their statuses, another part for preset data, and another for retaining counter and timer values.
  - **System Read-Only Memory (ROM)** used to offer permanent storage for the operating system and fixed data employed by the CPU. Optionally, an Erasable and Programmable Read-Only Memory (EPROM) module can be incorporated for ROMs that can be programmed and subsequently have the program made permanent.

- **I/O unit:** The input/output unit serves as the intermediary between the system and external devices, enabling connections through input/output channels to such us sensors, motors, and solenoids. Programs are also entered through this unit from a program panel. Each input/output point is assigned a unique address for CPU use.

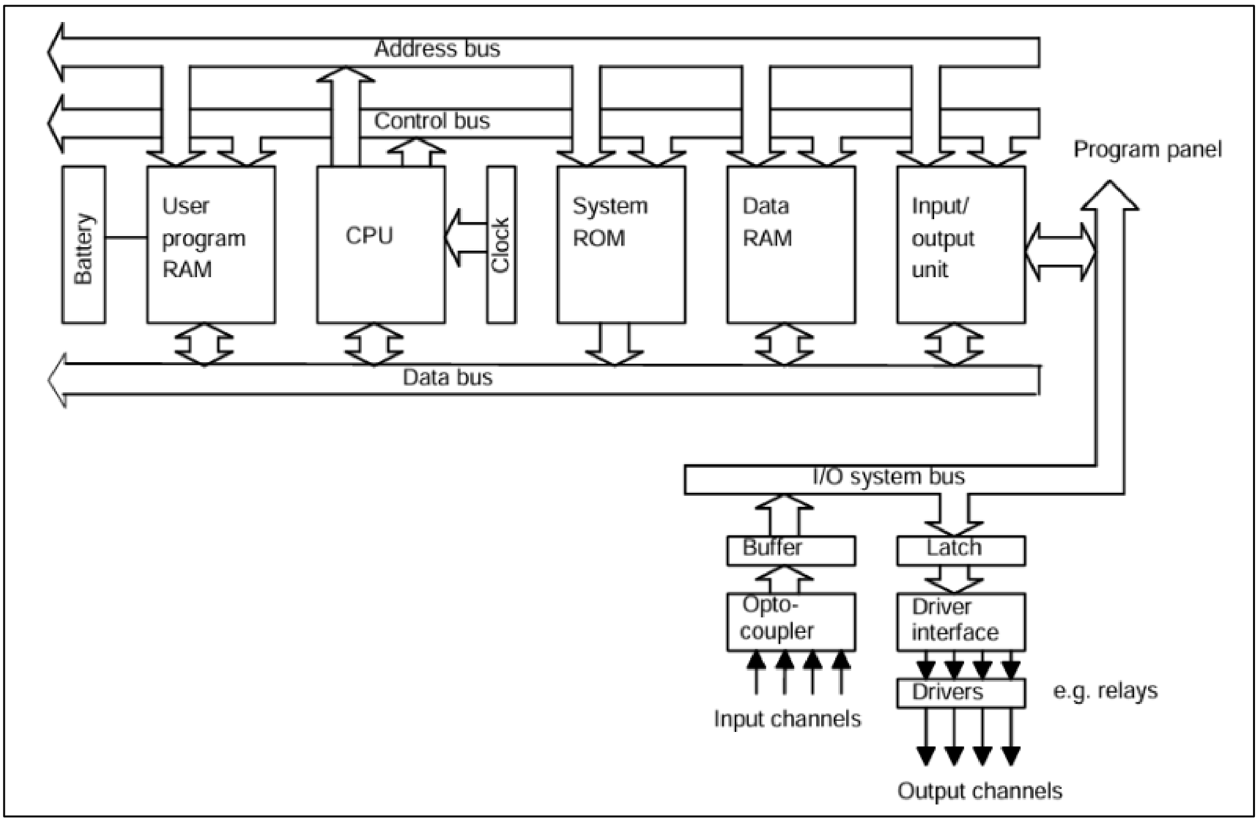


Figure III.2: Architecture of a PLC

III.2.4. Types of PLCs

There are two subcategories of PLCs: compact and modular.

- **Compact PLCs:** predominantly employed in small industries and are designed for simple applications. They integrate all components into a single unit, including a power supply, CPU, and a fixed number of I/O pins that cannot be expanded. However, this fixed functionality means that if your project requires expansion, a new compact PLC must be installed. Additionally, the self-contained nature of compact PLCs can make troubleshooting and repairs more challenging. Despite these limitations, compact PLCs offer advantages such as their small size, affordability, and ability to perform basic functions.

Figure III.3: Compact PLC - SIEMENS S7-1200

- **Modular PLCs:** They are well-suited for large-scale projects, offering multiple compartments that can each accommodate different functions. Their modular design allows for easy repair, as individual blocks can be removed and replaced as needed. This design also facilitates troubleshooting, as the I/O pins, CPU, and power supply are separated, making it easier to identify and address issues. Additionally, sensors are located on each block, further aiding in quick troubleshooting.

Figure III.4: Modular PLC - SIEMENS S7-1500

III.2.5. PLC Programming Languages:

There are five main PLC programming languages

Ladder logic (LAD): A graphical programming language derived from electrical circuit drawings, resembling a ladder. It uses instructions to represent electrical contacts and coils, with vertical rails and horizontal rungs. The representation of registers can vary across platforms (in figure 3.5, Inputs are denoted by "X" addresses, outputs by "Y" addresses, and internal memory bits by "M"s). In real-time monitoring, colours indicate the state of contacts and coils, with "On" or "True" indicating continuity from the left rail to the coil.

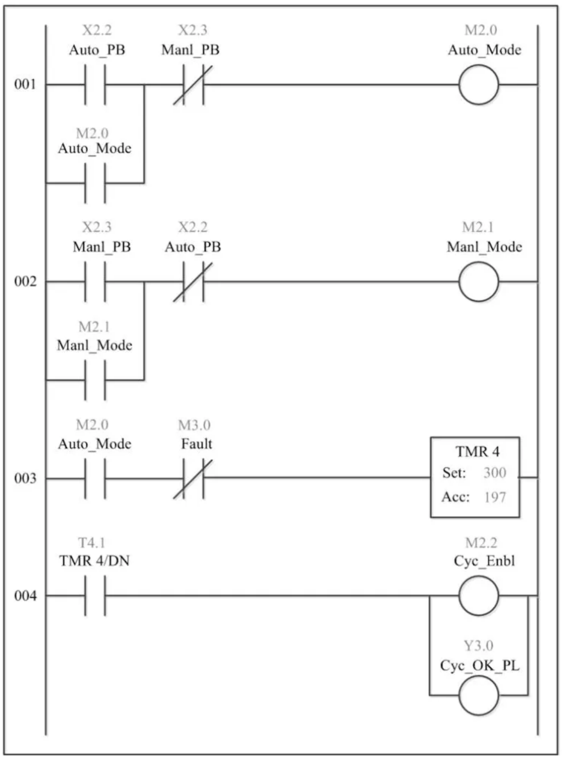


Figure III.5: Example of Ladder Logic (LAD)

- **Function block diagram (FBD)** Function blocks have their origins in Boolean algebra, with basic logic operations such as AND and OR. These blocks have evolved to include more complex functions like math operations, data loading, comparison, data transfer, timing, and counting.

  Certain functions like XOR (Exclusive OR) cannot be directly represented in ladder logic. Additionally, due to the complexity of some Function Block Diagram (FBD) drawings, the logic can span multiple pages. Off-page connector symbols are used to indicate connections that extend beyond a single page.

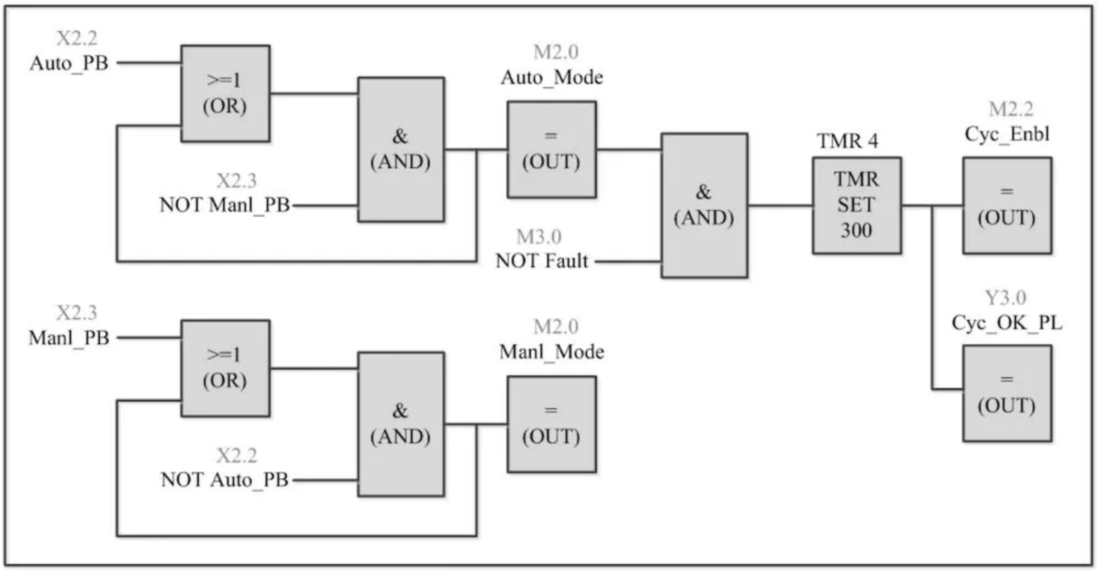


Figure III.6: Example of Function Block Diagram (FBD)

- **Instruction list (IL):** Graphical languages are converted to text-based Instruction List (IL) before being compiled into machine language. Handheld programmers were historically used to input instructions into PLCs, featuring keys with ladder logic contact pictures. IL's text-based nature allows easy manipulation in third-party editors like Excel, facilitating import/export with PLC software. This simplifies creating tables with common structures, which can then be converted into repetitive rungs or blocks with different addresses, saving time in writing large amounts of code.

```
LD X2.2 Auto_PB
O M2.0 Auto_Mode
AN X2.3 Manl_PB
= M2.0 Auto_Mode
LD X2.3 Manl_PB
O M2.1 Manl_Mode
AN X2.2 Auto_PB
= M2.1 Manl_Mode
LD M2.0 Auto_Mode
AN M3.0 Fault
= TMR 4 Set 300
LD T4.1 TMR 4/DN
= M2.2 Cyc_Enbl
= Y3.0 Cyc_OK_PL
```

Figure III.7: Example of an Instruction List (IL)

- **Structured Text (ST):** resembling high-level languages like Pascal or C, starts with variable declarations and configuration of parameters. It uses constructs such as "If-Then-Else," "Do-While," and "Jump" for program flow control, requiring strict syntax adherence and making error detection challenging.

Despite its complexity, Structured Text is more powerful than ladder logic or function blocks, allowing the development of libraries for tasks like data searching with SQL or complex mathematical algorithms. However, due to its linear nature, responding to multiple inputs simultaneously can be difficult, and program control may become complex with numerous loops.

```
// PLC Configuration
CONFIGURATION DefaultCfg
VAR_GLOBAL
        Auto_PB      :IN @ %X2.2      // Auto Pushbutton
        Manl_PB      :IN @ %X2.3      // Manual Pushbutton
        Cyc_OK_PL    :OUT @ %Y3.0     // Cycle OK Pilot Light
        Auto_Mode    :BOOL @ M2.0     // Automatic Mode
        Manl_Mode    :BOOL @ M2.1     // Manual Mode
        Cyc_Enbl     :BOOL @ M2.2     // Cycle Enable
        Fault        :BOOL @ M3.0     // Machine Fault
        TMR 4        :TIMER @ T4      // 10ms Base Timer
END_VAR

END_CONFIGURATION

PROGRAM Main

STRT    IF (Auto_PB=1 OR Auto_Mode=1) AND Manl_PB=0 THEN Auto_Mode=1
        ELSE IF (Manl_PB=1 OR Manl_Mode=1) AND Auto_PB=0 THEN Manl_Mode=1
        End IF

        IF Auto_Mode=1 AND Fault=0  THEN
        START TMR 4
        END IF

        IF TMR 4.ACC GEQ 300 THEN
        Cyc_Enbl=1
        Cyc_OK_PL=1
        END IF

        JMP STRT

END_PROGRAM
```

Figure III.8: Example of a Structured Text (ST)

- **Sequential Function Chart (SFC)**: based on Grafcet and uses blocks containing code to activate outputs or perform specific functions. These blocks, known as "steps," can include code written in various programming languages.

Steps in an SFC diagram can be active or inactive. Actions are executed only for active steps, which are either defined as initial steps or were activated during a scan cycle and have not been deactivated.

Transitions control the movement between steps. When a transition is activated, it triggers the subsequent step(s) and deactivates the preceding step. The program scans the logic in a step until the transition logic becomes true, deactivating the current step and activating the next one.

Actions associated with steps include set (S), reset (R), and continuous (N). Continuous actions remain active as long as the step is active, while set and reset actions function like other PLC languages. Steps and transitions can incorporate code from other PLC languages, with structured text commonly used for action blocks and ladder logic for transitions.

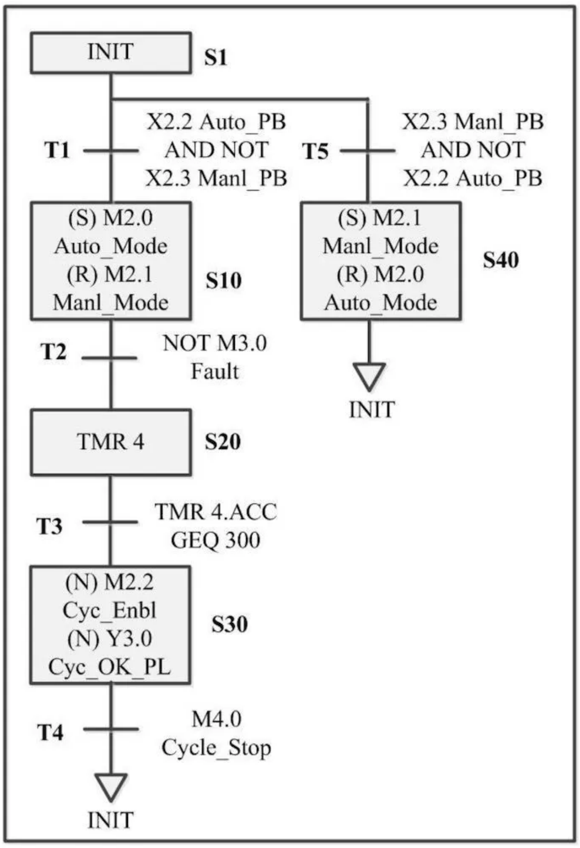


Figure III.9: Example of a Sequential Function Chart (SFC)

III.3. Choice of PLC

The selection of a PLC is primarily influenced by:

- The preference of a company or group.
- Existing commercial contacts and experience.

Large companies often prefer to choose two manufacturers to foster competition and have an alternative if one loses momentum. However, it is crucial for automation and maintenance staff to be trained on the equipment, as too much diversity can have serious consequences.

Additionally, having programming software can lead to cost savings. It's also beneficial to purchase the software. Next, you need to quantify your requirements:

- **Number of I/O**: The number of cards can affect the number of racks needed as the input/output requirements increase.
- **Type of processor**: The memory size, processing speed, and special functions offered by the processor help in selecting from a wide range of options.
- **Specificity of I/O modules**: This includes features like diagnostic systems and configurable process alarms.
- **Communication protocols**: The PLC should be able to communicate with other control systems (PLC, supervision, etc.) and offer standardized communication options (e.g., PROFINET, Profibus).

In our project, the PLC envisaged for the automation of the seawater demineralisation plant was imposed by the host company following after-sales service contracts which consist of systematic revisions and renovations of the installations with the plant manufacturer (Siemens). A programmable logic controller from the Siemens SIMATIC S7 range, the S7-1500 was chosen for this purpose.

III.4. Siemens SIMATIC S7-1500 PLC

The Siemens SIMATIC S7-1500 is a top-performance controller designed for industrial automation applications. It features a modular structure that allows for customization and scalability to meet specific needs. Here are some key features and specifications:

III.4.1. Key Features

- **Modular Design:** The S7-1500 has a modular structure that enables users to adapt the controller to their specific requirements by adding or removing modules.

- **High Performance:** The controller is designed for high-performance applications, providing reliable operation and efficient processing of complex tasks.

- **Extended Ambient Conditions Protection:** The S7-1500 is protected against extreme environmental conditions, ensuring reliable operation in harsh environments.

- **Communication Options**: The controller supports various communication protocols, including Ethernet/IP, PROFINET, IO-Link, and RS232.

III.4.2. Technical Specifications

- **CPU Options:** The S7-1500 offers different CPU options, such as the CPU 1511-1PN and CPU 1512C-1 PN, which provide varying levels of processing power and memory capacity.

- **Memory Capacity:** The controller has a memory capacity of up to 1.5 MB for program data and 300 KB for program code.

- **Power Supply:** The S7-1500 can operate on a wide range of power supplies, including 24V DC and 120/230V AC.

- **Inputs and Outputs:** The controller supports various input and output modules, including analog inputs and outputs, and can handle high-speed communication.

III.5. Hardware Configuration for Demineralisation Station Automated Solution

III.5.1. Power Supply: PS 25W 24VDC

The Siemens SIMATIC S7-1500 PS 25W 24V DC power supply provides essential operating voltage via the backplane bus, ensuring reliable and stable power distribution for the S7-1500 system in industrial automation. With 25W output and 24V DC rating, it powers the PLC's modules and components, supporting seamless communication and control.

III.5.2. CPU: 1515T-2 PN

The Siemens SIMATIC S7-1500 CPU 1515T-2 PN is a powerful and versatile controller, some of its characteristics are:

A. Memory

- Work memory for program: 750 KB
- Work memory for data: 3 MB
- Load memory: Plug-in via SIMATIC Memory Card

B. Interfaces

- 1st interface: PROFINET IRT with 2-port switch
- 2nd interface: Ethernet

C. Power Supply

- Type of supply voltage: 24V DC
- Permissible range, lower limit (DC): 19.2V
- Permissible range, upper limit (DC): 28.8V
- Reverse polarity protection: Yes

D. Power Consumption

- Infeed power to the backplane bus: 12W
- Power consumption from the backplane bus (balanced): 6.2W
- Power loss: 6.3W

Figure III.10: SIMATIC S7 CPU 1515T-2 PN

III.5.3. Input Modules

Input modules are directly related to the type and number of signals the PLC receives from different sources. It is divided into two categories, digital and analogue inputs

A. **Digital inputs:** they are 24VDC signals, we have 170 digital inputs:

- Digital sensors: 30
- Switches signals: 44
- Pumps and Air boosters' failure signals: 16
- Valves limit switches: 80 (40 valves, each valve has two (2), one for completely open position, the other for completely closed position)

To cover these digital inputs, we need at least five (5) digital input modules of 32 pins and one (1) module of 16 pins (5×32 + 16 = 176)

B. **Analog inputs:** they are signals that vary in the range of 4-20 mA, each one is stored in 32 Bytes. we have 9 analogue signal that come from:

- Conductivity meters: 4
- PH meters: 3
- Silica sensors: 2

To cover these analogue inputs, we need at least three (3) analogue input modules of 8 pins each pin has 16 bytes resolution.

III.5.4. Output Modules

In the output module, there are no analogue outputs, only digital ones. There are 64 signals in total, which are 24VDC and divided as follows:

- Valves control signals (Open/Close): 40
- Pumps and air boosters control signals (Run/Stop): 16
- Indicating lamps in the control room: 8

To accommodate these digital outputs, we need at least two (2) digital output modules, each with 32 channels (2×32=64)

III.5.5. Human Machine Interface Panel: SIMATIC HMI TP1500 Comfort

In addition to the PLC hardware, we already listed, we suggested a new sophisticated human machine interface to replace panel showed on Figure II.2.

The Siemens SIMATIC HMI TP1500 Comfort is a 15-inch touch-screen panel designed for industrial automation applications. It features a high-resolution TFT display with 16 million colours, making it ideal for displaying complex control and diagnostic information. The panel supports various communication protocols, including PROFINET, Ethernet, MODBUS TCP/IP, and MODBUS 485, ensuring seamless integration with other devices in the automation system.

Table III. 1: Hardware Configuration for Demineralisation Station Automation

Module	Type	Quantity
Power Supply	PS 25W 24VDC	1
CPU	CPU 1515T-2 PN	1
Digital Input Modules	DI 32×24VDC	5
	DI 16×24VDC	1
Analog Input Modules	AI 8×U/I	3
Digital Output Modules	DQ 32×24VDC	2
HMI Panel	SIMATIC TP1500 Comfort	1

III.6. Conclusion

In this chapter, we provided a comprehensive overview of PLCs, emphasizing their reliability as an automation solution for a wide range of industries, from small operations to large-scale industries. We explored several critical aspects, including the architecture, types, and programming languages of PLCs, as well as the factors to consider when selecting a PLC for a specific project. In the concluding section, we detailed the hardware configuration chosen for our project, outlining the components and their roles in the overall system. This foundation sets the stage for the practical application and implementation of our automation project.

Chapter IV

Automation Software and PLC Programming

IV.1. Introduction

After examining the processes in the demineralisation station and identifying all the equipment involved, as detailed in Chapter II, and after selecting the PLC hardware for the project, this chapter introduces the automation software for programming: the Totally Integrated Automation (TIA) Portal. Additionally, it highlights key improvements made to enhance station security measures and optimize processes in order to increase the station reliability.

IV.2. Totally Integrated Automation (TIA) Portal

The Totally Integrated Automation (TIA) Portal is Siemens' advanced development and engineering environment designed for PLC programming, as well as visualization and monitoring tasks through WinCC. This platform allows for the implementation of automation solutions using an integrated engineering system. It provides a robust development system for efficient programming and configuration of automation systems.

IV.2.1. TIA Portal Views

IV.2.1.1. Portal View

The portal view offers a task-oriented perspective of the tools, allowing users to quickly determine their desired action and access the appropriate tool. If needed, the view automatically switches to the project view for the selected task. The Portal view consists of:

1 **Portals for different tasks:** The portals offer fundamental functions for various task areas. The available portals in the portal view depend on the installed products.

2 **Actions for the selected portal:** When a portal is selected, the available actions are displayed. The help function can be accessed contextually in each portal.

3 **Selection panel for the selected action:** The selection panel is accessible in all portals, with its content adapting to the current selection.

4 **Switch to project view:** Use the "Project view" link to switch to the project view.

5 **Display of the project that is currently open:** Provides information on the currently open project.

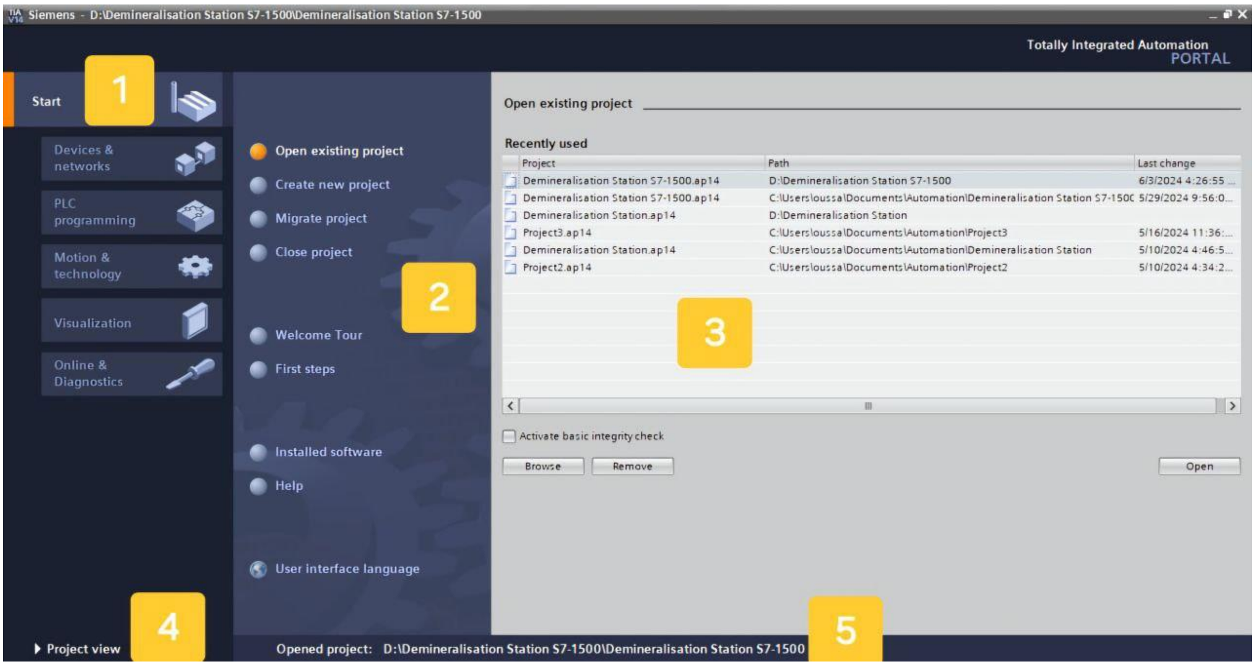


Figure IV.1: Layout of the Portal View

IV.2.1.2. Project View

The project view is a structured view of all components of the project.

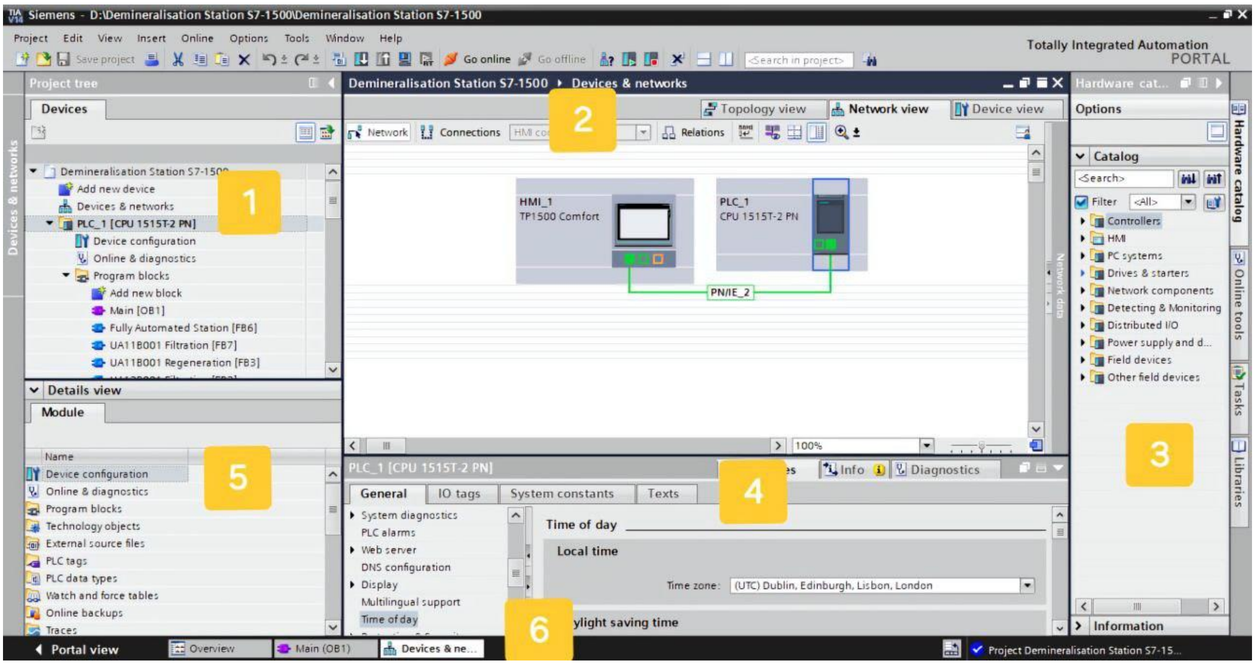


Figure IV.2: Layout of the Project View

1 **Project**: contains all the elements and data required to implement the desired automation solution.

2 **Work area:** used to view the elements selected in the project for processing. These may include hardware components, program blocks, variable tables, HMIs, etc.

3 **Task selection tabs:** have contents that vary according to the item selected in the work window.

4 **Inspector window:** used to view additional information on a selected object or on actions being object or the actions being executed (properties of the selected equipment, messages, etc.).

5 **Detailed view:** The detail view shows certain content of the selected object is in the overview window or in the project tree. This might include text lists or tags.

6 **Editor bar:** The Editor bar shows the open editors, enabling swift navigation between them. If multiple editors are open, you can group editors of the same type together.

IV.3. The Automated Solution Design Procedure

IV.3.1. Project Creation

To create a project in the portal view, select the 'Create a project' action. You can specify the project's name, choose a save location, add a comment, and define the author.

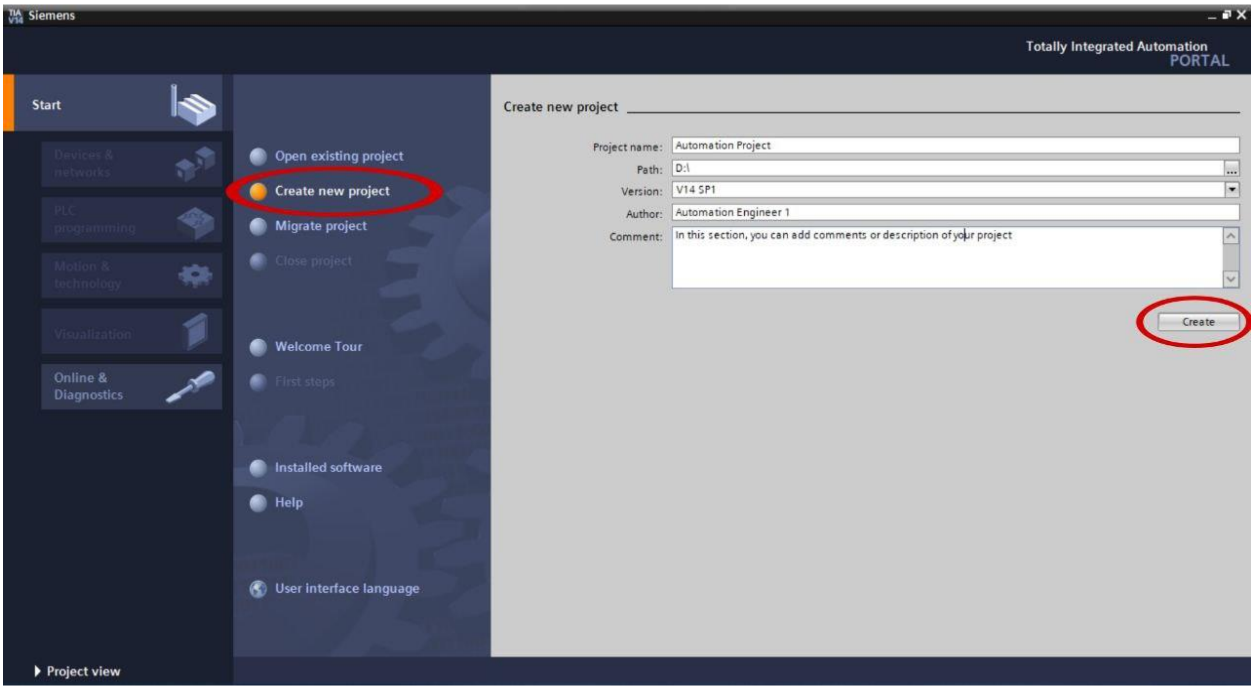


Figure IV.3: Project Creation

IV.3.2. Hardware Configuration

Once the project was created, we configured the workstation by defining the hardware listed in Table III.1, Chapter III. In the project view, we selected 'Add a device' in the project browser to access the list of available elements, including PLCs, HMIs, and PC systems. We chose the CPU and HMI, and established the connection using the PROFINET ports.

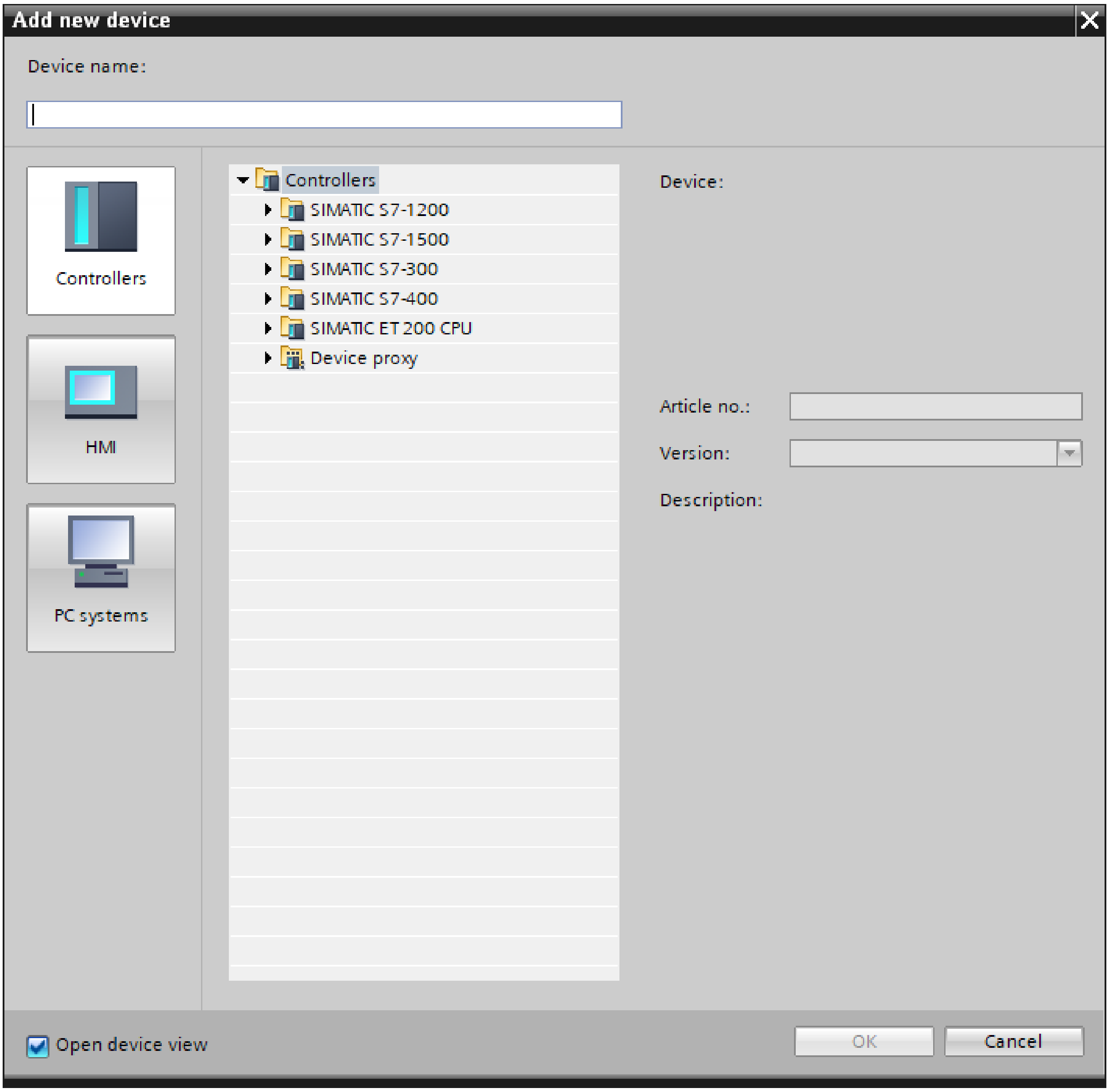


Figure IV.4: Device Addition Menu

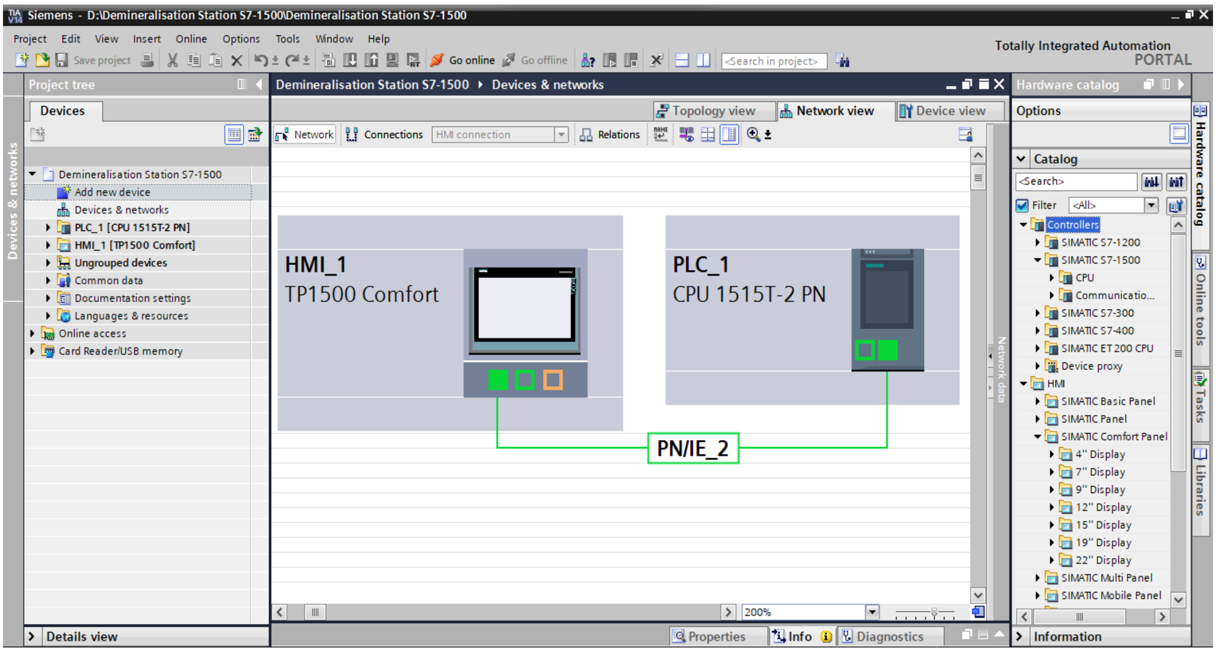


Figure IV.5: Hardware Editor

After inserting the S-7 1515T-2 PN and the HMI panel, we added the PLC add-on modules, such as the power supply and digital or analogue I/O modules, from the catalogue. To add additional devices, like another screen, we can use the 'Add a device' command in the project browser. Descriptions of selected elements were available in the information tab.

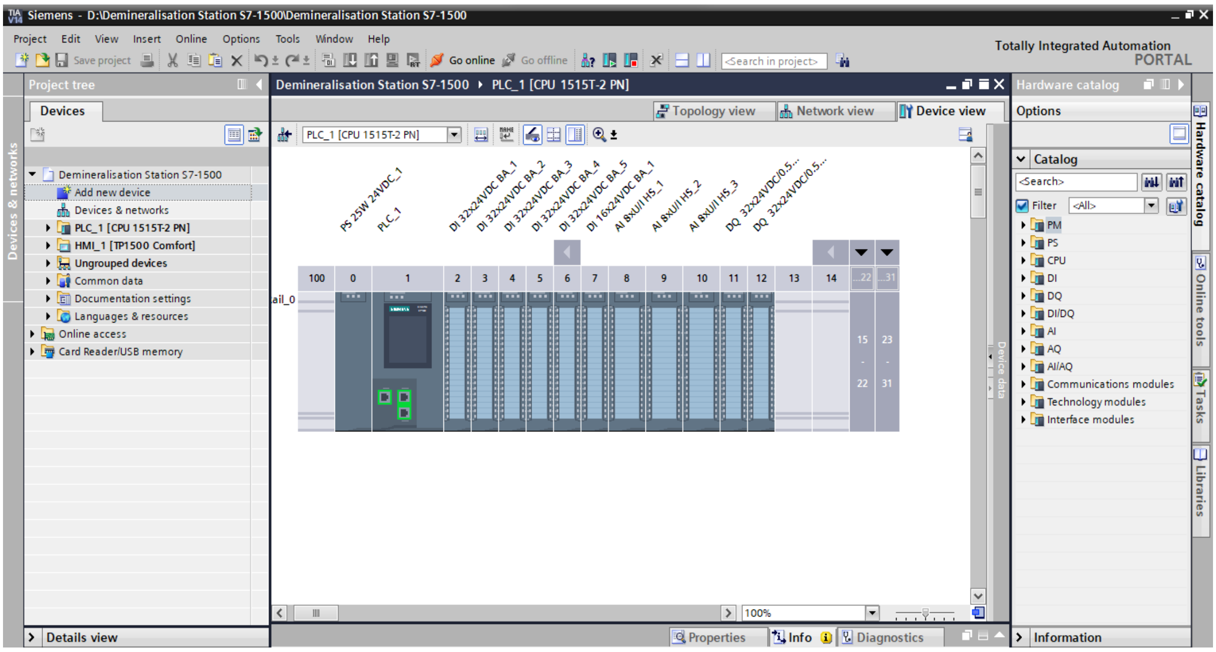
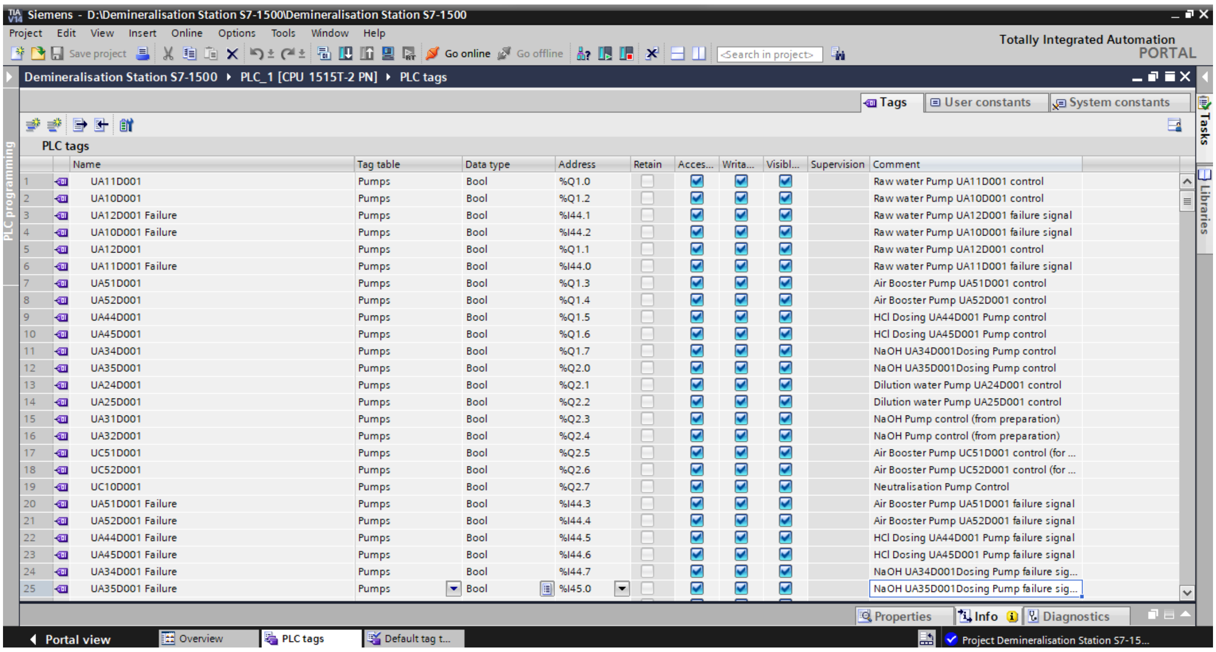


Figure IV.6: PLC Adds-on Modules (PS, I/O Modules)

IV.3.3. Defining PLC Tags

PLC tags in TIA Portal are names assigned to specific addresses of a programmable logic controller (PLC). These tags are used to simplify programming and troubleshooting by providing a more readable and understandable representation of the PLC's memory locations.

PLC tag tables contain the definitions of PLC tags and symbolic constants valid for the entire CPU. A PLC variable table is automatically created for the CPU in the project. In the project navigation, there is a 'PLC variables' folder for the CPU in the project, which contains the table of standard variables.



	Name	Tag table	Data type	Address	Retain	Acces...	Writa...	Visibl...	Supervision	Comment
1	UA11D001	Pumps	Bool	%Q1.0		✓	✓	✓		Raw water Pump UA11D001 control
2	UA10D001	Pumps	Bool	%Q1.2		✓	✓	✓		Raw water Pump UA10D001 control
3	UA12D001 Failure	Pumps	Bool	%I44.1		✓	✓	✓		Raw water Pump UA12D001 failure signal
4	UA10D001 Failure	Pumps	Bool	%I44.2		✓	✓	✓		Raw water Pump UA10D001 failure signal
5	UA12D001	Pumps	Bool	%Q1.1		✓	✓	✓		Raw water Pump UA12D001 control
6	UA11D001 Failure	Pumps	Bool	%I44.0		✓	✓	✓		Raw water Pump UA11D001 failure signal
7	UA51D001	Pumps	Bool	%Q1.3		✓	✓	✓		Air Booster Pump UA51D001 control
8	UA52D001	Pumps	Bool	%Q1.4		✓	✓	✓		Air Booster Pump UA52D001 control
9	UA44D001	Pumps	Bool	%Q1.5		✓	✓	✓		HCl Dosing UA44D001 Pump control
10	UA45D001	Pumps	Bool	%Q1.6		✓	✓	✓		HCl Dosing UA45D001 Pump control
11	UA34D001	Pumps	Bool	%Q1.7		✓	✓	✓		NaOH UA34D001Dosing Pump control
12	UA35D001	Pumps	Bool	%Q2.0		✓	✓	✓		NaOH UA35D001Dosing Pump control
13	UA24D001	Pumps	Bool	%Q2.1		✓	✓	✓		Dilution water Pump UA24D001 control
14	UA25D001	Pumps	Bool	%Q2.2		✓	✓	✓		Dilution water Pump UA25D001 control
15	UA31D001	Pumps	Bool	%Q2.3		✓	✓	✓		NaOH Pump control (from preparation)
16	UA32D001	Pumps	Bool	%Q2.4		✓	✓	✓		NaOH Pump control (from preparation)
17	UC51D001	Pumps	Bool	%Q2.5		✓	✓	✓		Air Booster Pump UC51D001 control (for ...
18	UC52D001	Pumps	Bool	%Q2.6		✓	✓	✓		Air Booster Pump UC52D001 control (for ...
19	UC10D001	Pumps	Bool	%Q2.7		✓	✓	✓		Neutralisation Pump Control
20	UA51D001 Failure	Pumps	Bool	%I44.3		✓	✓	✓		Air Booster Pump UA51D001 failure signal
21	UA52D001 Failure	Pumps	Bool	%I44.4		✓	✓	✓		Air Booster Pump UA52D001 failure signal
22	UA44D001 Failure	Pumps	Bool	%I44.5		✓	✓	✓		HCl Dosing UA44D001 Pump failure signal
23	UA45D001 Failure	Pumps	Bool	%I44.6		✓	✓	✓		HCl Dosing UA45D001 Pump failure signal
24	UA34D001 Failure	Pumps	Bool	%I44.7		✓	✓	✓		NaOH UA34D001Dosing Pump failure sig...
25	UA35D001 Failure	Pumps	Bool	%I45.0		✓	✓	✓		NaOH UA35D001Dosing Pump failure sig...

Figure IV.7: PLC Tags Table

To enhance project organization, we implemented a hierarchical structure for our PLC tags. This approach transformed previously unwieldy tag lists into a modular and aesthetically pleasing application. Furthermore, it facilitated efficient access and modification of variables during the programming phase (Appendix A).

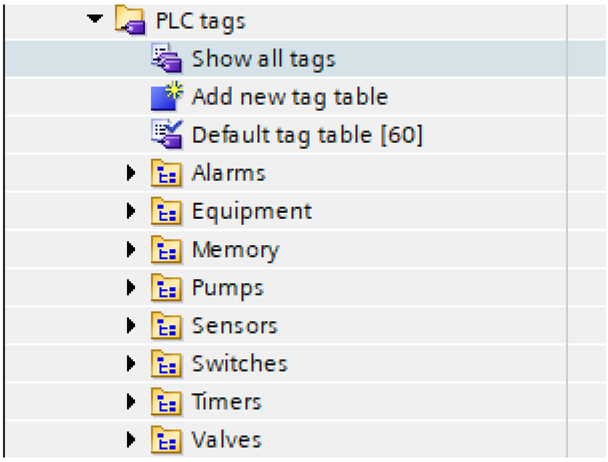


Figure IV.8: PLC Tags Groups

IV.3.4. PLC Programming

PLC programming involves creating control programs for industrial automation systems using specialized blocks and programming languages with a focus on understanding the underlying physical processes and systems being controlled. Effective PLC program management is crucial for successfully delivering multiple PLC programming projects.

Various types of blocks are accessible for executing tasks within an automation system. These blocks are:

IV.3.4.1. Organization blocks (OB): Organization blocks define the structure of the user program.

IV.3.4.2. Functions (FC): Functions contain program routines for recurring tasks. They have no "memory".

IV.3.4.3. Function blocks (FB): Function blocks are code blocks that store their values permanently in instance data blocks, so that they remain available even after the block has been executed.

IV.3.4.4. Data Blocks (DB):

- **Instance data blocks:** Instance data blocks are assigned to a function block when it is called for the purpose of storing program data.
- **Global data blocks:** Global data blocks are data areas for storing data that can be used by any blocks.

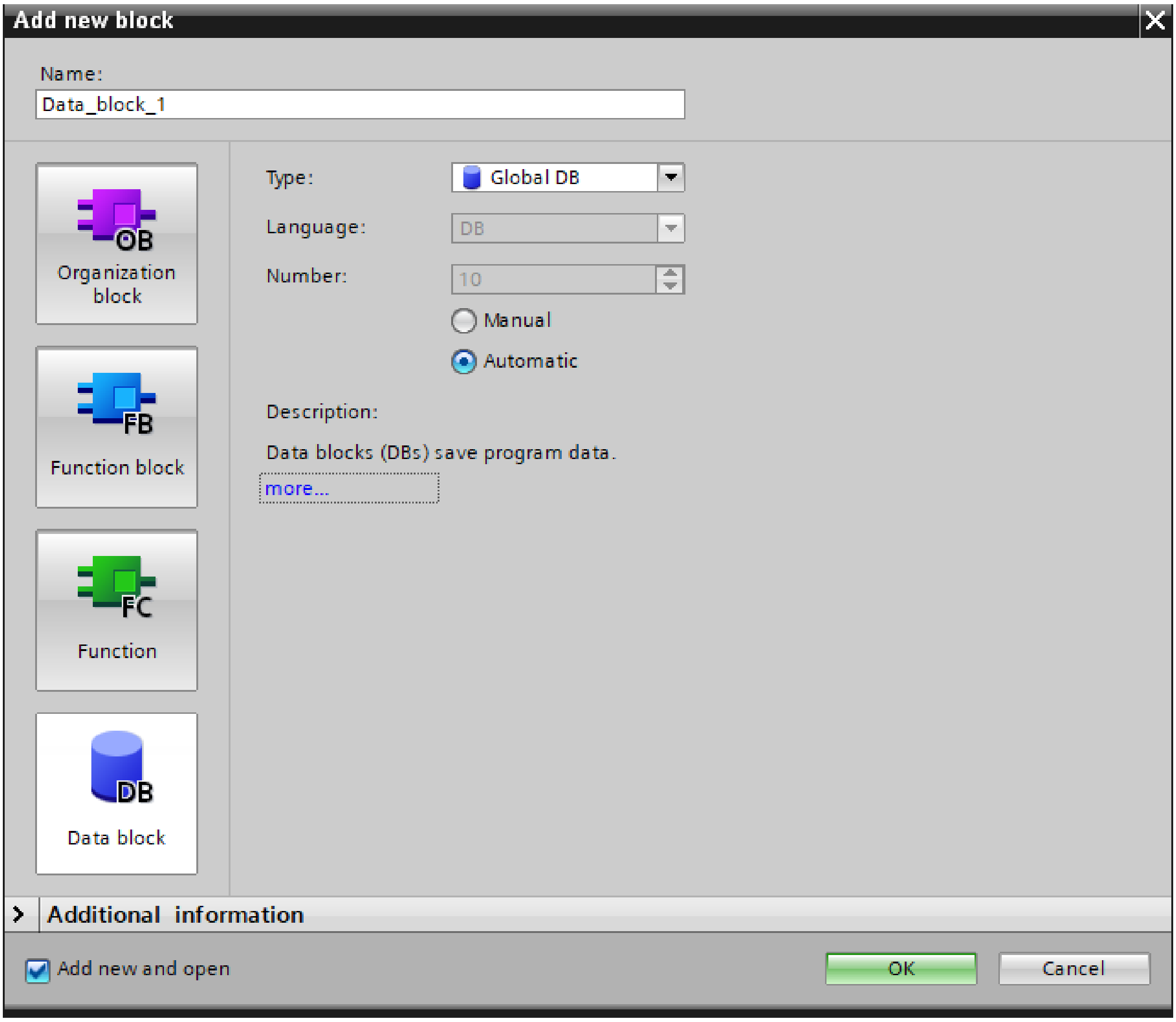


Figure IV.9: Blocks Addition

In our automated solution for the demineralisation station, we used one (1) organization block (OB) programmed in ladder logic (LAD) and 6 other function blocks (FB) programmed in sequential function chart (SFC) in order to insure the efficiency and the reliability of our program.

IV.4. Demineralisation Station Automated Solution Program

Our program is structured into a single organization block (OB1) programmed in Ladder Logic (LAD) and six function blocks (FB1 to FB6). These function blocks are programmed using Sequential Function Chart (SFC or GRAPH), as our process is sequential and comprises numerous chronological steps.

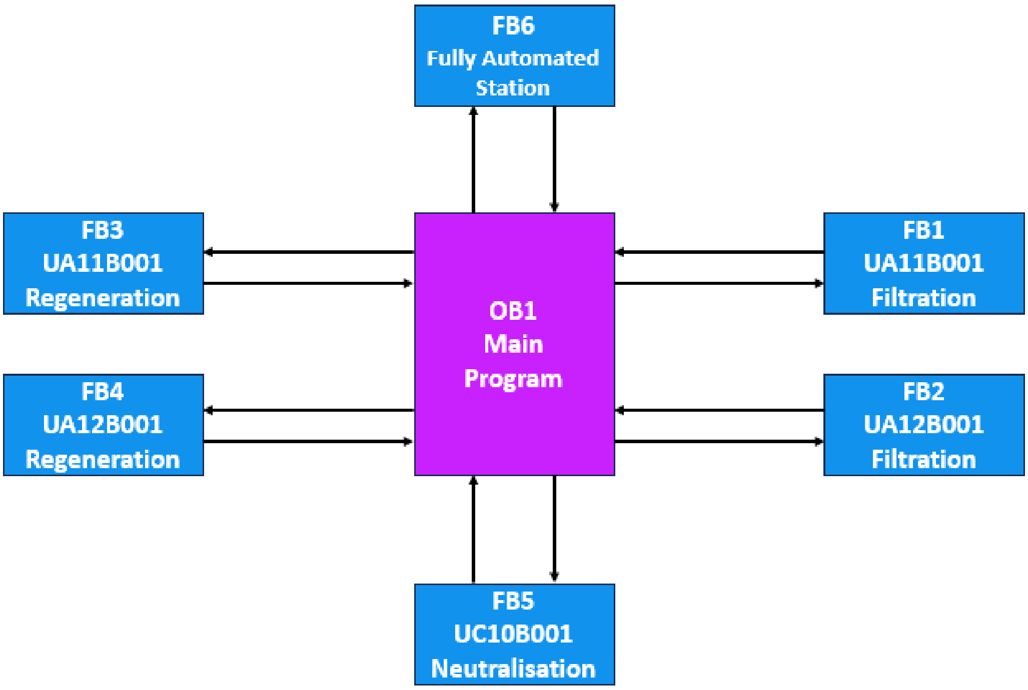


Figure IV.10: Program Structure

The main program block (OB1) encompasses the station start networks and the analogue sensor signals. Additionally, it includes the transition activation networks for the functions and timers.

The function blocks FB1 to FB5 execute various processes of the demineralisation station, which are:

- **FB1:** Filter UA11B001 filtration process
- **FB2**: Filter UA12B001 filtration process
- **FB3**: Filter UA11B001 filtration regeneration
- **FB4**: Filter UA12B001 filtration regeneration
- **FB5**: Pit UC10B001 neutralisation

In addition to these functions, we have implemented a new function block, FB6, named "Fully Automated Station." This function autonomously performs all station processes without any operator intervention, simply by calling the function blocks listed below.

- **Station Mode and Start**

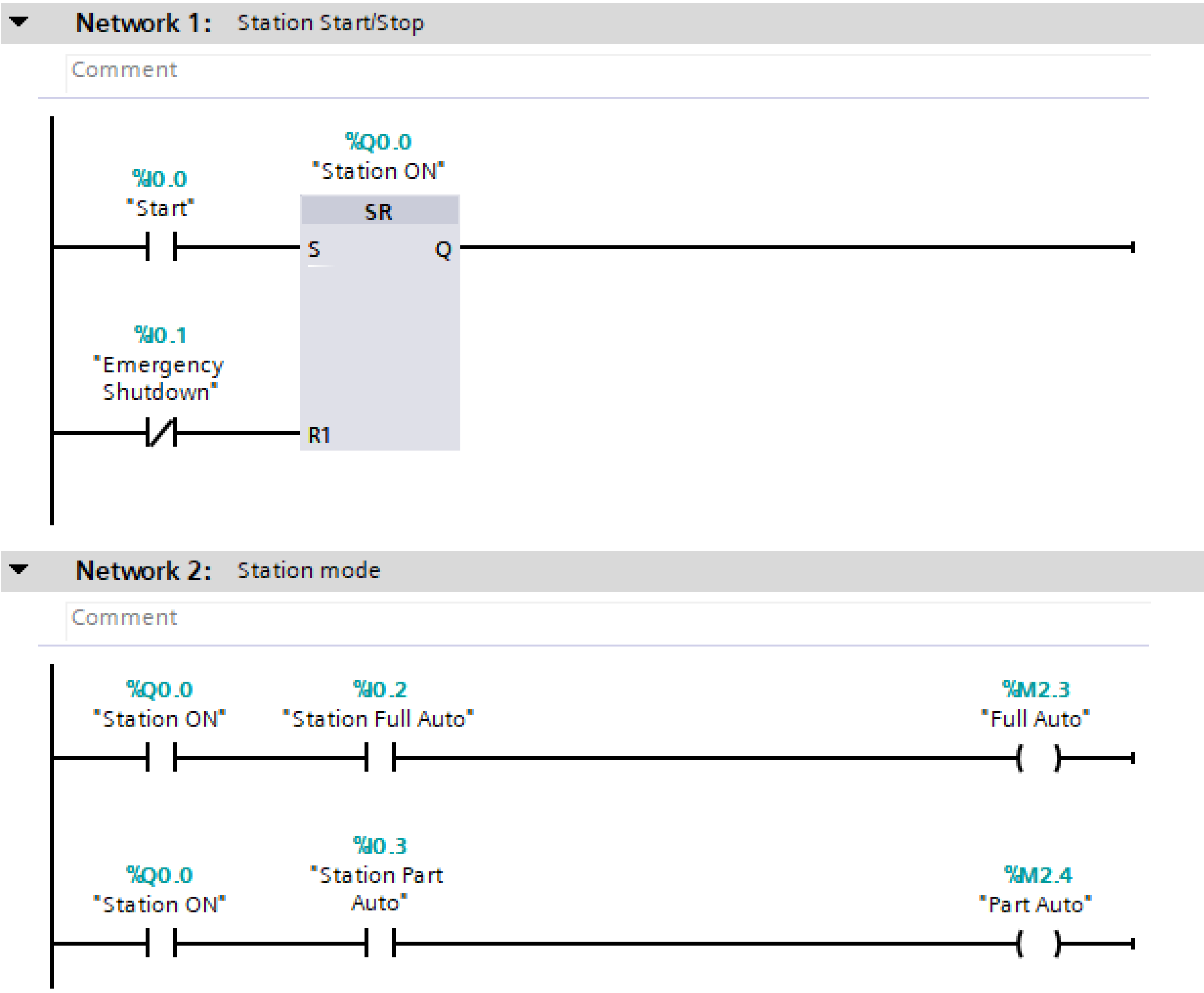


Figure IV.11: Station Start and Operating Mode Networks [OB1]

To activate the station, the operator must press the push button (I0.0) in the control room. This action sets the output (Q0.0) to 1, initiating the station's operation and illuminating an indicator lamp in the control room to Indicate that the station is now in operational mode. In case of an emergency, the operator activates the emergency shutdown button (I0.1), which resets the station to off-service mode.

Once the station is activated, it will not commence any operations until the operator selects one of the two operating modes: “Full Auto” (M2.3) or “Part Auto” (M2.4). The operator does this by turning the switch to either the “Station Full Auto” (I0.2) or “Station Part Auto” (I0.3) position.

In the partially automated mode, the operator manually starts operations such as filtration, regeneration, and neutralisation. In the fully automated mode, all operations will commence automatically based on the required conditions.

Note: In the following section, we will focus on the details of filter UA11B001. The same principles apply to filter UA12B001, with differences only in their respective inputs and outputs.

- **Filter UA11B001 Operating Mode**

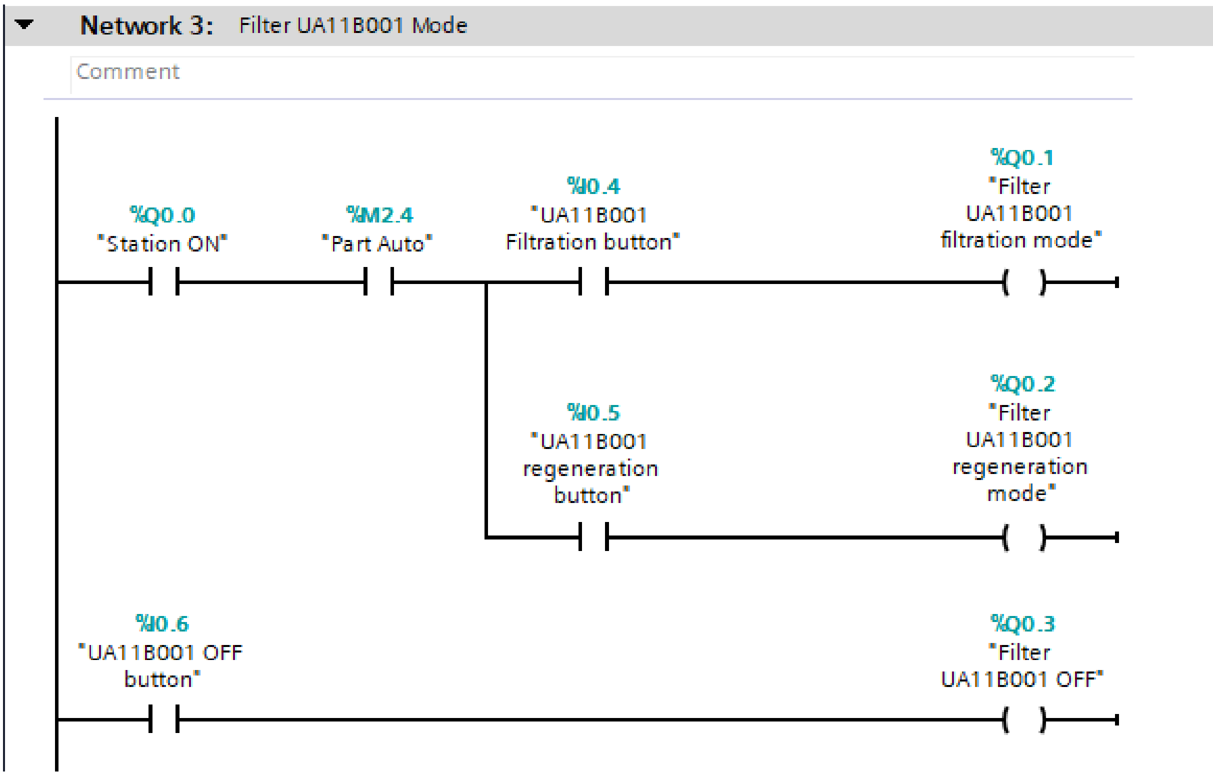


Figure IV.12: Filter UA11B001 Operating Mode Network [OB1]

To manually set filter UA11B001 to either filtration or regeneration mode, the station must be in service and operating in partially automated mode (Q0.0 and M2.4 must be true). The operator can switch between modes by turning the control room switch to (I0.4) for filtration mode or (I0.5) for regeneration mode. To deactivate the filter, the operator should turn the switch to the off position (I0.6).

- **Neutralisation Start**

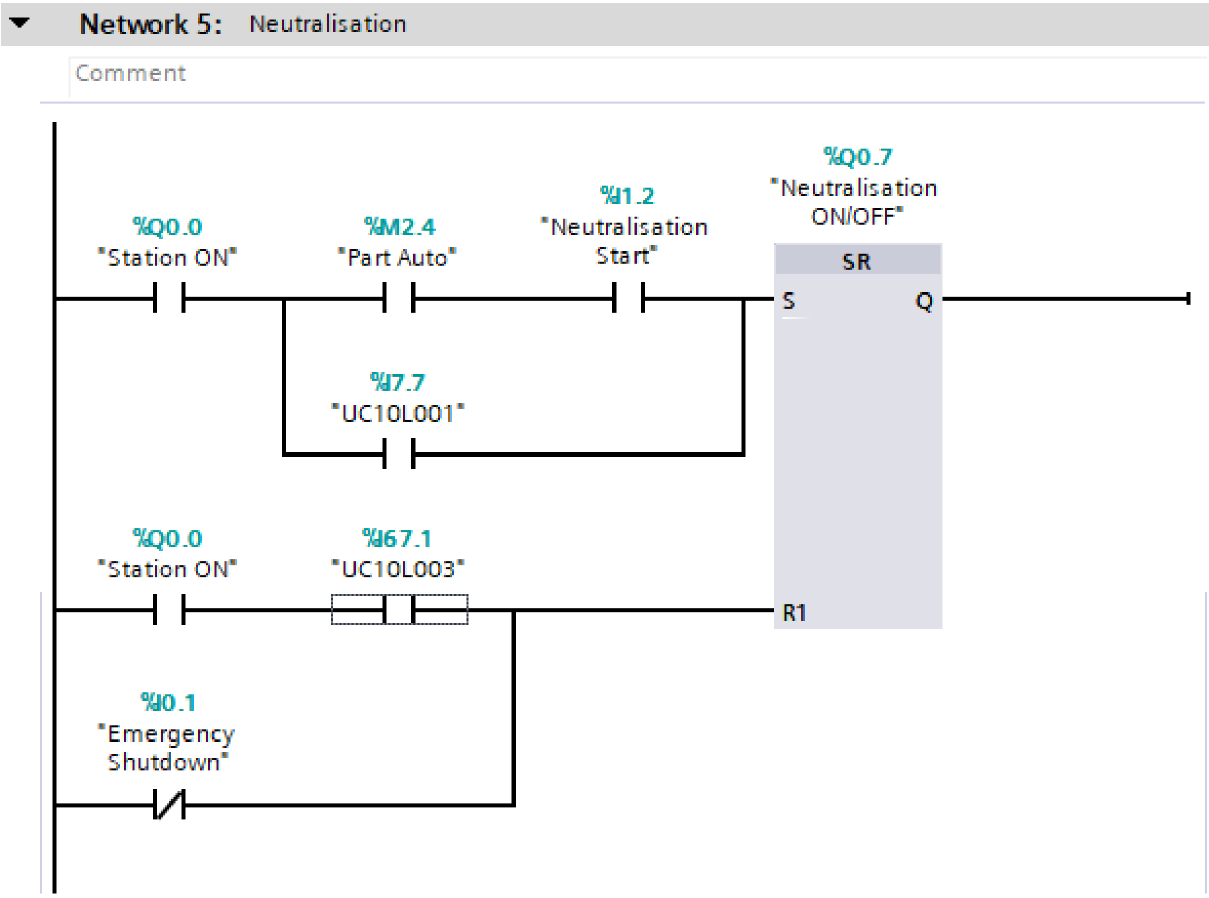


Figure IV.13: Neutralisation Start Network [OB1]

Neutralisation can be initiated either manually or automatically when the station is in partially automated mode. When the high-level sensor UA10CL002 in the neutralisation pit triggers an alarm in the control room, it alerts the operator to start neutralisation by pressing the momentary switch (I1.2).

If the operator is absent or does not start the neutralisation manually and the level reaches a critical high, the sensor UC10L001 (I7.7) sends a signal to automatically begin the neutralisation process to empty the pit.

Neutralisation will stop either when the low-level sensor UC10L003 (I67.1) indicates that the pit has reached the low level or in the event of an emergency shutdown (I0.1).

- **Analog Input Conditioning:**

Example: Water Conductivity out of filter UA11B001

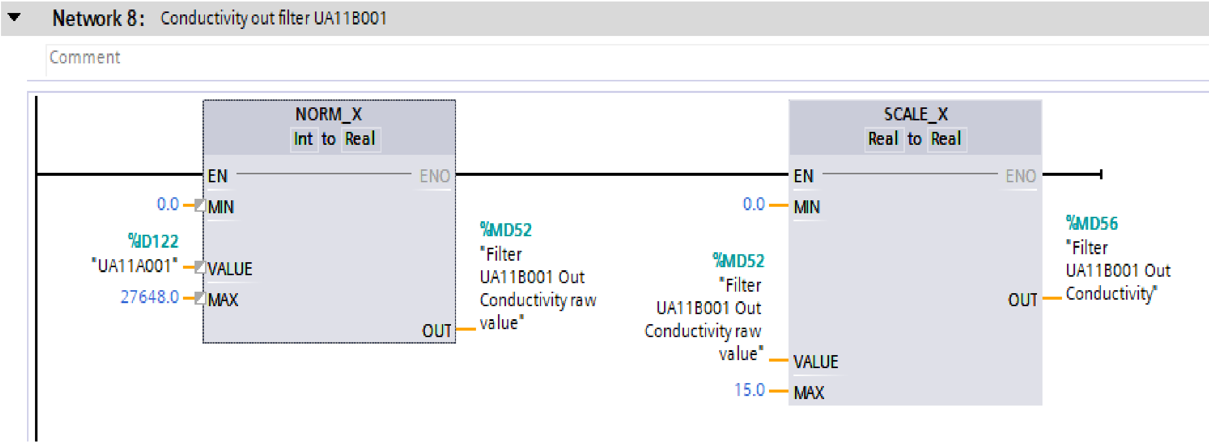


Figure IV.14: Analog Input Normalization and Scaling [OB1]

- **NORM_X:** The "Normalize" instruction maps the value of the tag at the VALUE input to a linear scale defined by the MIN and MAX parameters. The output, stored as a floating-point number, depends on where the VALUE lies within this range. If VALUE equals MIN, the output is "0.0"; if VALUE equals MAX, the output is "1.0".
- **SCALE_X:** The "Scale" instruction maps the floating-point value at the VALUE input to a specified range defined by the MIN and MAX parameters. The result of this scaling is a value stored in the OUT output.

The NORM_X block normalizes the raw conductivity value (ID122) within the range of 0.0 to 27648.0 to a value between 0.0 and 1.0, outputting it to (MD52). The SCALE_X block then takes this normalized value and scales it to a range of 0.0 to 15.0, storing the final and real conductivity value in (MD56).

