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

Institute of Electrical and Electronic Engineering
Department of Power and Control

Project Report Presented in Partial Fulfilment of

The Requirements of the Degree of

'MASTER'

In Electrical and Electronic Engineering

Option: Control Engineering

Title:

Control and Protection Simulation of Steam Turbine, in Cap Djinet Power Plant, Using S7-400 PLC

Presented By:

SELLAMI ABDELMOUMEN

Supervisor:

Dr. OUADI Abderrahmane

Registration Number:......../2020

ABSTRACT

This final year project aim is to study of a safety protection system of the steam turbine in Cap Djinet power plant. The first step is understanding the operation of this steam turbine and its protection system, that is actually based on the wired logic (electronic boards). The second step is selecting the PLC and its modules. A program solution has been developed. This developed solution has been tested and simulated using Siemens software tools (TIA Portal V15).

ACKNOWLEDGEMENTS

First and foremost, I am grateful and thankful to Allah, the most gracious, the most merciful for helping me to finish this modest work.

I place on record my sincere thanks and appreciation to my supervisor Mr. OUADI for the golden opportunity he gave me and all his tremendous efforts in helping. It has been an absolute privilege working with him.

I would like to express my deepest gratitude to my Parents, Family, and Friends for their invaluable support and encouragements.

Finally, a thank you to everyone else who, directly or indirectly, has contributed and helped me accomplish my project.

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

HP: High Pressure
IP: Intermediate Pressure
LP: Low Pressure
MV/LV: MEDUIM VOLTAGE/LOW VOLTAGE
PLC: Programmable Logic Controller
CPU: Central Processing Unit
I/O: input / output
CR: Central Rack
ER: Expansion Rack
UR: Universal Rack
ROM: Read Only Memory
RAM: Read Access Memory
AC: Alternating Current
DC: Direct Current
PS: Power Supply
DI: Digital Input
DO: Digital Output
AI: Analog Input
AO: Analog Output
SM: Signal Module
CM: Communication Module
FM: Function Module
IM: Interface Module
SCADA: Supervisory Control and Data Acquisition
LD: Ladder Diagram
FBD: Function Block Diagram
SFC: Sequential Function Chart
IL: Instruction List
ST: Structured text
OEE: Overall Equipment Effectiveness
TIA: Totally Integrated Automation
OB: Organizational Block
FB: Function Block
FC: Function
DB: Data Block

General Introduction

Modern life requires more and more electrical energy that cannot be found in nature in a directly exploitable form, it is obtained by conversion of other forms of energy such as: hydro, solar, thermal, wind and nuclear energy in production plants. Water and its vapour play particularly an important role in the power plant of "Cap Djinet". Their thermodynamic properties are used when designing the components of the thermal power plant (boiler, turbine, pump and condenser).

Problematic:

Electrical control and monitoring of thermal power plant equipment are currently carried out by a system based on wired logic presenting a major drawback for the maintenance of this equipment and the unavailability of replacement electronic circuit boards, it requires to adopt an adequate programmable control solution.

Constraint:

The quick evolution of new technologies has made it possible to circumvent most of the difficulties encountered in the industry, and provided several possibilities to satisfy the requirements and criteria requested. For this, the thermal power plant launched the project automation of its groups by replacing conventional control devices based on logic wired by others much more efficiently and advantageously, that would certainly be the industrial programmable logic controller that is becoming in our days the heart of all modern industrial units.

Solution:

Industrial programmable logic controllers (PLC) are used to control the industrial systems with more ease of operation. The sensors are connected via the input interfacing to enter the information whereas the commands (the orders) are returned to actuators via the output interfaces, in order to perform the desired tasks according to a user program written in the memory of a central processing unit (CPU). PLCs, then give the control of more reliable, efficient industrial systems and reduce the time of performance of operations as well as the maintenance costs.

Study development:

In this final year project, we will be particularly interested in the steam turbine protection control system. Our project consists in the migration of the control and protection system from the wired technology located at the power plant to the programmed technology based on a PLC. Hence, our goal is to develop a program for the control of these protections and we will have opted for the choice of a PLC.

To do this we will organize the plan of our memory as follows:

- The first chapter will be devoted to the presentation and principle of the operation of the power plant.
- Next, the second chapter describes the steam turbine.
- After that in the third chapter, the turbine protection control system is presented.
- The fourth chapter includes the hardware selection and programming.
- Finally, we will end with a general conclusion.

Chapter 01:
Presentation of the power plant "Cap Djinet"

Introduction:

The production of electricity with large quantities is a major challenge because of the continuous increase in energy consumption, so it is necessary to ensure safe, efficient and continuous production. To achieve this, human beings have developed several ways of producing electrical energy, the most common ones are: nuclear power plants, fossil fuel power plants and hydroelectric power plants.

In this chapter, a general presentation of the CAP DJINET thermal power plant will be given, with a brief description of a production unit, the general auxiliaries and the electrical auxiliaries involved in the electrical energy production cycle.

1.1 Presentation of the power plant: [2]

1.1.1 Location of the plant:

The power station is located on the seaside 65 km east of Algiers near the town of RAS DJINET in the Willaya of BOUMERDES and occupies an area of 35 hectares. The choice of this site was made based on the following criteria:

- The proximity of the sea.
- The proximity of important consumers located notably in the industrial zone of ROUIBA - REGHAIA.
- Possibility of extension.
- Favourable subsoil (underground) conditions that do not require deep foundations.

1.1.2 History:

The plant was built by a consortium of: Austro - German: SIEMENS-KWU-SGP, SIEMENS (Austria), KWU: KRAFTWERK-AG (RFA) and SGP: SIMMERING GRAZ PAUKER (Austria). The first delivery of electrical energy to the grid took place on 17 June 1986 [1].

The commissioning of the production units took place as follows:

Table 1.1-1 The commissioning of the production units

1st unit	2nd unit	3rd unit	4th unit
December 1985	April 1986	September 1986	December 1986.

1.2 Organization of the power plant:

It is made up of four (04) groups with a power of 176 MW each with a total capacity of 704 MW. The total consumption of the auxiliaries is about 32 MW so that the net power supplied to the national grid is 672MW.

Each group of the plant is composed of: steam generators (boiler), turbines, condenser, pumps, heaters, feed water tank, deaerator and alternator.

1.2.1 Steam generator (boiler): [3]

A steam generator or boiler is a device designed to produce a specific amount of water vapour under certain pressure and temperature conditions. The steam generators are of the natural circulation type because the water in the steam drum falls to the lower collector, with the combustion chamber pressurized and with heating.

The fuel supply is provided by eight burners in four levels on the front wall before each steam generator.

Each steam generator includes: Carrier tubes, three (03) superheater (a primary superheater (convection), a secondary superheater (radiation) and a tertiary superheater (convection)), a reheater, a steam drum, an economizer, three (03) water coolers, two (02) recycling ventilators to control the temperature of the reheater and two (02) feed air ventilators providing to ensure the required air flow of the combustion.

It is characterized by:

Table 1.2-1 characteristics of the boiler

Minimum steam flow rate	Qmin=130 litter/sec
Maximum steam flow rate	Qmax=530 litter/sec
Nominal steam flow rate	Qnom=523 litter/sec
Superheated steam pressure	160 bar
Reheated steam pressure	36bars
Overheated steam temperature	540°C
Superheated steam temperature	540°C
Feed water temperature	246°C

1.2.1.1 Operation principle :

the feed water flows to increase its temperature within the economizer, then passes the steam drum through the combustion chamber, this water flows through the circulating tubes (carrier tubes) that are exposed by the rays of the flames(burners), a water-vapour mixture is obtained that goes up to the steam drum in which we will have the lower part that consists of water and the upper part which consists of the steam.

Figure 1.2-1 Boiler

1.2.2 Turbine: [3]

It is the most essential element in the power plant, it transforms thermal energy contained in the steam from the boiler in a rotational movement of the shaft, the mechanical work obtained is used to drive the alternator. The turbine has six (06) outlets which feed three (03) LP feed heaters, and two (02) HP feed heaters (HP) and the feed water tank. The turbine and alternator rotors are rigidly coupled.

The turbine of the power plant is composed of three (03) cores which are:

1.2.2.1 High pressure(HP) core :

It is a single flow turbine with an outlet S6 that feeds the HP6 high pressure feed heaters.

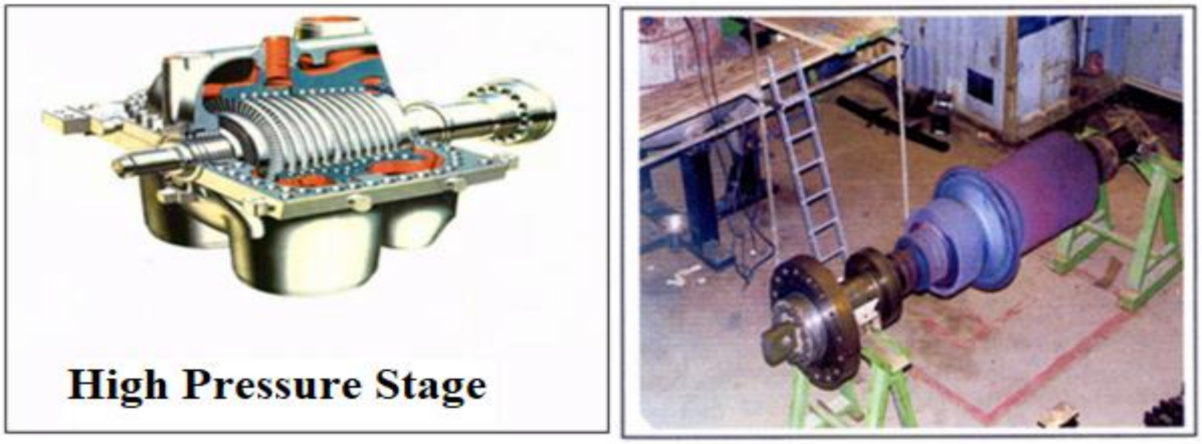


Figure 1.2-2 HP stage

1.2.2.2 Intermediate pressure(IP) core :

It is a double flow turbine with two outlets S4 and S5. The S4 outlet feeds the feed water tank and the S5 outlet feeds the HP5 high-pressure feed heater.

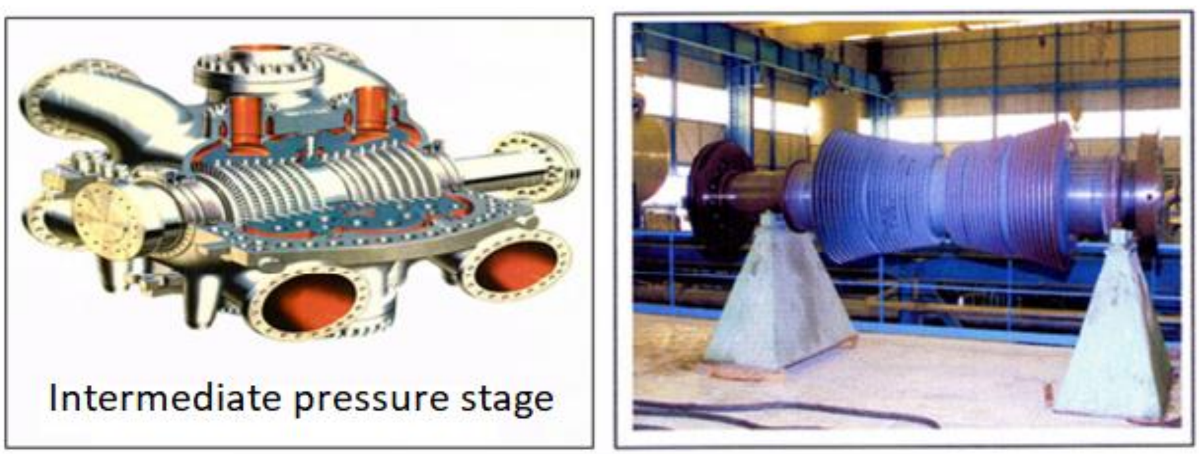


Figure 1.2-3 IP stage.

1.2.2.3 Low pressure(LP) core :

It is a double flow turbine with three (03) outlets S1, S2 and S3. The inlet of this body is directly connected to the MP body by a pipe. Bleed steam S1 feeds the 1st low pressure feed heater LP01, bleed steam S2 feeds the 2nd low pressure feed heater LP02 and bleed steam S3 feeds the 3rd low pressure feed heater LP03.

Figure 1.2-4 LP stage

1.2.3 The condenser: [3]

1.2.3.1 Role :

The condenser used in the installation is a surface heat exchanger. It is placed under the low-pressure turbine. The steam condenses on contact with the walls of the tubes, through which the cooling sea water passes. The main functions of the condenser are:

- To ensure the condensation of the water vapour discharged from the turbine casing (LP) and to reintroduce condensate into the water-steam circuit (water station).
- To increase the enthalpy of the expanded steam by establishing a depression, in order to obtain the highest possible turbine efficiency.
- To deaerate the condensate and to evacuate the noncondensable compounds (mostly air).
- Also receives the condensate from the reheaters (LP).

1.2.3.2 Description :

The condenser used at cap Djinet is a surface exchanged condenser where the cooling water (sea water) and steam are separated by the tube walls. A surface condenser consists essentially of:

- A water box
- A tube plate at each end of the condenser body
- A titanium tube bundle
- A sleeve connecting the condenser casing to the turbine exhaust flange.
- A well located at the lower part of the condenser casing where the condensed steam is collected.

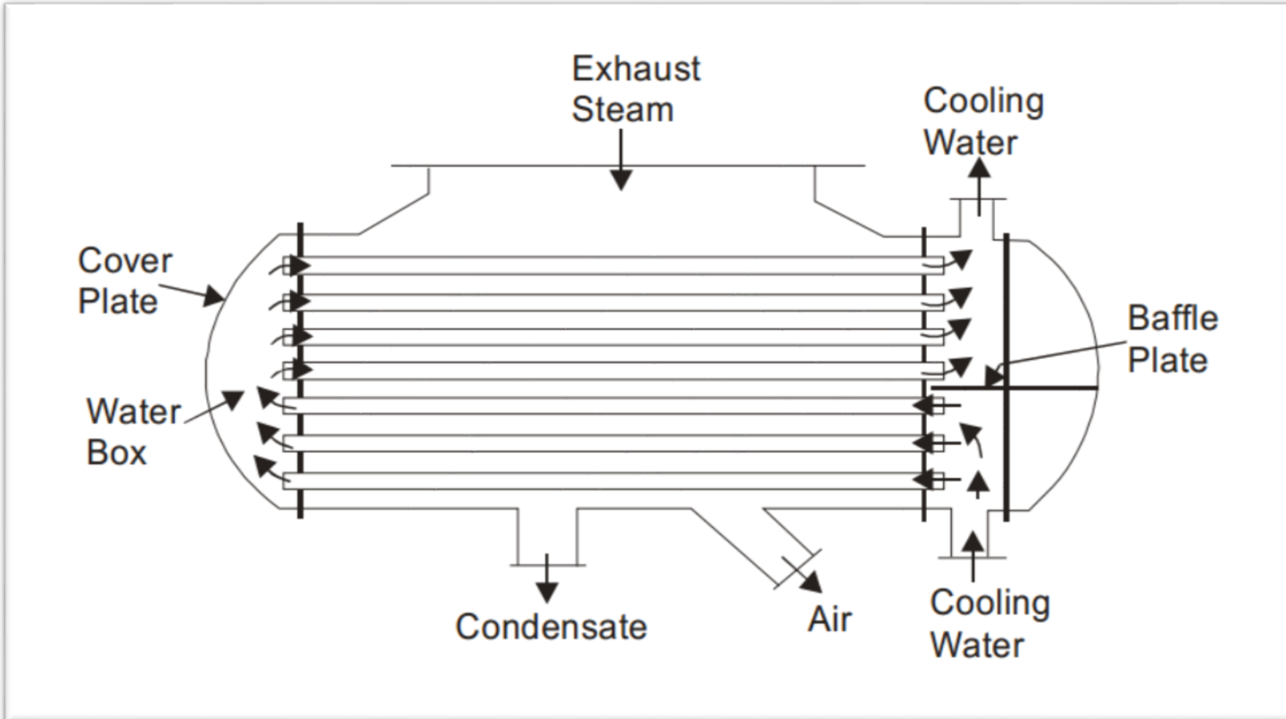


Figure 1.2-5 the condenser

1.2.3.3 Condenser Specifications :

Figure 1.2-6 Condenser Specifications

Condenser pressure	0.07 bar absolute
Well capacity inlet/outlet	sea water 6° to 8°c
Exchange surface	10101 m².
Mass of empty condenser	258.5 tons
Tube material	titans
Water velocity in the tubes	1.8 m/s.
Steam flow rate	98.25 kg/s.
Cooling water flow rate	6500 kg/s (sea water).
Number of tubes	14850
Tube length	11490 mm.
Outlet temperature	32.9°c.
Outlet pressure	0.05 bars

1.2.4 Pumps: [3]

1.2.4.1 Extraction pumps :

The function of the extraction pumps is to convey the main condensate from the condenser outlet to the feed water tank via the low pressure heaters, the summer refrigerants, hydrogen refrigerants. There are two (02) pumps per group, one in operation and the other in reserve in case of failure, with a voltage of 63 KV and a power of 300 KW.

Characteristics of extraction pumps:

- Pump type: 3-stage centrifugal.
- Inlet temperature: 32.9°C.
- Working pressure (total height): 16.8 bar.
- Pressure (height at zero flow): 19.7 bar.
- Nominal flow rate: 414 m^3 /h.
- Outlet temperature: 33°C.

1.2.4.2 Boiler feed pumps :

1.2.4.2.1 Three (03) feeder pumps:

Feed water is taken from the feed water tank by feeding pumps, and pumped back to the boiler via HP heaters. There are two types of pumps:

- **Feed pumps:** These are single-stage centrifugal type auxiliary pumps; they are used to increase the feed water pressure from 4.9 bars to 11 bars with a flow rate of 261.6 m3/h.
- **Main pumps:** these are 6-stage radial centrifugal pumps. They are placed downstream of the feeder pumps; they increase the water pressure from 11 bar up to 177 bar.

For each group there are three feeder pumps and three main pumps. And each feed water pump group is driven by a common motor of a voltage of 6.3 kV and a power of 300KW.

1.2.4.2.2 Two (02) circulating pumps:

Each pump has a flow rate of 12,000 m3/h and it is used to pump seawater back to the condenser. After passing through the condenser, the water of refrigeration is discharged to the discharge channel that ends in the sea.

Characteristics of feed pumps:

- Type: centrifugal pump.
- Water temperature: 151.4°C.
- Nominal flow rate: 261.6 m3/h.
- Suction pressure: 5.6 bar.
- Discharge pressure: 177 bars.

1.2.5 The reheaters: [3]

1.2.5.1 Air heaters:

The air heater of the power plant is of the rotary type (LINJUSTROM), this heater is a metallic mass of circular shape rotating on a vertical shaft, which is located at the bottom of the unit alternately immersed in the hot gas and in the air to be heated, among the advantages of this heater is the acceleration of combustion reactions and reduction of fouling by reduction of soot due to a more complete combustion.

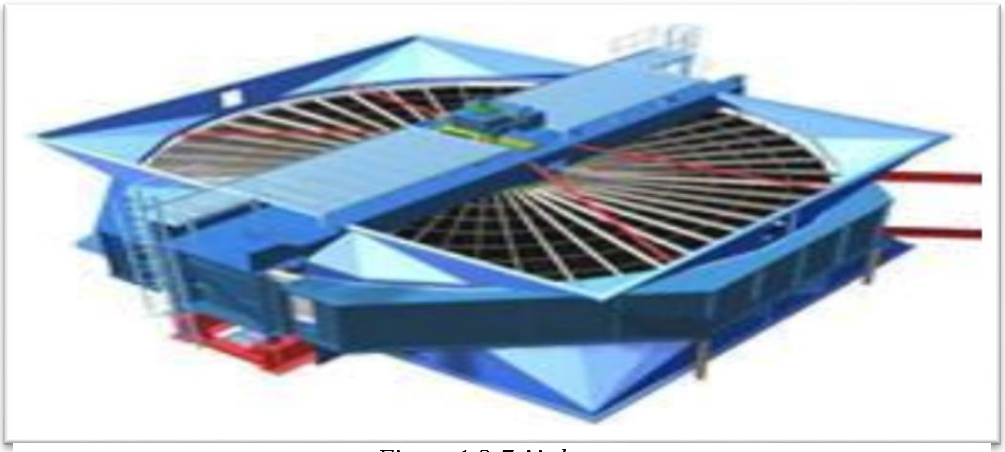


Figure 1.2-7 Air heater

1.2.5.1.1 Low pressure heaters (LP):

The role of these three (03) heaters is to heat the condensate during its transfer to the feed water tank. They are fed by the three (03) under drafts (S1), (S2) and (S3) which come from the turbine body (LP). The heaters used are surface heat exchangers. They are positioned horizontally in tubes (U-shaped), and the condensate flow is cascade, in the tube side the main condensate circulates and in the shell side the steam circulates, and the temperature exceeds 100°C.

Figure 1.2-8 LP reheater

1.2.5.1.2 High pressure heaters (HP):

There are two (02), their role is to heat the feed water during its transfer to the boiler. They are fed by the two extractions (S5) and (S6) coming respectively from the medium pressure (IP) and high pressure (HP) turbine bodies.

The heaters used are surface heat exchangers. They are positioned vertically with curved tubes in the form of a coil, where the steam flows on the shell side and the feed water (condensate) flows on the tube side at a pressure of 160 bar and a temperature of 145 °C.

1.2.6 The feed water tank: [3]

1.2.6.1 Role and operation:

The feed water tank has a heating role and regulates the suction pressure of the feed pump. It is a horizontally mounted cylindrical tank combined with a deaerator. It receives water from the extraction pumps, water which passes through a certain number of heaters. It also receives vapour from the steam bleed (S4) which comes from the IP (intermediate pressure) stage. The water heats up to the saturation temperature corresponding to the extraction pressure by condensing the steam which is taken from the turbine.

Figure 1.2-9 Feed water tank

1.2.6.2 Characteristics of the feed water tank:

- Total volume: 163 m3
- The diameter of the casing: 3.6 m.
- Length of the tank: 16.5 m
- Outlet temperature: 150-151°c.
- Pressure: 4.9 - 5 bar.
- Flow rate: 145.34 kg/s.
- Inlet temperature: 114°c.

1.2.7 The deaerator: [3]

The role of the deaerator is to remove aggressive gases such as oxygen and carbon dioxide dissolved in the feed water to protect installations such as the boiler. The removal of aggressive gases is done by the evaporation of gases dissolved in water by increasing the temperature. The deaerator and the feed water tank are protected by safety valves installed in the piping.

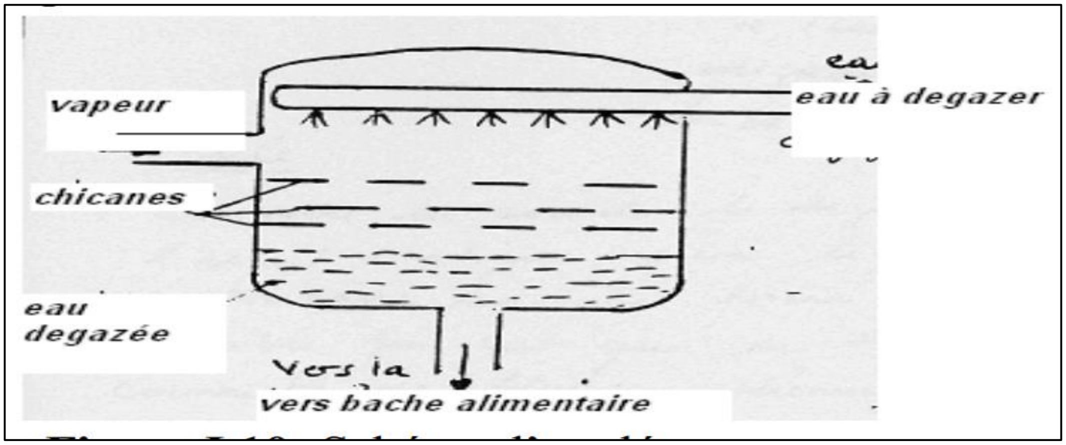


Figure 1.2-10 deaerator

1.2.8 Alternator: [3]

1.2.8.1 Role :

It is an electricity generator directly linked to the turbine shaft, it is used to transform the mechanical energy produced by the turbine shaft into electrical energy. It is a smooth pole alternator and the electric current created is a three-phase alternating current. This transformation gives off a large amount of heat, hence the need to cool the alternator. Cooling is done by a closed hydrogen circuit which is itself cooled with demineralized water. The alternator comprises the following components: stationary stator windings, a rotor and stationary rotor windings.

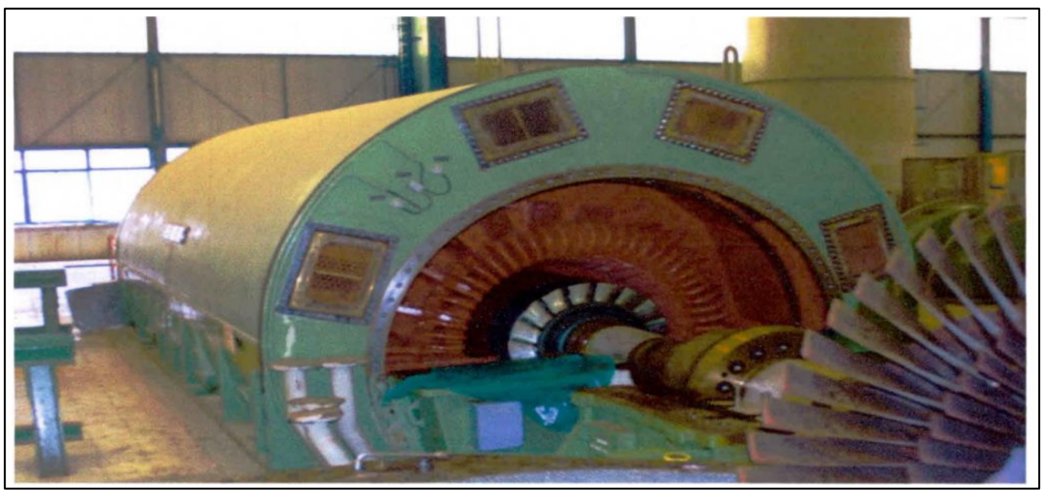


Figure 1.2-11 Alternator

1.2.8.2 Characteristics :

- Active power: 176 MW.
- Rated power: 220 MVA.
- Rated voltage: 15.5 KV.
- Frequency: 50 HZ.
- Power factor: Cos φ = 0,8
- Complete stator weight: 198 tons.
- Weight of rotor alone:36.7 tons.

1.2.9 Transformer: [4]

Each unit has four types of transformers that perform different functions.

1.2.9.1 Principal transformer (15.5 kV/235 kV) :

This transformer steps up the delivered voltage from the alternator for transmission purposes. It has a power of 220 MVA. Since all four units are identical, so the transformers will have the same power.

Figure 1.2-12 Principal transformer

1.2.9.2 Grid transformer (63 kV/6.3 kV) :

The grid transformer is also called a back-up transformer. Its role is to start the generator in case of alternator failure or a fault in the circuit-breaker.

1.2.9.3 Extraction transformer (15.5kV/ 6.3kV) :

This transformer has a rated power of 20 MVA and supplies all the low-voltage "LV" and medium-voltage "MV" auxiliaries via the high-voltage cables. The low-voltage auxiliaries operate using direct current as well as the generator auxiliaries.

1.2.9.4 MV/LV transformer (6.3kV/ 400V) :

These transformers supply the LV auxiliaries with a rated power of 1250 kVA and are connected to the MV busbar.

Table 1.2-2 Characteristics of MV/LV transformer

	Medium Voltage winding	**Low Voltage Winding**
apparent power	1250 kVA	
rated voltage	6.3 kV.	380 V
coupling	delta	star
power factor		0.8.

1.2.10 Filtering and pumping station: [2], [5]

Three pipelines with a diameter of 03 meters are installed at a depth of 06 meters from the land surface with a length of 900 meters into the sea, allowing water to pass automatically to the basin because of the gravity effect.

Figure 1.2-13 Pumping station

1.2.10.1 Sea water filtration:

Seawater filtration is a two-stage process:

- ➢ A first filtration is carried out at the level of the grapple grids to stop and recover the large waste and organisms arriving with the sea water, such as Mussels, sea urchins, …
- ➢ A second filtration is carried out at the level of the filtering drums for the recovery of small organisms, which could not be stopped by the grapple grids.

1.2.10.2 Sea water pumping :

Pumping is carried out in wells located after the filter station by three different pump groups:

- Feeding pumps for cooling sea water.
- Seawater feeding pumps for desalination units.
- Seawater feeding pumps for the electro-chlorination plant.

1.2.11 Desalination plant: [2]

This station consists of four (04) identical and independent units with a unit capacity of 500m3/day which needs to feed the boiler with water. The principle used is the multi-flash distillation where the water vaporizes abruptly (FLASH). After several successive flashes, the condensed steam (pure water) is recovered and stored in two (02) tanks each of 2700m 3.

1.2.12 Demineralization station: [2]

The water arrives from the desalination plant to the demineralization plant and passes through two (02) tanks containing tubes filled with chemical substances introduced inside, whose main role is the absorption of minerals to obtain demineralized water ready to use it in the water-steam cycle later. It contains two (02) demineralization lines with a flow rate of 40m3/h for each of them they have the purpose of treating the water to return it to perfect conditions where: the PH = 7 and the electrical conductivity = 0.1µs at max (almost zero). The storage of demineralized water is performed in two tanks each of 1500 m^3.

1.2.13 Hydrogen station: [2]

Its role is to produce the hydrogen needed to cool the four (04) alternators of the power plant.

Figure 1.2-14 Hydrogen bottles (cylindrical).

1.2.14 Electrochlorination station:

The chlorination of sea water helps to preserve the equipment through which sea water flows from the proliferation of marine organisms. It is done by injecting sodium hypochlorite; the production is ensured by an electro-chlorination station (by electrolysis of sea water with a capacity of 150kg/h of active chlorine).

1.3 Operating principle of the power plant:

In a steam power plant, the production of electrical energy consists of the following three main phases:

- The transformation of the chemical energy of the fuel into the heat energy of the steam in the boiler.
- The transformation of the heat energy into mechanical energy by the turbine.
- The transformation of mechanical energy into electrical energy by the generator.

The power station of Cap Djinet operates according to the following circuits:

1.3.1 Combustion cycle:

The main fuel used in the boilers is the natural gas from HASSI R'MEL delivered by a gas pipeline at a flow rate of 160,000 m3/*h* is necessary to ensure that the four groups are fully charged. In the case of unavailability, back-up is provided by domestic fuel oil. It comes from the refinery by truck, deposited and stored in two tanks with 10,000 m3/ of each one. The boilers are supplied with fuel oil in the same way as gas. [3]

1.3.2 Combustion air cycle (air-smoke cycle):

The air is taken from the atmosphere and set in speed by fans, it is first heated to 315 °C by the auxiliary steam in the rotary air heater. This heated air goes to the burners by turning the oxygen supplement necessary for combustion, this circuit results from the outlet of the burners, it is traced in such a way that on the first hand the burnt gases continuously find walls to be heated so that can induce heat exchanges. Moreover, on the other hand, the fluid is behind the wall of the cooling fumes. [3]

1.3.3 Water - Steam cycle:

This is the main cycle and all the others revolve around it.

1.3.3.1 First transformation :

The water arriving from the condenser and the make-up water or after condensation is discharged into the feed water tank, it is compressed successively by the pumps; low pressure and high pressure is heated by the low and high pressure heaters using the extraction steam, it finally passes to the economizer where the combustion gases still raise its temperature before it will be inserted in the boiler; at the beginning of the transformation, the water was at 33 °C and absolute pressure of 0,05 bar while at the end it will be at 282 °C and 160 bar approximately. [3]

1.3.3.2 Second transformation :

It takes place in the boiler, the compressed hot water reaches the upper tank, it flows through the tubular walls lining the combustion chamber through these tubes, the combustion gases, which have a temperature of 1300 °C, first provide the water with additional heat of vaporization. At the upper part of the tank, wet saturated steam is collected, which is divided by three tube bundles in series. Steam dries out and then it's superheated in the following bundles.