- **UA11B001 Filtration Function Block [FB1]**

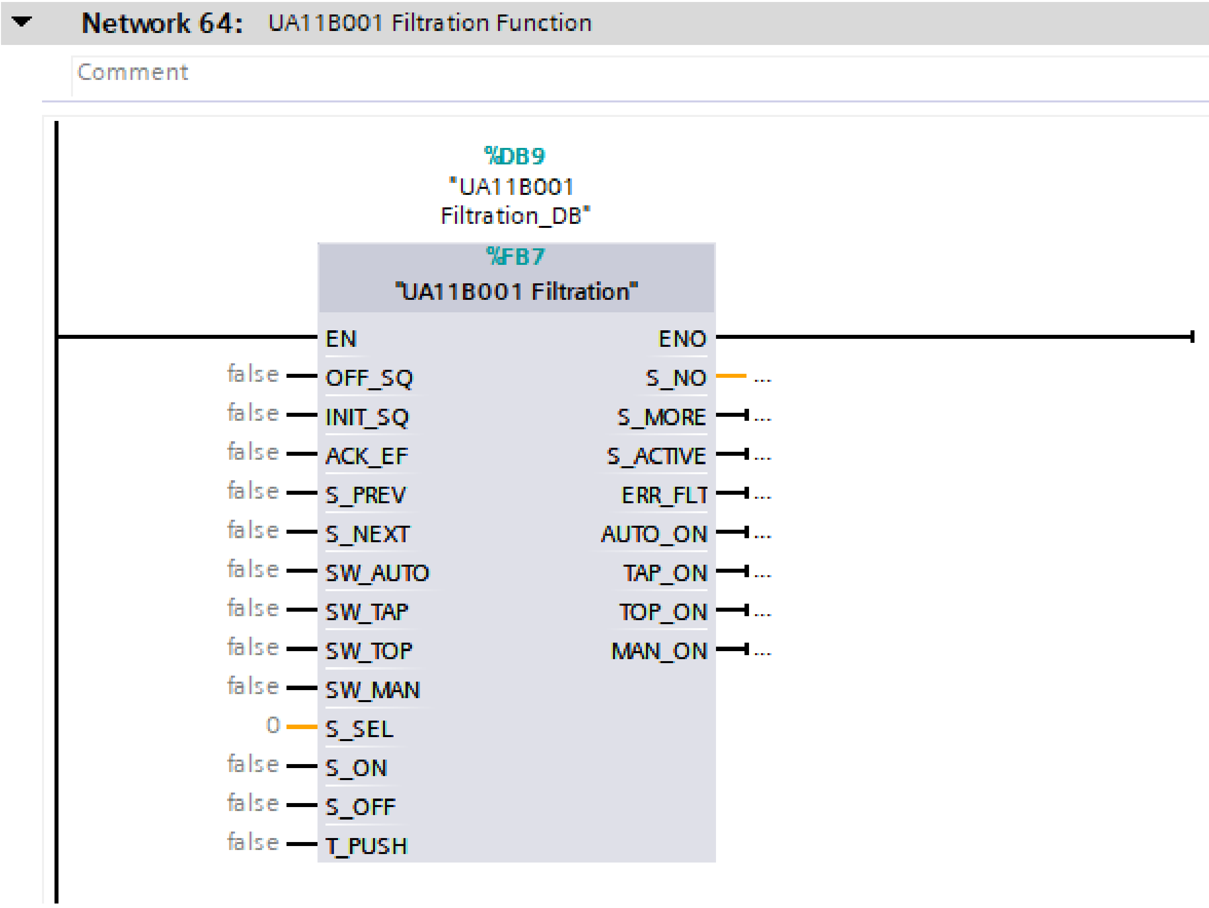


Figure IV.15: Filter UA11B001 Filtration Function Block [OB1]

The filtration function block continuously collects data as it operates constantly. However, it does not perform filtration unless the operator sets the filter UA11B001 to filtration mode (when Q0.1 is true) or triggers the auto-filtration contact (M600.0) through a fully automated function.

Once one of these conditions is met, the sequence advances to the start step via transition (T9), and the filtration step is activated.

Upon activation, the filtration step initiates and the second sequence is activated. The filtration sequence starts reading inputs and conditions in OB1 and executing the program written in Sequential Function Chart (SFC). It then directly controls valves or sends requests to OB1 to start pumps and air boosters by activating memory bits (Appendix C).

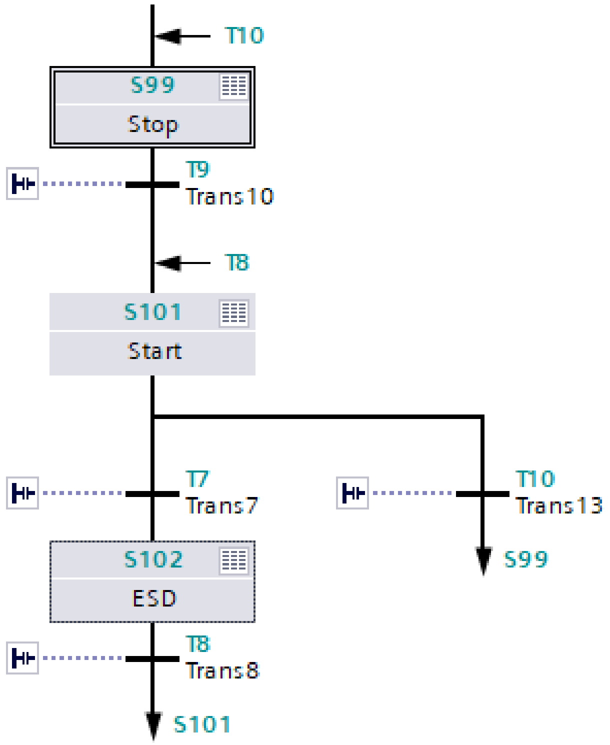


Figure IV.16: UA11B001 Filtration Start and Stop Sequence (Minimized) [FB1]

If any error or critical alarm is triggered, transition (T7) is activated, and the sequence moves to the emergency shutdown step, where all equipment ceases operation. This sequence is applied to all functions to maintain a high level of security.

- **UA11B001 Filtration First Step: Pre-service**

The first step of the filtration process involves opening the necessary valves and starting the raw water pump. Previously, the system would start the pumps immediately after initiating filtration. This approach caused numerous problems, particularly when a valve failed to open, resulting in pumps operating in a closed pipe or filter. This could lead to increased pressure, potentially damaging the filter, pipe, or pumps.

To address this issue, we separated the valve operations and pump start into two distinct steps. The first step involves opening valves UA11S007 and UA11S012. This is achieved by using the qualifier (S) to activate outputs (Q4.0) and (Q4.3), while the qualifier (R) deactivates other vales and the second step request the start of the raw water pumps by activating the memory bit (M500.0)

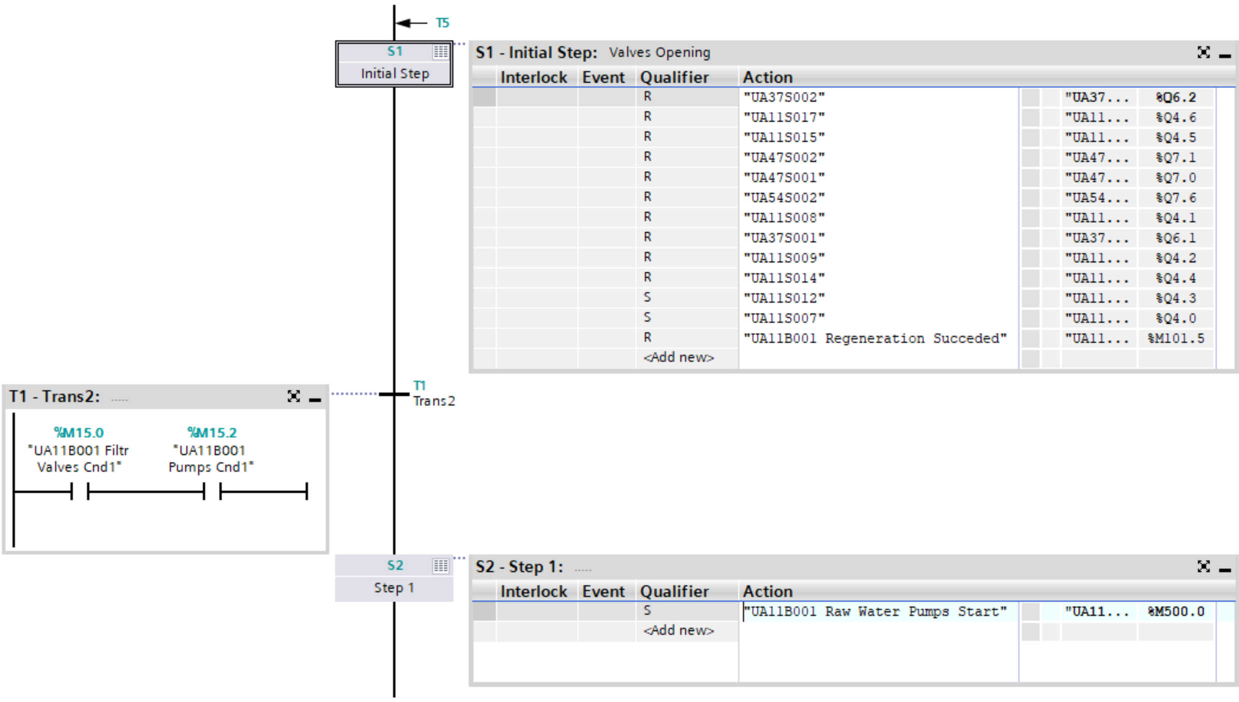


Figure IV.17: UA11B001 Filtration First Step (Separated) [FB1]

Once valves UA11S007 and UA11S012 are fully open, their respective limit switches (I62.7) and (I63.3) become true. Additionally, the limit switches for the other valves indicate they are fully closed. When the necessary limit switches are active, the first condition (M15.0) to proceed to the next step is met.

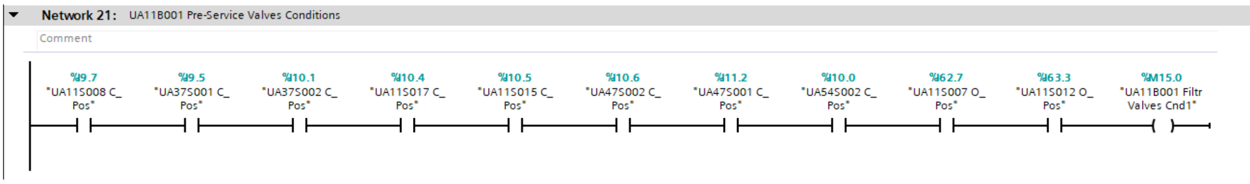


Figure IV.18: UA11B001 Filtration First Step Valves Conditions Network [OB1]

The second condition requires at least one of the water pumps assigned to filter UA11B001 to be in automatic mode. The operator achieves this by setting pump UA11D001 (Main) to automatic mode (I66.0 true) or pump UA10D001 (Backup) to automatic mode (I3.6), or both. This activates the second condition (M15.2).

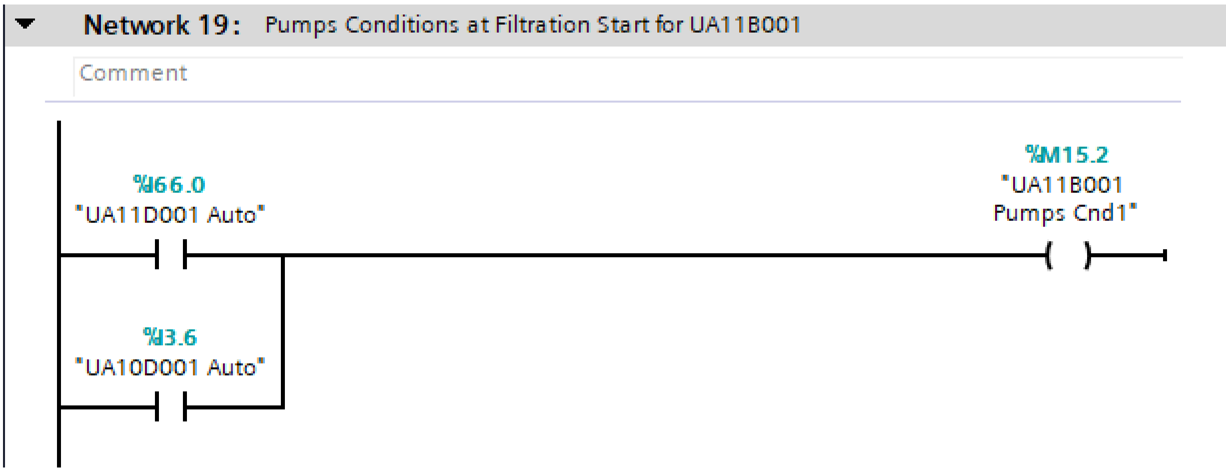


Figure IV.19: UA11B001 Filtration Pumps Condition Network [OB1]

Once both conditions are satisfied, the process advances to the second step, which involves starting the raw water pumps by activating the memory bit (M500.0). This ensures that the pumps only start when it is confirmed that safe conditions for pumping are met. Once the raw water pumping starts, the pre-service step is considered started.

This principle is applied not only to the filtration of UA11B001 but also to every other function in any step that requires pumping fluids in order to enhance process safety measures.

- **UA11B001 Raw Water Pumps start**

After the filtration function activates the memory bit (M500.0) that requests the raw water pumps to start (or any other function that needs the raw water to do its operation). The memory bit (M500.0) sets the bit that starts the raw water pumps.

The raw water pumps start order (M550.0) can start only be set if:

- The raw water storage tanks level is not low (M60.0 is false)
- In case of filtration, the dilution water storage tank level is not high (M60.2 is false)

If any of these conditions is true, the raw water pumps will not start or it will stop during any step even if the request to start (M500.0) is true.

When the memory bit (M500.0) turns to 0, it resets the raw water pumps order to 0 through the normally closed contact in the reset channel R1

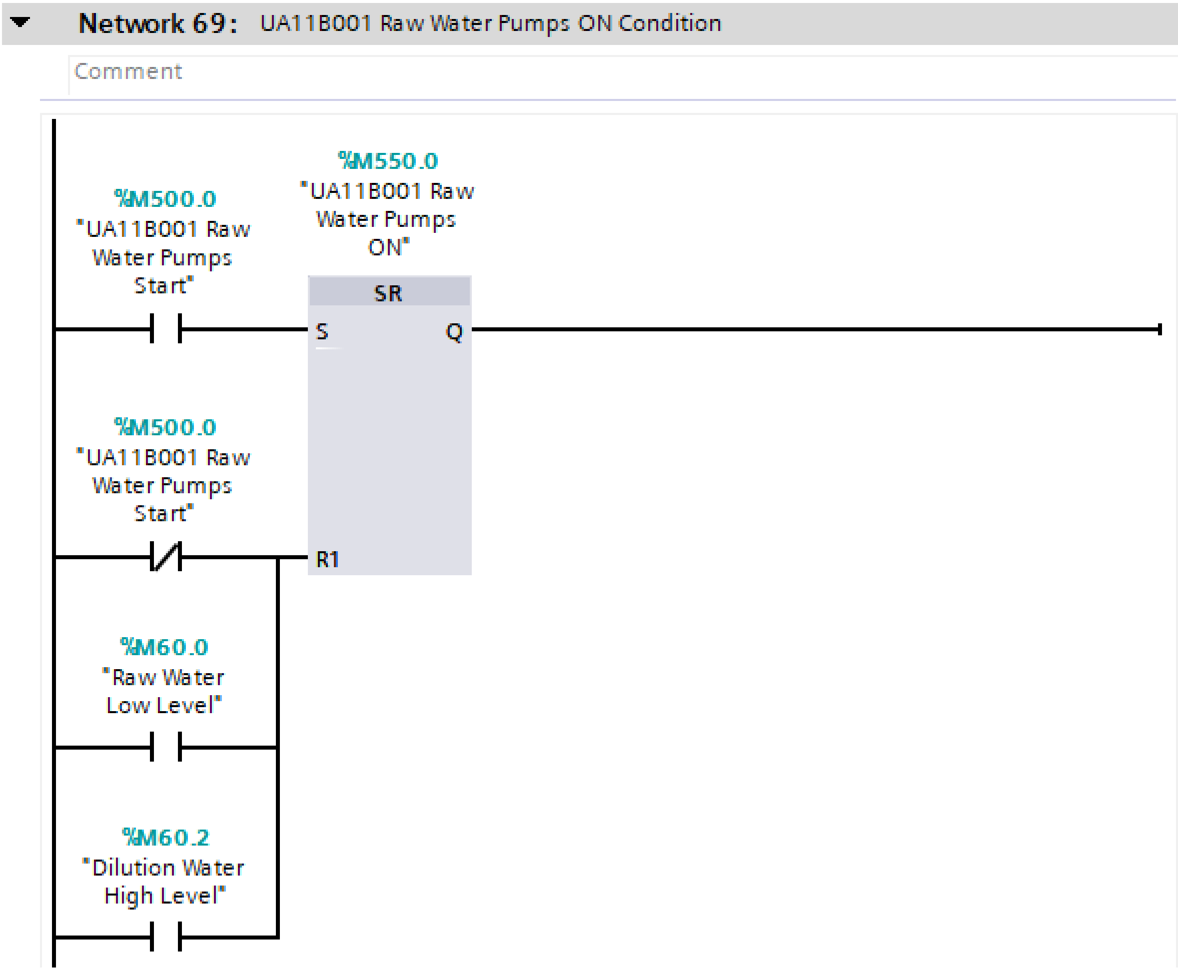


Figure IV.20: Raw Water Pumps Start Order [OB1]

- **UA11B001 Raw Water Main Pumps**

In the current control system, the operator can select only one pump to operate at a time, either the main pump UA11D001 or the backup pump UA10D001. If both pumps are set to automatic mode, they will both start when the order (M550.0) is active. This undesired behaviour can lead to an increased flow beyond safe limits or cause damage to the equipment.

Our solution retains the current configuration, allowing the operator to choose only one pump to operate if the other encounters issues. In this case, only the selected pump will run. Additionally, we have introduced the option to set both pumps to automatic mode without running them simultaneously. The system will initially start the main pump UA11D001, and if it fails, it will automatically switch to the backup pump UA10D001.

Main Pump (UA11D001)

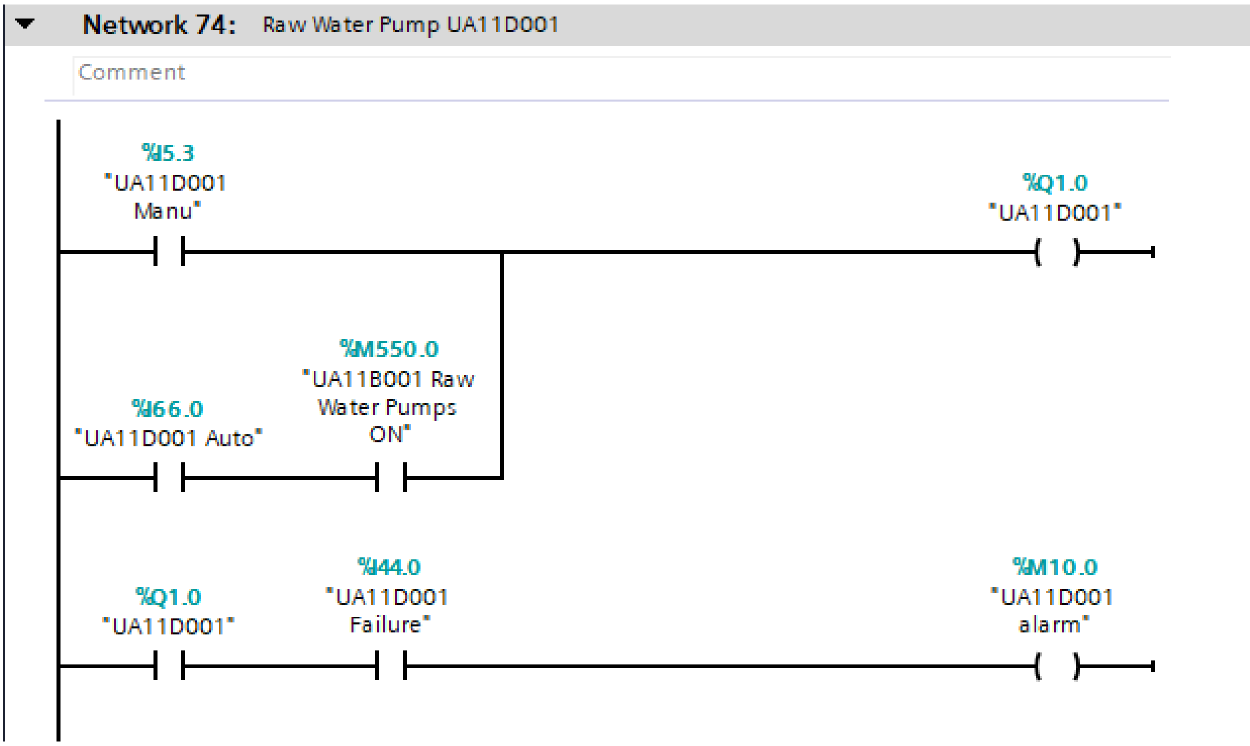


Figure IV.21: Pump UA11D001 Control Network [OB1]

The pump UA11D001 is designed to pump raw water into filter UA11B001 as needed. It can be started manually by the operator bypassing all conditions, by turning the switch to activate input (I5.3).

Alternatively, the pump can be set to automatic mode by ensuring input (I66.0) is true. Once this condition is met and the raw water pumps order (M550.0) is active (figure 4.20), the pump will start operating.

If the pump is running and an error occurs causing the pump to fail, a feedback signal is sent through input (I44.0), triggering an indicating alarm (M10.0).

Backup Pump (UA10D001)

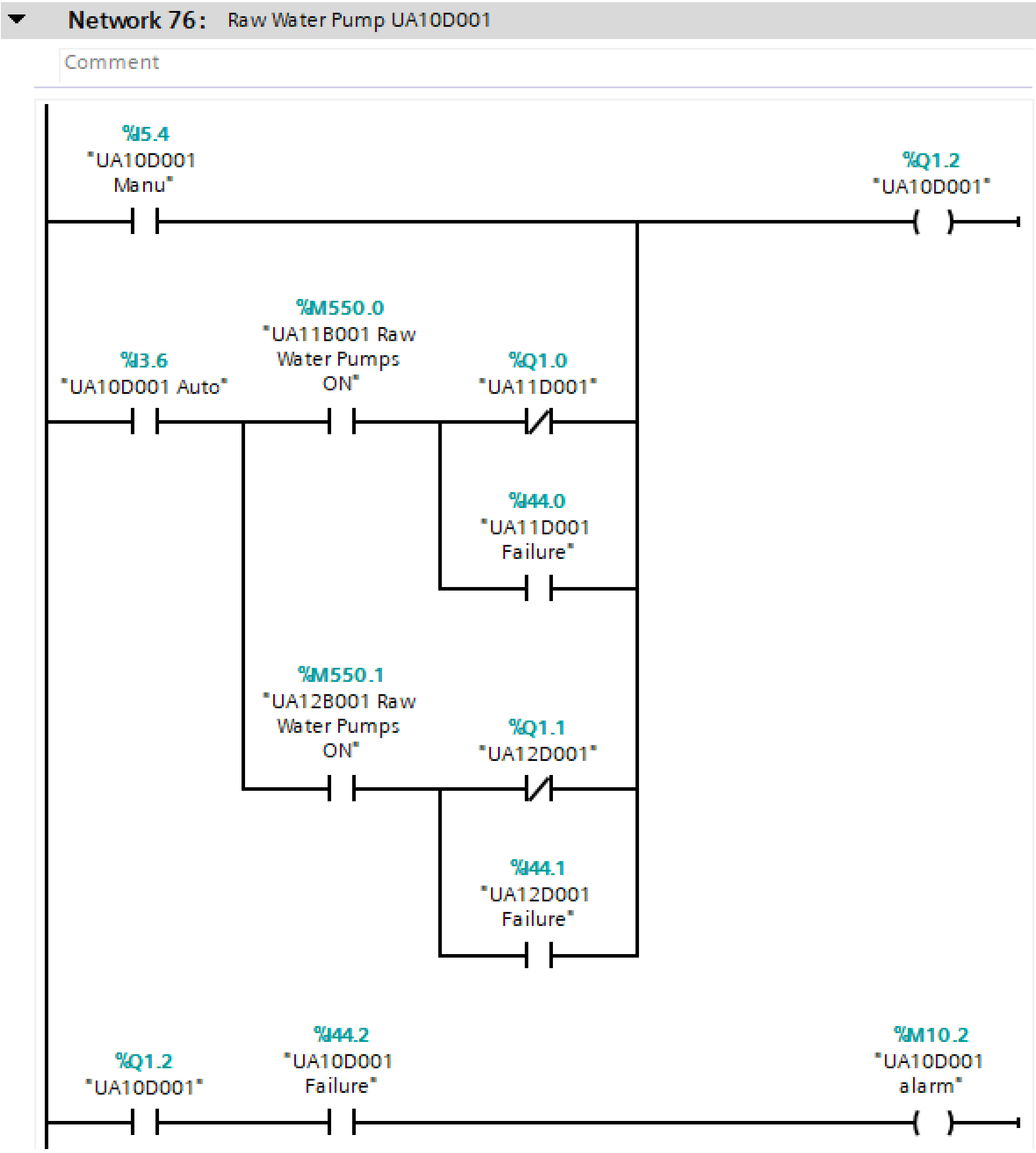


Figure IV.22: Pump UA10D001 Control Network [OB1]

The pump UA10D001 is designed to pump raw water into filter UA11B001 in the event of unavailability or failure of the main pump, UA11D001. It can also be started manually by the operator, bypassing all conditions, by turning the switch to activate input (I5.4).

To start pump UA10D001 automatically, the operator must set it to automatic mode via the switch (I3.6). There are two scenarios for automatic operation:

- If pump UA11D001 is out of service (Q1.0 is false), pump UA10D001 will start as the main pump.
- If pump UA11D001 is in service, pump UA10D001 will act as a backup and will only start if UA11D001 fails (I44.0 is true).

If an error occurs while the pump is running, causing it to fail, a feedback signal is sent through input (I44.2), triggering an indicating alarm (M10.2).

- **UA11B001 Filtration Step**

In this step, the operator manually forces the filter to recirculate the water by adjusting the low and high conductivity setpoints. The recirculation continues until the operator observes that the conductivity has stabilized below 0.1 µS/cm, typically taking 5 to 7 minutes. Once the conductivity stabilizes, the operator raises the low conductivity setpoint to 0.1 µS/cm, allowing the filter to start sending water to the storage tanks.

If the conductivity exceeds the low limit afterward, it indicates that the resins are saturated and require regeneration. Conversely, if the operator notices that the conductivity cannot stabilize below the low limit, showing peaks or anomalies for more than one hour, it indicates that the filter needs regeneration.

To eliminate the need for operator presence during the filtration process, we developed a solution using timers to automate the transitions between recirculation, filtration, storage, and determining the necessity for regeneration.

Timer T100: this timer is set to check the stability of conductivity below 0.1 µS/cm time. This timer is an S_ODTS timer (Set on Delay Time and Save). It starts once the raw water pumps are running and the conductivity is less than 0.1 µS/cm (Q0.1, M550.0, and M16.0 are true). The timer's output remains at 0 until 10 minutes have passed, a duration significantly longer than the average conductivity stabilization time. After 10 minutes, the timer's output becomes true (1). If the conductivity exceeds the 0.1 µS/cm limit, the timer stops and resets, then restarts counting when the conductivity drops below 0.1 µS/cm again. (Figure IV.23)

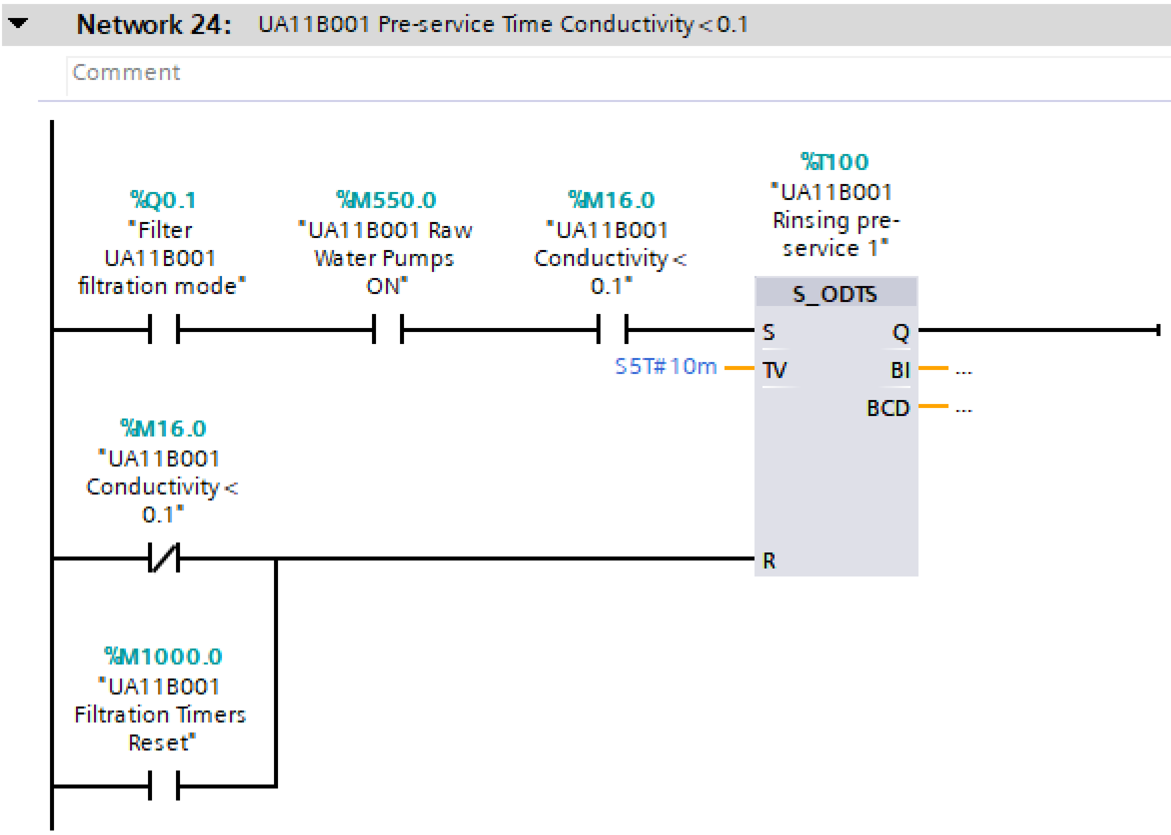


Figure IV.23: Conductivity Stabilization Timer Network [OB1]

Timer T101: designed to track the maximum duration of the water recirculation process. It is an S_ODTS type timer also. This timer activates at the beginning of the recirculation step when both (Q0.1) and (M550.0) are true. (Figure IV.24)

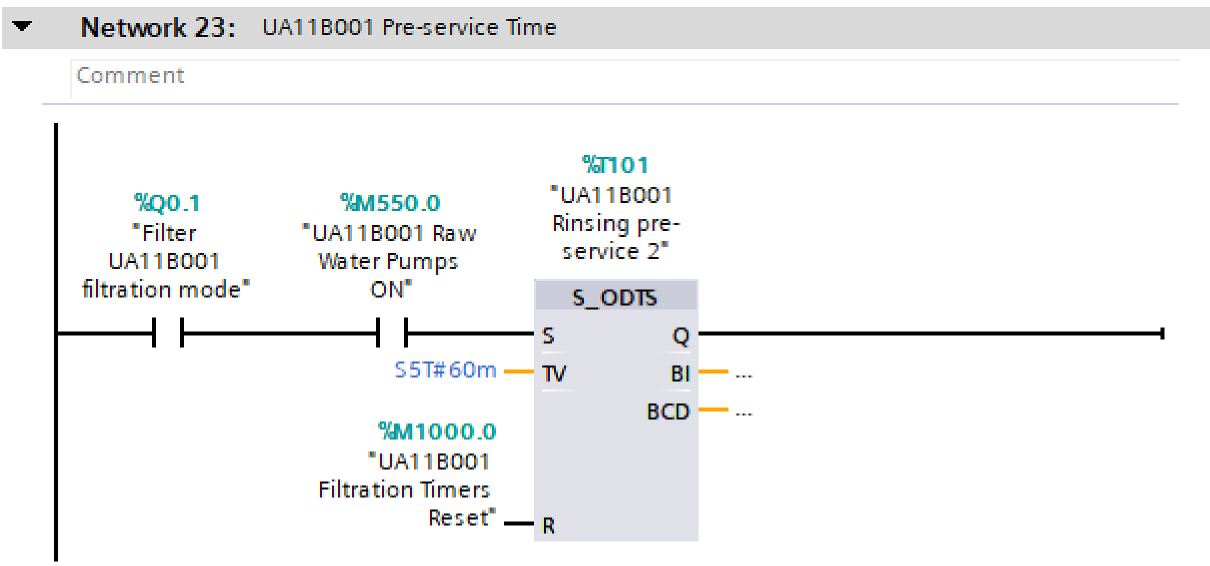


Figure IV.24: UA11B001 Water Recirculation Timer Network [OB1]

When the recirculation begins (S2 is active), water flows through valve UA11S012 and returns to filter UA11B001.

If timer (T101) activates before timer (T100), indicating that the conductivity did not stabilize below 0.1 µS/cm for at least 10 consecutive minutes during the 60-minute recirculation period, transition (T4) is triggered. This causes the sequence to jump from S2 to S4, where it indicates that the filter needs regeneration and the water pumps stop.

Conversely, if timer (T100) activates before timer (T101), meaning that the water conductivity stabilized below 0.1 µS/cm for at least 10 minutes before the recirculation time elapses, transition (T2) is triggered. This moves the sequence to S3, where valve UA11S012 is closed and valve UA11S009 is opened, directing the water into the storage tanks.

While in S3, if the conductivity rises above 0.1 µS/cm, transition (T3) is activated. This indicates that the resins are saturated, prompting the sequence to move to S4, where the raw water pumps are stopped and the need for filter regeneration is indicated.

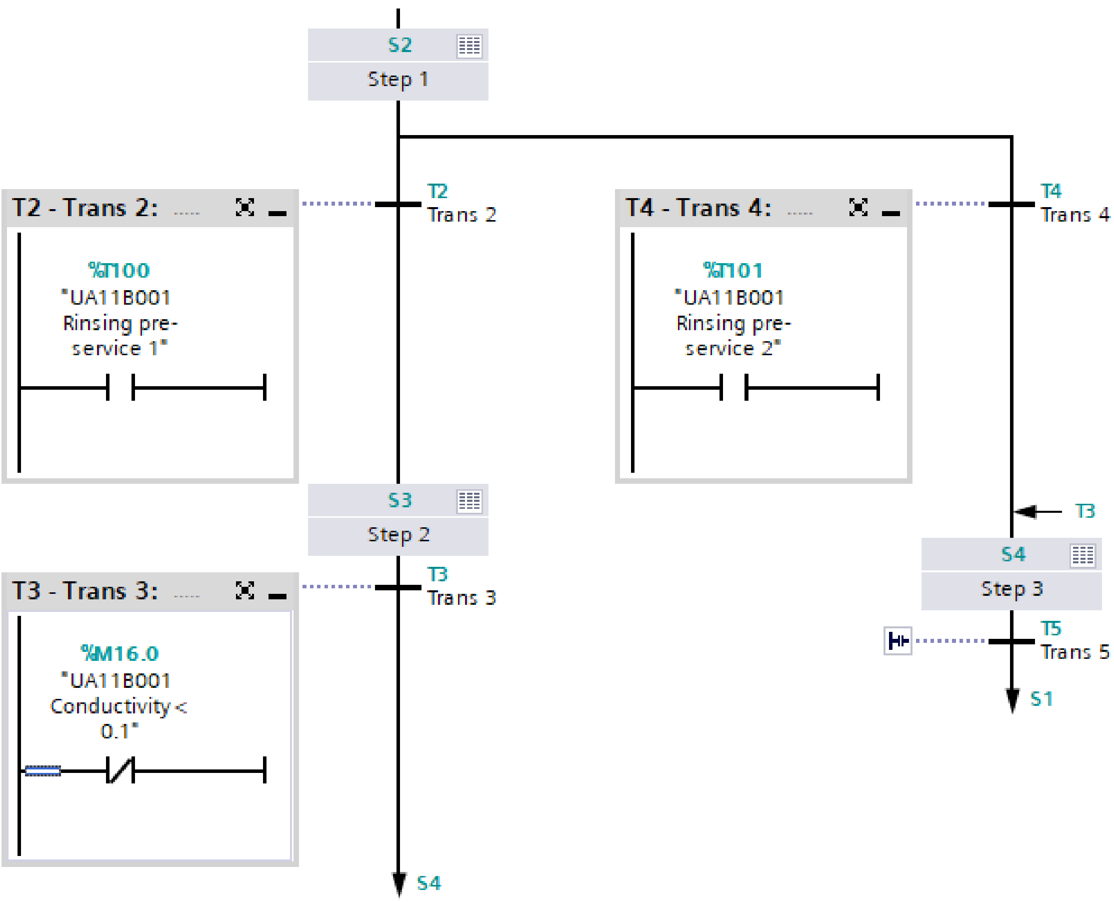


Figure IV.25: UA11B001 Filtration Step and Filtration End [FB1]

- **Raw Water Valves Switchover**

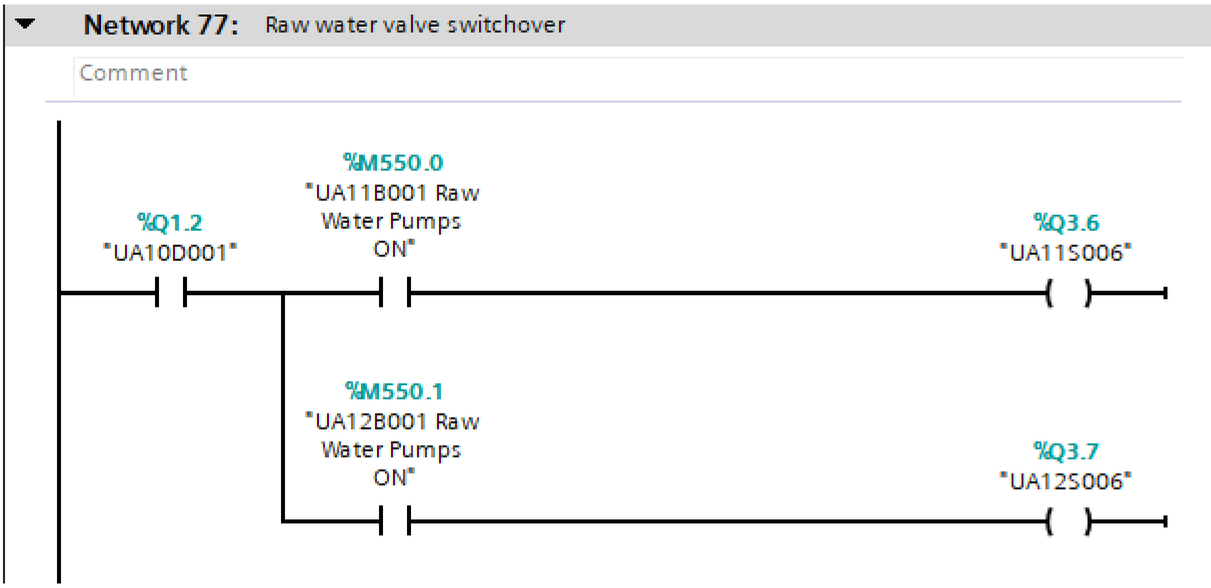


Figure IV.26: Raw Water Valves Switchover Network [OB1]

The currently installed valves, UA11S006 and UA12S006, are manual valves that the operator must open locally before allowing pump UA10D001 to operate as a backup for pumps UA11D001 or UA12D001. To improve this process, we replaced the manual valves with controllable pneumatic valves.

These valves open based on the direction of the flow. If the memory (bit M550.0) for pump UA11D001 is true, indicating that the flow is directed to filter UA11B001, valve UA11S006 opens. Conversely, if the memory bit (M550.1) is true, signalling that the flow is directed to filter UA12B001, valve UA12S006 opens.

- **Storage/Dilution Water Valves Switchover**

The valves UA14S001 and UA15S001, which direct filtered water to the storage and dilution tanks, are currently manual valves operated locally by an operator. In our solution, we replaced these manual valves with controllable pneumatic valves.

The opening and closing of these pneumatic valves are regulated based on the water levels in tanks 12UD10B001 and 34UD10B001.

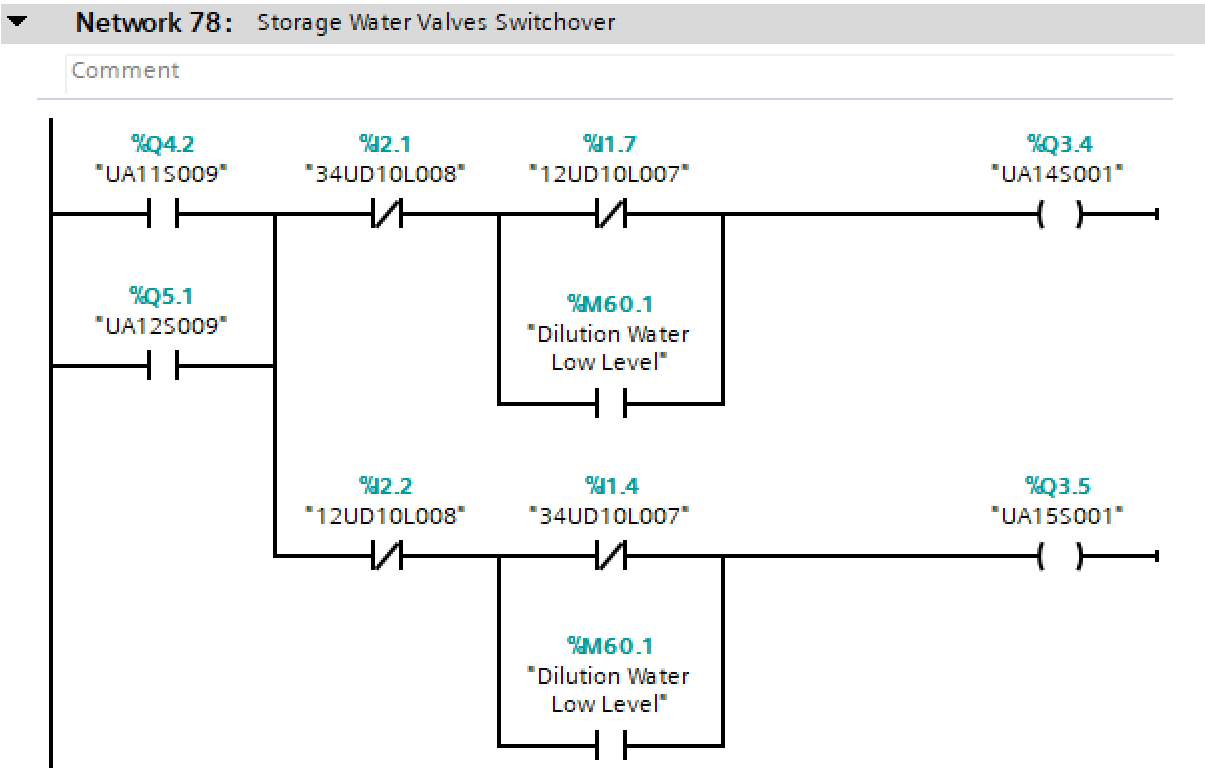


Figure IV.27: Storage/Dilution Water Valves Switchover Network [OB1]

When valves UA11S009 and UA12S009, corresponding to filters UA11B001 and UA12B001 respectively, are open, they allow water to flow into the tanks.

For example, if the water level is between the high and low thresholds in both tanks, both valves will open to direct water to each tank.

If the water level in tank 34UD10B001 reaches a high value (I2.1 is true), valve UA14S001 closes, directing all the water flow to the other tank through valve UA15S001. Conversely, if the water level drops in tank 34UD10B001 (I4.1 is true), valve UA15S001 closes, directing the flow to tank 12UD10B001.

If the water level drops in both tanks, the memory bit M60.1 will be activated, causing both valves UA14S001 and UA15S001 to open.

- **UA11B001 Regeneration Function Block [FB3]**

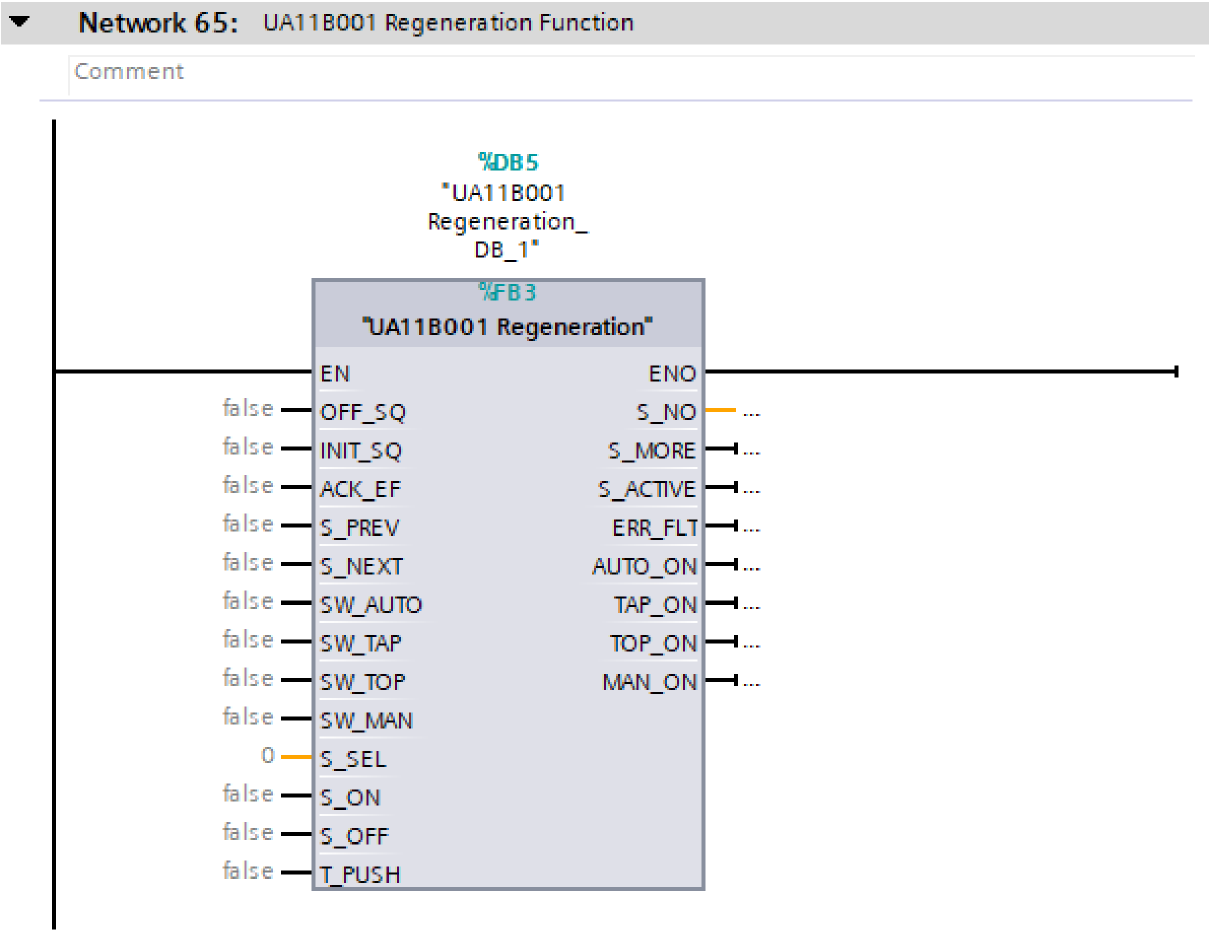


Figure IV.28: Filter UA11B001 Regeneration Function Block [OB1]

The regeneration function block constantly collects data as it operates. However, it does not perform regeneration unless the operator sets the filter UA11B001 to regeneration mode (when Q0.2 is true) or activates the auto-regeneration contact (M600.2) through a fully automated function.

Once the sequence is activated, the regeneration process begins by reading inputs and conditions in OB1 and executing the program written in Sequential Function Chart (SFC). It then directly controls valves or sends requests to OB1 to start pumps and air boosters by activating memory bits (Appendix E).

- **Water Presence or Absence Alarm**

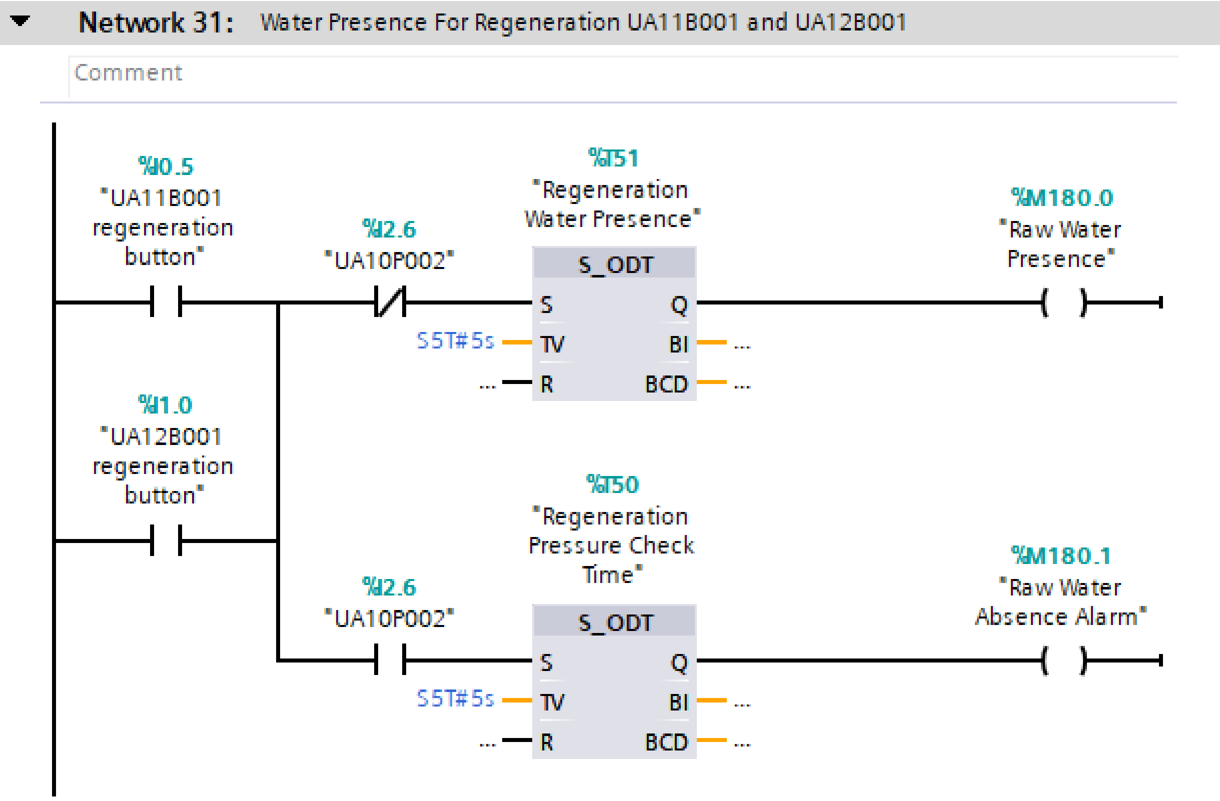


Figure IV.29: Water Presence or Absence Alarms Network [OB1]

To protect the raw water pumps from running without water, a pressure meter (UA10P002) is installed in the raw water channel just before the three pumps. This pressure meter sends a signal when the pressure drops below the low limit, indicating that the pipe is empty and there is no water.

When filter UA11B001 is in regeneration mode (I0.5 is true) and the pressure in the raw water channel is above the low limit (I2.6 is false), timer T51 will count for 5 seconds. If uninterrupted, it will signal the presence of water (M180.0). Conversely, if the pressure drops below the low limit, timer T50 will count for 5 seconds. If uninterrupted, it will trigger the alarm indicating the absence of water (M180.1).

These water presence and absence signals are crucial as safety measures for the raw water pumps during regeneration operations. If water is present (M180.0 is true), the regeneration sequence can advance from the pre-start step (S1) to the start step (S2) by activating transition (T1), which opens the valves then starts the raw water pumps in the next step. If there is no water in the raw water channel (M180.1 is true), the sequence will not advance as a safety precaution, and transition (T1) will not be activated (Figure IV.30).

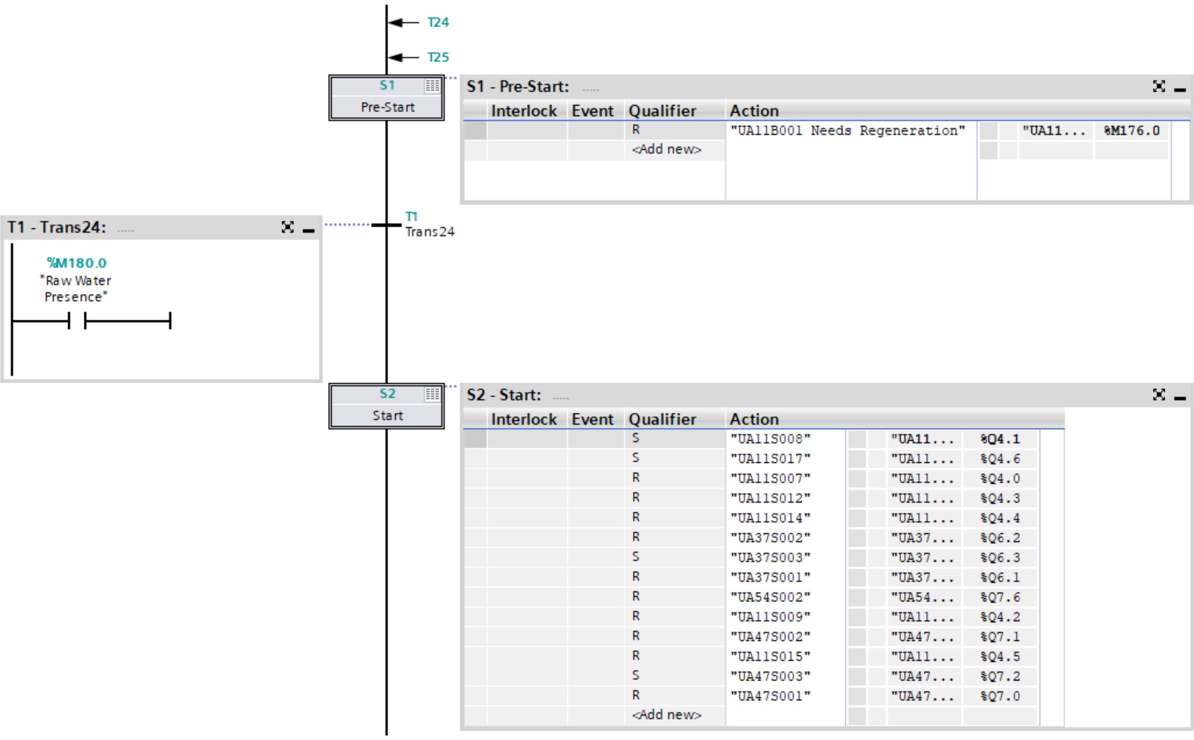


Figure IV.30: UA11B001 Pre-start and Start steps [FB3]

- **UA11B001 Regeneration Running-in Step**

This step marks the final phase of the regeneration operation, focusing on testing its efficiency. The process itself is divided into two sub-steps, both governed by time and water conductivity.

The first sub-step utilizes a Set-On Delay Timer (S_ODTS), denoted as T10, which counts for 2 hours during which the filter is either recirculating or discharging. Once T10 completes, an IEC TON (Start on-Delay Timer) begins.

We chose to use an IEC timer for the second sub-step because S5T timers (such as S_Pulse, S_ODTS) are limited to a maximum counting time of 2 hours and 46 minutes. The second phase of the running-in process may extend up to 24 hours, necessitating the use of a timer that can accommodate longer durations.

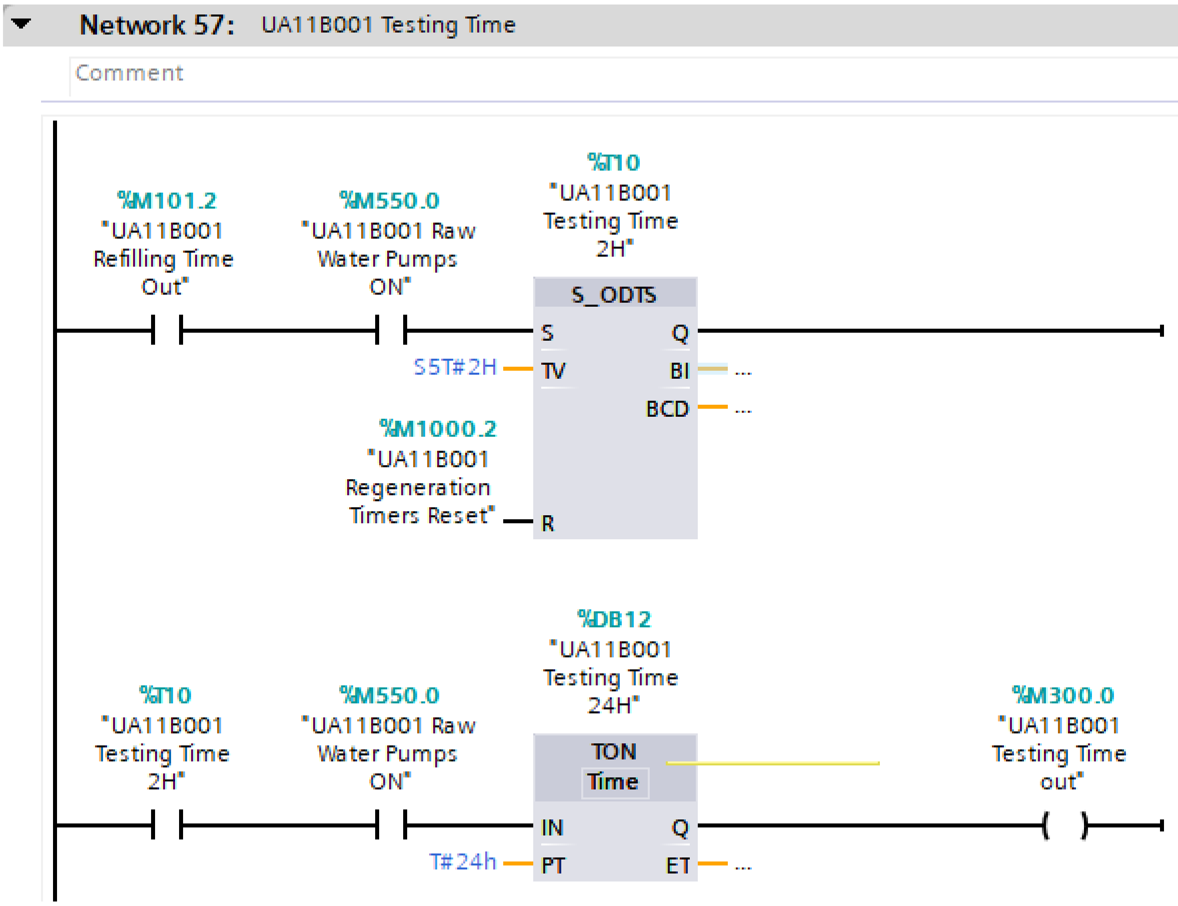


Figure IV.31: UA11B001 Running-in Timers Networks [OB1]

When the filter enters the running-in phase (S16), timer T10 starts counting. If the conductivity is below 10 µS/cm, transition (T15) is activated, advancing the sequence to step S17, where recirculation begins. If the conductivity exceeds 10 µS/cm, the sequence moves from S16 to S18 via transition (T16) to start discharging water. If the filter is in the recirculation phase (S17) and the conductivity rises above 10 µS/cm, it transitions to the discharge phase (S18) through transition (T18), and vice versa via transition (T21).

After two hours (when T10 output is true), if the filter is either recirculating or discharging and the conductivity has not dropped below 0.1 µS/cm, either transition (T19) or (T20) is activated. This moves the sequence to step S21, indicating that the regeneration failed and the filter needs to regenerate again.

Conversely, if two hours elapse and the conductivity is below 0.1 µS/cm, transition (T17) is activated, moving the sequence to step S19. Here, water is redirected towards the storage and dilution tanks, and the second timer begins counting. If the conductivity remains below 0.1 µS/cm for the entire 24-hour period, transition (T22) activates, moving the sequence to step S20 and indicating that the regeneration succeeded and the filter is ready for operation. If the conductivity exceeds 0.1 µS/cm within the 24 hours, transition (T23) is activated, moving the sequence to step S21 and indicating that the filter needs to regenerate again.

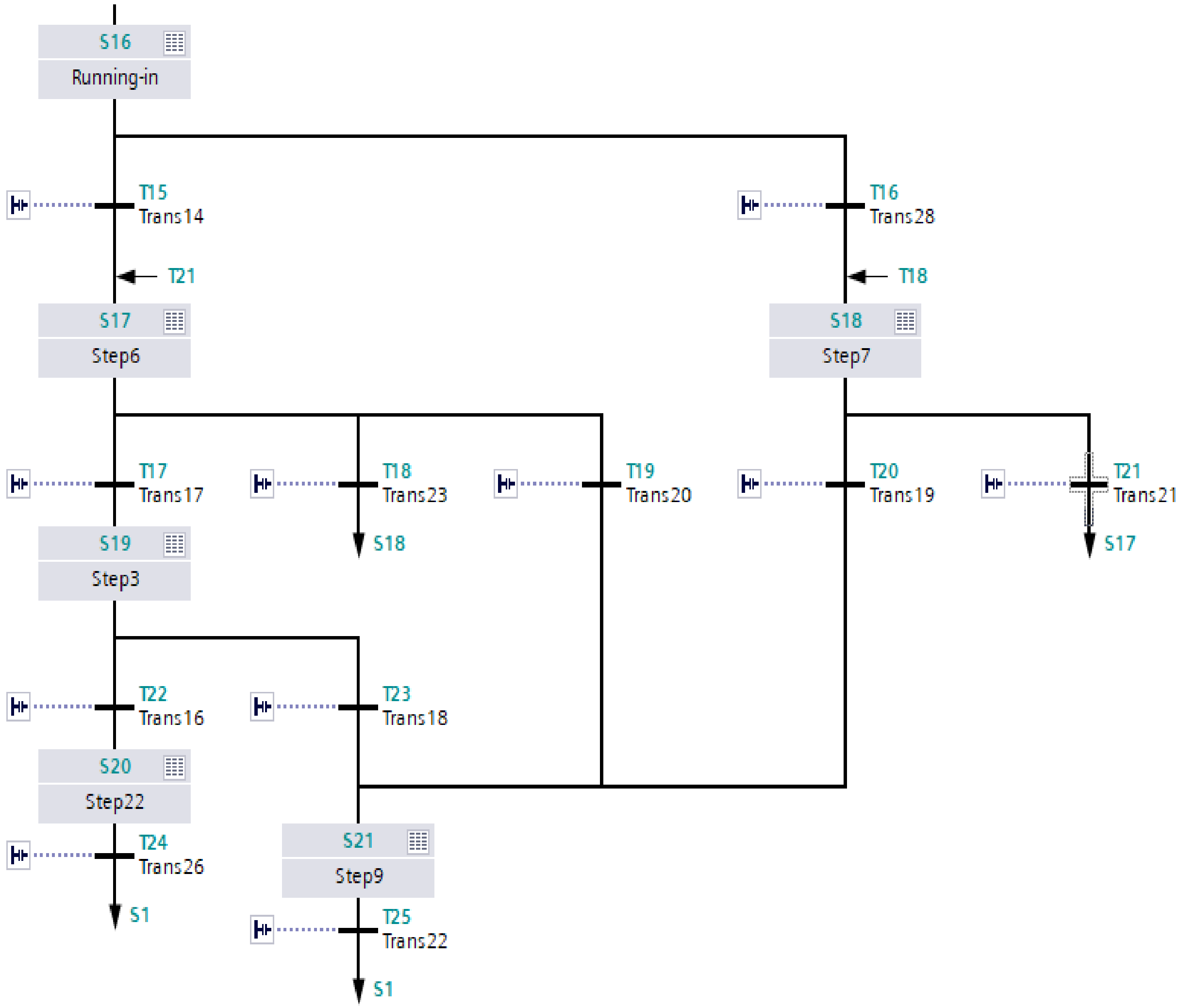


Figure IV.32: UA11B001 Regeneration Running-in Step Sequence [FB3]

- **UC10B001 Neutralisation Function Block [FB5] Call**

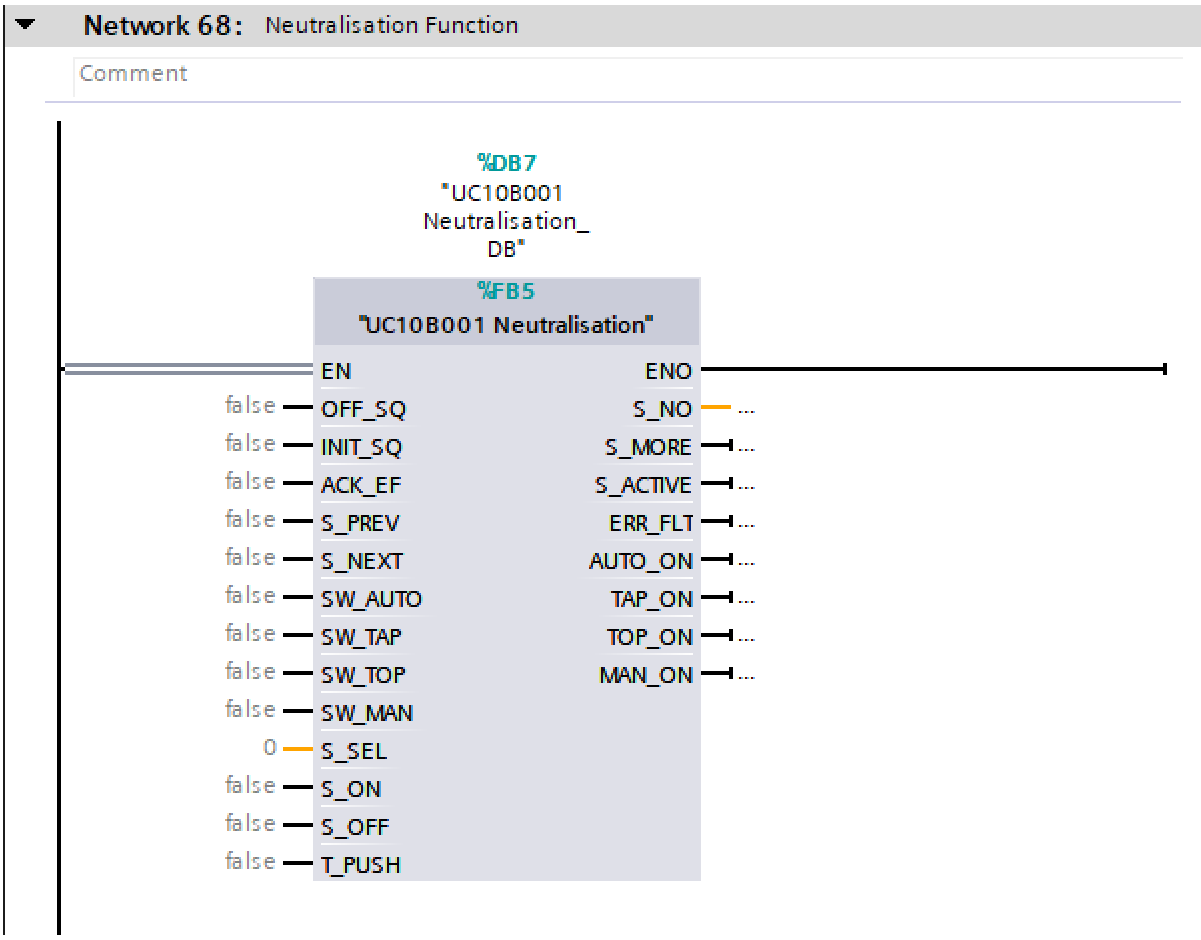


Figure IV.33: Pit UC10B001 Neutralisation Function Block [OB1]

The neutralisation function block continuously collects data as it operates. However, it does not perform neutralization unless the operator initiates it manually (when Q0.7 is true) or triggers the auto-neutralization contact (M600.4) through a fully automated function.

Once activated, the neutralisation sequence begins by reading inputs and conditions in OB1 and executing the program written in Sequential Function Chart (SFC). It then directly controls valves or sends requests to OB1 to start pumps and air boosters by activating memory bits (Appendix G).

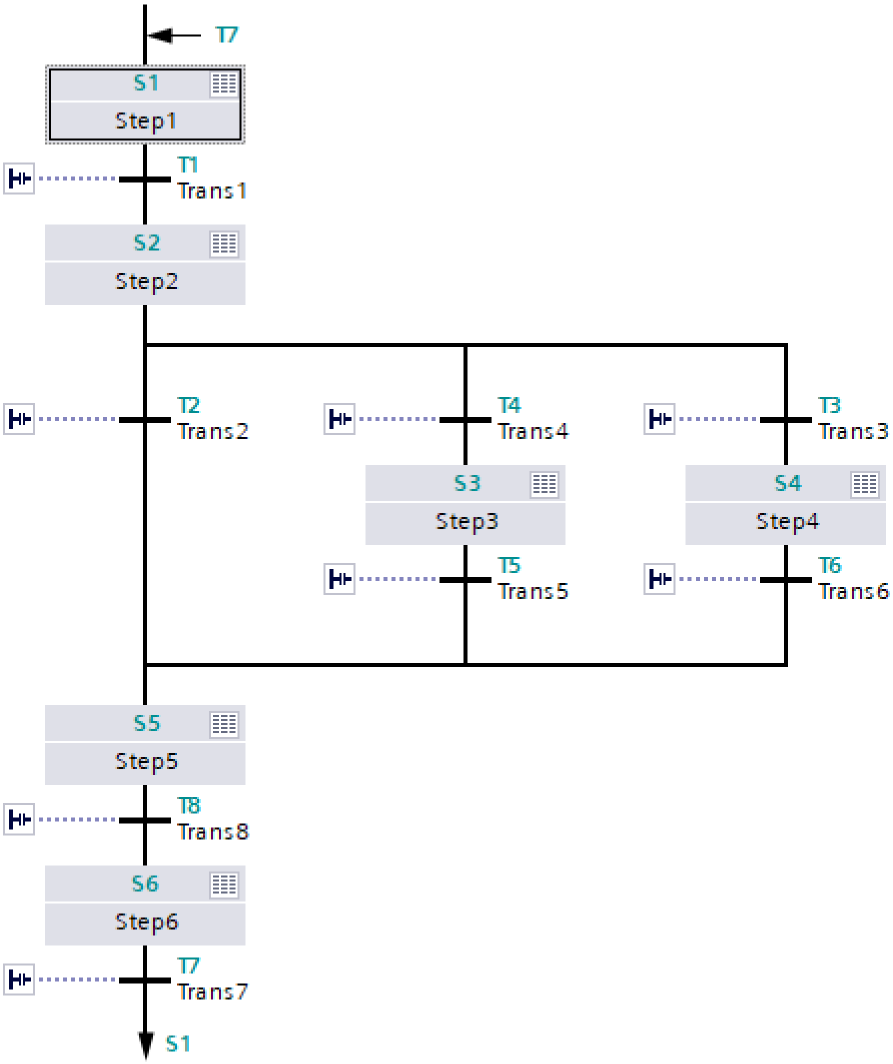


Figure IV.34: UC10B001 Neutralisation Sequence (Minimized) [FB5]

This sequence neutralizes the pit UC10B001 by emptying it of discharged water from the regeneration process and releasing it to the sea while maintaining a nearly neutral pH of around 7.

The sequence begins with step S1, where valve UC10S002 is opened, and valve UC10S001 is closed. In step S2, the water pump UC10D001 and air boosters UC51D001 or UC52D001 are started by activating memory bit (M500.6). After 40 minutes, if the pH is between 6.5 and 7.5, transition (T2) is activated, and the sequence moves to step S5.

If the pH is below 6.5, transition (T4) is activated, and the sequence moves to step S3, where valve UC30S003 (Q3.2) is opened until the pH reaches the acceptable range. Once the pH is within the acceptable range, transition (T5) is activated, moving the sequence to step S5. If the pH is above 7.5, transition (T3) is activated, and the sequence moves to step S4, where valve UC40S003 (Q3.3) is opened until the pH reaches the acceptable range. Then, transition (T6) is activated, moving the sequence to step S5.

In step S5, valve UC10S001 is opened, valve UC10S002 is closed, and the water is directed towards the sea. The discharging continues until sensor UC10L003 indicates that the water level is low (I67.1 is true).

- **Fully Automated Station Function Block [FB6]**

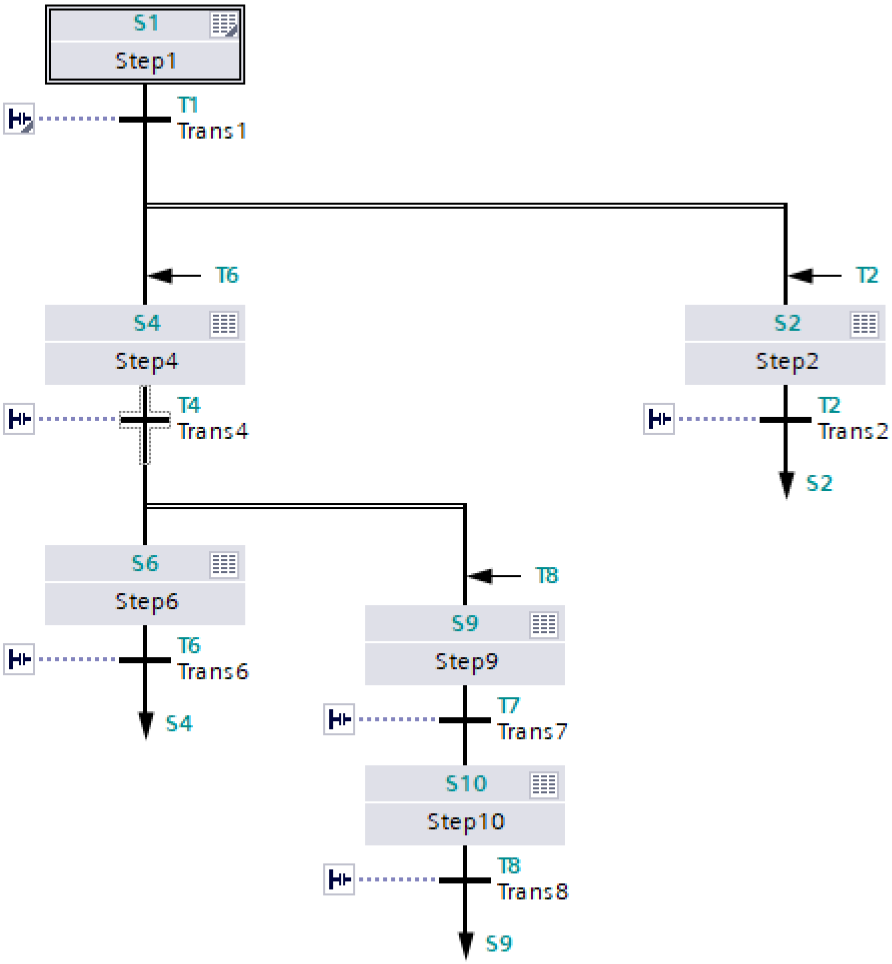


Figure IV.35: Fully Automated Station Sequence (Minimized) [FB6]

We implemented this mode to completely eliminate the need for operator intervention at the station, ensuring that even the operation start is automatic and does not require manual initiation (Appendix H).

This mode is managed through function block FB6, which operates by calling the previously mentioned function blocks (FB1 to FB5) using memory bits M600.0 to M600.5.

For instance, when specific conditions are met for filter UA11B001 to begin filtration, FB6 activates FB1 (the UA11B001 filtration function block) through memory bit (M600.0) without any operator involvement.

At the end of filtration, if the resins in UA11B001 are saturated and the filter requires regeneration, the system automatically switches to filter UA12B001, provided it is not already saturated or undergoing regeneration. Conversely, UA11B001 will begin regenerating automatically if UA12B001 is available for filtration. This continuous swapping ensures maximum filtration capacity and always keeps a filter ready for use.

This mode guarantees seamless swapping and synchronization between filters and various operations, enhancing overall efficiency and reliability.

IV.5. Conclusion

In conclusion, this chapter presented the automation software for programming, the Totally Integrated Automation (TIA) Portal, and demonstrated its use in developing an automated solution. Additionally, it showcased our automated solution for the demineralisation station, emphasizing key improvements to enhance station security measures and optimize process.

Chapter V

Station Supervision and Monitoring

V.1. Introduction

In the previous chapters, after successfully developing our automated solution for the demineralisation station, we recognized the need for real-time supervision. This necessity led us to create a Human-Machine Interface (HMI) that enables us to monitor the station.

This chapter discusses the importance of HMI and introduces the software we used, SIMATIC WinCC Runtime Professional V14. Additionally, it provides detailed insights into our HMI setup, ensuring clarity and understanding for the user.

V.2. Human Machine Interface

V.2.1. Definition

Human Machine Interface (HMI) is a system that enables interaction between a human operator and an automated machine or system. It serves as a point of connection and communication between the user and the system, providing an intuitive and efficient way for operators to control, monitor, and configure devices and processes.

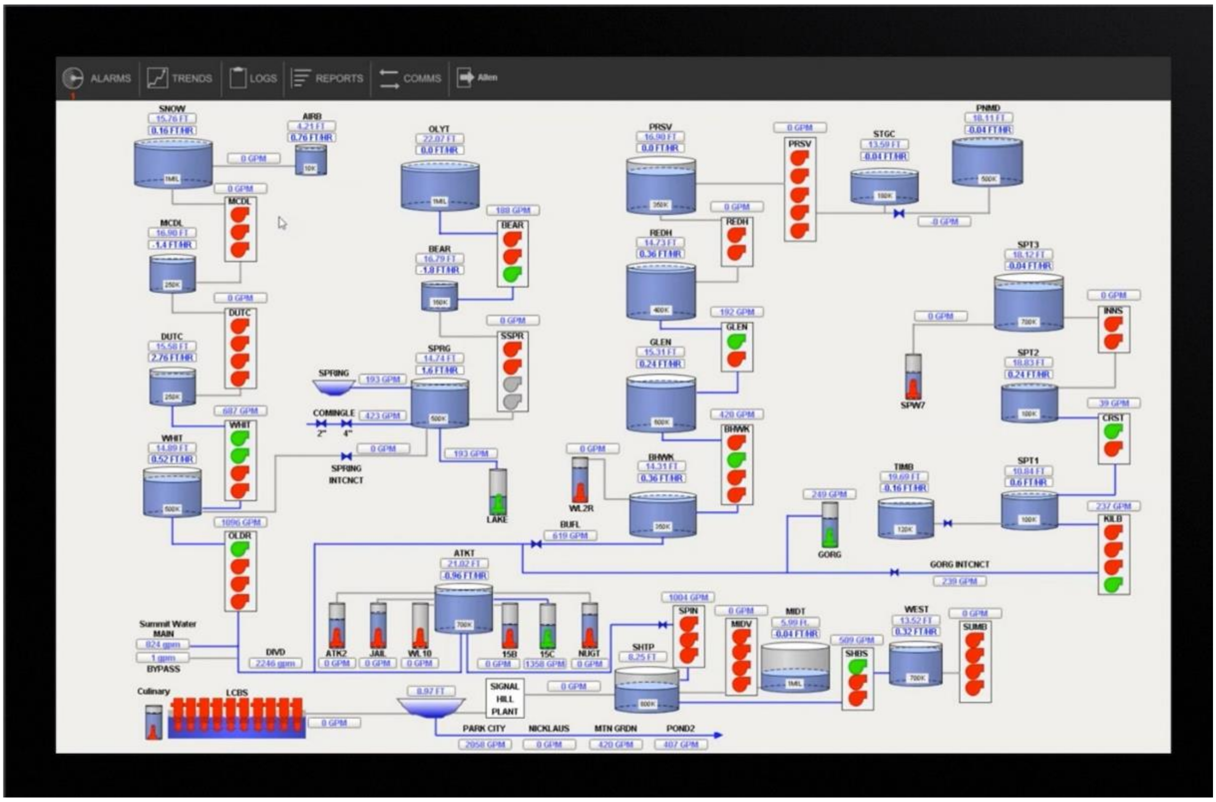


Figure V.1: Example of a Human Machine Interface

V.2.2. Components of an HMI

An HMI system consists of hardware, software, and communication components that facilitate interaction between humans and machines.

- **Hardware:** Includes tangible parts like screens, keyboards, and processors. Input devices (touchscreens, buttons) send commands, while output devices (monitors, speakers) display machine status. The processor manages commands and runs the software.

- **Software:** The user interface that allows control and displays data. It includes tools for custom screens, performance tracking, and identifying improvements.

- **Communication:** Connects the HMI to machines via wired or wireless methods, ensuring fast, reliable real-time control and monitoring.

V.2.3. HMIs Advantages

The Human-Machine Interface (HMI) is immensely valuable for overseeing and managing industrial operations. Here's why it's so advantageous:

- **Boosts efficiency:** HMI simplifies the process of accessing crucial information and managing operations, resulting in smoother workflows. Its clear displays enable workers to make quicker, more informed decisions.

- **Improves safety:** HMIs contribute to workplace safety by clearly presenting alerts and critical updates. This allows workers to promptly address issues before they become serious.

- **Remote monitoring and control:** HMIs can be utilized from a distance, which is particularly beneficial for overseeing and controlling operations in remote or hazardous environments.

- **Easy usage:** HMIs are designed to be easily understandable, even for individuals with limited technical expertise. This accessibility ensures that everyone can efficiently manage and monitor industrial processes.

V.3. Demineralisation Station Supervision and Monitoring System

V.3.1. Hardware: SIMATIC HMI TP1500 Comfort

The SIMATIC HMI TP1500 Comfort is a human machine interface (HMI) panel designed by Siemens for various industrial automation applications. Here are some key technical details about the TP1500 Comfort:

- **Display**
  - 15.4-inch TFT widescreen display
  - 16 million colours
  - Resolution of 1280 x 800 pixels
  - LED backlight with a lifetime of 80,000 hours at 25°C
- **Dimensions**
  - Mounting cutout: 396 x 291 mm (W x H)
  - Front panel: 415 x 310 mm (W x H)
  - Device depth: 75 mm
- **Electrical**
  - Supply voltage: 24 V DC
  - Permissible voltage range: 19.2 to 28.8 V DC
  - Current consumption: 1.7 A
- **Memory**
  - User memory: 24 MB
- **Interfaces**
  - 2 x RJ45 for PROFINET (with integrated switch)
  - MPI/PROFIBUS DP interface
  - USB 2.0
- **Environmental**
  - Operating temperature: 0 to +50°C
  - Degree of protection: IP65 (front), IP20 (rear)

These specifications highlight the TP1500 Comfort's versatility and powerful capabilities, making it an excellent choice for a wide range of industrial automation applications. We selected this HMI panel for our station supervision because our station contains numerous pieces of equipment, which can lead to a crowded display and potential operator confusion. The TP1500 Comfort's high-quality display ensures that information is presented clearly, minimizing confusion and enhancing operational efficiency.

Figure V.2: SIMATIC HMI TP1500 Comfort Touchscreen Panel

V.3.2. Software: SIMATIC WinCC Runtime Professional V14

SIMATIC WinCC Runtime Professional V14 is an advanced, scalable visualization software for industrial automation, offering comprehensive monitoring and control solutions. Its intuitive, user-friendly interface features customizable screens with high-resolution graphics. The software supports a range of applications from small single-user systems to large multi-user systems and integrates seamlessly with Siemens PLCs and other devices, supporting protocols like OPC UA, TCP/IP, and PROFINET.

WinCC Runtime Professional excels in real-time data management, logging, and analysis, with a robust alarm and event management system. Security is prioritized with advanced user management, secure communication protocols, and compliance with industry standards. Maintenance is facilitated by built-in diagnostic tools and detailed logging.

The software's flexibility is evident in its extensive library of pre-configured objects, scripting capabilities, and integration with Siemens solutions. Its high-performance runtime environment is optimized for fast response times and handling complex visualizations. Suitable for various industrial sectors, it enhances automation efficiency and reliability through its comprehensive features and seamless integration.

Figure V.3: SIMATIC WinCC Runtime Professional V14 Startup

V.4. Demineralisation Station HMI User Guide

V.4.1. General Template

Our HMI general template is divided into four main areas (Figure V.4), which are consistently displayed across all screens. These areas are:

1. **Company Logo:** Displays the Society of Electricity Production (SPE) logo.
2. **Date and Time:** Shows the current date and time.
3. **Navigation Buttons:** Provides buttons for the operator to switch between different process screens.
4. **Visualization and Supervision:** Allows the operator to view all processes, equipment statuses, and process advancements based on the selected screen.

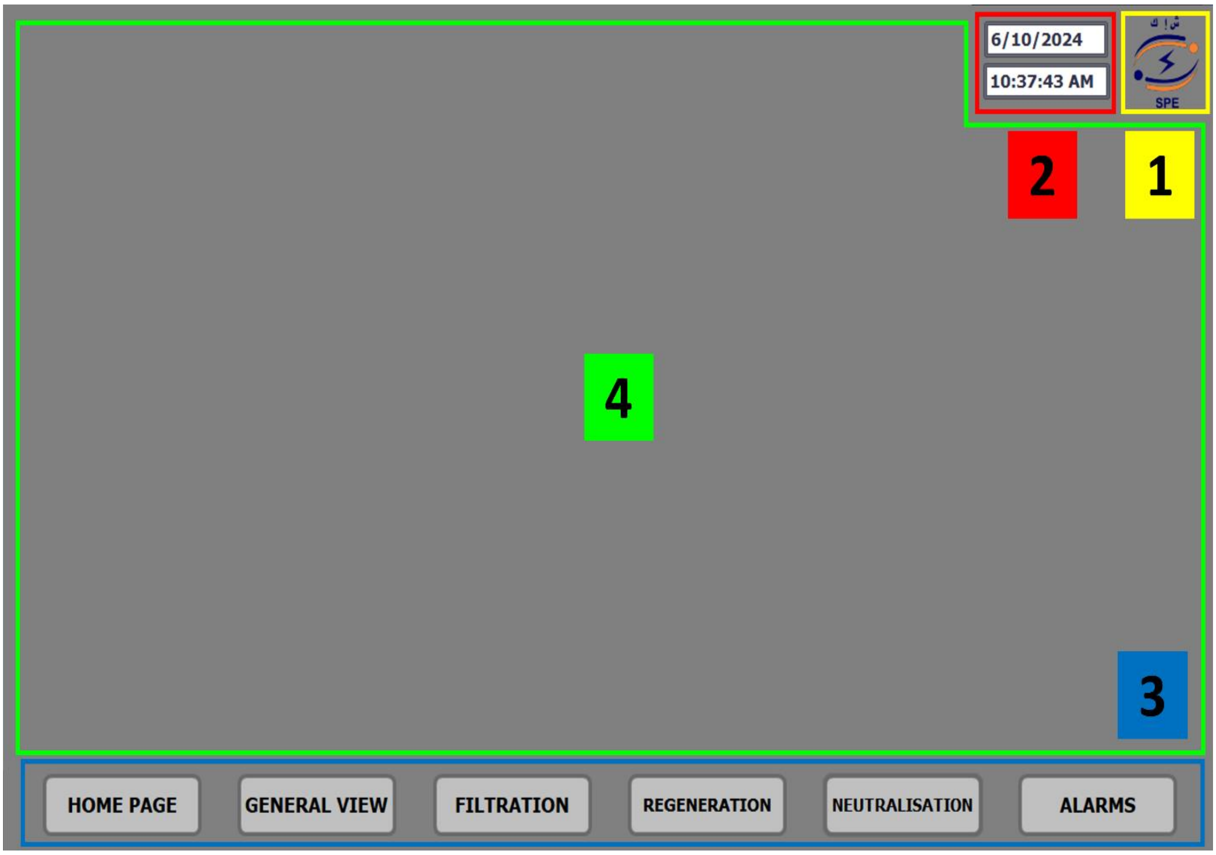


Figure V.4: Demineralisation Station HMI General Template

V.4.2. Graphical Elements Guide

This guide provides a detailed overview of the elements displayed on the HMI screen, particularly in the visualization and supervision area, to help operators accurately read and interpret the information.

V.4.2.1. Filters

The HMI's graphical representation of the filters includes the filter name and three indicator lamps: Filtration, Regeneration, and OFF (Figure V.5).

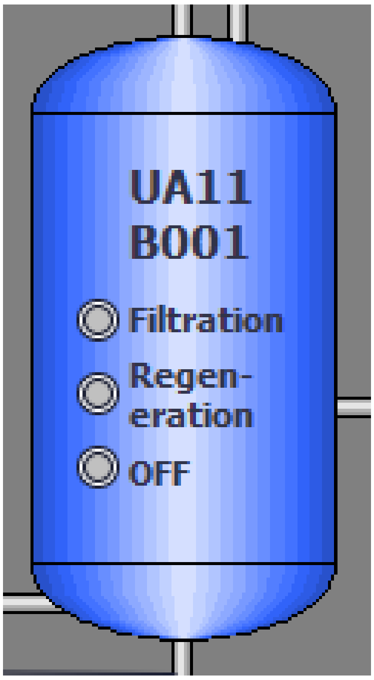


Figure V.5: Filter Graphical Representation

Filtration Lamp

- When the Filtration lamp is green, the filter is in filtration mode.
- When the Filtration lamp is orange, it indicates that the resins are saturated and the filter needs regeneration.

Regeneration Lamp

- When the Regeneration lamp is green, the filter is in regeneration mode.
- When the Regeneration lamp is orange, it indicates that the regeneration operation has ended successfully and the filter is operational.

OFF Lamp

- When the OFF lamp is green, the filter is out of service.

V.4.2.2. Valves

In our HMI, valve positions are indicated by different colours. Additionally, the status of each valve, whether flashing or steady, provides further information (Figure V.6).

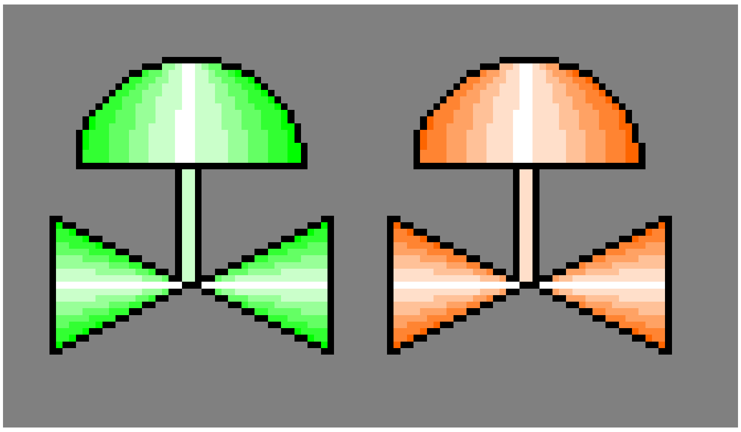


Figure V.6: Valves Graphical Representation

- **Flashing Green:** Valve is ordered to open, but the fully open limit switch is not yet activated.
- **Steady Green:** Valve is fully open, and the fully open limit switch is activated.
- **Flashing Orange:** Valve is ordered to close, but the fully closed limit switch is not yet activated.
- **Steady Orange:** Valve is fully closed, and the fully closed limit switch is activated.

V.4.2.3. Pumps and Air Boosters

Pumps and air boosters maintain a consistent colour in the HMI. Instead, their status is indicated by a nearby indicator lamp (Figure V.7).

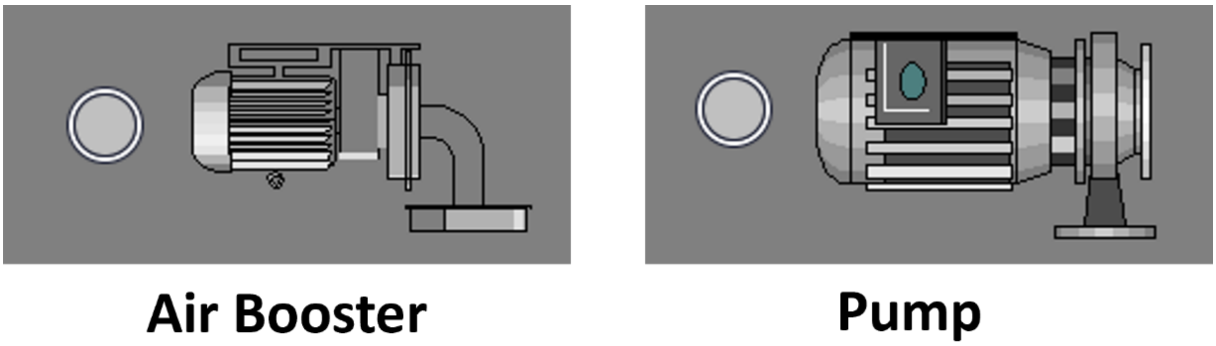


Figure V.7: Pumps and Air Boosters Graphical Representation

- **Green Indicating Lamp:** Indicates the pump is operational.
- **Orange Indicating Lamp:** Indicates the pump is off.
- **Red Indicating Lamp:** Indicates a pump failure.

V.4.2.4. Fluids Storage Tanks

The fluid storage tanks in our HMI are represented by various shapes, each corresponding to the type of fluid they contain (Figure V.8).

Figure V.8: Examples of Fluids Storage Tanks Graphical Representation

While the tanks themselves do not display the exact fluid level, the indicating lamps show whether the fluid has reached the high or low level. Tanks with two indicating lamps use the lower lamp turning red to indicate a low level and the upper lamp turning red to indicate a high level. Tanks with only one lamp at the bottom use a red lamp to indicate a low fluid level.

V.4.2.5. Pipes

The colors of the pipes in our HMI are selected based on the type of fluid they convey, just as the shapes of the fluid storage tanks are chosen according to the type of fluid they hold. This color coding helps operators differentiate between fluids and their respective circulation channels.

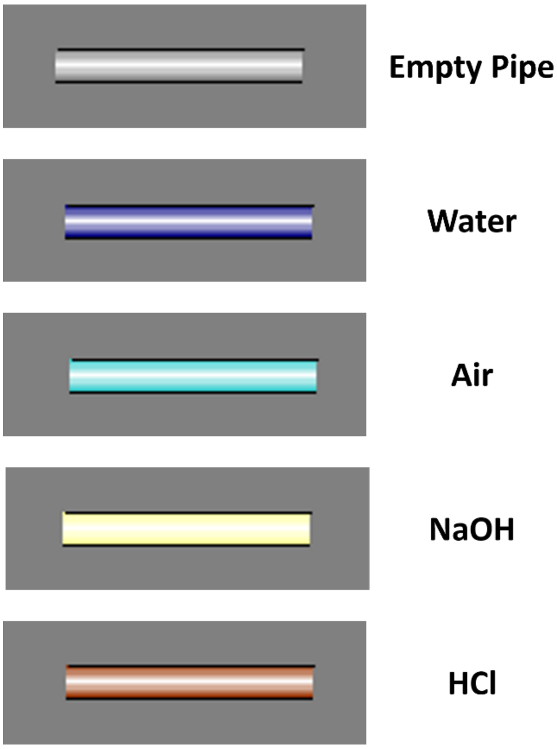


Figure V.9: Pipes Color Code

V.4.2.6. Physical Measurements Values Display

Some screens display important physical quantity measurements relevant to the operation shown. The values of these physical quantities are presented in white boxes, while the type of physical quantity is displayed in a grey box above the value.

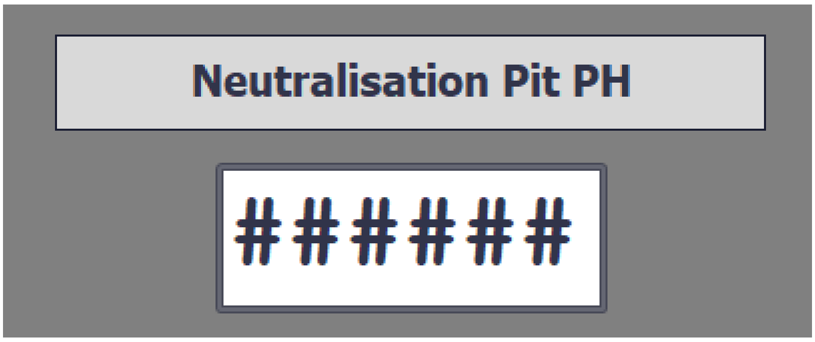


Figure V.10: Physical Measurements Visualisation Example: Neutralisation Pit PH

V.5. HMI Screens

Our Human Machine Interface consists of six screens: a home screen and five additional screens. Each screen provides detailed visualizations and specific operational information pertinent to its function, offering unique data that is not available on the other screens.

V.5.1. Home Page Screen

The home screen is the starting point of our HMI and the first interface the operator encounters upon launching the system. While it does not display monitoring data, it features the logos of the companies owning the power plant “SONELGAZ”, the parent company, and its subsidiary, “SPE” along with the name of the station, "Demineralisation Station."

Figure V.11: Home Page Screen

V.5.2. General View Screen

The general view screen provides a comprehensive overview of the entire station's operations and equipment on a single display. It enables the operator to monitor the real-time status of all equipment and processes, including Filtration, Regeneration, and Neutralisation. Although this screen presents a wealth of information, operators needing more detailed data—such as valve names, pump names, or the conductivity value at a filter's output—must switch to the specific screen designed to display the desired information.

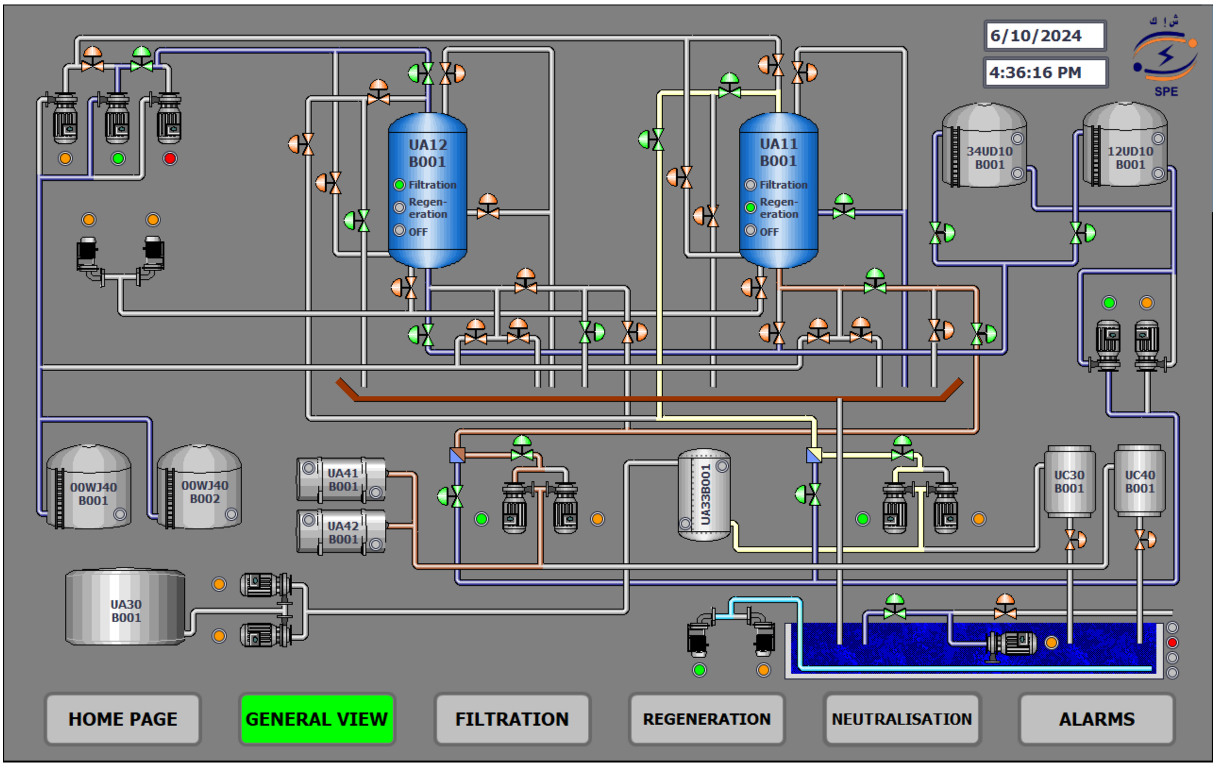


Figure V.12: General View Screen

V.5.3. Filtration Screen

This screen is less crowded than the general view screen because it focuses only on the equipment involved in the filtration operation. This enables us to provide more detailed information about these components, such as valve and pump names. Additionally, it displays the most important parameter the station is designed to monitor: conductivity. The operator can view the water conductivity values of both filters UA11B001 and UA12B001 simultaneously, with these values prominently shown in large boxes at the bottom of the screen.

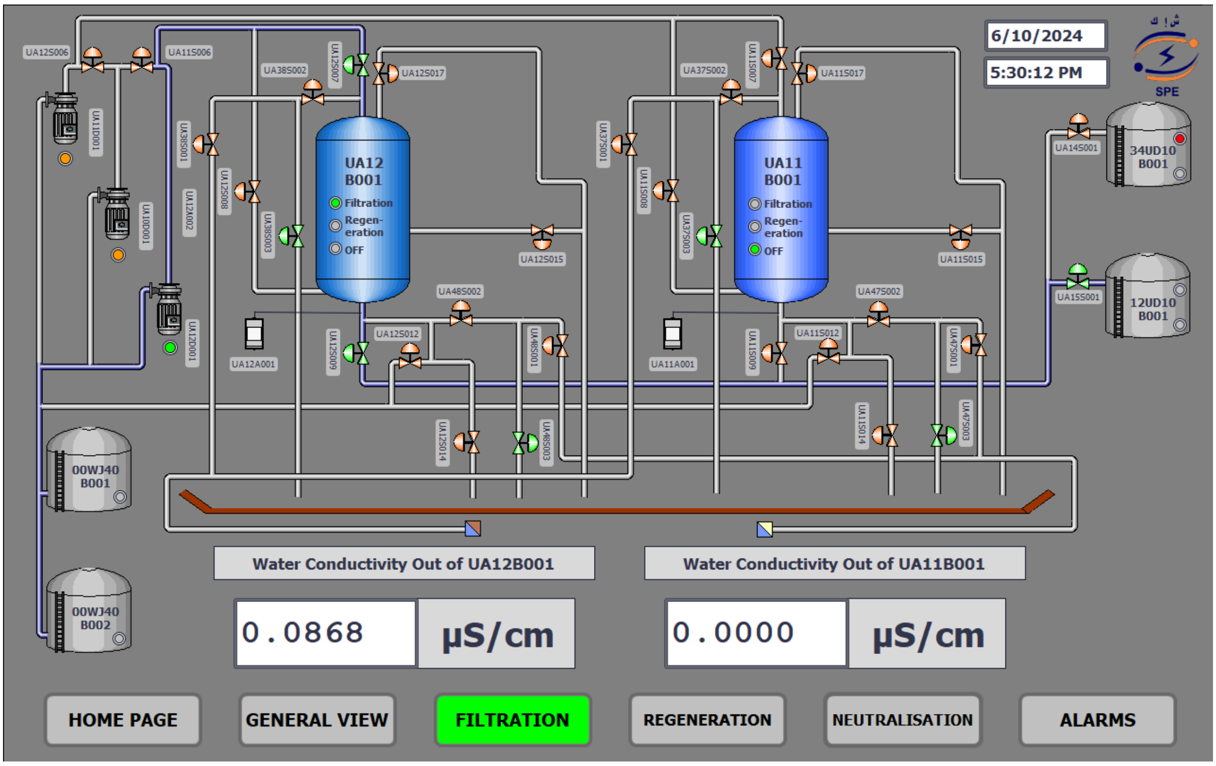


Figure V.13: Filtration Screen

V.5.4. Regeneration Screen

The regeneration screen displays all the equipment involved in regenerating both filters UA11B001 and UA12B001, along with their detailed information. Although this screen is somewhat crowded, it includes nearly all the equipment in the demineralisation station, with the exception of the pit UC10B001 and its neutralisation equipment.

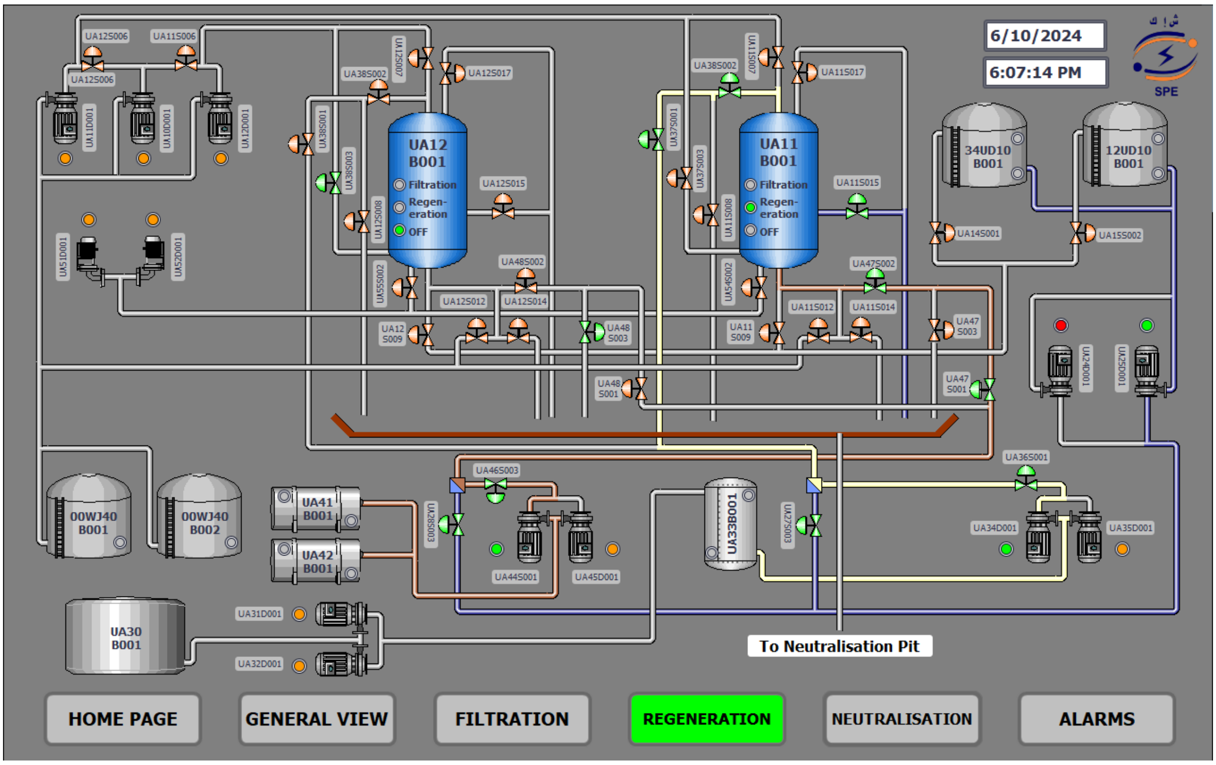


Figure V.14: Regeneration Screen

V.5.5. Neutralisation Screen

The neutralisation screen is much simpler than the previous screens, displaying only the equipment involved in the neutralisation of UC10B001. On this screen, the operator can find the real-time pH value of the pit and the pit level indicators.

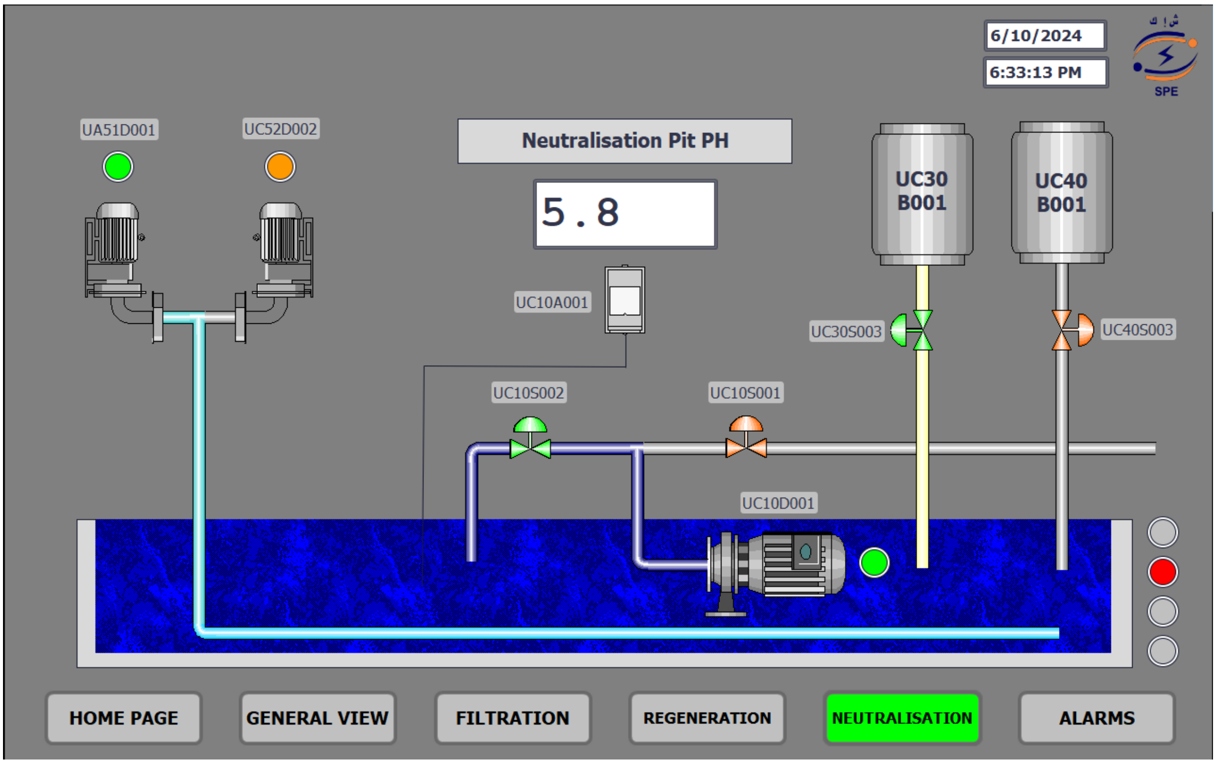


Figure V.15: Neutralisation Screen

V.5.6. Alarms Screen

For any process to operate safely and efficiently, it is crucial to display and communicate system faults and errors to notify the operator of potential risks. The alarms screen serves this purpose by showing system faults such as pump failures and high conductivity alerts. Each alarm is displayed with its date and time and is archived for reference.

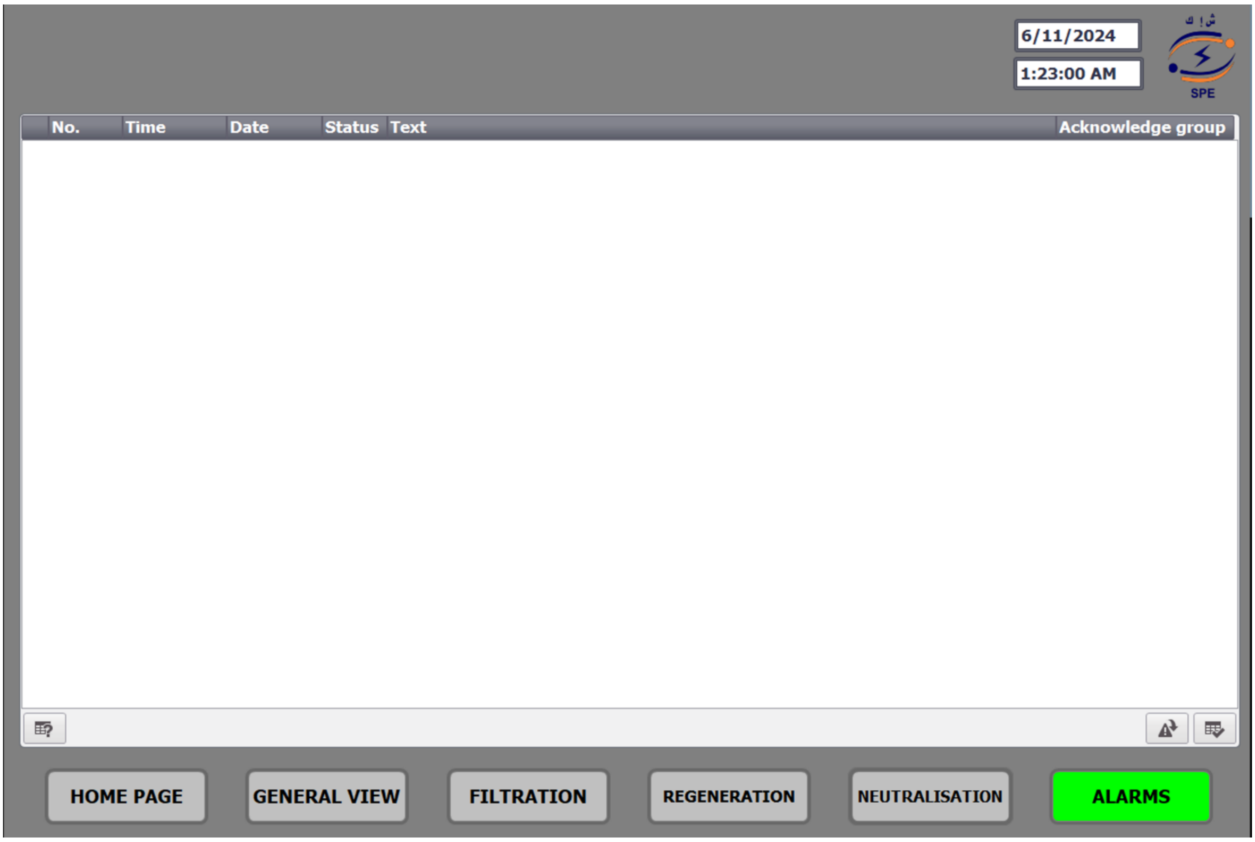


Figure V.16: Alarms Screen

V.6. Conclusion

In this chapter, we discussed the HMI, emphasizing its importance in supervising and monitoring the demineralisation station. We explored how it facilitates and enhances the clarity of interactions between the operator and the controlled system. Additionally, we outlined the different screens of our HMI and provided a guide to help operators better understand the displayed information. This chapter complements the work done in previous chapters, contributing to the creation of a comprehensive automated solution.

General Conclusion

General Conclusion

At the conclusion of our project and internship, we are pleased to report that the automated solution we developed for the demineralisation station at the Ras Djinet power plant successfully met our initial objectives and remained within the scope of the project.

This internship provided us with a valuable opportunity to apply the theoretical knowledge we acquired during our university studies in a real-world industrial environment, facilitating a smooth transition from student to professional life. Additionally, it allowed us to analyse and understand the demineralisation process and its importance, along with the various related processes.

We utilized the SIMATIC S7-1500, a powerful PLC with a wide range of functionalities, to develop our automated solution. Moreover, we deepened our understanding of the TIA Portal V14 programming software. Throughout the project, we enhanced our skills in PLC programming, particularly in Ladder (LAD) programming language, and explored new functions. We also gained experience with Sequential Function Chart (SFC); a programming language not covered in our university curriculum.

In the programming phase, we minimized human intervention to the greatest extent possible. Moreover, by utilizing feedback signals from valve limit switches, we significantly enhanced the safety and reliability of the station. We also incorporated feedback signals from pumps and air boosters. This allowed us to seamlessly switch between the main and backup pumps and air boosters based on operating conditions. Lastly, we implemented an essential emergency shutdown feature to further ensure operational safety.

Furthermore, our work with SIMATIC WinCC enabled us to create a Human-Machine Interface (HMI) that provides real-time visualization and interpretation of the demineralisation processes, enhancing operational efficiency.

In conclusion, we hope this project serves as a gateway for our transition from student life to professional careers. We also aspire for it to be a valuable resource for future students, offering them insights and practical knowledge to support their educational and professional journeys.

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Appendix A

Demineralisation Station S7-1500 / PLC_1 [CPU 1515T-2 PN] / PLC tags / Alarms

Alarms [33]

PLC tags									
	Name	Data type	Address	Retain	Accessible from HMI/OPC UA	Writable from HMI/OPC UA	Visible in HMI engineering	Supervision	Comment
	Raw water high conductivity	Bool	%M0.0	False	True	True	True		
	Filter UA11B001 Low Pressure	Bool	%M0.3	False	True	True	True		
	Filter UA11B001 high resistance	Bool	%M0.4	False	True	True	True		
	Filter UA12B001low Pressure	Bool	%M0.5	False	True	True	True		
	Filter UA12B001 high resistance	Bool	%M0.6	False	True	True	True		
	Filter UA11B001 Out Conductivity high V1	Bool	%M0.7	False	True	True	True		
	Filter UA11B001 Out Silica high	Bool	%M1.0	False	True	True	True		
	Filter UA11B001 Out Flow Low	Bool	%M1.1	False	True	True	True		
	Filter UA12B001 Out Conductivity high	Bool	%M1.2	False	True	True	True		
	Filter UA12B001 Out Silica high	Bool	%M1.3	False	True	True	True		
	Filter UA12B001 Out Flow Low	Bool	%M1.4	False	True	True	True		
	storage water Conductivity high	Bool	%M1.5	False	True	True	True		
	storage water PH Low	Bool	%M1.6	False	True	True	True		
	Storage water Flow high	Bool	%M1.7	False	True	True	True		
	HCl dilution water Flow high	Bool	%M2.0	False	True	True	True		
	NaOH dilution water Flow high	Bool	%M2.1	False	True	True	True		
	Neutralisation basin PH high	Bool	%M2.2	False	True	True	True		
	UA12D001 alarm	Bool	%M10.1	False	True	True	True		Pump UA12D001 Failure alarm
	UA11D001 alarm	Bool	%M10.0	False	True	True	True		Pump UA11D001 Failure alarm
	UA10D001 alarm	Bool	%M10.2	False	True	True	True		Pump UA10D001 Failure alarm
	UA44D001 alarm	Bool	%M10.5	False	True	True	True		Pump UA44D001 Failure alarm
	UA45D001 alarm	Bool	%M10.6	False	True	True	True		Pump UA45D001 Failure alarm
	UA34D001 alarm	Bool	%M10.7	False	True	True	True		Pump UA34D001 Failure alarm

	Name	Data type	Address	Retain	Acces-sible from HMI/OPC UA	Writa-ble from HMI/OPC UA	Visi-ble in HMI engi-neer-ing	Supervision	Comment
	UA35D001 alarm	Bool	%M11.0	False	True	True	True		Pump UA35D001 Failure alarm
	UA31D001 alarm	Bool	%M11.3	False	True	True	True		Pump UA31D001 Failure alarm
	UA32D001 alarm	Bool	%M11.4	False	True	True	True		Pump UA32D001 Failure alarm
	UC10D001 alarm	Bool	%M11.7	False	True	True	True		Pump UC10D001 Failure alarm
	UA24D001 alarm	Bool	%M11.1	False	True	True	True		Pump UA24D001 Failure alarm
	UA25D001 alarm	Bool	%M11.2	False	True	True	True		Pump UA25D001 Failure alarm
	UA51D001 alarm	Bool	%M10.3	False	True	True	True		Air Booster UA51D001 Failure alarm
	UA52D001 alarm	Bool	%M10.4	False	True	True	True		Air Booster UA52D001 Failure alarm
	UC51D001 alarm	Bool	%M11.5	False	True	True	True		Air Booster UC51D001 Failure alarm
	UC52D001 alarm	Bool	%M11.6	False	True	True	True		Air Booster UC52D001 Failure alarm

Demineralisation Station S7-1500 / PLC_1 [CPU 1515T-2 PN] / PLC tags / Equipment

General Equipments [10]

PLC tags

	Name	Data type	Address	Retain	Accessible from HMI/OPC UA	Writable from HMI/OPC UA	Visible in HMI engineering	Supervision	Comment
	Station Mode ON/OFF	Bool	%M5.0	False	True	True	True		Station mode
	Filter UA11B001 filtration mode	Bool	%Q0.1	False	True	True	True		
	Filter UA11B001 regeneration mode	Bool	%Q0.2	False	True	True	True		
	Filter UA12B001 filtration mode	Bool	%Q0.4	False	True	True	True		
	Filter UA12B001 regeneration mode	Bool	%Q0.5	False	True	True	True		
	Filter UA11B001 OFF	Bool	%Q0.3	False	True	True	True		
	Filter UA12B001 OFF	Bool	%Q0.6	False	True	True	True		
	Neutralisation ON/OFF	Bool	%Q0.7	False	True	True	True		
	Full Auto	Bool	%M2.3	False	True	True	True		Station runs on fully automatic mode
	Part Auto	Bool	%M2.4	False	True	True	True		Station runs on partially automatic mode

Demineralisation Station S7-1500 / PLC_1 [CPU 1515T-2 PN] / PLC tags / Memory

Memory [114]

PLC tags

	Name	Data type	Address	Retain	Accessible from HMI/OPC UA	Writable from HMI/OPC UA	Visible in HMI engineering	Supervision	Comment
	raw water conductivity raw value	Real	%MD0	False	True	True	True		
	Raw water conductivity	Real	%MD4	False	True	True	True		
	raw water PH raw value	Real	%MD172	False	True	True	True		
	Raw water PH	Real	%MD8	False	True	True	True		
	Filter UA11B001 Out Conductivity raw value	Real	%MD52	False	True	True	True		
	Filter UA11B001 Out Conductivity	Real	%MD56	False	True	True	True		
	Filter UA11B001 Out Silicaraw value	Real	%MD60	False	True	True	True		
	Filter UA11B001 Out Silica	Real	%MD64	False	True	True	True		
	Filter UA12B001 Out Conductivity raw value	Real	%MD76	False	True	True	True		
	Filter UA12B001 Out Conductivity	Real	%MD80	False	True	True	True		
	Filter UA12B001 Out Silica raw value	Real	%MD84	False	True	True	True		
	Filter UA12B001 Out Silica	Real	%MD88	False	True	True	True		
	Storage water conductivity raw value	Real	%MD100	False	True	True	True		
	Storage water conductivity	Real	%MD104	False	True	True	True		
	Storage water PH raw value	Real	%MD108	False	True	True	True		
	Storage water PH	Real	%MD112	False	True	True	True		
	Neutralisation Pit PH raw value	Real	%MD140	False	True	True	True		
	Neutralisation Pit PH	Real	%MD144	False	True	True	True		
	UA11B001 Filtr Valves Cnd1	Bool	%M15.0	False	True	True	True		
	UA12B001 Filtr Valves Cnd1	Bool	%M15.1	False	True	True	True		
	UA11B001 Pumps Cnd1	Bool	%M15.2	False	True	True	True		
	UA12B001 Pumps Cnd1	Bool	%M15.3	False	True	True	True		
	UA11B001 Conductivity < 0.1	Bool	%M16.0	False	True	True	True		

	Name	Data type	Address	Retain	Accessible from HMI/OPC UA	Writable from HMI/OPC UA	Visible in HMI engineering	Supervision	Comment
	UA11B001 Conductivity [0.1-10]	Bool	%M16.1	False	True	True	True		
	UA11B001 Conductivity > 10	Bool	%M16.2	False	True	True	True		
	UA11B001 Recycling Time Out	Bool	%M16.4	False	True	True	True		
	Storage Water Low Level	Bool	%M50.0	False	True	True	True		
	Storage Water High Level	Bool	%M50.1	False	True	True	True		
	UA12B001 Conductivity < 0.1	Bool	%M16.5	False	True	True	True		
	UA12B001 Conductivity [0.1-10]	Bool	%M16.6	False	True	True	True		
	UA12B001 Conductivity > 10	Bool	%M16.7	False	True	True	True		
	UA12B001 Recycling Time Out	Bool	%M17.0	False	True	True	True		
	UA11B001 Reg Valves Cnd1	Bool	%M18.0	False	True	True	True		
	UA12B001 Reg Valves Cnd1	Bool	%M18.1	False	True	True	True		
	Station ON	Bool	%Q0.0	False	True	True	True		
	UA11B001 Counter Wash Time Out	Bool	%M100.1	False	True	True	True		
	UA11B001 Pause 1 Time Out	Bool	%M100.2	False	True	True	True		
	UA11B001 Dosing Conditions	Bool	%M100.3	False	True	True	True		
	UA11B001 HCl Dosing Finished	Bool	%M100.4	False	True	True	True		
	UA11B001 Washing Time Out	Bool	%M100.5	False	True	True	True		
	UA11B001 Pause 2 Time Out	Bool	%M100.6	False	True	True	True		
	UA11B001 Water Lowering Time Out	Bool	%M100.7	False	True	True	True		
	UA11B001 Mixing Conditions	Bool	%M101.0	False	True	True	True		
	UA11B001 Resin Mixing Time Out	Bool	%M101.1	False	True	True	True		
	UA11B001 Refilling Time Out	Bool	%M101.2	False	True	True	True		
	Testing Time Out	Bool	%M101.3	False	True	True	True		
	UA11B001 Regeneration Failed	Bool	%M101.4	False	True	True	True		
	UA11B001 Regeneration Succeded	Bool	%M101.5	False	True	True	True		
	UA12B001 Counter Wash Time Out	Bool	%M102.0	False	True	True	True		
	UA12B001 Pause 1 Time Out	Bool	%M102.1	False	True	True	True		

	Name	Data type	Address	Retain	Accessible from HMI/OPC UA	Writable from HMI/OPC UA	Visible in HMI engineering	Supervision	Comment
	UA12B001 Dosing Conditions	Bool	%M102.2	False	True	True	True		
	UA11B001 NaOH Dosing Finished	Bool	%M102.3	False	True	True	True		
	UA12B001 Washing Time Out	Bool	%M102.4	False	True	True	True		
	UA12B001 Pause 2 Time Out	Bool	%M102.5	False	True	True	True		
	UA12B001 Water Lowering Time Out	Bool	%M102.6	False	True	True	True		
	UA12B001 Mixing Conditions	Bool	%M102.7	False	True	True	True		
	UA12B001 Resin Mixing Time Out	Bool	%M103.0	False	True	True	True		
	UA12B001 Refilling Time Out	Bool	%M103.1	False	True	True	True		
	UA12B001 Regeneration Failed	Bool	%M103.2	False	True	True	True		
	UA12B001 Regeneration Succeded	Bool	%M103.3	False	True	True	True		
	Neutralisation Valves Condition	Bool	%M104.0	False	True	True	True		
	UC10B001 Mixing Time Out	Bool	%M104.1	False	True	True	True		
	UC10B001 PH < 6.5	Bool	%M104.5	False	True	True	True		
	UC10B001 PH > 7.5	Bool	%M104.6	False	True	True	True		
	UC10B001 PH [6.5-7.5]	Bool	%M104.7	False	True	True	True		
	UA12B001 Filtering	Bool	%M110.1	False	True	True	True		
	UA11B001 Filtering	Bool	%M110.0	False	True	True	True		
	UA11B001 Regenerating	Bool	%M110.2	False	True	True	True		
	UA12B001 Regenerating	Bool	%M110.4	False	True	True	True		
	UA11B001 Needs Regeneration	Bool	%M176.0	False	True	True	True		
	UA12B001 Needs Regeneration	Bool	%M176.1	False	True	True	True		
	UA11B001 Filtration End	Bool	%M200.0	False	True	True	True		
	Raw Water Presence	Bool	%M180.0	False	True	True	True		
	Raw Water Absence Alarm	Bool	%M180.1	False	True	True	True		
	HCl dilution Water Low	Bool	%M150.0	False	True	True	True		
	NaOH dilution Water Low	Bool	%M150.1	False	True	True	True		
	UA11B001 Refiling conditions	Bool	%M160.0	False	True	True	True		
	UA11B001 Raw Water Pumps Start	Bool	%M500.0	False	True	True	True		

	Name	Data type	Address	Retain	Accessible from HMI/OPC UA	Writable from HMI/OPC UA	Visible in HMI engineering	Supervision	Comment
	UA12B001 Raw Water Pumps Start	Bool	%M500.1	False	True	True	True		
	HCL Dosing Pumps Start	Bool	%M500.2	False	True	True	True		
	NaOH Dosing Pumps Start	Bool	%M500.3	False	True	True	True		
	Dilution Water Pumps Start	Bool	%M500.4	False	True	True	True		
	Mixing Air Boosters Start	Bool	%M500.5	False	True	True	True		
	Neutralisation Mixing/Discharge Start	Bool	%M500.6	False	True	True	True		
	UA11B001 Regeneration Pumps Condition	Bool	%M15.4	False	True	True	True		
	UA12B001 Regeneration Pumps Condition	Bool	%M15.5	False	True	True	True		
	UA12B001 Refilling Conditions	Bool	%M160.1	False	True	True	True		
	Neutralisation Pumps Condition	Bool	%M104.2	False	True	True	True		
	Neutralisation Start Conditions	Bool	%M104.3	False	True	True	True		
	UA12B001 HCl Dosing Finished	Bool	%M105.0	False	True	True	True		
	UA12B001 NaOH Dosing Finished	Bool	%M105.1	False	True	True	True		
	UA11B001 Auto Filtration	Bool	%M600.0	False	True	True	True		
	UA12B001 Auto Filtration	Bool	%M600.1	False	True	True	True		
	UA11B001 Auto Regeneration	Bool	%M600.2	False	True	True	True		
	UA12B001 Auto Regeneration	Bool	%M600.3	False	True	True	True		
	UA11B001 Raw Water Pumps ON	Bool	%M550.0	False	True	True	True		
	UA12B001 Raw Water Pumps ON	Bool	%M550.1	False	True	True	True		
	HCL Dosing Pumps ON	Bool	%M550.2	False	True	True	True		
	NaOH Dosing Pumps ON	Bool	%M550.3	False	True	True	True		
	Dilution Water Pumps ON	Bool	%M550.4	False	True	True	True		
	UA11B001 Filtration Timers Reset	Bool	%M1000.0	False	True	True	True		
	Raw Water Low Level	Bool	%M60.0	False	True	True	True		
	Dilution Water Low Level	Bool	%M60.1	False	True	True	True		
	Dilution Water High Level	Bool	%M60.2	False	True	True	True		
	HCL Tank Low Level	Bool	%M60.3	False	True	True	True		
	NaOH Tank Low Level	Bool	%M60.4	False	True	True	True		

	Name	Data type	Address	Retain	Accessible from HMI/OPC UA	Writable from HMI/OPC UA	Visible in HMI engineering	Supervision	Comment
	UA12B001 Filtration Timers Reset	Bool	%M1000.1	False	True	True	True		
	UA11B001 Regeneration Timers Reset	Bool	%M1000.2	False	True	True	True		
	UA12B001 Regeneration Timers Reset	Bool	%M1000.3	False	True	True	True		
	Neutralisation Timers Reset	Bool	%M1000.4	False	True	True	True		
	Neutralisation Ended	Bool	%M103.4	False	True	True	True		
	Auto Neutralisation	Bool	%M600.4	False	True	True	True		
	UA11B001 Testing Time out	Bool	%M300.0	False	True	True	True		
	UA12B001 Testing Time Out	Bool	%M300.1	False	True	True	True		

Demineralisation Station S7-1500 / PLC_1 [CPU 1515T-2 PN] / PLC tags / Pumps

Pumps [32]

PLC tags									
	Name	Data type	Address	Retain	Accessible from HMI/OPC UA	Writable from HMI/OPC UA	Visible in HMI engineering	Supervision	Comment
	UA11D001	Bool	%Q1.0	False	True	True	True		Raw water Pump UA11D001 control
	UA10D001	Bool	%Q1.2	False	True	True	True		Raw water Pump UA10D001 control
	UA12D001 Failure	Bool	%I44.1	False	True	True	True		Raw water Pump UA12D001 failure signal
	UA10D001 Failure	Bool	%I44.2	False	True	True	True		Raw water Pump UA10D001 failure signal
	UA12D001	Bool	%Q1.1	False	True	True	True		Raw water Pump UA12D001 control
	UA11D001 Failure	Bool	%I44.0	False	True	True	True		Raw water Pump UA11D001 failure signal
	UA51D001	Bool	%Q1.3	False	True	True	True		Air Booster Pump UA51D001 control
	UA52D001	Bool	%Q1.4	False	True	True	True		Air Booster Pump UA52D001 control
	UA44D001	Bool	%Q1.5	False	True	True	True		HCl Dosing UA44D001 Pump control
	UA45D001	Bool	%Q1.6	False	True	True	True		HCl Dosing UA45D001 Pump control
	UA34D001	Bool	%Q1.7	False	True	True	True		NaOH UA34D001Dosing Pump control
	UA35D001	Bool	%Q2.0	False	True	True	True		NaOH UA35D001Dosing Pump control
	UA24D001	Bool	%Q2.1	False	True	True	True		Dilution water Pump UA24D001 control
	UA25D001	Bool	%Q2.2	False	True	True	True		Dilution water Pump UA25D001 control
	UA31D001	Bool	%Q2.3	False	True	True	True		NaOH Pump control (from preparation)
	UA32D001	Bool	%Q2.4	False	True	True	True		NaOH Pump control (from preparation)
	UC51D001	Bool	%Q2.5	False	True	True	True		Air Booster Pump UC51D001 control (for neutralisation)
	UC52D001	Bool	%Q2.6	False	True	True	True		Air Booster Pump UC52D001 control (for neutralisation)
	UC10D001	Bool	%Q2.7	False	True	True	True		Neutralisation Pump Control
	UA51D001 Failure	Bool	%I44.3	False	True	True	True		Air Booster Pump UA51D001 failure signal
	UA52D001 Failure	Bool	%I44.4	False	True	True	True		Air Booster Pump UA52D001 failure signal
	UA44D001 Failure	Bool	%I44.5	False	True	True	True		HCl Dosing UA44D001 Pump failure signal
	UA45D001 Failure	Bool	%I44.6	False	True	True	True		HCl Dosing UA45D001 Pump failure signal

	Name	Data type	Address	Retain	Accessible from HMI/OPC UA	Writable from HMI/OPC UA	Visible in HMI engineering	Supervision	Comment
	UA34D001 Failure	Bool	%I44.7	False	True	True	True		NaOH UA34D001Dosing Pump failure signal
	UA35D001 Failure	Bool	%I45.0	False	True	True	True		NaOH UA35D001Dosing Pump failure signal
	UA24D001 Failure	Bool	%I45.1	False	True	True	True		Dilution water Pump UA24D001 failure signal
	UA25D001 Failure	Bool	%I45.2	False	True	True	True		Dilution water Pump UA25D001 failure signal
	UA31D001 Failure	Bool	%I45.3	False	True	True	True		NaOH Pump control (from preparation) failure signal
	UA32D001 Failure	Bool	%I45.4	False	True	True	True		NaOH Pump control (from preparation) failure signal
	UC51D001 Failure	Bool	%I45.5	False	True	True	True		Air Booster Pump UC51D001(for neutralisation) failure signal
	UC52D001 Failure	Bool	%I45.6	False	True	True	True		Air Booster Pump UC52D001 (for neutralisation) failure signal
	UC10D001 Failure	Bool	%I45.7	False	True	True	True		Neutralisation Pump failure signal

Demineralisation Station S7-1500 / PLC_1 [CPU 1515T-2 PN] / PLC tags / Sensors

Sensors [39]

PLC tags

	Name	Data type	Address	Retain	Accessible from HMI/OPC UA	Writable from HMI/OPC UA	Visible in HMI engineering	Supervision	Comment
	UA10A001	Real	%ID100	False	True	True	True		Raw water channel conductivity
	UA10A002	Real	%ID106	False	True	True	True		Raw water channel PH
	UA10P002	Bool	%I2.6	False	True	True	True		Raw water channel Pressure
	UA12P002	Bool	%I3.4	False	True	True	True		UA12B001 low pressue indicator
	UA12P004	Bool	%I3.5	False	True	True	True		UA12B001 filter resistance
	UA12A001	Real	%ID112	False	True	True	True		UA12B001 water conductivity at output
	UA12A002	Real	%ID116	False	True	True	True		UA12B001 water conductivity at output
	UA11A001	Real	%ID122	False	True	True	True		UA11B001 water conductivity at output
	UA11A002	Real	%ID128	False	True	True	True		UA11B001 water Silica at output
	UA11P002	Bool	%I3.2	False	True	True	True		UA11B001 low pressue indicator
	UA11P004	Bool	%I3.1	False	True	True	True		UA11B001 filter resistance
	UA11F002	Bool	%I3.0	False	True	True	True		UA11B001 water flow at output
	UA12F002	Bool	%I2.7	False	True	True	True		UA12B001 water flow at output
	UA13A001	Real	%ID132	False	True	True	True		Water conductivity before storage
	UA13A002	Real	%ID138	False	True	True	True		Water PH before storage
	UA13F001	Bool	%I2.5	False	True	True	True		Water Pressure before storage
	UA34Z001	Bool	%I2.4	False	True	True	True		NaOH dosing pump meter
	UA35Z001	Bool	%I2.3	False	True	True	True		NaOH dosing pump meter
	UA27F001	Bool	%I3.3	False	True	True	True		NaOH dilution water flow
	UA33L002	Bool	%I66.4	False	True	True	True		NaOH Reservoir high level
	UA33L003	Bool	%I2.0	False	True	True	True		NaOH Reservoir low level
	UA44Z001	Bool	%I66.5	False	True	True	True		HCl dosing pump meter
	UA45Z001	Bool	%I6.1	False	True	True	True		HCl dosing pump meter
	UA28F001	Bool	%I6.2	False	True	True	True		HCl dilution water flow
	UA41L002	Bool	%I7.4	False	True	True	True		HCl Reservoir UA41B001 high level
	UA41L003	Bool	%I7.5	False	True	True	True		HCl Reservoir UA41B001 low level

	Name	Data type	Address	Retain	Accessible from HMI/OPC UA	Writable from HMI/OPC UA	Visible in HMI engineering	Supervision	Comment
	UA42L002	Bool	%I7.6	False	True	True	True		HCl Reservoir UA42B001 high level
	UA42L003	Bool	%I6.7	False	True	True	True		HCl Reservoir UA42B001 low level
	UC10L001	Bool	%I7.7	False	True	True	True		Neutralisation basin very high level
	UC10L002	Bool	%I67.0	False	True	True	True		Neutralisation basin high level
	UC10L003	Bool	%I67.1	False	True	True	True		Neutralisation basin low level
	UC10L004	Bool	%I1.3	False	True	True	True		Neutralisation basin very low level
	34UD10L007	Bool	%I1.4	False	True	True	True		Demineralised water tank 34UD10B001very low level
	UC10A001	Real	%ID144	False	True	True	True		Neutralisation basin PH
	00WJ40L001	Bool	%I1.5	False	True	True	True		Raw Water reservoir 00WJ40B001 low level
	00WJ40L002	Bool	%I1.6	False	True	True	True		Raw Water reservoir 00WJ40B02 low level
	12UD10L007	Bool	%I1.7	False	True	True	True		Demineralised water tank 12UD10B001very low level
	34UD10L008	Bool	%I2.1	False	True	True	True		
	12UD10L008	Bool	%I2.2	False	True	True	True		

Demineralisation Station S7-1500 / PLC_1 [CPU 1515T-2 PN] / PLC tags / Switches

Switches [44]

PLC tags

	Name	Data type	Address	Retain	Accessible from HMI/OPC UA	Writable from HMI/OPC UA	Visible in HMI engineering	Supervision	Comment
	UA11D001 Auto	Bool	%I66.0	False	True	True	True		Raw water Pump Automatic mode switch
	UA10D001 Auto	Bool	%I3.6	False	True	True	True		Raw water Pump Automatic mode switch
	UA12D001 Auto	Bool	%I3.7	False	True	True	True		Raw water Pump Automatic mode switch
	UA51D001 Auto	Bool	%I4.0	False	True	True	True		Air Booster Pump Automatic mode switch
	UA52D001 Auto	Bool	%I4.1	False	True	True	True		Air Booster Pump Automatic mode switch
	UA44D001 Auto	Bool	%I4.2	False	True	True	True		HCl Dosing Automatic mode switch
	UA45D001 Auto	Bool	%I4.3	False	True	True	True		HCl Dosing Automatic mode switch
	UA34D001 Auto	Bool	%I4.4	False	True	True	True		NaOH Dosing Automatic mode switch
	UA35D001 Auto	Bool	%I4.5	False	True	True	True		NaOH Dosing Automatic mode switch
	UA31D001 Auto	Bool	%I4.6	False	True	True	True		NaOH Pump control (from preparation) Automatic mode switch
	UA32D001 Auto	Bool	%I4.7	False	True	True	True		NaOH Pump control (from preparation) Automatic mode switch
	UC51D001 Auto	Bool	%I5.0	False	True	True	True		Air Booster Pump control (for neutralisation) Automatic mode switch
	UC52D001 Auto	Bool	%I5.1	False	True	True	True		Air Booster Pump control (for neutralisation) Automatic mode switch
	UC10B001 ON/OFF	Bool	%I5.2	False	True	True	True		Neutralisation process On/OFF
	UA11D001 Manu	Bool	%I5.3	False	True	True	True		Raw water Pump Manual mode switch
	UA10D001 Manu	Bool	%I5.4	False	True	True	True		Raw water Pump Manual mode switch
	UA12D001 Manu	Bool	%I5.5	False	True	True	True		Raw water Pump Manual mode switch
	UA51D001 Manu	Bool	%I5.6	False	True	True	True		Air Booster Pump Manual mode switch
	UA52D001 Manu	Bool	%I5.7	False	True	True	True		Air Booster Pump Manual mode switch
	UA44D001 Manu	Bool	%I6.0	False	True	True	True		HCl Dosing Manual mode switch
	UA45D001 Manu	Bool	%I6.4	False	True	True	True		HCl Dosing Manual mode switch
	UA34D001 Manu	Bool	%I6.5	False	True	True	True		NaOH Dosing Manual mode switch

	Name	Data type	Address	Retain	Accessible from HMI/OPC UA	Writable from HMI/OPC UA	Visible in HMI engineering	Supervision	Comment
	UA35D001 Manu	Bool	%I6.6	False	True	True	True		NaOH Dosing Manual mode switch
	UA31D001 Manu	Bool	%I7.1	False	True	True	True		NaOH Pump control (from preparation) Manual mode switch
	UA32D001 Manu	Bool	%I66.1	False	True	True	True		NaOH Pump control (from preparation) Manual mode switch
	UC51D001 Manu	Bool	%I66.2	False	True	True	True		Air Booster Pump control (for neutralisation) Manual mode switch
	UC52D001 Manu	Bool	%I66.3	False	True	True	True		Air Booster Pump control (for neutralisation) Manual mode switch
	Start	Bool	%I0.0	False	True	True	True		Station start button
	Emergency Shutdown	Bool	%I0.1	False	True	True	True		Emergency Shut down button
	UC10D001 Auto	Bool	%I66.6	False	True	True	True		Neutralisation water Pump Automatic mode switch
	UC10D001 Manu	Bool	%I66.7	False	True	True	True		Neutralisation water Pump Manual mode switch
	UA24D001 Auto	Bool	%I7.0	False	True	True	True		Distilation Water Pump Automatic mode
	UA24D001 Manu	Bool	%I7.2	False	True	True	True		Distilation Water Pump Manual mode
	UA25D001 Auto	Bool	%I6.3	False	True	True	True		Distilation Water Pump Automatic mode
	UA25D001 Manu	Bool	%I7.3	False	True	True	True		Distilation Water Pump Manual mode
	UA11B001 Filtration button	Bool	%I0.4	False	True	True	True		Filter UA11B001 working mode is filtration
	UA11B001 regeneration button	Bool	%I0.5	False	True	True	True		Filter UA11B001 working mode is regeneration
	UA11B001 OFF button	Bool	%I0.6	False	True	True	True		Filter UA11B001 is OFF
	UA12B001 Filtration button	Bool	%I0.7	False	True	True	True		Filter UA12B001 working mode is filtration
	UA12B001 regeneration button	Bool	%I1.0	False	True	True	True		Filter UA12B001 working mode is regeneration
	UA12B001 OFF button	Bool	%I1.1	False	True	True	True		Filter UA12B001 is OFF
	Neutralisation Start	Bool	%I1.2	False	True	True	True		start of neutralisation process
	Station Full Auto	Bool	%I0.2	False	True	True	True		Station run mode fully automated or partially automated
	Station Part Auto	Bool	%I0.3	False	True	True	True		

Demineralisation Station S7-1500 / PLC_1 [CPU 1515T-2 PN] / PLC tags / Timers

Timers [31]

PLC tags									
Name	Data type	Address	Retain	Accessible from HMI/OPC UA	Writable from HMI/OPC UA	Visible in HMI engineering	Supervision	Comment
Recycling Time	Timer	%T1	False	True	True	True		
UA12B001 Recycling Time	Timer	%T2	False	True	True	True		
UA11B001 Cou_Wash_T	Timer	%T3	False	True	True	True		
UA11B001 Pause 1 Time	Timer	%T4	False	True	True	True		
UA11B001 Dosing Time	Timer	%T5	False	True	True	True		
UA11B001 Washing Time	Timer	%T6	False	True	True	True		
UA11B001 Water Lowering Time	Timer	%T7	False	True	True	True		
UA11B001 Resin Mixing Time	Timer	%T8	False	True	True	True		
UA11B001 Refiling Time	Timer	%T9	False	True	True	True		
UA11B001 Testing Time 2H	Timer	%T10	False	True	True	True		
UA11B001 Pause 2 Time	Timer	%T11	False	True	True	True		
UA11B001 Testing Time 2	Timer	%T12	False	True	True	True		
UA12B001 BK_Wash_T	Timer	%T13	False	True	True	True		
UA12B001 Pause 1 Time	Timer	%T14	False	True	True	True		
UA12B001 Dosing Time	Timer	%T15	False	True	True	True		
UA12B001 Washing Time	Timer	%T16	False	True	True	True		
UA12B001 Pause 2 Time	Timer	%T17	False	True	True	True		
UA12B001 Water Lowering Time	Timer	%T18	False	True	True	True		
UA12B001 Resin Mixing Time	Timer	%T19	False	True	True	True		
UA12B001 Refilling Time	Timer	%T20	False	True	True	True		
UA12B001 Testing Time 2H	Timer	%T21	False	True	True	True		
UA12B001 Testing Time 2	Timer	%T22	False	True	True	True		
UC10B001 Mixing Time	Timer	%T23	False	True	True	True		

	Name	Data type	Address	Retain	Accessible from HMI/OPC UA	Writable from HMI/OPC UA	Visible in HMI engineering	Supervision	Comment
	UA11B001 Rinsing pre-service 1	Timer	%T100	False	True	True	True		
	UA11B001 Rinsing pre-service 2	Timer	%T101	False	True	True	True		
	UA12B001 Rinsing pre-service 2	Timer	%T201	False	True	True	True		
	UA12B001 Rinsing pre-service 1	Timer	%T200	False	True	True	True		
	Regeneration Pressure Check Time	Timer	%T50	False	True	True	True		
	Regeneration Water Presence	Timer	%T51	False	True	True	True		
	HCl Dilution Water Presence	Timer	%T60	False	True	True	True		
	NaOH Dilution Wate Presence	Timer	%T61	False	True	True	True		

Demineralisation Station S7-1500 / PLC_1 [CPU 1515T-2 PN] / PLC tags / Valves

Valves [120]