During this transformation, the pressure does not change, while the temperature reaches its maximum i.e. 540 °C. [3]

1.3.3.3 Third transformation :

The superheated steam arrives at the high pressure stage where it expands to 40 bar and cools down to 357 °C, thus providing a driving force and then returns to the furnace of the boiler where it circulates in the reheater bundles. [3]

The pressure does not vary but the temperature reaches its maximum for the second time, i.e. 540°C, the steam returns to the turbine to expand and cool down in the intermediate pressure core, and then in the low pressure core, once again providing a driving force. [3]

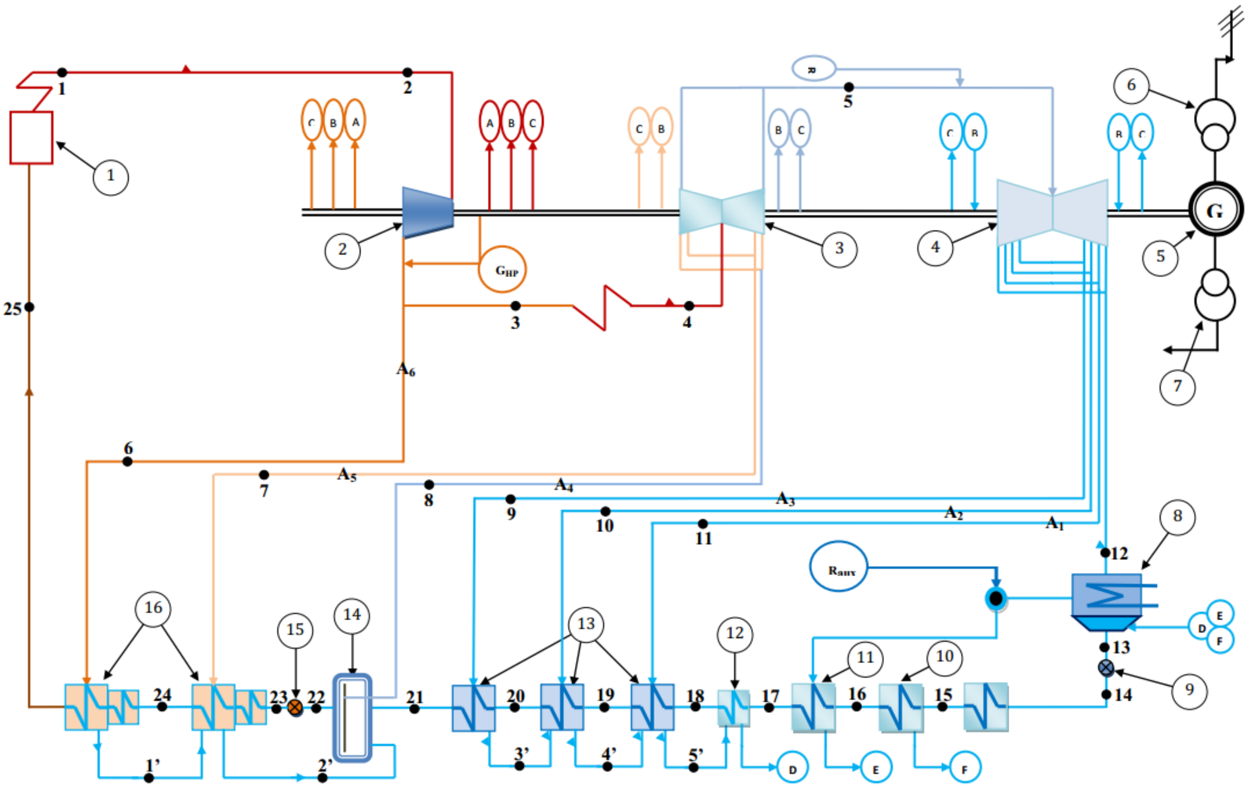
1.3.3.4 Fourth transformation :

The steam is condensed in the vacuum condenser at 0.03 bar at a temperature of approx. 33°c. The water collected is cold, and the cycle starts again. [3]

1.3.4 Cooling water cycle:

To condense the steam, it is necessary to cool it and lower its pressure, these two operations are performed in the condenser, the cooling is provided by cold water circulating in an independent cycle of the water-steam cycle. [3]

The schema below describes how the steam circulates:



1. Steam generator (boiler)
2. High pressure stage
3. Intermediate pressure stage
4. Low pressure stage
5. Generator
6. Principal transformer
7. Auxiliary transformer
8. Condenser
9. Extraction pump
11. Steam injector
12. purges cooler
13. LP reheaters
14. Feed water tank
15. Feed pump
16. HP reheaters

Figure 1.3-1 Power plant schema

Conclusion:

In this section, we have presented the equipment as well as their respective roles of the Ras-DJINET thermal power plant. We have highlighted all the different components that enter into the cycle of electrical energy production.

The next chapter will be devoted to a more detailed study of the description and operation of a steam turbine.

Chapter 02:
Description of the steam turbine

Introduction:

Nuclear and coal-based thermal power plants together produce almost half of the world's power. Steam turbines lie at the heart of these power plants.

A turbine is a rotating device designed to use the kinetic energy of a liquid fluid such as water or a gaseous medium (steam, air, combustion gases) to rotate a shaft supporting the turbine blades. The energy of the fluid, characterized by its speed and enthalpy, is partially converted into mechanical energy to drive an alternator. This energy produced must be delivered of a certain quality defined by two main factors: voltage and frequency.

2.1 Presentation of the steam turbine:

2.1.1 The role:

The turbine transforms the thermal energy (heat energy) from the boiler into a rotational movement of the shaft, the mechanical work obtained is used to drive the alternator.

2.1.2 Specifications: [1]

- Length: 16.125 m
- Width: 13 m
- Weight: 500*10^3 Kg
- Power: 176 MW
- Pressure: 138.2 bar
- Steam temperature: 535 °C
- Speed: 3000 tr/min

2.1.3 Description: [1]

The turbine is of the condensing and single superheating type, has a single shaft line consisting of three separate stages (HP, IP, LP):

- The HP stage is single-flow while the IP and LP cores are double-flow.
- The cores are double jacketed (double envelope).
- Turbine and alternator rotors are rigidly constructed.

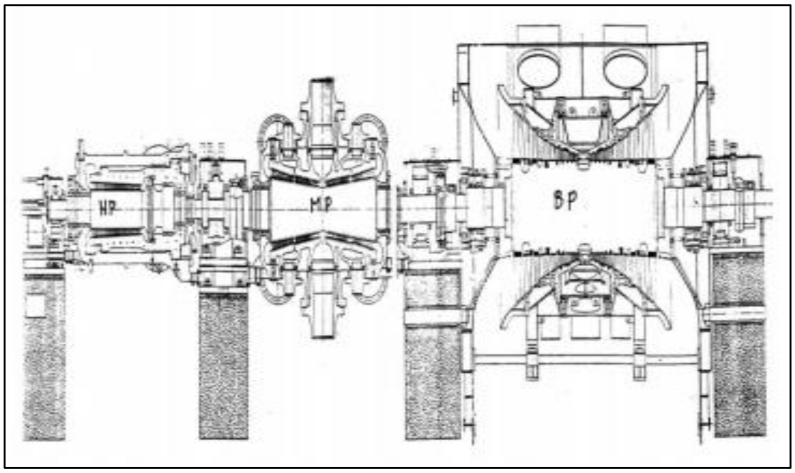


Figure 2.1-1 longitudinal section of the turbine

2.1.3.1 High pressure core (HP):

2.1.3.1.1 Constitution and operation:

The HP body of the turbine is a barrel construction. It is equipped with an adjustment stage for regulation by the nozzle group. Four combined shut-off valves/regulating valves are associated with as many nozzle groups. They are placed on either side of the body.

The steam conducted to the turbine through the piping system reaches the regulating valves after passing through the shut-off valves. From these valves, the steam flows into the envelope. Non-return valves are mounted on the superheater piping between the HP body and the superheater to prevent hot backflow from the superheater to the HP body.

2.1.3.1.2 Casing:

The outer casing is a barrel construction without axial joints. An inner casing divided according to an axial parting line is mounted on the barrel within the outer casing.

2.1.3.1.3 Adjustment stage:

The adjustment stage is designed as an action stage. The energy corresponding to the difference in steam pressure upstream of the nozzles is converted in these nozzles into kinetic energy and then transmitted to the rotor blades as driving energy. The nozzles are divided into groups, each of these groups is associated with a regulating valve.

2.1.3.1.4 Sealing boxes:

The HP stage is composed of two sealed housings which ensure the tightness of the inside of the casing with respect to the atmosphere at the point of the passage of the shaft on the steam outlet side. The sealed boxes are labyrinth seals through which the steam flows axially and whose sealing channels are alternately in the shaft and in the boundings in the form of radially deviated circle sectors according to labyrinth principle. The pressure difference is converted into velocity in the successive expansion sections.

2.1.3.1.5 Moving blades and fixed blades:

The vanes of the HP body consist of several stages in drums. All stages are of the reaction type with a 50% degree of reaction. The rotor blades are milled from the mass with a hammer-shaped foot. The fixed blades are manufactured in the same way.

2.1.3.1.6 Bearings:

2.1.3.1.6.1 End bearings:

The end bearing is a carrier with two oil wedges mounted at the top of the machine which supports the rotor and the HP body and contains the following equipment:

- HP rotor bearing bush;
- Main oil pump;
- Hydraulic speed converter;
- Electrical speed converter;
- Overspeed trip devices;
- Indicator of differential expansions.

2.1.3.1.7 Rear bearings:

The rear bearing is mounted between the HP and IP housings. It is used to support the casings and rotors of the HP and IP housings and to take up the axial force acting on the rotor. The rear bearing contains the following equipment:

- Shaft vibration sensor.
- Bearing vibration sensor.
- Release device for thrust bearing wear detector.

2.1.3.2 Intermediate pressure core (housing):

2.1.3.2.1 Constitution and operation:

The IP body is equipped with two shut-off valves and two moderating valves arranged symmetrically on both sides of the housing. The re-heated steam in the piping system passes through the interceptor valves to the moderator valves. From the moderator valves the steam flows through the turbine housing to the upper and lower housing halves. It enters the inner casing through the inlet pipes flanged to the center of the outer casing. This arrangement, which results in opposite flow directions in both flows, balances the axial thrusts. The steam inlet in the middle of the housing removes the influence of the steam inlet temperature on the support legs and bearings.

2.1.3.2.2 Casing:

The outer casing has a horizontal joint plane. It carries the double-flow inner casing mounted so as not to impede thermal expansion. The guide blades are housed in the inner casing. The re-heated steam enters the middle of the inner casing from the bottom and from the top.

2.1.3.2.3 Sealing boxes:

Like the HP body, the IP body is equipped with two sealing housings which ensure the sealing inside the casing against the atmosphere at the shaft passage point on the inlet side and on the outlet side of the steam.

2.1.3.2.4 Moving blades and fixed blades:

All stages of the IP body are reaction stages with a 50% degree of reaction. A part of these stages is in the steam flow on the HP side while the other part is in the steam flow on the LP side. The moving blades which are attached to the IP body are designed in the same way as the HP body.

2.1.3.2.5 Bearings:

The rear bearing of the IP housing is arranged between the IP and LP housings. It serves to support the IP housing and the rotors of the IP and LP housings. The bearing unit contains the following equipment:

- Shaft vibration sensor.
- Bearing vibration sensor.
- Indicator of differential expansion.
- Hydraulic turning device.

2.1.3.3 Low pressure core (housing):

2.1.3.3.1 Constitution and operation:

The BP body is of the double flow type. It is a mechanically welded construction consisting of a frame and a double casing. The steam which comes from the MP body enters the inner body of the double casing upstream of the BP blades via inlet pipes located on both sides of the BP body. Some compensators are mounted on the steam sheaths to prevent any deformation of the casings caused by thermal expansion.

2.1.3.3.2 Casing:

The body is composed of three casings. These envelopes are rigid welded constructions with a horizontal joint plane. The inner casing, which carries the first guide stages, is mounted in the intermediate casing in such a way that it can expand freely. The intermediate casing, which is independent of the outer casing, is supported in four points on side rails.

2.1.3.3.3 Safety membrane:

The LP housing is equipped with four safety diaphragms. If the pressure in the condenser exhaust box exceeds the permissible value, the diaphragm, which consists of a thin rolled lead foil, tears on contact with the knife and releases the steam into the atmosphere. Interceptor clamps are provided to prevent the membrane and knife fragments from being carried along by the steam flow.

2.1.3.3.4 Sealing boxes:

The LP body is equipped with two sealing boxes which ensure the sealing of the inside of the casing against the atmosphere at the shaft passage points on the front and rear sides.

2.1.3.3.5 Moving blades and fixed blades:

The stages that a drum 1 to 5 of the two streams of the LP core are reaction stages with a 50% degree of reaction. They are mounted inside the inner core and also form the inner part of the BP blades. The stationary vanes of stages 2 to 5 with a hooked foot are provided with riveted tires. All moving blades are provided with machined-in tires.

The group is formed by the last LP stages comprising three stages, which are all of the reaction type. The directors are made up of two half-directors formed by welding outer rings. Blades and inner rings bolted to the inner core. The last two stages are equipped with hollow sheet steel vanes with bleed holes. Water is deposited on the blades which are sent to the condenser through these holes. The moving blades have a hammer head foot.

2.1.3.3.6 Bearings:

The rear bearing housing is located between the LP housing and the alternator. It is used to support the rotor of the LP casing and contains the following equipment:

- Sensor for vibration of the bearing bracket.
- Bearing support.
- Indicator of differential expansion.
- Shaft vibration sensor.

Table 2.1-1 Characteristics of the three stages

	HP body	**IP body**	**LP body**
Inlet pressure	138 bar	35.9 bar	5.5 bar
Outlet pressure	40 bar	5.52 bars	/
Steam flow rate	532 T/H	467.9T/h	406T/h
Inlet steam temperature	535°C	535°C	282°C
Nbr. of reaction stages	23 stages	2x19 = 38 stages	2x8 = 16 stages
Nbr. of action stages	1 stage	None	None
Weight	4910 kg	326990 Kg	168100 Kg
Flow type	single-flow	double-flow	double-flow
Casing type	double envelope	double envelope	double envelope

2.2 Turbine operation circuits: [1]

2.2.1 Purge circuits:

The drain circuits discharge the condensate from the turbine and its auxiliary systems to the condenser. Condensate is formed primarily during start-up and shutdown. During the preheating of the live steam, reheat steam, and reheated steam piping, the blowdown circuit discharges preheat steam and condensate from the HP and IP inlet and control components to the turbine condenser. The condensate passes through three-stage drain valves that are placed on manifolds. The HP and IP inlet and control valves are connected to the manifolds by drain and preheat valves.

2.2.2 Oil circuits:

The oil circuit performs the following functions:

- Lubrication and cooling of the bearings.
- Actuation of the control elements and the hydraulic safety devices (control oil).
- Control of the hydraulic turning gear.
- Lifting of the shaft line.

2.2.2.1 Pressurized Oil Circuit :

In normal operation, the main pump is located in the front and rear bearing directly coupled to the turbine shaft which sucks oil directly from the tank and delivers it into the pressurised oil circuit. The injector, which facilitates the suction of oil by the main pump, produces sufficient pressure at the suction side of the main pump regardless of the operating speed. The injector produces sufficient pressure at the suction side of the main pump at all operating speeds. This ensures that the main pump fulfils its function perfectly and prevents the cavitation phenomena which could occur due to excessive suction heights.

The driving oil is taken from the pressurised oil circuit and its flow rate is regulated by means of a diaphragm. The oil for the control units and the safety devices is taken from the pressurised system. The oil for the turning gear is also taken from the same circuit. The pressurised oil is returned to lubricating oil pressure in a diaphragm and cooled in the refrigerants. The diaphragm is adjusted once and for all during commissioning. The oil flow rate for each bearing is adjusted by means of the diaphragm during commissioning.

2.2.2.2 Shaft Lifting Oil Circuit :

2.2.2.2.1 Role:

The lifting device is used to form or maintain an oil thread between the rotor and the bearing bushings when starting and stopping the turbo generator set in order to reduce the torque to be overcome by the hydraulic turning gear.

2.2.2.2.2 Operating principle:

An oil injection under high pressure at the lower part of the rotor trunnions (journals) lifts the rotors and relieves the bearings. The lifting pump must be activated when the turbine speed drops below 510 rpm, it stops at a speed higher than 540 rpm.

2.2.2.2.3 Design:

The lifting oil circuit consists of:

- Two motorized lifting pumps SC18D001 and SC18D002.
- Two oil filters SC18N005 left and right.
- A controlled relief (overflow) valve SC18S515.
- Flow limiters.
- Non-return valves.
- Two safety valves (pressure relief valves).

The lifting oil circuit is supplied with high pressure oil by a lifting pump. The lifting pumps, which are installed in the oil tank, are submerged screw pumps; the oil is sucked directly by one of the full-flow pumps.

2.2.2.3 Extraction System for Oil Mist:

2.2.2.3.1 Mist (Wet Steam) Ventilator:

After the bearings have been lubricated and cooled, the oil returns to the tank via a collector (manifold). The oil mist forms in the bearing housings, the return oil lines and the oil tank are extracted by the mist extraction ventilators. The oil contained in the mist is extracted in an oil separator and fed into a leakage oil tank.

2.2.2.3.2 Oil Tank:

The oil tank or oil box contains the necessary oil for the lubrication, the cooling and the control of the turbo generator unit, and it is used for oil storage and degassing purposes only. The motorized pump bodies are immersed in the oil of the tank and the suction is carried out at the lowest point in order to supply the connected circuits with oil that is as degassed as possible. The oil tank is equipped with a local oil level indicator as well as level sensors.

2.2.2.3.3 Oil Refrigerators (Coolers):

Oil coolers are used to cool the lubricating oil before it passes through the bearings when the pressurised oil system is supplied by the main pump or by a first backup pump. Only one of the two oil coolers is in service. A three-way valve is provided for adjusting the lubricating oil temperature to a set value of 45°C.

2.2.2.3.4 Oil Filter:

Two oil filters are provided for the continuous cleaning of the lubricating and cooling oil of the bearing. Thanks to the reversing system, it is possible to change the filters (if the filter is dirty) without disturbing the operation of the turbo generator set. A differential pressure indicator measures and indicates the differential pressure of a filter as it becomes clogged or fouled.

2.2.2.3.5 Oil Throttle Sequence:

The oil throttle devices are placed directly upstream of the bearings whose lubrication circuits are used to adjust the quantity of oil required for the bearings.

Conclusion:

In this section, we have presented the different equipment of the steam turbine of the CAP-DJINET thermal power plant and its operating principle.

The next chapter is devoted to the turbine starting, stopping and protection processes.

Chapter 03:
The turbine protection control system

Introduction:

The operation of a power plant can lead to unsafe operating conditions for the turbine-generator unit, that can result major faults and failures. As a consequence, the turbine must be protected against all types of accidents and faults. A good safety system must include different kinds of control instrumentation equipments like sensors, transmitters, …

I. SECTION ONE: The Turbine Start-Up, Shutdown and Protection Processes

Introduction:

The operating part of the turbine contains instructions for starting at the normal speed and shutting down the turbine.

The operation of a power plant can lead to unsafe operating conditions for the turbine-generator unit. One of these dangerous faults is, for example, the unit's overspeed rise significantly above 3000 rpm. The centrifugal force on the moving blades, especially on those of the last stages of the LP housing, may result in stresses exceeding the breaking limits of the metal. This could lead to a real explosion of the rotor, which would destroy the turbine and endanger personnel. The turbine must therefore be protected against this type of accidents.

3.1 The start-up: [1]

The start-up of the turbine and auxiliary systems must always be carried out in such a way that the reliability and profitability of the operation is ensured. The turbine starting process consists of the following steps:

- Checking the preparation of the turbine-generator unit.
- Steam generator commissioning.
- Fresh steam piping reheats (shut-off valves have been opened).
- Manual start of the turbine from the control room by manipulating the control devices according to the information provided by the analog feedback.
- During turning, the turning gear is operated at an oil temperature greater than 30°C, a lifting oil pressure greater than 100 bar and a speed greater than 240 rpm.
- The turning gear must stop at a speed of 510 rpm which is caused by the starting of the lifting pump.
- The lifting pump (motor) must stop at a speed higher than 450 rpm, which is caused by starting the emergency pump to lubricate the turbine.
- If the turbine speed rotation increases up to 3000 rpm and during the rotation, the lubrication is done by the main pump.

3.2 The stop: [1]

In the case of a trip or a fault caused by the stopping of the turbo alternator group, it is done automatically with the following steps:

- The LP bypass valves open when the power of the steam generator is greater than the ones of the turbo generator.
- Isolation of the alternator from the national grid (protection against the returned power).
- When the speed set point value is lower than the rated speed, the control valves and the moderating valves of the HP housing close.
- The shut-off valves and the interceptor valves of the HP housing close (turbine trip);
- The check valves of the superheated steam are closing.
- Empty boxes cause an increase in the absolute pressure at the condenser (greater than 0.2 bar) to accelerate the turbine shutdown, which reduces the time delay;
- The purges before the HP control valves are open.
- If the oil pressure is less than 4.8 bar, the first back-up oil pump starts up.
- If the oil pressure is less than 1.2 bar, the first back-up oil pump is switched off and the second back-up oil pump is switched on to ensure lubrication.
- If the turbine speed rotation is less than 540 rpm, the lifting oil pump is switched on with a lifting oil pressure greater than 100 bar;
- The valves of the turbine extraction (A1-A6) are close.
- The steam isolation devices are close.
- If the turbine speed rotation is less than 240 rpm, the moderating valve is open and the turning gear is turned on.

3.3 Turbine protection system: [1]

The role of the protection is to:

- Protect the turbine against certain impermissible operating conditions;
- Avoid consecutive damages due to disturbances on the unit;
- Minimize the incurred damage.

When the turbine protection is triggered, the shut-off and interceptor valves are quickly closed. The power supply to this unit with fresh and reheated steam is automatically switched off. The control valves are closed as a result of the pressure drop in the secondary oil. The steam backflow prevents to close the non-return valves at the outlets. The turbine protection system consists essentially of:

- Fault detection devices;
- Quick closing devices;
- Solenoid valves.

It operates on the shut-off devices. These devices are held in the open position by means of quick-closing oil. Any drop in pressure of the quick-closing oil therefore causes the shut-off devices to close quickly. When the turbine is switched off, the oil pressure drops via the quick-closing devices as a result of the triggering of a detection device.

The design of the protection systems must ensure that the turbine can be safely and quickly switched off in case of serious malfunctions and at the same time prevent undesired switching off. The protection is divided into hydromechanical and electro-hydraulic protection.

3.3.1 Hydromechanical protection: [1]

The hydromechanical protection of the turbine consists of:

- The quick closing devices (SC14K001/002);
- The overspeed releasing devices (SB11K001/002);
- Thrust bearing wear protection (SB12K011);
- The pressure switch for condenser protection (SC24K011).

The sensing devices (SC14K001, SB11K001/002, SB12K011, SC24K011) are connected to the quick-closing devices via the auxiliary quick-closing oil circuit. The quick-closing oil is taken from the control oil circuit through a quick-closing device and is fed to the shut-off and the interceptor valves, the non-return valves (outlets) and the secondary oil circuits.

The turbine is switched off as follows:

- the triggering of a detection device (the pressure of the auxiliary quick-closing oil drops) or:
- the closing of a solenoid valve (SC11S041/042) with consequent drop in control oil pressure.

Any drop in oil pressure causes a drop in the quick-closing oil pressure via a quick-closing device. The quick-acting shut-off devices are then quick-closed.

3.3.1.1 Quick-closing devices (SC14K001/002): [1]

The function of the quick-closing devices is to amplify and memorize the hydraulic or the mechanical release signal (manual release).

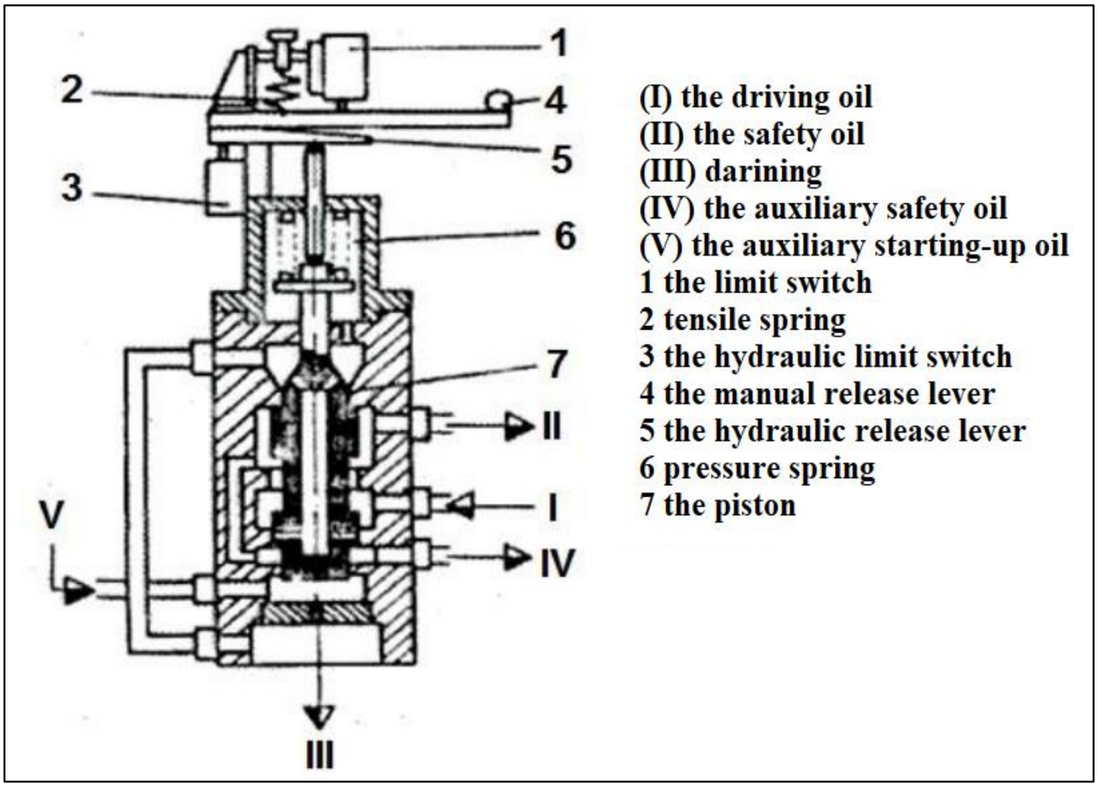


Figure 3.3-1 Quick-closing device structure

3.3.1.1.1 Operation:

Each quick-closing device is held in its operating position by the auxiliary safety oil pressure. If this pressure is suppressed due to the triggering of a protection device, the quick-release device falls out. As a result, the safety circuit and the auxiliary safety circuit are connected to the oil drain and the supply of motive oil is interrupted. At the same time, the hydraulic limit switch (3) of the hydraulic release reacts. If the manual release lever (4) is actuated, it produces the same process as in case of the hydraulic release only the limit switch (1) releases itself. There is therefore a selective signalling of the manual release. The auxiliary starting oil pressure pushes the piston (7) back into its operating position. The driving oil (I) has free passage and pressurizes the driving oil (I), the safety oil (II) and the auxiliary safety oil (IV). The normal build-up of pressure in the auxiliary starting oil after the start-up is controlled by means of pressure switches (SC223 P211 and SC23).

3.3.1.2 Overspeed trip (SB11K001/002) : [1]

The two overspeed trip devices protect the turbine against inadmissible runaway during load shedding and in the event of simultaneous control failure. They can also be tested manually on site while the unit is running at the rated speed.

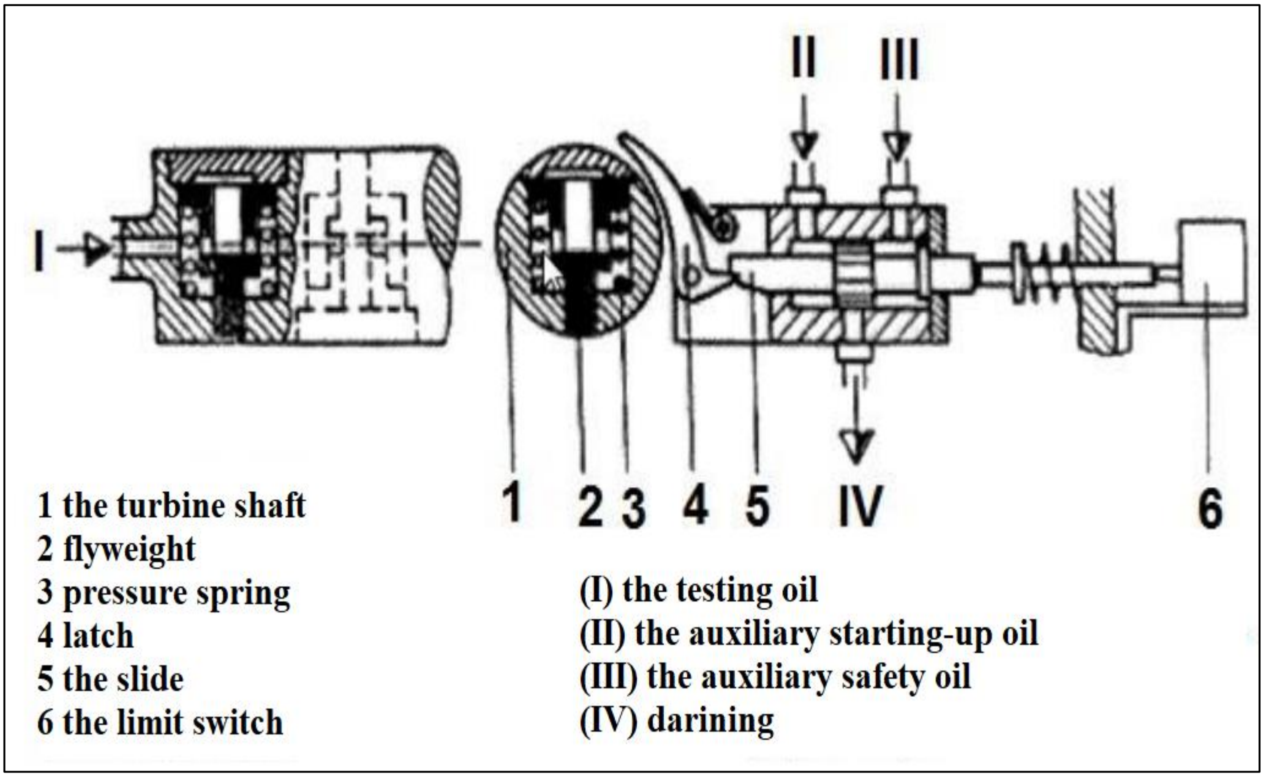


Figure 3.3-2 Overspeed trip device structure

3.3.1.2.1 Operation:

Each flyweight (2) on the overspeed trip devices triggers the slide (5) and the limit switch (6) by means of a latch (4) when the set overspeed is reached. The auxiliary safety circuit is connected to the drain and therefore loses its pressure. This is necessary so that the quick-closing device is triggered and the safety circuit loses its pressure in turn. In order that the overspeed release trips at the rated speed, a force is required which corresponds exactly to the increase in the centrifugal force resulting from the change of the rated speed to the tripping speed. The tripping speed is 3300 rpm (110%) greater than the rated speed of 3000 rpm.

3.3.1.3 Hydraulic protection against lack of vacuum at the condenser (SC24K04): [1]

The function of the hydraulic protection is to trigger the quick shut-off when the vacuum in the condenser is required, i.e. the pressure in the condenser is greater than 0.3 bar.

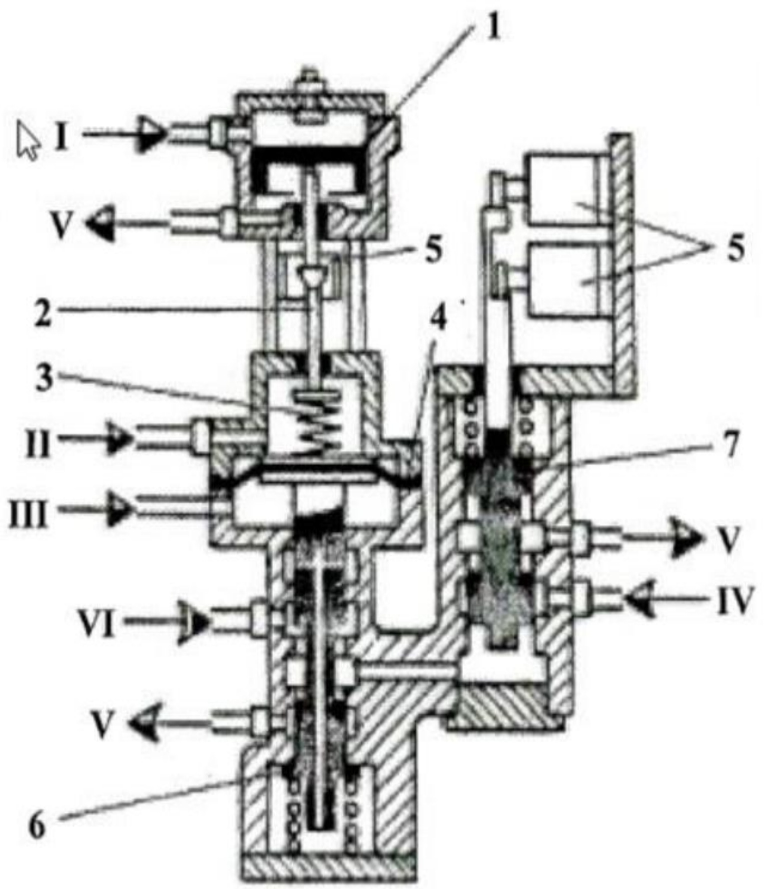


Figure 3.3-3 Hydraulic protection against lack of vacuum at the condenser

3.3.1.3.1 Operation:

On each protection, the spring (3), which is set to a certain limit pressure and located above the diaphragm (4) on which the vacuum acts, moves the drawer (6) downwards when the pressure drops below this limit. As a result, the pressure below the drawer (7) is relieved and the auxiliary safety circuit is connected to the drain. If there is no pressure in the auxiliary safety circuit, the quick-closing devices (SC14 K001/002) are triggered and thus all the valves in the turbine are closed.

3.3.1.4 Thrust bearing wear protection (SB12K011): [1]

The function of the thrust bearing wear protection is to monitor the position of the turbine shaft in the bearing and to depressurize the auxiliary safety circuit as quickly as possible, thus triggering the quick-closing safety circuit in case of fire.

3.3.1.4.1 Operation:

The two rows of stop cams (2) mounted on the turbine shaft (1) and arranged on both sides at a certain permissible travel distance from the pawl (3) of the thrust bearing wear protection triggers the quick closing if the maximum permissible shaft travel is exceeded via the pawl (3), the signalling piston (7) and the auxiliary safety circuit. The limit switch (10) is actuated at the same time.