PLC tags									
	Name	Data type	Address	Retain	Acces-sible from HMI/OPC UA	Writa-ble from HMI/OPC UA	Visi-ble in HMI engi-neer-ing	Supervision	Comment
	UA12S007	Bool	%Q4.7	False	True	True	True		
	UA12S017	Bool	%Q5.5	False	True	True	True		
	UA12S015	Bool	%Q5.4	False	True	True	True		
	UA12S008	Bool	%Q5.0	False	True	True	True		
	UA12S009	Bool	%Q5.1	False	True	True	True		
	UA12S012	Bool	%Q5.2	False	True	True	True		
	UA12S014	Bool	%Q5.3	False	True	True	True		
	UA38S003	Bool	%Q6.6	False	True	True	True		
	UA38S001	Bool	%Q6.4	False	True	True	True		
	UA55S002	Bool	%Q7.7	False	True	True	True		
	UA48S002	Bool	%Q7.4	False	True	True	True		
	UA38S002	Bool	%Q6.5	False	True	True	True		
	UA48S003	Bool	%Q7.5	False	True	True	True		
	UA48S001	Bool	%Q7.3	False	True	True	True		
	UA37S001	Bool	%Q6.1	False	True	True	True		
	UA37S003	Bool	%Q6.3	False	True	True	True		
	UA11S008	Bool	%Q4.1	False	True	True	True		
	UA54S002	Bool	%Q7.6	False	True	True	True		
	UA37S002	Bool	%Q6.2	False	True	True	True		
	UA11S009	Bool	%Q4.2	False	True	True	True		
	UA11S007	Bool	%Q4.0	False	True	True	True		
	UA11S017	Bool	%Q4.6	False	True	True	True		
	UA11S015	Bool	%Q4.5	False	True	True	True		
	UA47S002	Bool	%Q7.1	False	True	True	True		
	UA11S012	Bool	%Q4.3	False	True	True	True		
	UA11S014	Bool	%Q4.4	False	True	True	True		
	UA47S003	Bool	%Q7.2	False	True	True	True		
	UA47S001	Bool	%Q7.0	False	True	True	True		
	UA36S001	Bool	%Q6.0	False	True	True	True		
	UA27S003	Bool	%Q5.6	False	True	True	True		
	UA46S003	Bool	%Q6.7	False	True	True	True		
	UA28S003	Bool	%Q5.7	False	True	True	True		
	UC40S003	Bool	%Q3.3	False	True	True	True		
	UC30S003	Bool	%Q3.2	False	True	True	True		
	UC10S002	Bool	%Q3.1	False	True	True	True		

	Name	Data type	Address	Retain	Accessible from HMI/OPC UA	Writable from HMI/OPC UA	Visible in HMI engineering	Supervision	Comment
	UC10S001	Bool	%Q3.0	False	True	True	True		
	UA12S007 C_Pos	Bool	%I65.7	False	True	True	True		
	UA12S017 C_Pos	Bool	%I8.0	False	True	True	True		
	UA12S015 C_Pos	Bool	%I8.1	False	True	True	True		
	UA12S008 C_Pos	Bool	%I8.2	False	True	True	True		
	UA12S009 C_Pos	Bool	%I8.3	False	True	True	True		
	UA12S012 C_Pos	Bool	%I8.4	False	True	True	True		
	UA12S014 C_Pos	Bool	%I8.5	False	True	True	True		
	UA38S003 C_Pos	Bool	%I8.6	False	True	True	True		
	UA38S001 C_Pos	Bool	%I8.7	False	True	True	True		
	UA55S002 C_Pos	Bool	%I9.0	False	True	True	True		
	UA48S002 C_Pos	Bool	%I9.1	False	True	True	True		
	UA38S002 C_Pos	Bool	%I9.2	False	True	True	True		
	UA48S003 C_Pos	Bool	%I9.3	False	True	True	True		
	UA48S001 C_Pos	Bool	%I9.4	False	True	True	True		
	UA37S001 C_Pos	Bool	%I9.5	False	True	True	True		
	UA37S003 C_Pos	Bool	%I9.6	False	True	True	True		
	UA11S008 C_Pos	Bool	%I9.7	False	True	True	True		
	UA54S002 C_Pos	Bool	%I10.0	False	True	True	True		
	UA37S002 C_Pos	Bool	%I10.1	False	True	True	True		
	UA11S009 C_Pos	Bool	%I10.2	False	True	True	True		
	UA11S007 C_Pos	Bool	%I10.3	False	True	True	True		
	UA11S017 C_Pos	Bool	%I10.4	False	True	True	True		
	UA11S015 C_Pos	Bool	%I10.5	False	True	True	True		
	UA47S002 C_Pos	Bool	%I10.6	False	True	True	True		
	UA11S012 C_Pos	Bool	%I10.7	False	True	True	True		
	UA11S014 C_Pos	Bool	%I11.0	False	True	True	True		
	UA47S003 C_Pos	Bool	%I11.1	False	True	True	True		
	UA47S001 C_Pos	Bool	%I11.2	False	True	True	True		
	UA36S001 C_Pos	Bool	%I11.3	False	True	True	True		
	UA27S003 C_Pos	Bool	%I11.4	False	True	True	True		
	UA46S003 C_Pos	Bool	%I11.5	False	True	True	True		
	UA28S003 C_Pos	Bool	%I11.6	False	True	True	True		
	UC40S003 C_Pos	Bool	%I11.7	False	True	True	True		
	UC30S003 C_Pos	Bool	%I60.0	False	True	True	True		
	UC10S002 C_Pos	Bool	%I60.1	False	True	True	True		
	UC10S001 C_Pos	Bool	%I60.2	False	True	True	True		
	UA12S007 O_Pos	Bool	%I60.3	False	True	True	True		
	UA12S017 O_Pos	Bool	%I60.4	False	True	True	True		
	UA12S015 O_Pos	Bool	%I60.5	False	True	True	True		
	UA12S008 O_Pos	Bool	%I60.6	False	True	True	True		

	Name	Data type	Address	Retain	Accessible from HMI/OPC UA	Writable from HMI/OPC UA	Visible in HMI engineering	Supervision	Comment
	UA12S009 O_Pos	Bool	%I60.7	False	True	True	True		
	UA12S012 O_Pos	Bool	%I61.0	False	True	True	True		
	UA12S014 O_Pos	Bool	%I61.1	False	True	True	True		
	UA38S003 O_Pos	Bool	%I61.2	False	True	True	True		
	UA38S001 O_Pos	Bool	%I61.3	False	True	True	True		
	UA55S002 O_Pos	Bool	%I61.4	False	True	True	True		
	UA48S002 O_Pos	Bool	%I61.5	False	True	True	True		
	UA38S002 O_Pos	Bool	%I61.6	False	True	True	True		
	UA48S003 O_Pos	Bool	%I61.7	False	True	True	True		
	UA48S001 O_Pos	Bool	%I62.0	False	True	True	True		
	UA37S001 O_Pos	Bool	%I62.1	False	True	True	True		
	UA37S003 O_Pos	Bool	%I62.2	False	True	True	True		
	UA11S008 O_Pos	Bool	%I62.3	False	True	True	True		
	UA54S002 O_Pos	Bool	%I62.4	False	True	True	True		
	UA37S002 O_Pos	Bool	%I62.5	False	True	True	True		
	UA11S009 O_Pos	Bool	%I62.6	False	True	True	True		
	UA11S007 O_Pos	Bool	%I62.7	False	True	True	True		
	UA11S017 O_Pos	Bool	%I63.0	False	True	True	True		
	UA11S015 O_Pos	Bool	%I63.1	False	True	True	True		
	UA47S002 O_Pos	Bool	%I63.2	False	True	True	True		
	UA11S012 O_Pos	Bool	%I63.3	False	True	True	True		
	UA11S014 O_Pos	Bool	%I63.4	False	True	True	True		
	UA47S003 O_Pos	Bool	%I63.5	False	True	True	True		
	UA47S001 O_Pos	Bool	%I63.6	False	True	True	True		
	UA36S001 O_Pos	Bool	%I63.7	False	True	True	True		
	UA27S003 O_Pos	Bool	%I64.0	False	True	True	True		
	UA46S003 O_Pos	Bool	%I64.1	False	True	True	True		
	UA28S003 O_Pos	Bool	%I64.2	False	True	True	True		
	UC40S003 O_Pos	Bool	%I64.3	False	True	True	True		
	UC30S003 O_Pos	Bool	%I64.4	False	True	True	True		
	UC10S002 O_Pos	Bool	%I64.5	False	True	True	True		
	UC10S001 O_Pos	Bool	%I64.6	False	True	True	True		
	UA14S001	Bool	%Q3.4	False	True	True	True		
	UA15S001	Bool	%Q3.5	False	True	True	True		
	UA14S001 O_Pos	Bool	%I64.7	False	True	True	True		
	UA14S001 C_Pos	Bool	%I65.0	False	True	True	True		
	UA15S001 O_Pos	Bool	%I65.1	False	True	True	True		
	UA15S001 C_Pos	Bool	%I65.2	False	True	True	True		
	UA11S006	Bool	%Q3.6	False	True	True	True		
	UA12S006	Bool	%Q3.7	False	True	True	True		
	UA11S006 O_Pos	Bool	%I65.3	False	True	True	True		

	Name	Data type	Address	Retain	Acces-sible from HMI/OPC UA	Writa-ble from HMI/OPC UA	Visi-ble in HMI engi-neer-ing	Supervision	Comment
	UA11S006 C_Pos	Bool	%I65.4	False	True	True	True		
	UA12S006 O_Pos	Bool	%I65.5	False	True	True	True		
	UA12S006 C_Pos	Bool	%I65.6	False	True	True	True		

Appendix B

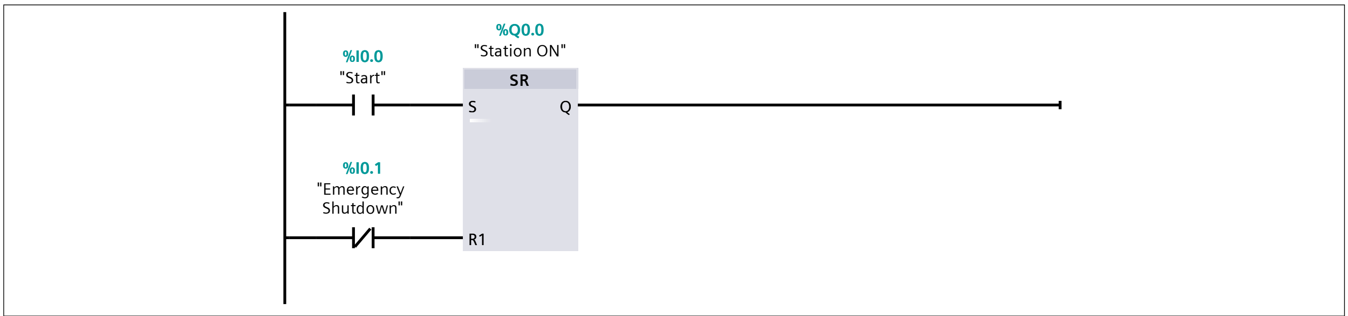
Demineralisation Station S7-1500 / PLC_1 [CPU 1515T-2 PN] / Program blocks

Main [OB1]

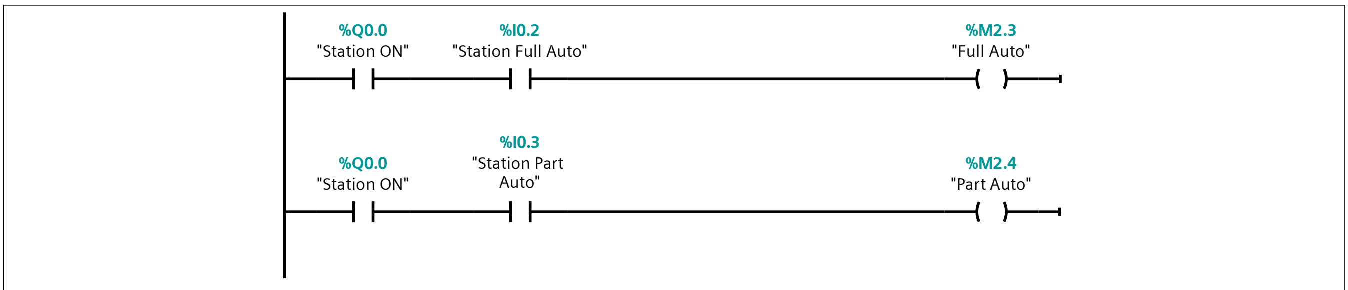
Main Properties					
General					
Name	Main	**Number**	1	**Type**	OB
Language	LAD	**Numbering**	Automatic		
Information					
Title	"Main Program Sweep (Cycle)"	**Author**		**Comment**	
Family		**Version**	0.1	**User-defined ID**	

Main				
Name	**Data type**	**Default value**	**Supervi-sion**	**Comment**
▼ Input				
Initial_Call	Bool			Initial call of this OB
Remanence	Bool			=True, if remanent data are available
Temp				
Constant				

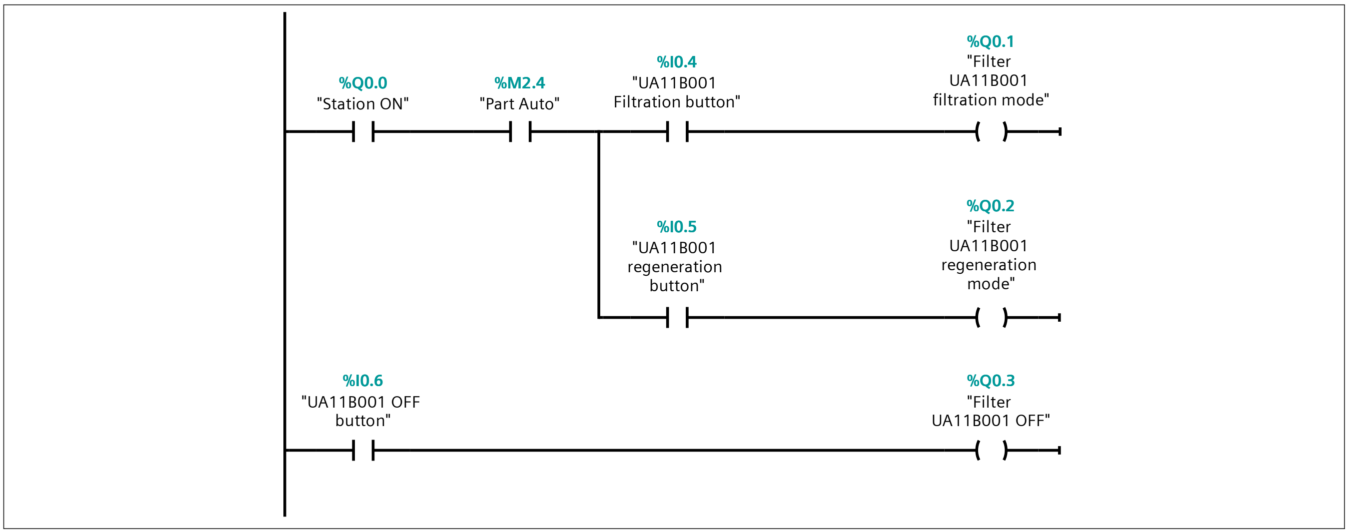
Network 1: Station Start/Stop



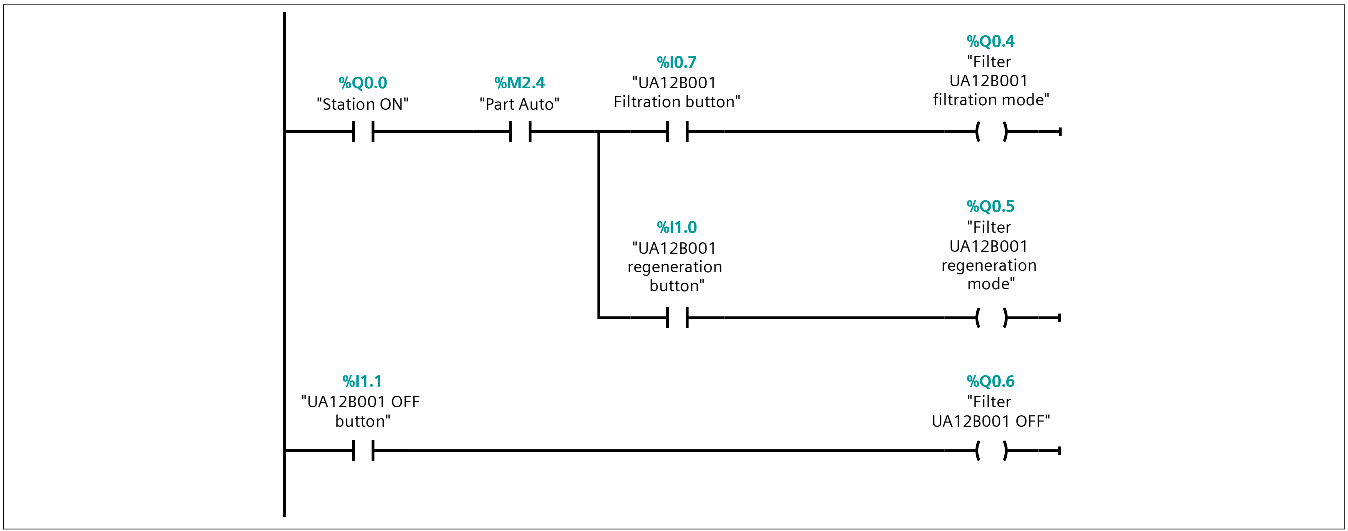
Network 2: Station mode



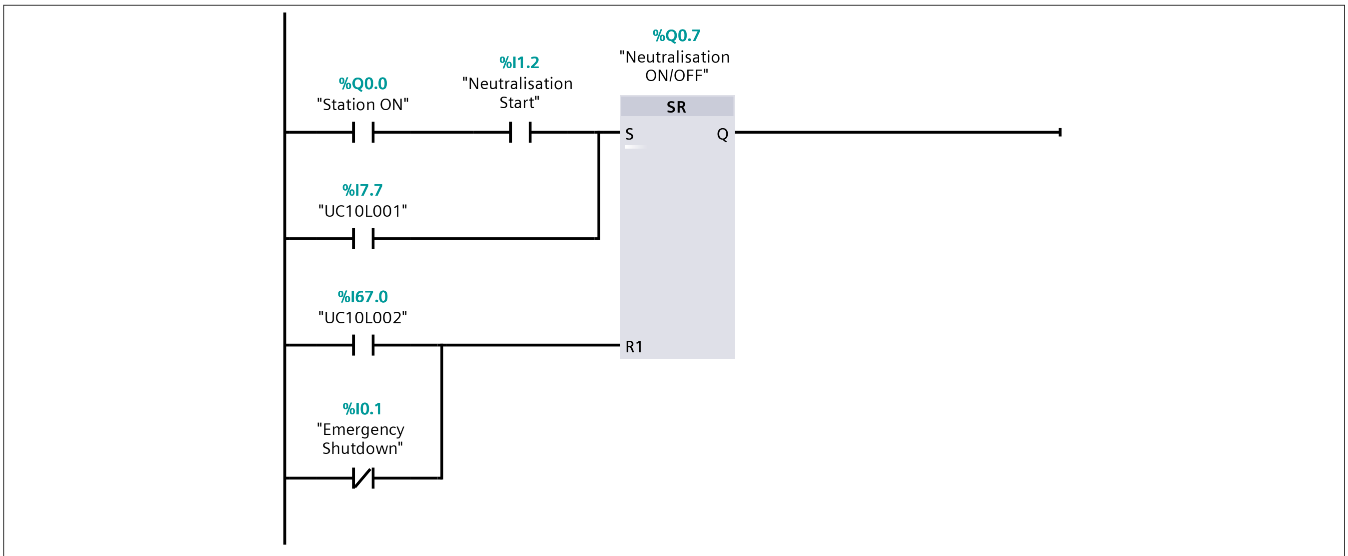
Network 3: Filter UA11B001 Mode



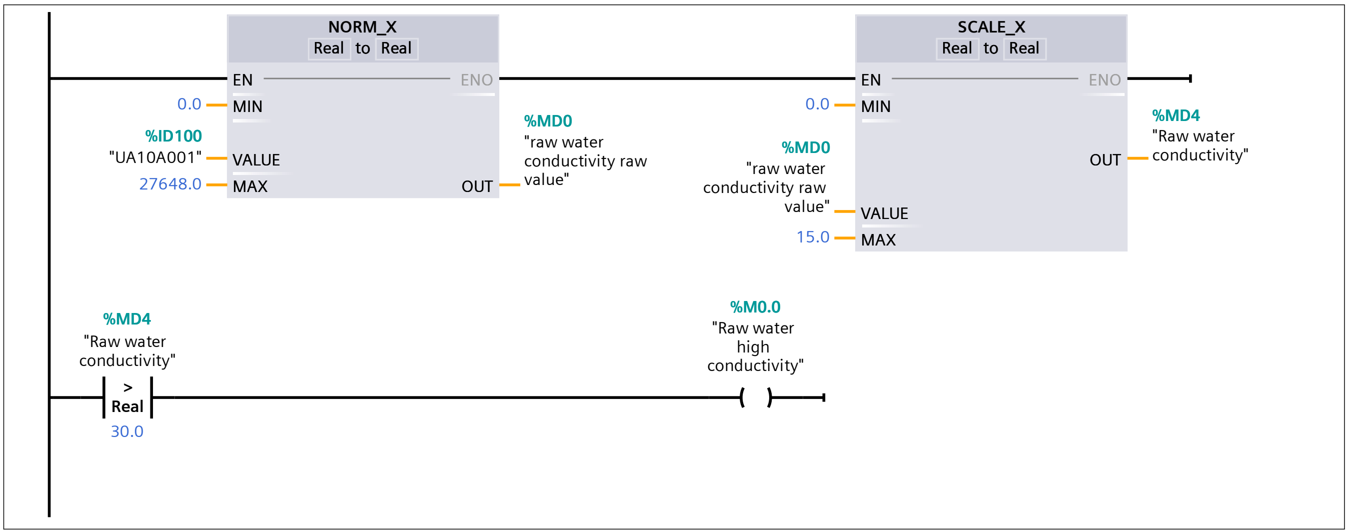
Network 4: Filter UA12B001 Mode



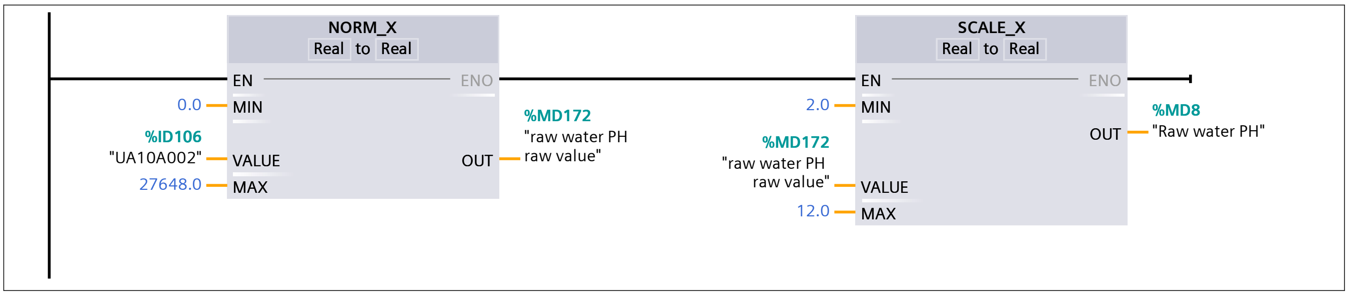
Network 5: Neutralisation



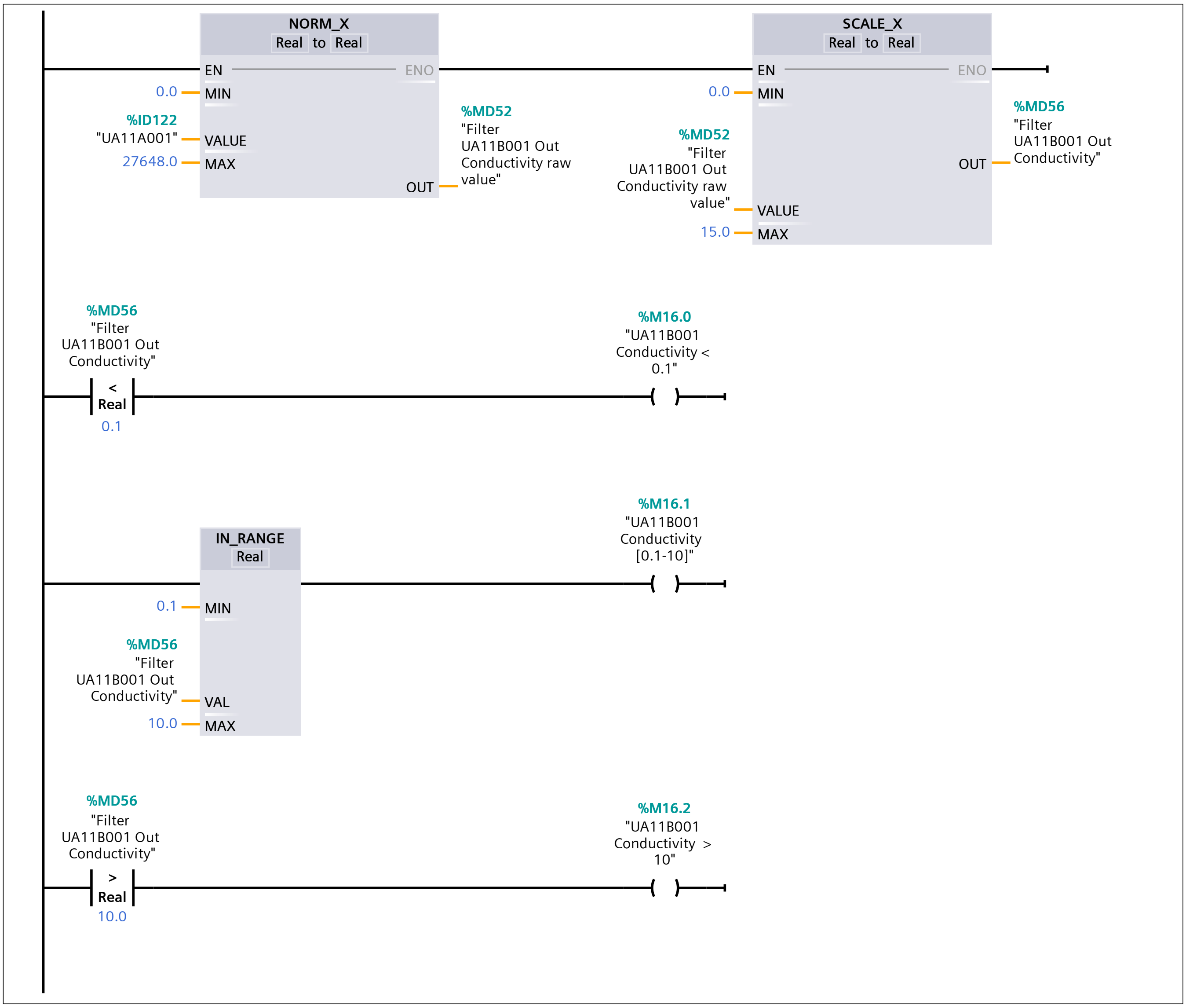
Network 6: Conductivity in raw water channel



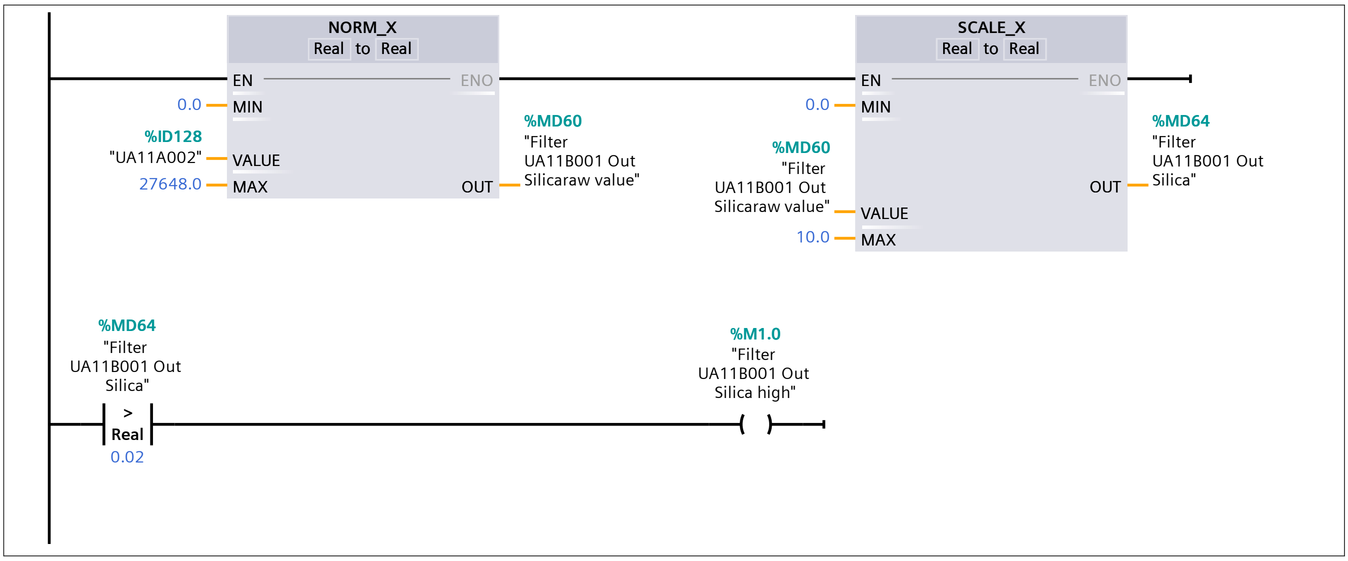
Network 7: PH in raw water channel



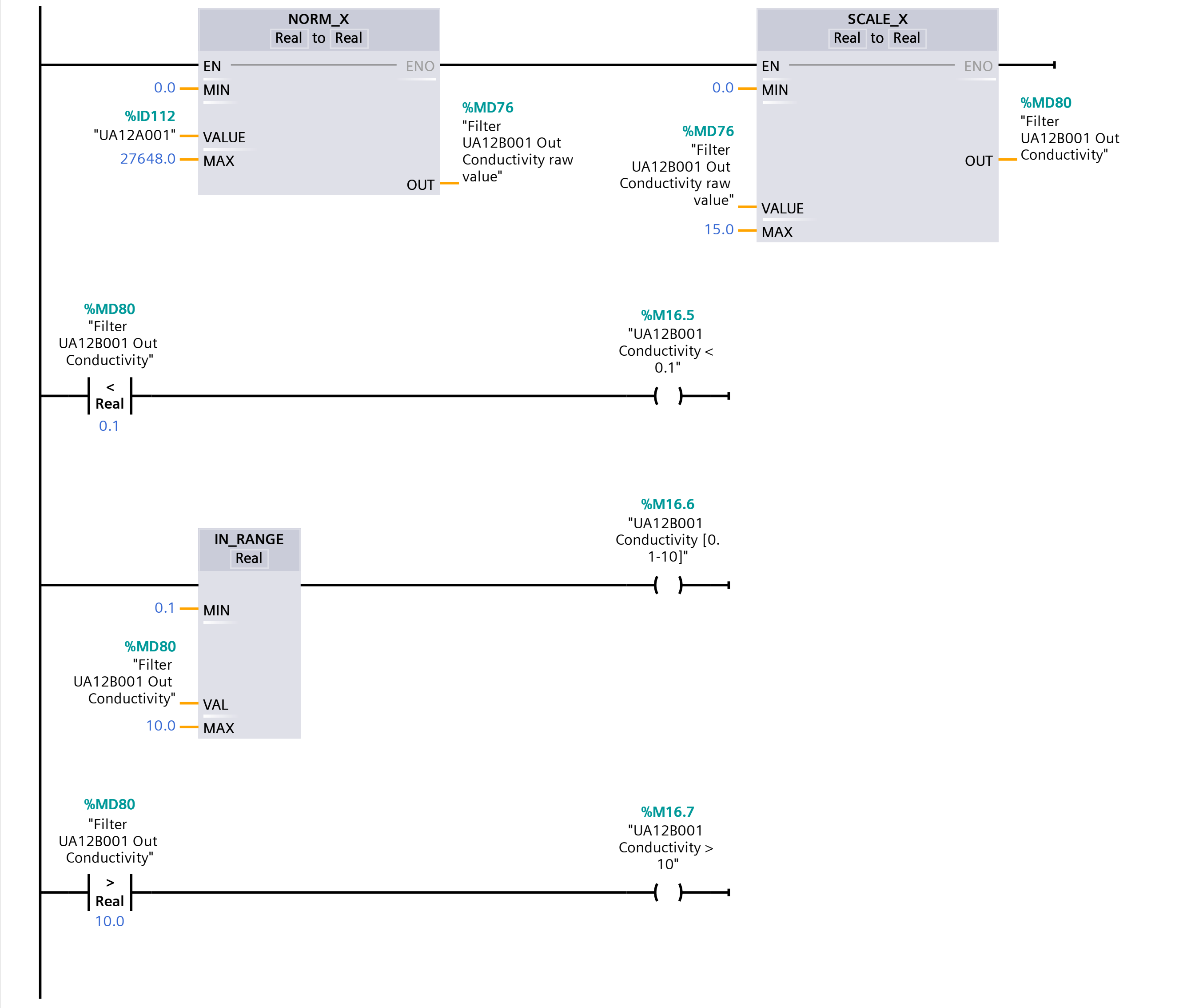
Network 8: Conductivity out filter UA11B001



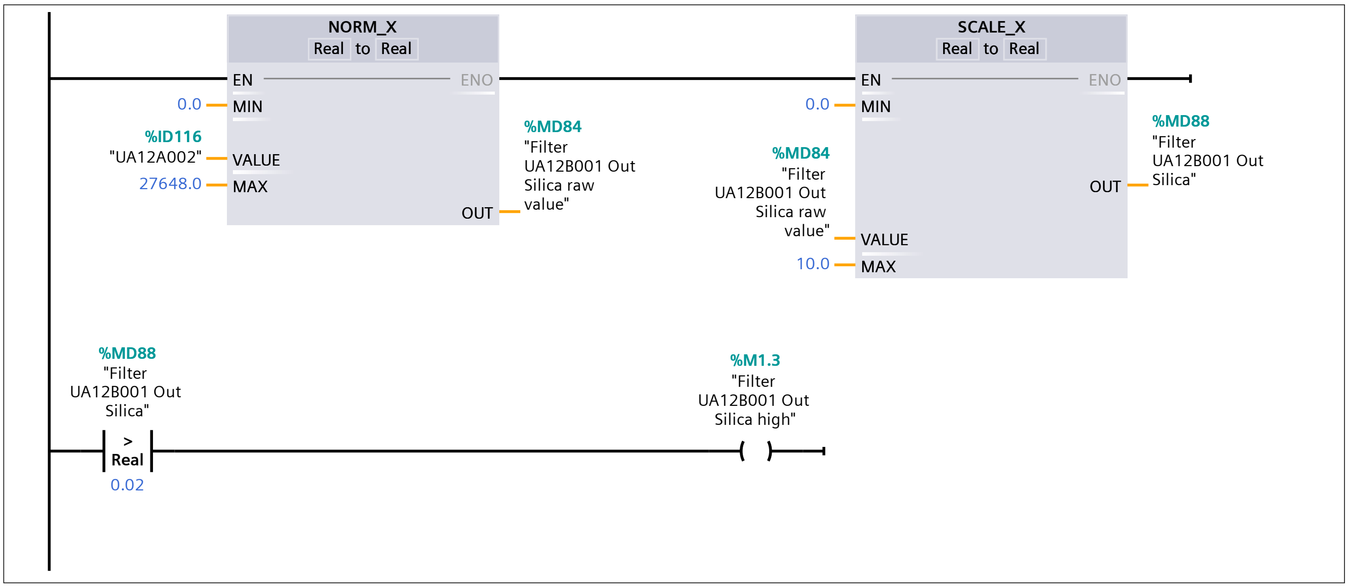
Network 9: Silica out filter UA11B001



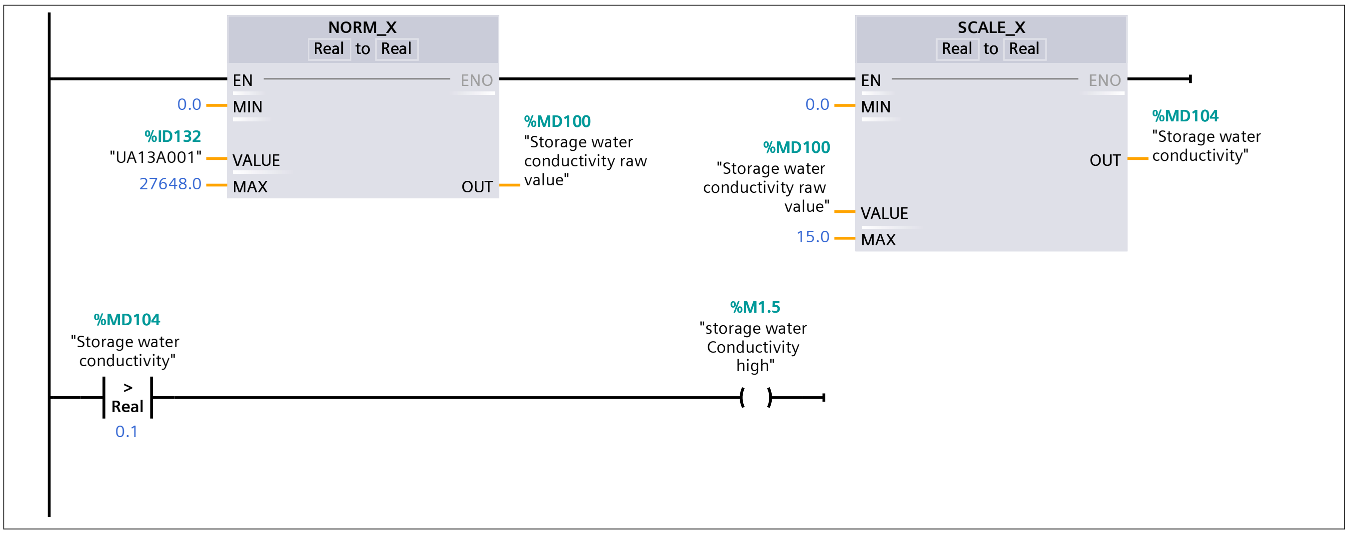
Network 10: Conductivity out filter UA12B001



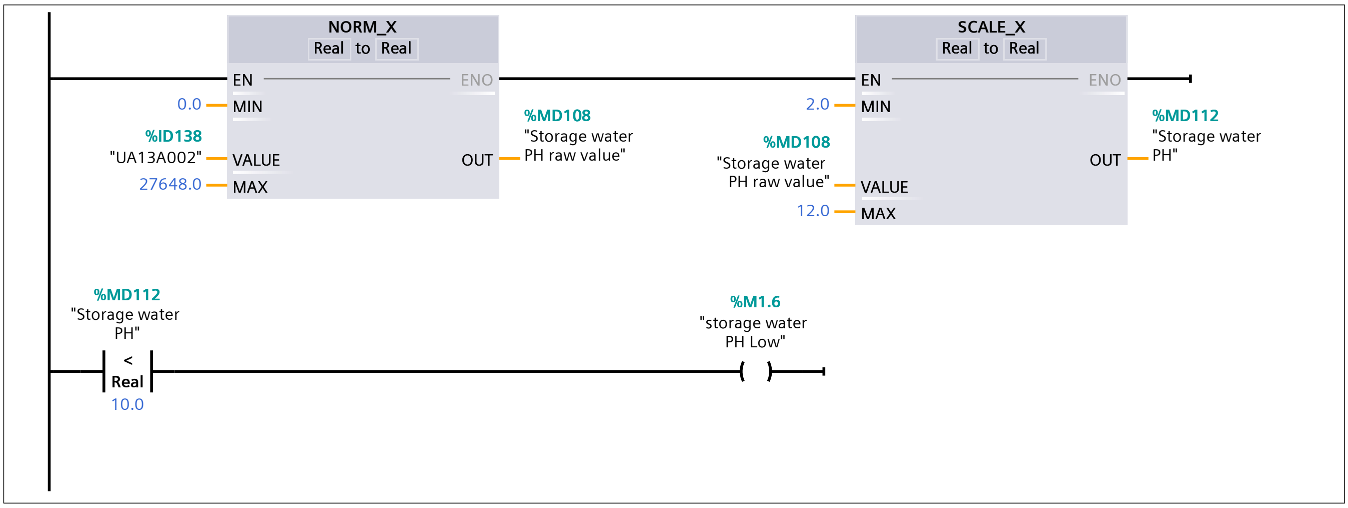
Network 11: Silica out filter UA12B001



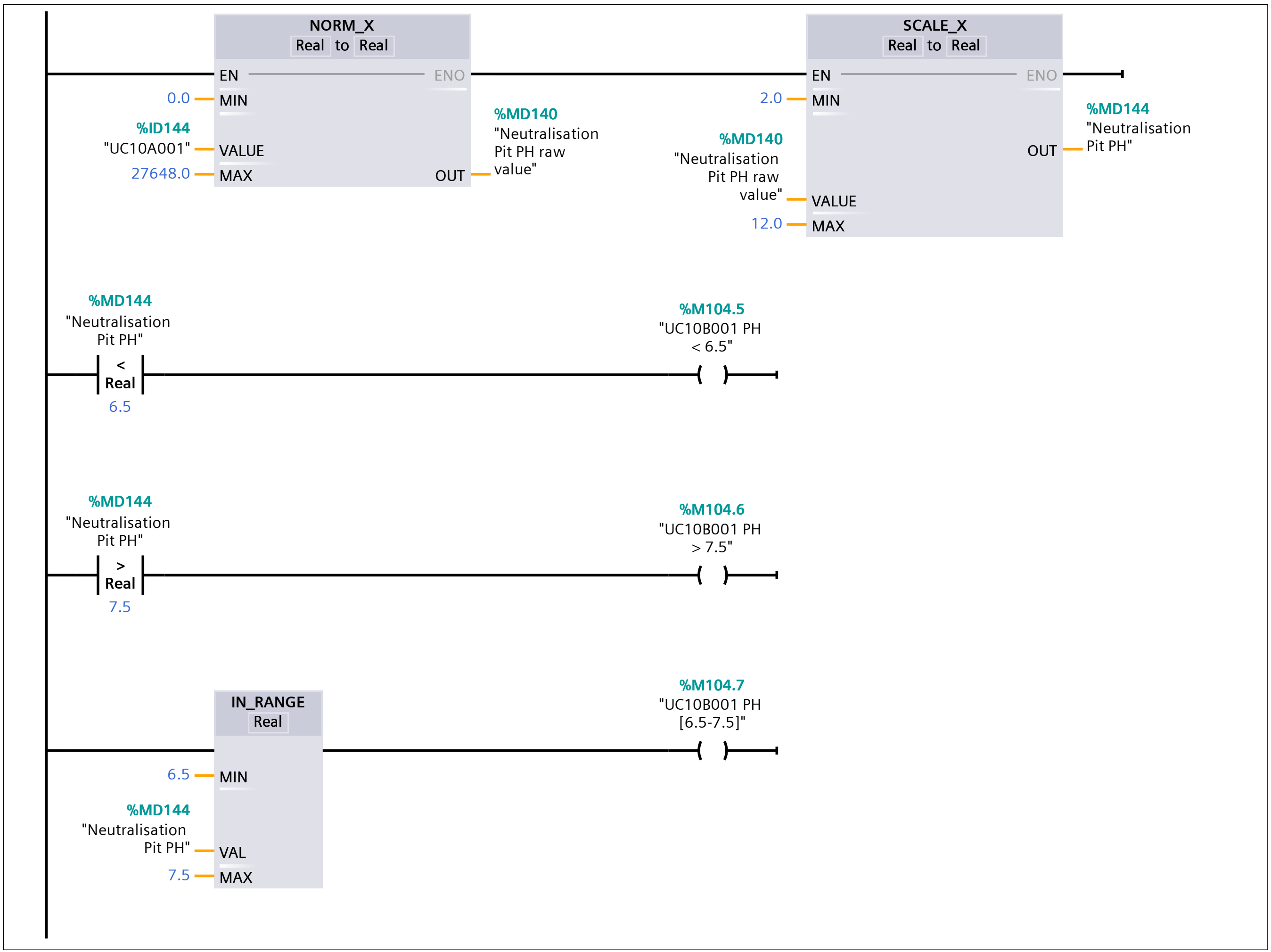
Network 12: Conductivity before storage



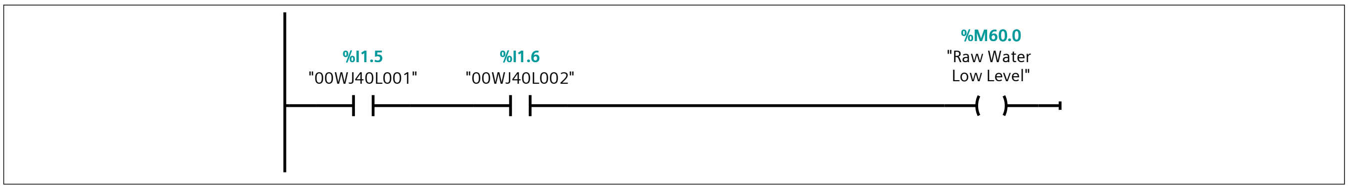
Network 13: PH before storage



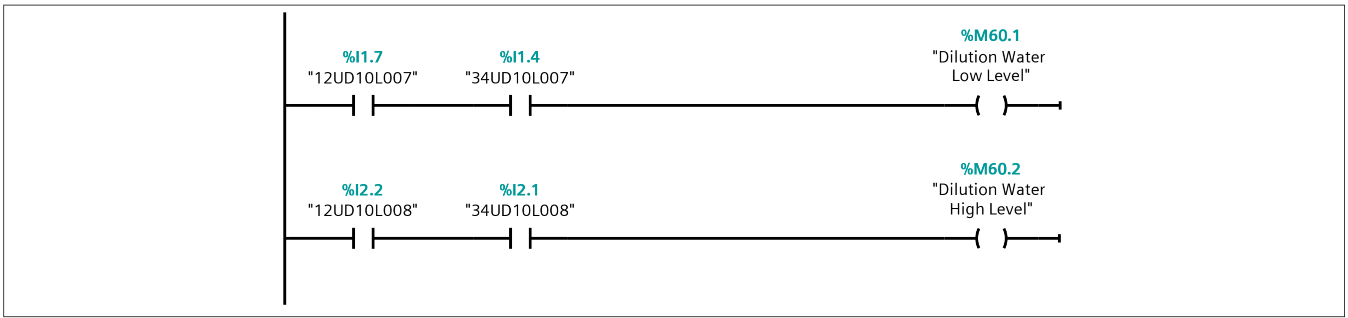
Network 14: Neutralisation Basin PH



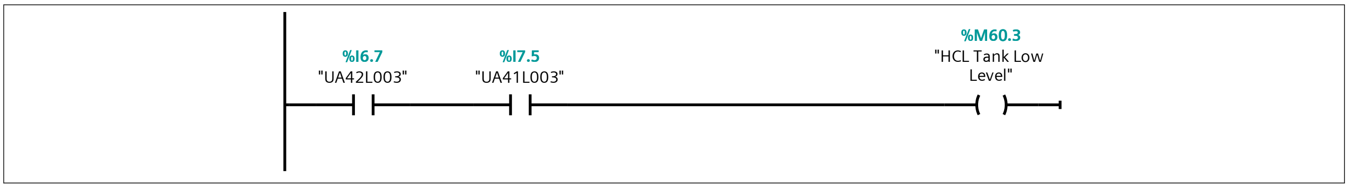
Network 15: Raw Water Low Level



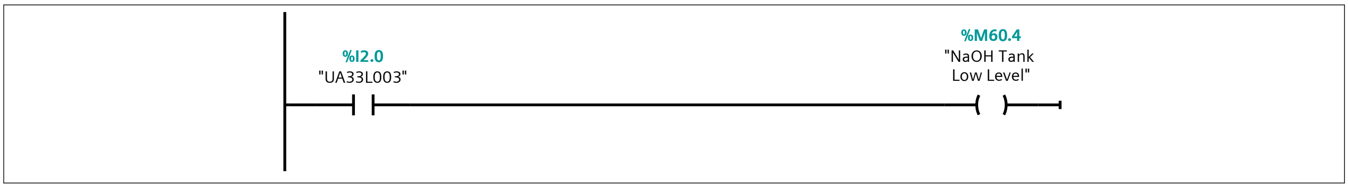
Network 16: Dilution Water Level



Network 17: HCl Tank Low Level

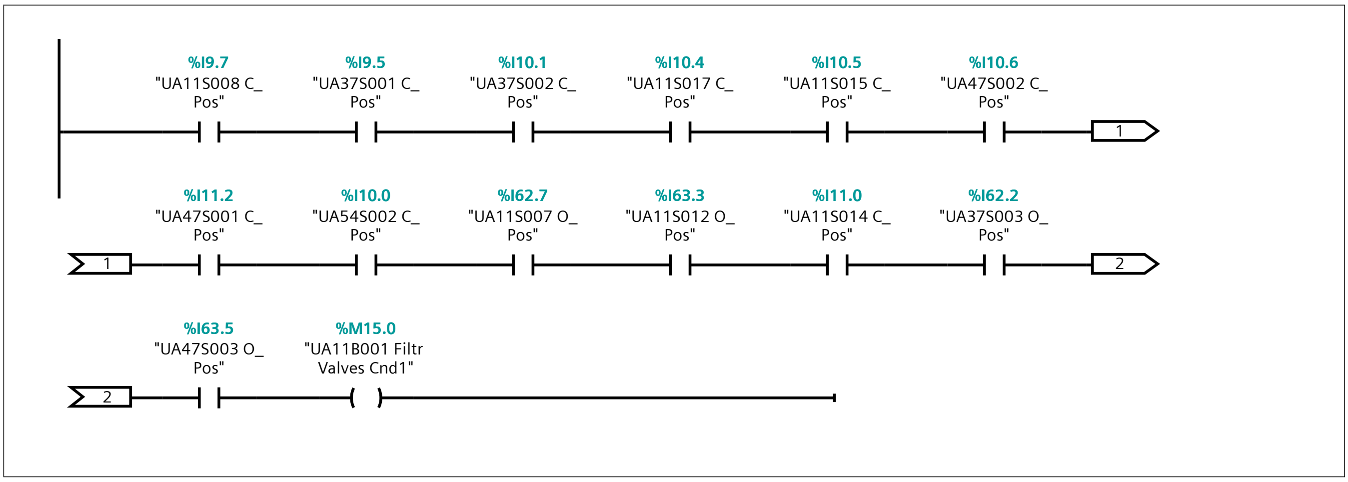


Network 18: NaOH Tank Low Level



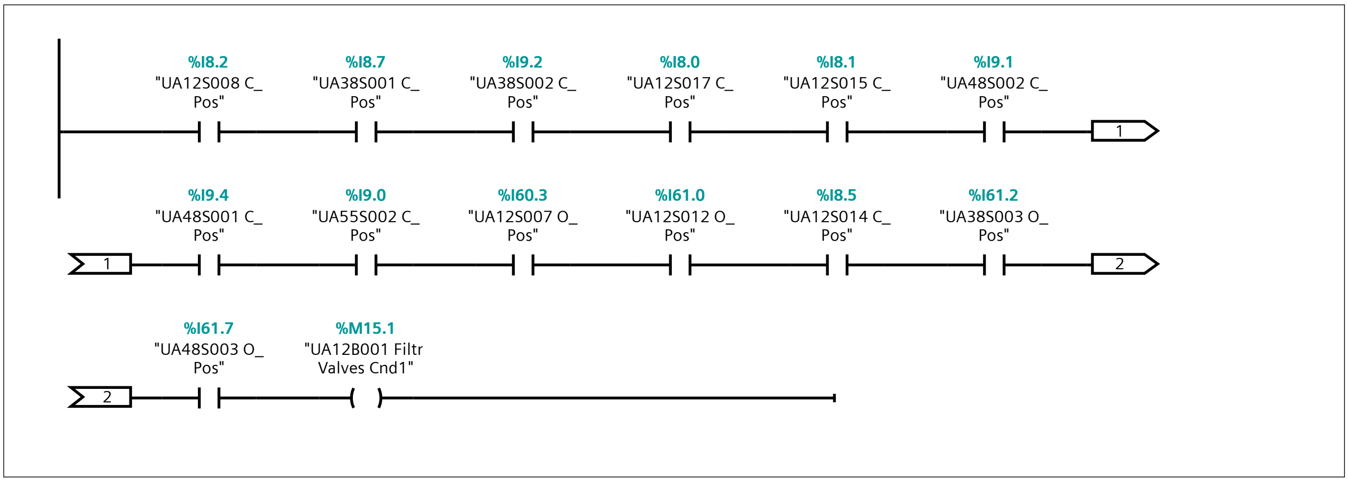
Network 19: UA11B001 Pre-Service Valves Conditions

Network 19: UA11B001 Pre-Service Valves Conditions

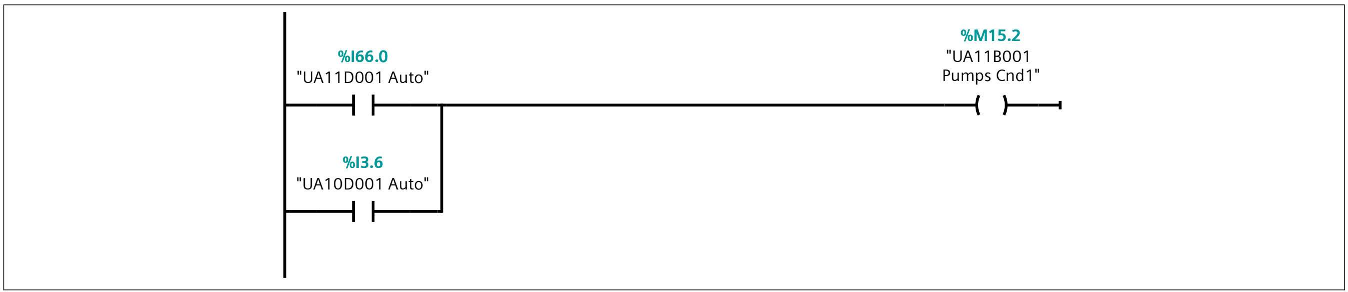


Network 20: UA12B001 Pre-Service Valves Conditions

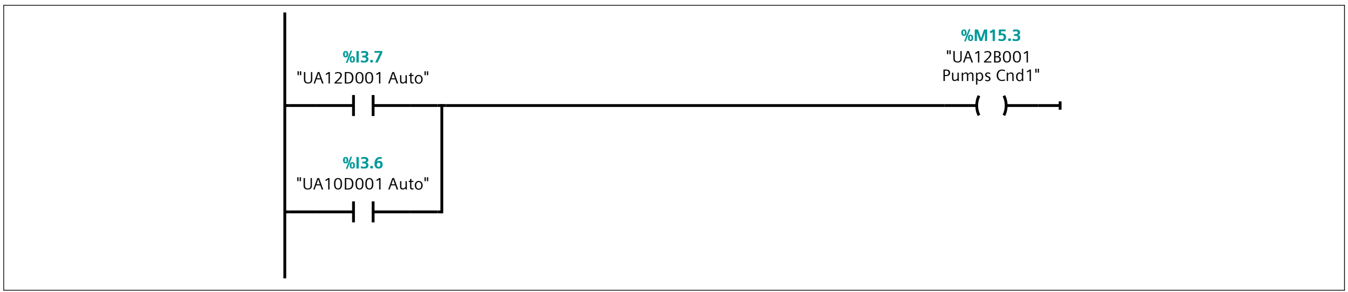
Network 20: UA12B001 Pre-Service Valves Conditions



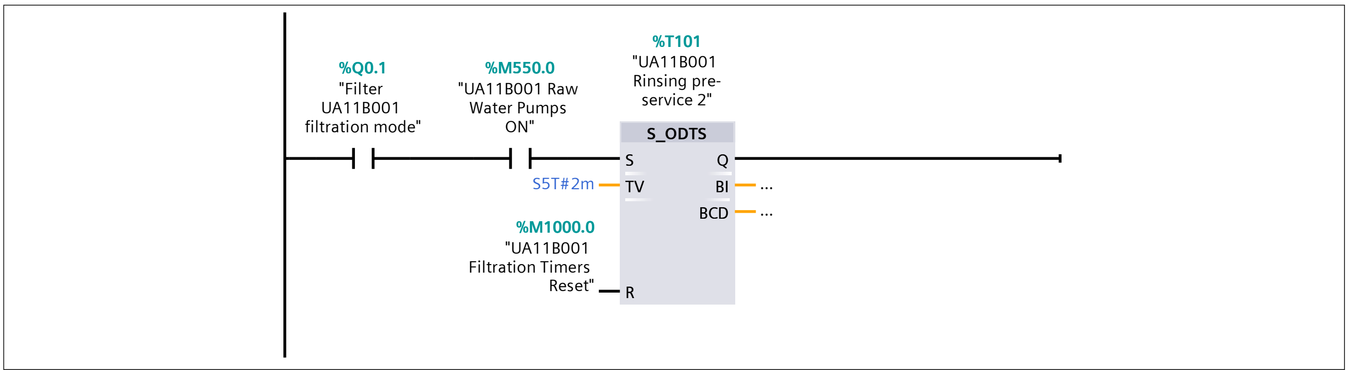
Network 21: Pumps Conditions at Filtration Start for UA11B001



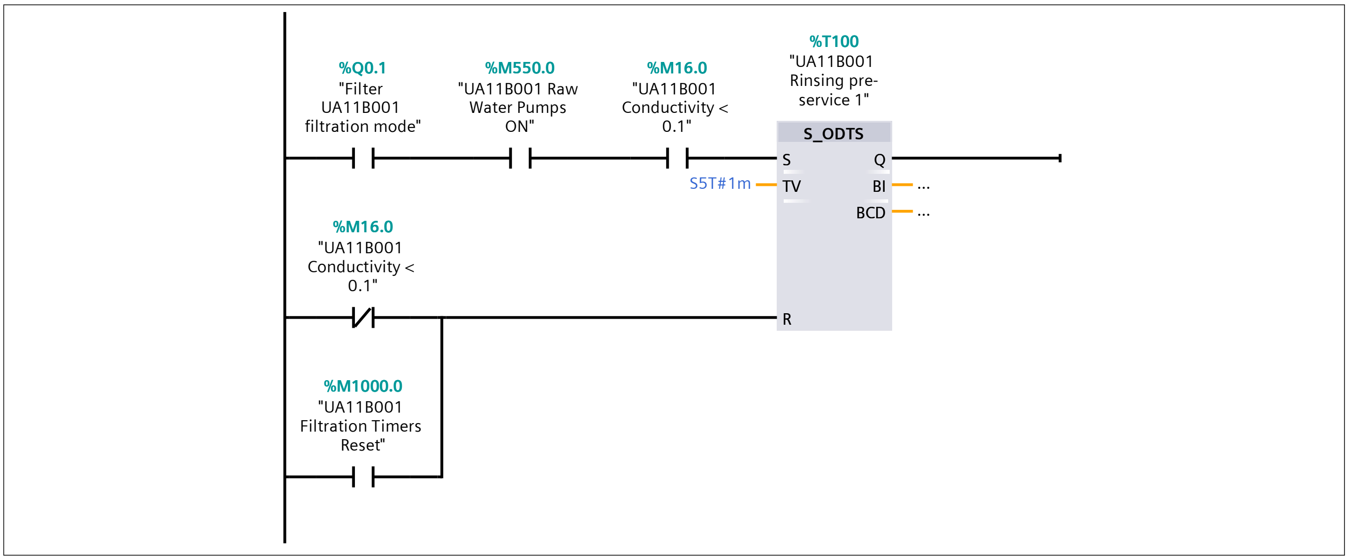
Network 22: Pumps Conditions at Filtration Start for UA12B001



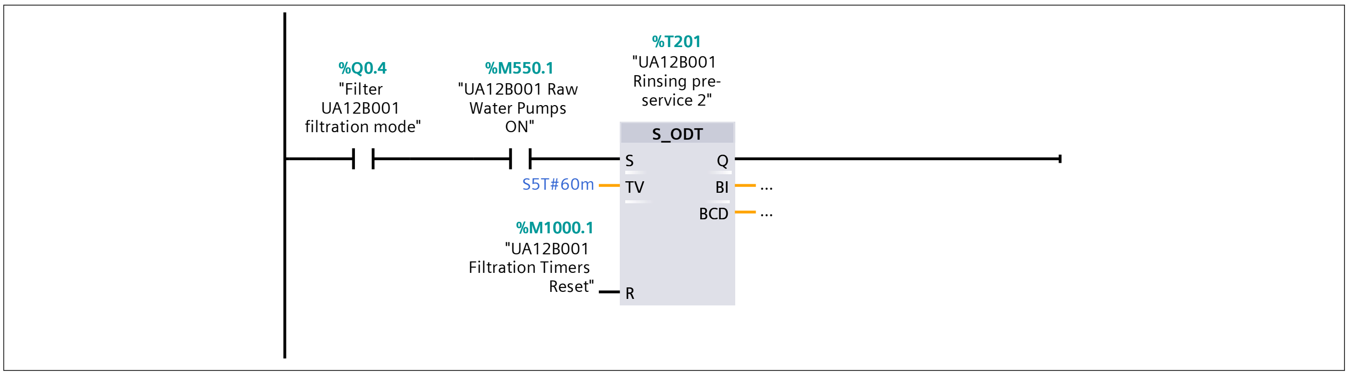
Network 23: UA11B001 Pre-service Time



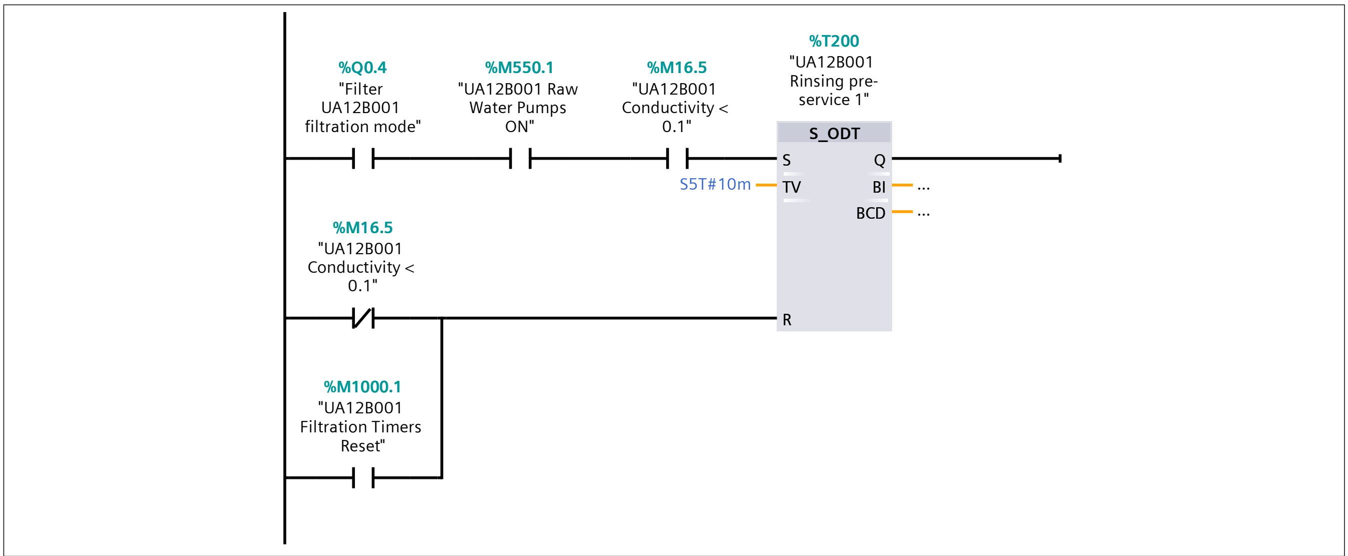
Network 24: UA11B001 Pre-service Time Conductivity < 0.1



Network 25: UA12B001 Pre-service Time

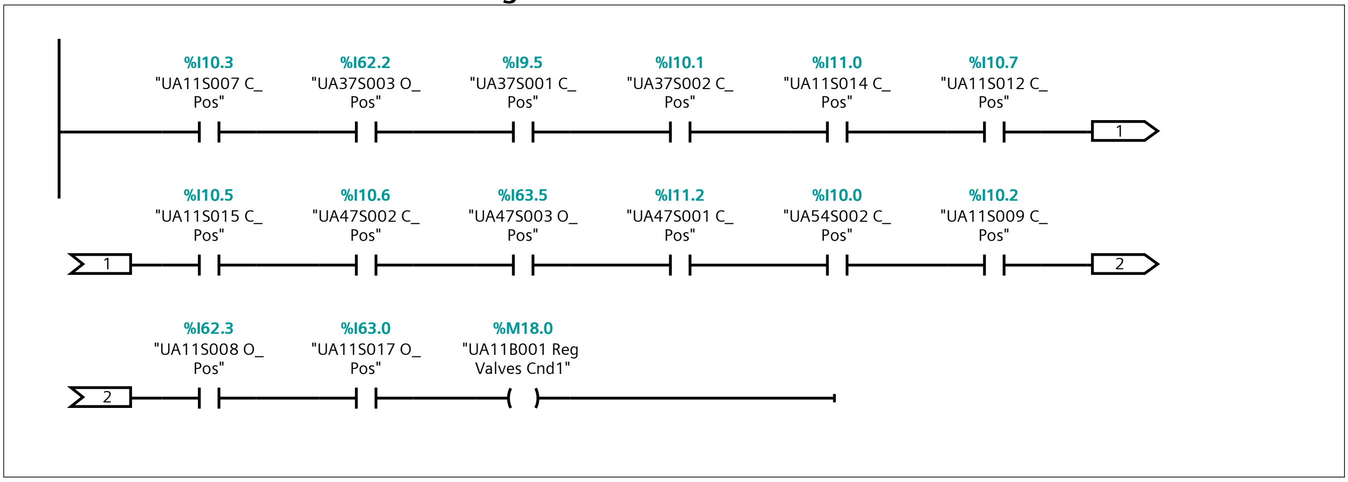


Network 26: UA12B001 Pre-service Time Conductivity < 0.1



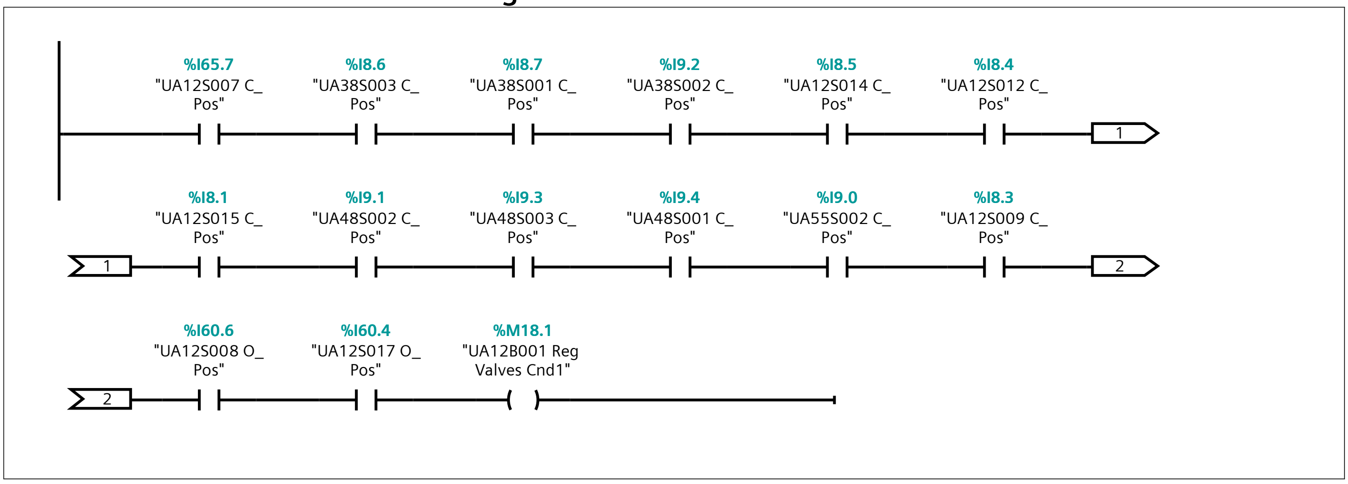
Network 27: Valves Conditions at Regeneration Start for UA11B001

Network 27: Valves Conditions at Regeneration Start for UA11B001

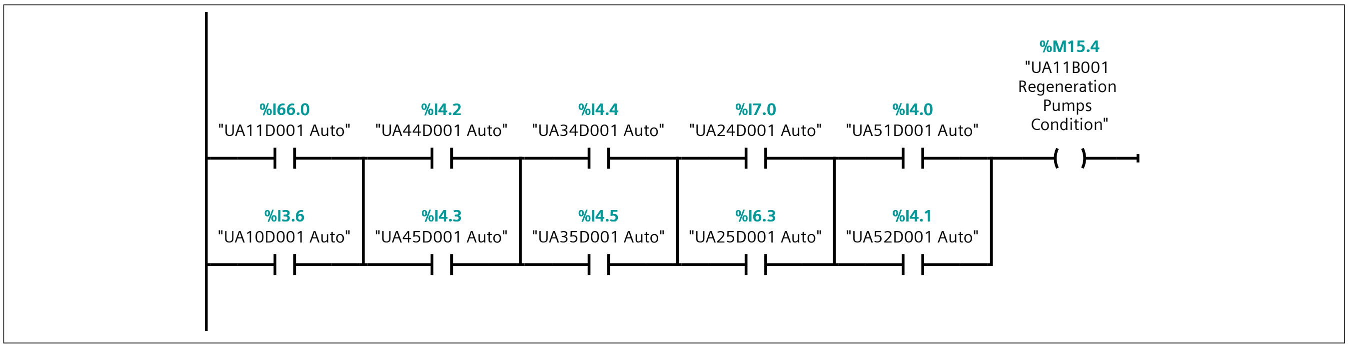


Network 28: Valves Conditions at Regeneration Start for UA12B001

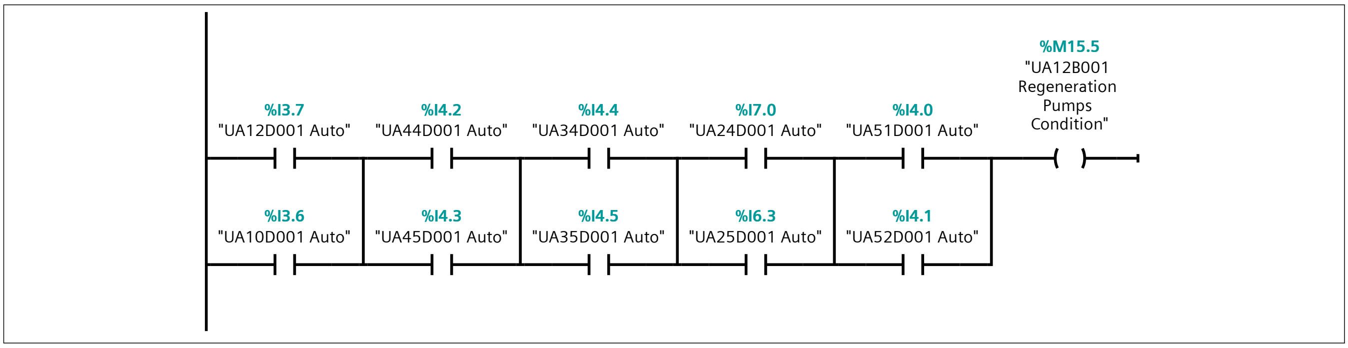
Network 28: Valves Conditions at Regeneration Start for UA12B001



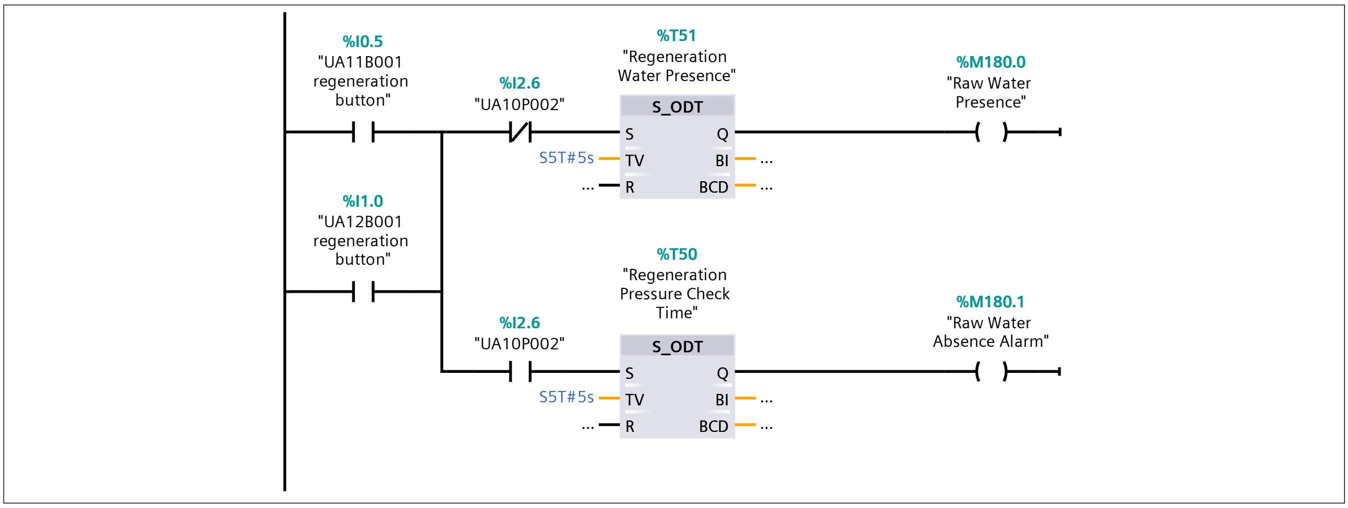
Network 29: UA11B001 Regeneration Pumps Condition