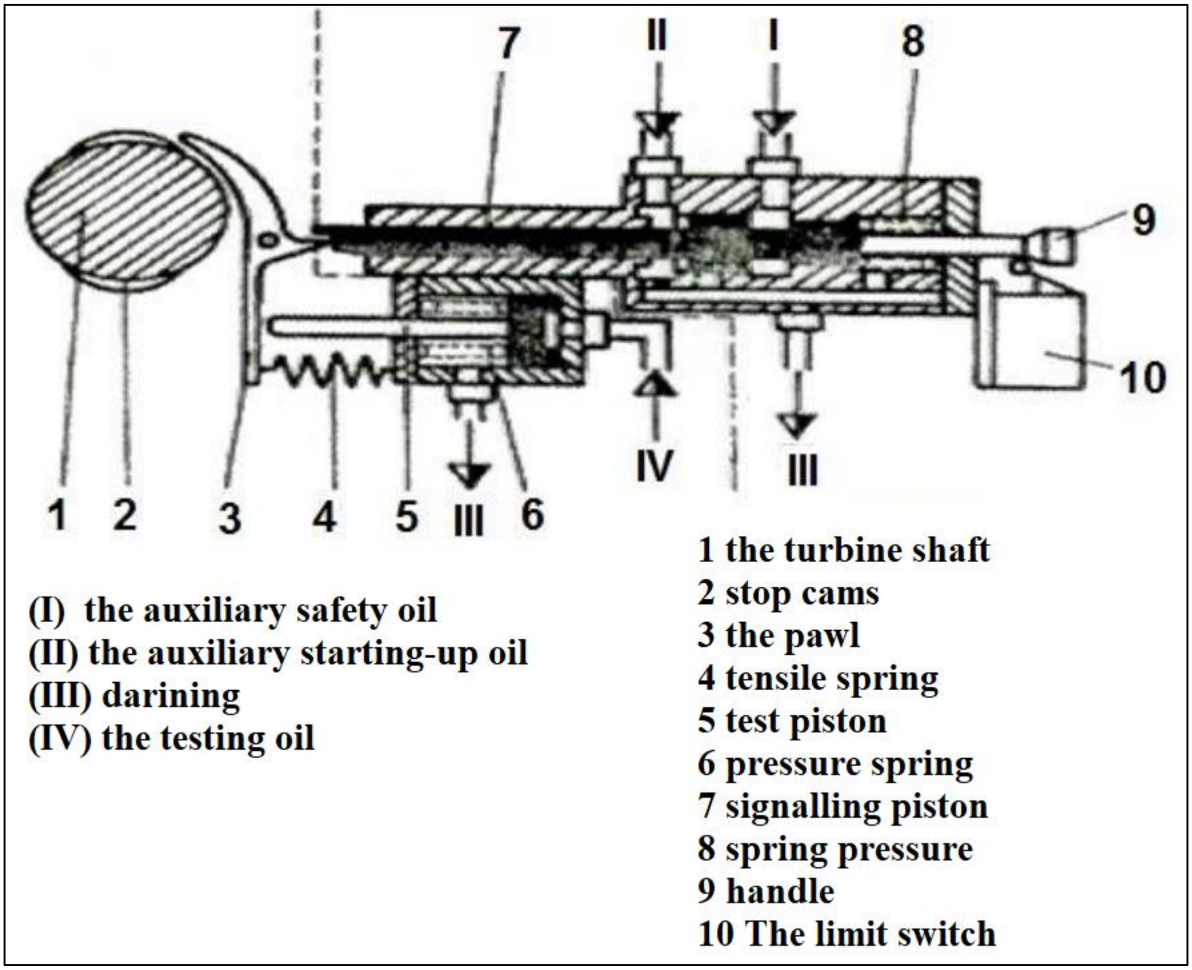


Figure 3.3-4 Thrust bearing wear protection device structure

3.3.2 Electrohydraulic protection: [1]

The electro-hydraulic protection acts via two solenoid valves (SC11S041/042) on the quick-closing oil circuit. It is two-way and operates according to the current-emission scheme.

The shunt circuit means that the shut-off devices only move to the shut-off position if at least one of the solenoid valves (quick-closing release solenoid valve) is powered. The power supply to the solenoid valves opens the control oil circuit, which supplies the quick-closing oil circuit via the quick-closing device. This leads to the pressure drop of the quick-closing oil and the rapid closing of the shut-off devices.

The protection consists mainly of:

- two electrovalves for quick closing tripping (SC11S041/042) that constitute the interface between the electrical part and the hydraulic part.
- converters or pressure switches (e.g. for pressure, level) which are used to set the tripping criteria.

The protection ensures the following functions:

- Electrical protection of the condenser; SC011 P007XG01.
- Protection of too high water level in the condenser; SD11L006XG01.
- Lubricating oil pressure protection; SC17P023, 024, 025.
- Fire protection; SC11 U02 XU03.
- Additional protection (Vibration, Bearing temperature); S010 K020 XM40

3.3.2.1 Electrical protection of the condenser:

The trigger is controlled by a pressure transmitter. This pressure transmitter is connected to the condenser operating at the highest pressure with a choice of maximum mechanical value. As the condenser vacuum has not yet reached a sufficient value during the starting of the turbo alternator, the pressure transmitter that controls the trip is electrically locked against another transmitter that determines the function mode.

3.3.2.2 Protection of excessive water level in the condenser:

If the water level in the turbine condenser is too high, a quick shutdown of the turbo generator is triggered. This measurement limits the weight that has to be supported by the condenser and by the foundations of the condenser frame SD11 L006 XG01.

3.3.2.3 Protection of the lubricating oil pressure:

When the bearing oil pressure drops, the oil supply to the bearings is in danger. For this reason, the shutdown of the turbine is triggered, so that the supply can be cut off after the turbo generator has been switched off.

The set point for the electrical triggering of the quick closing by the oil pressure has been selected to ensure sufficient oil supply to the bearings by means of an emergency oil pump during the slowdown phase of the turbo generator after the protection system has been triggered. Tripping is triggered when the oil pressure is less than 1.2 bar.

3.3.2.4 Fire protection :

As part of the fire-fighting system, a quick shutdown of the turbine is triggered to rapidly stop the flow of the main oil pump. The protection is triggered via the level sensor when the oil level in the oil tank is too low (automatic control). The fire protection system can be manually operated by means of special "fire protection" push-buttons provided on the turbine.

3.3.2.5 Additional protection (vibration, bearing temperature):

3.3.2.5.1 Excessive bearing vibration:

If the bearing vibrations become too high, a damage must be admitted (e.g. blade breaking), the quick-closing of the turbine is triggered to prevent a larger damage.

3.3.2.5.2 Excessive bearing temperature:

The protection of too high bearing temperature prevents excessive wear of the anti-friction bearing lining. The treatment of the measuring steam and the triggering of the quick-closing device is carried out via two channels in a circuit 2 to 2.

3.4 The turbine trip: [1]

The turbine can be switched off by:

- The hydro-mechanical protection.
- The electrohydraulic protection.
- The remote control from the control room.
- The generator protection.
- The boiler protection.
- The manual electric release SDC S010 K010 XG03

Conclusion:

In this section, we have presented the steam turbine start and stop sequences. We have also presented the operating principle of the turbine protection system and its various protection devices as well as the faults that cause the turbine to trip.

The next section is devoted to the instrumentation of the turbine measurement and control systems.

II. SECTION TWO: Instrumentation of Measurement and Control of the Turbine Protection

Introduction:

Control is necessary for observing, monitoring and adjusting the values of various parameters that characterize the technological process of the steam circuit and also for collecting information about the state of the equipment and the turbine apparatus.

3.5 Sensors: [1]

The following sensors are used to collect information about the state of the turbine:

- Two (02) sensors of absolute expansion in the front and the rear bearings of the HP stage.
- Three (03) sensors for relative expansion of the HP, IP, LP rear bearings.
- Shaft position sensors of the HP rear bearings.
- Two absolute vibration sensors of the HP front bearings.
- Six absolute vibration sensors of the HP, IP, LP stages.
- Four sensors for relative vibration of the different parts of the shaft (HP, IP, LP).
- Four temperature sensors of the HP front bearings.
- Four temperature sensors of the HP rear bearings.
- Four temperature sensors of the IP rear bearings.
- Four temperature sensors of the LP rear bearings.
- Two thrust bearing sensors in the front (on the left and the right sides).
- Two thrust bearing sensors in the rear (on the left and the right sides).

3.5.1 Expansion sensor (C74451-A4390-A2): [1]

The sensor is mounted with three M12 screws in such a way that the relative shift of the core with respect to the function is done in the direction of the sensor cable. With the increasing expansions, the cable is fed back into the sensor. Therefore, it provides a fixing in the measuring direction so that the loop of the sensor cable can be hooked in and the instrument can be adjusted to the measuring range. The sensor scale is factory-set for the nominal measuring range 0 to 50 mm (scale on the disc). After mounting the sensor and adjusting the output, the graduated disk must be turned in such a way that the scaling flow corresponds to the flow of the expansion displacement.

3.5.2 Absolute vibration sensor (C71451-1196-A11):

The sensor detects the absolute mechanical vibrations. It is attached to the bearing cap to prevent damage to the bearing or the shaft. The sensor is suitable for a measuring direction from vertical to horizontal; connected to the amplifier of absolute vibration measurement. The mechanical vibration conversion works according to the process of permanent dynamics. The output voltage is proportional to the speed of vibration. To measure the vibration velocity, the output signal is amplified using an amplifier. [1]

3.6 Transmitters: [1]

The following transmitters are used to send information about the state of the turbine:

3.6.1 Temperature transmitters:

- The inlet temperature of the HP stage (SA11 T133/144).
- The temperature of the HP stage (SA11 T 151/152).
- The differential temperature of the HP casing (SA11 T951).
- The inlet temperature of the IP stage (SA12 T113/114).
- The differential temperature of the IP casing (SA12 T941/961).
- The exhaust temperature of the LP stage (SA13 T066).
- The temperature of bearing 1 (SB11 T021- 24).
- The temperature of bearing 2 (SB12 T011- 14).
- The temperature of bearing 4 (SB14 T 014/18).
- The temperature of thrust bearing (SB 12 T 031-34).
- The temperature of lubricating oil (SC17 T016).

3.6.2 Pressure transmitters:

- The pressure of the HP stage exhaust steam (SA12P036).
- The pressure of the IP stage inlet steam (SA12 P051-57).
- The pressure of the controlling oil (SC11 POO1).
- The pressure the lubrication oil (SC17 P006).
- The pressure of the lifting oil SC17 P006 oil (SC18 P001).
- The pressure of the thrust bearing oil (SC17 P031).

3.6.3 Other transmitters:

- Transmitter of the level in the turbine oil tank (SC10 L001/2/3).
- Transmitter of the turbine speed (S010 Y10).

3.7 Actuators: [1]

The actuators are as follows:

- Four shut-off and control valves.
- Two interceptor valves, moderator valves.
- Safety Servomotor for the shut-off valve.
- Servomotor for adjusting the control valve.
- Safety Servomotor for the interceptor valve.
- Servomotor for adjusting the moderating valve.

3.7.1 Control valve:

The plug (18) and the operating stem of the control valve form a single-piece unit. Overflow ports are drilled in the plug to reduce the opening force of the valve. The plug and plug stem (18) are guided by the bushing, while rings (21) seal the stem as it passes through the bushing. When the valve is fully open, the rear sealing port of the plug presses against the bottom gain (19). This system completes the sealing of the stem passage, as on the shut-off valve, the bushing is fixed to the body (16) by a threaded ring (23) and the sealing between the bushing and the body is ensured and actuated by the servomotor piston (27) which is moved by a Belleville spring on the closing and by the operating oil at the opening. [1]

The triggering of the quick-closing device or a fire in the control circuit causes the shut-off valve and the control valve to close abruptly.

3.7.2 Check (non-return) valve:

The check valves are mounted on the turbine extractions A1, A2, A3, A4, and A5. They are shut-off devices whose function is to isolate the extractions in the event of load shedding or tripping of the unit to prevent steam rising to the turbine. This discrete steam in fact causes an unacceptable turbine acceleration and thermal shock sometimes to the components that are very hot. [1]

3.7.3 Shut-off valve:

The steam enters the valve body (16) through the inlet turbine and flows over the main plug together with the valve stem (13). Rings (12) seal the stem as it passes through the guide bushing (9). In addition, when the valve is open, the pilot plug is pressed by steam with its rear sealing port against the screw (14), which in turn is pressed against the bottom grain. This system completes the tightness of the stem passage. Both stem and plug are equipped with an anti-torsion protection. The bushing (9) is attached to the body (16) with a thread (10). A U-profile spring ring (11) seals the plug stem to the body. The arms of this spring ring are spread apart by the steam pressure and press against the sealing surfaces of the body. [1]

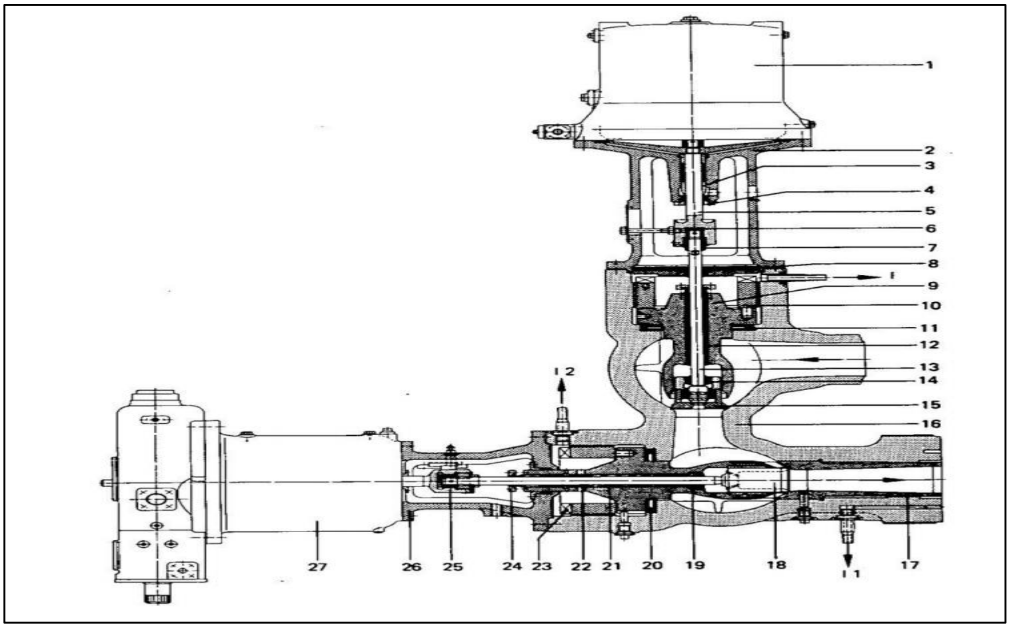


Figure 3.7-1 Shut-off valve structure

3.8 Converters: [1]

3.8.1 The electric vacuum converters of the speed (SB11 Y011):

The remote indication of the angular velocity is ensured by an electrical speed converter mounted on the shaft of the main oil pump. The converter consists of a disc (made of aluminium) with 60 pairs of magnets mounted in holes distributed around the circumference of the disc. Since this magnetic disc is connected to the shaft of the main oil pump, which is also connected to the turbine shaft, it rotates at the same speed as the turbine. The magnetic disc rotates in front of hall generators (hall soda) which deliver a voltage pulse at each passage a magnet. There are three hall rounds, a fourth is put in reserve. The digital signals from the three-way hall rounds are transformed into an analog signal via a frequency-to-voltage converter. A selection circuit chooses the average pulse series, which is converted to a DC voltage by the frequency-to-voltage converter and in case of track failure, the switching is carried out on a different track.

3.8.2 Electro-hydraulic converters:

The electro-hydraulic converter is the interface between the electrical and the hydraulic part of the turbine control system. It converts the electrical signal corresponding to the secondary oil pressure.

3.8.2.1 Constitution :

It consists of a movable electric coil whose means is attached to a control drawer by a rod, a driving piston (amplifier) which is connected to three pistons controlled by a spring and two differential transformers that provide the electrical control. [1]

3.8.2.2 Operation :

The electrical signals of the controller act on the moving coil which actuates the control spool via a bushing. In the equilibrium state, the control spool is in the rest position, the quick-closing oil pressure and the spring force naturally cancelling each other. If the electric regulator issues an opening command to the components, the mobile coil bushing moves upwards. The pressure below the control spool increases. The spool moves upwards. The control oil flows under the drive piston which, as it moves downwards, the pressure of the secondary oil increases. The displacement of the driving piston actuates the electrical servo system via differential transformers. The bushing is pushed back sufficiently so that the control spool returns to its rest position in the new position of the working piston. The moderator valves open according to the opening of the control valves. This relationship can be changed via the valves adjustment device, which helps to limit the temperature of the HP housing. In case of wire breakage of the plunger coil, the hydraulic regulator immediately loads the adjustment, in this case the plunger coil moves to the position of end stroke 100%. [1]

3.9 Detectors: [1]

3.9.1 Overspeed detector:

3.9.1.1 The role :

The overspeed governor ensures that the turbine is stopped if the allowed speed is exceeded. It is mounted in the turbine rotor.

3.9.1.2 Operation :

The displacement speed is adjusted by means of the screw (6). This adjusting screw is used to move the center of gravity of the centrifugal weight (4) and to center it in relation to the turbine shaft in such a way that the restoring force of the spring is greater than the centrifugal force of the centrifugal weights, as long as the turbine speed is less than the release speed. In this position the centrifugal weight presses against the threaded cap (1). If the switching-off speed is reached, the centrifugal force overcomes the restoring force (5) and the centrifugal weight (4) is pushed out of the turbine shaft, which triggers the quick closure. [1]

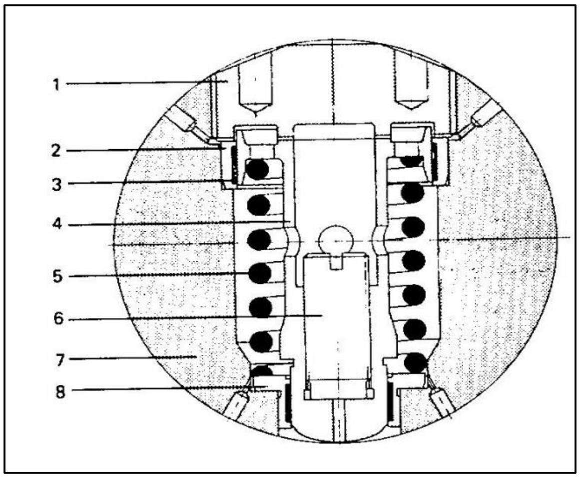


Figure 3.9-1 Overspeed detector structure

3.9.2 Thrust bearing wear detector SB12K011:

In the event of axial release of the rotor due to a wear force on the thrust pads, the release device opens the circuit of the auxiliary safety oil which causes the turbine to stop.

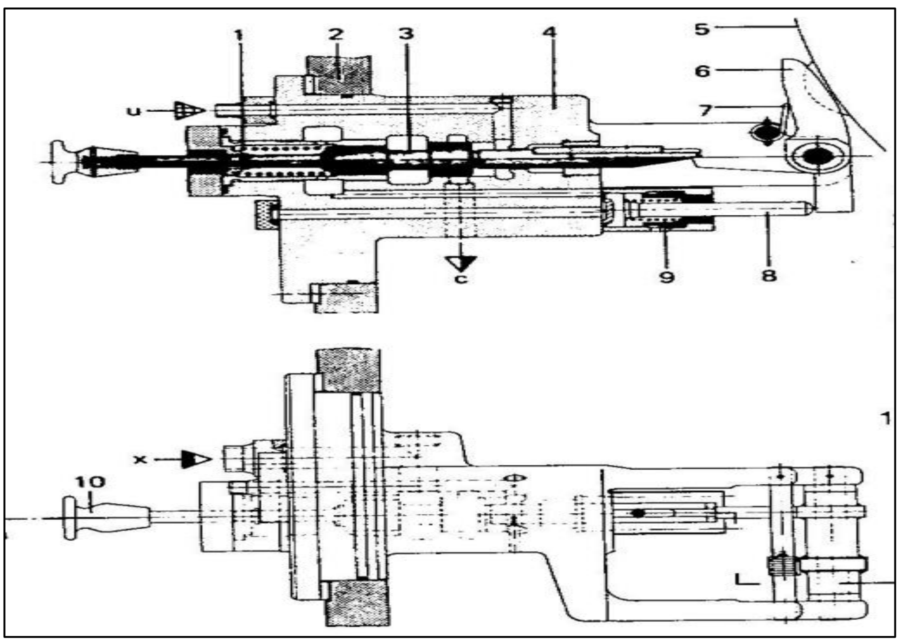


Figure 3.9-2 Thrust bearing wear detector structure

3.9.2.1 Operation :

When the rotor (5) is moved axially, the pawl (6) which is engaged between two rotor cams overlaps one of the cams. The spool (3) is released by turning the pawl (6) on its axis. The spool (3) is moved towards the rotor (5) under the action of the spring (1) and the differential pressure of the oil. The auxiliary safety oil circuit X is then connected to the oil drain C via the ports in the spool body (4). The resulting drop in pressure causes the turbine to shut down quickly. [1]

3.9.3 Detector for lack of vacuum at the condenser SC24K004:

The vacuum detector triggers the rapid closing of the turbine when the pressure at the condenser exceeds the permissible value.

3.9.3.1 Operation :

The steam space of the condenser communicates via the connection with the pressure switch chamber located above the membrane. The vacuum below the diaphragm is the atmospheric pressure. If the pressure in the condenser exceeds the permissible limit, the diaphragm and the spool valves are piloted downwards as a result of the pressure increase and they are spring-loaded. The auxiliary safety oil is then drained off, resulting in a rapid turbine tripping. [1]

Conclusion:

The instrumentation of the turbine measurement and control sequences ensures the protection of the most sensitive elements of the power plant. The quality of the information collected by these instruments increases the safety performance of the installation. In the following section, we will focus on the description of the control of the steam turbine protections.

III. SECTION THREE: Description of The Turbine Protection Control System

Introduction:

The turbine protection and control devices are equipment whose functioning is essential for the operational safety and the plant availability. It is therefore essential that this equipment is always in working condition. It is necessary to check the correct functioning of these devices at regular intervals during operation because the turbine overhauls are increasingly spaced out over time for economic reasons and their shutdown frequency decreases as their power increases.

The automatic control device ensures a fully automatic control process, which avoids inconveniences and incorrect operations that may result from manual operation of the control equipment. In addition, there are circuits to ensure that the generator set is fully protected during the test. This improves the operational safety and the plant availability.

3.10 Description of the existing control system: [1]

The wired control system is based on panels that contain the discrete components; these in turn are used to interconnect the electronic boards used for the control task. Each electronic board is carried out for a particular task which is defined by the rear of the panels, the whole panels are connected to a central panel where the relationships between the panels are established in such a way to have a general wired control system to control the whole thermal power plant. The control of the thermal power plant, concerns the following operations:

- Unit control (set)
- Control of electrical auxiliaries
- Protection system

3.10.1 Difficulties and problems of hard-wired logic:

The power plant controlled by a hard-wired logic, is functioning well, but at least there are some difficulties that can be mentioned, for example: at the beginning of the work, the operators take time to know which indicator corresponds to which information in order to take the corrective actions.

3.10.2 Proposed solution:

Our study allowed us to know and improve our knowledge in programmable automatons, and to discover their usefulness of great importance in industrial environment.

For this purpose, we proposed to replace the existing wired control at the production unit with a programmable logic controller (PLC) S7-400, which provides us with a safe, fast and reliable automatic control system for the turbine protection. As well as the reduction of the number of faults and the search for useful productivity.

3.10.3 Expected impact of the proposed solution:

- Solve the control problem of the outdated system: (availability of spare parts)
- Improve the system performances and make them more flexible
- Improve the safety of equipments
- Improve the management of the thermal power plant
- Facilitates the operator's work
- Find the faults faster

3.11 The turbine protection control hydraulics control system:

The protection of the turbine against various faults is based on this hydraulic system as shown in below (the next page). [1]

This circuit includes:

3.11.1 The protection devices to be controlled:

- Electrovalves for remote tripping of the quick-closing SC11S041/S042
- Over-speed trip device SB11K001/K002.
- Protection device against lack of vacuum at the condenser SC24K011.
- Thrust bearing wear protection SB12K001.

3.11.2 The devices used during the control process:

- Electrovalves for remote tripping of the quick-closing during the control process SC11S241/S242.
- Electrovalve SC11S242 for changing the spool position.
- Control spool (drawer) SC14S201.
- Overspeed trip test device SC24K001.
- Electrovalve SC11S243.
- Solenoid valve SC23S241/S242 for resetting the spool position.
- Solenoid valve for controlling the lack of vacuum in the condenser SC10S241.
- Pressure sensors, pressure switches SC11P232/P243/P243....

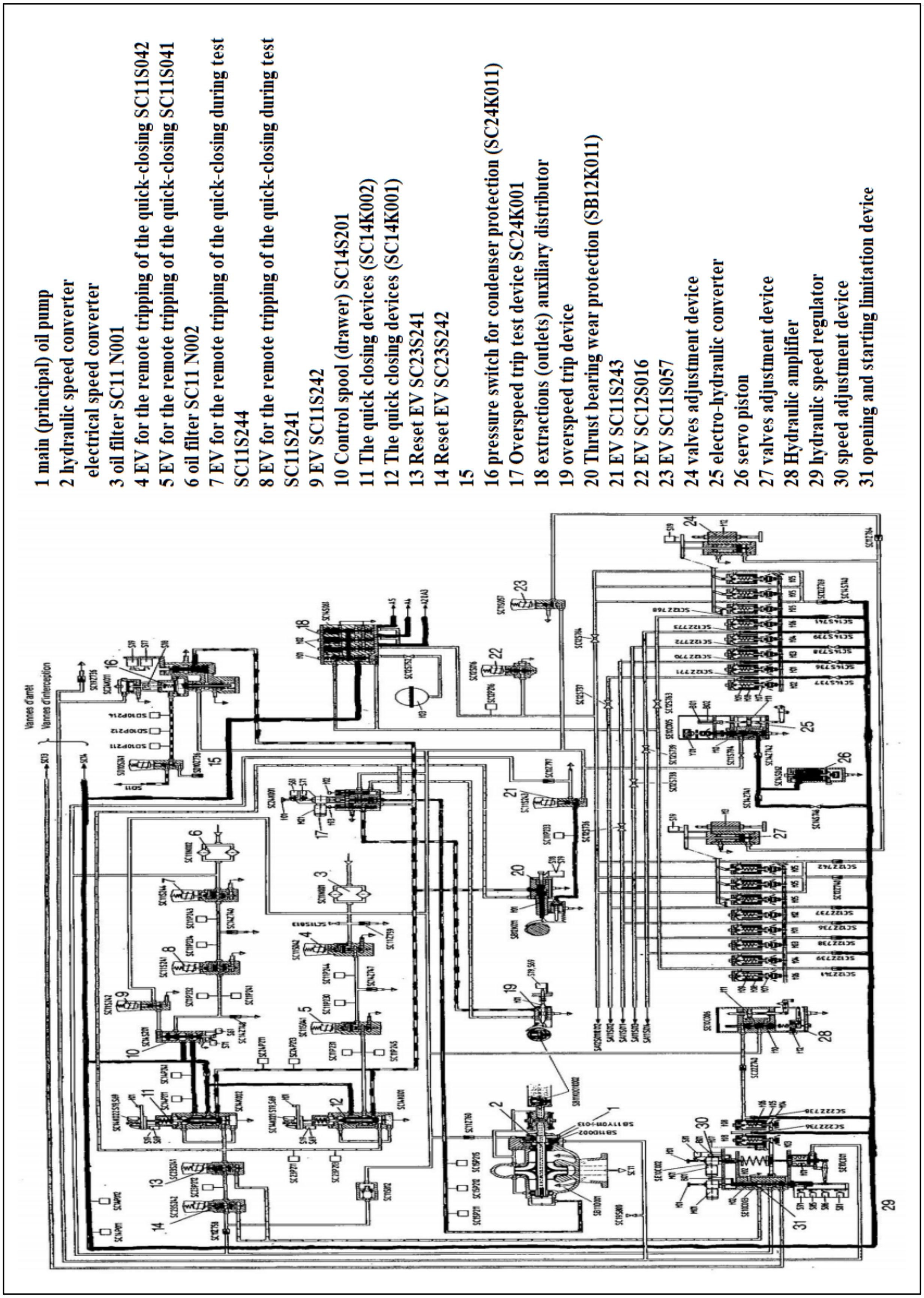


Figure 3.11-1 Hydraulic control system

3.11.3 Automatic turbine protection control system:

The automatic turbine protection control system performs the following functions:

- Functional check of the solenoid valves for remote tripping of the quick-closing valves.
- Checking that the quick-closing devices respect the tripping ranges.

When the automatic control of the turbine protection system is launched, the hydraulic protection devices are no longer available to protect the turbine and the condenser. The following measures are then taken to protect them during the test:

3.11.3.1 Remote triggering of the quick closing:

All the excitation signals connected to the remote tripping of the quick-closing device (1/2) control simultaneously the remote quick-closing during test (1/2) i.e. (solenoid valves SC11S241/244).

3.11.3.2 Overspeed trips :

Their function is taken over by two electrical rotation limit values.

3.11.3.3 Thrust bearing wear protection :

Safety limit switches are used to form the trip criteria.

3.11.3.4 Pressure switch for the condenser protection:

The function of the pressure switch is assumed by the electrical protection of the condenser.

3.11.4 Automatic control process of the turbine protections:

Before starting the turbine protection tests, a few conditions must be met:

- Set the program in auto position.
- Choose the protection to be tested among the protections checked.
- Run the program on.

3.11.5 The starting conditions of the automatic control of the turbine protections:

- Get permissive by clicking on the “P” Button.
- Put the man/auto toggle in the auto position by clicking on the Auto Push Button.
- All controllers set in service position (release AB).
- Select a protection to be controlled.
- Start the control program by clicking on the ON button.
- Once these conditions have been met, the program moves on to the preliminary test.

3.11.5.1 The preliminary test:

The preliminary test allows to check the correct operation of the test circuit devices, this test is essential for each control and is carried out like this one:

- During the test SC11S241/S242, the two remote tripping electrovalves of the quick closing are excited, the opening of these two electrovalves is controlled by the pressure switch (SC11P241>5bar).
- By a simulation, the speed is increased up to 3300 rpm to control the triggering of SC11S241, this triggering is controlled by the two pressure switches (SC11P232<2bar) and (SC11P243>5bar).
- By another simulation, the speed is increased up to 3300 rpm to control the triggering of SC11S242, this triggering is controlled by the pressure switch (SC11P234<2bar).
- The two electrovalves SC11S241/S242 are available to smooth the oil flow, the opening of these two electrovalves is controlled by (SC11P241>5bar).
- The electrovalve SC11S242 is excited to let the oil pass to the spool SC14S201 in order to switch this spool there to the high point under the action of the differential pressure, this switching which is controlled by the limit switch (S71) and the pressure switch (SC14P241>5 bar) ensures the passage of oil to keep the stop valves open. The auxiliary starting oil pressure is controlled by the pressure switch (SC23P211<2bar).

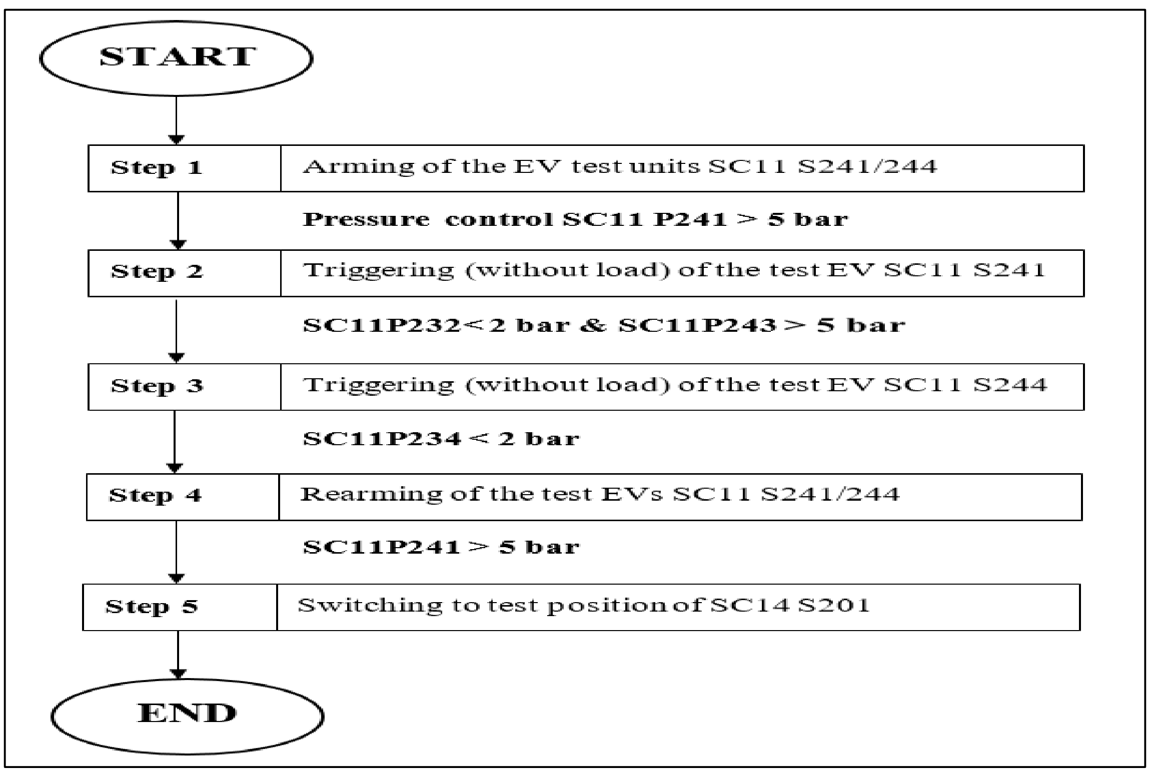


Figure 3.11-2 The preliminary program block diagram

3.11.5.2 Turbine protection controls :

After the preliminary test, the program performs one of the following checks:

3.11.5.2.1 Electrovalves control (SC11S041) and (SC11S042):

- During the control, the program gives a command to excite the electrovalve (SC11S041) or (SC11S042) to close it, this action causes the blocking of the passage of control oil and the absence of the latter puts the quick-closing oil in communication with the drain, hence the two quick-closing devices (SC14K001/K002) are triggered.
- The closing of the electrovalve (SC11S041) and the triggering of the two quick-closing devices are controlled by the pressure switches (SC11P244>5bar), (SC11P231<2bar), (SC14P211<2bar), (SC24P211<2bar) and the limit switches (S19) of (SC14K001/K002).
- However, the closing of the electrovalve (SC11S042) and the triggering of the two quick-closing devices are controlled by the pressure switches (SC11P23<2bar), (SC14P211<2bar), (SC24P211<2bar) and the limit switches (S19) of (SC14K001/K002).

3.11.5.2.2 Control of overspeed trip protection device:

- During this check, the program gives a command to the servomotor of the overspeed trip test device to change the position of its piston, this leaves the test oil passage to push the two centrifugal weights in order to jump the pawl which causes the displacement of the overspeed trip piston and puts the auxiliary quick-closing oil in communication with the drain, hence both quick-closing devices (SC14K001/K002) are triggered.
- The triggering of the overspeed trip devices and the two quick-closing devices (SC14K001/K002) is controlled by the limit switches S19 of the overspeed trip device and also of the two quick-closing devices (SC14K001/K002).

3.11.5.2.3 Control of condenser protection device:

During this check, the electrovalve (15) is excited, which causes the pressure switch (16) to be connected to the atmosphere and the vacuum to be reduced. The spool of the pressure switch is pushed down and the pressure of the quick-closing auxiliary oil drops, this is indicated by the pressure switches SD10 P212/P214/P211 mounted in the oil line.

3.11.5.2.4 Control of thrust bearing wear protection device:

During this check, the program gives a command to switch on the electrovalve (SC11S243) to allow the control oil to flow to the test piston in order to override the pawl which causes the signalling piston to move to the release position, this puts the auxiliary quick-closing oil in communication with the drain, hence both quick-closing devices (SC14K001/K002) are triggered.

The opening of the electrovalve, the change of the signalling piston position and the triggering of the two quick-closing devices are monitored by the pressure switch (SC11P233), the end of course (S19) of the signalling piston and the limit switches (S19) of the two quick-closing devices (SC14K001/K002).

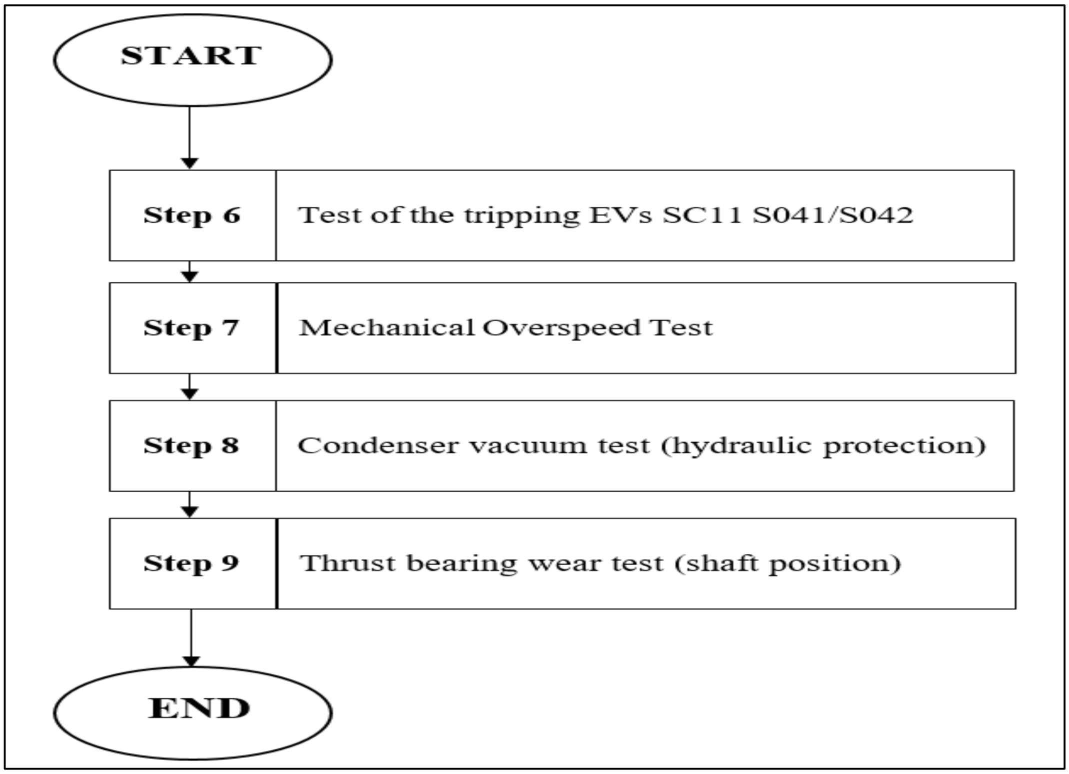


Figure 3.11-3 The block diagram of the turbine protection control

3.11.5.3 Reset program :

After each check, it is obliged to reset all the tripping devices to the operating position, to carry out this task the program gives a command to excite the two reset electrovalves (SC23S242/S241) to allow the starting auxiliary oil to flow to all the tripping devices to put it back in the operating position. These actions are controlled by several pressure switches and limit switches.

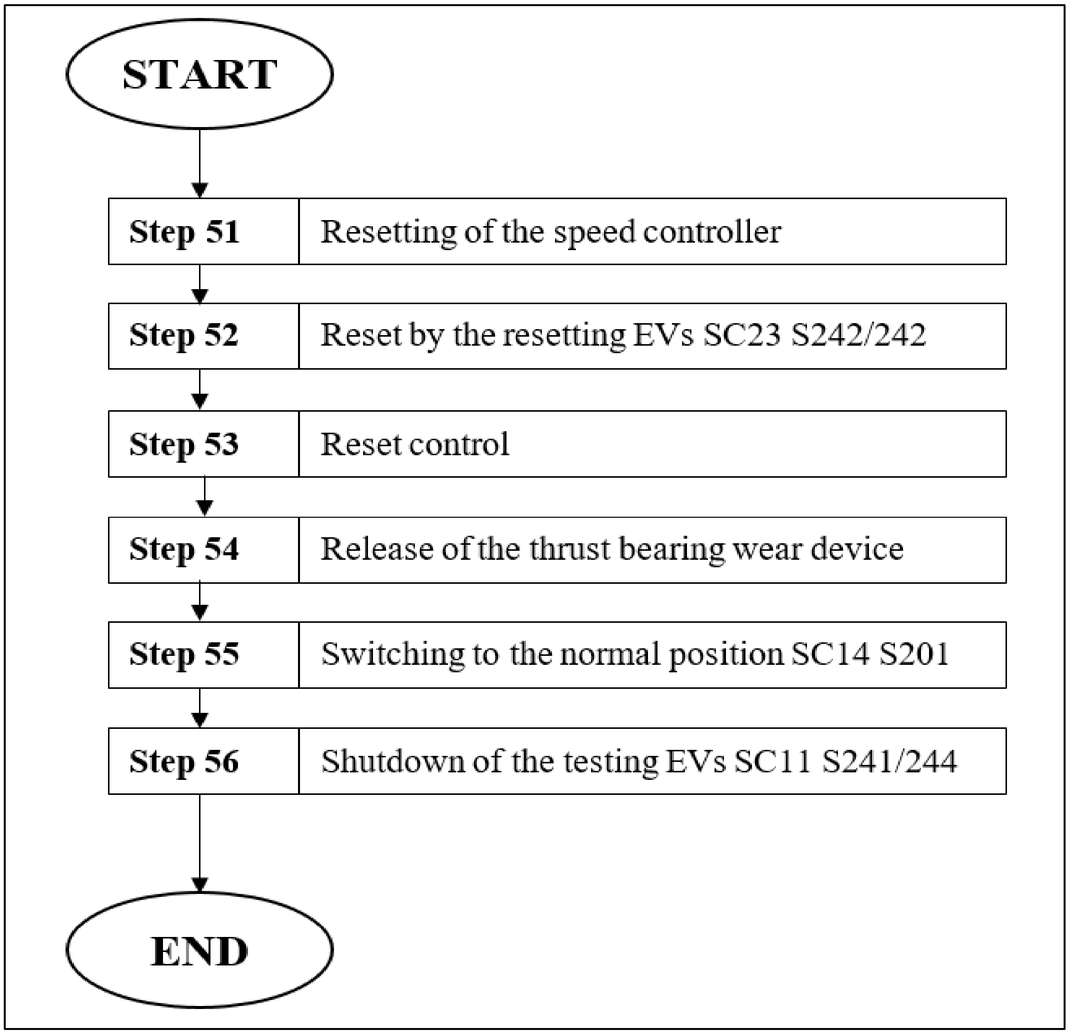


Figure 3.11-4 The block diagram of the resetting program

Conclusion:

In this chapter, we have presented the functioning of the automatic control system of the turbine protection devices.

In the next chapter, we will focus on the presentation of the PLC and its programming in STEP7.

Chapter 04:
Hardware selection and Programming

I. SECTION ONE: Presentation of the PLC and its programming using STEP7

Introduction:

The modern industry, which can be described as an industry of quality and quantity, is constantly demanding more and more efficient control equipment in order to achieve both objectives simultaneously. This is why the aim was to replace the conventional control devices with all the disadvantages that this entails (very complicated cable logic, space requirement, difficulty in maintenance, etc.) by a much more efficient and advantageous one. It would certainly be the Programmable Logic Controller that is nowadays the heart of any modern industrial unit.

4.1 General Definition of a PLC:

PLC stands for "Programmable Logic Controller". A PLC is a computer specially designed to operate reliably under harsh industrial environments – such as extreme temperatures, wet, dry, and/or dusty conditions. PLCs are used to automate industrial processes such as a manufacturing plant's assembly line, an ore processing plant, or a wastewater treatment plant.

PLCs share many features of the personal computer you have at home. They both have a power supply, a CPU (Central Processing Unit), inputs and outputs (I/O), memory, and operating software (although it's a different operating software). The biggest differences are that a PLC can perform discrete and continuous functions that a PC cannot do, and a PLC is much better suited to rough industrial environments.

A PLC can be thought of as a 'ruggedized' digital computer that manages the electromechanical processes of an industrial environment.

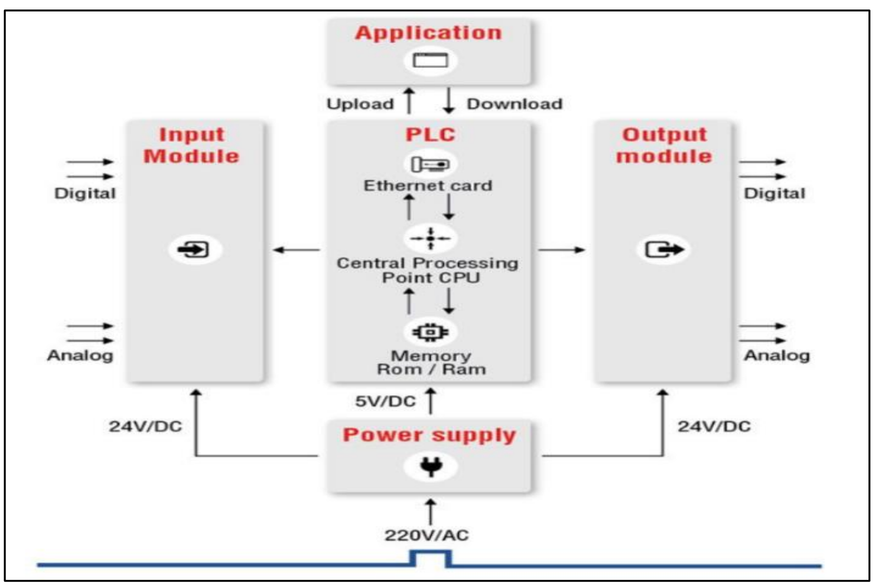


Figure 4.1-1 PLC architecture diagram

4.2 Purpose of Automation:

The PLC is designed as a replacement for the hardwired relay and timer logic to be found in traditional control panels, where PLC provides ease and flexibility of control based on programming and executing logic instructions. PLCs require shorter installation and commissioning times than do hard-wired systems. Although PLCs are similar to 'conventional' computers in term of hardware technology, they have specific features suited for industrial control:

- Rugged, noise immune equipment;
- Modular plug-in construction, allowing easy replacement or addition of units (modules);
- Standard input/output connections and signal levels;
- Easily understood programming language;
- Ease of programming and reprogramming in-plant;
- Capable of communicating with other PLCs, computers and intelligent devices;
- Competitive in both cost and space occupied with relay and solid-state logic systems;

These features make programmable controllers highly desirable in a wide variety of industrial-plant and process-control situations.

4.3 PLC Architecture:

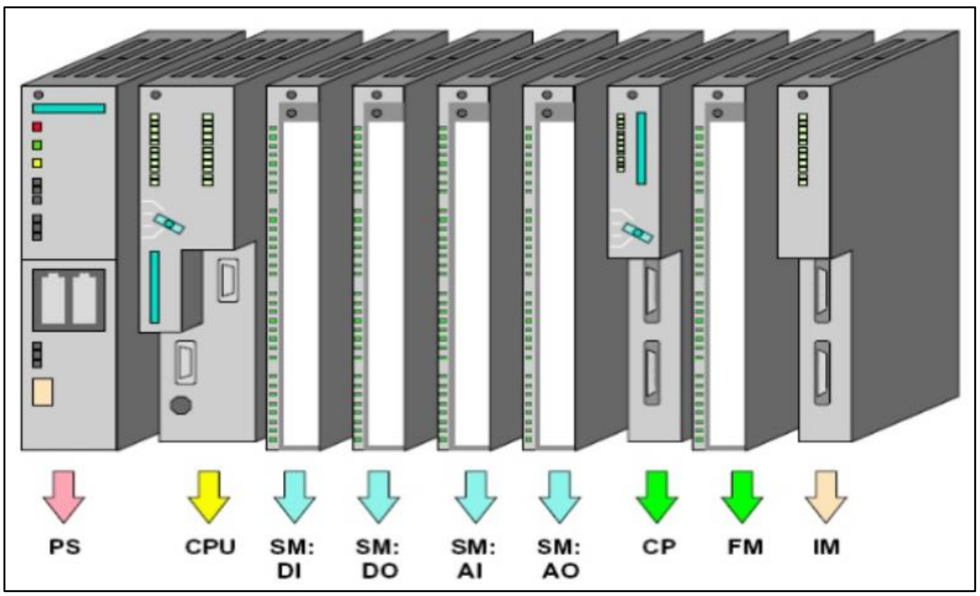


Figure 4.2-1 PLC Modules Configuration

4.3.1 Rack or Chassis:

In all PLC systems, the PLC rack or chassis forms the most important module and acts as a backbone to the system. A PLC rack or chassis constituting the metal framework of a PLC which consists of a support profile, backplane bus for the communication of the CPU with the modules and a connection. It is usually installed in electrical cabinets. [8]

In a small system, you may have only one rack while in a larger system you may have, in addition to the central rack (CR) which contains the CPU, many additional racks connected to the

CR which are referred to as expansion racks (ERs). The rack has divisional lines that are not seen, just assumed. These divisions are called Slots. A Slot is simply a position in which you will place a module. Though Slots are not seen, they are definitely used in the programming software. Each module that is fitted in a Slot has a callout within the software. [8] (see the appendix A)

4.3.2 Central Process Unit (CPU):

The CPU is the brain of PLC. It is always placed in the second Slot in the Rack. It has a central processor, a memory (ROM & RAM) and buses (data, address and control buses). ROM memory includes an operating system, drivers, and application programs. RAM memory is used to store programs and data.

CPU reads the input data from sensors, processes it, and finally sends the command to controlling devices. CPU also contains other electrical parts to connect cables used by other units. (see the appendix A)

4.3.3 Power Supply Module (PS):

The power supply module is a necessary and an important component of the control system. It is used to safely regulate and supply the necessary voltage for the PLC and other modules installed on the rack (the whole PLC system). The power supply module should be selected based on the power usage of the components that will be placed on the rack. The power supply always occupies the first slot in the rack. [10]

The output voltage of the power supply that we use is typically 24 volts DC. The output current varies depending on the number of the modules needed in the control system. For instance, this output current could be 2, 5 or 10 Ampere. Depending on which and how many modules are used, the output current of the power supply may need to be higher. Few PLC uses an isolated power supply. [10] (see the appendix A)

The power supply, unlike the rest of the PLC modules, has no data communication with the CPU or any other modules. The only purpose for the power supply is to supply a safe DC voltage to the modules in order for them to function properly. [10]

4.3.4 Input and Output Modules:

The I/O modules form the interface between the microprocessor of the PLC and the input (start and stop pushbuttons, switches, etc.) / output (an electric heater, valves, relays, etc.) devices, and must therefore provide all necessary signal conditioning and isolation functions. This often allows a PLC to be directly connected to process actuators and input devices without the need for intermediate circuitry or relays. The I/O modules reside in the Rack slots after the CPU.

4.3.4.1 Discrete I/O Modules (DI/DO):

Discrete I/O modules take care of items in the field that are in (input) or want to be controlled (output) in one of two states, either on or off. (see the appendix A)

4.3.4.2 Analog I/O Modules (AI/AO):

Analog I/O modules are responsible for reading (input) or controlling (output) items that are of a variable state such as a heater that is controlled by thermostat. (see the appendix A)

4.3.5 Communication Processor Module (CM):

The CPU is typically equipped with a single or multiple communication protocol port. It may be necessary, in a particular installation, for additional communications ports. When they are required, use of a Communications Module or CM may be employed. The placement of this module should follow the standard I/O or after an FM is used. [11]

4.3.6 Function Module (FM):

There are occasions when a special module is needed for different types of control processing. These special control modules are called Function Modules or FM's. These modules handle signals outside of the CPU and are not typical. When using FM's, they should be placed in Slots after standard I/O modules. [11]

4.3.7 Interfacing Module (IM):

They are used to connect remote racks (remote I/O modules) with the main rack (the one that contains the CPU). Remote I/O rack(s) is(are) used to reduce long wire run, reduce complexity while troubleshooting, and provide a cost-effective solution.

4.4 Types of PLCs:

PLC are divided into three types based on output namely Relay output, Transistor output, and Triac Output PLC. The relay output type is best suited for both AC and DC output devices. Transistor output type PLC uses switching operations and used inside microprocessors. [9]

The two main types of PLC are fixed / compact PLC and modular PLC.

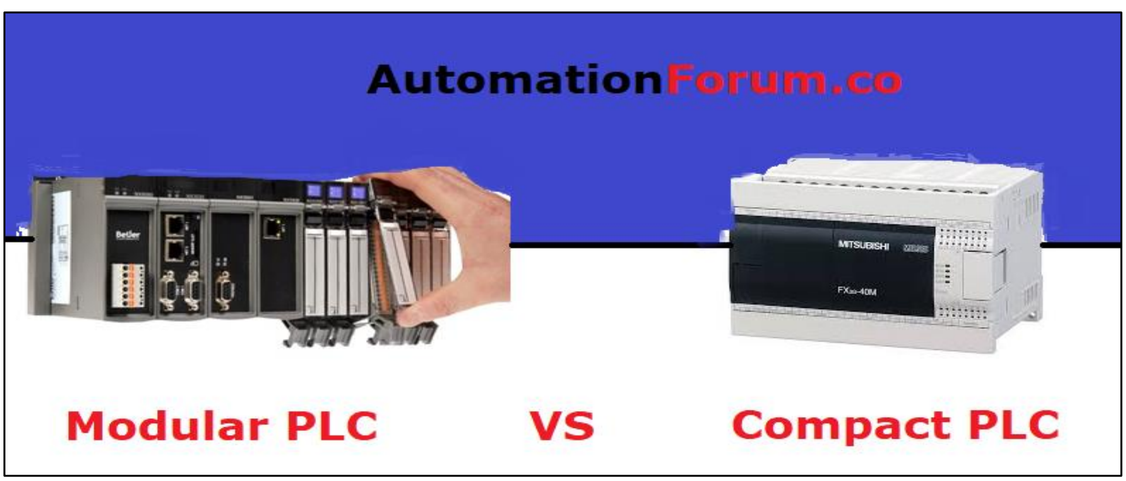


Figure 4.4-1 Types of PLCs : modular and compact

4.4.1 Compact/Fixed/Integrated PLC:

A compact PLC is built by several modules within a single case. The I/O capabilities are decided by the manufacturer, not by the user. Therefore, it has a fixed number of I/O modules and external I/O cards. Some of the integrated PLCs allow to connect additional I/O modules to make them somewhat modular. These PLCs, which are simple to operate, are generally designed to control small automation systems. [9]

4.4.2 Modular PLC:

A modular PLC is built with several modules that are plugged into one common rack or several rucks with extendable I/O capabilities according to the needs of the application, hence the term "modular". [9]

Modular PLCs are further divided into small, medium and large PLCs based on the program memory size and the number of I/O features. [9]

4.4.2.1 Small PLC (Nano type):

It is a mini-sized PLC that is designed as compact and robust unit mounted or placed beside the equipment to be controlled. This type of PLC is used for replacing hard-wired relay logics, counters, timers, etc. This PLC I/O module expandability is limited for one or two modules, and it uses logic instruction list or relay ladder language as programming language.

4.4.2.2 Medium-sized PLC (Micro type):

It is mostly used PLC in industries which allows many plug-in modules that are mounted on backplane of the system. Some hundreds of input/ output points (up to 400) are provided by adding additional I/O modules. In addition, communication module facilities are provided by this PLC.

4.4.2.3 Large PLC (Mini type):

They are used wherein complex process control functions are required. These PLCs' capacities are quite higher than the medium PLCs in terms of memory, programming languages, I/O points (up to 2048 I/O), and communication modules, and so on. Mostly, these PLCs are used in supervisory control and data acquisition (SCADA) systems, larger plants, distributed control systems, etc.

4.5 Hardware Selecting Criteria and Configuration:

4.5.1 System Requirements:

- The starting point in determining any solution must be to understand what is to be achieved.
- The program design starts with breaking down the task into a number of simple understandable elements, each of which can be easily described.

4.5.2 Inputs/Outputs Requirements:

Inputs and outputs are fundamental to the operation of a PLC. Two factors to consider are:

- Evaluating the number and types of inputs and outputs that the application will require. This crucial step lead to determine the proper chassis size and to use the PLC to its full potential.
- The location of I/Os also makes a difference in the selection. Will the system require a local I/O, or will it need both local and remote I/Os? The answer to this question depends on whether the application will have subsystems that are a long distance from the CPU. In addition, investigating whether the speeds and distances of the remote I/O are sufficient for the application is needed. (see the appendix A)

4.5.3 CPU Requirement:

With multiple I/O's and types of data collection, the CPU in the PLC must be checked if it is fast enough, and has enough processing power to handle the various tasks and programs that may be running on the PLC. Memory is also another factor. The application requires more or less memory based on instructions and programs that need to run, set points and internal flags. (see the appendix A)

4.5.4 Electrical Requirements:

The electrical requirements for inputs, outputs, and system power; When determining the electrical requirements of a system, consider three items:

- Incoming power (power for the control system);
- Input device voltage; and
- Output voltage and current.
  (see the appendix A)

4.5.5 Communication Requirements:

The type of communication protocols that the system will use is another factor in PLC selection. What kind of networks or devices will the PLC be communicating with? Sometimes PLCs are equipped with communication ports, but others require additional communication modules. Other options are to communicate remotely via Ethernet or to build upon multiple types of communications as the system requires. It is important that the PLC can work with the rest of the system and be adaptable in order to accommodate changes made to the system. (see the appendix A)

4.5.6 Programming of the PLC:

Just as the hardware, consider the long-term capabilities of your PLC's programming must be discussed. If it must to gather production data for OEE (Overall Equipment Effectiveness) or other efficiency measures, then the PLC must have enough memory and processing speed to account for the I/Os, alarms, communication, historical data – and then some, to create margins for program additions in the future.

The ease or difficulty of programming the PLC also impacts the initial price tag and the overall cost of maintenance and upgrades. PLC programming should be selected not only for accessibility, but adaptability over time. Choosing the right software can be difficult when considering options that are compatible with the existing system while also moving toward modernization. (see the appendix C)

4.5.7 Physical Environment:

It means the physical environment in which the control system will be located. In harsh environments, the control system must be appropriately housed. In the other hand, accessibility for maintenance, troubleshooting or reprogramming must be taken in consideration.

4.6 SIMATIC S7 - a Few Highlights:

Three decades of innovation have not only made SIMATIC the global leader, it has also made it a synonym for programmable memory controllers. SIMATIC has not only influenced PLC engineering, it has also set the tone time and again as a trend setter. One of the exceptional features of SIMATIC is the consistent compatibility of the system. This compatibility is reflected in the following aspects: Programming; Configuration; Data storage; Communication; Documentation; Operator control and monitoring. [15]

SIMATIC S7 consists of the following automation systems tiered in their range of performance and features:

- **SIMATIC S7-300**, the modular small controller for the lower performance range.
- **SIMATIC S7-400**, high-performance, optimized for systems in the middle and upper performance range.
- The PC-based control system, the **WinAC Slot** version offers the functionality of S7-400 CPUs in PC plug-in cards. [15]

Why PLC S7-400? The table below lists a few of the performance characteristics of the automation systems, which may make it easier to decide if a system is the right one. [15]

The S7-400 PLC has been used to realise this proposed solution. Most useful S7-400 PLC hardware (modules) are mentioned in the appendix (see appendix A)

Figure 4.6-1 Comparison between S7-300, S7-400 and WinAC

Performance Characteristics	S7-300	S7-400	WinAC Slot
Maximum user memory for approx. instructions	512 KB 170 K	20 MB 6.7 M	3.2 MB 1.1 M
Execution times • Bit operations • Word operations • Fixed-point arithmetic • Floating-point arithmetic	 0.1 µs 0.1 µs 0.1 µs 0.6 µs	 0.03 µs 0.03 µs 0.03 µs 0.09 µs	 0.04 µs 0.04 µs 0.04 µs 0.12 µs
Address areas (Inputs/outputs)	8 KB/8 KB	16 KB/16 KB	16 KB/16 KB
Maximum digital inputs/outputs	65536/65536	131072/131072	via PROFIBUS DP 131073/131073
Maximum analog inputs/outputs	4096/4096	8192/8192	via PROFIBUS DP 8192/8192
Expansions with maximum configuration	4 expansion	21 expansion	-
Maximum space between modules	30 m	605 m	-
Distributed I/O available	Yes	Yes	Yes
Number of DP masters • integrated • via interface modules • via CP	 2 - 4	 4 2 10	 2 - -
Networking via integrated interfaces or via CP	MPI PROFIBUS DP PROFINET/ Industrial Ethernet	MPI PROFIBUS DP PROFINET/ Industrial Ethernet	MPI PROFIBUS DP Industrial Ethernet

Conclusion:

The ease and flexibility offered by the PLC for its programming, connection, and adaptation to industrial conditions, with all the functionalities indispensable for process automation, can be seen. The diversity of possibilities, implementation and cost, make it a necessary part of a solution.

However, it should not be forgotten that it is necessary to have a good analysis of the problem to solve while ensuring compliance with the installation rules.

In the next section, the programming and simulation part will be seen.

II. SECTION TWO: Programming and simulation

Introduction:

Programming is the last part of our work, it translates all the structures defined using the Step 7 TIA Portal software. The software offers an interface consisting of a menu bar, a toolbar and a work window.

4.7 Symbols (Mnemonics):

4.7.1 Input Variables:

Table 4.7-1 Identification of the inputs

SC14K001 XG03	Bool	%I0.0	INST .FERM .RAPIDE .1 NON DE-CLENCHEE
SC14K002 XG03	Bool	%I0.1	INST .FERM .RAPIDE 2 NON DE-CLENCHEE
SC14P241 XG01	Bool	%I0.2	PRESSION FLUIDE FERM RAP > 5 BAR
SC24P213 XG01	Bool	%I0.3	PRESSION FLUIDE AUX FERM RAP > 5 BAR
SB12K011 XG01	Bool	%I0.4	CONTROLEUR POS .ARBRE POS DE SERVICE
SB12K011 XG03	Bool	%I0.5	CONTROLEUR POS D'ARBRE POS DE SERVICE
SC14K021 XG03	Bool	%I0.6	DECLENCH .MANUEL FERM .RAP POS DE SERVICE
SC14K022 XG03	Bool	%I0.7	DECLENCH MANUEL FERM.RAP POS DE SERVICE
SC11S041 XT51	Bool	%I1.0	TELEDECLENCH.FERM.RAP.1 AR- RET
SC11S042 XT52	Bool	%I1.1	TELEDEDECLENCH.FERM.RAP 2 ARRET
SB11 K001 XG03	Bool	%I1.2	CONTROLEUR DE SURVITESSE 1 POS SERVICE
SB11K002 XG03	Bool	%I1.3	CONTROLEUR DE SURVITESSE 2 POS DE SERVICE
SC24K004 XG05	Bool	%I1.4	PROTECTION HYDR CONDEN- SEUR POS DE SERVICE
SC14P011 XG52	Bool	%I1.5	PRESSION FLUIDE FERM .RAP < 2.5 BAR
SC14P012 XG52	Bool	%I1.6	PRESSION FLUIDE FERM.RAP.<2.5 BAR
SC23P211 XG52	Bool	%I1.7	PRESS.FL..AUX..DEMARRAGE < 2 BAR
SC11S042 XT01	Bool	%I2.0	CONTACTEUR DS AIR FERM.RAP. 2 MARCHE
SC11S041 XT01	Bool	%I2.1	CONTACTEUR DS AIR FERM .RAP.1 MARCHE

SC11P233 XG52	Bool	%I2.2	FL.ESSAI CONTR.POS.ARBRE < 0.1BAR
SC24K001 XG09	Bool	%I2.3	DISP.ESSAI CONTROL.VITESSE 0%
SC11P241 XG01	Bool	%I2.4	PRESS.AMANT DISTRIB.ESSAI > 5 BAR
SC15P215 XG52	Bool	%I2.5	PRESSION HUILE D'ESSAI < 0.1 BAR
SC11P243 XG01	Bool	%I2.6	P.ENTRE INST.TELED.F.RAD.PD > 5 BAR
S011K010 XT53	Bool	%I2.7	RELAISD'INTERRUPTION 1 ARRET
S012K010 XT53	Bool	%I3.0	RELAIS D'INTERRUPTION 2 AR- RET
SC24K004 XG03	Bool	%I3.1	PROTECTION HYDR.CONDENS POS.DE SERVICE
SD10P211 XG51	Bool	%I3.2	PRESSION ABS.AV CONDEN- SEUR < 0.25 BAR abs
SC11P245 XG01	Bool	%I3.3	FL COMM.AMONT INST .FERM.R >5BAR
SC14S201 XG09	Bool	%I3.5	DISTRIBUTEUR D'ESSAI POS.DE SERVICE
SC23P212 XG52	Bool	%I3.6	PRESSION FL.DEMARRAGE < 2BAR
S011U101 XV02	Bool	%I3.7	DECL.F.RAP.PAR.CONT.P.ARB.PD .ESSAI LIBERE
S011U102 XV02	Bool	%I4.0	DECL.F.PAR.CONT.P.ARB.PD.ES- SAI LIBERE
SC14S201 XG10	Bool	%I4.1	DISTRIBUTEUR D'ESSAI POS.D'ESSAI
S011U001 XA11	Bool	%I4.2	EIN / AUS .AUTOMATISME MAR- CHE / ARRET (XA11)
SC11P232 XG52	Bool	%I4.3	PRES AMONT DISTRIB D'ESSAI < 2 BAR
SC11P234 XG52	Bool	%I4.4	PENTRE INST FERM RAP PJ ESSAI < 2 BAR
BETR	Bool	%I4.5	BOTTON MANUAL MARCHE
STAND	Bool	%I4.6	ORDRE MANUEL PROG.DE RE- MISE MARCHE
S012U001 XA01	Bool	%I4.7	VANNE D'ARRET DE VAPEUR MARCHE
SC11P230 XG52	Bool	%I5.0	FL.DE COMM .ENTRE ELECTROV < 2 BAR
SC11P231 XG52	Bool	%I5.1	FL DE COMM. AMONT INST .F .RAP < 2 BAR
SC11P244 XG01	Bool	%I5.2	FL.DE.COMM.ENTRE ELECTROV > 5 BAR
EIN L03	Bool	%I5.3	TELEDECLENCH.FERM.RAP.1 MARCHE
EIN L06	Bool	%I5.4	TELEDECLENCH.FERM.RAP.2 MARCHE

SC14K002 XG53	Bool	%I5.5	INST.FERMETURE RAPIDE DE- CLENCHEE
SC14K011 XG53	Bool	%I5.6	INST.FERMETEUR RAPIDE DE- CLENCHEE
SC14P211 XG52	Bool	%I5.7	PRESSION FLUIDE FERM.RAP. < 2 BAR
SC24P211 XG52	Bool	%I6.0	PRESSION FLU- IDE.AUX.FERM.RAP. < 2 BAR
SC15P212 XG52	Bool	%I6.1	PRESSION HUILE D'ESSAI < 4.8 BAR
SB11K001 XG53	Bool	%I6.2	CONTROLEUR SURVITESSE.1 DE- CLENCHE
SB11K002 XG53	Bool	%I6.3	CONTROLEUR SURVITESSE 2 DE- CLENCHEE
SC15P211 XG52	Bool	%I6.4	PRESSION HUILE D'ESSAI < 4.5 BAR
SD10P214 XG01	Bool	%I6.5	PRESSION ABS .AU CONDEN- SEUR > 035 BAR abs
SD10P212 XG01	Bool	%I6.6	PRESSION ABS.AV CONDEN- SEUR > 0.35 BAR
SD1024K004 XG55	Bool	%I6.7	PROTECTION HYD.CONDEN- SEUR DECLENCHEE
EIN L12	Bool	%I7.0	PROTECTION HYD.CONDEN- SEUR MARCHE
SB12K011 XG53	Bool	%I7.1	CONTRROLEURPOSITION ARBRE DECLENCHEE
SB12K011 XG51	Bool	%I7.2	CONTROLEUR POSITION ARBRE DECLENCHEE
S011U102 XV01	Bool	%I7.3	DECL.FERM.RAP.PAR CPA PD ES- SAI BLOQUE
S011U101 XV01	Bool	%I7.4	DECL.FERM.RAP.PAR CPA PD ES- SAI BLOQUE
EIN L09	Bool	%I7.5	CONTROLEUR DE SURVITESSE MARCHE
EIN L15	Bool	%I7.6	CONTROLEUR POSITION ARBRE MARCHE
SC24K001 XG10	Bool	%I7.7	DISP ESSAI CONTROLEUR SUR- VIT 100%
REMISE A R	Bool	%I8.0	
PERMISIF	Bool	%I8.1	