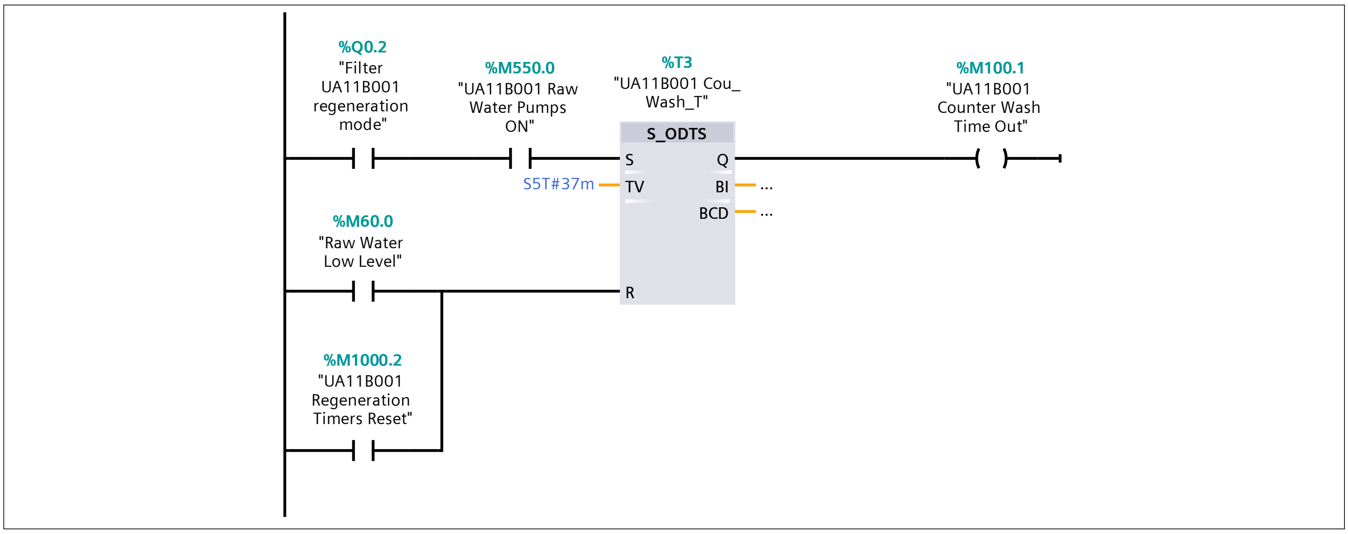
Network 30: UA12B001 Regeneration Pumps Condition



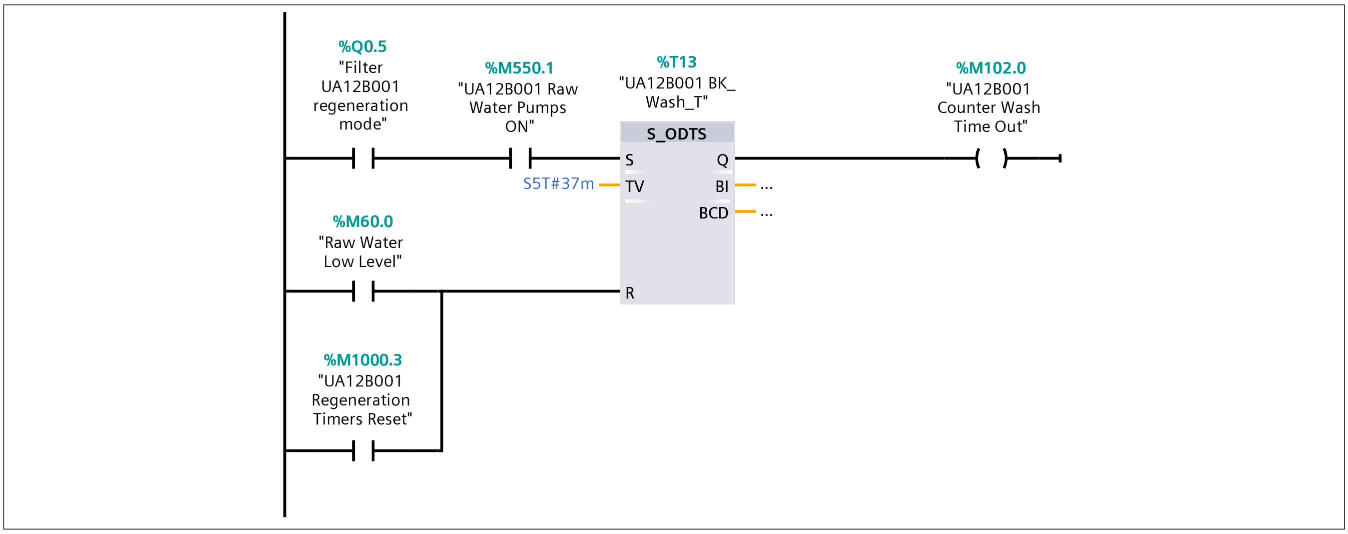
Network 31: Water Presence For Regeneration UA11B001 and UA12B001



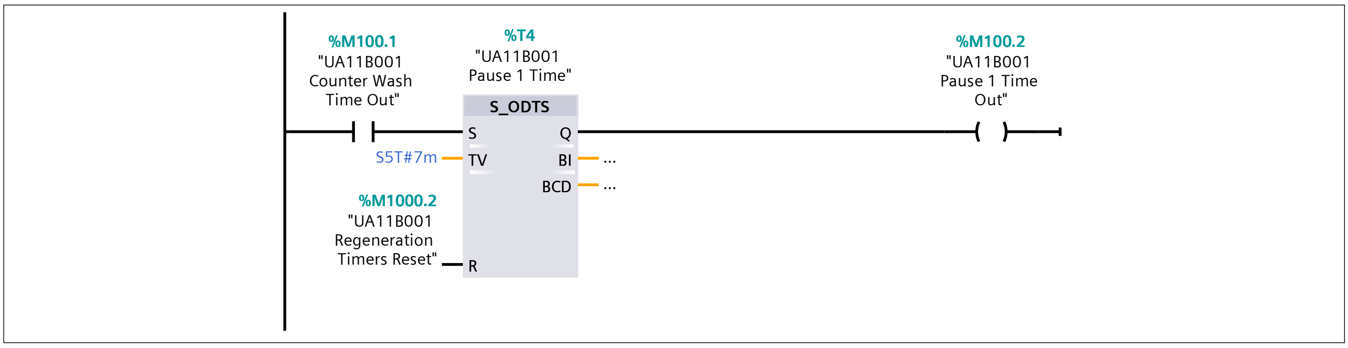
Network 32: UA11B001Counter Current Wash Time



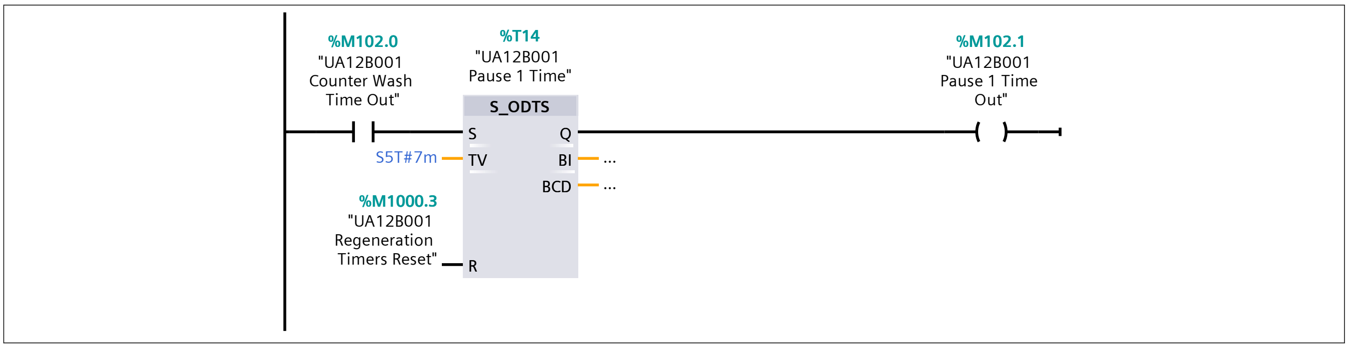
Network 33: UA12B001Counter Current Wash Time



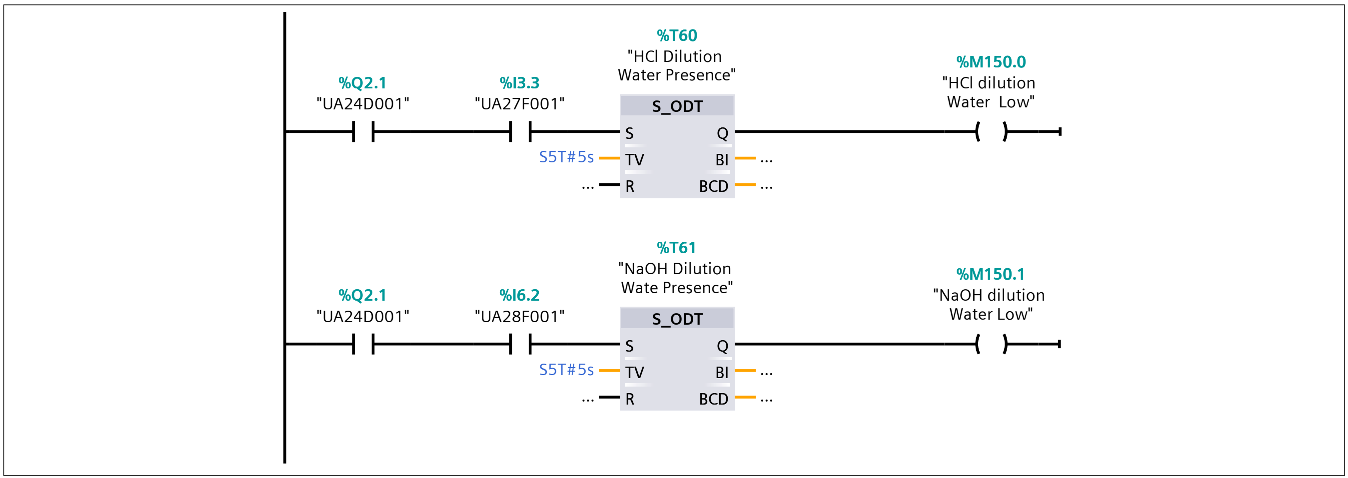
Network 34: UA11B001Pause 1 Time



Network 35: UA12B001Pause 1 Time

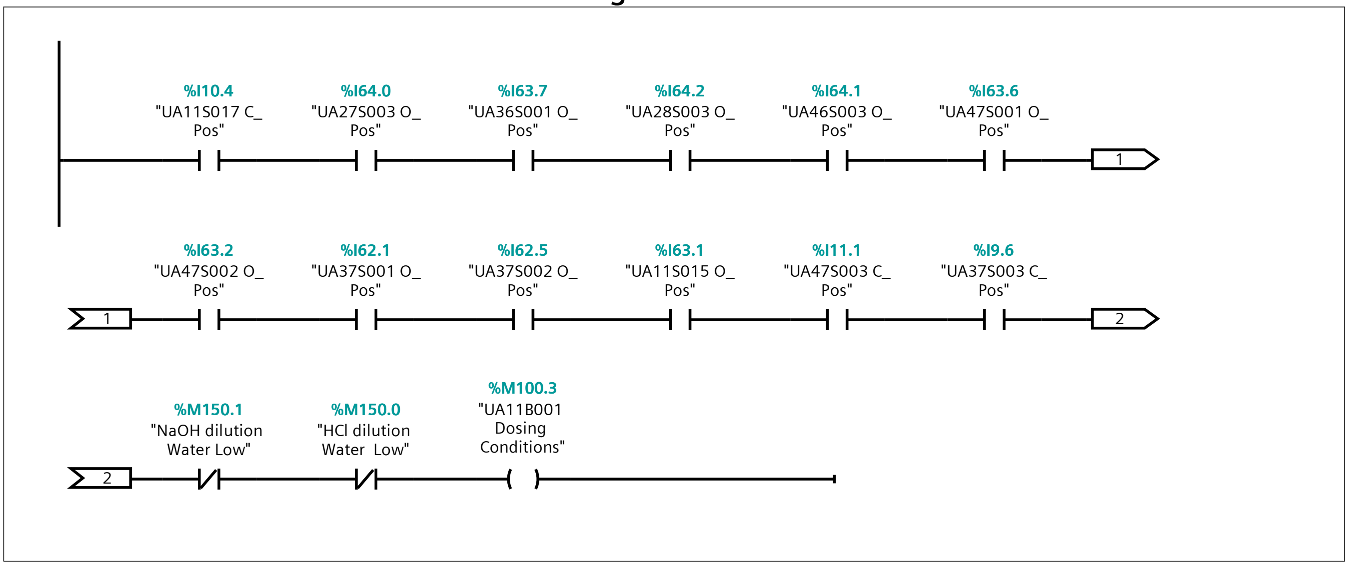


Network 36: NaOH and HCl Dilution Water Presence



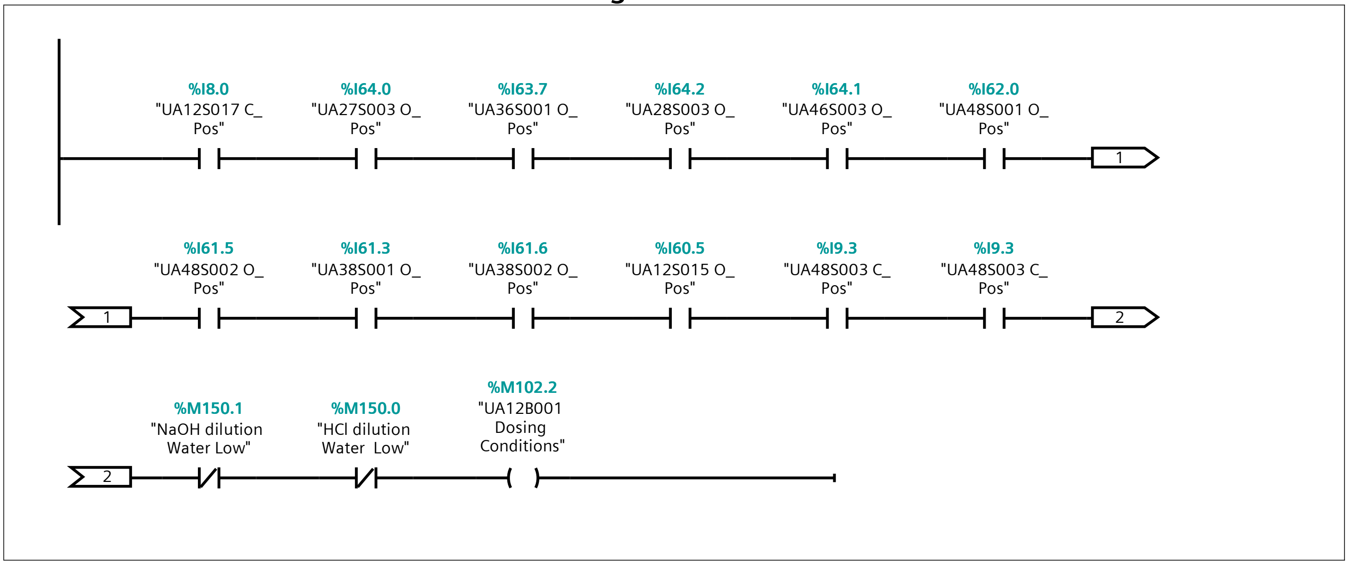
Network 37: UA11B001 HCl and NaOH Dosing Conditions

Network 37: UA11B001 HCl and NaOH Dosing Conditions

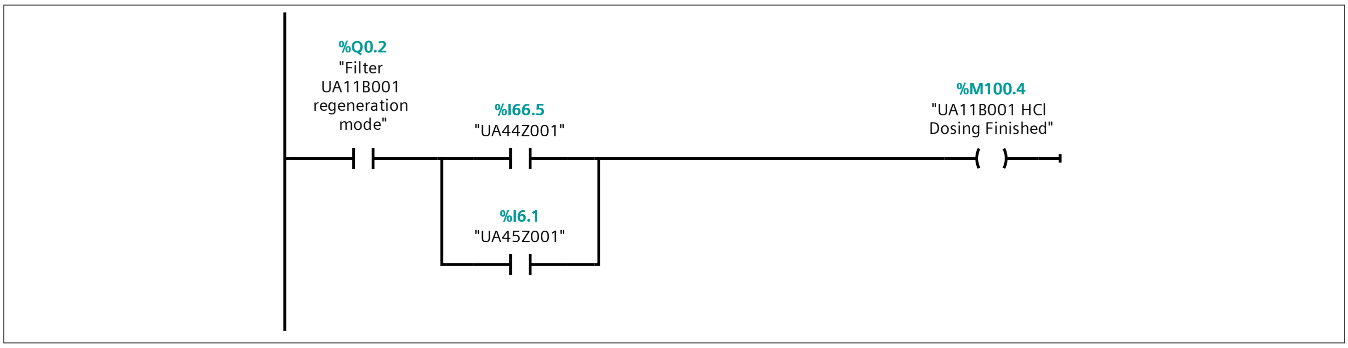


Network 38: UA12B001 HCl and NaOH Dosing Conditions

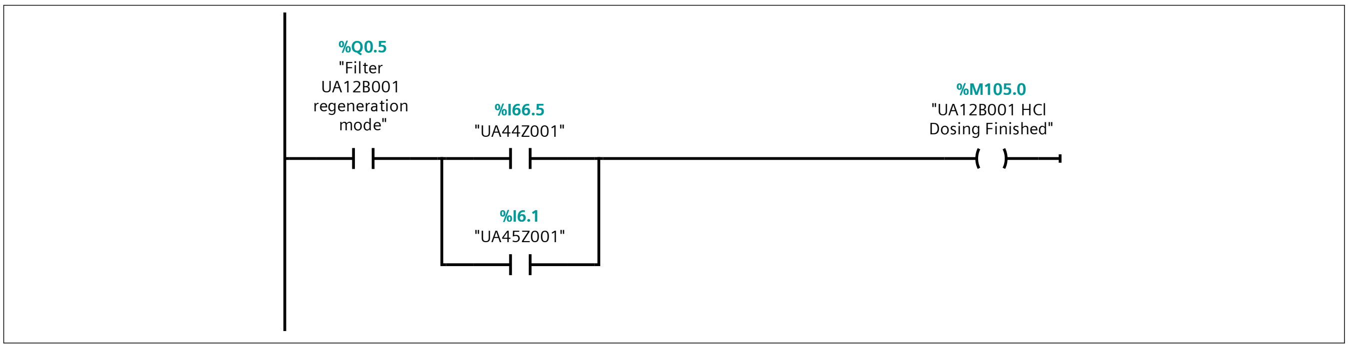
Network 38: UA12B001 HCl and NaOH Dosing Conditions



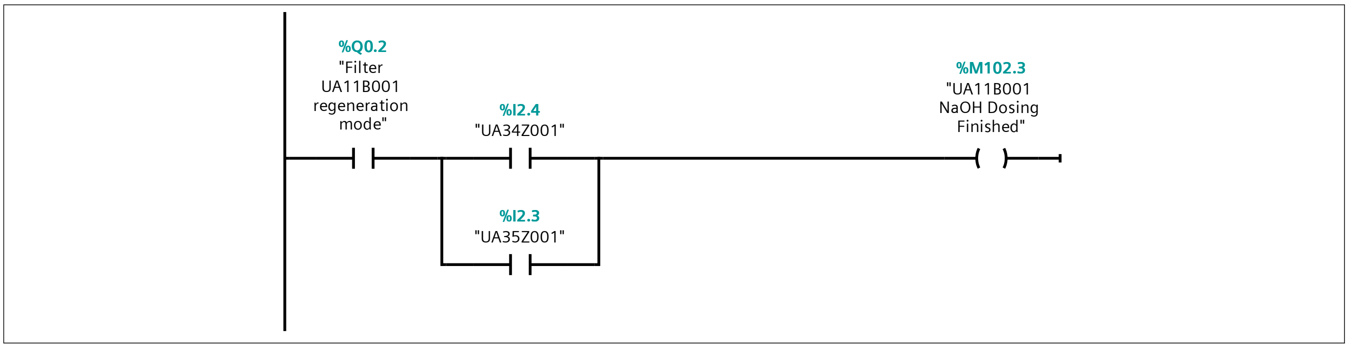
Network 39: UA11B001 HCL Dosing



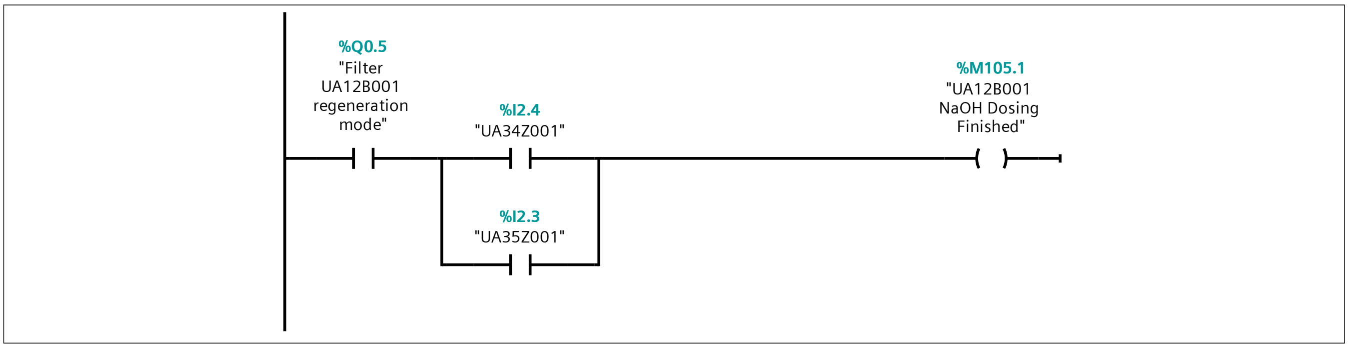
Network 40: UA12B001 HCL Dosing



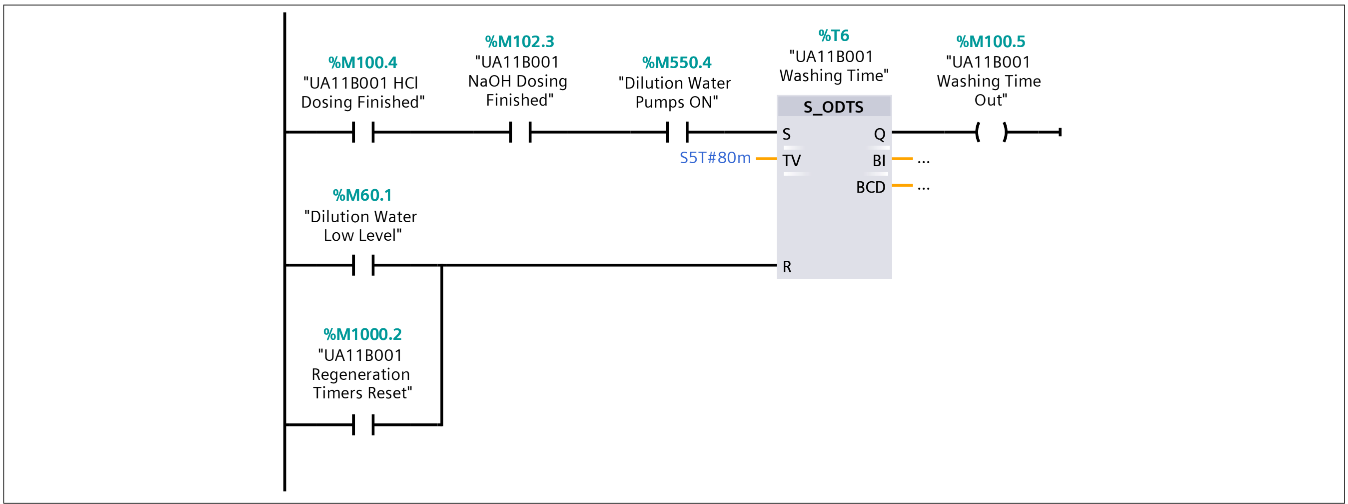
Network 41: UA11B001 NaOH Dosing



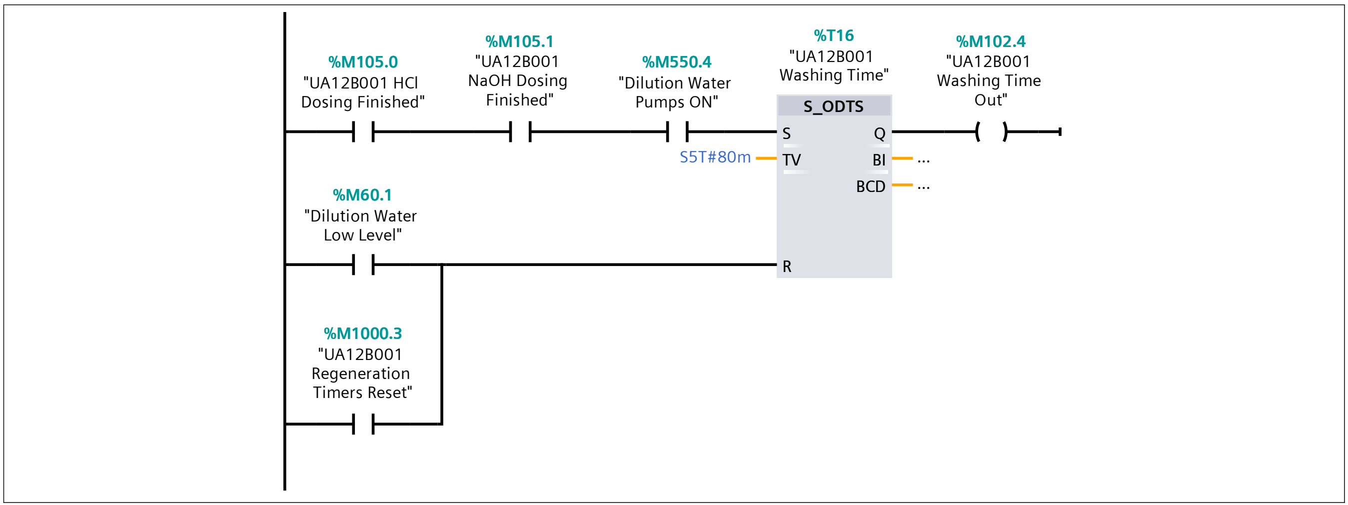
Network 42: UA12B001 NaOH Dosing



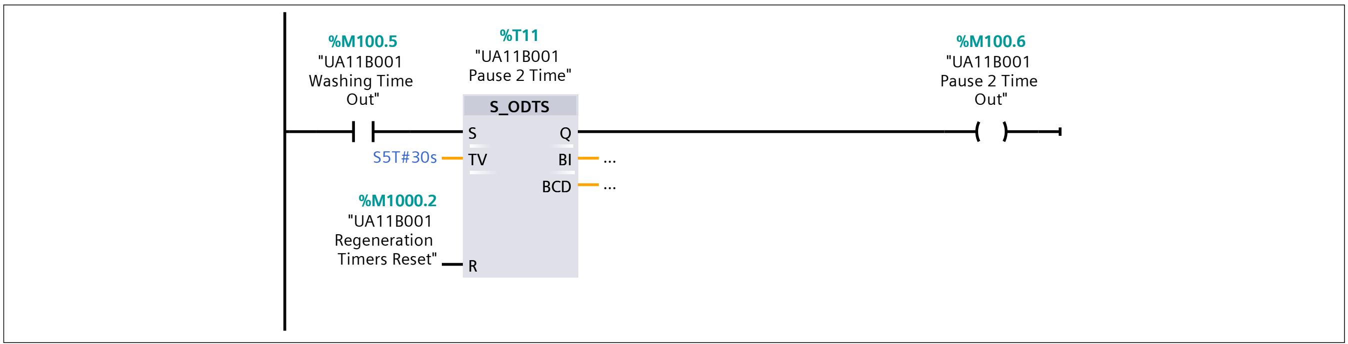
Network 43: UA11B001 HCL and NaOH Washing Time



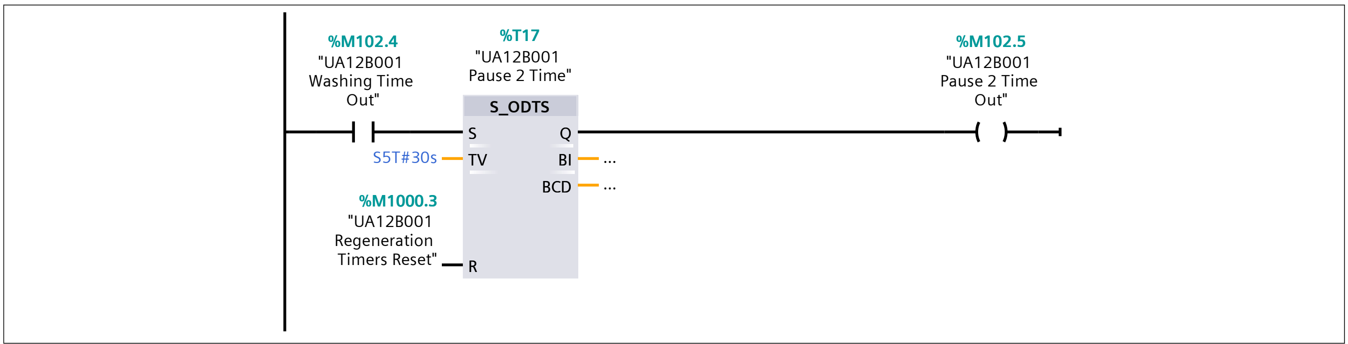
Network 44: UA12B001 HCL and NaOH Washing Time



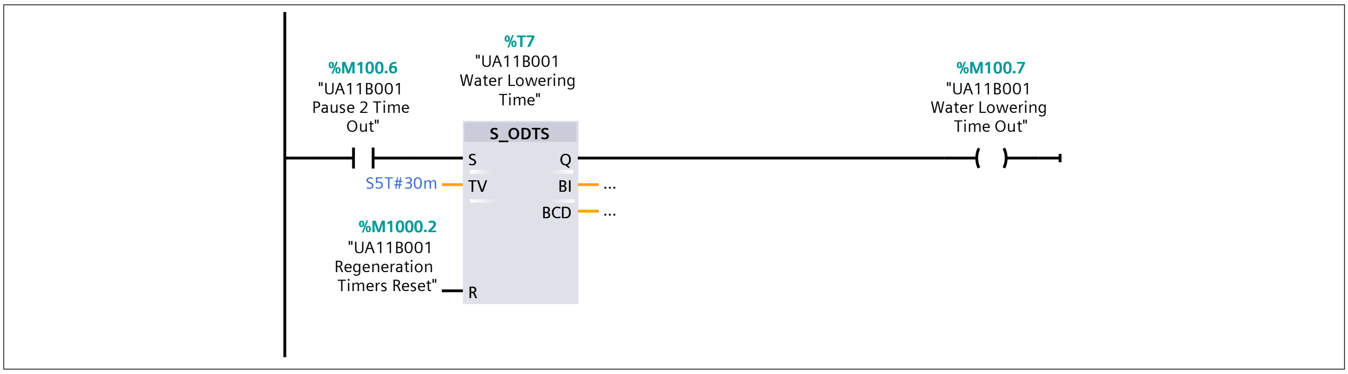
Network 45: UA11B001 Pause 2 Time



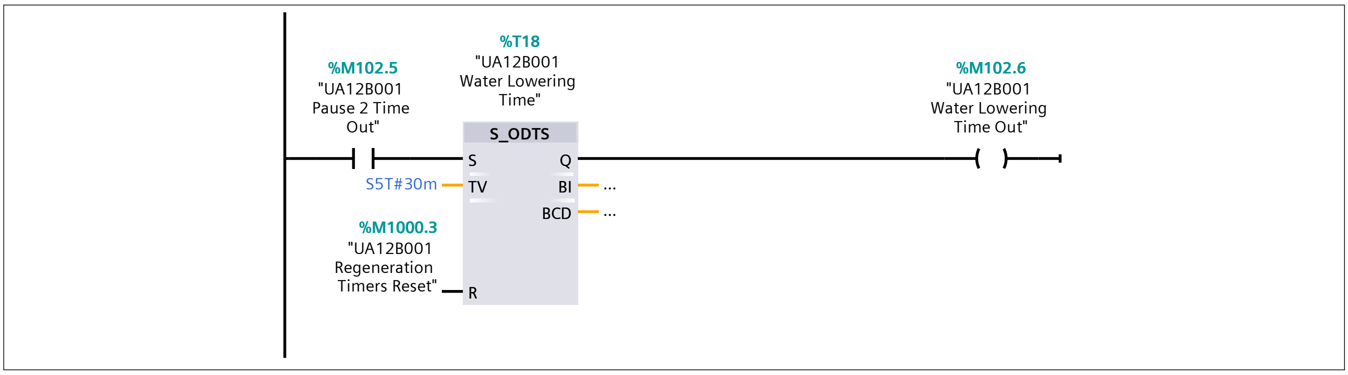
Network 46: UA12B001 Pause 2 Time



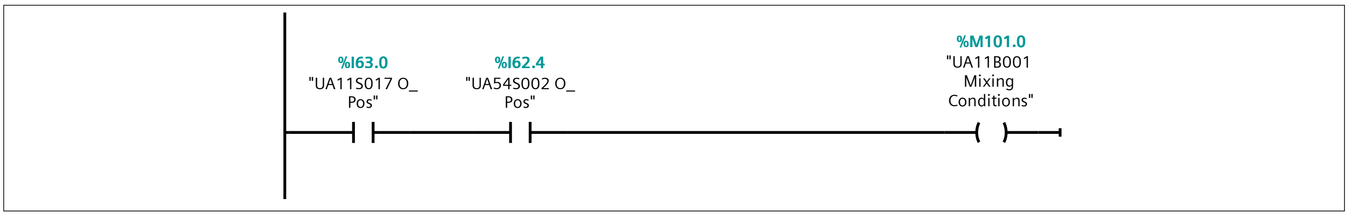
Network 47: UA11B001 Water Level Lowering Time



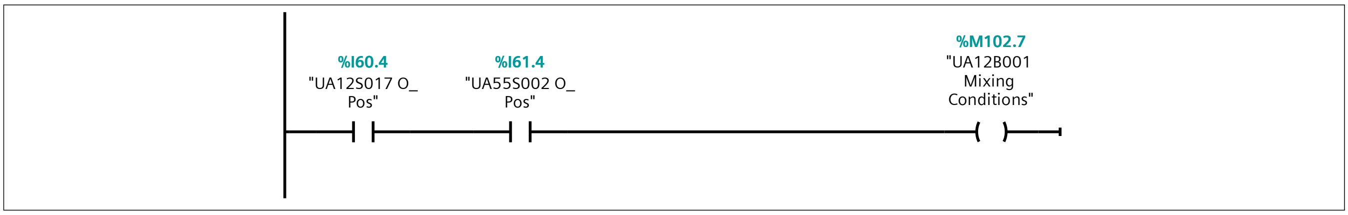
Network 48: UA12B001 Water Level Lowering Time



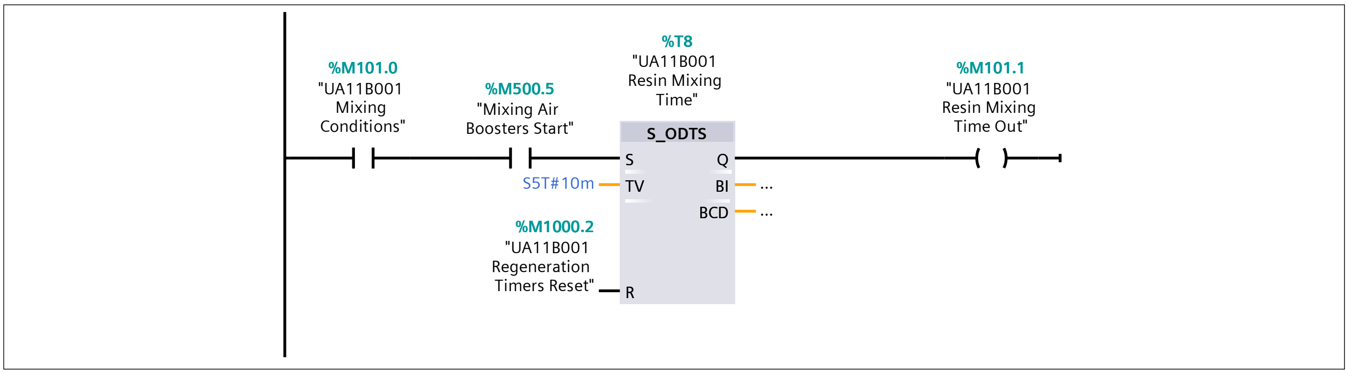
Network 49: UA11B001 Resin Mixing Conditions



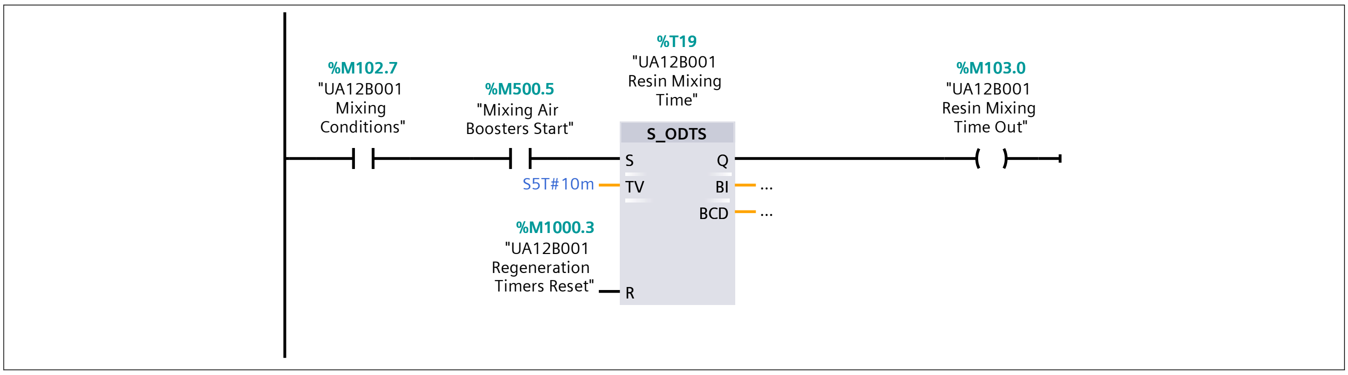
Network 50: UA12B001 Resin Mixing Conditions



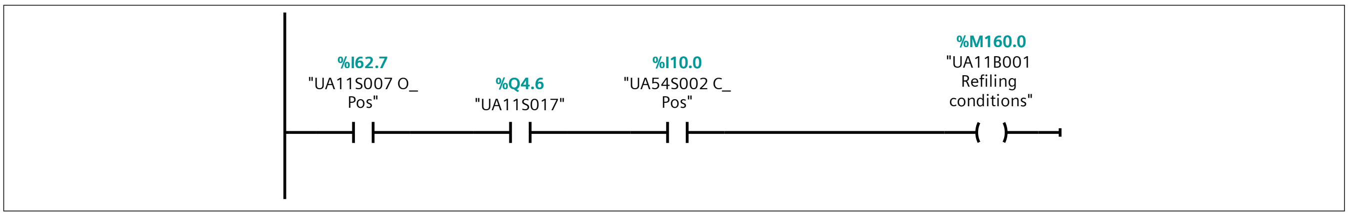
Network 51: UA11B001 Resin Mixing Time



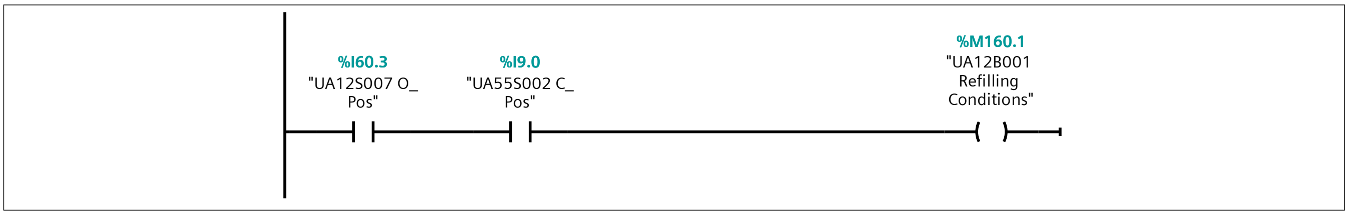
Network 52: UA12B001 Resin Mixing Time



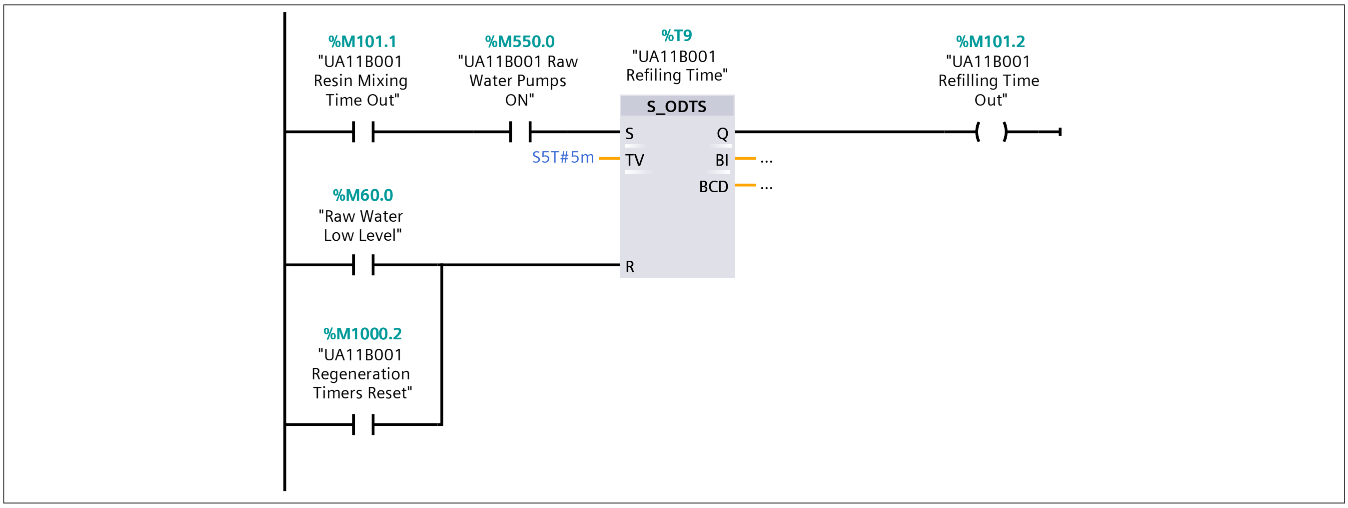
Network 53: UA11B001 Refilling Conditions



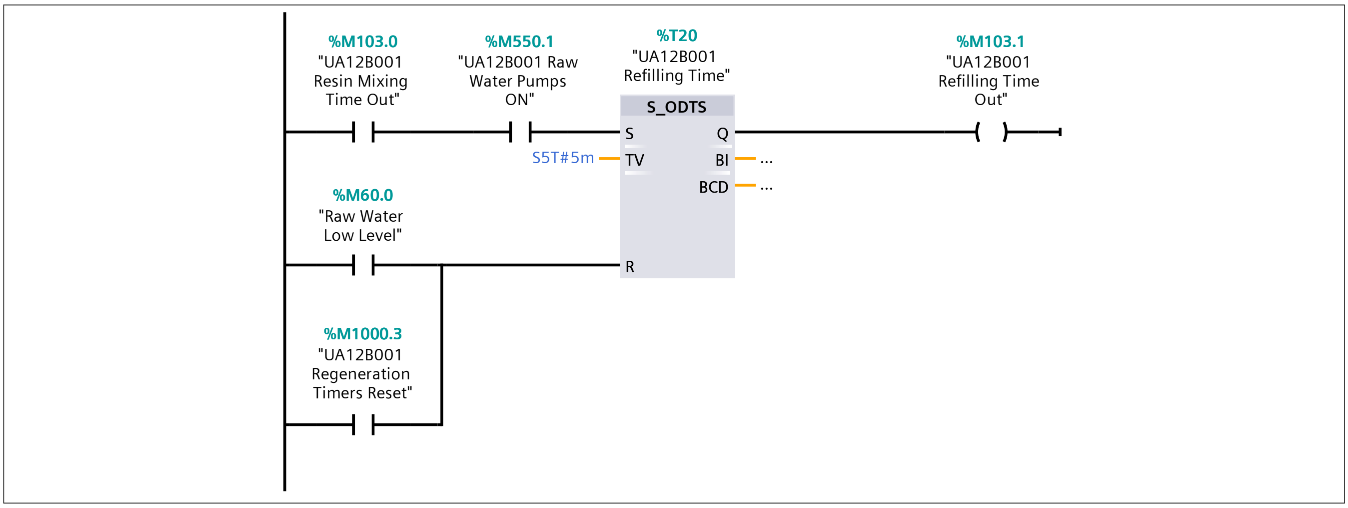
Network 54: UA12B001 Refilling Conditions



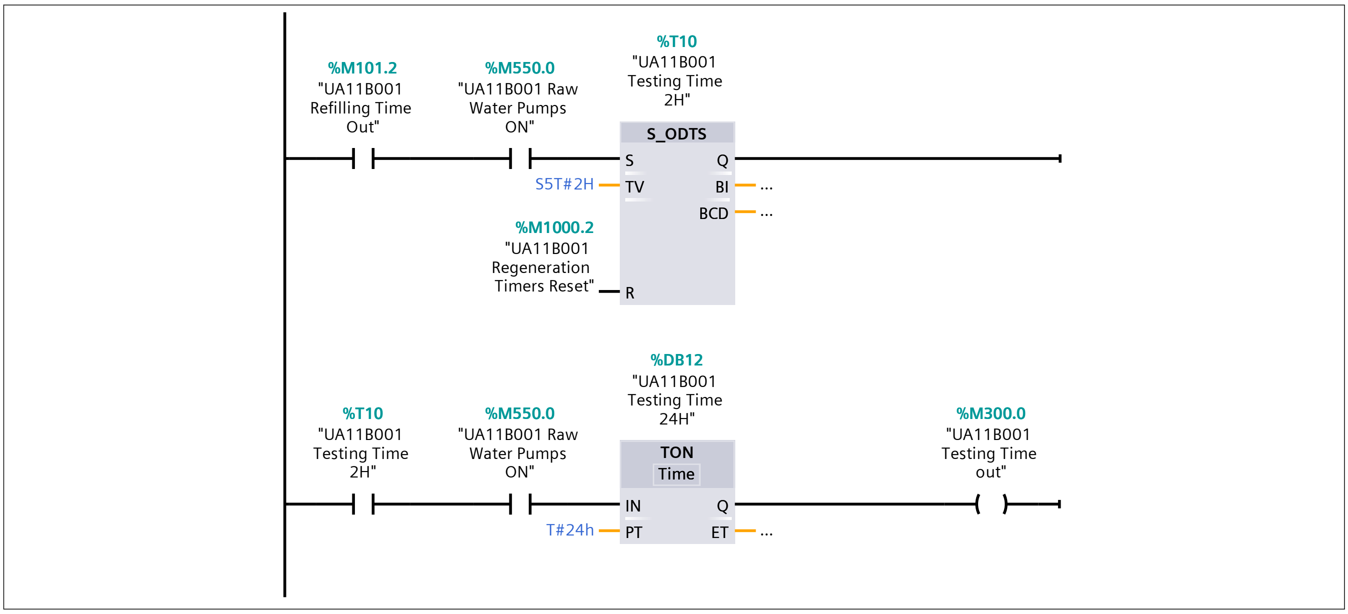
Network 55: UA11B001 Refiling Time



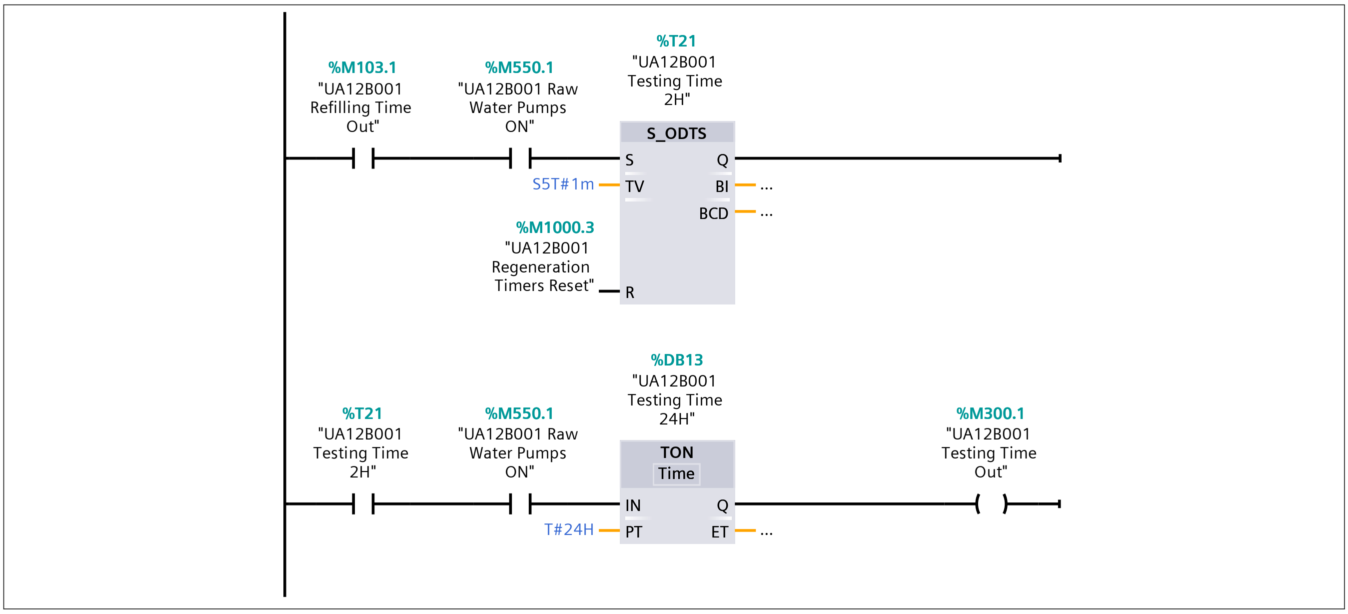
Network 56: UA12B001 Refiling Time



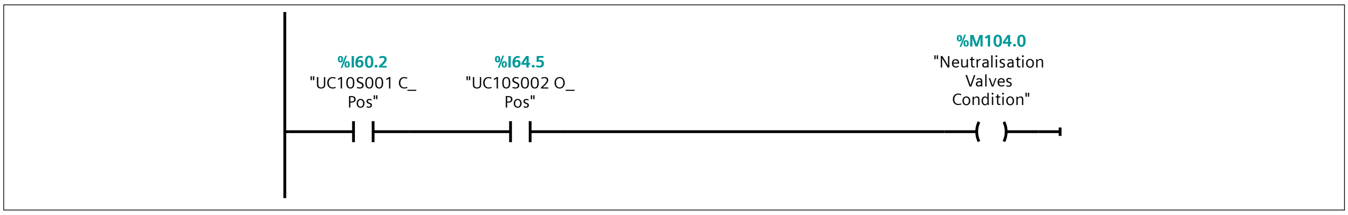
Network 57: UA11B001 Testing Time



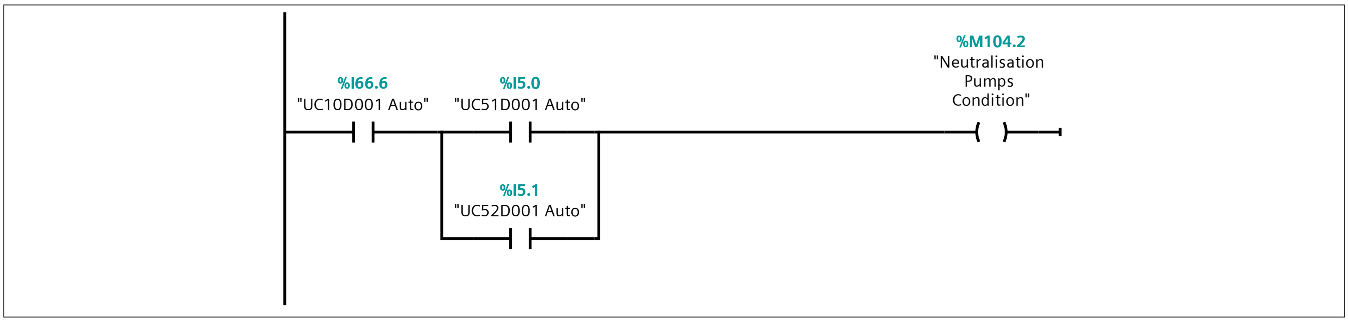
Network 58: UA12B001 Testing Time



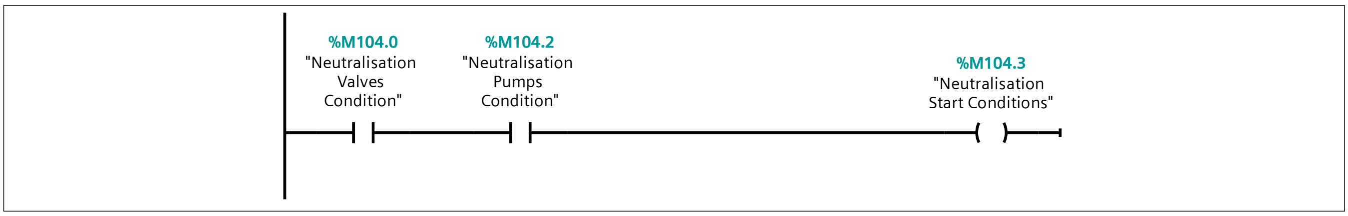
Network 59: Neutralisation Valves Condition



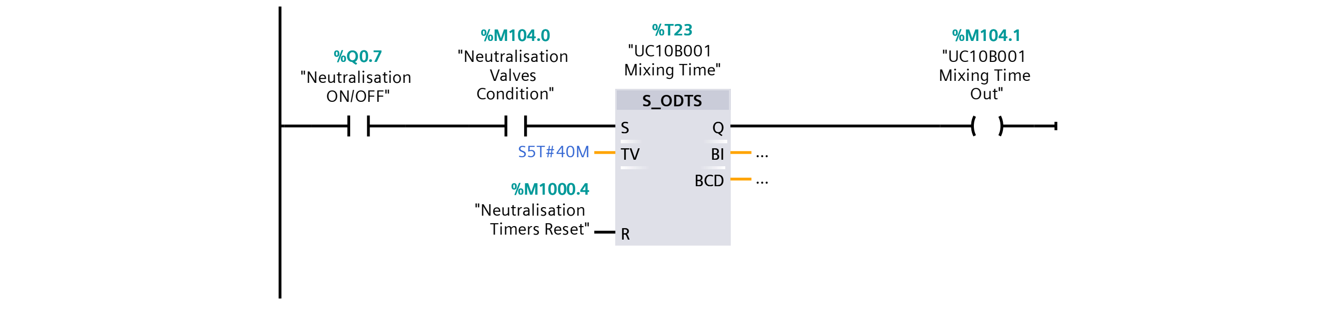
Network 60: Neutralisation Pump/Air Booster



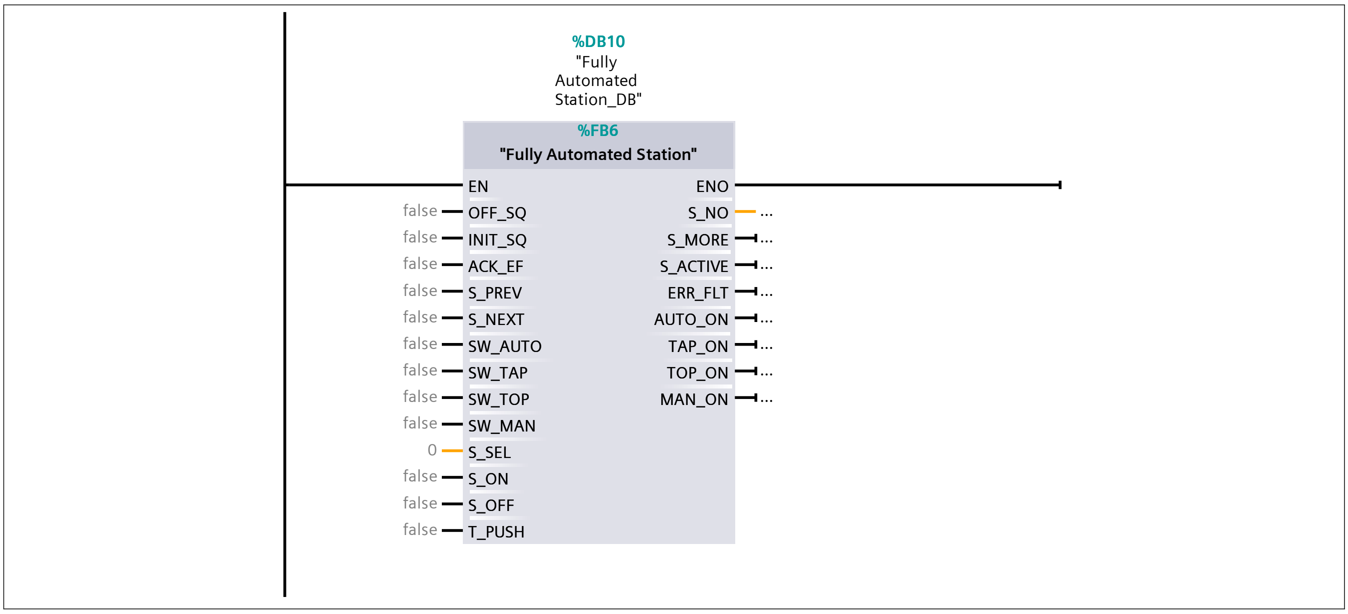
Network 61: Neutralisation Start Condition



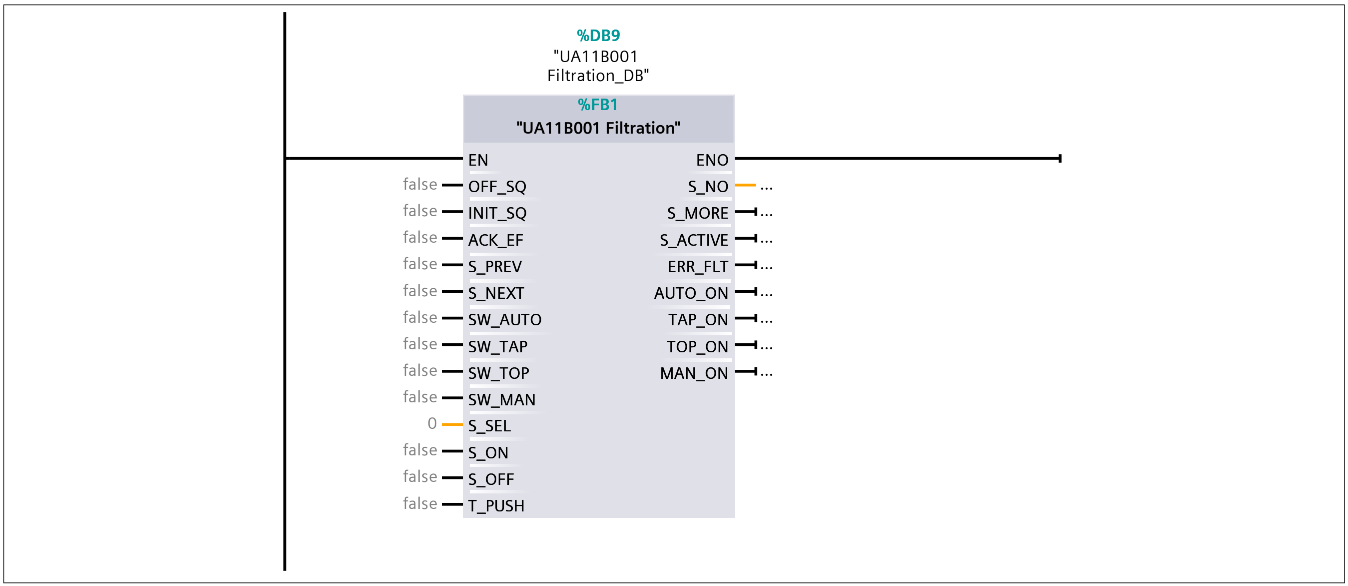
Network 62: Neutralisation Pit Mixing Time



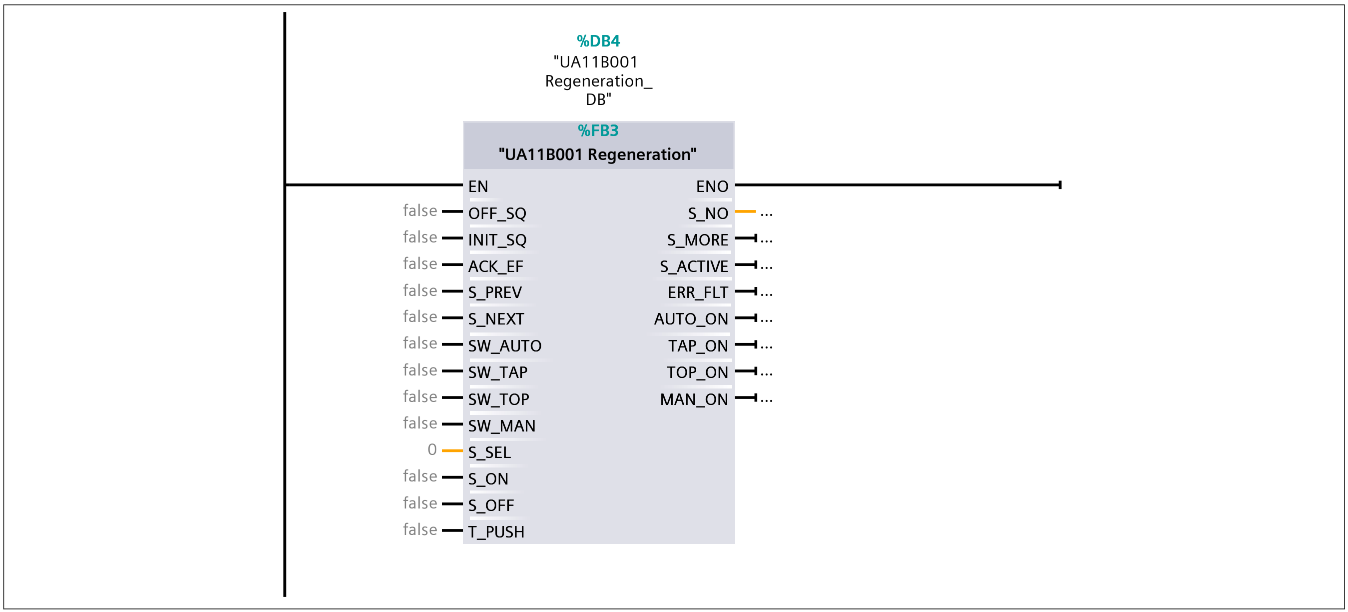
Network 63: Fully Automated Station Function



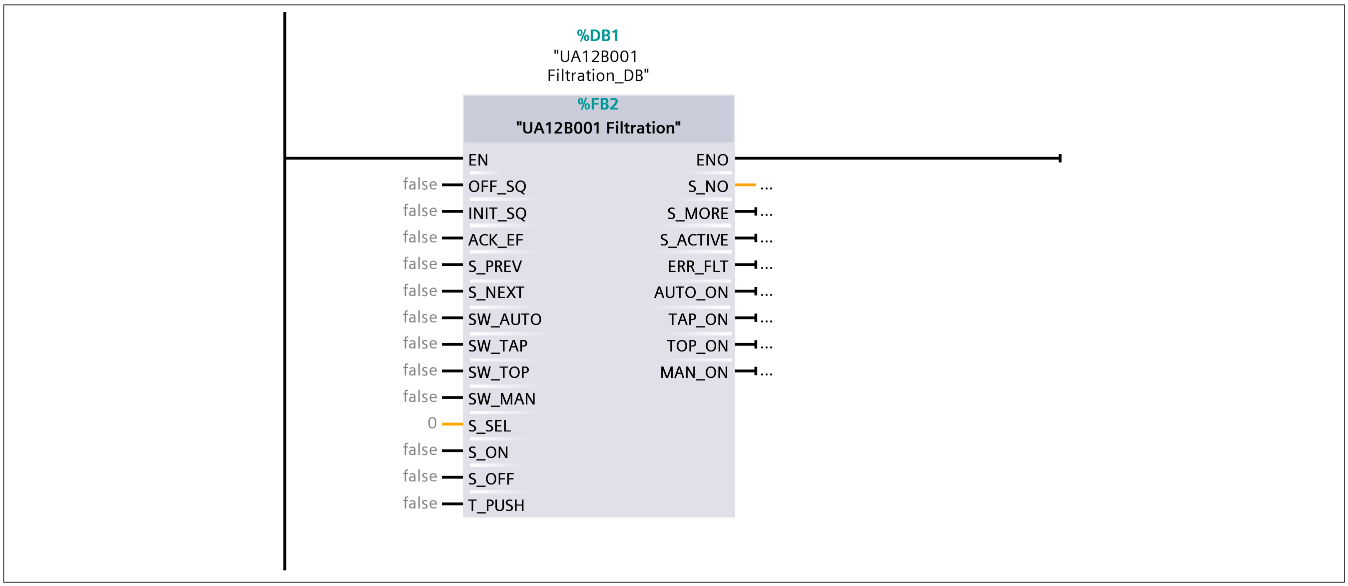
Network 64: UA11B001 Filtration Function



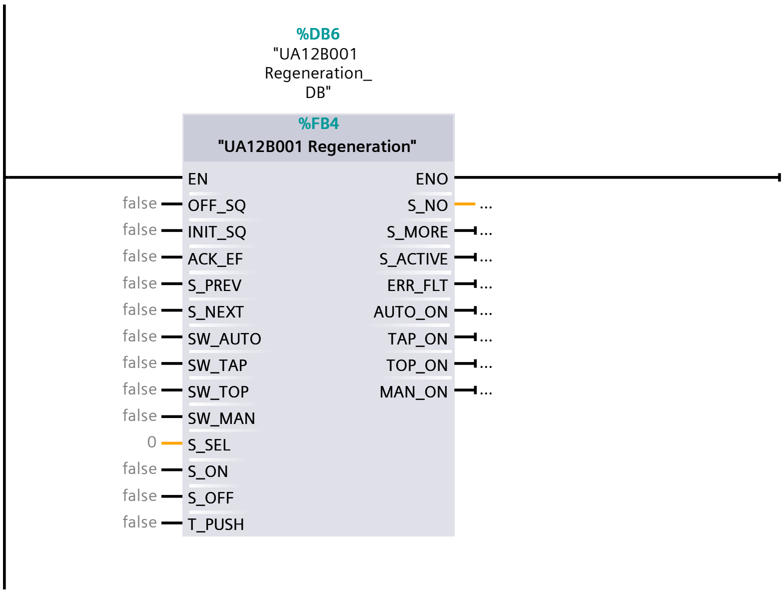
Network 65: UA11B001 Regeneration Function



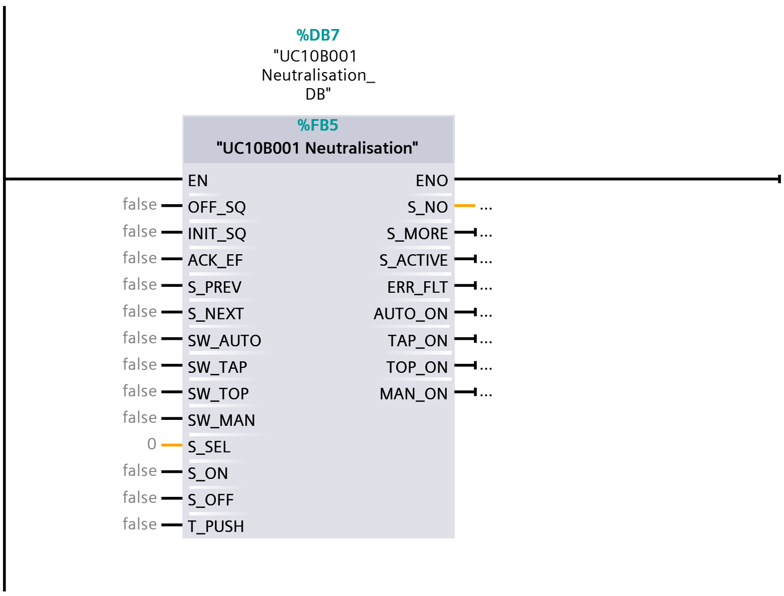
Network 66: UA12B001 Filtration Function



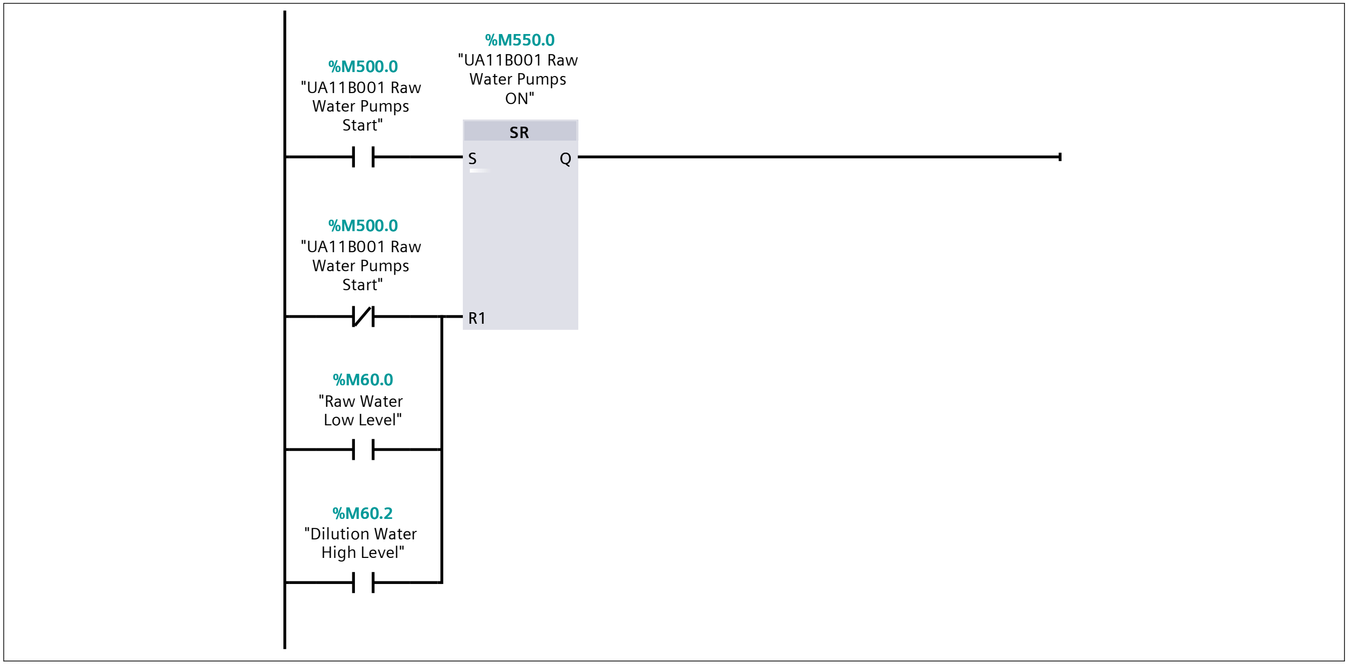
Network 67: UA12B001 Regeneration Function