4.7.2 Output Variables:

Table 4.7-2 Identification of the outputs

S011U001 XA01 LAMP	Bool	%Q0.0	AUTOMATIQUE MARCHE
S011U001 WA02	Bool	%Q0.1	AUTOMATIQUE ARRET
SC24K001 XS07	Bool	%Q0.2	DISP.ESSAI CONTROL.SURVIT 100%
S011K010 XU01	Bool	%Q0.3	RELAIS D'INTERRUPTION 1.MARCHE
S012K010 XU01	Bool	%Q0.4	RELAIS D'INTERRUPTION 2 MARCHE
SC23S241 XU02	Bool	%Q0.5	ELECTROVANNE DE REMISE 1.MARCHE
S011U101 XS54	Bool	%Q0.6	DECL.F.RAP.PAR.COST.P.ARB.PD .ESSAI LIBERE
S011U102 XS54	Bool	%Q0.7	DECL.F.RAP.PAR.CONT.ARB.PD ESSAI LIBERE
SC11S242 XS55	Bool	%Q1.0	DISTRIBUTEUR D'ESSAI POS.DE SERVICE
S011U001 XS55	Bool	%Q1.1	SELECTION ANNULER
S011U101 XS56	Bool	%Q1.2	T.DECL.F.RAP.ELECTROV.1 PD.ESSAI ARRET
S011U201 XS56	Bool	%Q1.3	T.DECL.F.RAP.ELECTROV.2 PD ESSAI ARRET
S011U101 XU01	Bool	%Q1.4	TELEDECL.FERM.RAP.1 ELECT.PD ESSAI MARCHE
S011U102 XU01	Bool	%Q1.5	TELEDECL.FERM.RAP.2 ELECT.PD ESSAI MARCHE
SE10C010 XS02	Bool	%Q1.6	SEUIT VITESSE 110% TESTER
S010Y010 XS03	Bool	%Q1.7	SEUIL VITESSE 110% TESTER
SC11S242 XU02	Bool	%Q2.0	DISTRIBUTEUR D'ESSAI POS.D'ESSAI
S011K010 XU03	Bool	%Q2.1	TELEDECLENCH.FERM.RAP.1 TESTER
S011K010 XU04	Bool	%Q2.2	TELEDECLENCH.FERM.RAP.1 TESTER
S011U001 XA23	Bool	%Q2.3	AUTOMATIQUE ORDRE DE CONTROLE
S011U001 XA03	Bool	%Q2.4	LAMPE PROGRAMME MISE EN MARCHE
S011U001 XA04	Bool	%Q2.5	LAMPE PROGRAMME REGIME D'ARRET
S011U001 XA05	Bool	%Q2.6	LEMPE PERTURBATION
SC24K001 XS51	Bool	%Q2.7	DISP ESSAI CONTROL SURVITESSE
SC23S242 XS52	Bool	%Q3.0	ELECTROVANNE DE REMISE 2 MARCHE
SD10S241 XS08	Bool	%Q3.1	PROTECTION HYD.CONDENSEUR TESTER
SC11S243 XS09	Bool	%Q3.2	CONTROLEUR POS.ARBRE TESTER
SC11S243 XS0 X	Bool	%Q3.3	LAMPE INDIC POS ESSAI

4.8 Programming part:

In this project, the **TIA Portal V15** software have been used to realise the simulation process. (see the appendix B)

Two types of programming languages have been utilized: Function Block Diagram (**FBD**) and Sequential Function Chart (**SFC**). (see the appendix C)

The blocks in this developed solution are: one organizational block (**OB**), one function (**FC**), six function blocks (**FB**) and five calling blocks. (see the appendix E)

4.8.1 The description of the different blocks:

- **Main [OB1] S011U001:** It is the block that controls and organizes all the programs; it also performs the calling of the different blocks and the communication between them (see the appendix E)

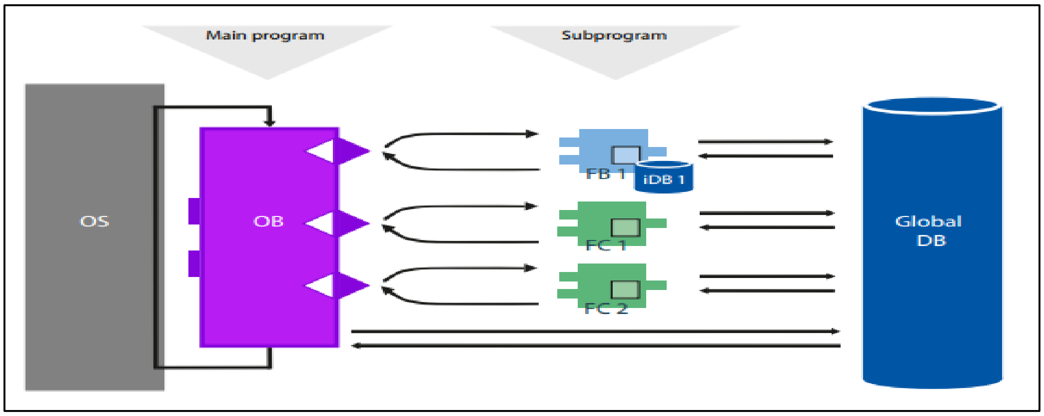


Figure 4.8-1 Call hierarchy of the blocks

- **SWITCHING AUTO/MANU [FC1]:** It performs the switching to the manual stop and the switching to the automatic run. (see the appendix E)
- **THE SELECTIONS [FB8]:** It contains the memories and the outputs that are needed in the execution of (some networks) of the selections program (some networks) in the OB1 (see the appendix E)
- **S011U002 [FB4]:** It is the program of the preliminary test (starting program) combined with the ones of the process of controls. (see the appendix E)
- **THE PROCESS OF CONTROL [FB6]:** It contains the memories and the outputs that are needed in the execution of the FB4. (see the appendix E)
- **THE RESETTING PROGRAM [FB3]:** It contains the memories and the outputs that are needed in the execution of the FB2. (see the appendix E)
- **THE PRELIMINARY TEST [FB8]:** It contains the memories and the outputs that are needed in the execution of the FB4. (see the appendix E)
- **S011U003 [FB2]:** It is an SFC program; It performs the resetting (stopping) program. (see the appendix E)

4.8.2 The control program of the turbine protections:

4.8.2.1 The preliminary test (the starting program):

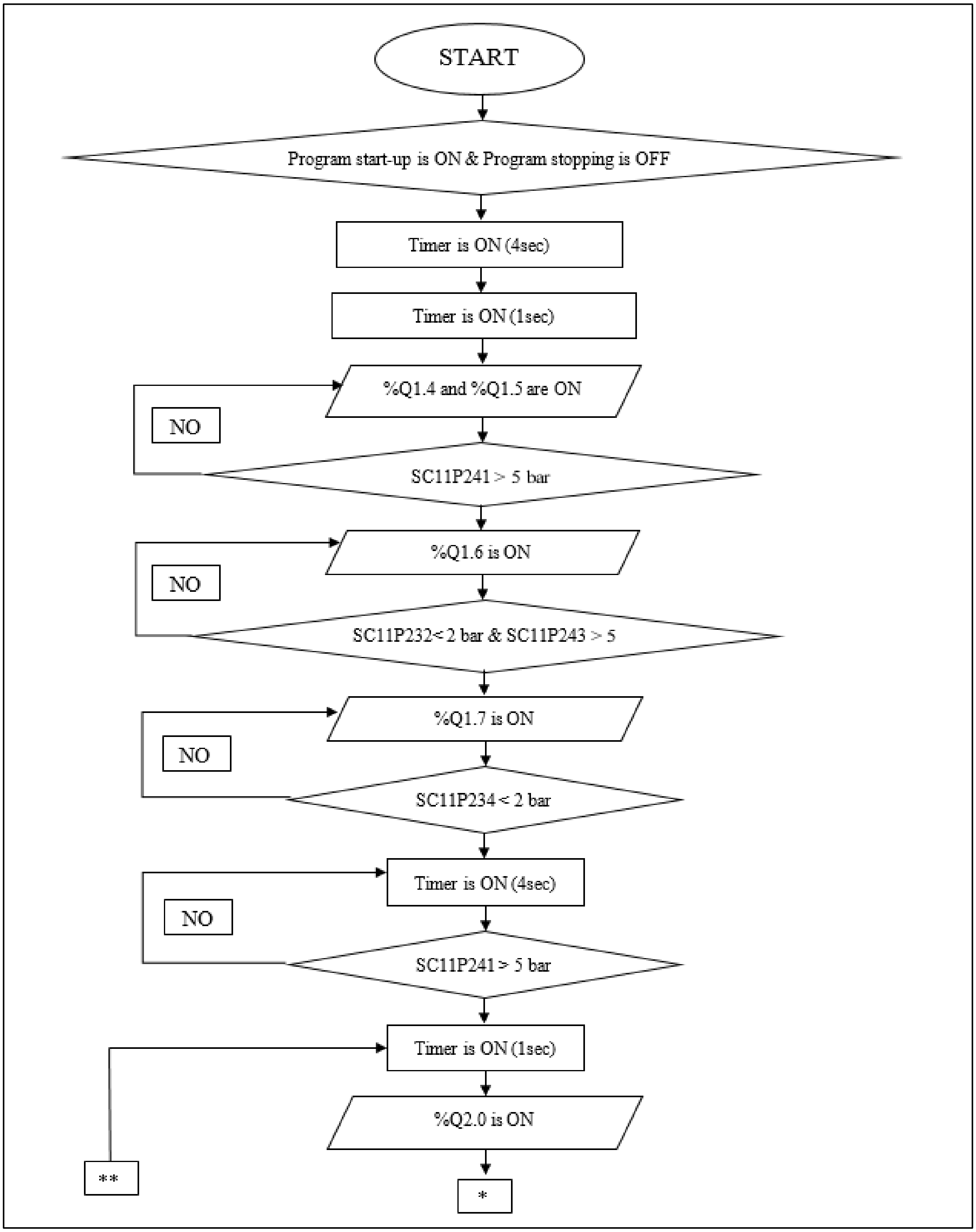


Figure 4.8-2 The preliminary test (the starting program) flowchart-a-

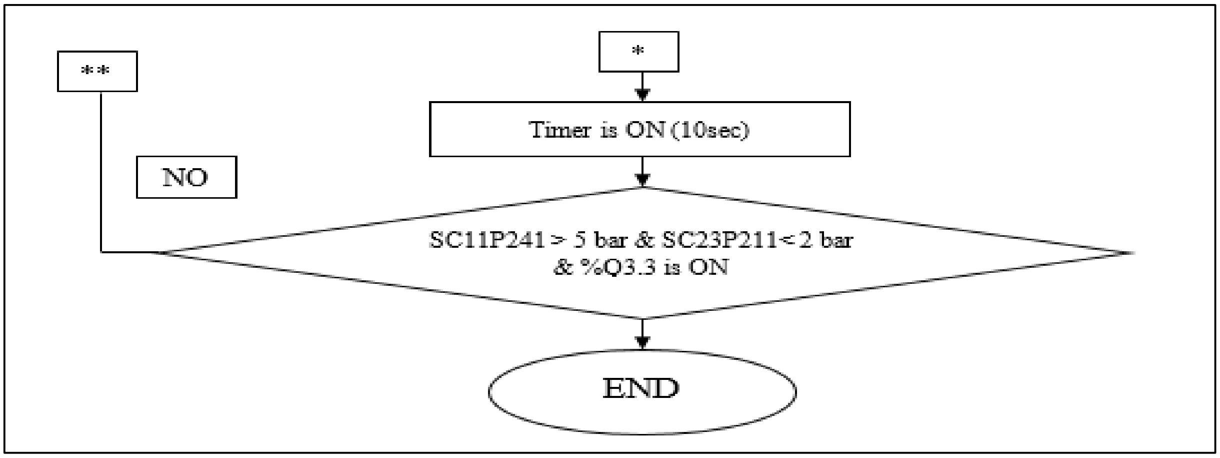


Figure 4.8-3 The preliminary test (the starting program) flowchart-b-

4.8.2.2 The process of controls program:

4.8.2.2.1 Electrovalves control (SC11S041) and (SC11S042):

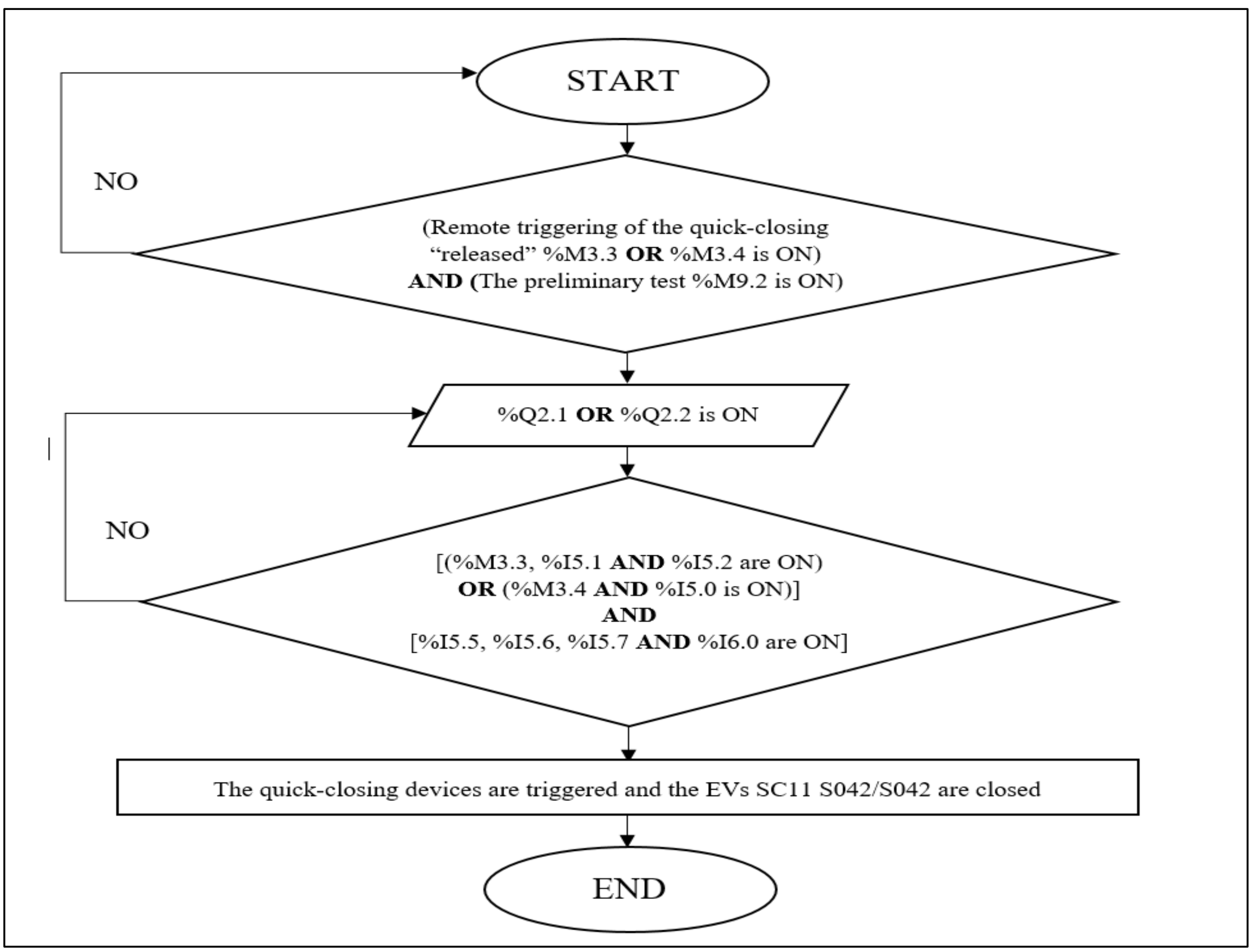


Figure 4.8-4 The flowchart of the tripping EVs control SC11 S041/S042

4.8.2.2.2 Control of overspeed trip protection:

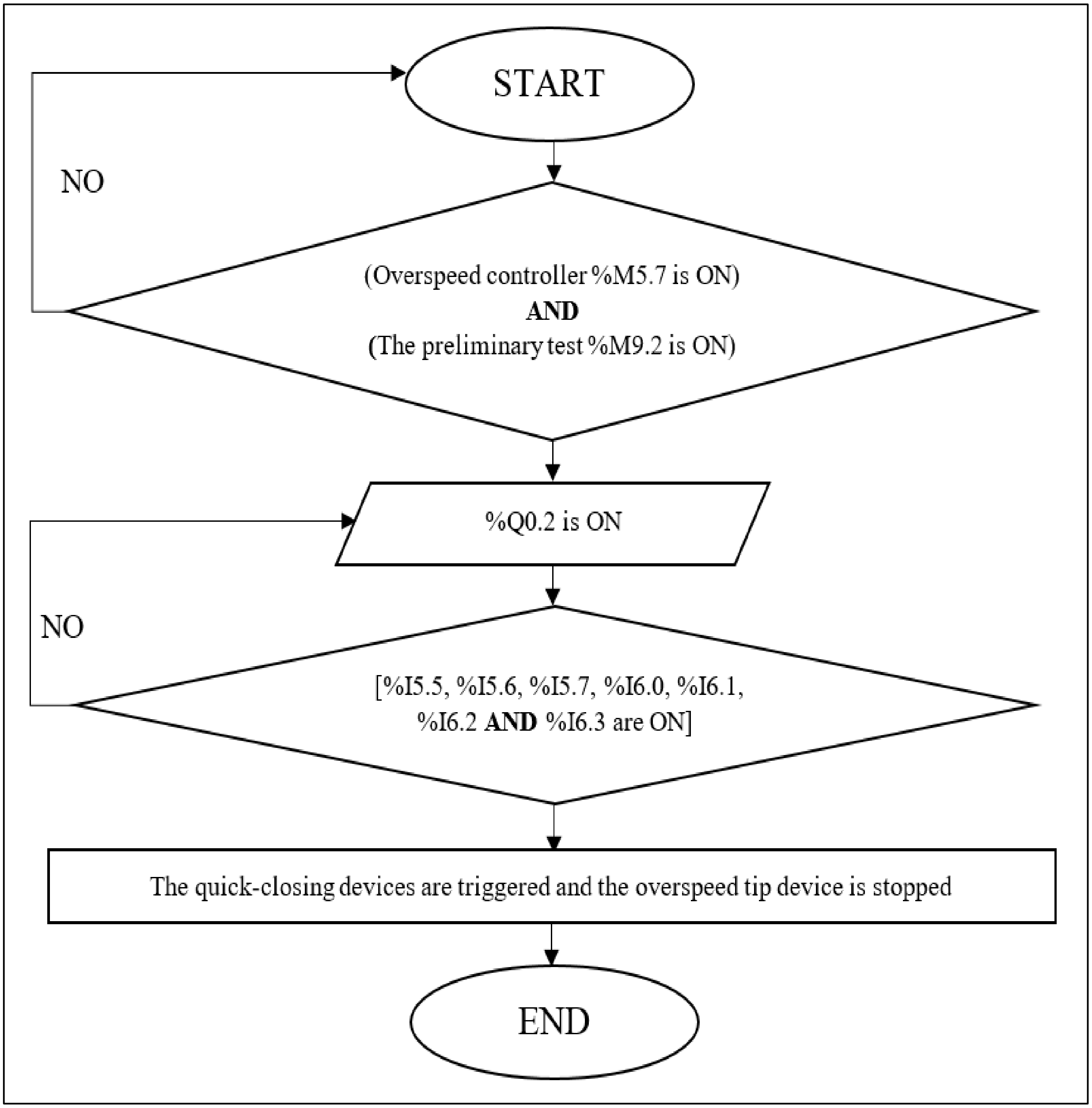


Figure 4.8-5 The flowchart of the mmechanical overspeed control

4.8.2.2.3 Control of condenser protection:

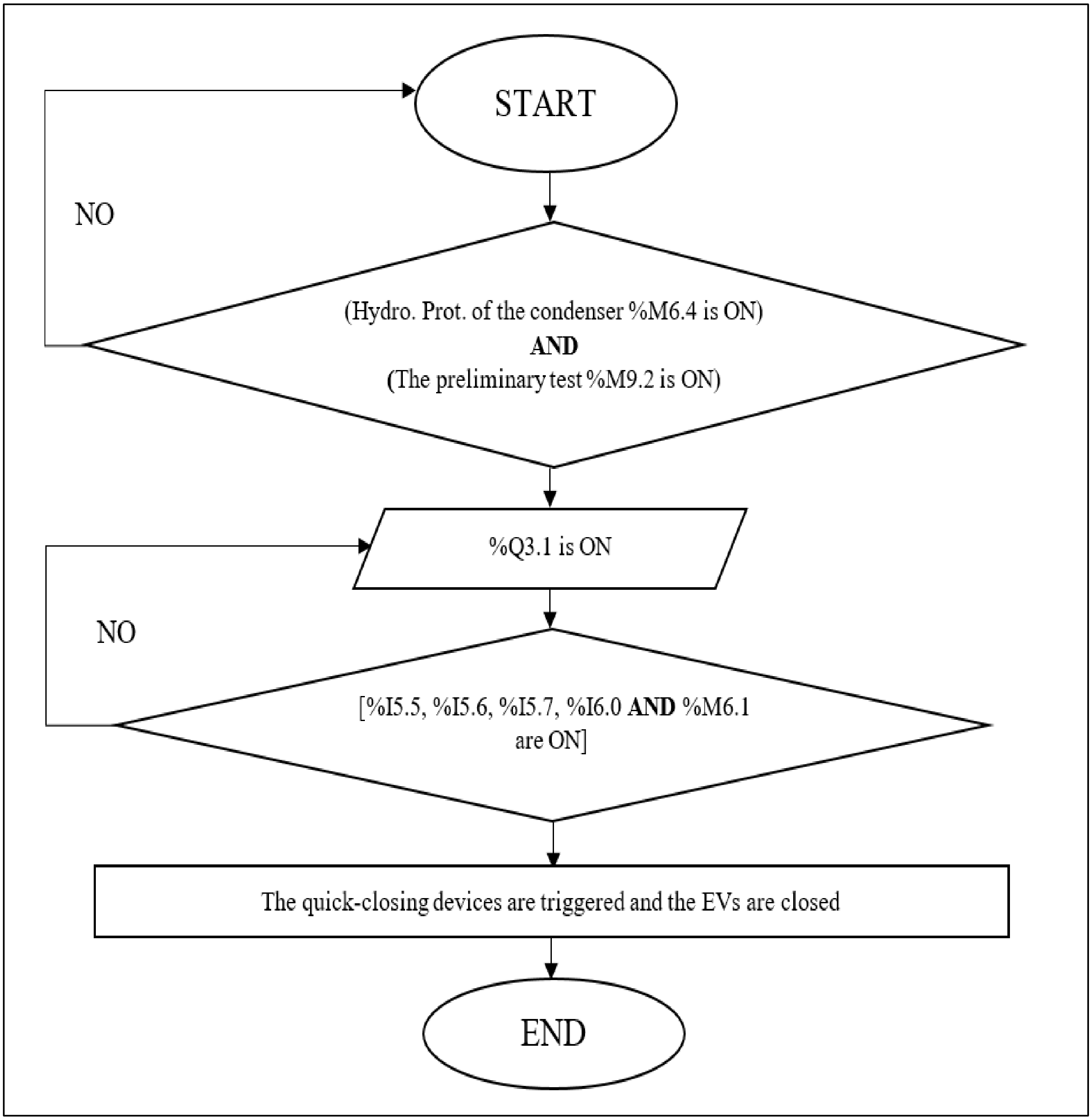


Figure 4.8-6 The flowchart of the condenser hydraulic protection

4.8.2.2.4 Control of thrust bearing wear protection:

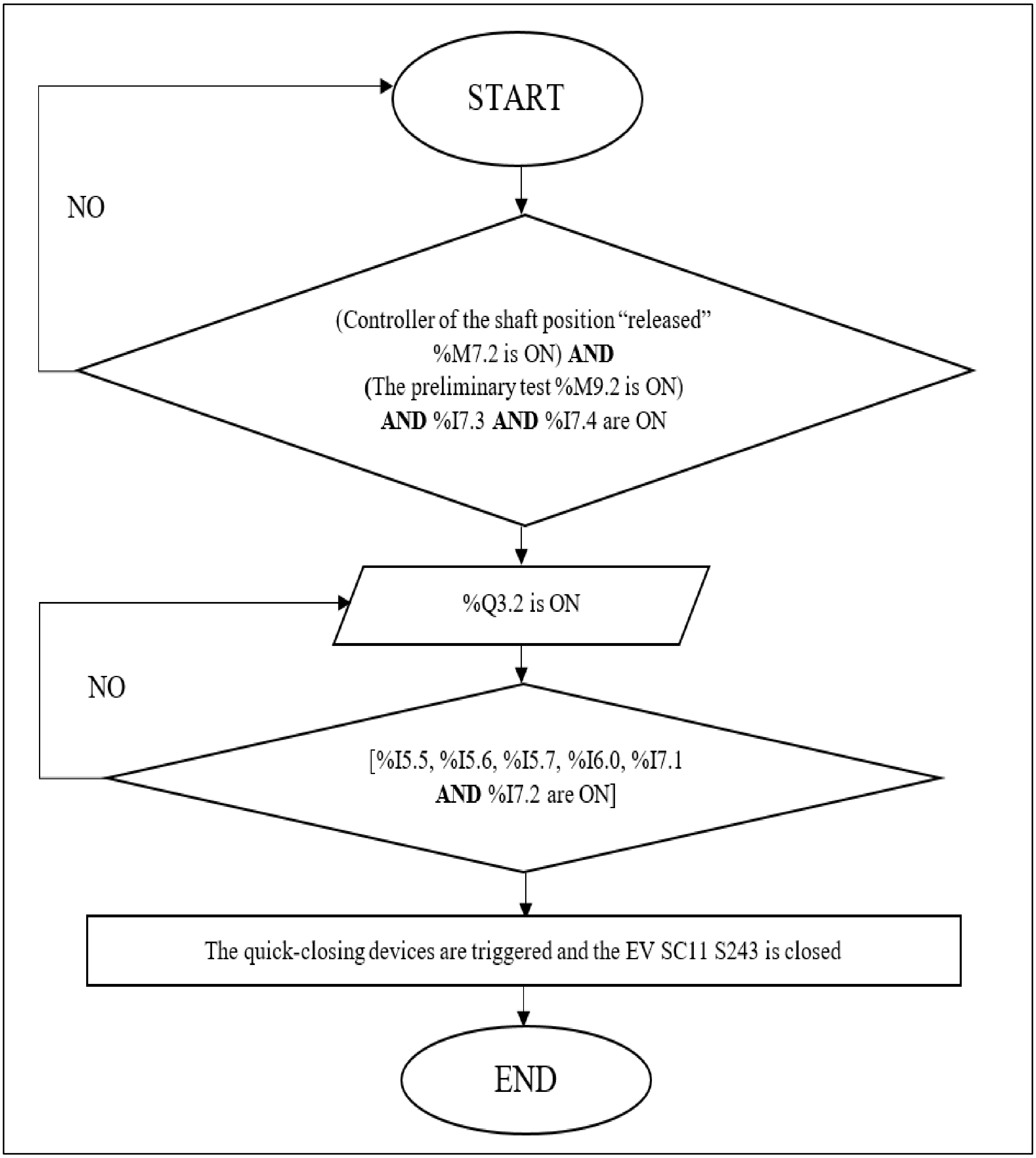


Figure 4.8-7 The flowchart of thrust bearing wear protection

4.8.2.3 The reset program (the stopping program):

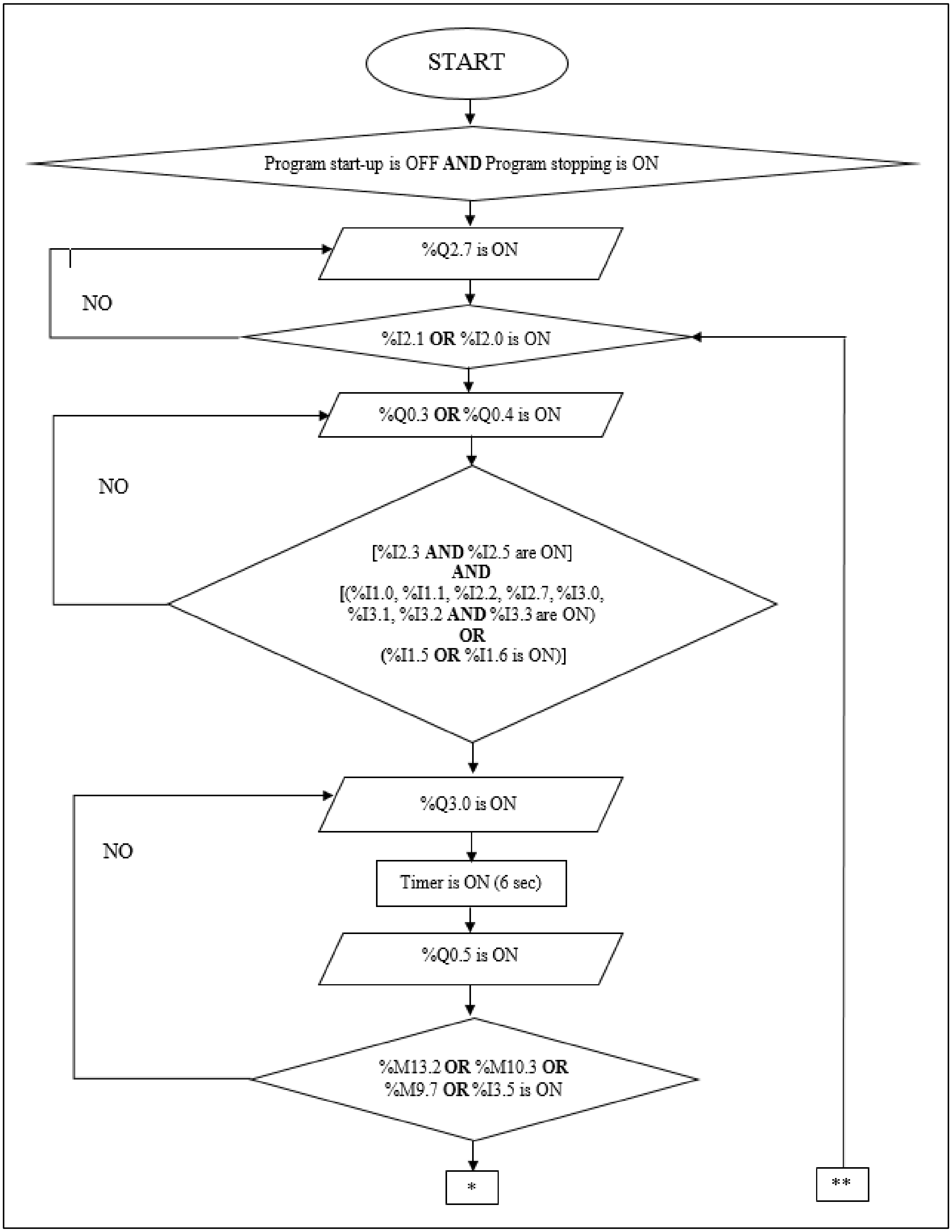


Figure 4.8-8 The flowchart of the resetting (stopping) program-a-

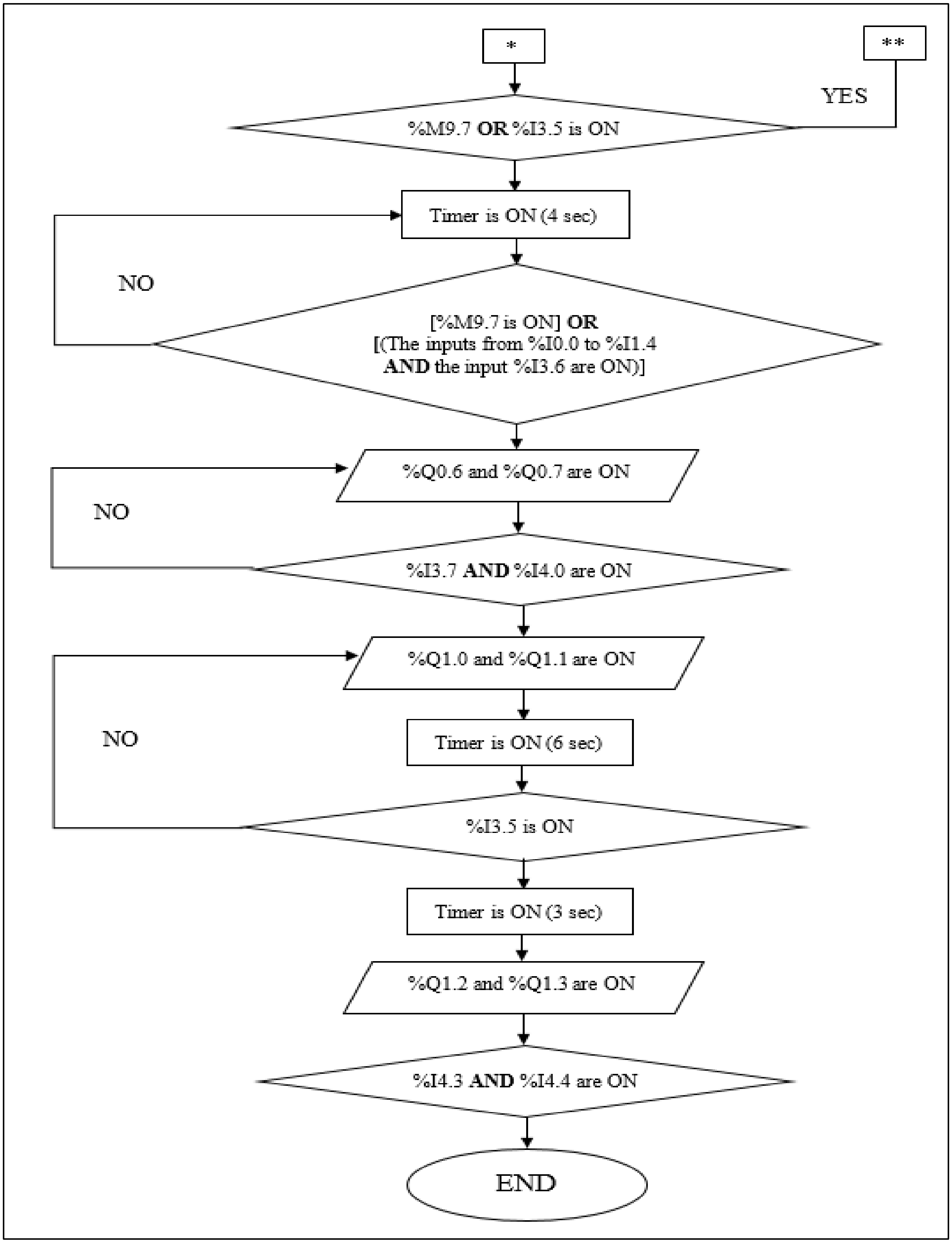


Figure 4.8-9 The flowchart of the resetting (stopping) program-b-

4.9 Simulation:

After the completion of the turbine protection test program, our program can be simulated with the following steps:

- Launching and configuring S7-PLCSIM: to test the program without connecting the PG to a PLC, simply activate the simulator. All accesses to the PLC interface are simulated internally by the S7-PLCSIM simulation software. To launch PLCSIM, the "*Simulator*" must be activated by the icon: 
- All that remains is to use the "Insert" menu to insert all the "Inputs" and "Outputs" data that have been utilized in the program to be tested.
- Simply enter the desired addresses, IB, MB, QB and the representation mode (*bits*). The S7 program to be tested can now be loaded into the simulated PLC.
- Select *PLC [CPU 412]* and click on "*Load*": 
- Click on "**View**": 

Activate the PLC to be simulated (**RUN** mode is activated) *and* activate the input bits with a mouse click. The outputs will be activated automatically.

Here are some simulation examples:

- **Step 5 of the preliminary test (starting program):**

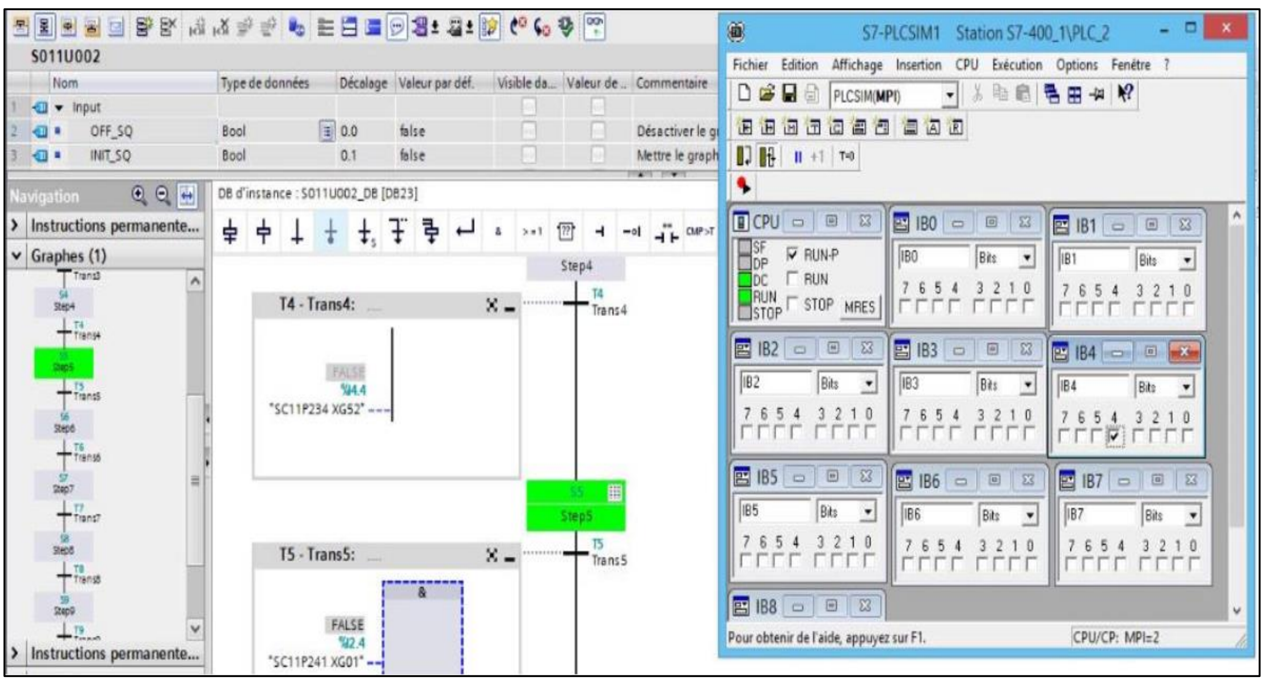


Figure 4.9-1 Step 5 of the preliminary test

- **Step 54 of the resetting (stopping) program:**

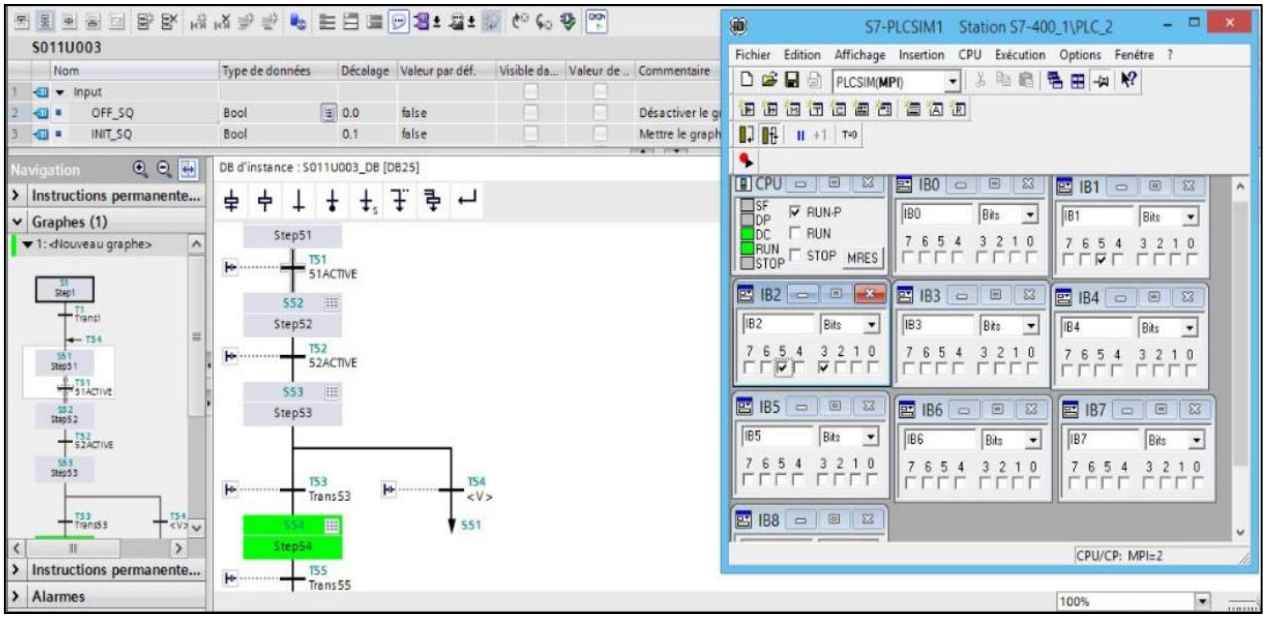


Figure 4.9-2 Step 54 of the resetting (stopping) program

Conclusion:

The program, that has been developed for the automatic control of the thermal power plant, has been validated using the simulation software **S7PLCSIM.** This software has an interface that allows the user to monitor and modify the developed program in order to make it operational for a possible real implementation on an industrial programmable logic controller (PLC).

General Conclusion

In this project, the SIMATIC S7-400 PLC from SIEMENS was been chosen for the application. The reasons why this type has been used are mainly manifested in:

- Technical performances (processing frequency, type of signals processed, etc.).
- Sufficient memory capacity.
- Possibility of extension in terms of the high number of process inputs and outputs required by some applications.
- Possibility to integrate special modules.

An economic calculation has not been made to say that the replacement cost (PLC instead of the wired control system) is more interesting, but it is certain that the power plant will have to gain in particular better by protecting the turbines more, and this for:

- Complexity of the existing installation (wired electrical logic).
- Relatively difficult troubleshooting and maintenance.
- Problem of inflexibility (fixed control system).
- Minimal efficiency and other economic problems such as: productivity rates, maintenance costs, etc.

It was proposed to replace the existing hardwired field control with a PLC for improved safety, speed and reliability of the turbine protection system. As well as reducing the number of breakdowns and research has useful productivity.

This work is done based on the assumption that all the I/Os are digital (bool), so as a further work, it is suggested to deal with both digital and analog I/Os. Also, it is better to realize the visualization part 'Human Interface Machine (**HMI**)' because it is better and easier to deal with the visualizing process instead of the internal program.

BIBLIOGRAPHY

[1] Internal documentation of the thermal power plant of Cap-Djinet.

[2] GHEZAL Taous and AGUENOU Nesrine. Développement d'une solution à logique programmée pour le contrôle et la surveillance des brûleurs 'Cap Djinet', Final year project, Univ. M'hamed Bougara, Boumerdes, 2017.

[3] DAFAL Noureddine and HAMRANI Lyes. Etude, supervision et régulation du niveau de la bâche alimentaire de la centrale de Cap Djinet avec un automate programmable Siemens S7-300 CPU315, Final year project, Univ. M'hamed Bougara, Boumerdes, 2017.

[4] BOUALLELI Ahmed and BOUSSAID Boualem. Etude de la protection électrique d'un alternateur Siemens de la centrale Cap-Djinet, Final year project, Univ. Mouloud Mammeri, Tizi Ouzou, 2008.

[5] DJATIT Farouk and AMRANI Mustapha. Commande et supervision de la pompe d'extraction de la centrale thermique de Ras-Djinet par un API S7 300, Final year project, Univ. M'hamed Bougara, Boumerdes, 2017.

[6] Rabie MEHIRA. Pilotage en temps réel d'une centrale électrique à vapeur Pour l'amélioration du rendement et de la consommation spécifique, Final year project, Univ. Hadj Lakhdar, Batna.

[7] https://realpars.com/plc-programming-languages/ on: Monday, October 26th,2020.

[8] https://www.electrical4u.com/programmable-logic-controllers/ on: Sunday, October 25th,2020.

[9] https://automationforum.co/difference-between-modular-plc-compact-plc/ on: Sunday, October 25th,2020.

[10] https://learn.realpars.com/videos/power-supply/ on: Sunday, October 25th,2020.

[11] https://learn.realpars.com/videos/2-what-components-makeup-a-plc/ on: Sunday, October 25th,2020.

[12] Automation System S7-400 Hardware and Installation, order number *6ES7498-8AA04-8BA0*, Edition 04/2004; SIEMENS documentation

[13] 'The most powerful PLC'; SIEMENS documentation

[14] S7-400 Automation System Module Data, part of the documentation package 6ES7498-8AA05-8BA0, Edition 09/2009; SIEMENS documentation

[15] Automation System S7-400 Configuration and Use, order number: *6ES7498-8AA00-8BB0*, Edition 10/2005; SIEMENS documentation.

APPENDIX A:
The PLC S7-400 and its components

1 Overview of the S7-400:

The S7-400 is the most powerful PLC in the SIMATIC Controller family; the range that enables successful automation solutions with Totally Integrated Automation. The S7-400 is an automation platform for system solutions in the manufacturing and process industries, and is distinguished above all by its modularity and performance reserves. [13]

The S7-400 is a programmable logic controller designed for medium to high-range automation tasks, the reason why almost any automation task can be implemented with a suitable choice of S7-400 components. S7-400 modules have a block design for swing-mounting in a rack. Expansion racks are available to extend the system. [12]

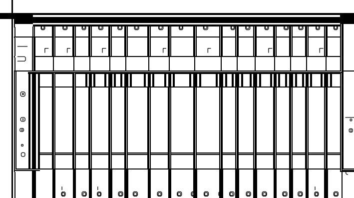
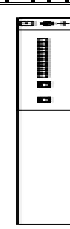
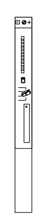
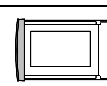
Application areas are found in the automobile industry (e.g. production lines), mechanical engineering, including specialist machine construction, warehousing, building systems automation, the steel industry, energy generation and energy distribution, the paper and printing industry, woodworking, the food and beverages industry, process engineering, e.g. water supply and disposal, the chemical and petrochemical industries, … [13]

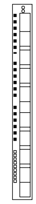
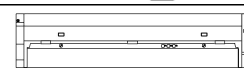
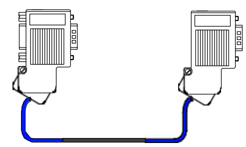
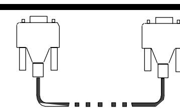
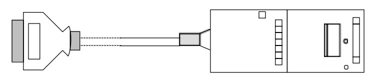
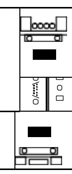
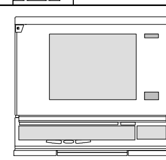
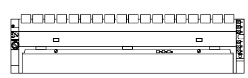
There are other versions of the S7-400 available for specialist applications:

- Applications requiring fault tolerance can be implemented with the S7-400H.
- For failsafe applications, there is the S7-400F that is also available in a fault-tolerant version.
- S7-400 CPUs are available as PC plug-in cards for PC-based solutions. [13]

2 S7-400 components: [12]

Table A-1 S7-400 components

Components	Function	Illustration
Racks (UR: Universal Rack) (CR: Central Rack) (ER: Expansion Rack)	... provide the mechanical and electrical connections between the S7-400 modules.	
Power Supply Modules (PS = Power Supply) Accessories: Backup battery	... convert the line voltage (120/230 VAC or 24 VDC) to the 5 VDC and 24 VDC operating voltages required to power the S7-400.	
CPUs Central Processing Units (CPUs)	... execute the user program; communicate via the multipoint interface (MPI) with other CPUs or with a programming device (PG).	
Memory cards	... store the user program and parameters.	

IF 964-DP **interface module**	... used to connect distributed I/Os via PROFIBUS-DP	
Signal Modules (SM = Signal Module) (digital input modules, digital output modules, analog input modules, analog output modules) Accessories: Front connector with three different terminal systems	... match the different process signal levels to the S7-400. ... form the interface between PLC and process.	
Interface modules **(IM = Interface Module)** Accessories: Connecting cable Terminator	... interconnect the individual racks of an S7-400.	
Cable ducts	...are used for routing cables and as ventilation.	
PROFIBUS bus cables	...connect CPUs to programming devices.	
PG cables	...connect a CPU to a programming device.	
PROFIBUS components for example, PROFIBUS bus terminal	... connect the S7-400 to other S7-400 devices or programming devices.	
RS 485 repeaters	...amplify data signals on bus lines and links bus segments.	
Programming device (PG) or PC with the STEP 7 software package	...configures, programs, debugs, and assigns parameters to the S7-400.	
Fan subassemblies (for special areas of application)	...ventilates modules in special cases; can be operated with or without a filter.	

2.1 Racks: [12]

Table A-2 The different types of racks and their specifications

Rack	No. of Slots	Available Buses	Applications	Characteristics
UR1	18	I/O bus Communication bus	CR or ER	Rack for all module types in the S7-400.
UR2	9			
ER1	18	Restricted I/O bus	ERs	Racks for signal modules (SMs), receive IMs, and all power supply modules. The I/O bus has the following restrictions: • Interrupts from modules have no effect because no interrupt lines exist. • Modules are not supplied with 24 V, i.e. modules requiring 24 V cannot be used (see technical data of the modules). • Modules are neither backed up by the battery in the power supply module nor by the voltage applied externally to the CPU or receive IM (EXT.BATT. socket).
ER2	9			
CR2	18	I/O bus, segmented Communication bus, continuous	Segmented CR	Rack for all module types in the S7-400 except receive IMs. The I/O bus is subdivided into 2 I/O bus segments of 10 and 8 slots respectively.
CR3	4	I/O bus Communication bus	CR in standard systems	Racks for all S7-400 module types except receive IMs. CPUs 41x-H only in stand-alone operation.

To connect one or more ERs to a CR, you must fit one or more send IMs in the CR. The send IMs have two interfaces. You can connect one chain of up to four ERs to each of the two interfaces of a send IM in the CR. Different IMs are available for local connection and remote connection. The table above shows the different types of racks, whereas the table below shows the connection rules, and the figure shows the ways of connecting central and expansion racks. [12]

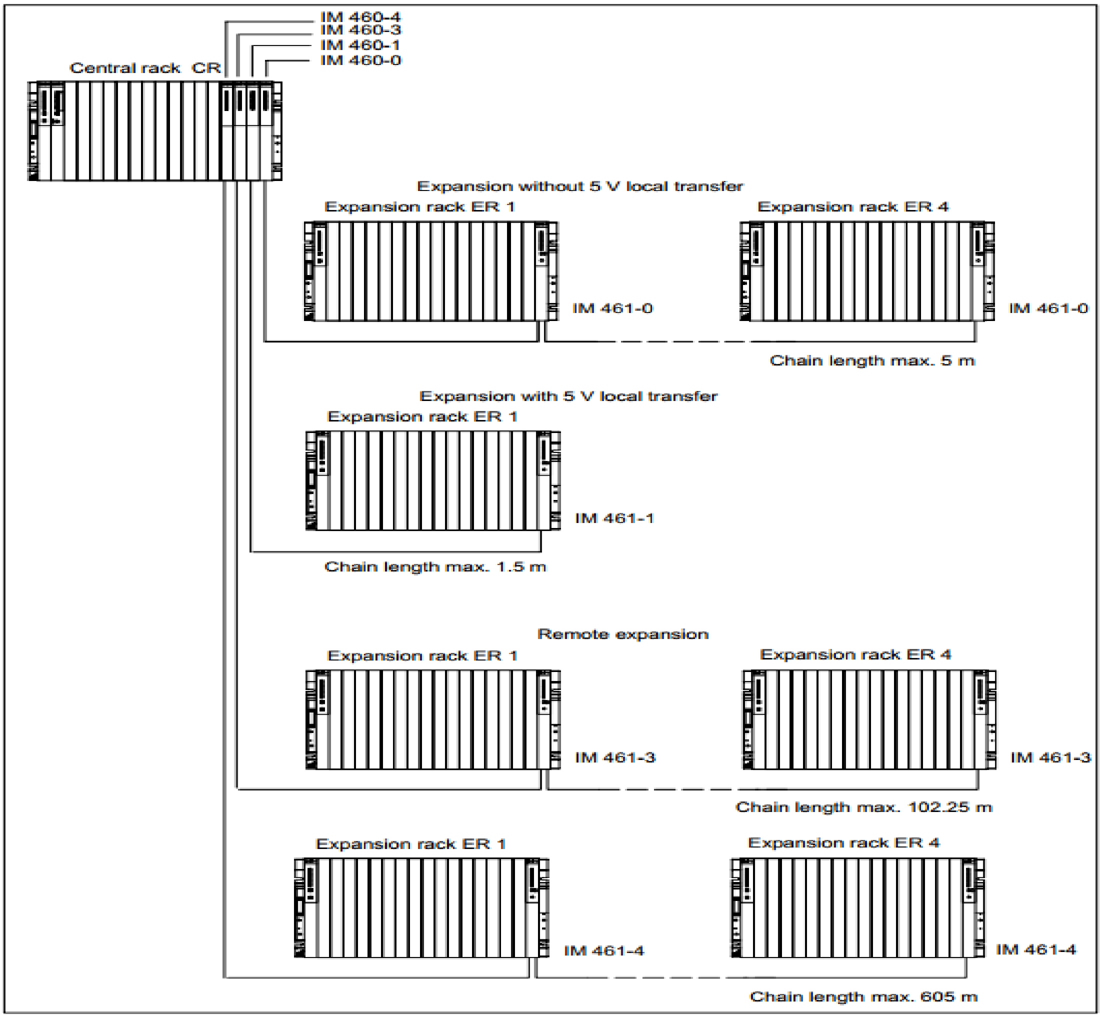


Figure A-1 The ways of connecting central and expansion racks

Table A-3 The connection rules between central and expansion racks

	Local Connection		**Remote Connection**	
Send IM	460-0	460-1	460-3	460-4
Receive IM	461-0	461-1	461-3	461-4
Max. number of connectable EMs per chain	4	1	4	4
Max. distance	5 m	1.5 m	102.25 m	605 m
5 V transfer	No	Yes	No	No
Max. current transfer per inter- face	–	5 A	–	–
Communication bus transmission	Yes	No	Yes	No

2.2 CPUs:

There is a tiered range of CPUs within the S7-400. You can therefore select the most suitable and economic solution for your application. The following will describe a few of the features that the S7-400 CPUs have in common and exemplify the system-wide compatibility. Figure below shows a double-width CPU with its interfaces, operator controls and display components. [15]

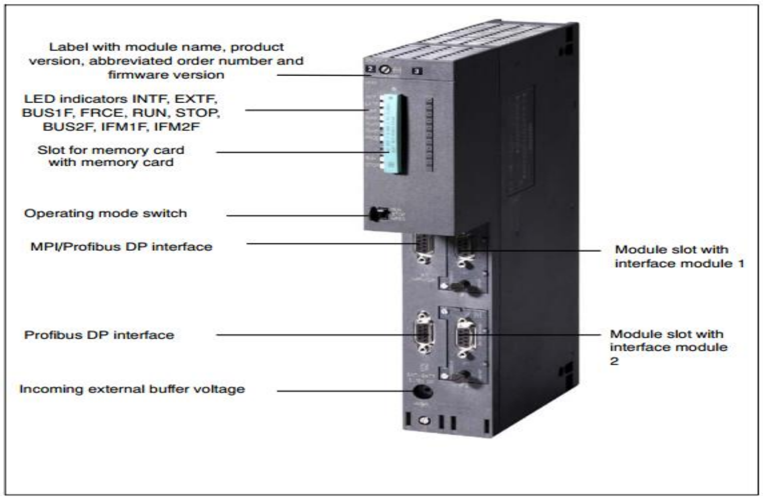


Figure A-2 Arrangement of the S7-400 CPUs' operator controls and display components

The table below illustrates the performance characteristics of the S7-400 CPUs: [15]

TableA-4 The performance characteristics of the S7-400 CPUs

CPU	412-1	412-2	414-2	414-3	416-2 416-2F	416-3	417-4
User (work) memory • integrated • integrated (for program) • integrated (for data)	512 KB 256 KB 256 KB	1 MB 512 KB 512 KB	02 MB 01 MB 01 MB	04 MB 02 MB 02 MB	08 MB 04 MB 04 MB	16 MB 08 MB 08 MB	32 MB 16 MB 16 MB
Loading memory • expandable FEPROM, max. • integrated RAM, max. • expandable RAM, max.	64 MB 512 KB 64 MB				64 MB 01 MB 64 MB		
Buffering (backup)	Yes						
Program execution • Free cycle • Time interrupts • Delay interrupts • Watchdog interrupts • Hardware interrupts • Multicomputing interrupts • Clock synchronization interrupts • Startup	1 2 2 2 2 1 4 3		1 4 4 4 4 1 4 3		1 8 4 9 8 1 4 3		1 8 4 9 8 1 4 3

Number of blocks • FC • FB • DB (DB0 reserved)	256 256 511		2048 2048 4095				6144 6144 8191
Execution times • Bit operations • Word operations • Fixed-point arithmetic • Floating-point arithmetic	31.25 ns 31.25 ns 31.25 ns 62.50 ns		18.75 ns 18.75 ns 18.75 ns 37.50 ns		12.50 ns 12.50 ns 12.50 ns 25.00 ns		07.50 ns 07.50 ns 07.50 ns 15.00 ns
Memory bits, timers, counters • Memory bits • S7 timers / S7 counters • IEC timers / IEC counters	4 KB 2048/2048 SFB/SFB		8 KB 2048/2048 SFB/SFB		16 KB 2048/2048 SFB/SFB		
Structure • Number Expansion devices • Number DP master via CP • Number FM • Number CP	21 maximum 10 limited by number of slots and number of connections limited by number of slots and number of connections						
MPI/DP interface • DP slaves • Transmission rate	maximum 32 up to 12 Mbps						
DP interface • Number • DP slaves • Transmission rate • Plug-in interface modules	- - - -	1 64 up to 12 Mbps -	1 96 up to 12 Mbps -	2 96 each up to 12 Mbps 1x DP	1 125 up to 12 Mbps -	2 125 each up to 12 Mbps 1x DP	3 125 each up to 12 Mbps 2x DP
I/O address area • Total address area • Process image • Digital channels • Analog channels	4 KB / 4 KB 4 KB / 4 KB 32768/32768 2048/2048		8 KB / 8 KB 8 KB / 8 KB 65536/65536 4096/4096		16 KB / 16 KB 16 KB / 16 KB 131072/131072 8192/8192		

2.3 Signal Modules: [14]

2.3.1 Digital Signal:

2.3.1.1 Inputs (SM 421):

Table A-5 The performance characteristics of the S7-400 digital inputs

Features	DI32x DC24V (-1BL0x-)	DI 16x DC24 V (-7BH0x-)	DI 16x AC 120 V (-5EH00-)	DI 16x UC 24/60 V (-7DH00-)	DI 16Xuc 120/230 V (-1FH00-)	DI 16xUC 120/230 V (-1FH20-)	DI 32x UC 120 V (-1EL00-)
Number of inputs	32 DI; isolated in groups of 32	16 DI; isolated in groups of 8	16 DI; isolated in groups of 1	16 DI; isolated in groups of 1	16 DI; isolated in groups of 4	16 DI; isolated in groups of 4	32 DI; isolated in groups of 8
Nominal input voltage	24 VDC	24 VDC	120 VAC	24 to 60 VUC	120VAC/ 230VDC	120/230 VUC	120 VAC/DC
Suitable for...	Switches; 2-wire proximity switches (BEROs)						
Configurable diagnostics	No	Yes	No	Yes	No	No	No
Diagnostic interrupt	No	Yes	No	Yes	No	No	No
Hardware interrupt at edge transition:	No	Yes	No	Yes	No	No	No
Adjustable input delays	No	Yes	No	Yes	No	No	No
Substitution value output	-	Yes	-	-	-	-	-
Special features	High packaging density	Quick and with interrupt capability	Channel-specific isolation	Interrupt capability with low, variable voltages	For high, variable voltages	For high, variable voltages Input characteristic curve in accordance with IEC 61131-2	High packaging density

2.3.1.2 Outputs (SM 422):

Table A-6 The performance characteristics of the S7-400 digital outputs

Features	DO 16xDC 24 V / 2 A (-1BH1x)	DO 16x DC 20-125 V/ 1.5A (-5EH10)	DO 32xDC 24 V / 0.5 A (-1BL00)	DO 32xDC 24 V / 0.5 A (-7BL00)	DO8x AC 120/230 V/ 5A (-1FF00)	DO 16xAC 120/230V/ 2A (-1FH00)	DO 16xAC 20-120 V/ 2A(-5EH00)
Number of outputs	16 DO; isolated in groups of 8	16 DO; isolated and reverse polarity protection in groups of 8	32 DO; isolated in groups of 32	32 DO; isolated in groups of 8	8 DO; isolated in groups of 1	16 DO; isolated in groups of 4	16 DO; isolated in groups of 1
Output current	2 A	1.5 A	0.5 A	0.5 A	5 A	2 A	2 A
Nominal load voltage	24 VDC	20 to 125 VDC	24 VDC	24 VDC	120/230 VAC	120/230 VAC	20 to 120 VAC
Configurable diagnostics	No	Yes	No	Yes	No	No	Yes
Diagnostic interrupt	No	Yes	No	Yes	No	No	Yes
Substitution value output	No	Yes	No	Yes	No	No	Yes
Special features	For high currents	For variable voltages	High packaging density	Particularly quick and with interrupt capability	For high currents with channel-specific isolation	-	For variable currents with channel-specific isolation

2.3.2 Analog Signal:

2.3.2.1 Inputs (SM 431):

Table A-7 The performance characteristics of the S7-400 analog inputs

Features	AI 8 x 13 bit (-1KF00-)	AI 8 x14 bit (-1KF10-)	AI 8 x14 bit (-1KF20-)	AI 16 x13 Bit (-0HH0-)	AI 16x16 it (-7QH00-)	AI 8 x RTD 16 bit (-7KF10-)	AI 8 x 16 bit (-7KF00-)
Number of inputs	8 AI for U/I measure ment 4 AI for resistance measure-ment	8 AI for U/I measure-ment 4 AI for resistance/ temperature measure-ment	8 AI for U/I measure-ment 4 AI for resistance measure-ment	16 inputs	16 AI for U/I/ temperature measure-ment 8 AI for resistance measure-ment	8 inputs	8 inputs
Resolution	13 bits	14 bits	14 bits	13 bits	16 bits	16 bits	16 bits

Measuring method	Voltage Current Resistance	Voltage Current Resistance Temperatur	Voltage Current Resistance	Voltage Current	Voltage Current Resistance Tempera-ture	Resistance	Voltage Current Tempera-ture
Measuring principle	Integrating	Integrating	Instantane-ous value encoding	Integrating	Integrating	Integrating	Integrating
Programmable diagnostics	No	No	No	No	Yes	Yes	Yes
Diagnostic interrupt	No	No	No	No	Adjustable	Yes	Yes
Limit value monitoring	No	No	No	No	Adjustable	Adjustable	Adjustable
Hardware interrupt when limit exceeded	No	No	No	No	Adjustable	Adjustable	Adjustable
Hardware interrupt at end of scan cycle	No	No	No	No	Adjustable	No	No
Voltage relationships	Analog section isolated from CPU			Electrical isolation	Analog section isolated from CPU		
Max. permissible common mode voltage	Between the channels or the reference potentials of the connected sensors and MANA: 30 VAC	Between the channels or between the channel and central ground point: 120 VAC	Between the channels or the reference potentials of the connected sensors and MANA: 8 VAC	Between the channels or the reference potentials of the connected Sensors and central ground point: 2 VDC/AC	Between the channels or between the channel and central ground point: 120 VAC	Between channel and central ground point: 120 VAC	Between the channels or between the channel and central ground point: 120 VAC
External voltage supply required	No	24 VDC (only with current, 2-DMU) 1	24 VDC (only with current, 2-DMU) 1	24 VDC (only with current, 2-DMU) 1	24 VDC (only with current, 2-DMU) 1	No	No
Special features	-	Suitable for temperature measurement Temperature sensor type configurable Linearization of the sensor characteristic curve Smoothing of the measured values	Rapid A/D change, suitable for highly dynamic processes Smoothing of the measured values	-	Suitable for temperature measurement Temperature sensor type configurable Linearization of the sensor characteristic curves Smoothing of the measured values	Resistance thermometer configurable Linearization of the sensor characteristic curve Smoothing of the measured values	Internal measuring shunt Field wiring with internal reference temperature (included in basic product package) Smoothing of the measured values

2.3.2.2 Outputs (SM 422):

Table A-8 The performance characteristics of the S7-400 analog outputs

Features	AO 8 x 13 Bit (-1HF00-)
Number of outputs	8 outputs
Resolution	13 bits
Output type	Each separate channel: • Voltage • Current
Programmable diagnostics	No
Diagnostic interrupt	No
Substitution value output	No
Voltage relationships	Analog section isolated from: • the CPU • Load voltage
Max. permissible common mode voltage	Between the channels and the channels against M_{ANA} 3 VDC
Special features	-

2.4 Power supplies (PS): [14]

Table A-9 The performance characteristics of the S7-400 power supplies

<table>
<tr><th colspan="4">PARAMETERS</th><th>PS 407 04A</th><th>PS 407 10A</th><th>PS 407 20A</th></tr>
<tr><td rowspan="9">Input parameters</td><td rowspan="2">Input voltage</td><td>Nominal value</td><td>120/240 VDC
20/240 VAC</td><td>Yes
Yes</td><td>Yes
Yes</td><td>Yes
Yes</td></tr>
<tr><td>Permissible range</td><td>88 to 300 VAC
85 to 264 VDC</td><td>Yes
Yes</td><td>Yes
Yes</td><td>Yes
Yes</td></tr>
<tr><td rowspan="2">Mains frequency</td><td>Nominal value</td><td>50/60 Hz</td><td>Yes</td><td>Yes</td><td>Yes</td></tr>
<tr><td>Permissible range</td><td>47 to 63 Hz</td><td>Yes</td><td>Yes</td><td>Yes</td></tr>
<tr><td rowspan="5">Nominal input current</td><td colspan="2">At 120 VAC</td><td>0.38 or 0.42 A</td><td>0.9 A</td><td rowspan="2">1.5 A or 1.4 A</td></tr>
<tr><td colspan="2">At 120 VDC</td><td>0.37 or 0.35 A</td><td>1.0 A</td></tr>
<tr><td colspan="2">At 240 VAC</td><td>0.22 or 0.31 A</td><td>0.5 A</td><td rowspan="2">0.8 A or 0.7 A</td></tr>
<tr><td colspan="2">At 240 VDC</td><td>0.19 or 0.19 A</td><td>0.5 A</td></tr>
<tr><td colspan="2">Leakage current</td><td>< 3.5mA</td><td>< 3.5mA</td><td>< 3.5mA</td></tr>
<tr><td rowspan="2">Output parameters</td><td>Output voltages</td><td>Nominal values</td><td>5 / 24 VDC</td><td>Yes</td><td>Yes</td><td>Yes</td></tr>
<tr><td>Output currents</td><td>Nominal values</td><td>5 VDC
24 VDC</td><td>4 A
0.5 A</td><td>10 A
1 A</td><td>20 A
1 A</td></tr>
<tr><td colspan="2" rowspan="2">Electrical parameters</td><td colspan="2">Power consumption 240 VDC</td><td>52 W</td><td>95 W</td><td>168 W or 158 W</td></tr>
<tr><td colspan="2">Power loss</td><td>20 W</td><td>20 W</td><td>44 W or 35 W</td></tr>
<tr><th colspan="4">PARAMETERS</th><th>PS 405 04A</th><th>PS 405 10A</th><th>PS 405 20A</th></tr>
<tr><td rowspan="5">Input parameters</td><td rowspan="2">Input voltage</td><td>Nominal value</td><td>24 VDC
48 VDC
60 VDC</td><td>Yes
Yes</td><td>Yes
Yes</td><td>Yes
Yes</td></tr>
<tr><td>Permissible range</td><td>Static: 19.2 – 72 VDC
Dynamic: 18.5 - 75.5 VDC</td><td>Yes
Yes</td><td>Yes
Yes</td><td>Yes
Yes</td></tr>
<tr><td rowspan="3">Nominal input current</td><td colspan="2">At 24 VDC</td><td>2.0 A</td><td>4.0 or 4.3 A</td><td>7.0 or 7.3 A</td></tr>
<tr><td colspan="2">At 48 VDC</td><td>2.0 A</td><td>2.0 or 2.1 A</td><td>3.2 or 3.75 A</td></tr>
<tr><td colspan="2">At 60 VDC</td><td>0.8 A</td><td>1.6 or 1.7 A</td><td>2.5 or 2.75 A</td></tr>
<tr><td rowspan="2">Output parameters</td><td>Output voltages</td><td>Nominal values</td><td>5 / 24 VDC</td><td>Yes</td><td>Yes</td><td>Yes</td></tr>
<tr><td>Output currents</td><td>Nominal values</td><td>For 5 VDC
For 24 VDC</td><td>4 A
0.5 A</td><td>10 A
1 A</td><td>20 A
1 A</td></tr>
<tr><td colspan="2" rowspan="2">Electrical parameters</td><td colspan="2">Power consumption 240 VDC</td><td>48 W</td><td>95 or 104W</td><td>168 W or 175 W</td></tr>
<tr><td colspan="2">Power loss</td><td>16 W</td><td>20 or 29 W</td><td>44 W or 51 W</td></tr>
</table>

APPENDIX B:

The Software Tool

'Totally Integrated Automation'

(TIA)

1 Presentation of the software:

The TIA (Totally Integrated Automation) Portal platform is the latest evolution of Siemens work software that allows the implementation of automation solutions with an integrated engineering system, in a single software this platform combines the programming of the different devices of a plant. It is therefore possible to program and configure, in addition to the PLC, HMI devices, drives, etc. Starting the software:

1.1 Views:

1.1.1 The Portal View:

It is task-oriented and very quick to learn. You can automatically switch to the project view of a selected task (*Figure*).