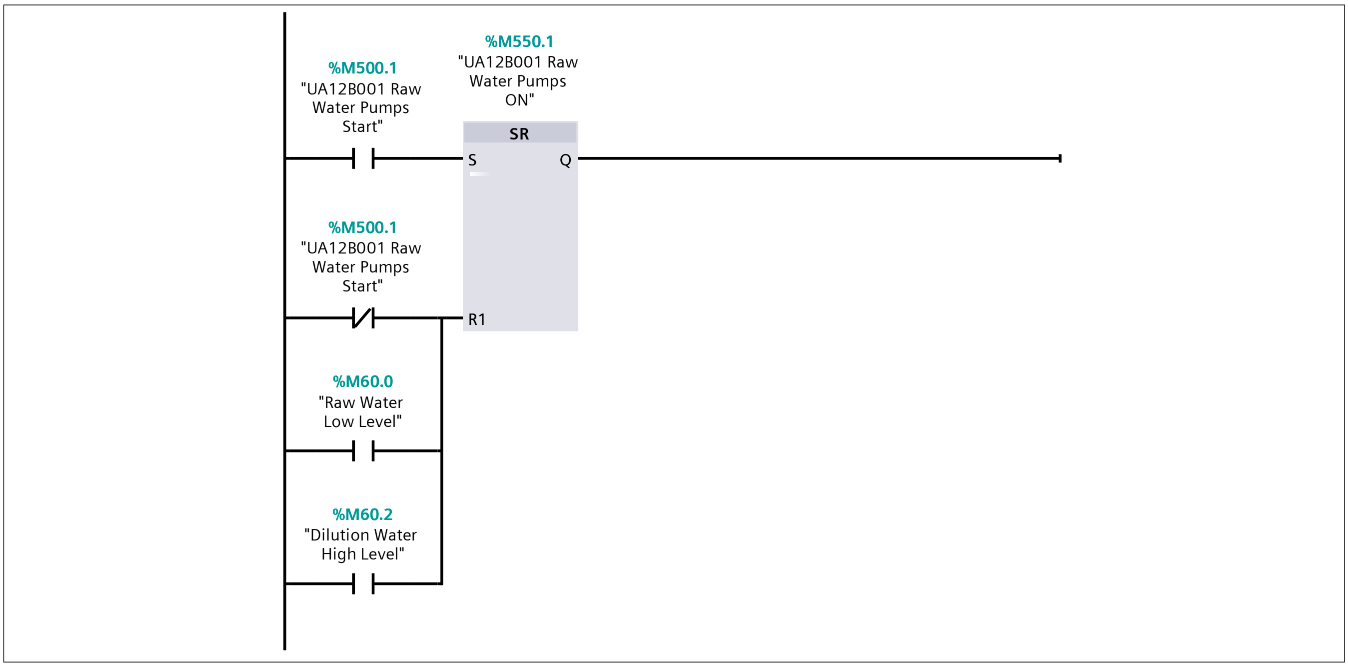
Network 68: Neutralisation Function



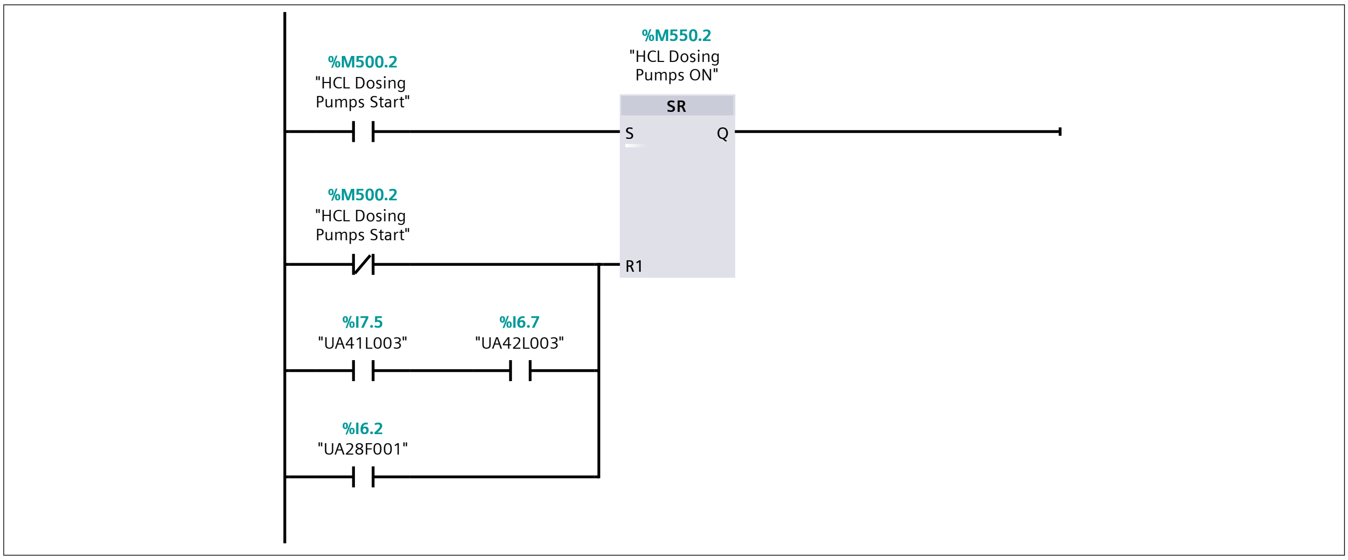
Network 69: UA11B001 Raw Water Pumps ON Condition



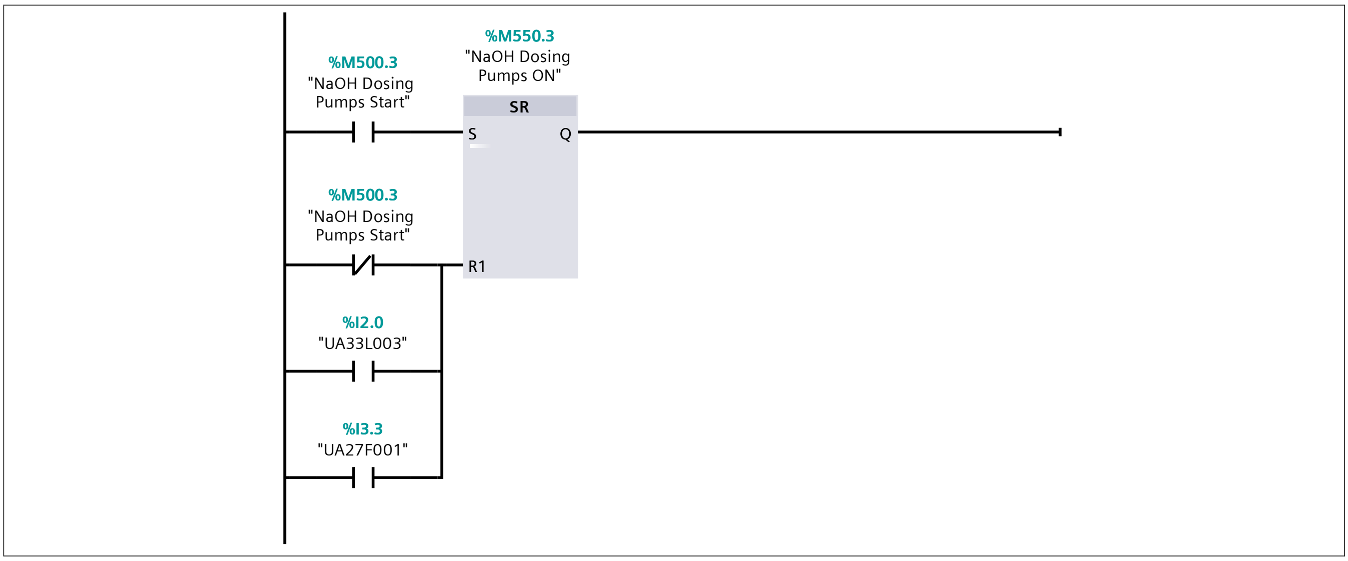
Network 70: UA12B001 Raw Water Pumps ON Condition



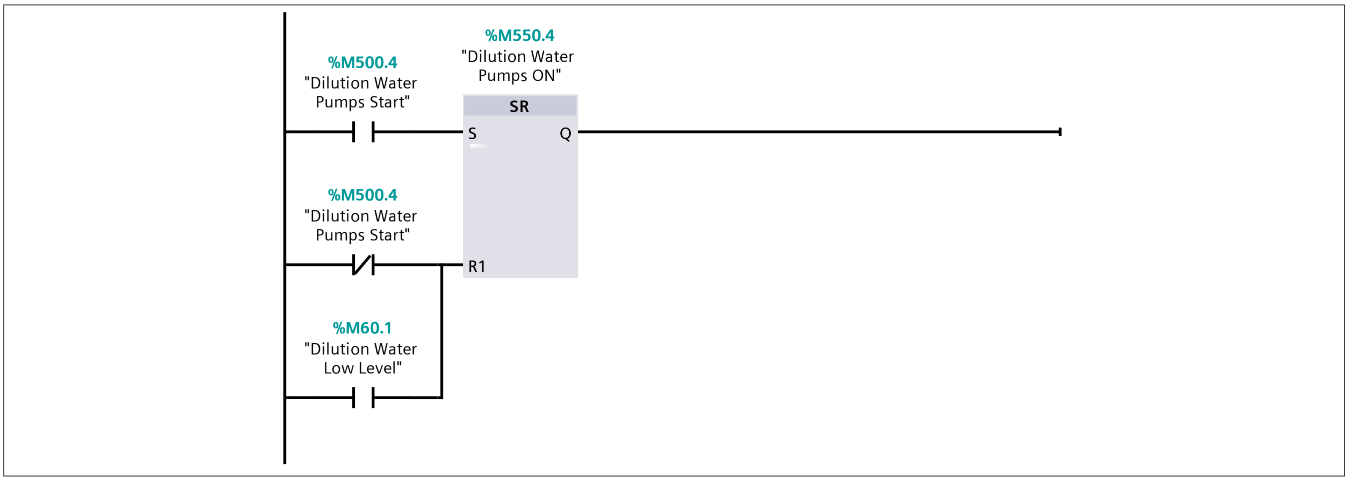
Network 71: HCL Dosing Pumps ON Condition



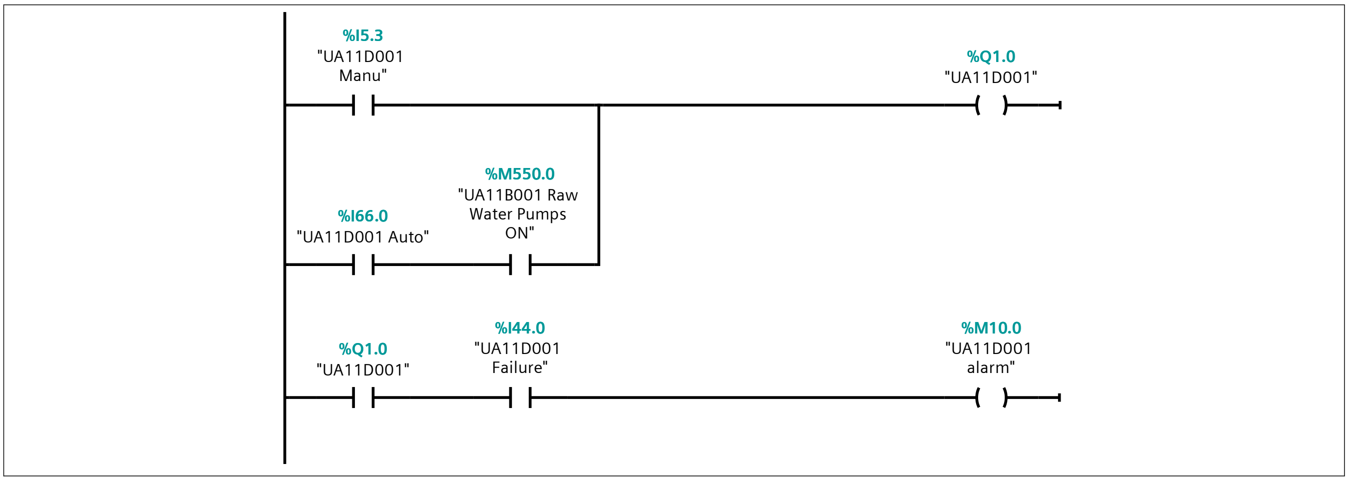
Network 72: NaOH Dosing Pumps ON Condition



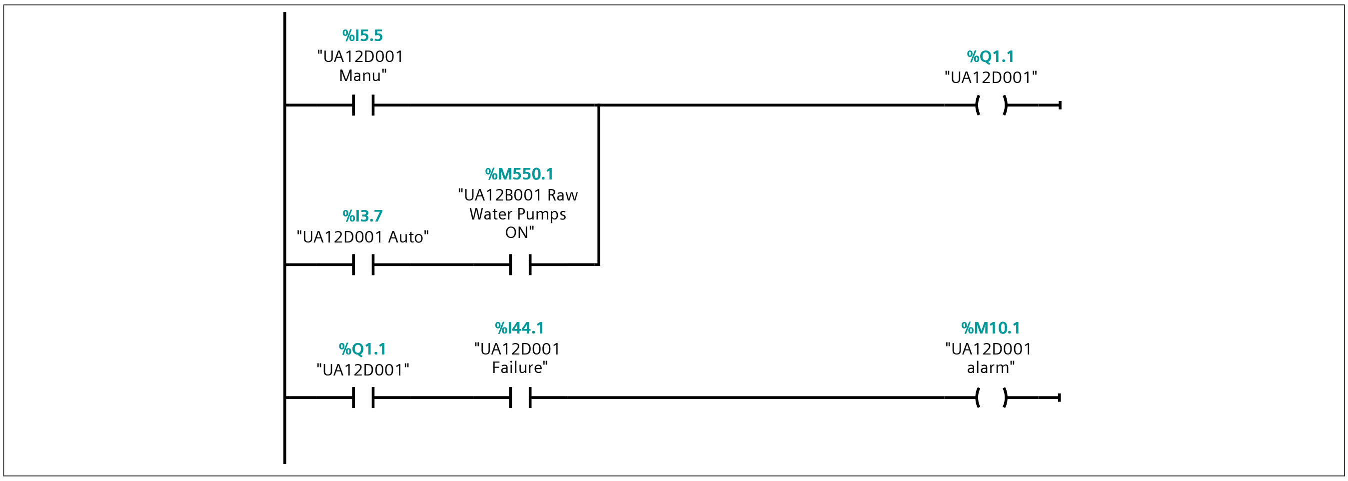
Network 73: Dilution Water Pumps ON Condition



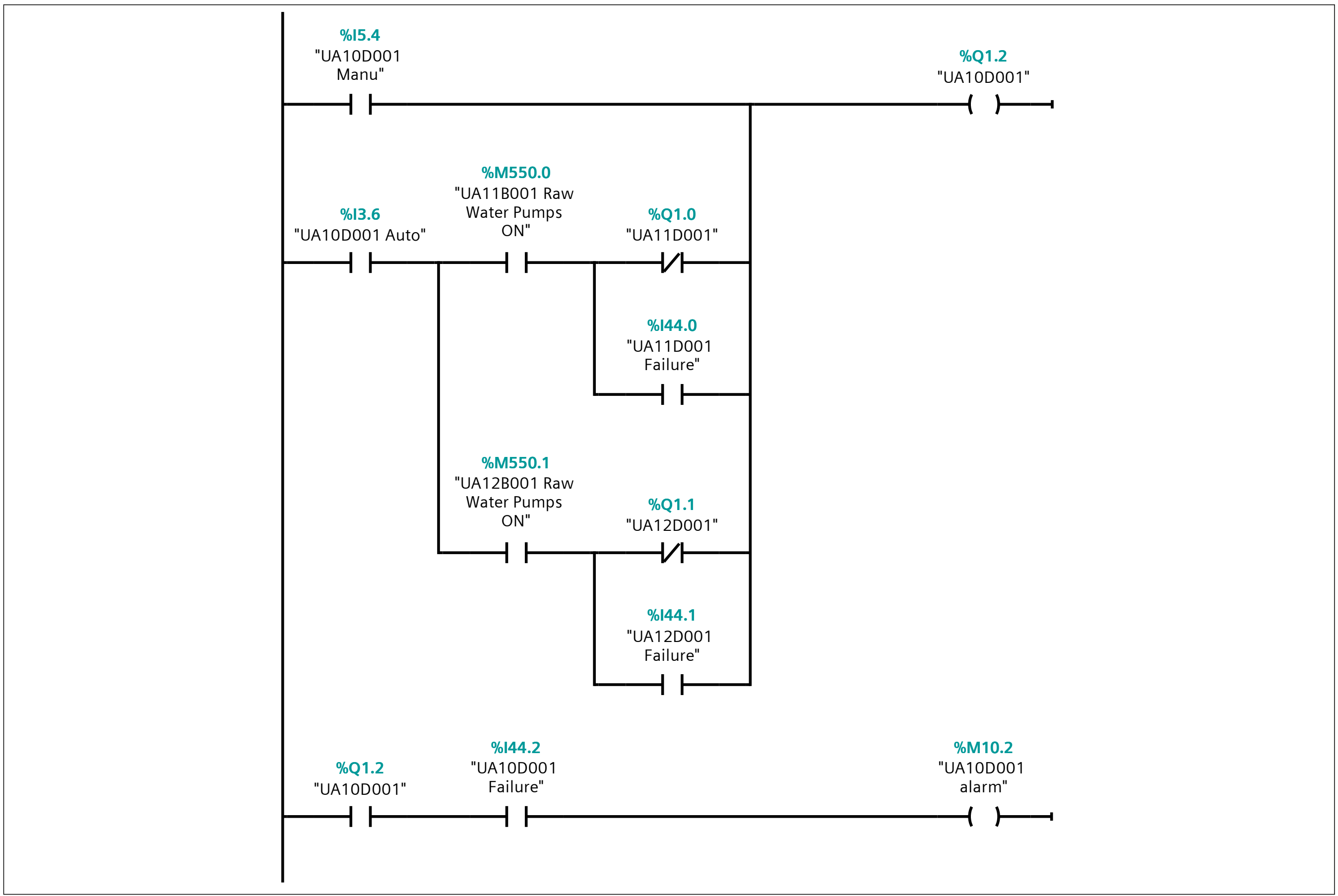
Network 74: Raw Water Pump UA11D001



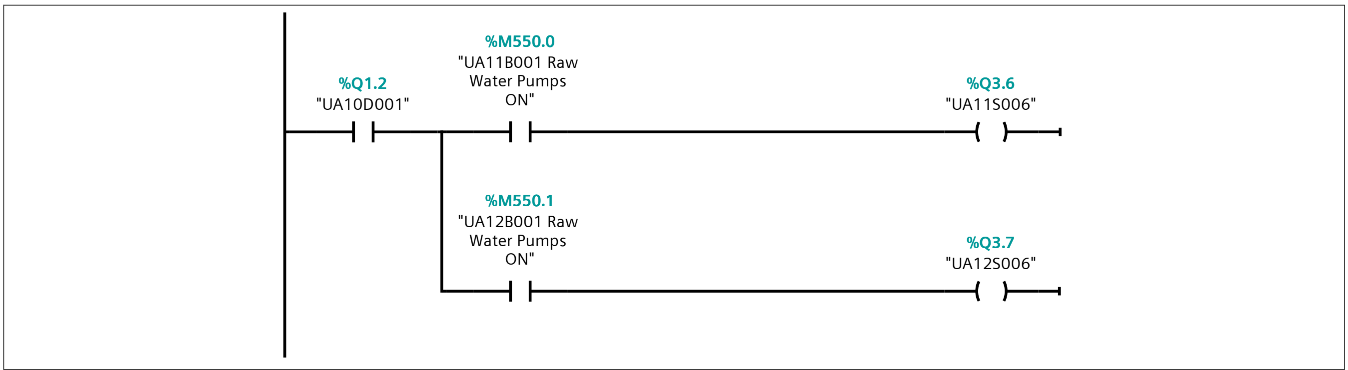
Network 75: Raw Water Pump UA12D001



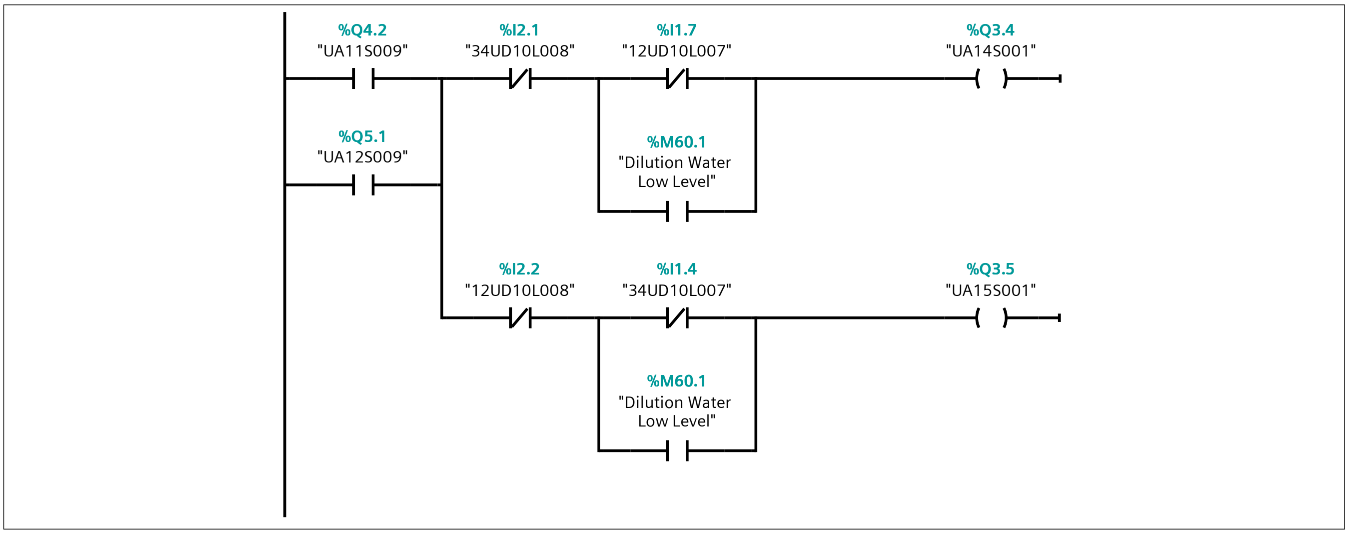
Network 76: Raw Water Pump UA10D001



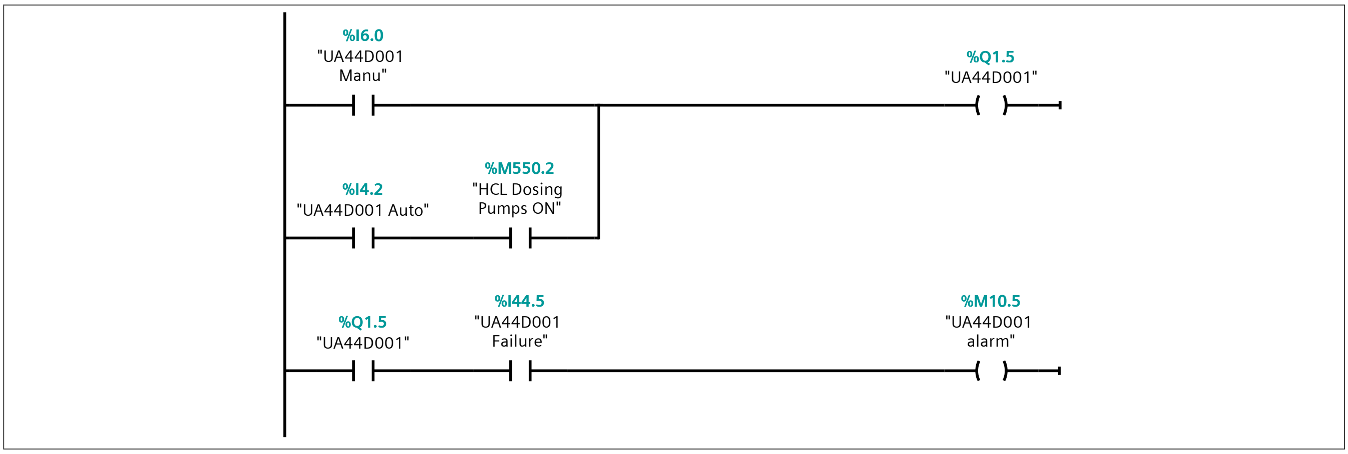
Network 77: Raw water valve switchover



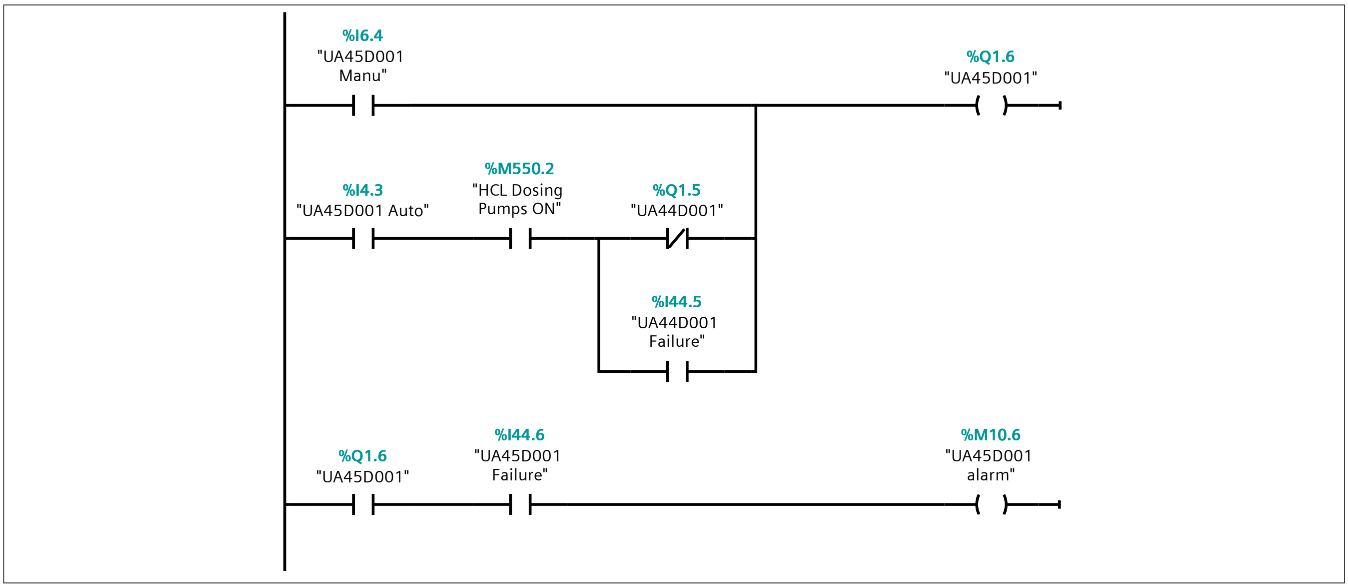
Network 78: Storage Water Valves Switchover



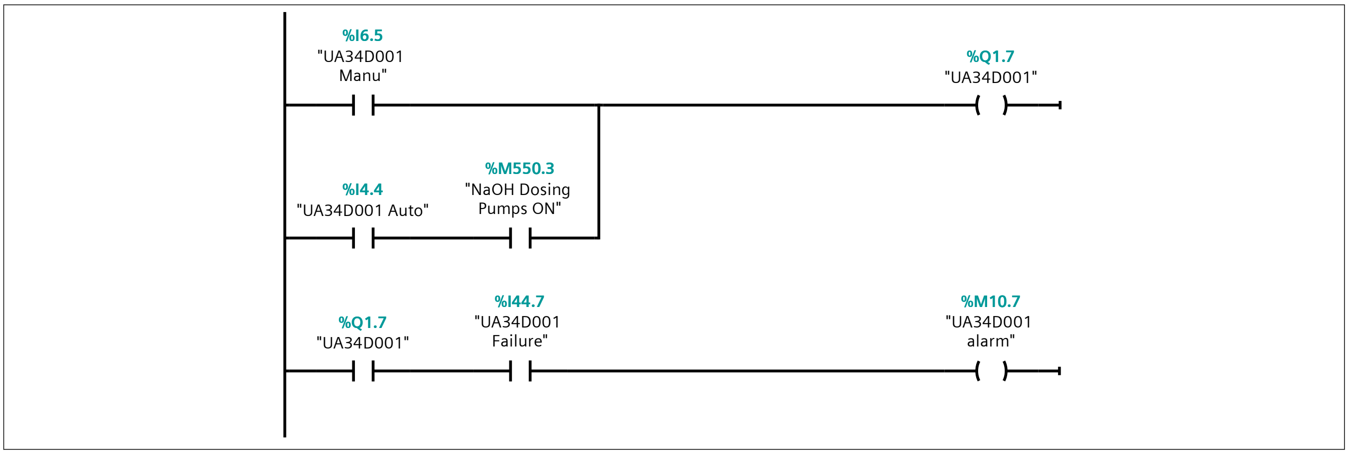
Network 79: HCl Dosing Pump UA44D001



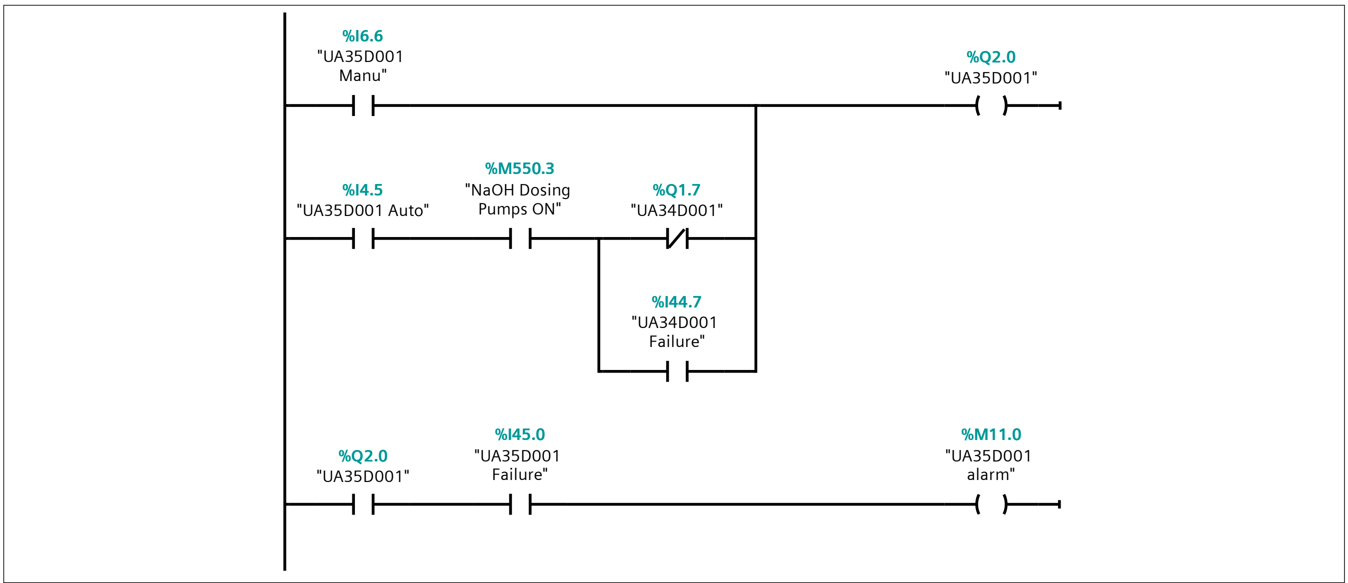
Network 80: HCl Dosing Pump UA45D001



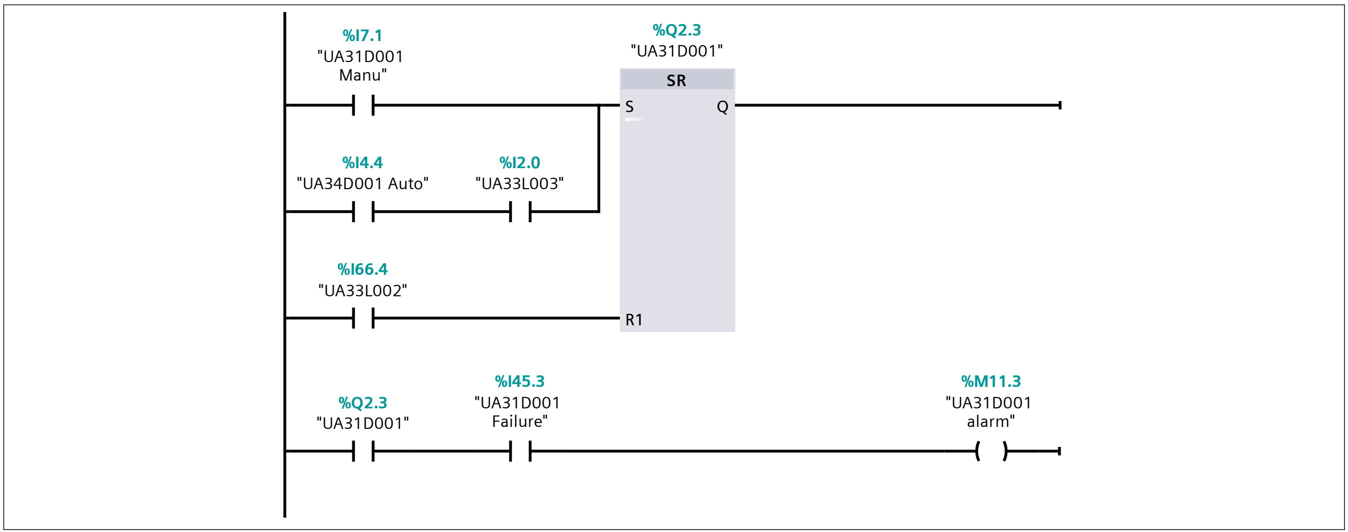
Network 81: NaOH Dosing Pump UA34D001



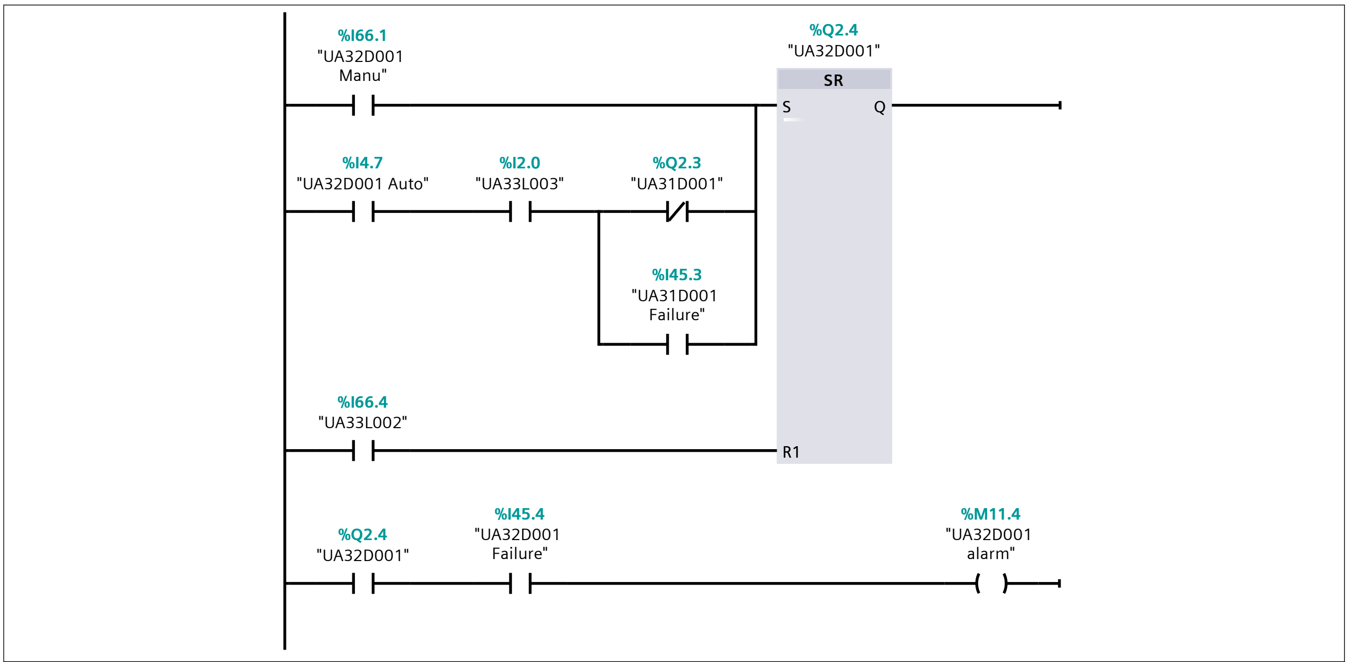
Network 82: NaOH Dosing Pump UA35D001



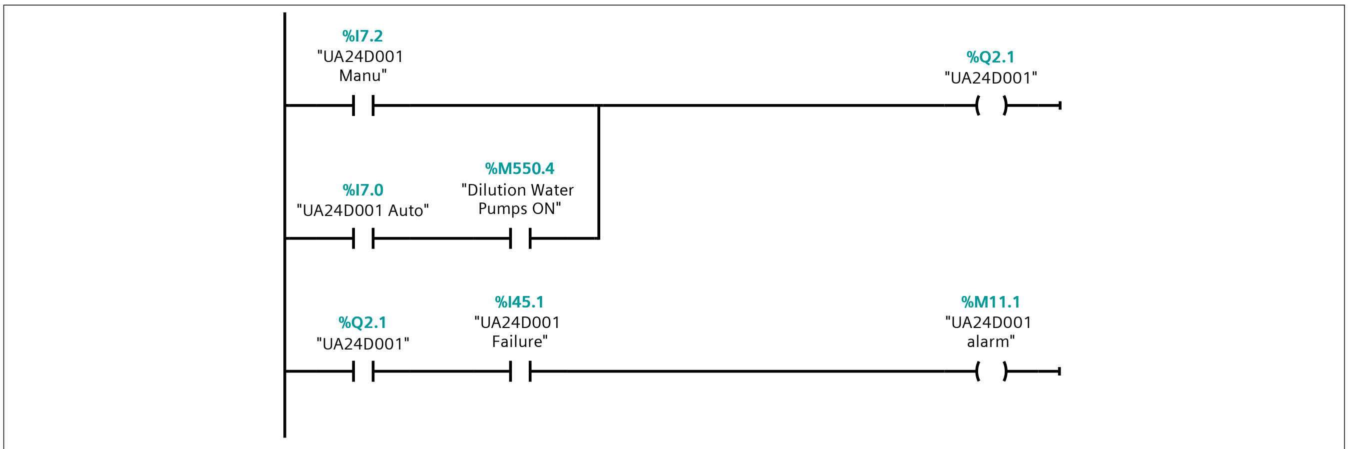
Network 83: NaOH refill Pump UA31D001



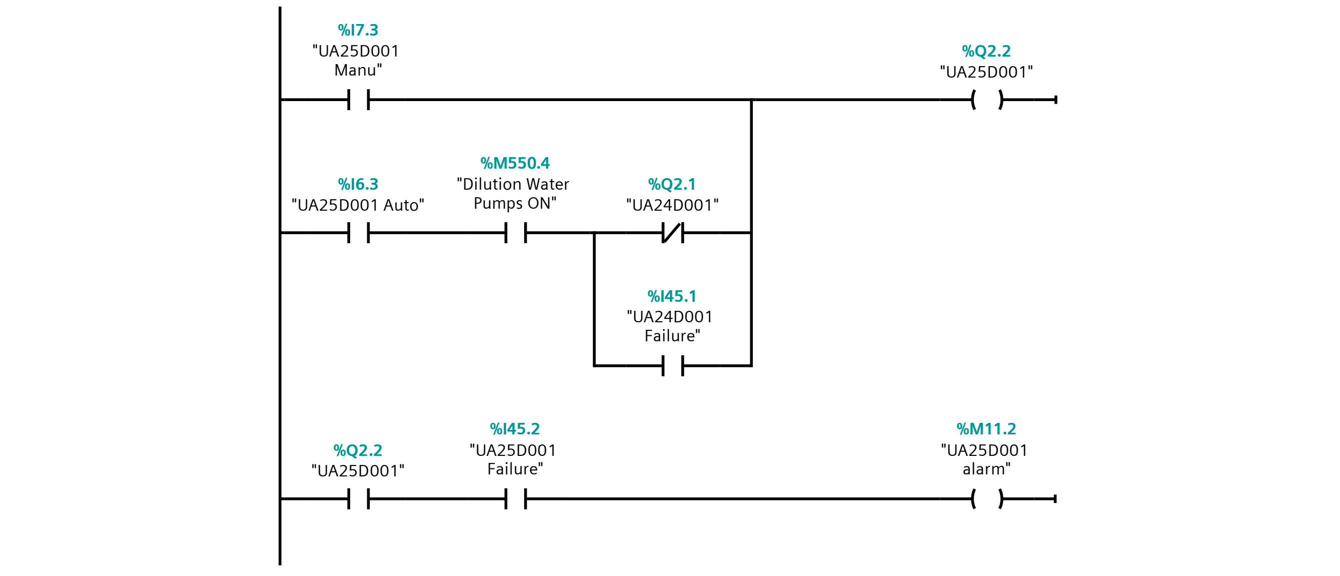
Network 84: NaOH refill Pump UA32D001



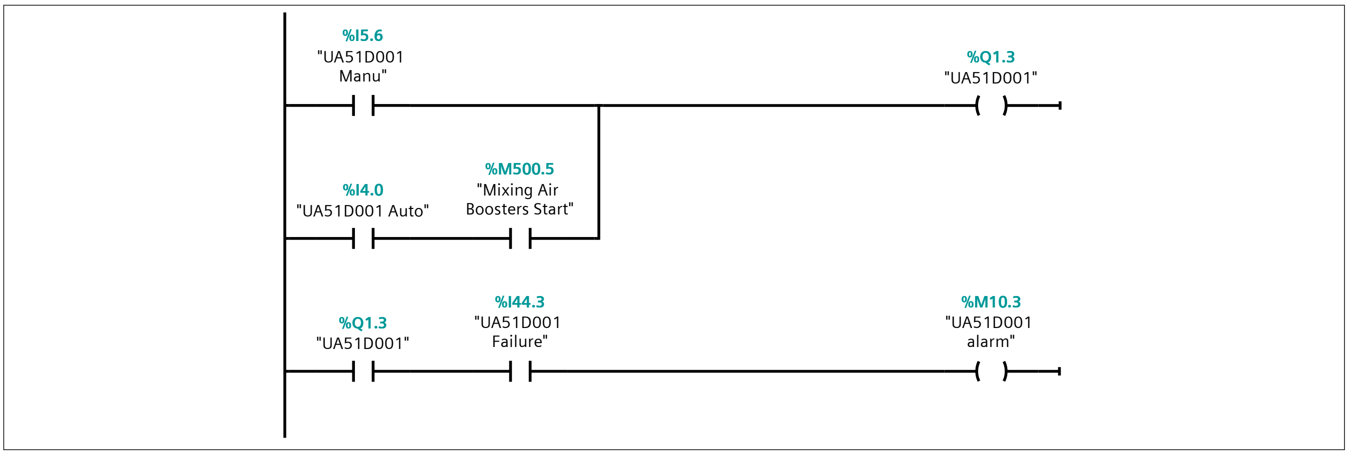
Network 85: Dilution Pump UA24D001



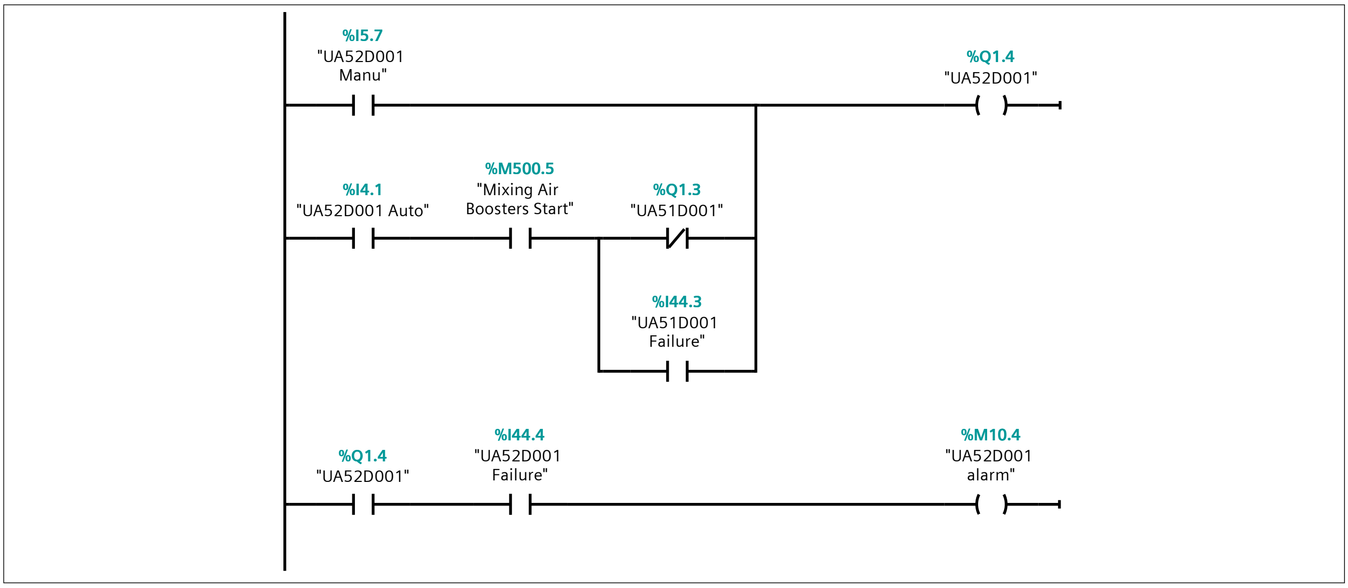
Network 86: Dilution Pump UA25D001



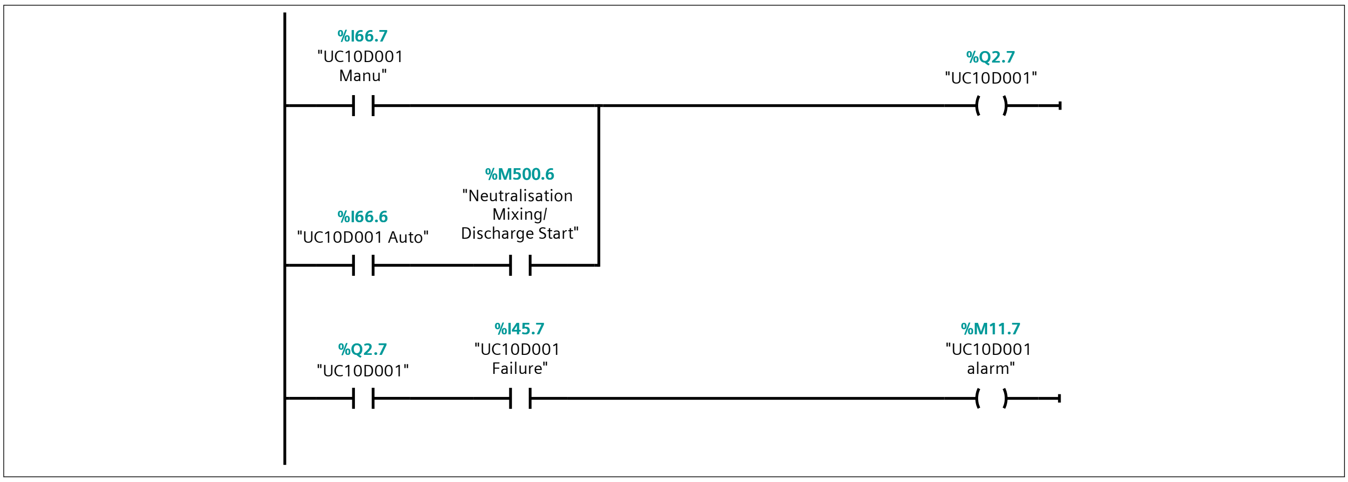
Network 87: Air Booster UA51D001



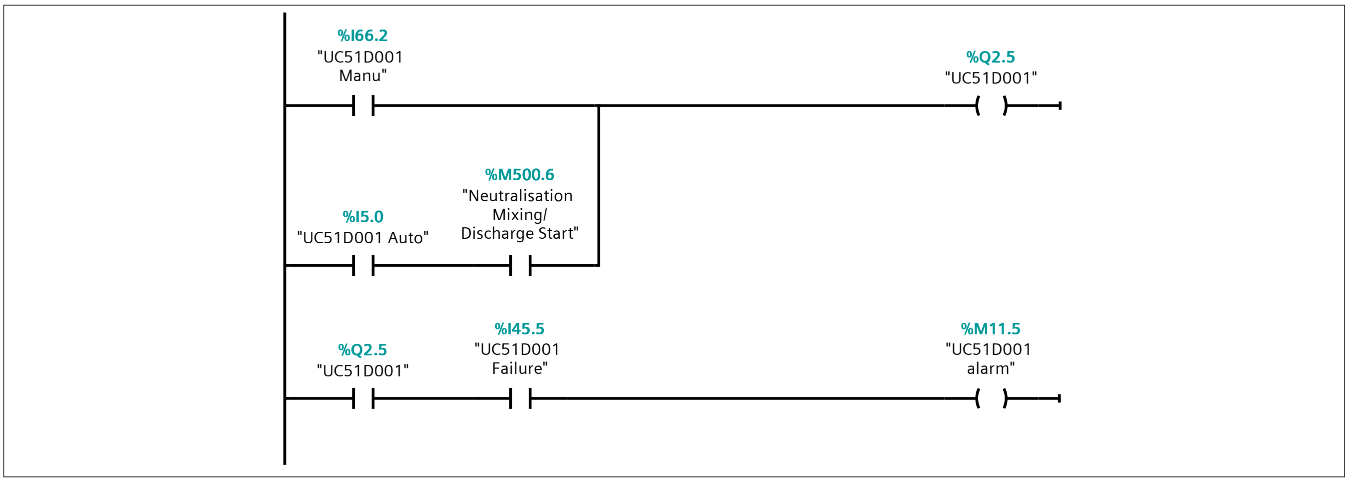
Network 88: Air Booster UA52D001



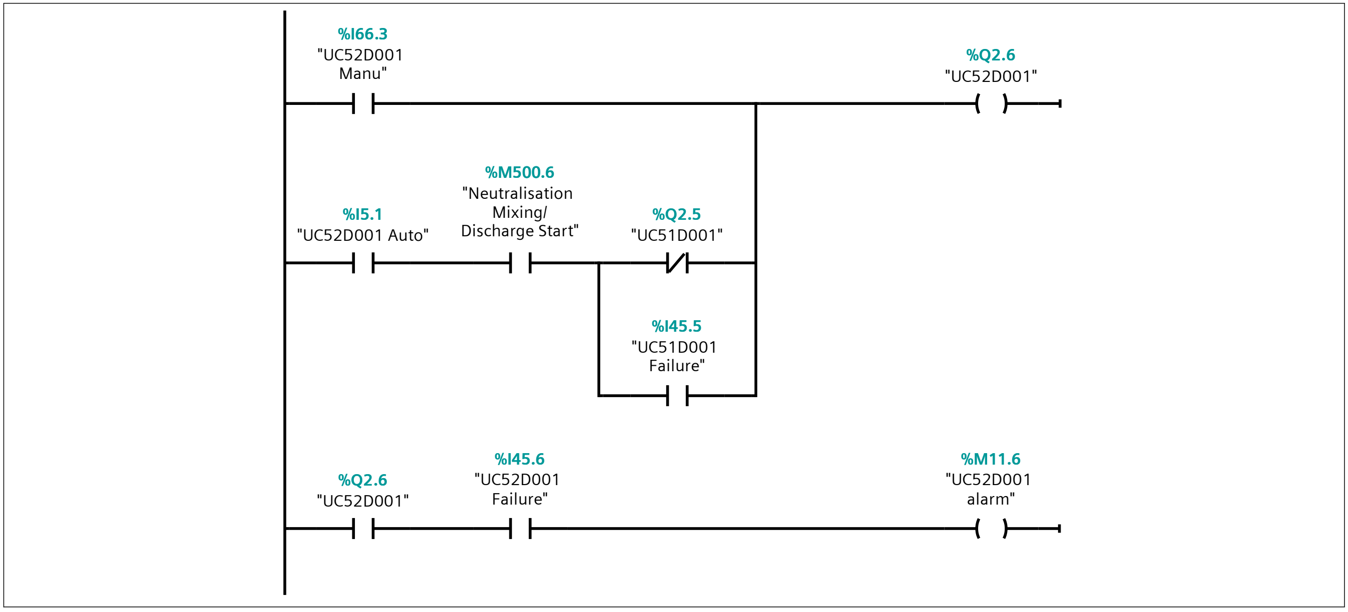
Network 89: Neutralisation water Pump UC10D001



Network 90: Air Booster UC51D001

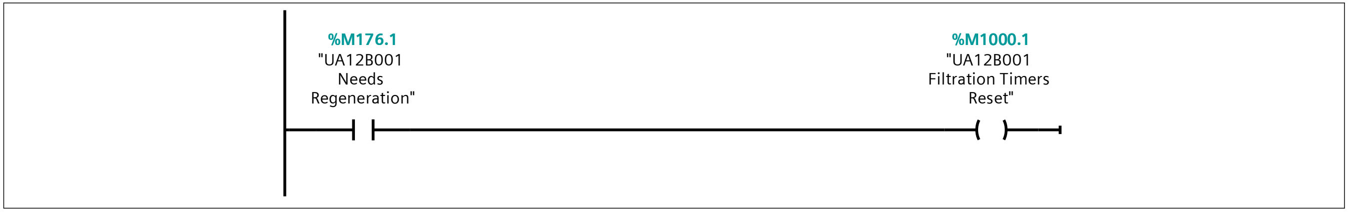


Network 91: Air Booster UC52D001

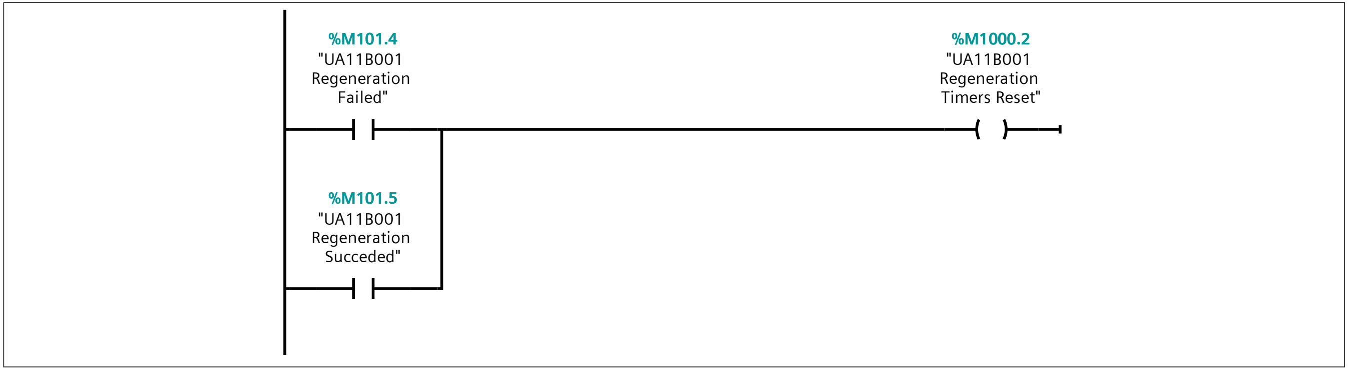


Network 92: UA11B001 Filtration Timers Reset

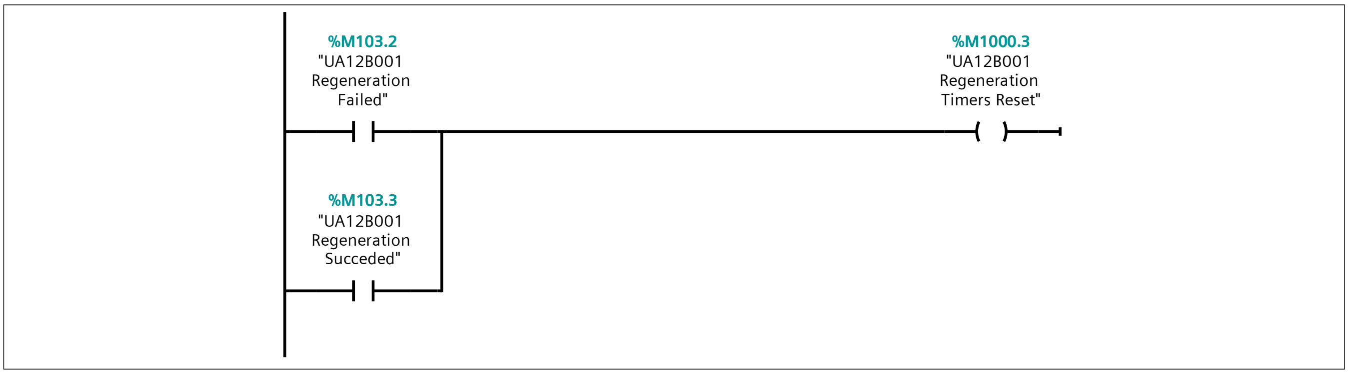
Network 93: UA12B001 Filtration Timers Reset



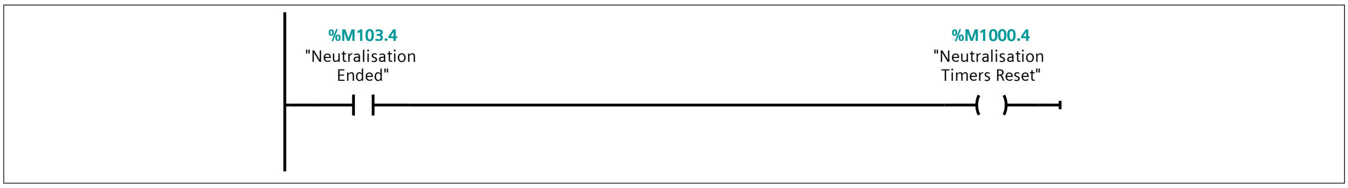
Network 94: UA11B001 Regeneration Timers Reset



Network 95: UA12B001 Regeneration Timers Reset



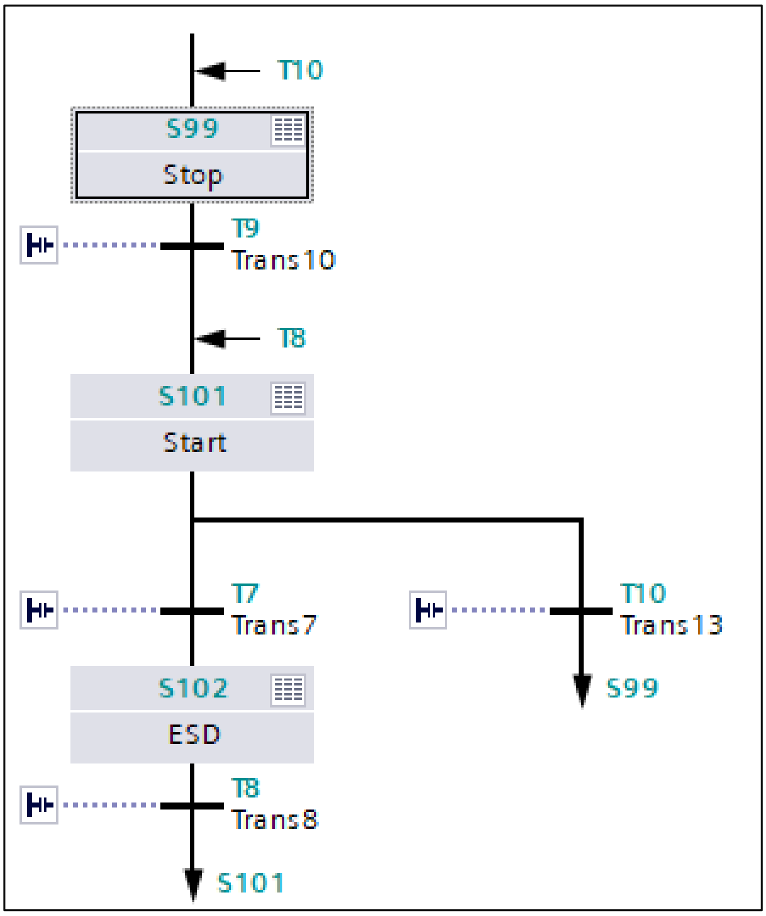
Network 96: Neutralisation timers reset



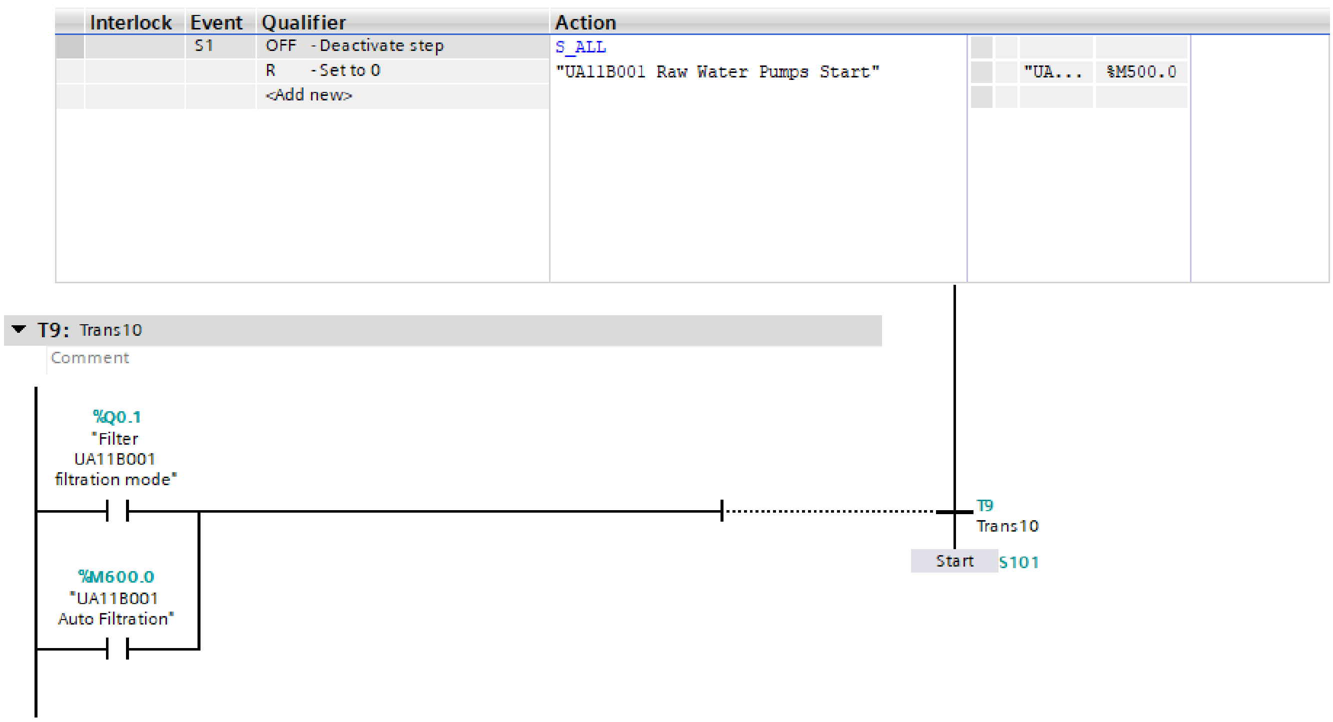
Appendix C

UA11B001 Filtration [FB1]

Sequence 1: Stop/Start/ESD

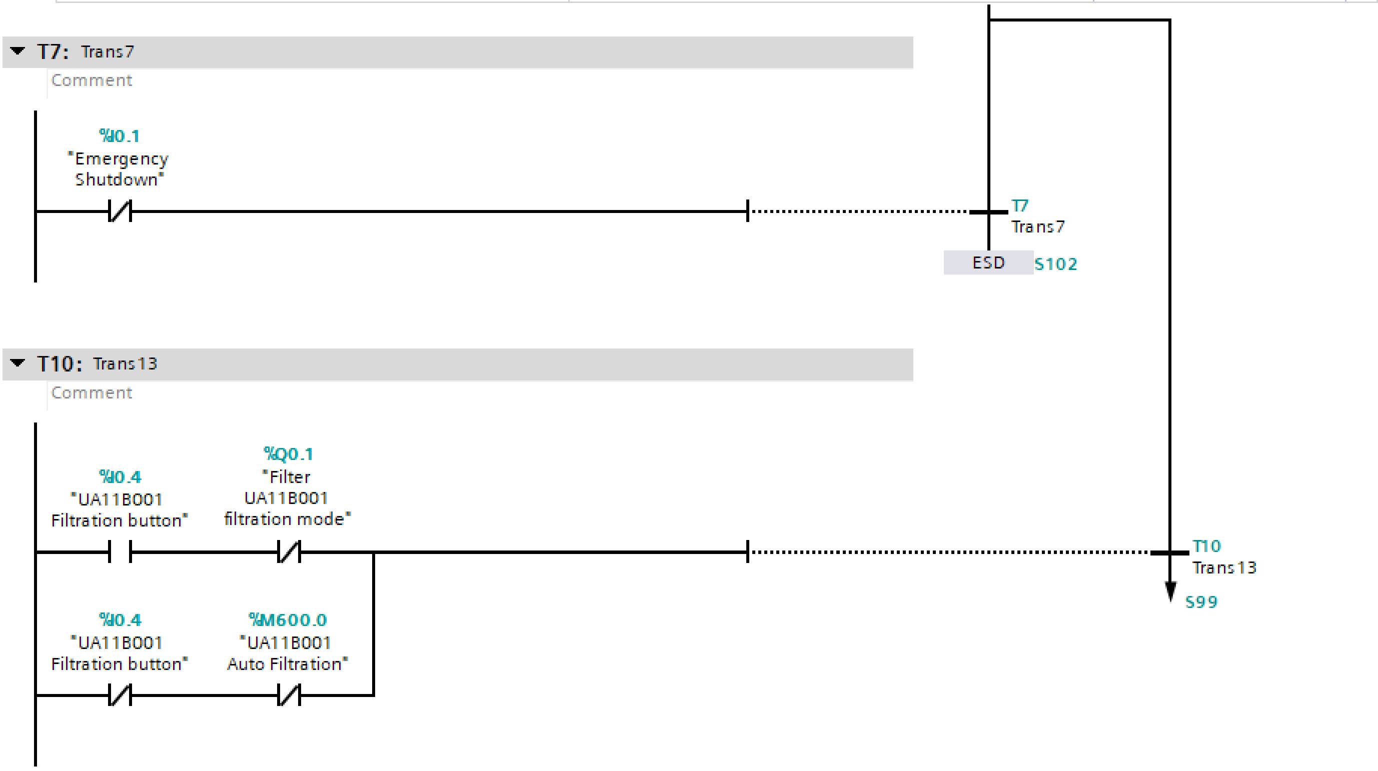


S99: Stop



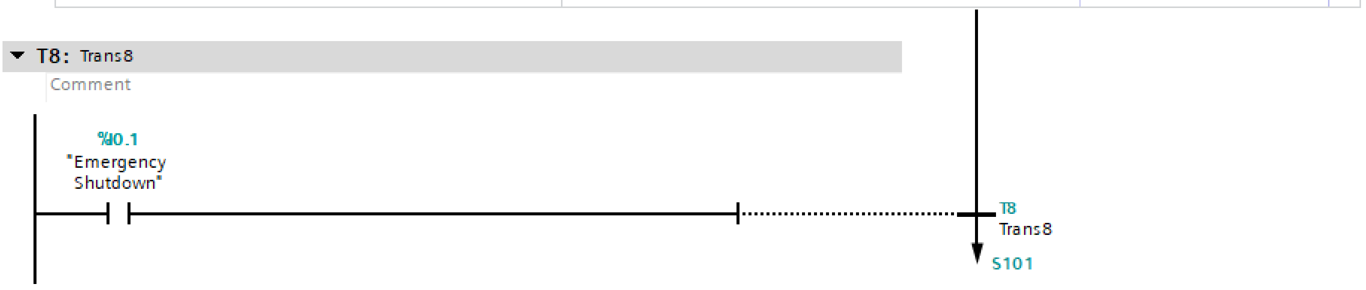
S101: Start

	Interlock	Event	Qualifier	Action			
		S1	ON - Activate step	#"Initial Step"			
			<Add new>				

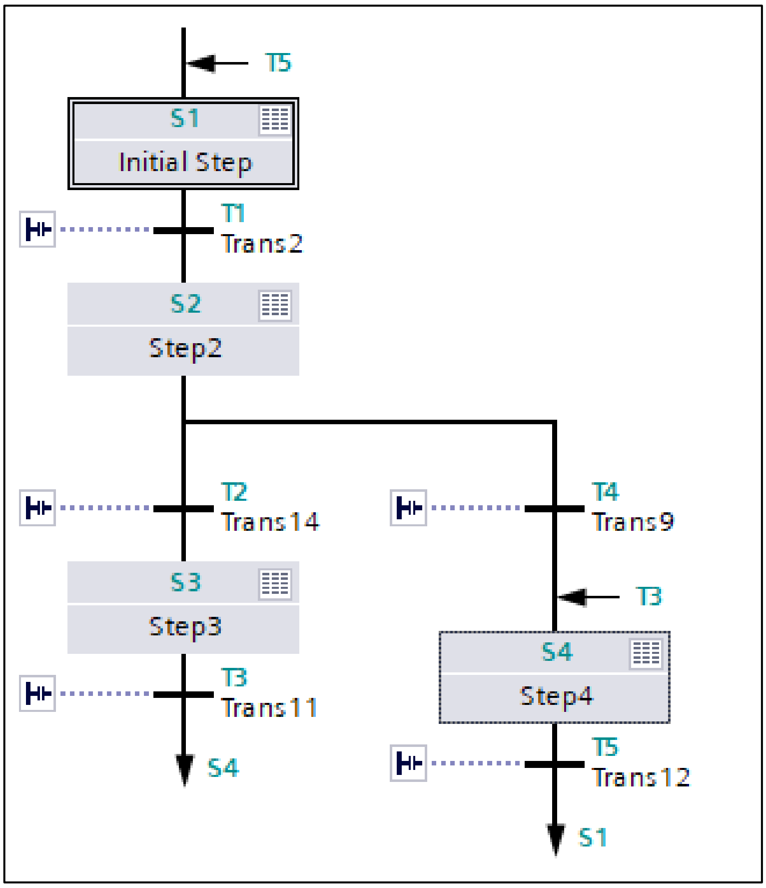


S102: ESD

	Interlock	Event	Qualifier	Action			
		S1	OFF - Deactivate step	S_ALL			
			R - Set to 0	"UA11B001 Raw Water Pumps Start"		"UA11...	%M500.0
			<Add new>				



Sequence 2: Filtration



S1: Initial Step

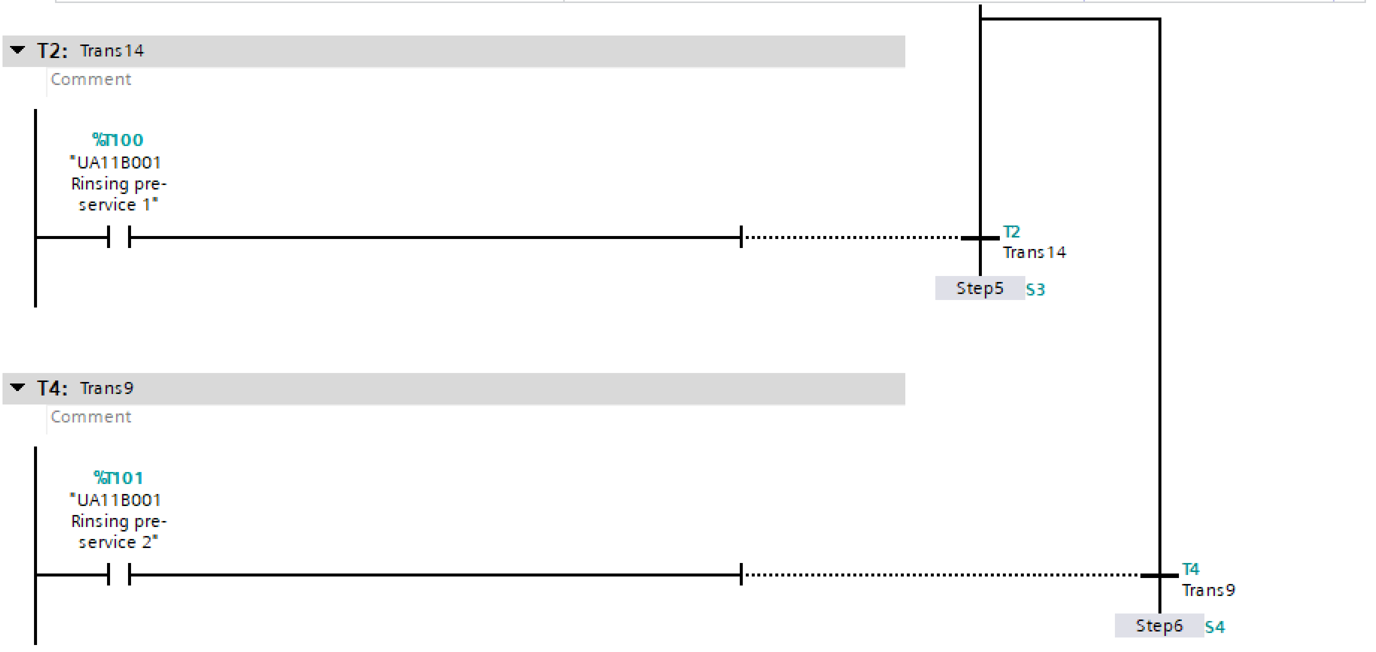
Interlock	Event	Qualifier		Action			
		R	- Set to 0	"UA37S002"		"UA37...	%Q6.2
		R	- Set to 0	"UA11S017"		"UA11...	%Q4.6
		R	- Set to 0	"UA11S015"		"UA11...	%Q4.5
		R	- Set to 0	"UA47S002"		"UA47...	%Q7.1
		R	- Set to 0	"UA47S001"		"UA47...	%Q7.0
		R	- Set to 0	"UA54S002"		"UA54...	%Q7.6
		R	- Set to 0	"UA11S008"		"UA11...	%Q4.1
		R	- Set to 0	"UA37S001"		"UA37...	%Q6.1
		R	- Set to 0	"UA11S009"		"UA11...	%Q4.2
		R	- Set to 0	"UA11S014"		"UA11...	%Q4.4
		S	- Set to 1	"UA11S012"		"UA11...	%Q4.3
		S	- Set to 1	"UA11S007"		"UA11...	%Q4.0
		R	- Set to 0	"UA11B001 Regeneration Succeded"		"UA11...	%M101.5
		S	- Set to 1	"UA11B001 Filtering"		"UA11...	%M110.0
		<Add new>					