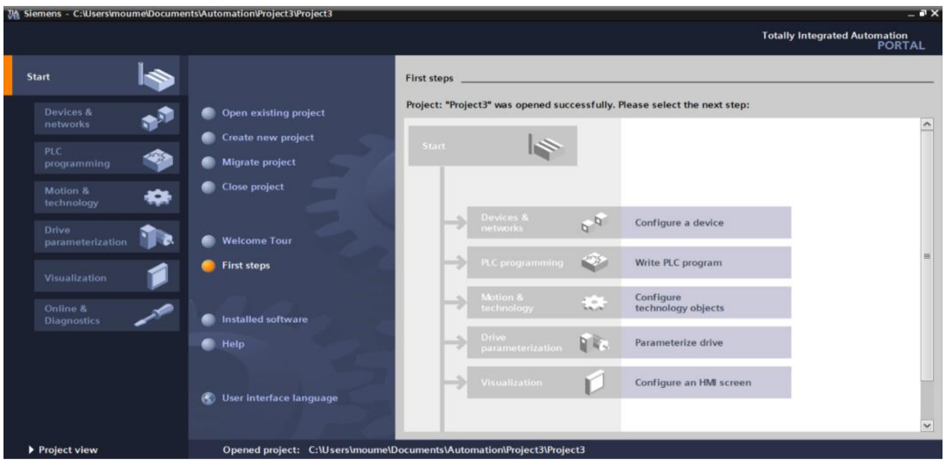


Figure B- 1 The portal view

1.1.2 The Project View:

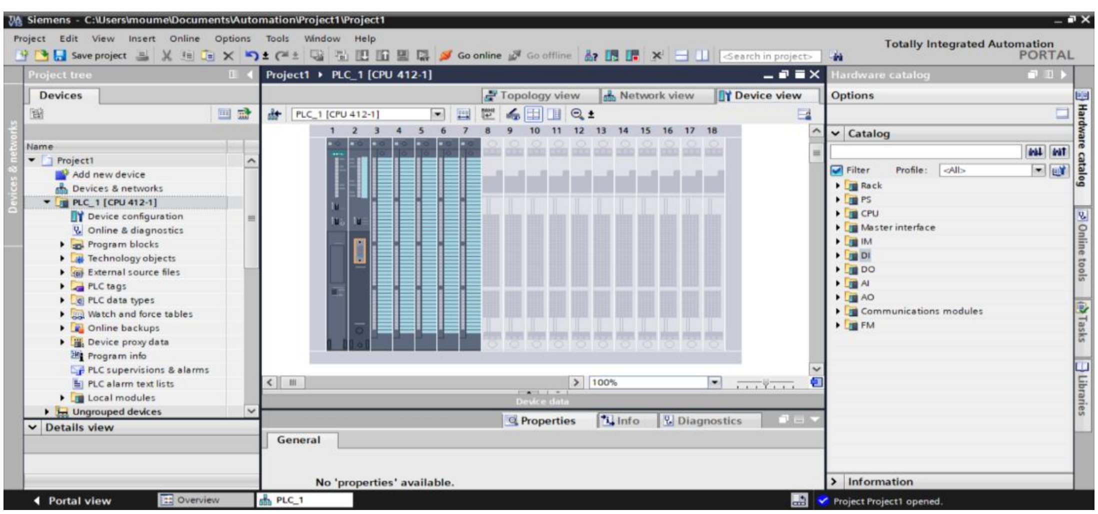


Figure B-2 The project view

The "project" element contains all the elements and data required to implement the desired automation solution. It contains a tree structure with the different project elements. The required editors are opened according to the tasks to be carried out. Data, parameters and editors can be viewed in a single view.

2 Program Design:

The strategy for designing a program using the TIA Portal V15 platform is:

- The creation of a new project;
- The hardware configuration;
- Loading the program;
- The creation of the mnemonic table;
- The development of the program;
- The simulation with the software;

The program status displays (the test). The design of an automation solution is done through two alternatives, either starting with programming or hardware configuration, in our case we started with configuration

2.1 Creating a New Project:

To create a project in the portal view, proceed as follows:

- Select the "create a project" action.
- Enter the desired name and path for the project or use the proposed data.
- Indicate a comment or define the author of the project.
- Once this information is entered, simply click on the "create" button (Figure).
- Finally, the new project is created and displayed in the project browser.

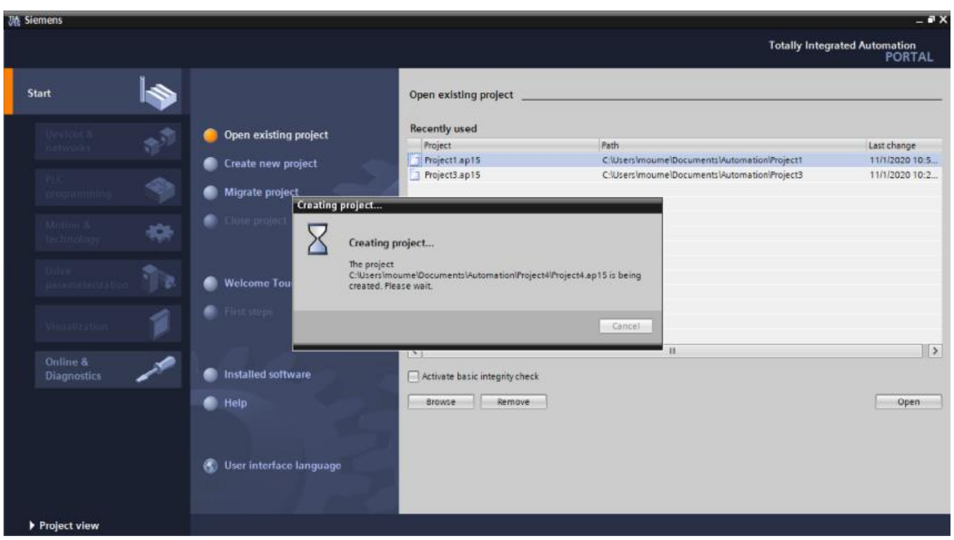


Figure B- 3 Creating a new project

2.2 Hardware Configuration:

Once our project is created, we can configure the workstation by defining the existing hardware. To do this, we will go the portal view: "devices and networks"→ "Add new device"→ “Controllers”→ “CPU”.

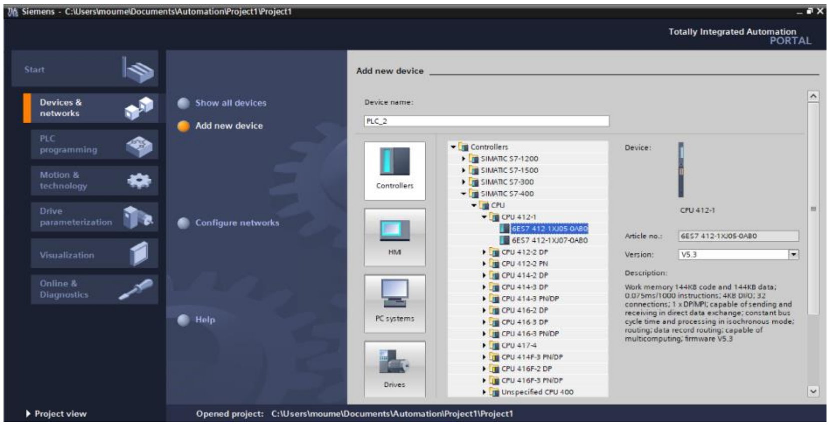


Figure B- 4 Selecting the CPU

This leads to the automatic creation of a station and a rack adapted to the selected device, then the additional modules (PS, SM,…) is added. When selecting an item to be inserted in the project, a description is proposed in the information tab.

2.3 The Creation of the mnemonic table:

In order to facilitate programming, it is interesting to create a table of variables. It is by means of which we will be able to declare all the variables and constants used. When defining a PLC’s variable, the followings have to be specified:

- **Its name:** This is the symbolic addressing of the variable.
- **Its data type:** BOOL (1 bit), Word (8bits), ...
- **Its absolute address:** Operand indication (For example I0.5, Q2.2, M0.0, ...).
- **One comment:** So that he can tell us about this variable.

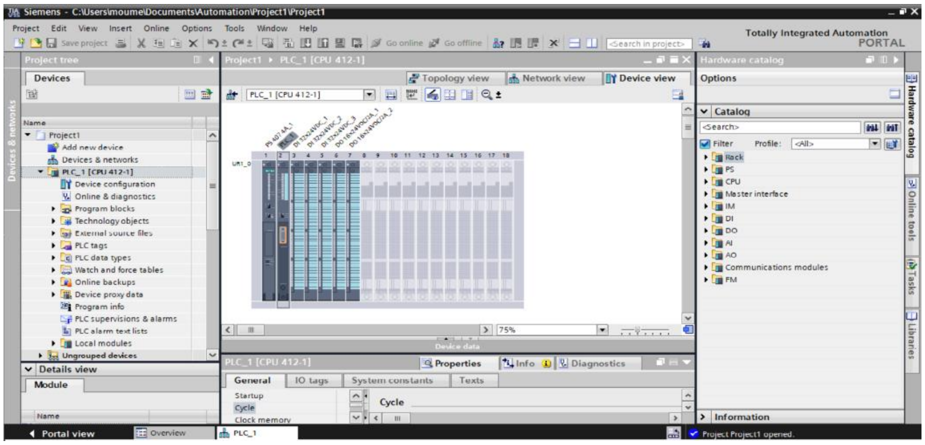


Figure B-5 The rack’s modules

For editing the mnemonic, the steps are as follows: “project view”→ the folder “PLC tags”→double click on “Add new tag table”→ double click on “the new tag table”. Mnemonics can be entered now or during programming. Click on Save and close the mnemonic editor.

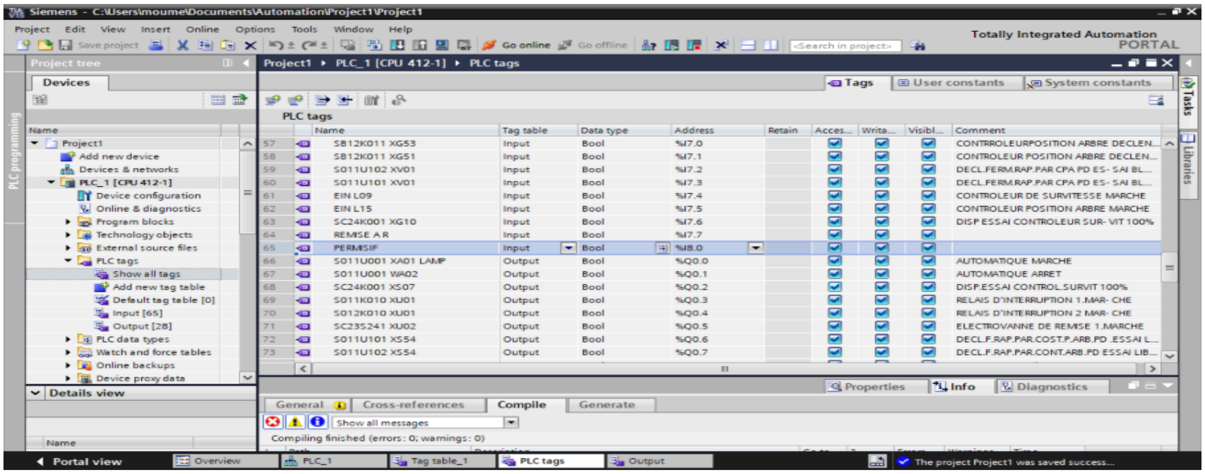


Figure B-6 Creating the mnemonics table

2.4 Writing the Program:

The program is written using different blocks:

- **Organizational block OB:** Controls the processing of the program. It is possible via OBs to react to cyclic, timed or alarm events during program execution. The OB program will be a call to the different functions (CALL block).
- **FB Function Block:** This is a block of code that permanently saves its value in a block of instance data that can be accessed even after the block has been processed.
- **FC function:** functions are blocks without memory
- **DB data block:** It is used to save the program data.

To generate a new block, the steps are: “Project view”→“Project tree”→“Program blocks”→ double click on "Add new block", selecting the programming language then choosing "Function block", "Function" or "Data block".

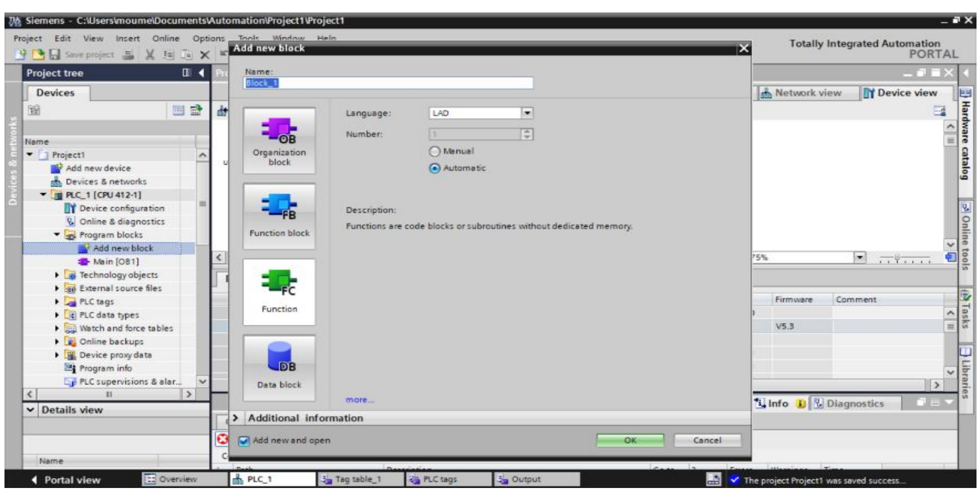


Figure B- 7 Creating the blocks

2.5 Simulation with S7-PLCSIM:

To use the simulation PLC, select the PLC and click on "Start Simulation" the simulator window will open. S7-PLSIM allows to test the program before its final implementation in the PLC.

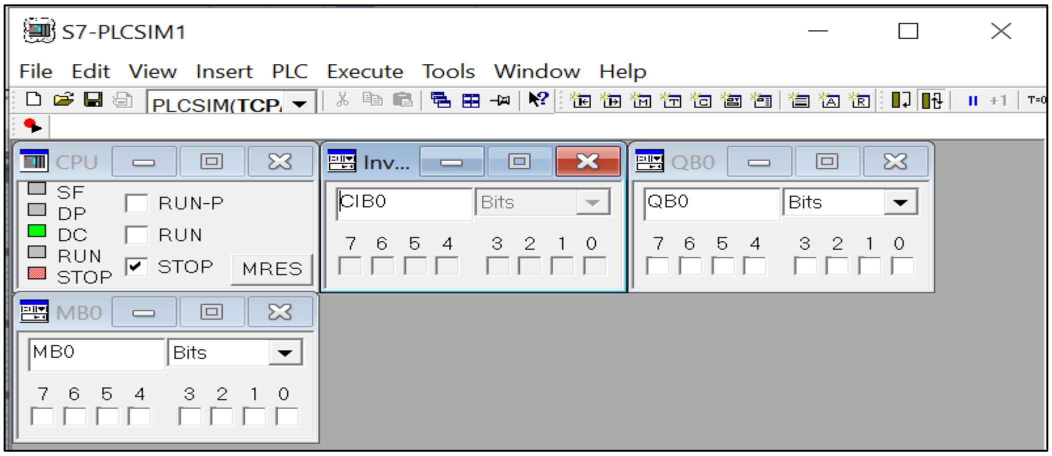


Figure B- 8 S7-PLCSIM

APPENDIX C:
The PLC programming languages

When using a PLC, it's important to design and implement concepts depending on your particular use case. To do this we first need to know more about the specifics of PLC programming.

There are 5 languages that are all a part of the IEC (International Electrotechnical Commission) Section 61131-3 Standard. This IEC standard allows some ground rules that standardize PLC's and their languages. There are two main classifications of PLC programming languages, which are further divided into many sub-classified types.

1 Graphical Form:

1.1 Ladder Diagrams (LD) (i.e. Ladder Logic):

Ladder Diagram was originally modeled from relay-logic which used physical devices, such as switches and mechanical relays to control processes. Ladder Diagram utilizes internal logic to replace all, except the physical devices that need an electrical signal to activate them.

Ladder Diagram is built in the form of horizontal rungs with two vertical rails that represent the electrical connection on relay-logic schematics. You can program all the necessary input conditions to affect the output conditions, whether logical or physical.

The main advantages of the Ladder Diagram language are:

- The rungs allow it to be organized and easy to follow.
- It also lets you document comments that are readily visible.
- It supports online editing very successfully.

The main disadvantage is that there are some instructions that are not available, which might make it more difficult for programming such as motion or batching.

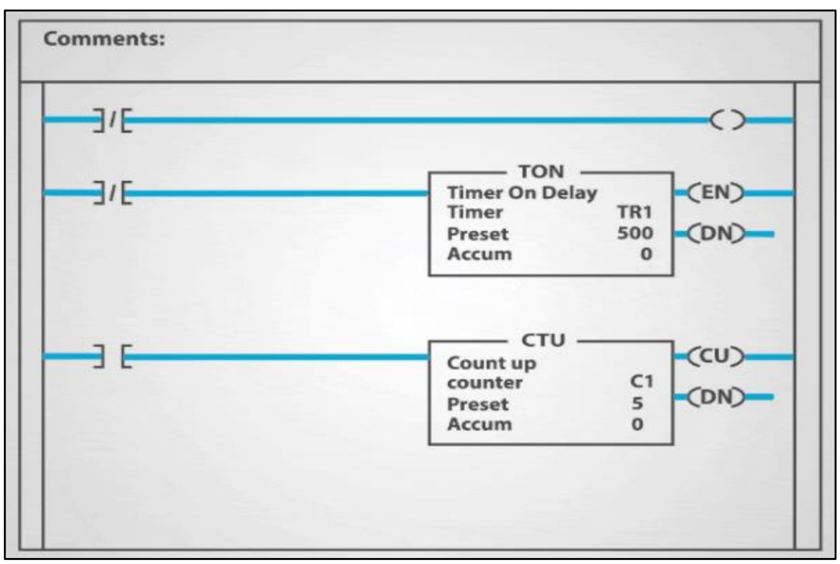


Figure C- 1 Example of a ladder diagram

1.2 Function Block Diagram (FBD):

The Function Block Diagram which is also a graphical type of language. The Function Block Diagram describes a function between inputs and outputs that are connected in blocks by connection lines.

Function Blocks were originally developed to create a system that could be set up many of the common, repeatable tasks, such as counters, timers, PID Loops, etc. The blocks are programmed onto sheets and then the PLC constantly scans the sheets in numerical order or is determined by connections that are programmed between the blocks.

The main advantages of the Function Block Diagram are:

- The Function Block Diagram does work well with motion controls.
- The visual method is easier for some users.
- The biggest advantage of Function Block Diagram is that you can take many lines of programming and put it into one or several function blocks.

However, the code can get disorganized using this PLC Programming Language because the function blocks can be placed anywhere on the sheet. This can also make it more difficult to troubleshoot.

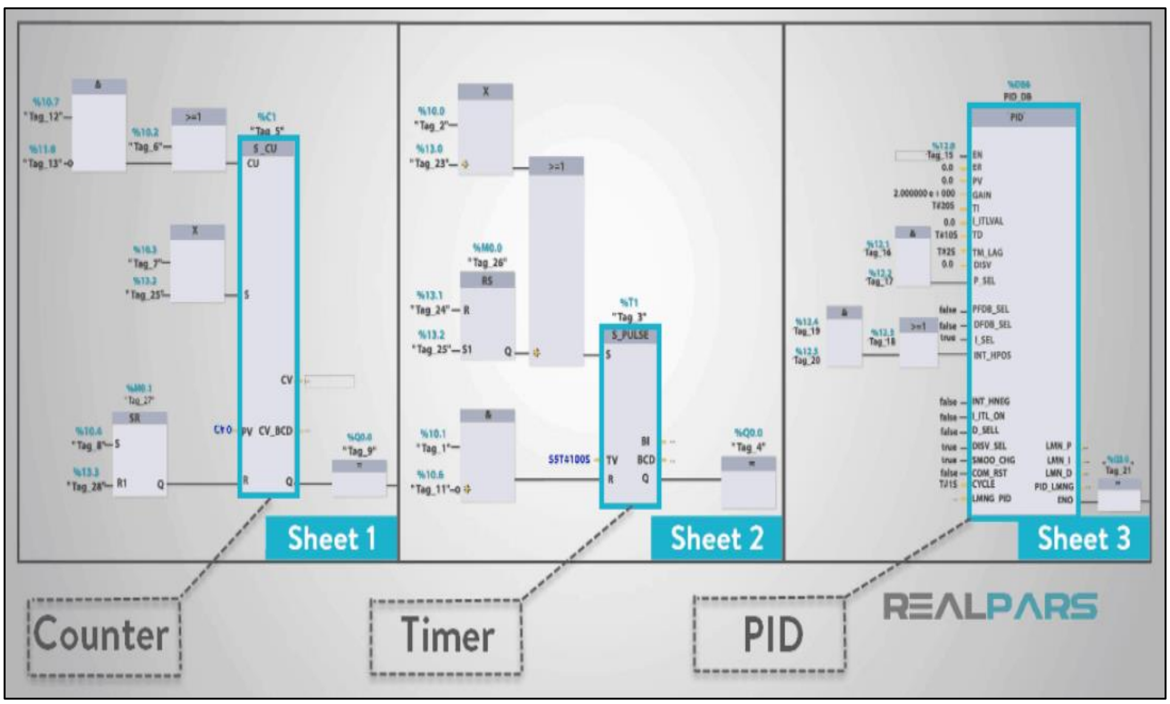


Figure C-2 Example of a Function Block Diagram

1.3 Sequential Function Chart (SFC):

In Sequential Function Charts, steps and transitions are used to achieve the final results. Steps act as a major function in your program. These steps house the actions that occur when they are programmed to happen. This decision can be based on timing, a certain phase of the process, or a physical state of an equipment. Transitions are the instructions that are used to move from one step to another step by setting conditions of true or false.

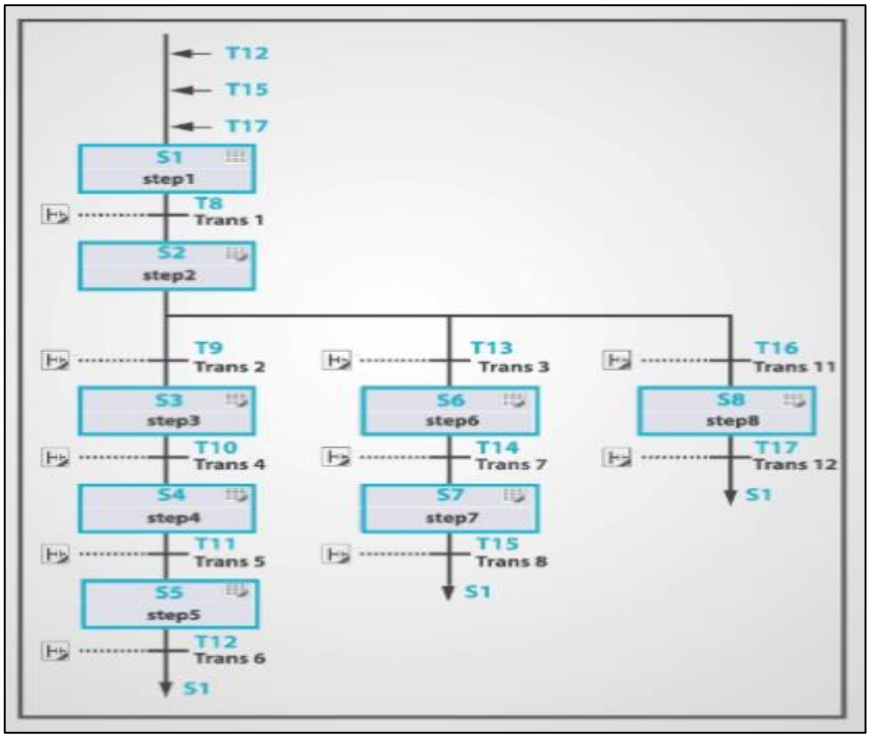


Figure C-3 Example of a Sequential Function Chart

A couple of the advantages of Sequential Function Charts are:

- Processes can be broken into major steps that can make troubleshooting faster and easier.
- It gives the programmer a direct access in the logic to see where a piece of equipment faulted.
- It can be faster to design and write the logic due to the ability to use repeated executions of individual pieces of logic.

Even when you consider the advantages of the Sequential Function Charts, this PLC Programming Language does not always fit every application.

2 Textual Language:

2.1 Instruction List:

The Instruction List language resembles Assembly Language. Dealing with this PLC Programming Language leads to the use of mnemonic codes such as LD (Load), AND, OR, etc. The Instruction List contains instructions with each instruction on a new line with any comments you might want to annotate at the end of each line. The Instruction List language is valuable for applications that need code that is compact and time critical.

The main disadvantages of this PLC Programming Language are:

- There are few structuring possibilities with the "Goto" command being one of them.
- There can also be many errors that are more difficult to deal with in comparison to many of the other languages that I have previously reviewed.

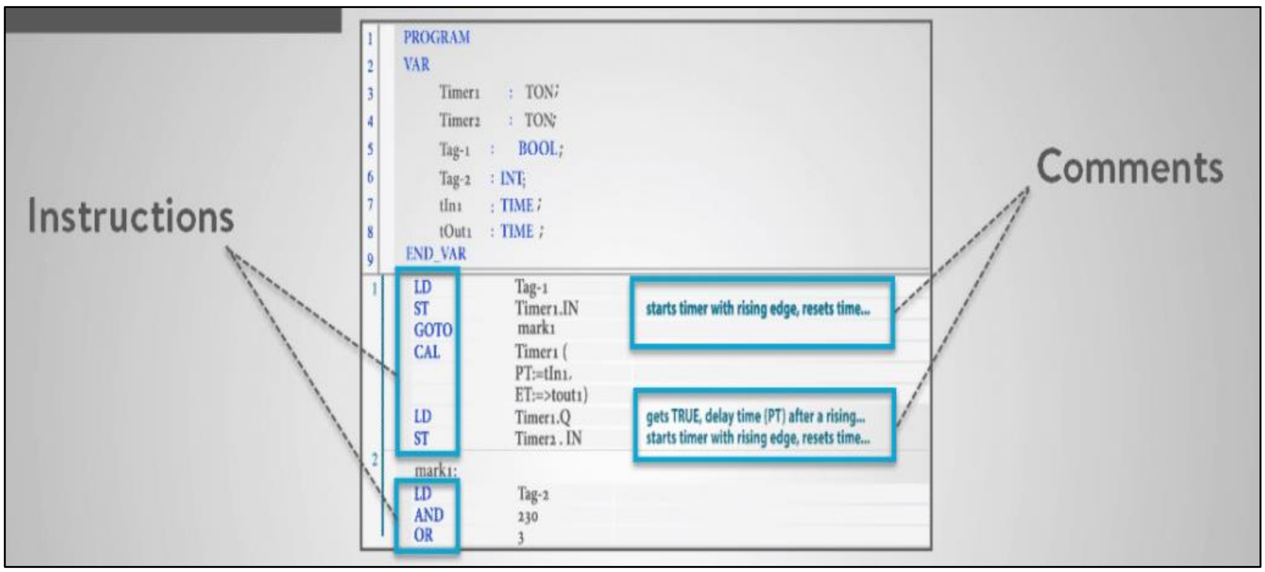


Figure C- 4 Example of an instruction list program

2.2 Structured text:

Structured Text is a high-level language that is like Basic, Pascal and “C”. It is a very powerful tool that can execute complex tasks utilizing algorithms and mathematical functions along with repetitive tasks. The code uses statements that are separated by semicolons and then either inputs, outputs, or variables are changed by these statements. Each line of code must be written out and it uses functions such as FOR, WHILE, IF, ELSE, ELSEIF AND CASE.

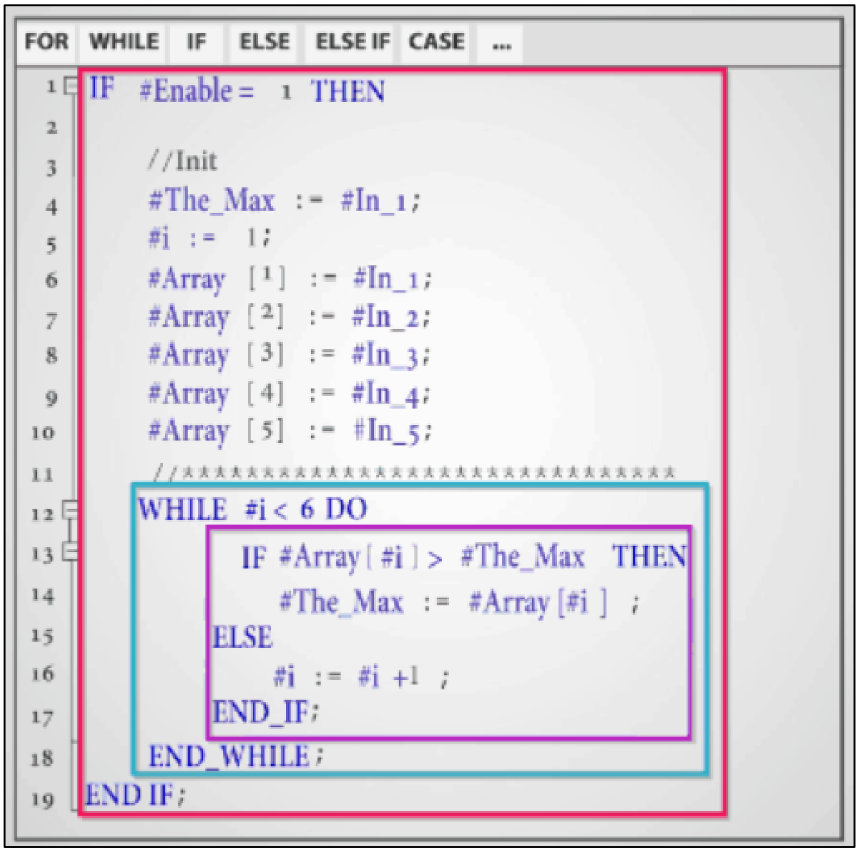


Figure C- 5 Example of a structured text program

Some of the advantages of Structured Text are:

- ➢ It is very organized and good at computing large mathematical calculations.
- ➢ It will enable you to cover some instructions that are not available in some other languages like the Ladder Diagram.

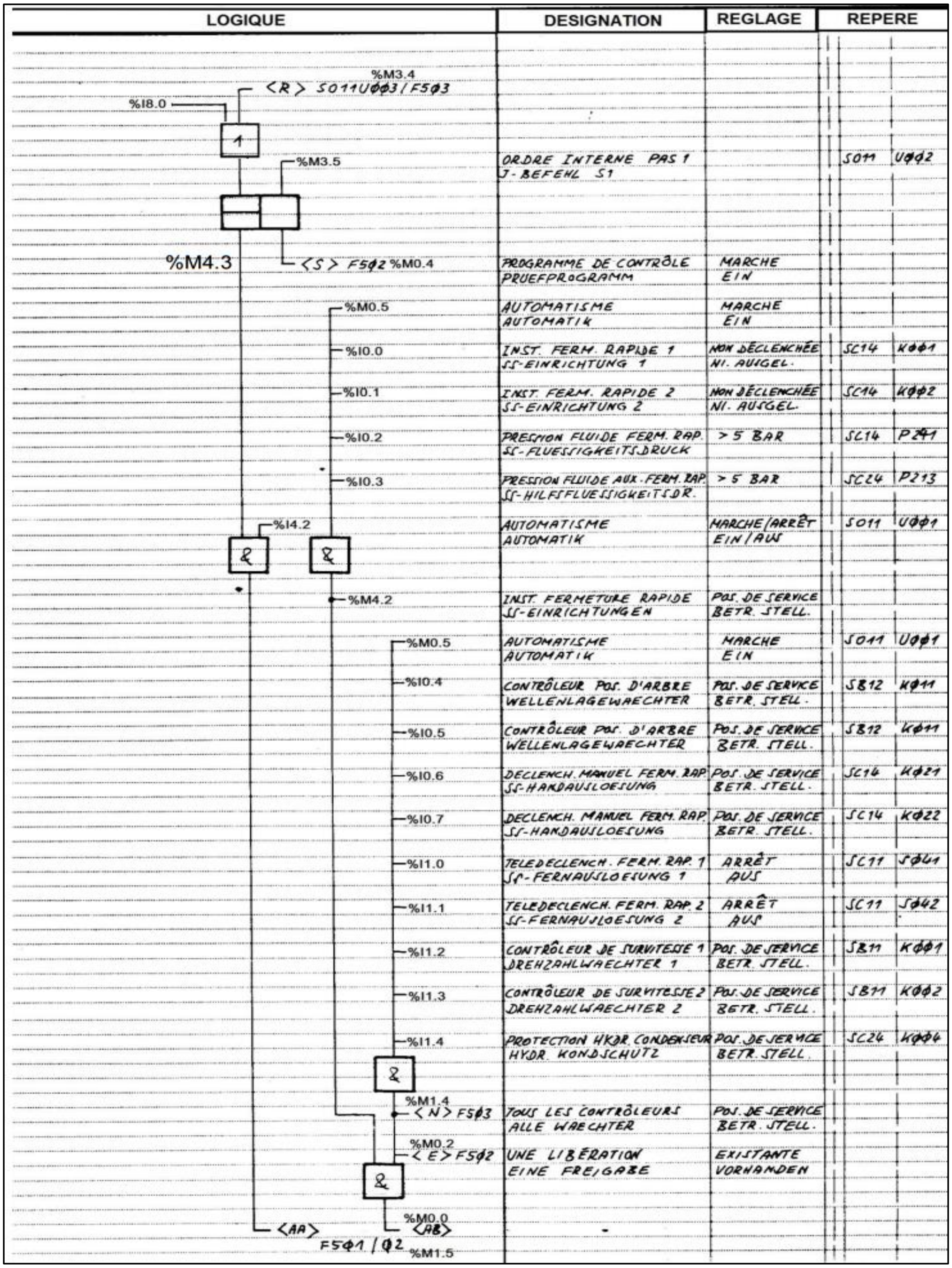
The disadvantages of the Structured Text PLC programming language are:

- ➢ The syntax can be difficult.
- ➢ It is hard to debug.
- ➢ It is difficult to edit online.