T1: Trans2

Comment

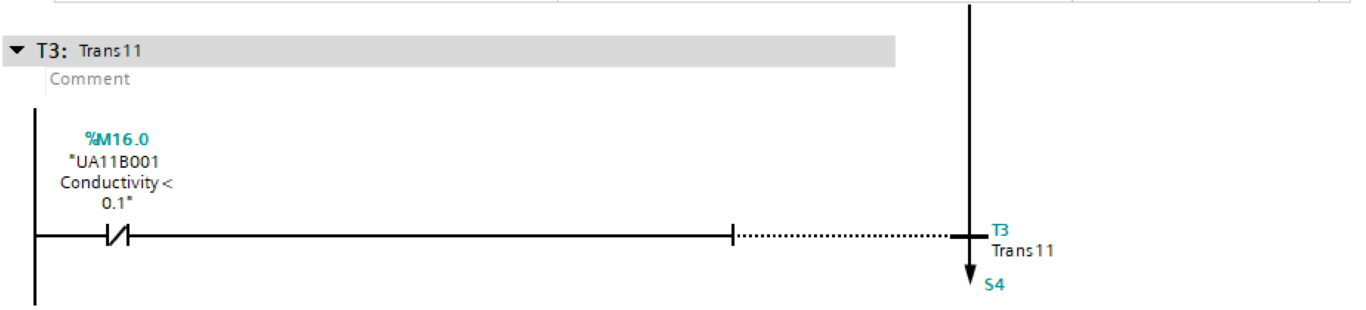
S2: Step2

Interlock	Event	Qualifier	Action		
		S - Set to 1	"UA11B001 Raw Water Pumps Start"	"UA11...	%M500.0
		<Add new>			



S3: Step3

Interlock	Event	Qualifier	Action		
		S - Set to 1	"UA11S009"	"UA11...	%Q4.2
		R - Set to 0	"UA11S012"	"UA11...	%Q4.3
		S - Set to 1	"UA11B001 Raw Water Pumps Start"	"UA11...	%M500.0
		<Add new>			



S4: Step4

	Interlock	Event	Qualifier	Action				
			R - Set to 0	"UA11B001 Raw Water Pumps Start"			"UA11...	%M500.0
			R - Set to 0	"UA11S012"			"UA11...	%Q4.3
			R - Set to 0	"UA11S007"			"UA11...	%Q4.0
			S - Set to 1	"UA11B001 Needs Regeneration"			"UA11...	%M176.0
			R - Set to 0	"UA11S009"			"UA11...	%Q4.2
			R - Set to 0	"UA11B001 Filtering"			"UA11...	%M110.0
			<Add new>					

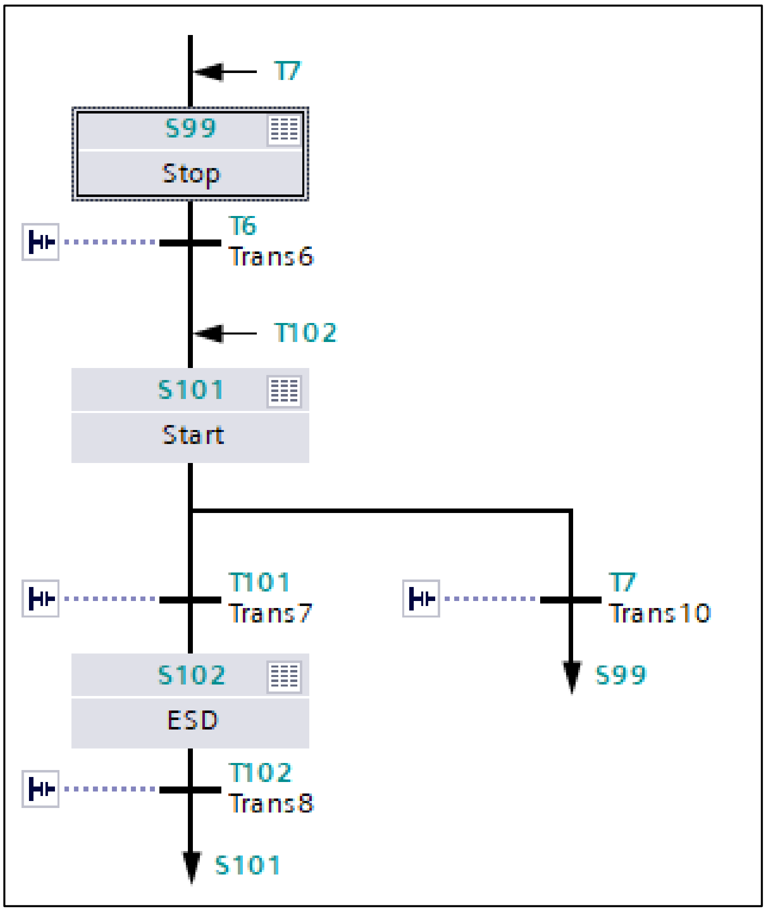
T5: Trans12

Comment

Appendix D

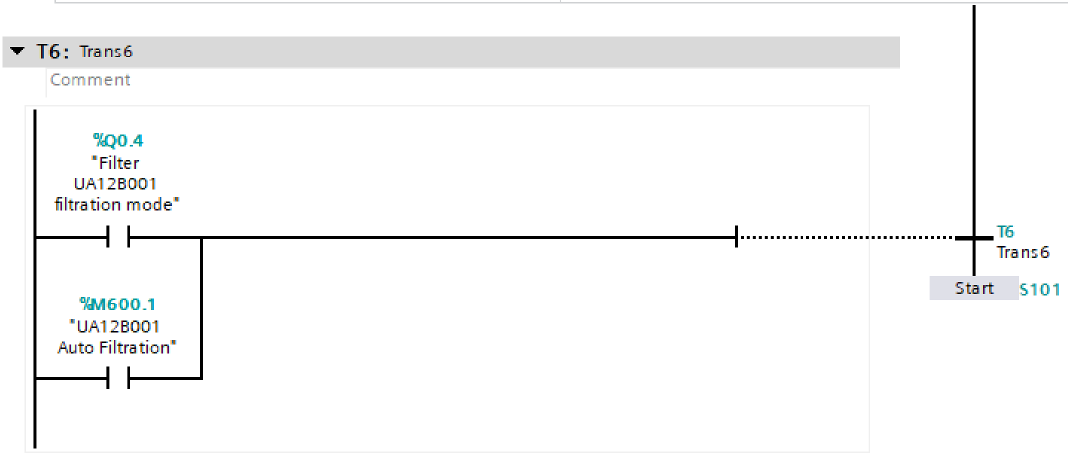
UA12B001 Filtration [FB2]

Sequence 1: Stop/Start/ESD



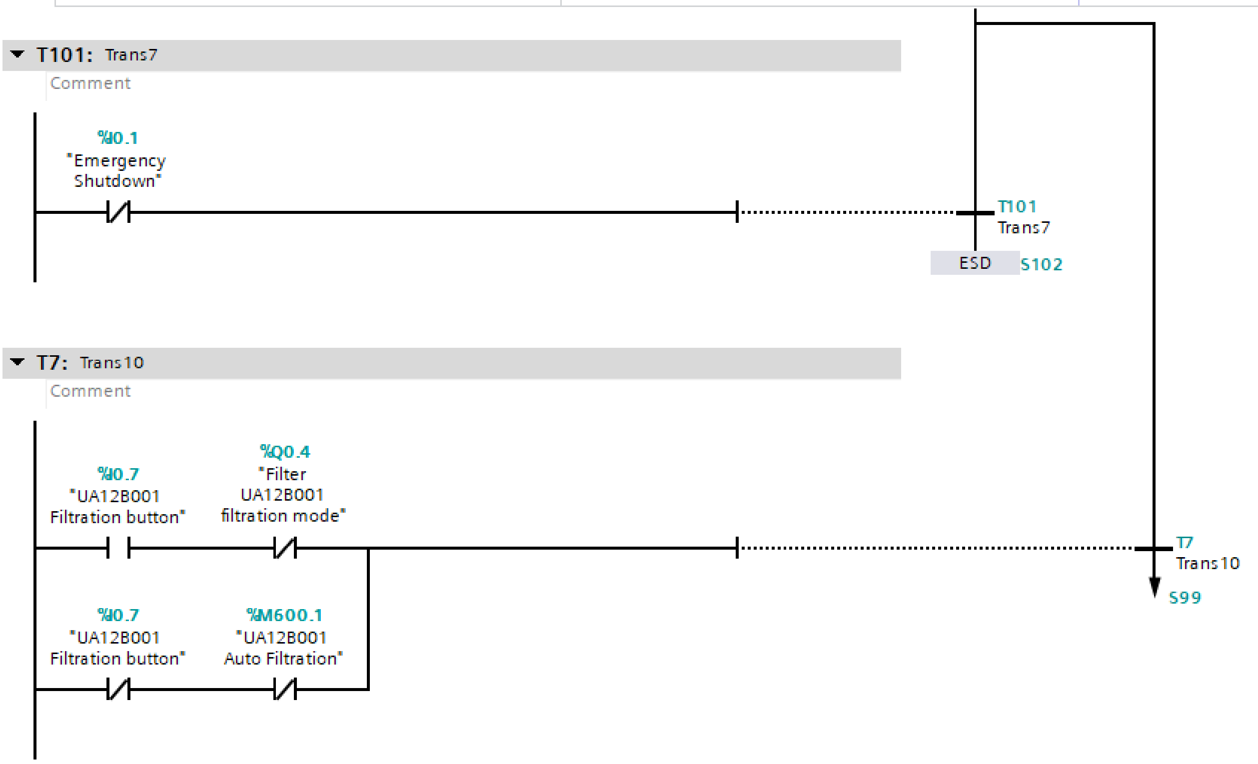
S99: Stop

Interlock	Event	Qualifier	Action			
	S1	OFF - Deactivate step	S_ALL			
		R - Set to 0	"UA12B001 Raw Water Pumps Start"		"UA12...	%M500.1
		<Add new>				



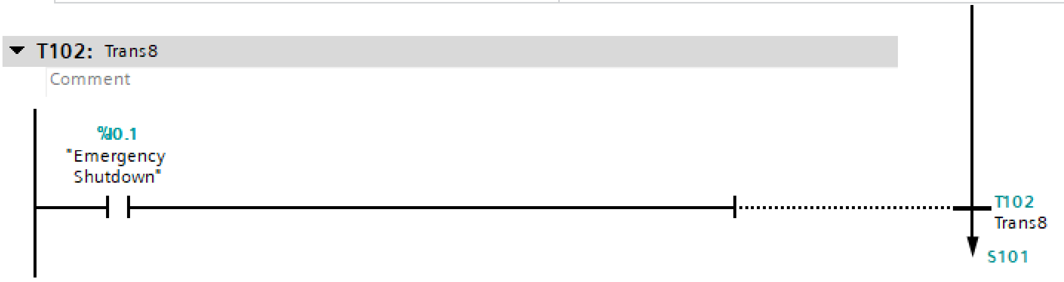
S101: Start

Interlock	Event	Qualifier	Action		
	S1	ON - Activate step	#"Initial Step_1"		
		<Add new>			

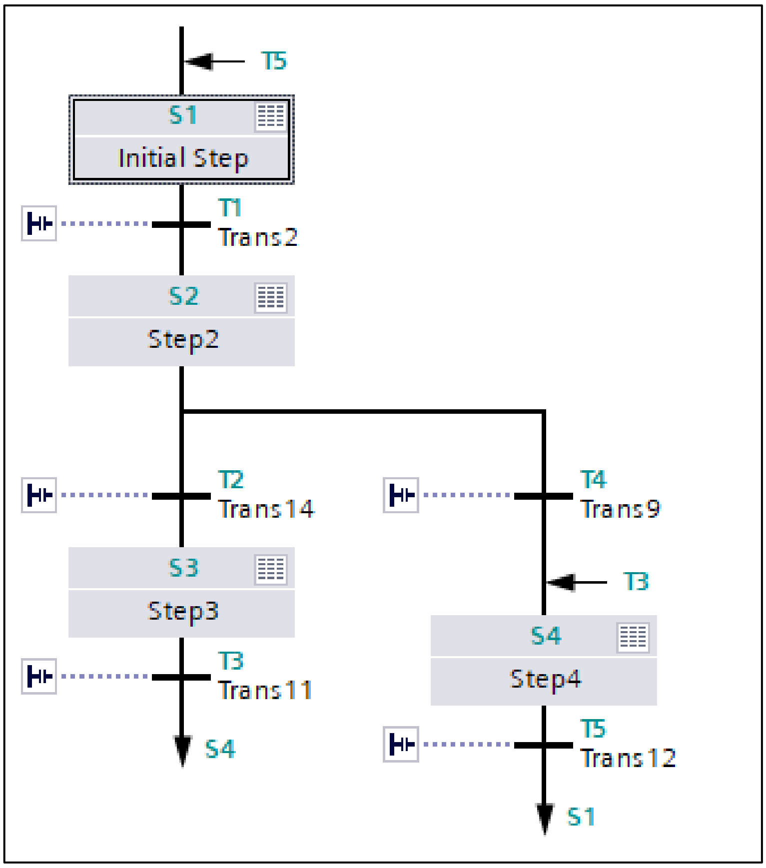


S102: ESD

Interlock	Event	Qualifier	Action		
	S1	OFF - Deactivate step	S_ALL		
		R - Set to 0	"UA12B001 Raw Water Pumps Start"	"UA12...	%M500.1
		<Add new>			



Sequence 2: Filtration

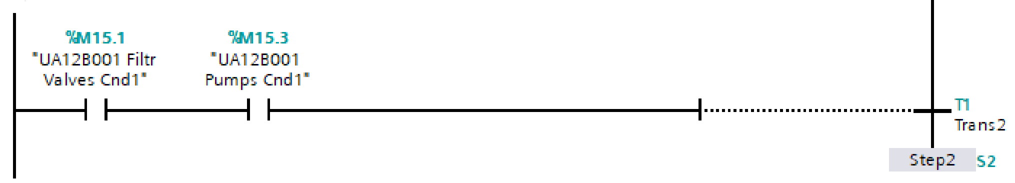


S1: Initial Step

Interlock	Event	Qualifier	Action		
		R -Set to 0	"UA38S002"	"UA38..."	%Q6.5
		R -Set to 0	"UA12S017"	"UA12..."	%Q5.5
		R -Set to 0	"UA12S015"	"UA12..."	%Q5.4
		R -Set to 0	"UA48S002"	"UA48..."	%Q7.4
		R -Set to 0	"UA48S001"	"UA48..."	%Q7.3
		R -Set to 0	"UA55S002"	"UA55..."	%Q7.7
		R -Set to 0	"UA12S008"	"UA12..."	%Q5.0
		R -Set to 0	"UA38S001"	"UA38..."	%Q6.4
		R -Set to 0	"UA12S009"	"UA12..."	%Q5.1
		R -Set to 0	"UA12S014"	"UA12..."	%Q5.3
		S -Set to 1	"UA12S012"	"UA12..."	%Q5.2
		S -Set to 1	"UA12S007"	"UA12..."	%Q4.7
		R -Set to 0	"UA12B001 Regeneration Succeded"	"UA12..."	%M103.3
		S -Set to 1	"UA12B001 Filtering"	"UA12..."	%M110.1
		<Add new>			

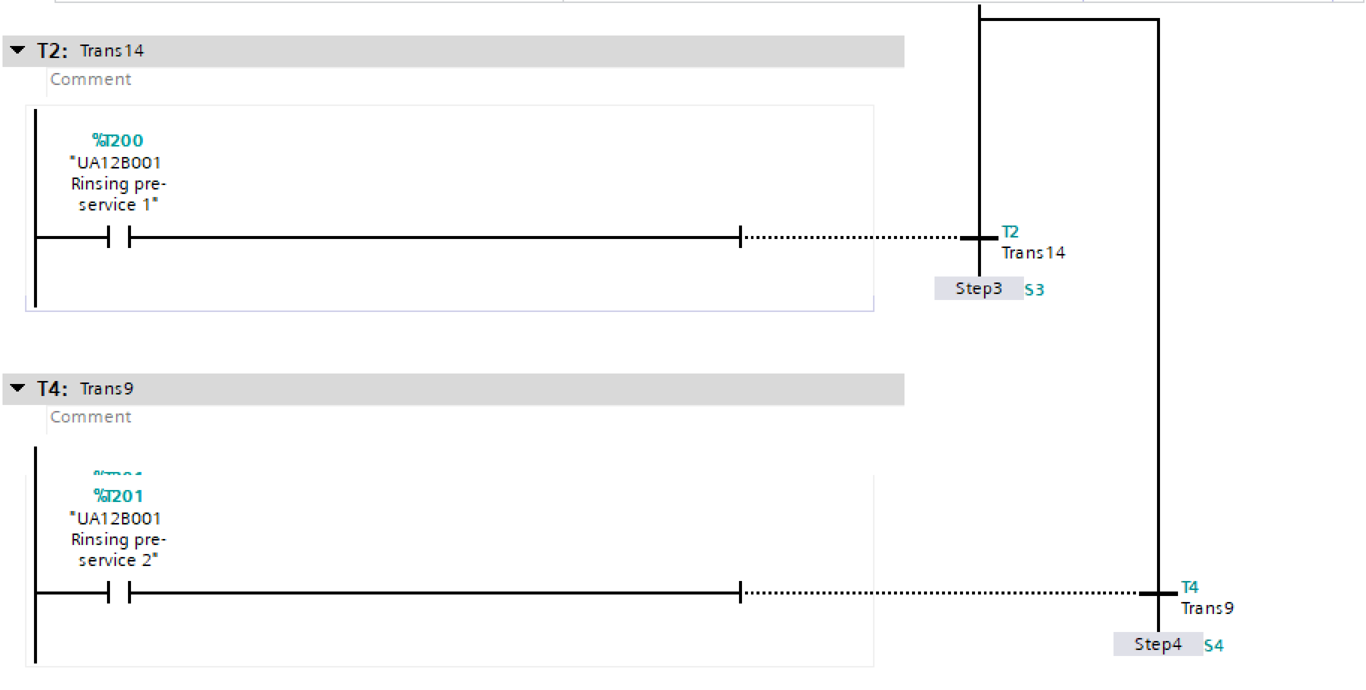
T1: Trans2

Comment



S2: Step2

Interlock	Event	Qualifier	Action		
		S - Set to 1	"UA12B001 Raw Water Pumps Start"	"UA12...	%M500.1
		<Add new>			



S3: Step3

Interlock	Event	Qualifier	Action		
		S - Set to 1	"UA12S009"	"UA12...	%Q5.1
		R - Set to 0	"UA12S012"	"UA12...	%Q5.2
		S - Set to 1	"UA12B001 Raw Water Pumps Start"	"UA12...	%M500.1
		<Add new>			

S4: Step4

Interlock	Event	Qualifier		Action		
		R	- Set to 0	"UA12B001 Raw Water Pumps Start"	"UA12...	%M500.1
		R	- Set to 0	"UA12S012"	"UA12...	%Q5.2
		R	- Set to 0	"UA12S007"	"UA12...	%Q4.7
		S	- Set to 1	"UA12B001 Needs Regeneration"	"UA12...	%M176.1
		R	- Set to 0	"UA12S009"	"UA12...	%Q5.1
		R	- Set to 0	"UA12B001 Filtering"	"UA12...	%M110.1
		<Add new>				

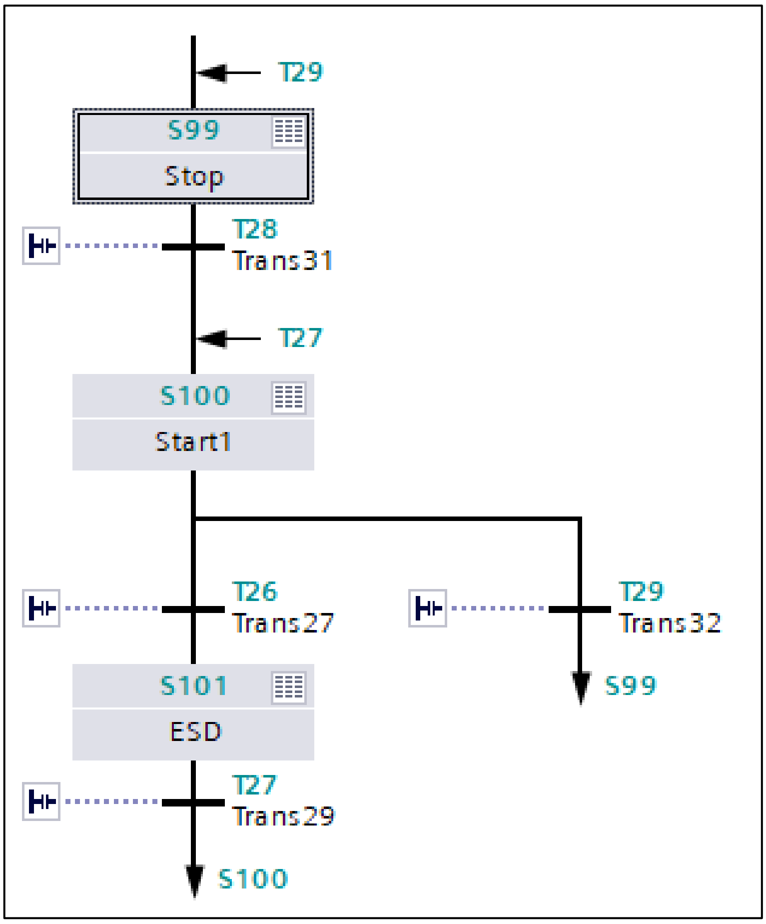
T5: Trans12

Comment

Appendix E

UA11B001 Regeneration [FB3]

Sequence 1: Stop/Start/ESD

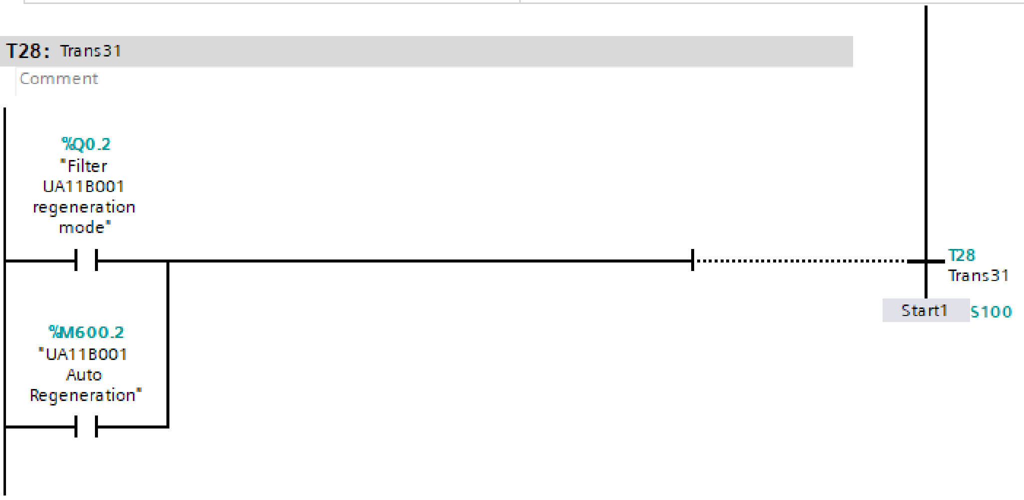


S99: Stop

Interlock	Event	Qualifier	Action		
	S1	OFF - Deactivate step	S_ALL		
		R - Set to 0	"UA11B001 Raw Water Pumps Start"	"UA11...	%M500.0
		R - Set to 0	"HCL Dosing Pumps Start"	"HCL ...	%M500.2
		R - Set to 0	"NaOH Dosing Pumps Start"	"NaOH...	%M500.3
		R - Set to 0	"Dilution Water Pumps Start"	"Dilu...	%M500.4
		R - Set to 0	"Mixing Air Boosters Start"	"Mixi...	%M500.5
		<Add new>			

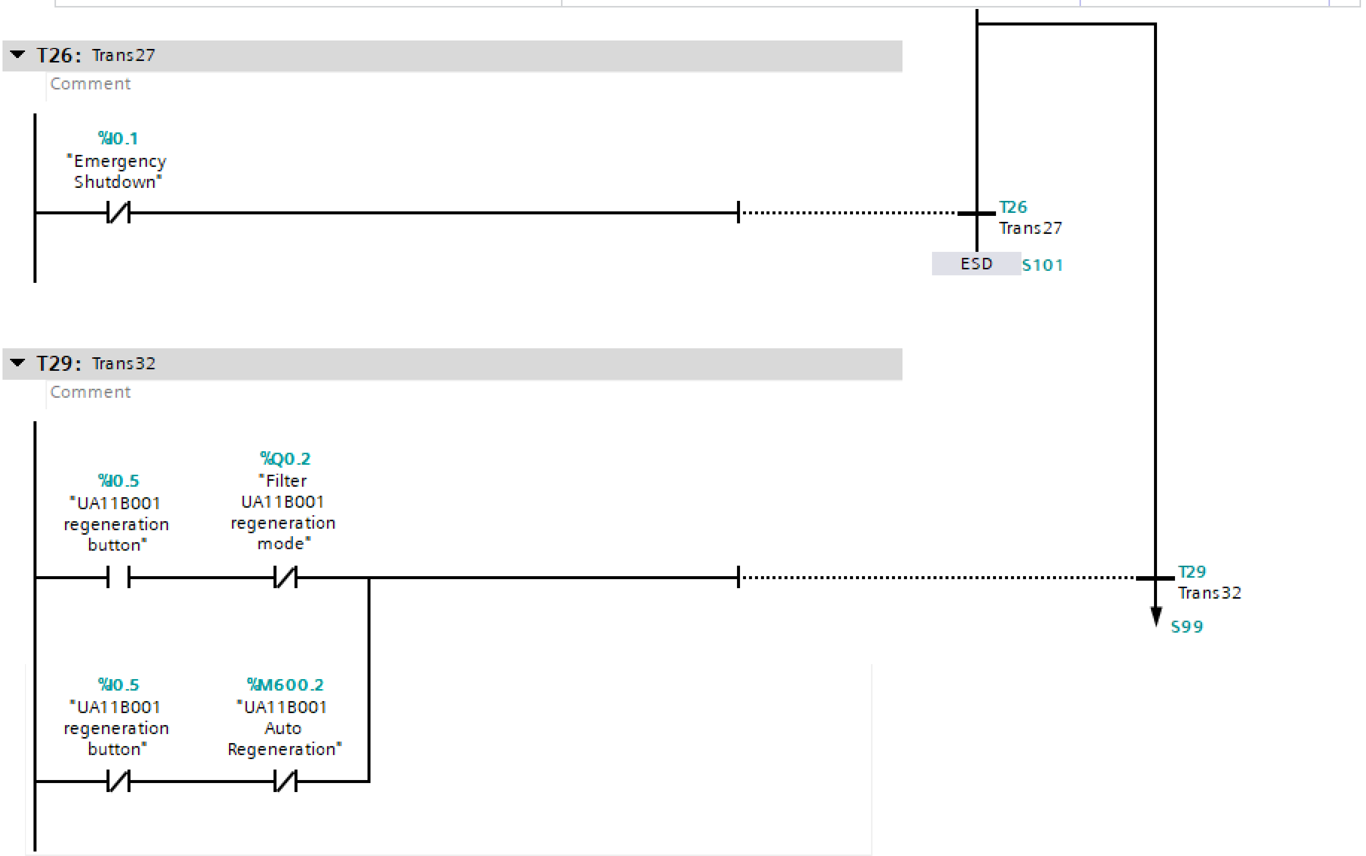
T28: Trans31

Comment



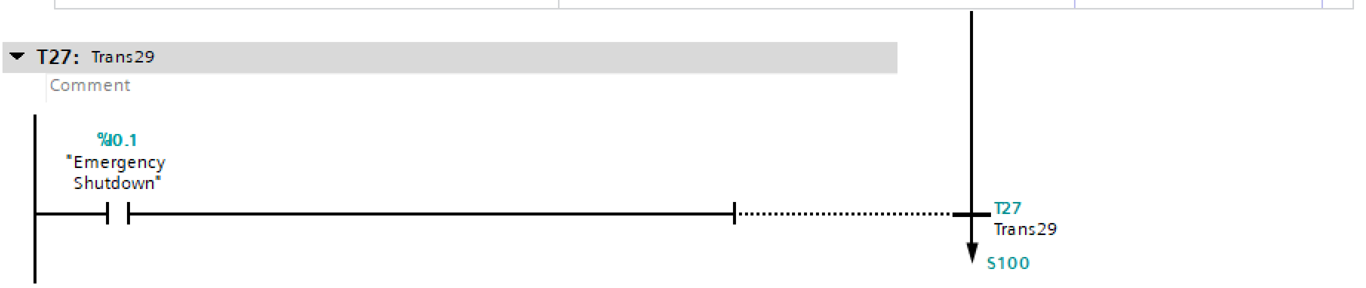
S100: Start1

Interlock	Event	Qualifier	Action		
	S1	ON - Activate step	#"Pre-Start"		
		<Add new>			

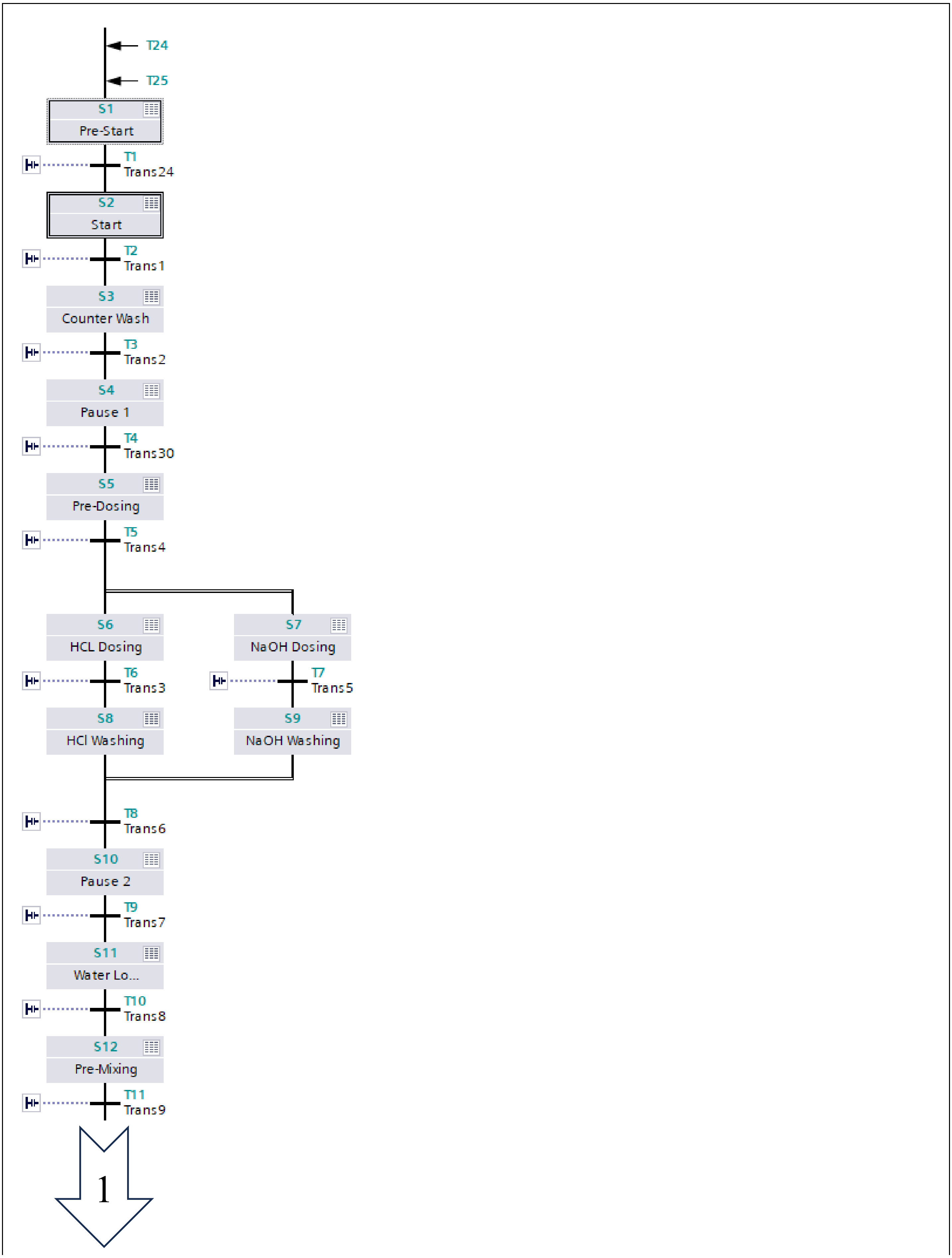


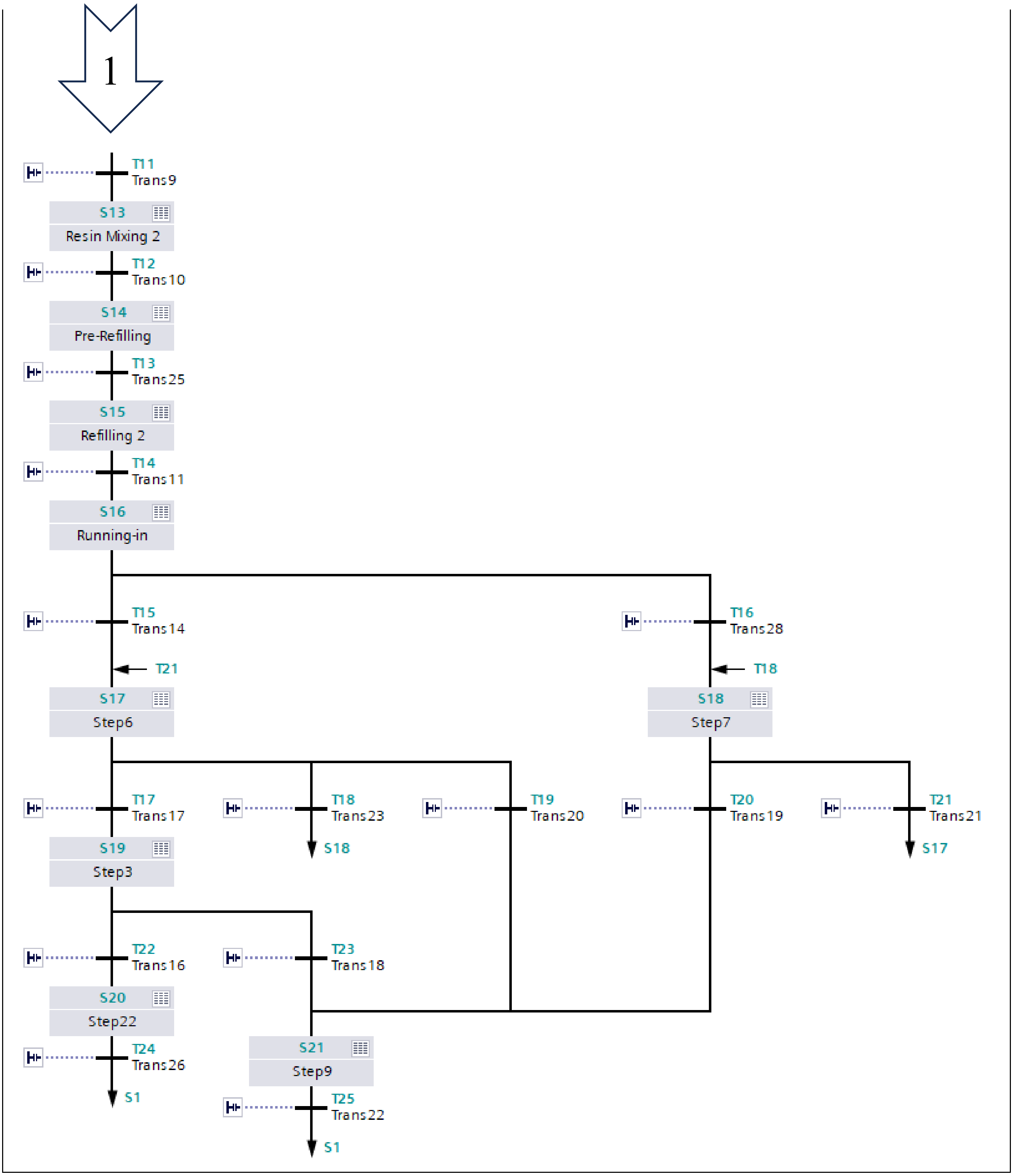
S101: ESD

Interlock	Event	Qualifier	Action		
	S1	OFF - Deactivate step	S_ALL		
		R - Set to 0	"UA11B001 Raw Water Pumps Start"	"UA11...	%M500.0
		R - Set to 0	"HCL Dosing Pumps Start"	"HCL ...	%M500.2
		R - Set to 0	"NaOH Dosing Pumps Start"	"NaOH...	%M500.3
		R - Set to 0	"Dilution Water Pumps Start"	"Dilu...	%M500.4
		R - Set to 0	"Mixing Air Boosters Start"	"Mixi...	%M500.5
		<Add new>			



Sequence 2: Regeneration

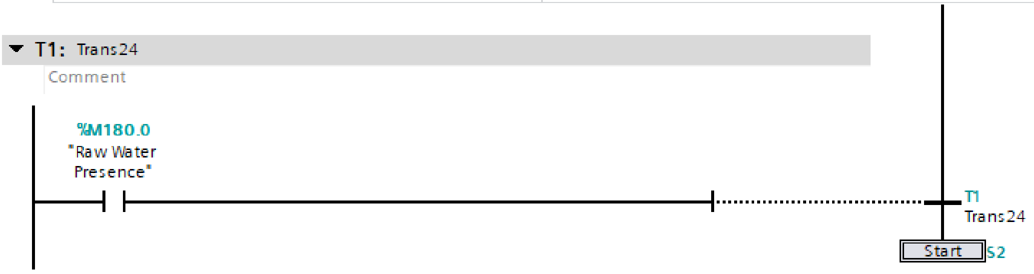




1
T11
Trans9
S13
Resin Mixing 2
T12
Trans10
S14
Pre-Refilling
T13
Trans25
S15
Refilling 2
T14
Trans11
S16
Running-in
T15
Trans14
T16
Trans28
T21
T18
S17
Step6
S18
Step7
T17
Trans17
T18
Trans23
S18
T19
Trans20
T20
Trans19
T21
Trans21
S17
S19
Step3
T22
Trans16
T23
Trans18
S20
Step22
S21
Step9
T24
Trans26
S1
T25
Trans22
S1

S1: Pre-Start

Interlock	Event	Qualifier	Action		
		R - Set to 0	"UA11B001 Needs Regeneration"	"UA11...	%M176.0
		S - Set to 1	"UA11B001 Regenerating"	"UA11...	%M110.2
		<Add new>			



S2: Start

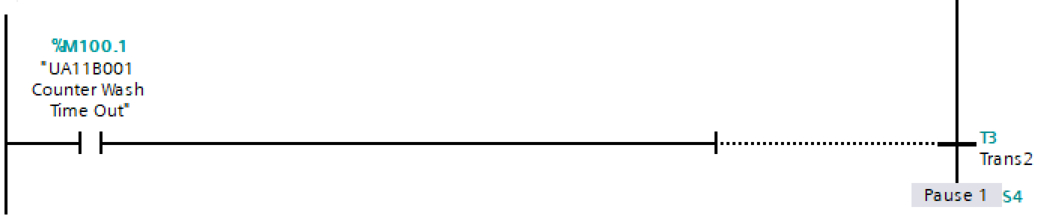
Interlock	Event	Qualifier	Action		
		S - Set to 1	"UA11S008"	"UA11...	%Q4.1
		S - Set to 1	"UA11S017"	"UA11...	%Q4.6
		R - Set to 0	"UA11S007"	"UA11...	%Q4.0
		R - Set to 0	"UA11S012"	"UA11...	%Q4.3
		R - Set to 0	"UA11S014"	"UA11...	%Q4.4
		R - Set to 0	"UA37S002"	"UA37...	%Q6.2
		S - Set to 1	"UA37S003"	"UA37...	%Q6.3
		R - Set to 0	"UA37S001"	"UA37...	%Q6.1
		R - Set to 0	"UA54S002"	"UA54...	%Q7.6
		R - Set to 0	"UA11S009"	"UA11...	%Q4.2
		R - Set to 0	"UA47S002"	"UA47...	%Q7.1
		R - Set to 0	"UA11S015"	"UA11...	%Q4.5
		S - Set to 1	"UA47S003"	"UA47...	%Q7.2
		R - Set to 0	"UA47S001"	"UA47...	%Q7.0
		<Add new>			

S3: Counter Wash

Interlock	Event	Qualifier	Action		
		N - Set as long as step is active	"UA11B001 Raw Water Pumps Start"	"UA11...	%M500.0
		<Add new>			

T3: Trans2

Comment



S4: Pause 1

Interlock	Event	Qualifier	Action		
		R - Set to 0	"UA11S008"	"UA11...	%Q4.1
		<Add new>			

T4: Trans30

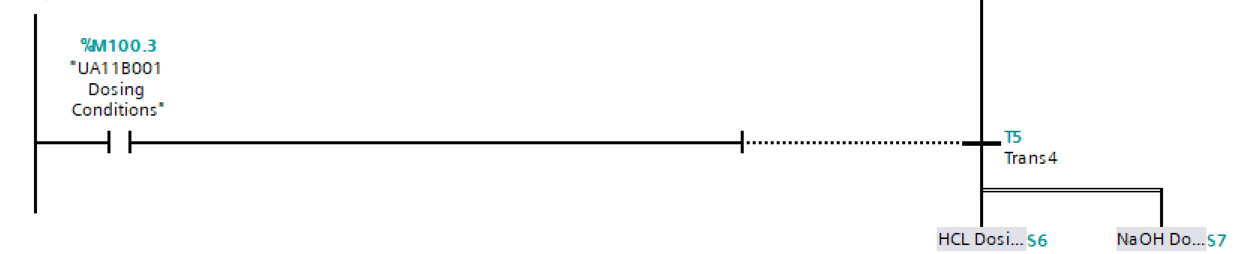
Comment

S5: Pre-Dosing

Interlock	Event	Qualifier		Action		
		R	- Set to 0	"UA11S017"	"UA11..."	%Q4.6
		S	- Set to 1	"UA27S003"	"UA27..."	%Q5.6
		S	- Set to 1	"UA36S001"	"UA36..."	%Q6.0
		S	- Set to 1	"UA28S003"	"UA28..."	%Q5.7
		S	- Set to 1	"UA46S003"	"UA46..."	%Q6.7
		S	- Set to 1	"UA47S001"	"UA47..."	%Q7.0
		S	- Set to 1	"UA47S002"	"UA47..."	%Q7.1
		S	- Set to 1	"UA37S001"	"UA37..."	%Q6.1
		S	- Set to 1	"UA37S002"	"UA37..."	%Q6.2
		S	- Set to 1	"UA11S015"	"UA11..."	%Q4.5
		R	- Set to 0	"UA37S003"	"UA37..."	%Q6.3
		R	- Set to 0	"UA47S003"	"UA47..."	%Q7.2
		<Add new>				

T5: Trans4

Comment



S6: HCl Dosing

Interlock	Event	Qualifier		Action		
		N	- Set as long as step is active	"HCL Dosing Pumps Start"	"HCL ...	%M500.2
		S	- Set to 1	"Dilution Water Pumps Start"	"Dilu...	%M500.4
		<Add new>				

T6: Trans3

Comment

S7: NaOH Dosing

Interlock	Event	Qualifier		Action		
		N	- Set as long as step is active	"NaOH Dosing Pumps Start"	"NaOH...	%M500.3
		S	- Set to 1	"Dilution Water Pumps Start"	"Dilu...	%M500.4
		<Add new>				

T7: Trans5

Comment

S8: HCl Washing

Interlock	Event	Qualifier		Action		
		R	- Set to 0	"HCL Dosing Pumps Start"	"HCL ...	%M500.2
		R	- Set to 0	"UA46S003"	"UA46...	%Q6.7
		<Add new>				

T8: Trans6

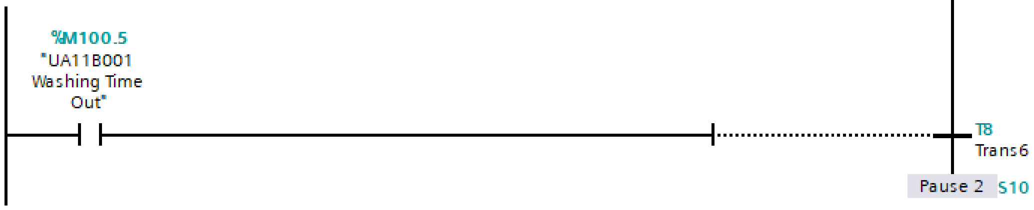
Comment

S9: NaOH Washing

Interlock	Event	Qualifier		Action		
		R	- Set to 0	"NaOH Dosing Pumps Start"	"NaOH...	%M500.3
		R	- Set to 0	"UA36S001"	"UA36...	%Q6.0
		<Add new>				

▼ T8: Trans6

Comment

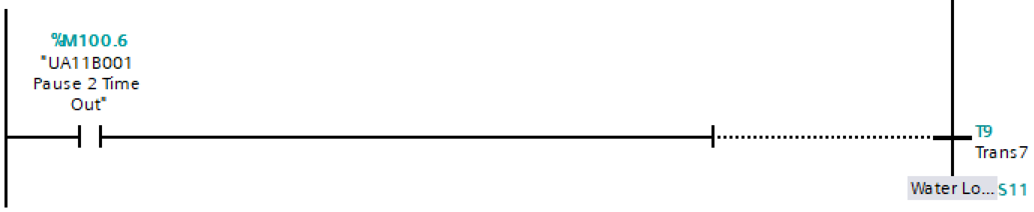


S10: Pause 2

Interlock	Event	Qualifier		Action		
		R	- Set to 0	"Dilution Water Pumps Start"	"Dilu...	%M500.4
		R	- Set to 0	"UA27S003"	"UA27...	%Q5.6
		R	- Set to 0	"UA28S003"	"UA28...	%Q5.7
		R	- Set to 0	"UA47S001"	"UA47...	%Q7.0
		R	- Set to 0	"UA47S002"	"UA47...	%Q7.1
		R	- Set to 0	"UA37S001"	"UA37...	%Q6.1
		R	- Set to 0	"UA37S002"	"UA37...	%Q6.2
		S	- Set to 1	"UA11S017"	"UA11...	%Q4.6
		S	- Set to 1	"UA47S003"	"UA47...	%Q7.2
		S	- Set to 1	"UA37S003"	"UA37...	%Q6.3
		R	- Set to 0	"UA11S015"	"UA11...	%Q4.5
		<Add new>				

▼ T9: Trans7

Comment



S11: Water Level Lowering

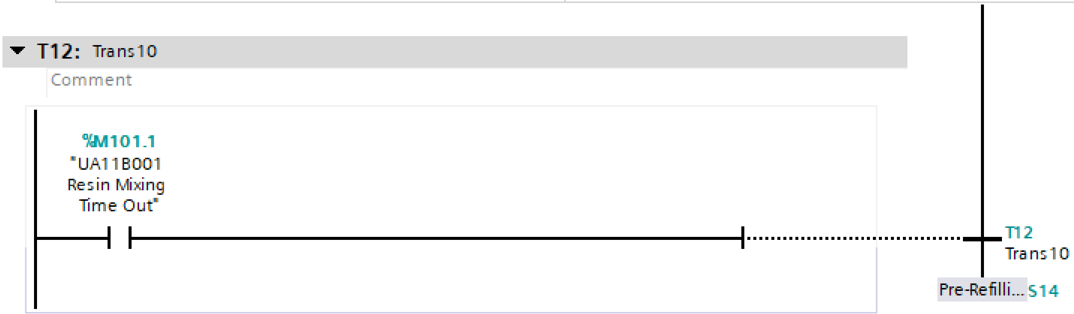
Interlock	Event	Qualifier	Action		
		S - Set to 1	"UA11S015"	"UA11...	%Q4.5
		<Add new>			

S12: Pre-Mixing

Interlock	Event	Qualifier	Action		
		S - Set to 1	"UA54S002"	"UA54...	%Q7.6
		S - Set to 1	"UA11S017"	"UA11...	%Q4.6
		R - Set to 0	"UA11S015"	"UA11...	%Q4.5
		<Add new>			

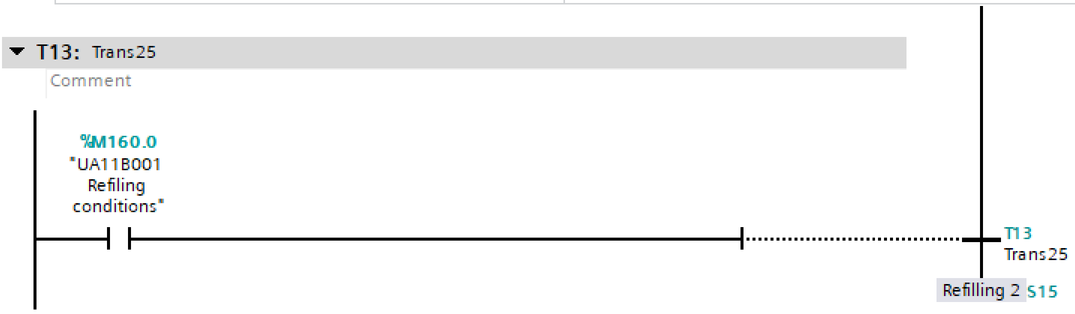
S13: Resin Mixing

Interlock	Event	Qualifier	Action		
		N - Set as long as step is active	"Mixing Air Boosters Start"	"Mixi...	%M500.5
		<Add new>			



S14: Pre-Refiling

Interlock	Event	Qualifier	Action		
		S - Set to 1	"UA11S007"	"UA11...	%Q4.0
		R - Set to 0	"UA54S002"	"UA54...	%Q7.6
		<Add new>			



S15: Refiling

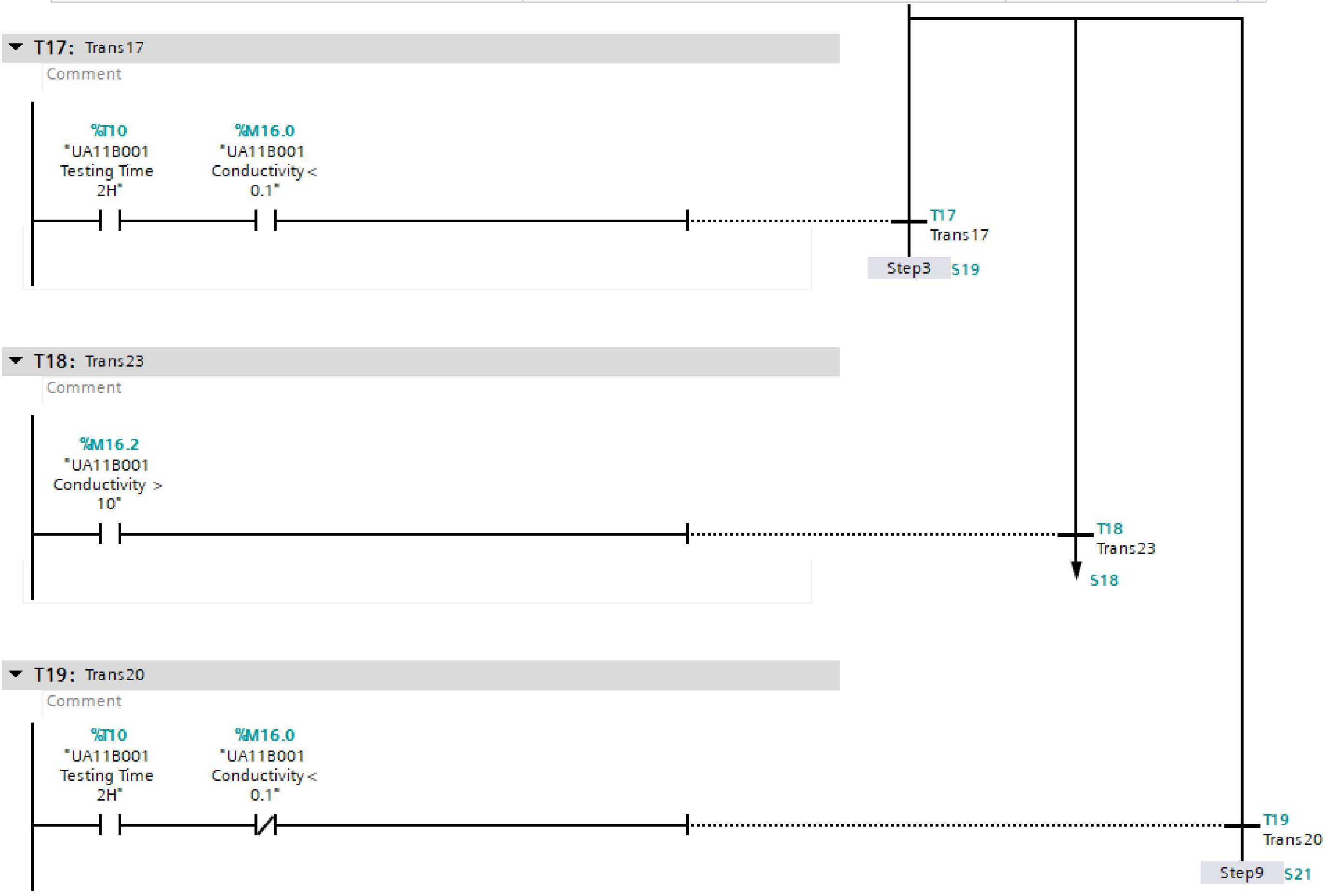
Interlock	Event	Qualifier	Action		
		S - Set to 1	"UA11B001 Raw Water Pumps Start"	"UA11...	%M500.0
		<Add new>			

S16: Running in

Interlock	Event	Qualifier	Action		
		R - Set to 0	"UA11S017"	"UA11...	%Q4.6
		<Add new>			

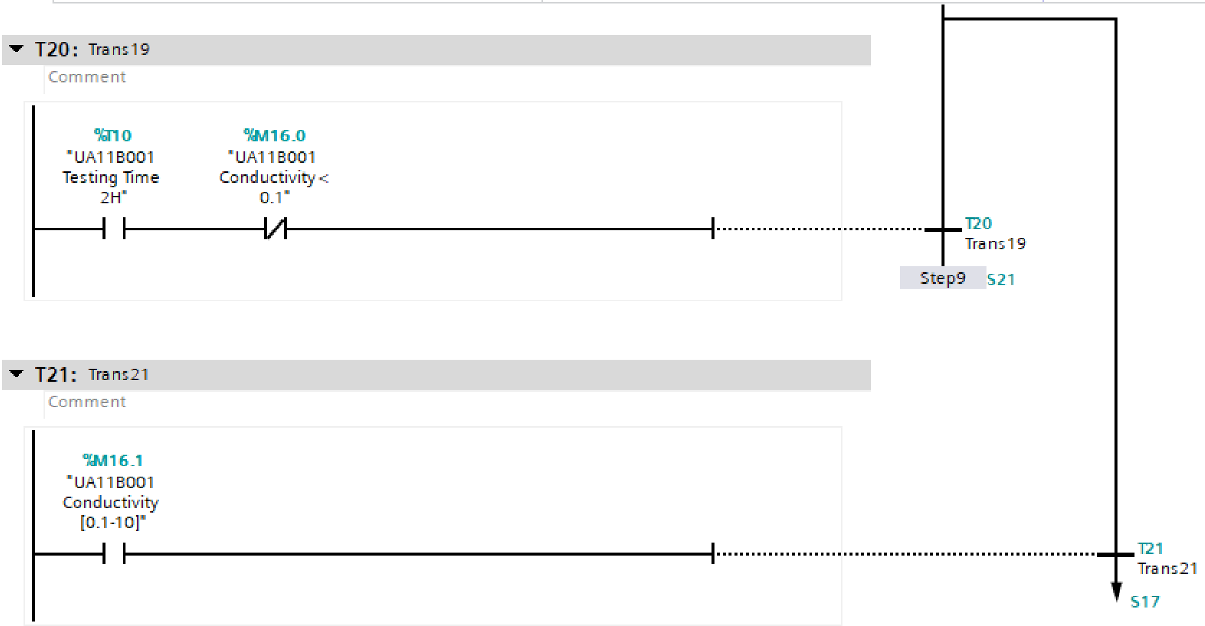
S17: Step6

	Interlock	Event	Qualifier	Action			
			N - Set as long as step is active	"UA11S012"		"UA11...	%Q4.3
			<Add new>				



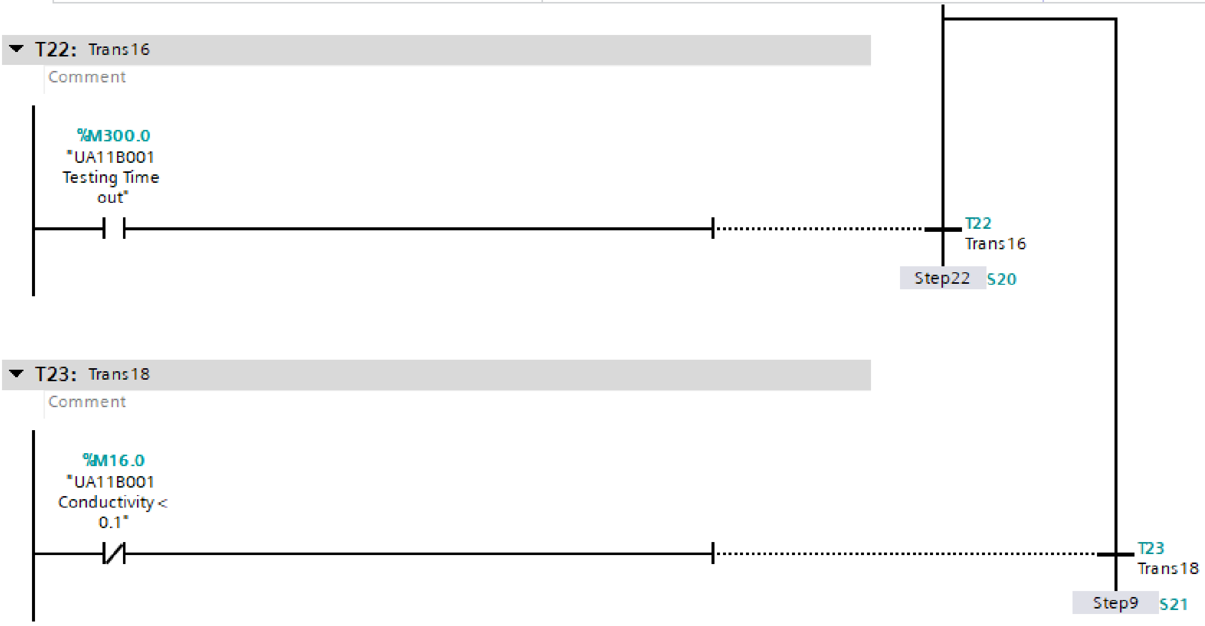
S18: Step7

Interlock	Event	Qualifier	Action		
		N - Set as long as step is active	"UA11S014"	"UA11...	%Q4.4
		<Add new>			



S19: Step3

Interlock	Event	Qualifier		Action		
		N	- Set as long as step is active	"UA11S009"	"UA11...	%Q4.2
		<Add new>				



S20: Step22

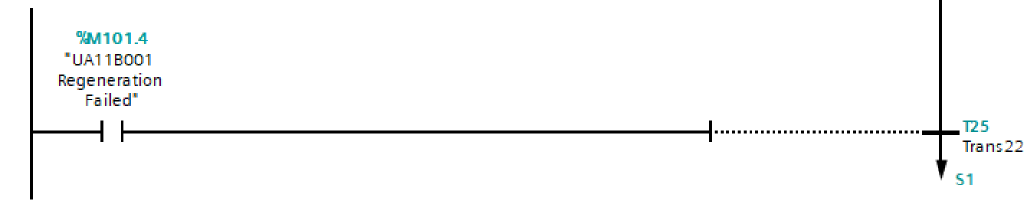
Interlock	Event	Qualifier		Action		
		S	- Set to 1	"UA11B001 Regeneration Succeded"	"UA11...	%M101.5
		R	- Set to 0	"UA11B001 Raw Water Pumps Start"	"UA11...	%M500.0
		R	- Set to 0	"UA11B001 Regenerating"	"UA11...	%M110.2
		<Add new>				

S21: Step9

	Interlock	Event	Qualifier	Action				
			R - Set to 0	"UA11S007"			"UA11..."	%Q4.0
			R - Set to 0	"UA11B001 Raw Water Pumps Start"			"UA11..."	%M500.0
			S - Set to 1	"UA11B001 Regeneration Failed"			"UA11..."	%M101.4
			<Add new>					

T25: Trans22

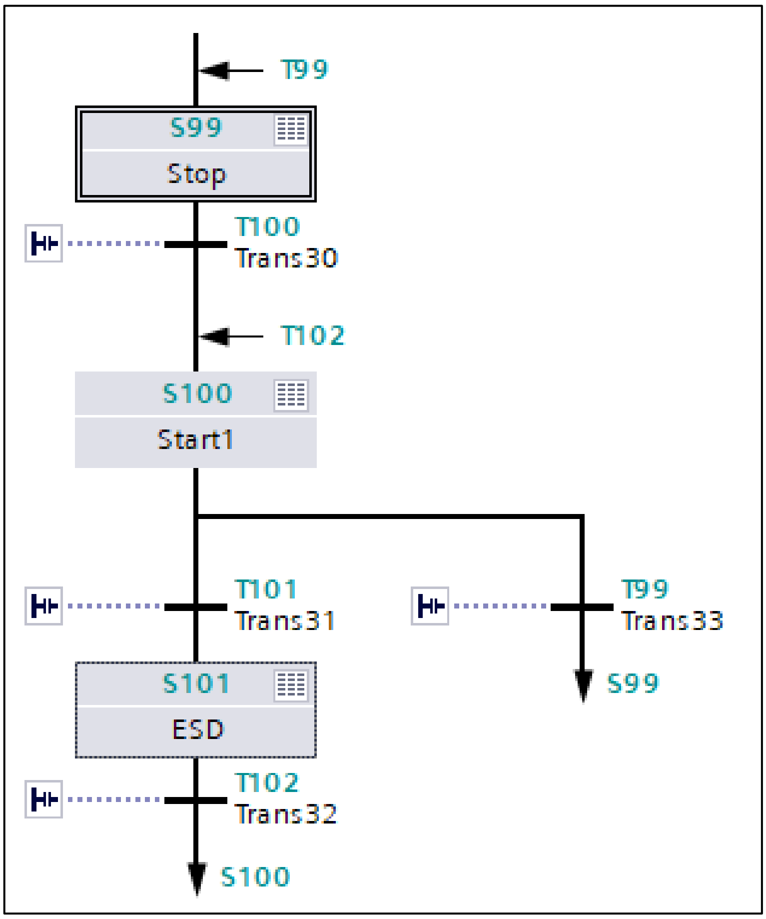
Comment



Appendix F

UA11B001 Regeneration [FB4]

Sequence 1: Stop/Start/ESD

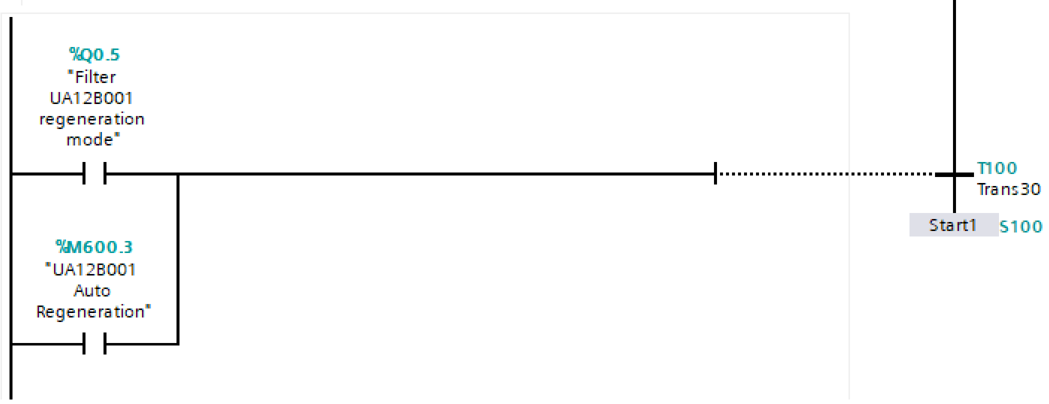


S99: Stop

Interlock	Event	Qualifier	Action		
	S1	OFF - Deactivate step	S_ALL		
		R - Set to 0	"UA12B001 Raw Water Pumps Start"	"UA12...	%M500.1
		R - Set to 0	"HCL Dosing Pumps Start"	"HCL ...	%M500.2
		R - Set to 0	"NaOH Dosing Pumps Start"	"NaOH...	%M500.3
		R - Set to 0	"Dilution Water Pumps Start"	"Dilu...	%M500.4
		R - Set to 0	"Mixing Air Boosters Start"	"Mixi...	%M500.5
		<Add new>			

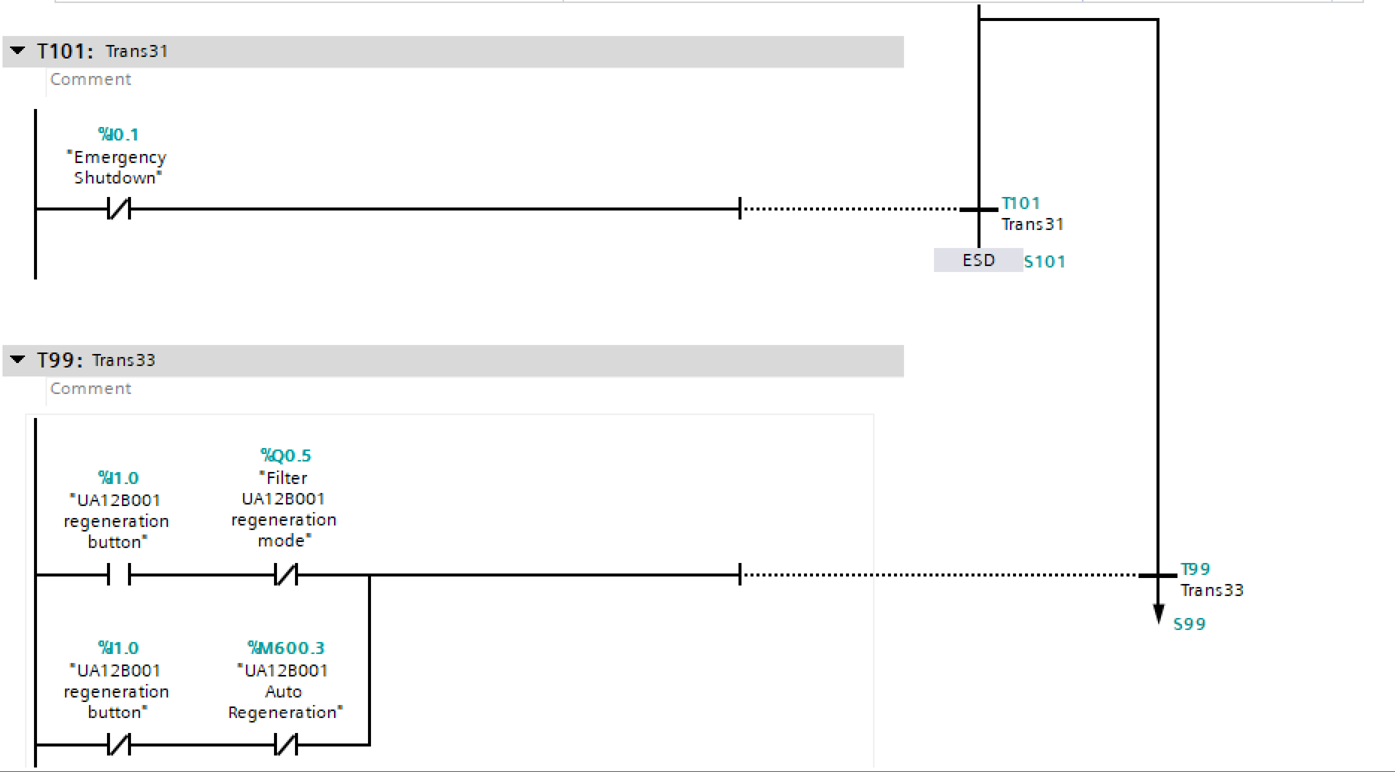
▼ T100: Trans30

Comment



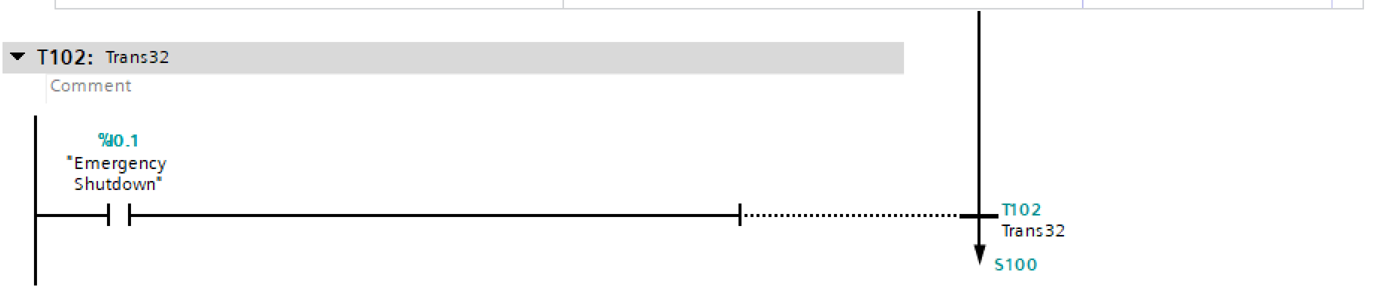
S100: Start1

Interlock	Event	Qualifier		Action		
	S1	ON	- Activate step	#"Pre-Start"		
		<Add new>				

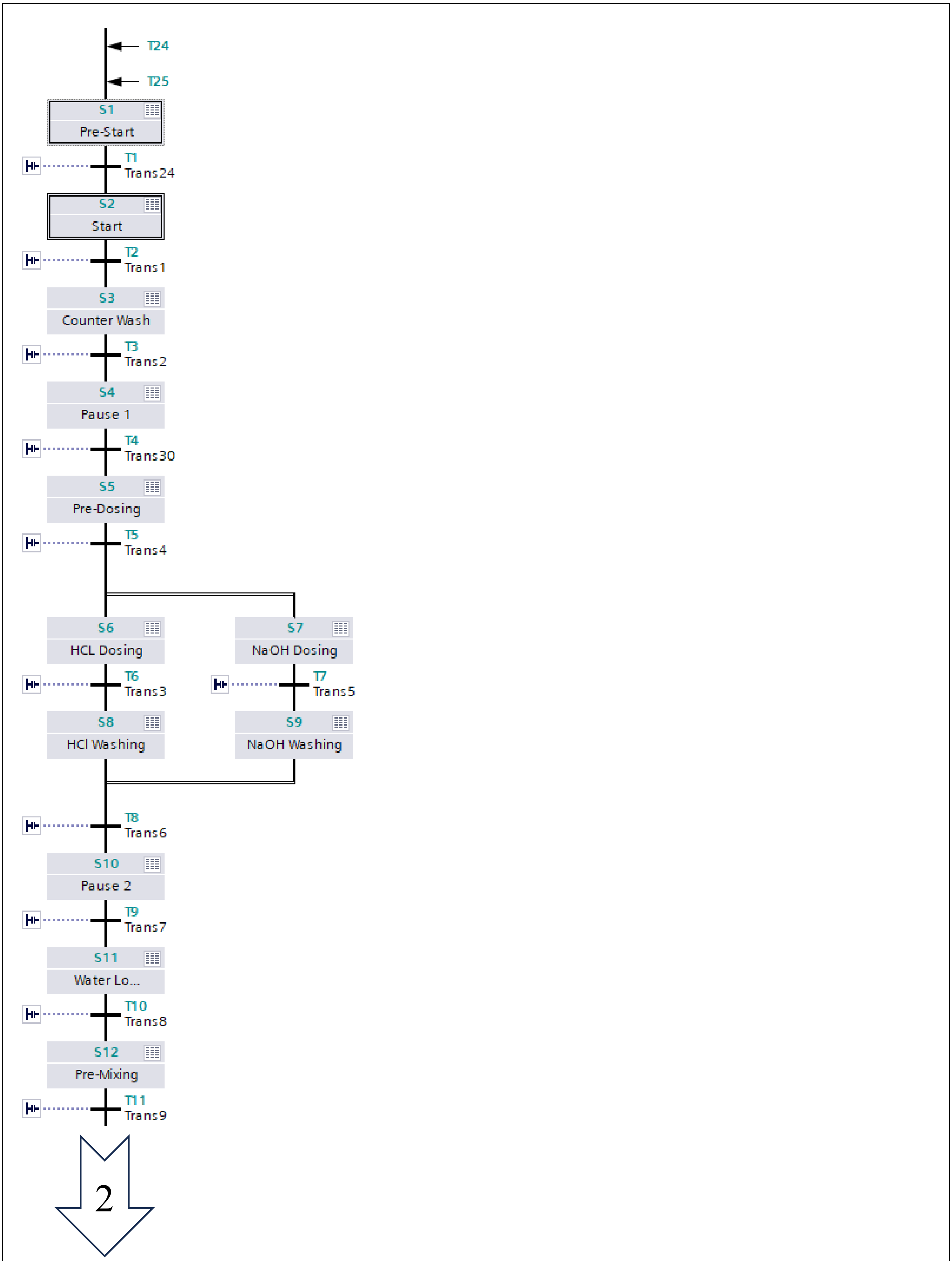


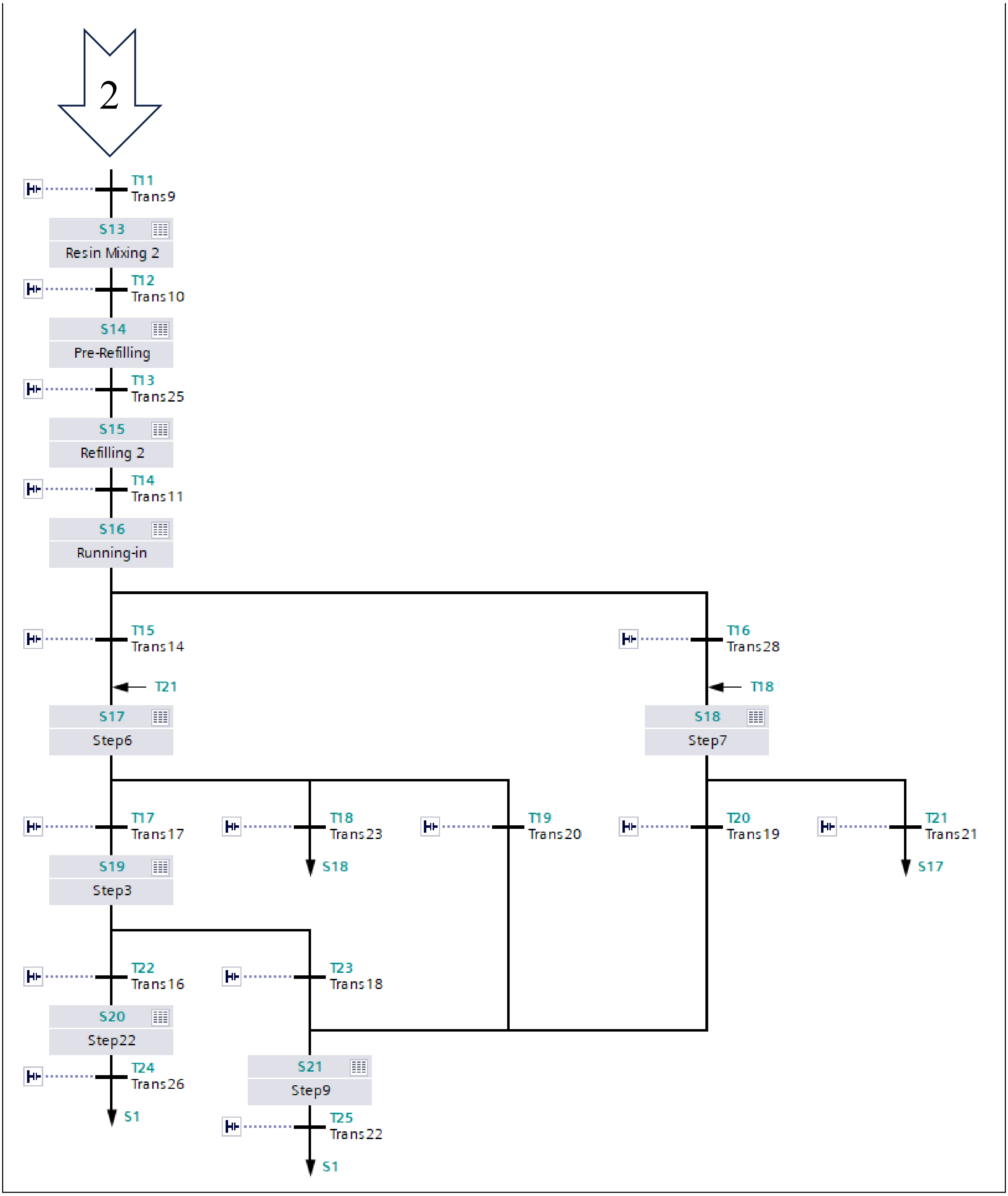
S101: ESD

Interlock	Event	Qualifier		Action		
	S1	OFF	- Deactivate step	S_ALL		
		R	- Set to 0	"UA12B001 Raw Water Pumps Start"	"UA12...	%M500.1
		R	- Set to 0	"HCL Dosing Pumps Start"	"HCL ...	%M500.2
		R	- Set to 0	"NaOH Dosing Pumps Start"	"NaOH...	%M500.3
		R	- Set to 0	"Dilution Water Pumps Start"	"Dilu...	%M500.4
		R	- Set to 0	"Mixing Air Boosters Start"	"Mixi...	%M500.5
		<Add new>				



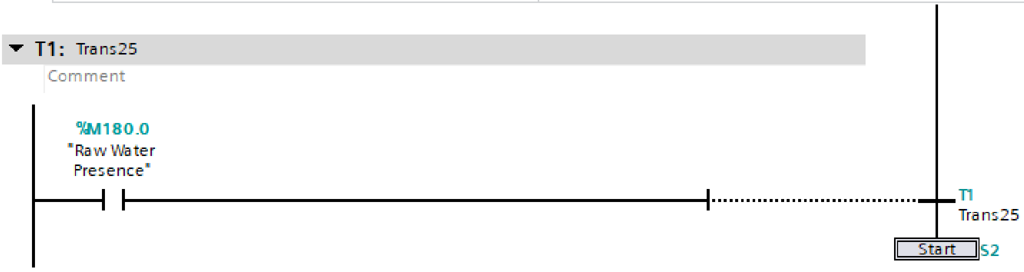
Sequence 2: Regeneration




2
T11
Trans9
S13
Resin Mixing 2
T12
Trans10
S14
Pre-Refilling
T13
Trans25
S15
Refilling 2
T14
Trans11
S16
Running-in
T15
Trans14
T16
Trans28
T21
T18
S17
Step6
S18
Step7
T17
Trans17
T18
Trans23
S18
T19
Trans20
T20
Trans19
T21
Trans21
S17
S19
Step3
T22
Trans16
T23
Trans18
S20
Step22
S21
Step9
T24
Trans26
S1
T25
Trans22
S1

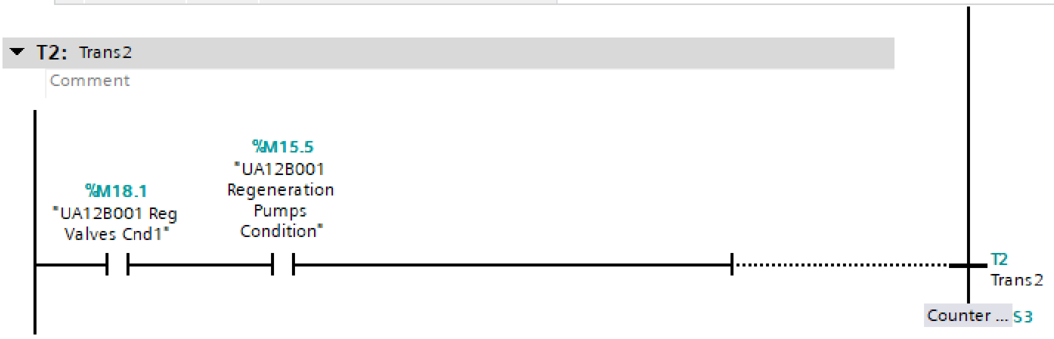
S1: Pre-Start

Interlock	Event	Qualifier	Action		
		R - Set to 0	"UA12B001 Needs Regeneration"	"UA12...	%M176.1
		S - Set to 1	"UA12B001 Regenerating"	"UA12...	%M110.4
		<Add new>			



S2: Start

Interlock	Event	Qualifier	Action		
		S - Set to 1	"UA12S008"	"UA12...	%Q5.0
		S - Set to 1	"UA12S017"	"UA12...	%Q5.5
		R - Set to 0	"UA12S007"	"UA12...	%Q4.7
		R - Set to 0	"UA12S012"	"UA12...	%Q5.2
		R - Set to 0	"UA12S014"	"UA12...	%Q5.3
		R - Set to 0	"UA38S002"	"UA38...	%Q6.5
		S - Set to 1	"UA38S003"	"UA38...	%Q6.6
		R - Set to 0	"UA38S001"	"UA38...	%Q6.4
		R - Set to 0	"UA55S002"	"UA55...	%Q7.7
		R - Set to 0	"UA12S009"	"UA12...	%Q5.1
		R - Set to 0	"UA48S002"	"UA48...	%Q7.4
		R - Set to 0	"UA12S015"	"UA12...	%Q5.4
		S - Set to 1	"UA48S003"	"UA48...	%Q7.5
		R - Set to 0	"UA48S001"	"UA48...	%Q7.3
		<Add new>			



S3: Counter Wash

	Interlock	Event	Qualifier	Action			
			N - Set as long as step is active	"UA12B001 Raw Water Pumps Start"		"UA12...	%M500.1
			<Add new>				

T3: Trans3

Comment

S4: Pause 1

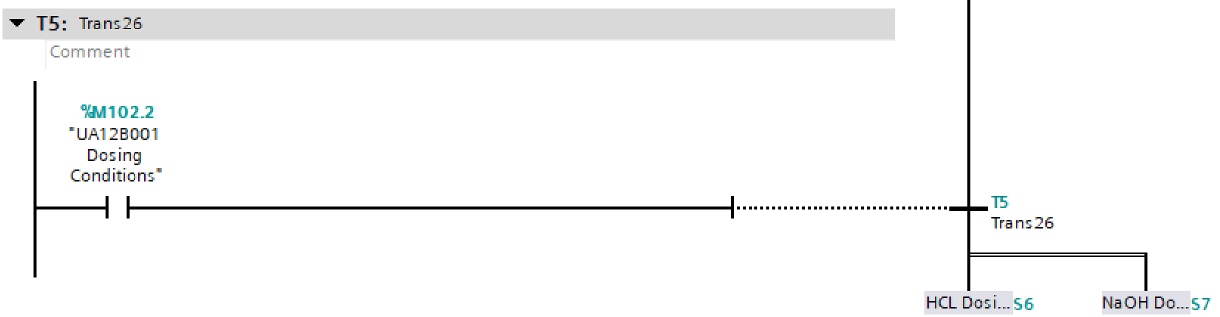
	Interlock	Event	Qualifier	Action			
			R - Set to 0	"UA12S008"		"UA12...	%Q5.0
			<Add new>				

T5: Trans5

Comment

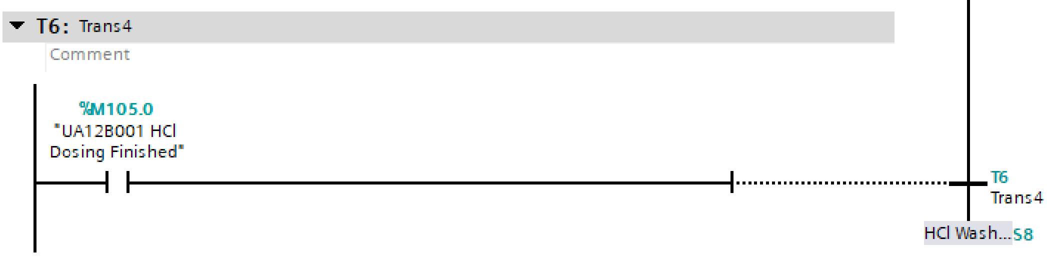
S5: Pre-Dosing

Interlock	Event	Qualifier		Action		
		R	- Set to 0	"UA12S017"	"UA12...	%Q5.5
		S	- Set to 1	"UA27S003"	"UA27...	%Q5.6
		S	- Set to 1	"UA36S001"	"UA36...	%Q6.0
		S	- Set to 1	"UA28S003"	"UA28...	%Q5.7
		S	- Set to 1	"UA46S003"	"UA46...	%Q6.7
		S	- Set to 1	"UA48S001"	"UA48...	%Q7.3
		S	- Set to 1	"UA48S002"	"UA48...	%Q7.4
		S	- Set to 1	"UA38S001"	"UA38...	%Q6.4
		S	- Set to 1	"UA38S002"	"UA38...	%Q6.5
		S	- Set to 1	"UA12S015"	"UA12...	%Q5.4
		R	- Set to 0	"UA48S003"	"UA48...	%Q7.5
		R	- Set to 0	"UA38S003"	"UA38...	%Q6.6
		<Add new>				



S6: HCl Dosing

Interlock	Event	Qualifier		Action		
		S	- Set to 1	"Dilution Water Pumps Start"	"Dilu...	%M500.4
		N	- Set as long as step is active	"HCL Dosing Pumps Start"	"HCL ...	%M500.2
		<Add new>				



S7: NaOH Dosing

Interlock	Event	Qualifier	Action		
		S - Set to 1	"Dilution Water Pumps Start"	"Dilu...	%M500.4
		N - Set as long as step is active	"NaOH Dosing Pumps Start"	"NaOH...	%M500.3
		<Add new>			

S8: HCl Washing

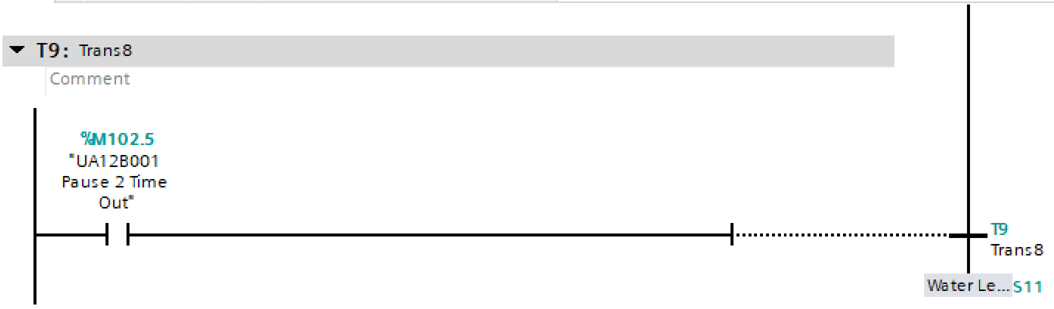
Interlock	Event	Qualifier	Action		
		R - Set to 0	"HCL Dosing Pumps Start"	"HCL ...	%M500.2
		R - Set to 0	"UA46S003"	"UA46...	%Q6.7
		<Add new>			

S9: NaOH Washing

Interlock	Event	Qualifier		Action		
		R	- Set to 0	"NaOH Dosing Pumps Start"	"NaOH...	%M500.3
		R	- Set to 0	"UA36S001"	"UA36...	%Q6.0
		<Add new>				

S10: Pause 2

Interlock	Event	Qualifier		Action		
		R	- Set to 0	"Dilution Water Pumps Start"	"Dilu...	%M500.4
		R	- Set to 0	"UA27S003"	"UA27...	%Q5.6
		R	- Set to 0	"UA28S003"	"UA28...	%Q5.7
		R	- Set to 0	"UA48S001"	"UA48...	%Q7.3
		R	- Set to 0	"UA48S002"	"UA48...	%Q7.4
		R	- Set to 0	"UA38S001"	"UA38...	%Q6.4
		R	- Set to 0	"UA38S002"	"UA38...	%Q6.5
		S	- Set to 1	"UA12S017"	"UA12...	%Q5.5
		S	- Set to 1	"UA48S003"	"UA48...	%Q7.5
		S	- Set to 1	"UA38S003"	"UA38...	%Q6.6
		R	- Set to 0	"UA12S015"	"UA12...	%Q5.4
		<Add new>				



S11: Water Level Lowering

Interlock	Event	Qualifier	Action		
		S - Set to 1	"UA12S015"	"UA12...	%Q5.4
		<Add new>			

T10: Trans9

Comment

S12: Pre-Mixing

Interlock	Event	Qualifier	Action		
		S - Set to 1	"UA55S002"	"UA55...	%Q7.7
		S - Set to 1	"UA12S017"	"UA12...	%Q5.5
		R - Set to 0	"UA12S015"	"UA12...	%Q5.4
		<Add new>			

T11: Trans10

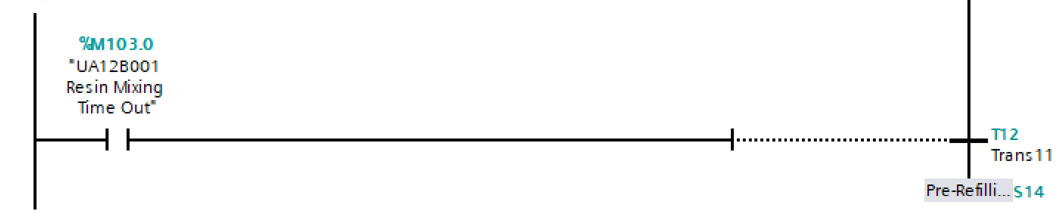
Comment

S13: Resin Mixing

	Interlock	Event	Qualifier	Action			
			N - Set as long as step is active	"Mixing Air Boosters Start"		"Mixi...	%M500.5
			<Add new>				

T12: Trans11

Comment

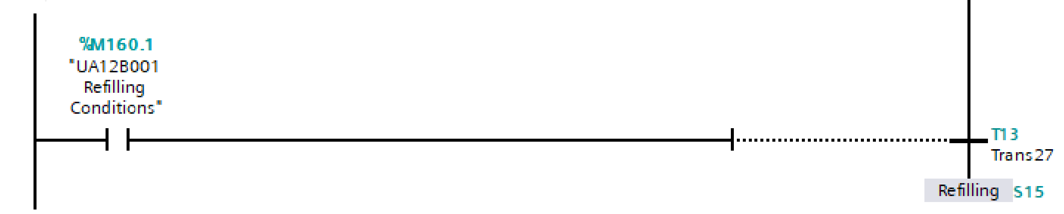


S14: Pre-Refiling

	Interlock	Event	Qualifier	Action			
			S - Set to 1	"UA12S007"		"UA12...	%Q4.7
			R - Set to 0	"UA55S002"		"UA55...	%Q7.7
			<Add new>				

T13: Trans27

Comment

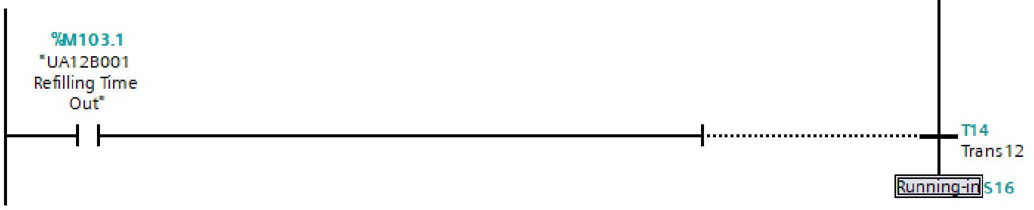


S15: Refiling

Interlock	Event	Qualifier	Action		
		S - Set to 1	"UA12B001 Raw Water Pumps Start"	"UA12...	%M500.1
		<Add new>			

T14: Trans12

Comment

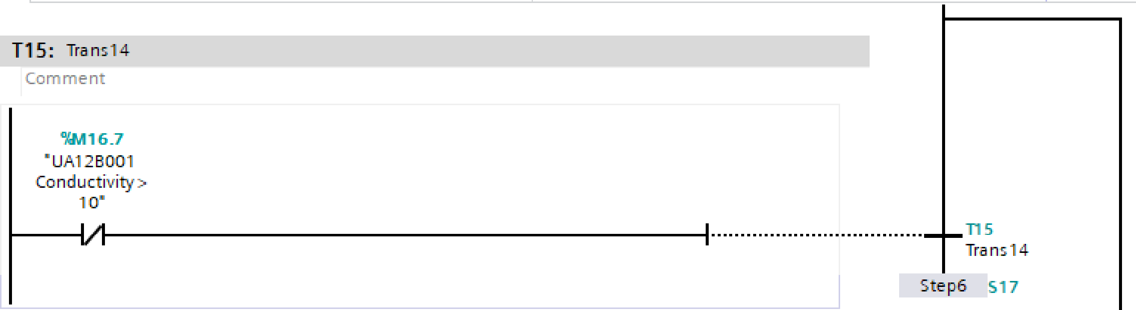


S16: Running in

Interlock	Event	Qualifier	Action		
		R - Set to 0	"UA12S017"	"UA12...	%Q5.5
		<Add new>			

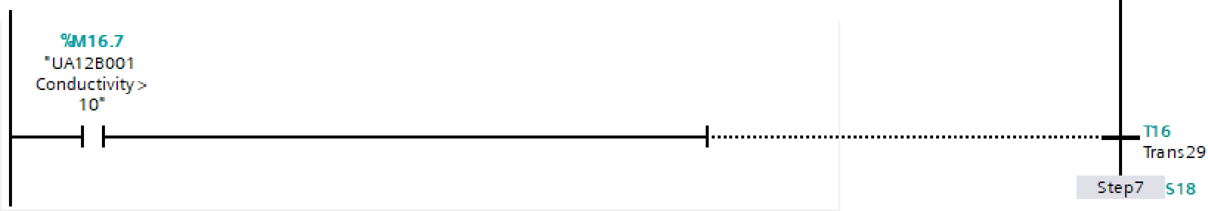
T15: Trans14

Comment



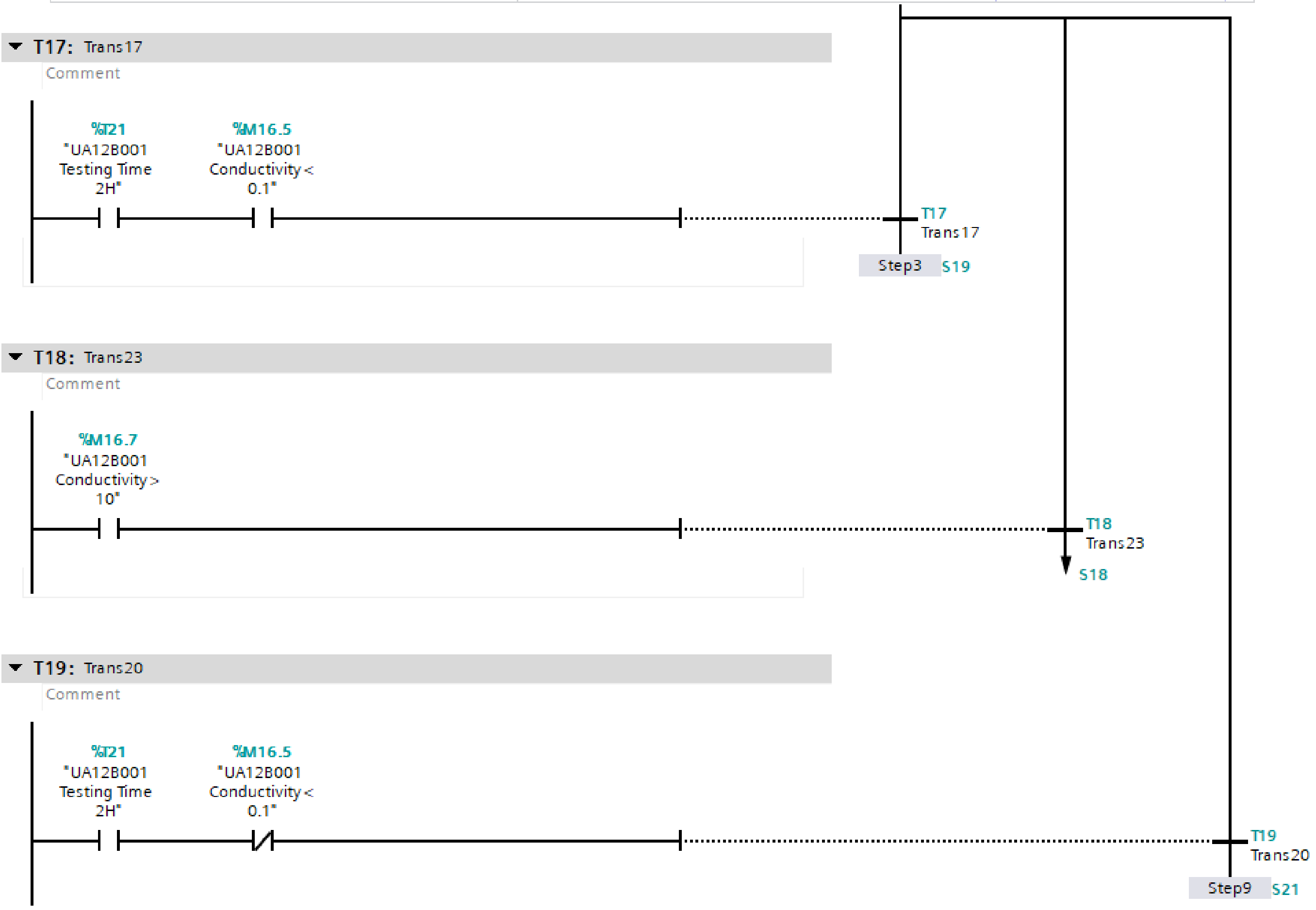
T16: Trans29

Comment



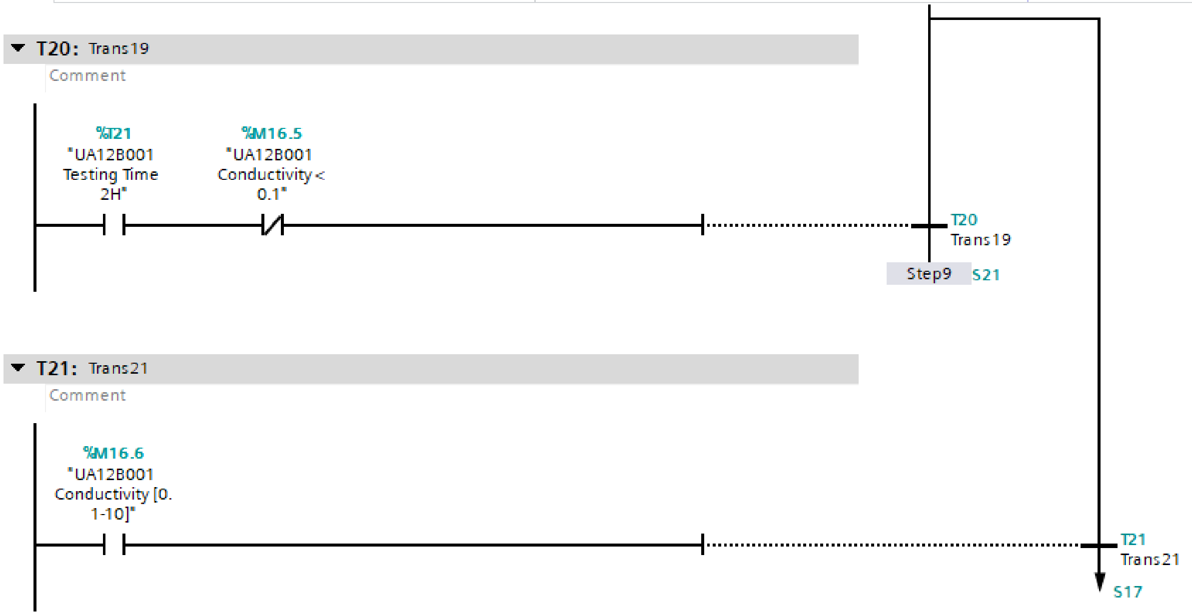
S17: Step6

Interlock	Event	Qualifier	Action		
		N - Set as long as step is active	"UA12S012"	"UA12...	%Q5.2
		<Add new>			



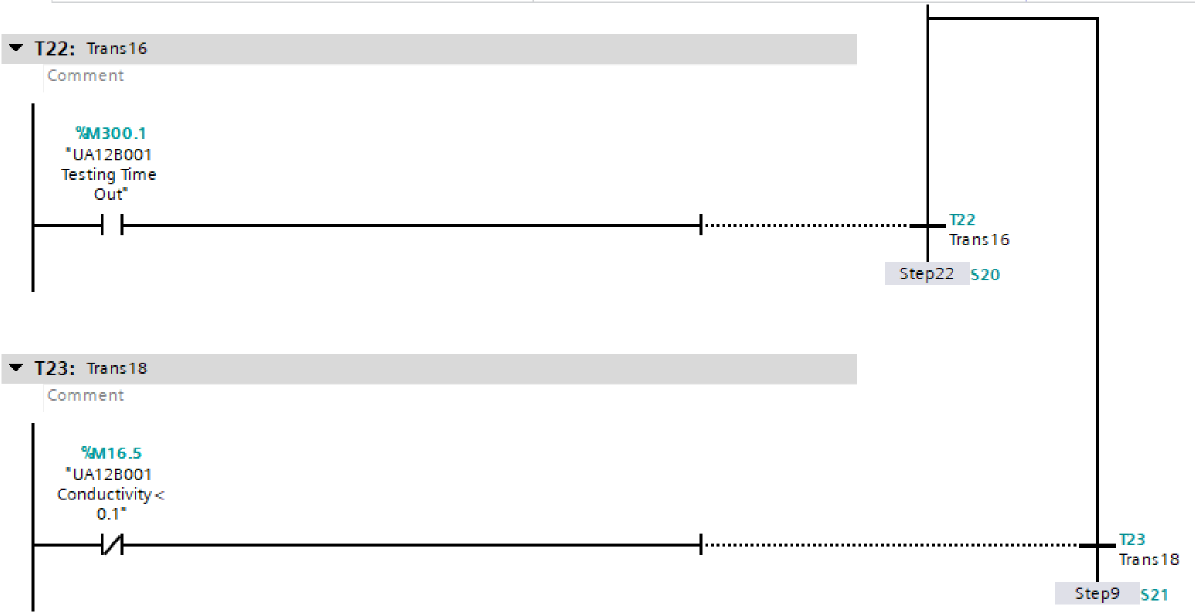
S18: Step7

	Interlock	Event	Qualifier	Action			
			N - Set as long as step is active	"UA12S014"		"UA12...	%Q5.3
			<Add new>				



S19: Step3

	Interlock	Event	Qualifier	Action			
			N - Set as long as step is active	"UA11S009"		"UA11...	%Q4.2
			<Add new>				



S20: Step22

	Interlock	Event	Qualifier	Action			
			S - Set to 1	"UA12B001 Regeneration Succeded"		"UA12...	%M103.3
			R - Set to 0	"UA12B001 Raw Water Pumps Start"		"UA12...	%M500.1
			R - Set to 0	"UA12B001 Regenerating"		"UA12...	%M110.4
			<Add new>				

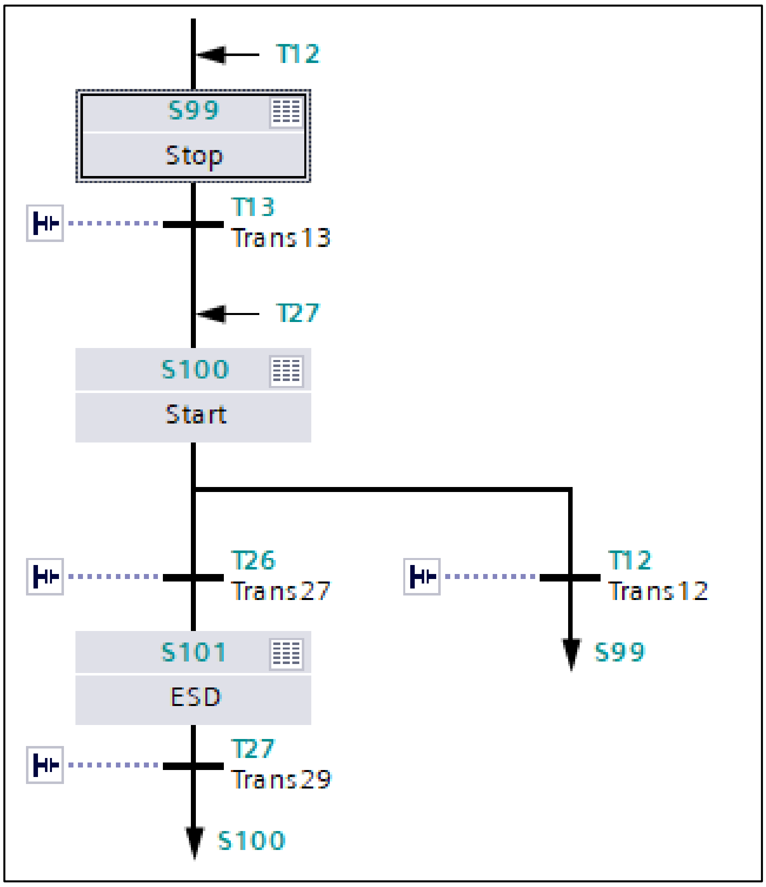
S21: Step9

	Interlock	Event	Qualifier	Action				
			R - Set to 0	"UA12B001 Raw Water Pumps Start"			"UA12...	%M500.1
			R - Set to 0	"UA12S007"			"UA12...	%Q4.7
			S - Set to 1	"UA12B001 Regeneration Failed"			"UA12...	%M103.2
			<Add new>					

Appendix G

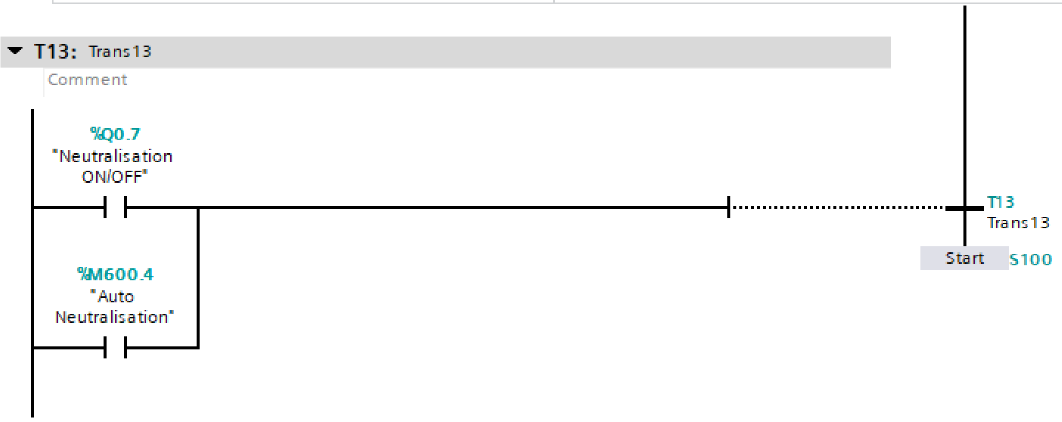
UC10B001 Neutralisation [FB5]

Sequence 1: Stop/Start/ESD



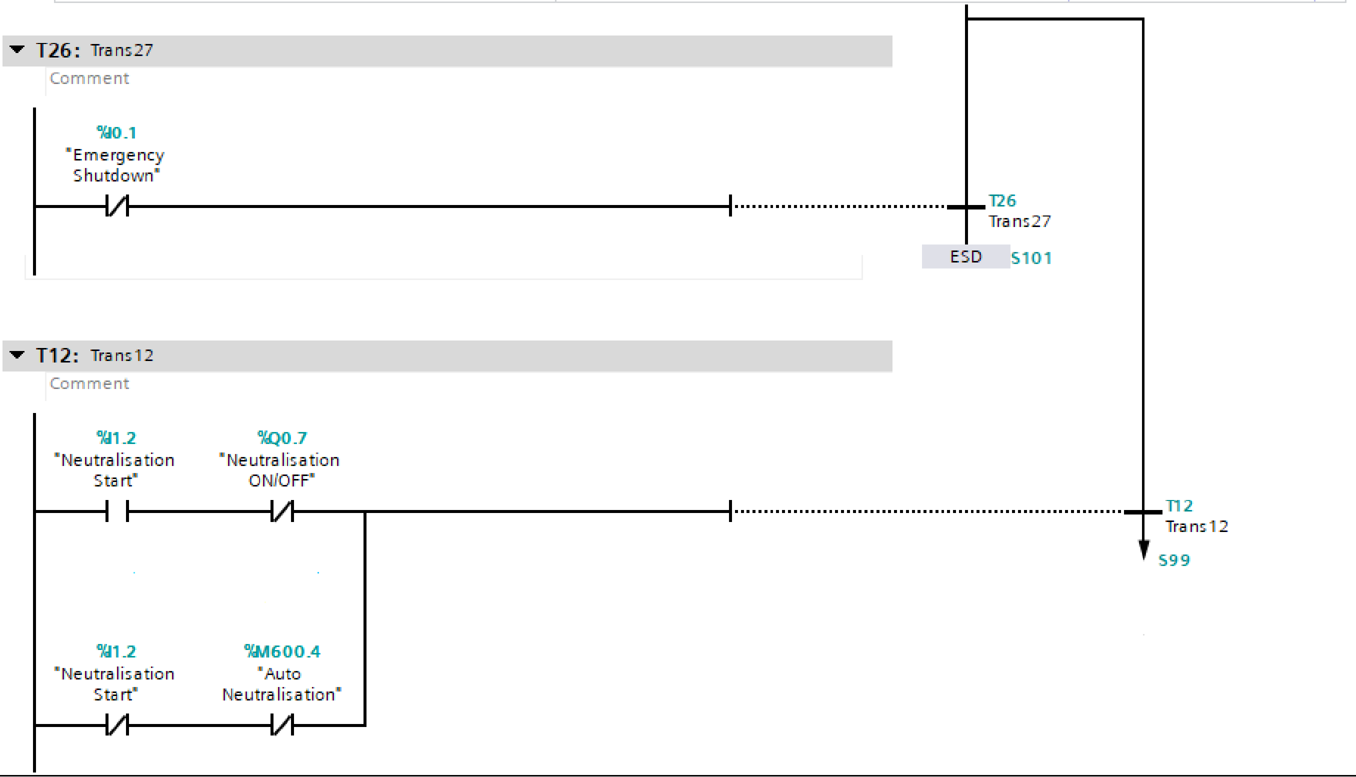
S99: Stop

Interlock	Event	Qualifier	Action			
	S1	OFF - Deactivate step	S_ALL			
		R - Set to 0	"Neutralisation Mixing/Discharge Start"		"Neut...	%M500.6
		<Add new>				



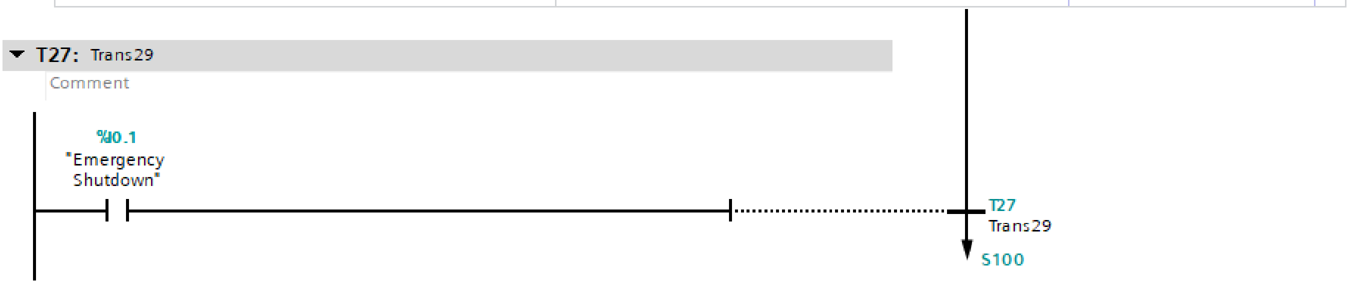
S101: Start

Interlock	Event	Qualifier	Action		
	S1	ON - Activate step	#Step1		
		<Add new>			

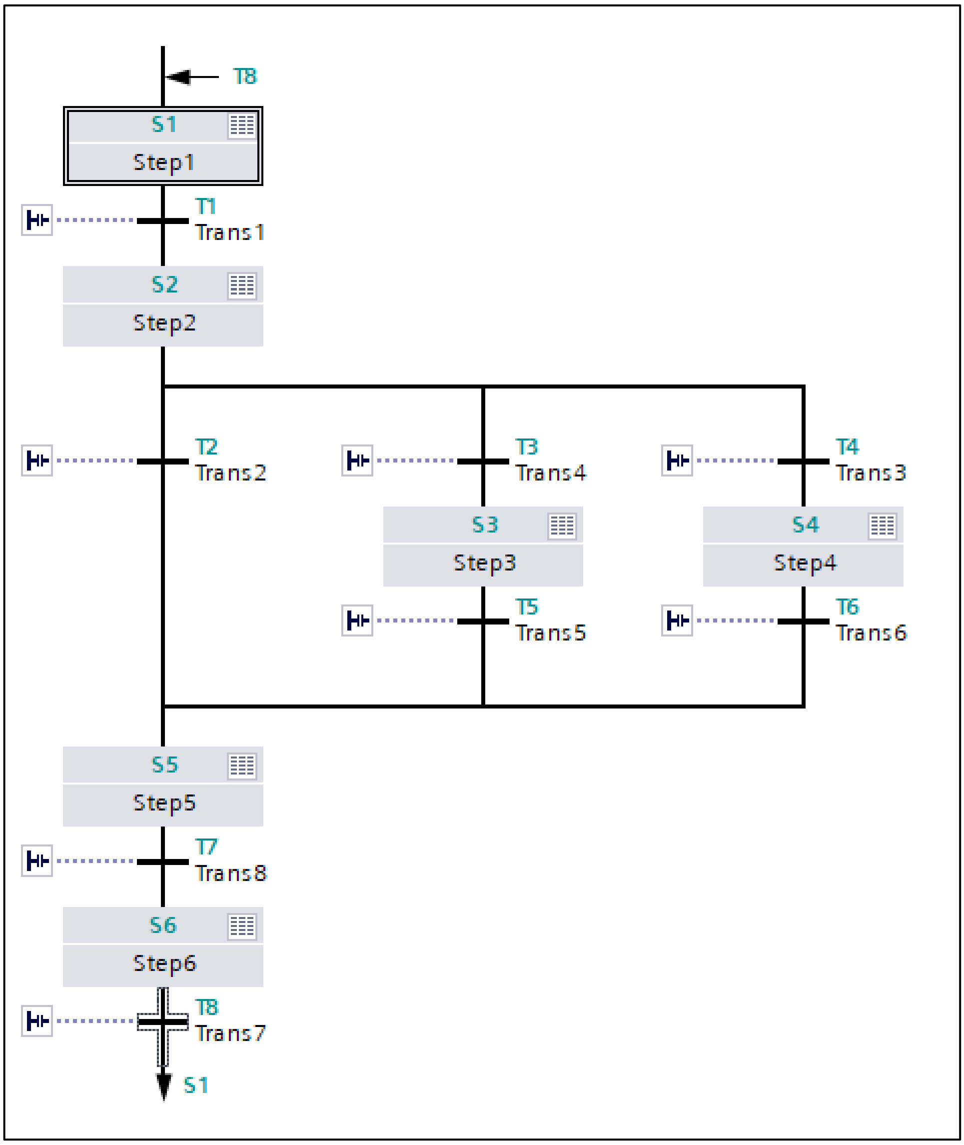


S102: ESD

Interlock	Event	Qualifier	Action		
	S1	OFF - Deactivate step	S_ALL		
		R - Set to 0	"Neutralisation Mixing/Discharge Start"	"Neut...	%M500.6
		<Add new>			



Sequence 2: Neutralisation

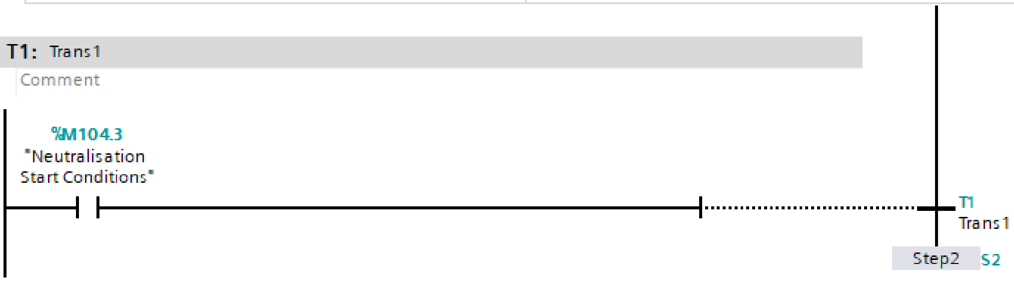


S1: Step1

Interlock	Event	Qualifier	Action		
		R - Set to 0	"UC10S001"	"UC10..."	%Q3.0
		S - Set to 1	"UC10S002"	"UC10..."	%Q3.1
		R - Set to 0	"UC30S003"	"UC30..."	%Q3.2
		R - Set to 0	"UC40S003"	"UC40..."	%Q3.3
		<Add new>			

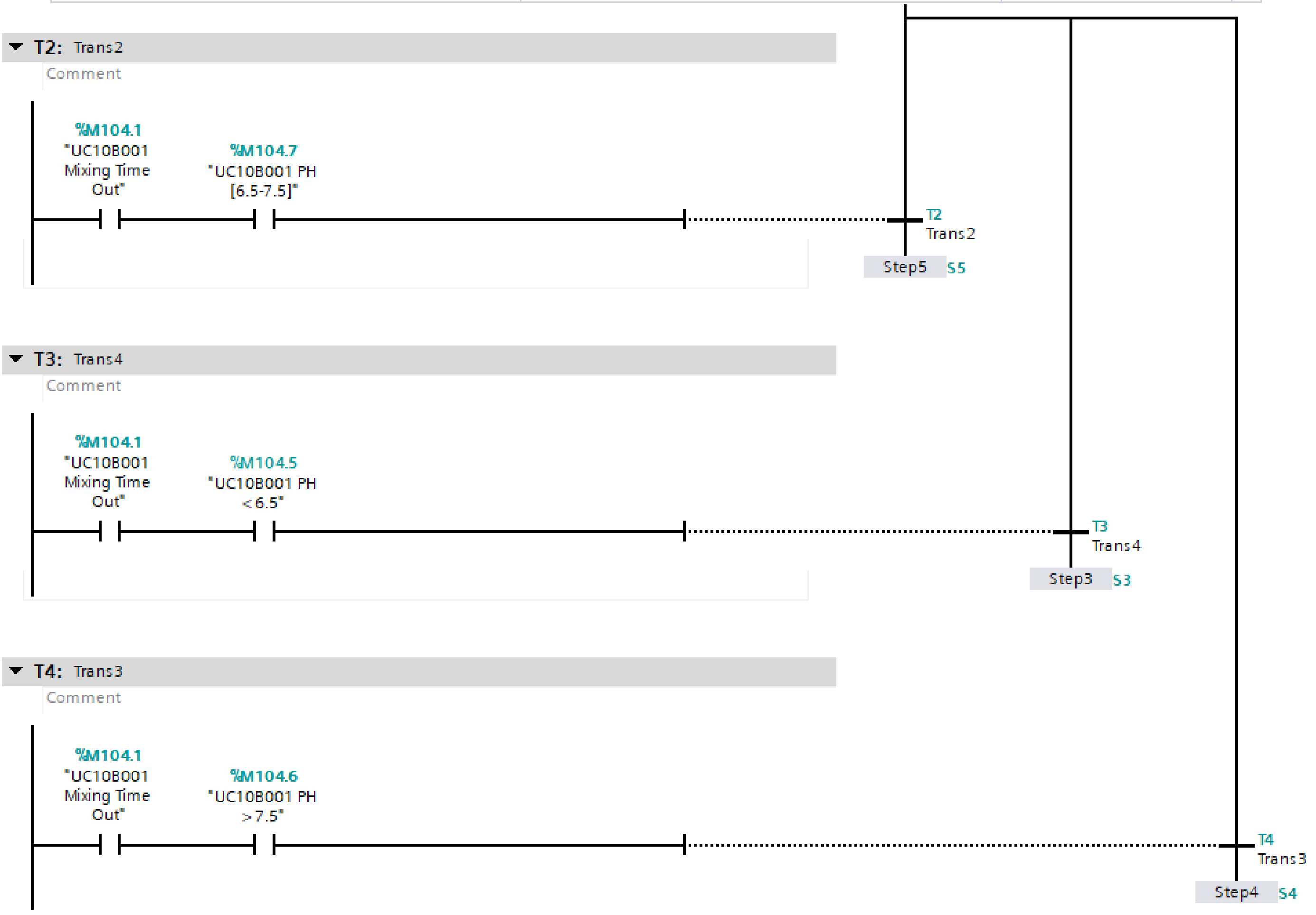
T1: Trans1

Comment

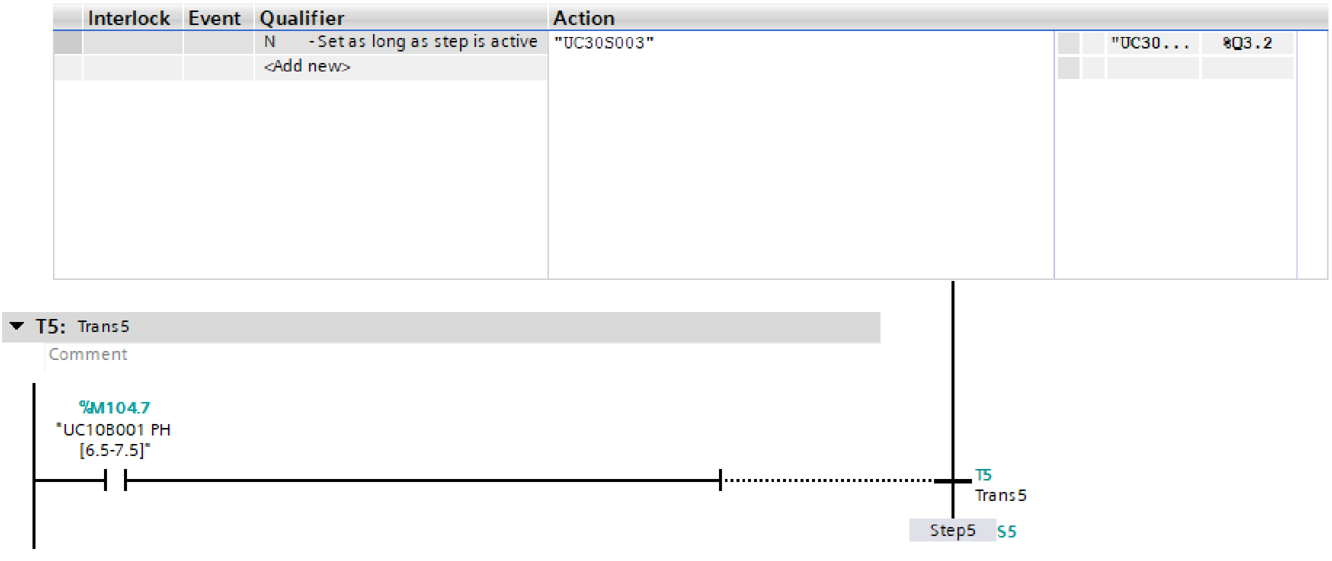


S2: Step2

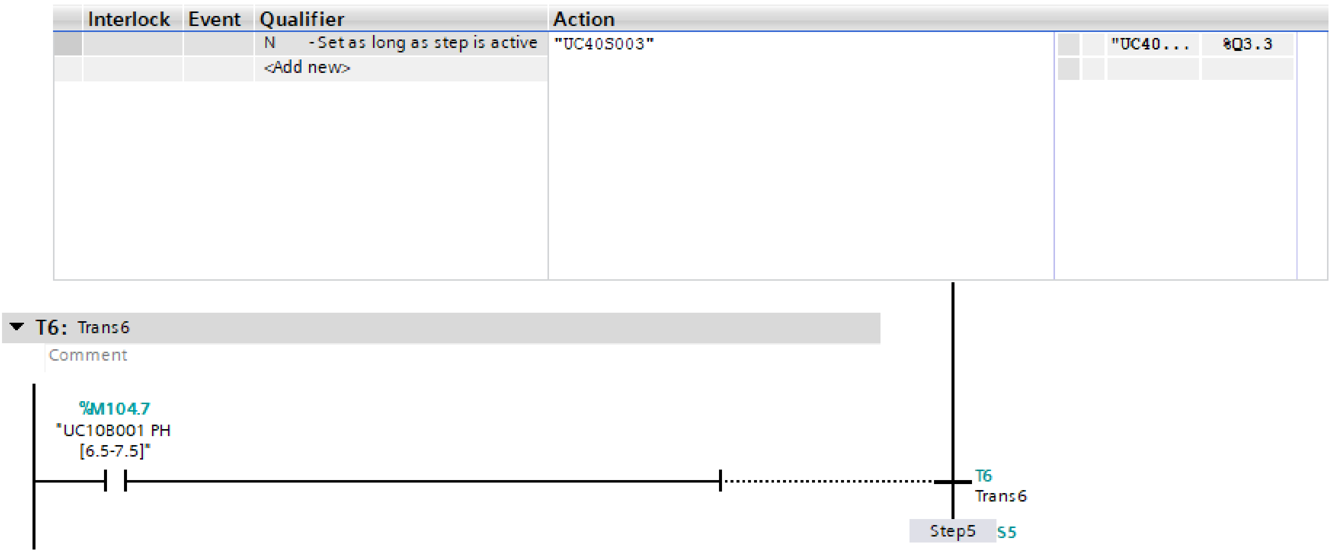
	Interlock	Event	Qualifier	Action			
			S - Set to 1	"Neutralisation Mixing/Discharge Start"		"Neut...	%M500.6
			<Add new>				



S3: Step3



S4: Step4

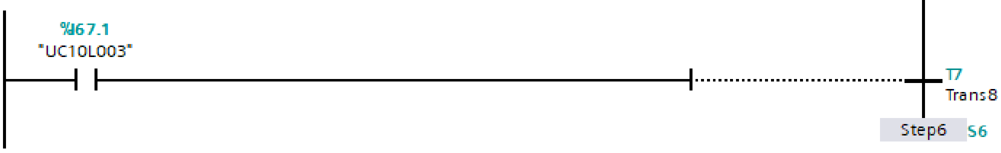


S5: Step5

Interlock	Event	Qualifier	Action		
		R - Set to 0	"UC10S002"	"UC10...	%Q3.1
		S - Set to 1	"UC10S001"	"UC10...	%Q3.0
		R - Set to 0	"UC30S003"	"UC30...	%Q3.2
		R - Set to 0	"UC40S003"	"UC40...	%Q3.3
		<Add new>			

T7: Trans8

Comment

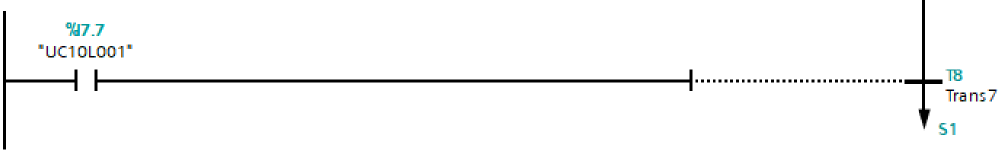


S6: Step6

Interlock	Event	Qualifier	Action		
		R - Set to 0	"Neutralisation Mixing/Discharge Start"	"Neut...	%M500.6
		N - Set as long as step is active	"Neutralisation Ended"	"Neut...	%M103.4
		R - Set to 0	"UC10S001"	"UC10...	%Q3.0
		<Add new>			

T8: Trans7

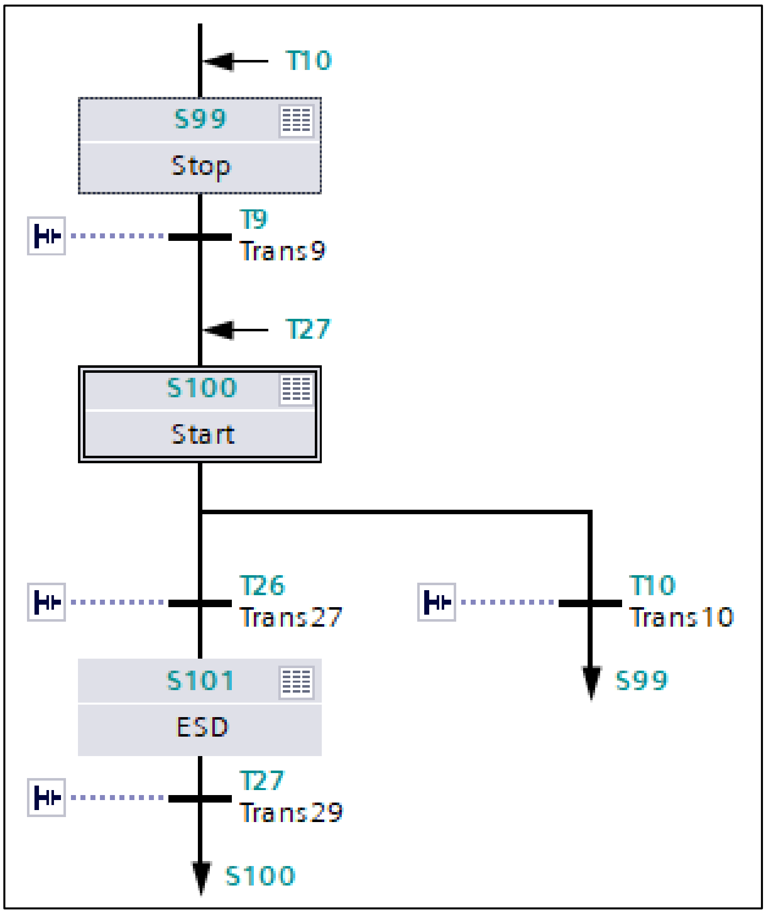
Comment



Appendix H

UC10B001 Fully Automated Station [FB6]

Sequence 1: Stop/Start/ESD

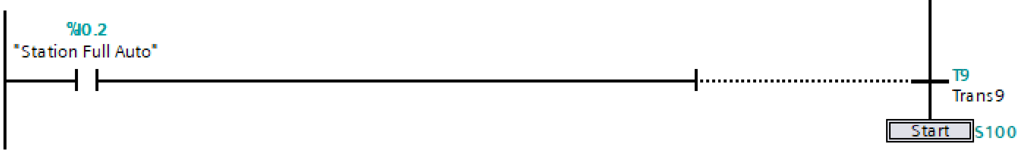


S99: Stop

Interlock	Event	Qualifier	Action		
	S1	OFF - Deactivate step	S_ALL		
		R - Set to 0	"UA11B001 Auto Filtration"	"UA11...	%M600.0
		R - Set to 0	"UA12B001 Auto Filtration"	"UA12...	%M600.1
		R - Set to 0	"UA11B001 Auto Regeneration"	"UA11...	%M600.2
		R - Set to 0	"UA12B001 Auto Regeneration"	"UA12...	%M600.3
		R - Set to 0	"Auto Neutralisation"	"Auto...	%M600.4
		<Add new>			

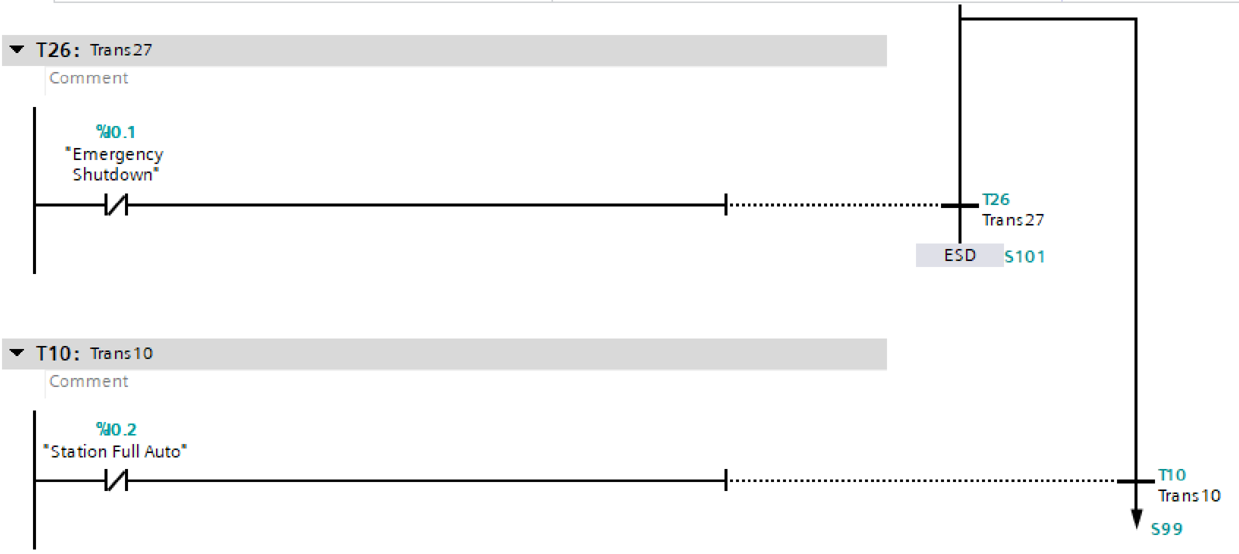
T9: Trans9

Comment



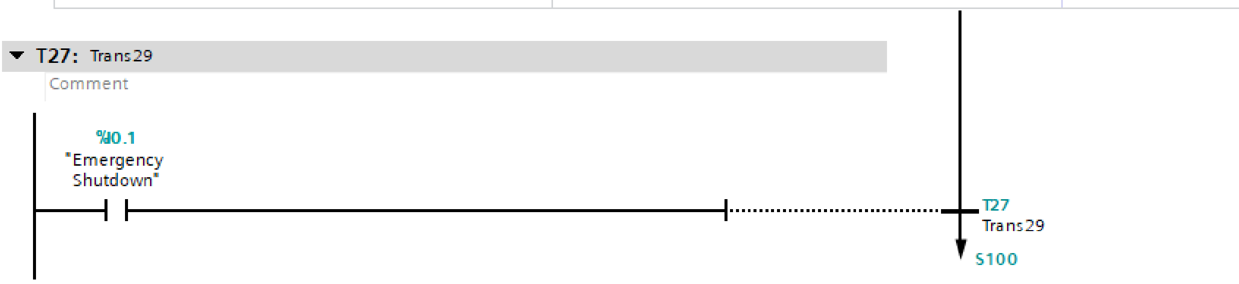
S101: Start

Interlock	Event	Qualifier	Action
	S1	ON - Activate step	#Start1
		<Add new>	

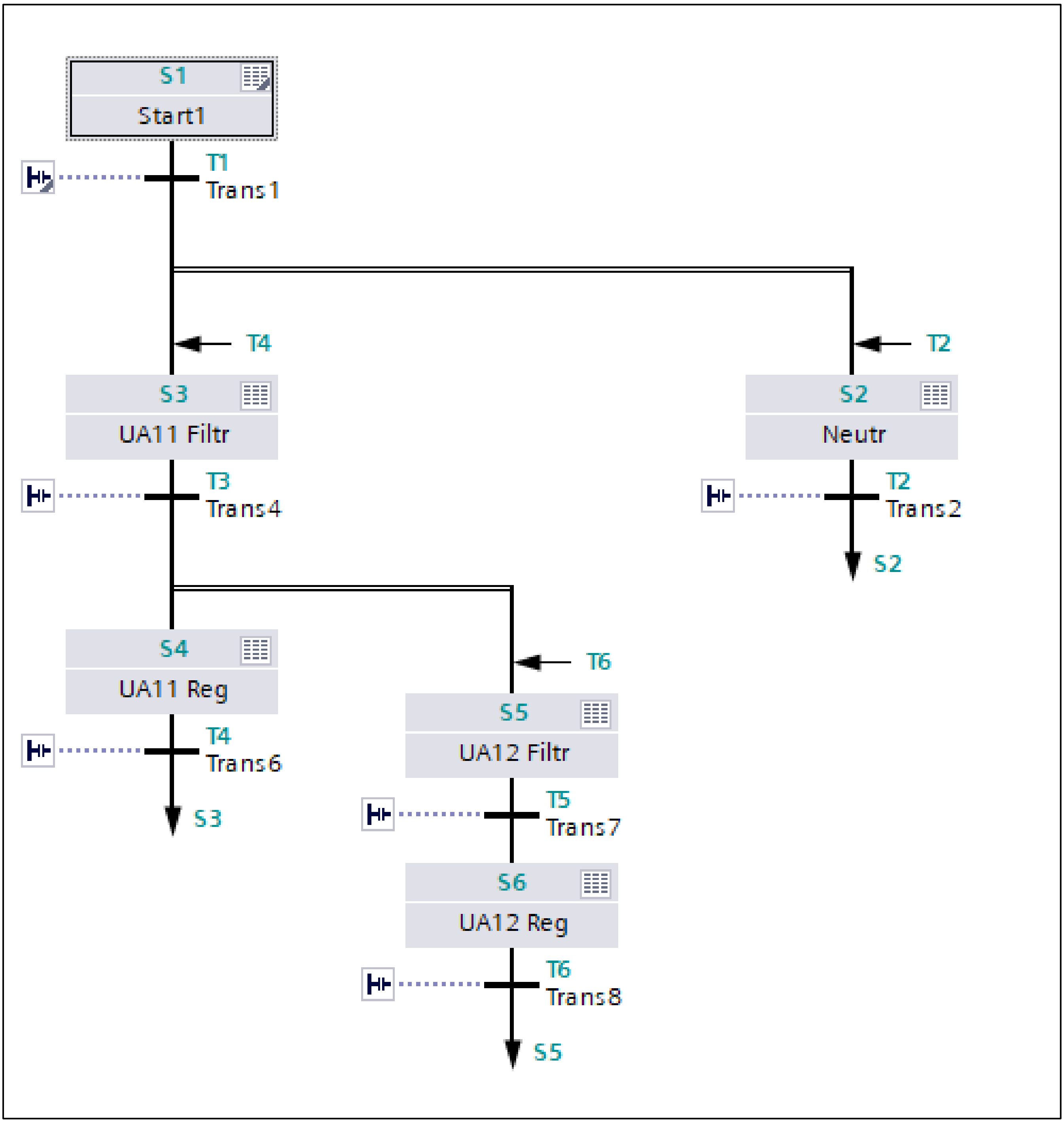


S102: ESD

Interlock	Event	Qualifier	Action		
	S1	OFF - Deactivate step	S_ALL		
		R - Set to 0	"UA11B001 Auto Filtration"	"UA11...	%M600.0
		R - Set to 0	"UA12B001 Auto Filtration"	"UA12...	%M600.1
		R - Set to 0	"UA11B001 Auto Regeneration"	"UA11...	%M600.2
		R - Set to 0	"UA12B001 Auto Regeneration"	"UA12...	%M600.3
		R - Set to 0	"Auto Neutralisation"	"Auto...	%M600.4
		<Add new>			



Sequence 2: Fully Automated Station

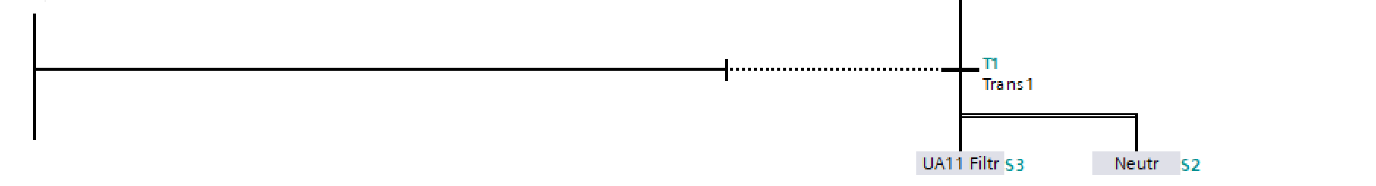


S1: Start1

	Interlock	Event	Qualifier	Action		
			<Add new>			

T1: Trans1

Comment

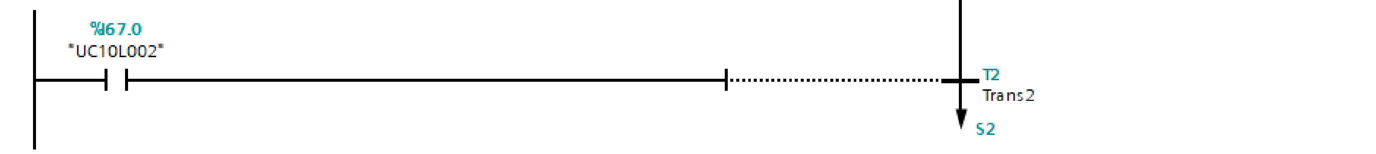


S2: Neutr

	Interlock	Event	Qualifier	Action		
			N - Set as long as step is active	"Auto Neutralisation"	"Auto...	%M600.4
			<Add new>			

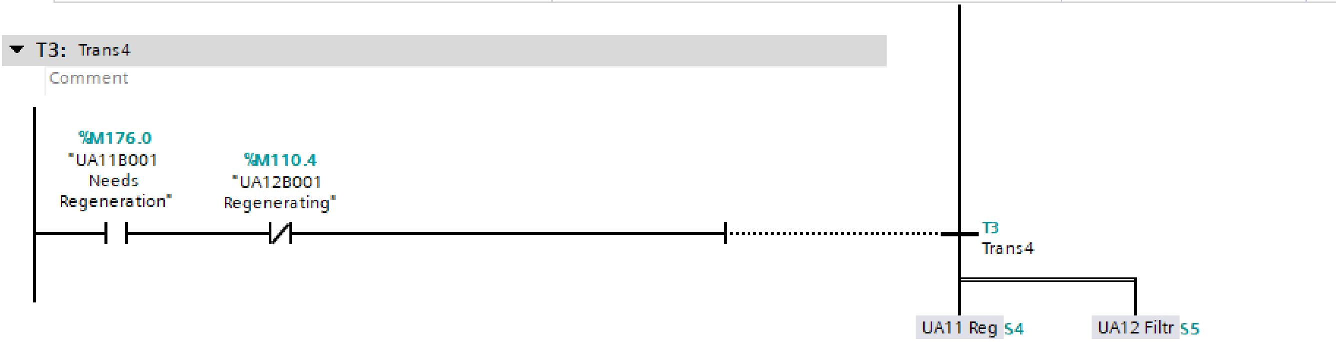
T2: Trans2

Comment



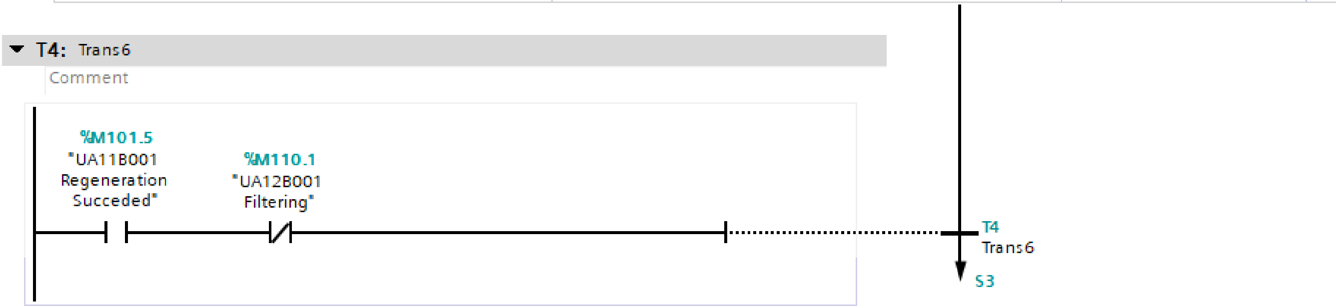
S3: UA11 Filtr

Interlock	Event	Qualifier	Action		
		N - Set as long as step is active	"UA11B001 Auto Filtration"	"UA11...	%M600.0
		<Add new>			



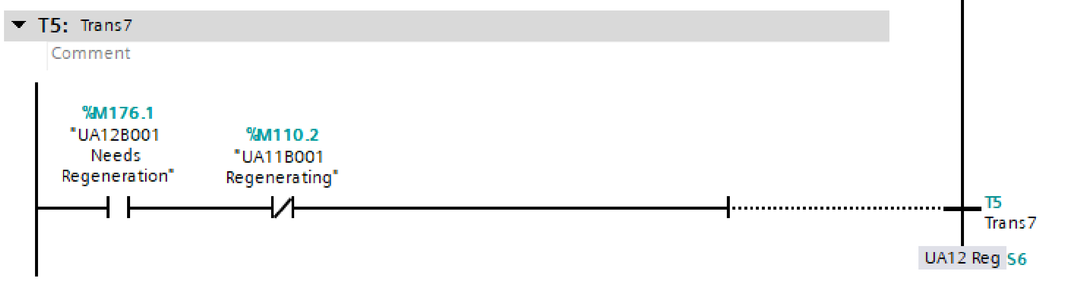
S4: UA11 Reg

Interlock	Event	Qualifier	Action		
		N - Set as long as step is active	"UA11B001 Auto Regeneration"	"UA11...	%M600.2
		<Add new>			



S5: UA12 Filtr

Interlock	Event	Qualifier	Action		
		N - Set as long as step is active	"UA12B001 Auto Filtration"	"UA12...	%M600.1
		<Add new>			



S6: UA12 Reg

Interlock	Event	Qualifier	Action		
		N - Set as long as step is active	"UA12B001 Auto Regeneration"	"UA12...	%M600.3
		<Add new>