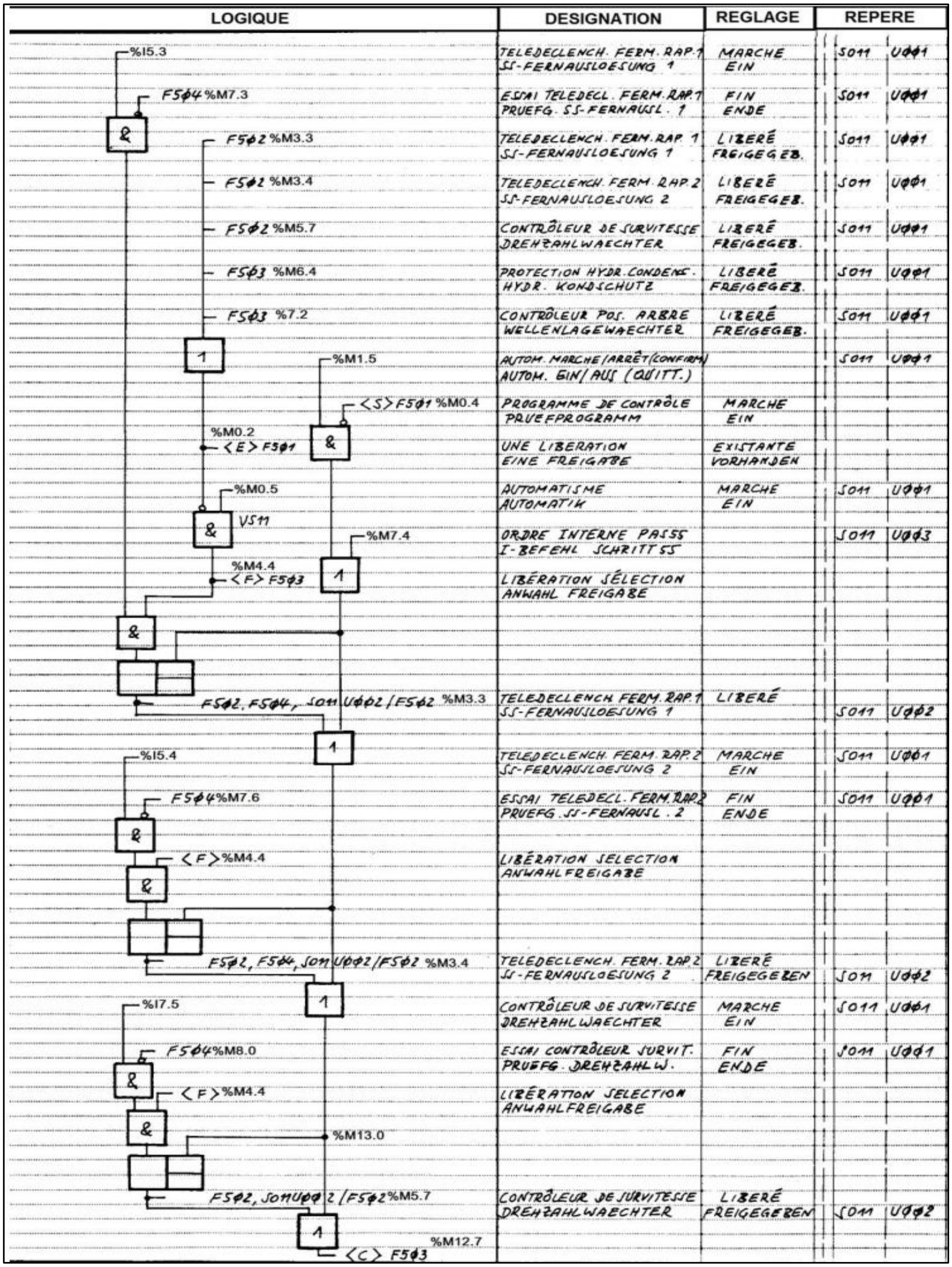
APPENDIX D:

The Control Program of the Turbine Protections

1. **The automatic release and switching:**

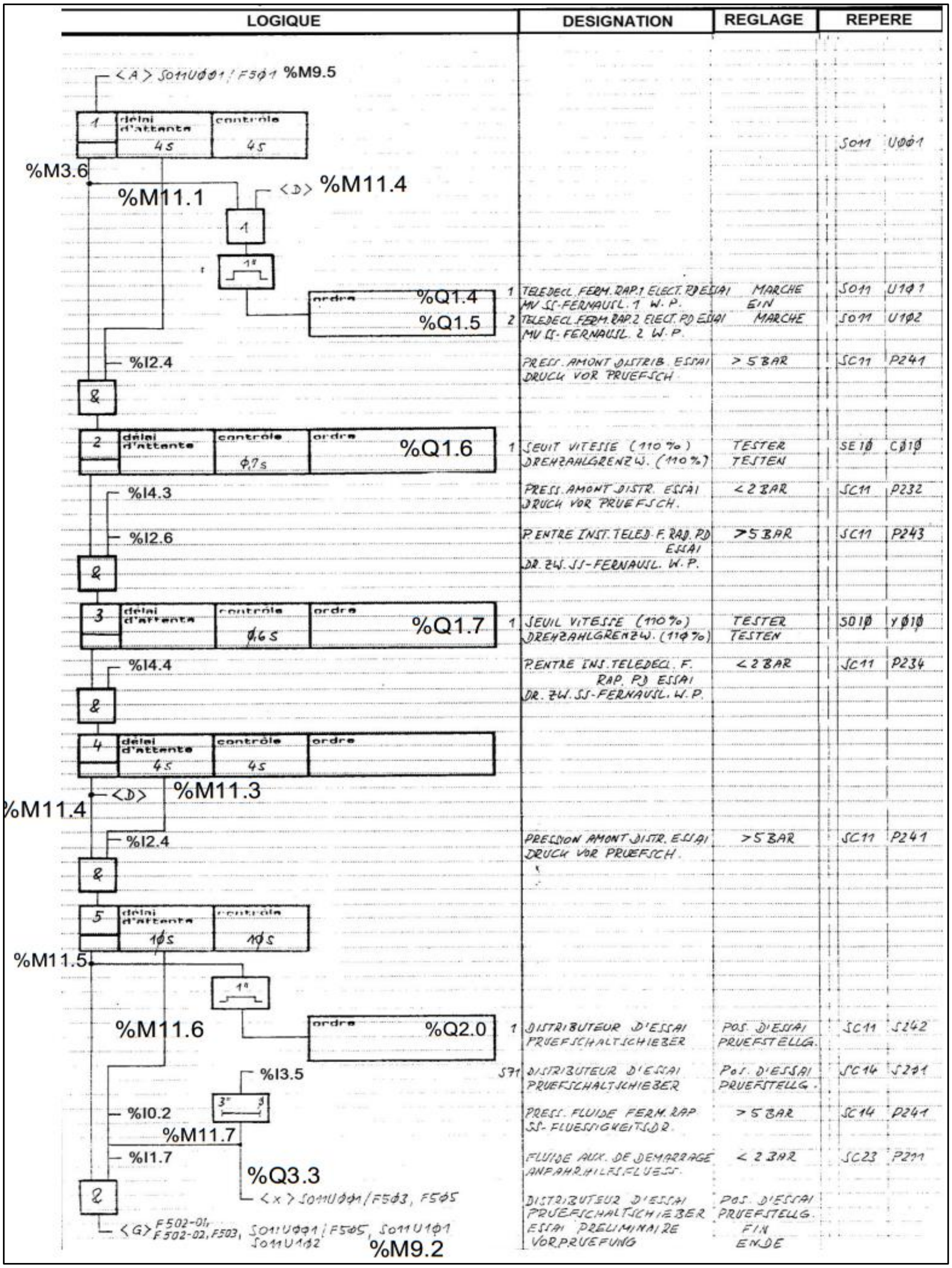


2. The selections:

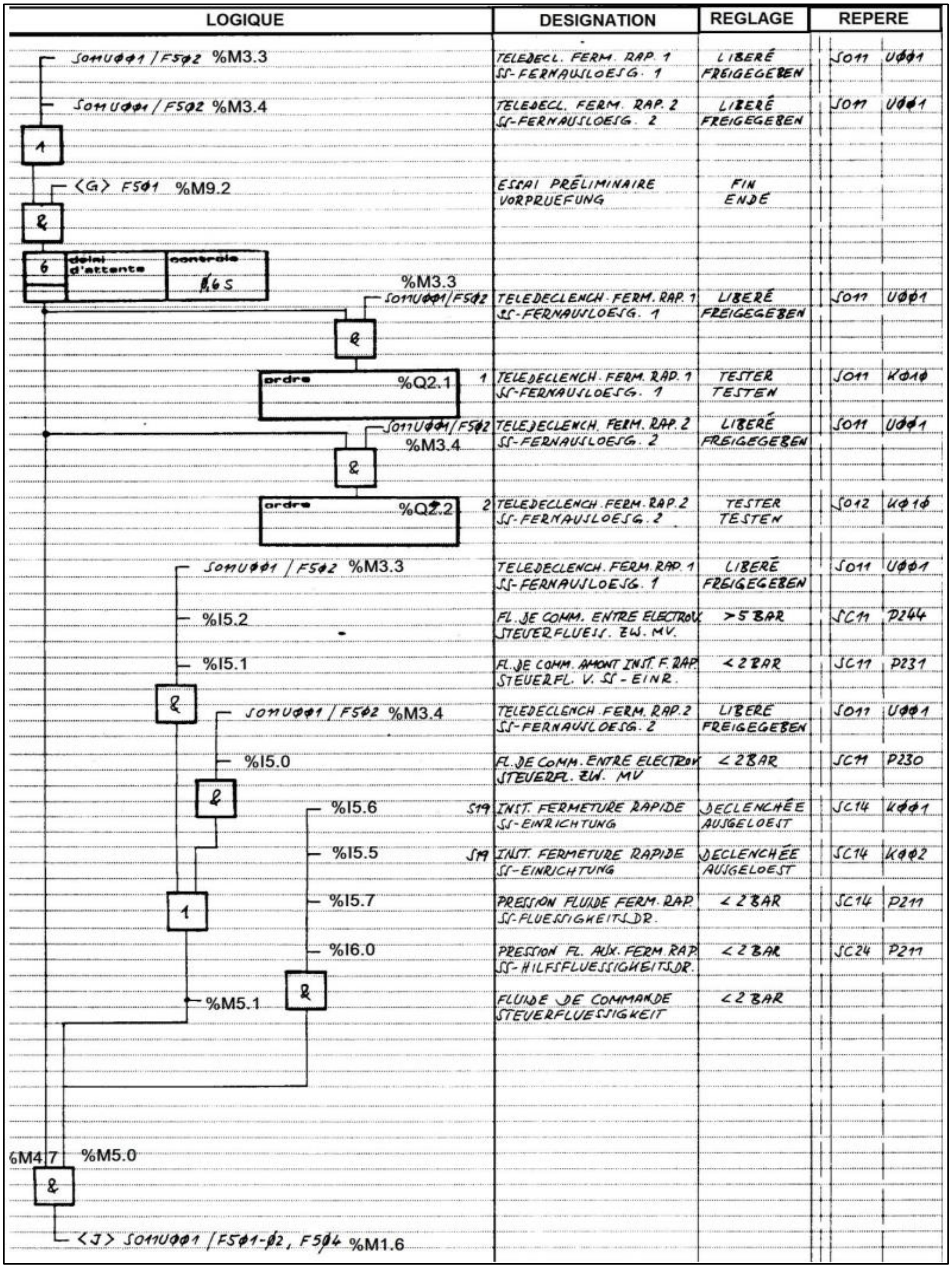


LOGIQUE	DESIGNATION	REGLAGE	REPERE
%I7.0	PROTECTION HYD. CONDENSEUR HYDR. KONDSCHUTZ	MARCHE EIN	S011 U001
F504 %M6.7	ESSAI PROTECT. HYD. CONDENS. PRUEFG. HYDR. KONDSCH.	FIN ENDE	S011 U001
<F> F502 %M4.4	LIBÉRATION SELECTION ANWAHLFREIGABE		
<C> <C> F502 %I12.7			
F502, S011U002/F503 %M6.4	PROTECTION HYD. CONDENSEUR HYDR. KONDSCHUTZ	LIBERÉE FREIGEGEBEN	S011 U002
%I7.6	CONTRÔLEUR POSITION ARBRE WELLENLAGEWAECHTER	MARCHE EIN	
F504 %M8.2	ESSAI CONTRÔLEUR POS. ARBRE PRUEFG. WELLENLAGEWAECHT.	FIN ENDE	S011 U001
%M4.4 <F> F502	LIBÉRATION SELECTION ANWAHLFREIGABE		
F502, S011U101/F201, S011U102/F201 S011U002/F503 %M7.2	CONTRÔLEUR POSIT. ARBRE WELLENLAGEWAECHTER	LIBERÉE FREIGEGEBEN	S011 U002 S011 U101

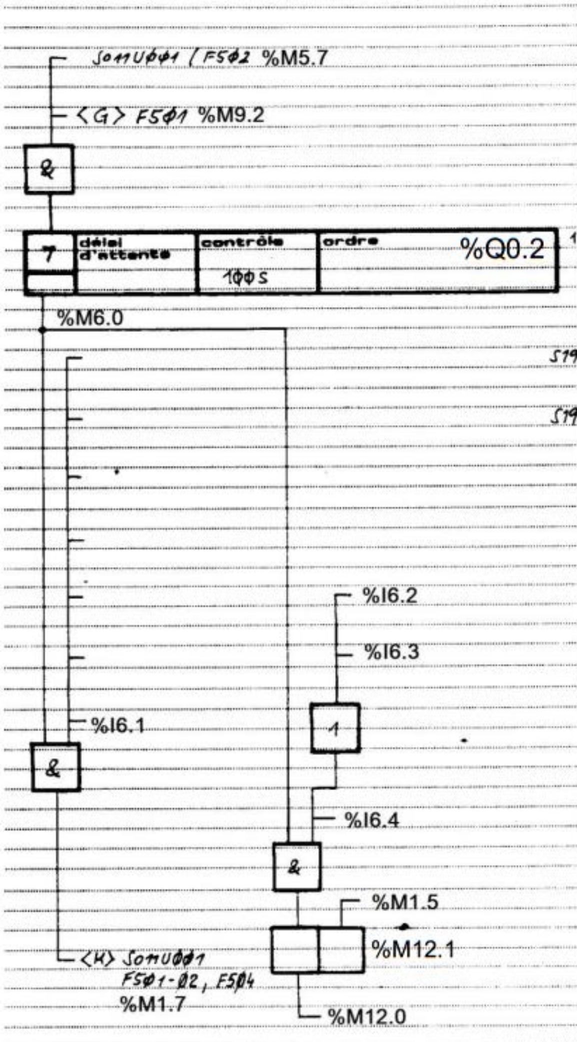
3. The preliminary test (the starting program):



4. The process of controls:



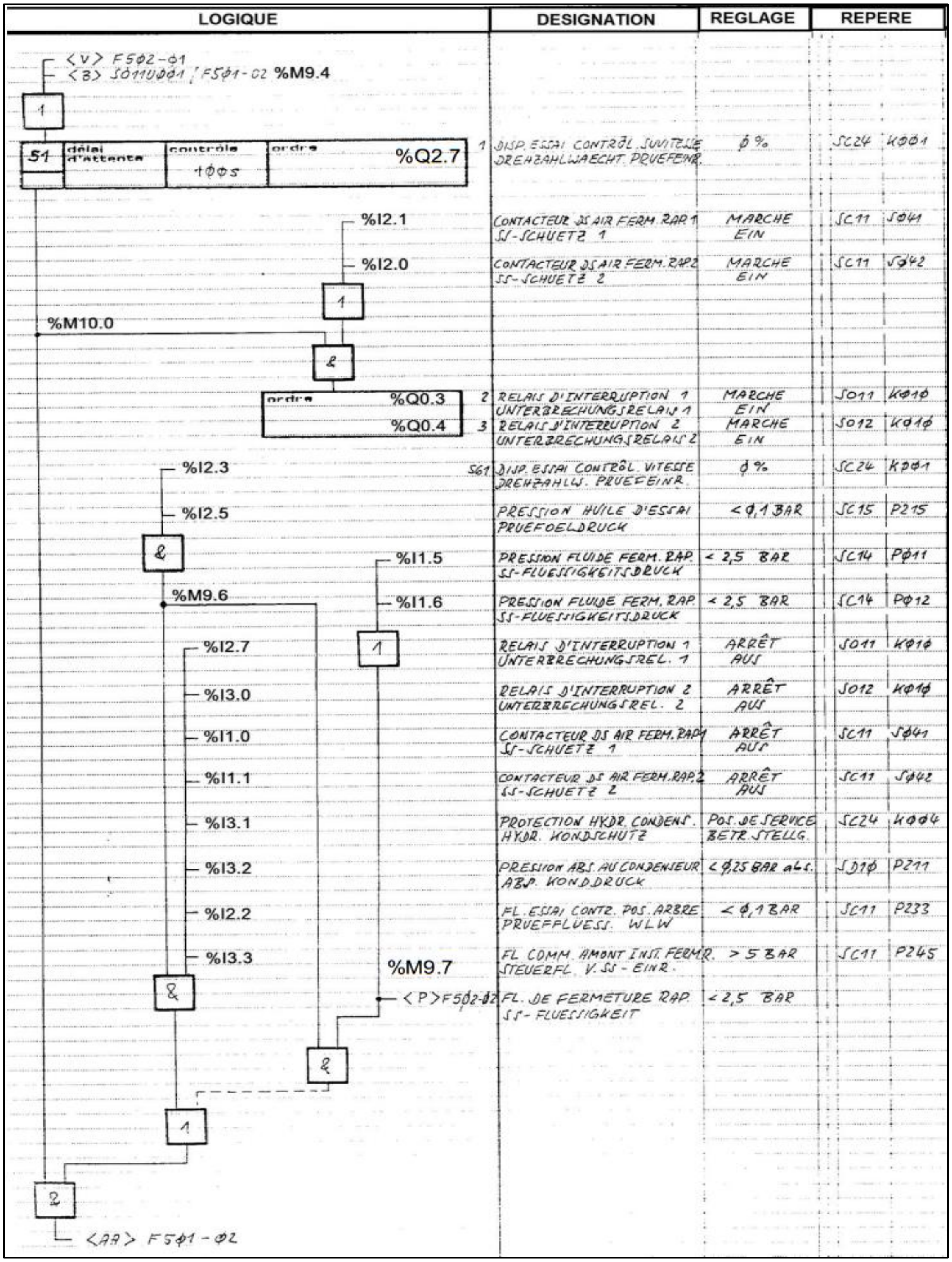
LOGIQUE



DESIGNATION	REGLAGE	REPERE	
CONTRÔLEUR DE SURVITESSE DREHZAHLWAECHTER	DECLENCHÉ FREIGEBEN	S011	UØØ1
ESSAI PRELIMINAIRE VORPRUEFUNG	FIN ENDE		
1 DISP. ESSAI CONTROL. SURVIT. DREHZAHLW. PRUEFEINR.	1ØØ %	SC24 S011	KØØ1 KØØ1
S19 INST. FERMETURE RAPIDE 1 SS-EINRICHTUNG 1	DECLENCHÉE AUSGELOEST	SC14	KØØ1
S19 INST. FERMETURE RAPIDE 2 SS-EINRICHTUNG 2	DECLENCHÉE AUSGELOEST	SC14	KØØ2
PRESSION FLUIDE FERM. RAP. SS-FLUESSIGKEITSDR.	< 2 BAR	SC14	P211
FLUIDE AUX. FERM. RAP. SS-HILFSFLUESSIGKEITSDR.	< 2 BAR	SC24	P211
CONTRÔLEUR SURVITESSE 1 DREHZAHLWAECHTER	DECLENCHE AUSGELOEST	SB11	KØØ1
CONTRÔLEUR SURVITESSE 2 DREHZAHLWAECHTER 2	DECLENCHÉE AUSGELOEST	SB11	KØØ2
PRESSION HUILE D'ESSAI PRUEFOELDRUCK	< 4,8 BAR	SC15	P212
PRESSION HUILE D'ESSAI PRUEFOELDRUCK	< 4,5 BAR	SC15	P211
AUTOM. MARCHE / ARRÊT (CONFIRM.) AUTOM. EIN / AUS (QUITT.)		S011	UØØ1
DECL. CONTRÔLEUR SURVIT. DZW - AUSLOESUNG	TROP TÔT ZU FRUEH		

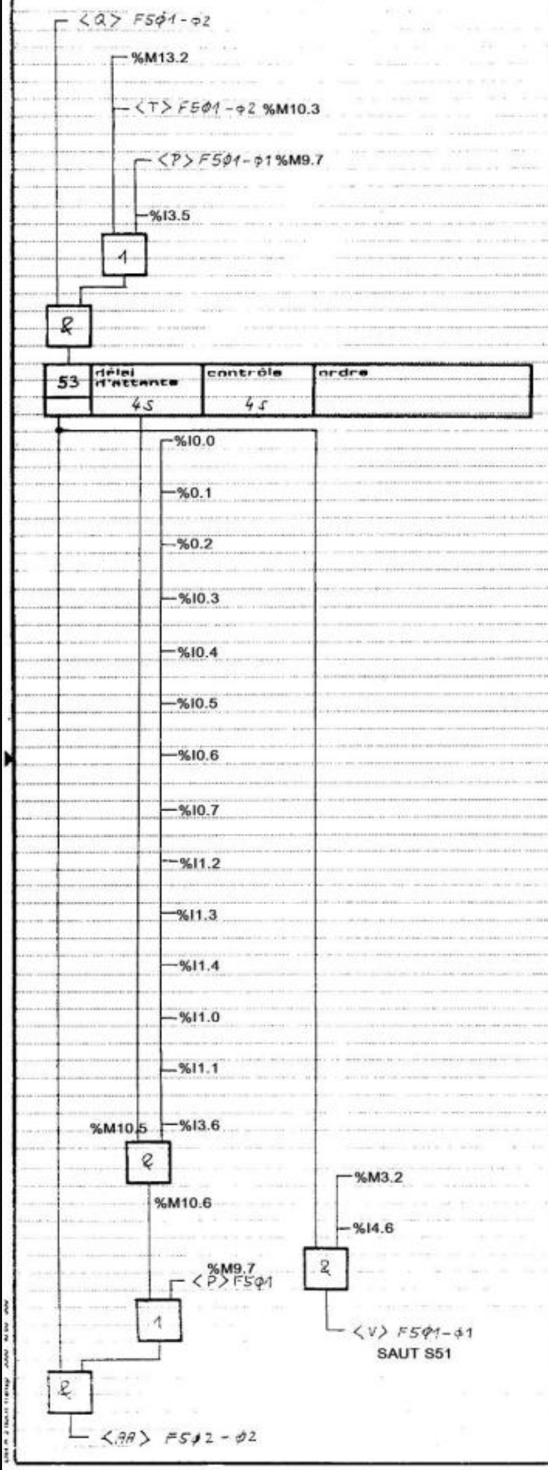
LOGIQUE		DESIGNATION	REGLAGE	REPERE	
S011UØØ1 / F5Ø3 %M6.4		PROTECTION HYD. CONDENSEUR HYDR. KONDSCHUTZ	LIBERE FREIGEGEBEN	S011	UØØ1
<G> F5Ø1 %M9.2		ESSAI PRÉLIMINAIRE VORPRUEFUNG	FIN ENDE		
&					
8 — délai d'attente / contrôle 4 s / ordre %Q3.1	1	PROTECTION HYD. CONDENSEUR HYDR. KONDSCHUTZ	TESTER TESTEN	SD1Ø	S241
%I6.7		PROTECTION HYD. CONDENSEUR HYDR. KONDSCHUTZ	DECLENCHÉE AUSGELOEST	SC24	KØØ4
%I6.6		PRESSION ABS. AU CONDENSEUR ABS. KONDDRUCK	> Ø,35 BAR abs	SD1Ø	P212
%M6.3 — %I6.5		PRESSION ABS. AU CONDENSEUR ABS. KONDDRUCK	> Ø,35 BAR abs	SD1Ø	P214
& — %M12.3		ORDRE INTERNE PAS 51 J-BEFEHL SCHRITT 51		S011	UØØ3
	S19	INSTAL. FERMETURE RAP. 1 SS-EINRICHTUNG 1	DECLENCHÉE AUSGELOEST	SC14	KØØ1
	S19	INSTAL. FERMETURE RAP. 2 SS-EINRICHTUNG 2	DECLENCHÉE AUSGELOEST	SC14	KØØ2
		PRESSION FLUIDE FERM. RAP. SS-FLUESSIGKEITSDRUCK	< 2 BAR	SC14	P211
		PRESS. FL. AUX. FERM. RAP. SS-HILFSFLUESSIGKEITSDR.	< 2 BAR	SC24	P211
%M6.1		PROTECTION HYD. CONDENSEUR HYDR. KONDSCHUTZ	DECLENCHÉE AUSGELOEST		
& <L> S011UØØ1 / F5Ø1, F5Ø4 %M2.1		ESSAI PROT. HYD. CONDENSEUR PRUEFG. HYDR. KONDSCH.	FIN ENDE		
S011UØØ1 / F5Ø3 %M7.2		CONTRÔLEUR POS. ARBRE (CPA) WELLENLAGEWAECHTER	LIBERÉ FREIGEGEBEN	S011	UØØ1
S011U1Ø1 / F2Ø1 %I7.4		DECL. FERM. RAP. PAR CPA PD ESSAI SS-AUSL. DURCH WLW W.P.	BLOQUÉ GESPERRT	S011	U1Ø1
S011U1Ø2 / F2Ø1 %I7.3		DECL. FERM. RAP PAR CPA PD ESSAI SS-AUSL. DURCH WLW W.P.	BLOQUÉ GESPERRT	S011	U1Ø2
<G> %M9.2		ESSAI PRÉLIMINAIRE VORPRUEFUNG	FIN ENDE		
&					
9 — délai d'attente / contrôle 1,5 s / ordre %Q3.2	1	CONTRÔLEUR POS. ARBRE WELLENLAGEWAECHTER	TESTER TESTEN	SC11	S243
	S19	INST. FERMETURE RAP. 1 SS-EINRICHTUNG 1	DECLENCHÉE AUSGELOEST	SC14	KØØ1
	S19	INST. FERMETURE RAP. 2 SS-EINRICHTUNG 2	DECLENCHÉE AUSGELOEST	SC14	KØØ2
		PRESS. FLUIDE FERM. RAP. SS-FLUESSIGKEITSDRUCK	< 2 BAR	SC14	P211
		PRESS. FL AUX FERM. RAP. SS-HILFSFLUESSIGKEITSDR	< 2 BAR	SC24	P211
%7.2	S18	CONTRÔLEUR POSITION ARBRE WELLENLAGEWAECHTER	DECLENCHÉE AUSGELOEST	SB12	KØ11
%M7.0 — %I7.1	S19	CONTRÔLEUR POSITION ARBRE WELLENLAGEWAECHTER	DECLENCHÉE AUSGELOEST	SB12	KØ11
& <M> S011UØØ1 / F5Ø1-02, F5Ø4 %M2.0		ESSAI CONTRÔLEUR POS. ARBRE PRUEFUNG WLW	FIN ENDE		

5. The reset program (the stopping program):



LOGIQUE	DESIGNATION	REGLAGE	REPERE	
<AA> F5Ø1-Ø1				
52 · délai d'attente 1Øs · contrôle 1Øs · ordre %Q3.0	1 ELECTROVANNE DE REMISE 2 SPANNMAGNETVENTIL 2	MARCHE EIN	SC23	S242
%M10.2				
6" · ordre %Q0.5	2 ELECTROVANNE DE REMISE 1 SPANNMAGNETVENTIL 1	MARCHE EIN	SC23	S241
%I0.0	INST. FERMETURE RAPIDE 1 SS-EINRICHTUNG 1	POS. DE SERVICE BETR. STELLG.	SC14	KØØ1
%I0.1	INST. FERMETURE RAPIDE 2 SS-EINRICHTUNG 2	POS. DE SERVICE BETR. STELLG.	SC14	KØØ2
%I0.2	PRESSION FL. FERM. RAP. SS-FLUESSIGKEITSDRUCK	> 5 BAR	SC14	P241
%I0.3	PRESSION FL. AUX. FERM. RAP. SS-HILFSFLUESSIGKEITSDR.	> 5 BAR	SC24	P213
%I0.4	CONTRÔLEUR POS. ARBRE WELLENLAGEWAECHTER	POS. DE SERVICE BETR. STELLG.	SB12	KØ11
%I0.5	CONTRÔLEUR POS. ARBRE WELLENLAGEWAECHTER	POS. DE SERVICE BETR. STELLG.	SB12	KØ11
%I1.2	CONTRÔLEUR DE SURVITESSE 1 DREHZAHLWAECHTER 1	POS. DE SERVICE BETR. STELLG.	SB11	KØØ1
%I1.3	CONTRÔLEUR DE SURVITESSE 2 DREHZAHLWAECHTER 2	POS. DE SERVICE BETR. STELLG.	SB11	KØØ2
%I1.4	PROTECTION HYD. CONDENSEUR HYDR. KONDSCHUTZ	POS. DE SERVICE BETR. STELLG.	SC24	KØØ4
%I1.0	CONTACTEUR DS AIR FERM. RAP. 1 SS-SCHUETZ 1	ARRÊT AUS	SC11	SØ41
%I1.1	CONTACTEUR DS AIR FERM. RAP. 2 SS-SCHUETZ 2	ARRÊT AUS	SC11	SØ42
%I0.6	DECL. MANDEL FERM. RAP. SS-HANDAUSLOESUNG	POS. DE SERVICE BETR. STELLG.	SC14	KØ21
%I0.7	DECL. MANDEL FERM. RAP. SS-HANDAUSLOESUNG	POS. DE SERVICE BETR. STELLG.	SC14	KØ22
%I1.7	PRESS. FL. AUX. DEMARRAGE ANFAHRHILFSFLUSSIGK. DR.	< 2 BAR	SC23	P211
&				
<T> F5Ø2-Ø1 %M10.3				
<Q> F5Ø2-Ø1				

LOGIQUE	DESIGNATION	REGLAGE	REPERE		SIG.	DEST.
					X	V



DESIGNATION	REGLAGE	REPERE		SIG.	DEST.
DEPASSEMENT DURÉE MARCHE LAUFZEITUEBERSCHREITUNG	S011 U	S011	UØØ1	M12	
PRESSION FL. FERM. RAP. SS-FLUESSIGKEITSDRUCK	< 2 BAR				
DISTRIBUTEUR D'ESSAI PRUEFSCHALTSCH.	POS. DE SERVICE BETR. STELLG.	SC14	S2Ø1	GØ9	
				S53	
INSTAL. FERMETURE RAP. 1 SS-EINRICHTUNG 1	POS. DE SERVICE BETR. STELLG.	SC14	KØØ1	GØ3	K51
INSTAL. FERMETURE RAP. 2 SS-EINRICHTUNG 2	POS. DE SERVICE BETR. STELLG.	SC14	KØØ2	GØ3	K52
PRESSION FL. FERM. RAP. SS-FLUESSIGKEITSDR.	> 5 BAR	SC14	P241	GØ1	K53
PRESSION FL. AUX. FERM. RAP. SS-HILFSFLUESSIGKEITSDR.	> 5 BAR	SC24	P213	GØ1	K54
CONTRÔLEUR POSITION ARBRE WELLENLAGEWAECHTER	POS. DE SERVICE BETR. STELLG.	SB12	KØ11	GØ1	K55
CONTRÔLEUR POSITION ARBRE WELLENLAGEWAECHTER	POS. DE SERVICE BETR. STELLG.	SB12	KØ11	GØ3	K56
DECL. MANUEL FERM. RAP. SS-HANDAUSLOESUNG	POS. DE SERVICE BETR. STELLG.	SC14	KØ21	GØ3	K62
DECL. MANUEL FERM. RAP. SS-HANDAUSLOESUNG	POS. DE SERVICE BETR. STELLG.	SC14	KØ22	GØ3	K63
CONTRÔLEUR DE SURVITESSE 1 DREHZAHLWAECHTER 1	POS. DE SERVICE BETR. STELLG.	SB11	KØØ1	GØ3	K57
CONTRÔLEUR DE SURVITESSE 2 DREHZAHLWAECHTER 2	POS. DE SERVICE BETR. STELLG.	SB11	KØØ2	GØ3	K58
PROT. HYD. CONDENSEUR HYDR. KONDSCHUTZ	POS. DE SERVICE BETR. STELLG.	SC24	KØØ4	GØ5	K59
CONTACTEUR DS AIR FERM. RAP. 1 SS-SCHUETZ 1	ARRÊT AUS	SC11	SØ41	T51	K6Ø
CONTACTEUR DS AIR FERM. RAP. 2 SS-SCHUETZ 2	ARRÊT AUS	SC11	SØ42	T51	K61
PRESSION FL. DEMARRAGE ANFAHRHILFSFLUESSIGK. DR.	< 2 BAR	SC23	P212	G52	K64
DEPASSEMENT DURÉE MARCHE LAUFZEITUEBERSCHR.		S011	UØØ1	M12	
ORDRE MANUEL PROG. DE REMISE HB RUECKSTELLPROGR.	MARCHE EIN	S011	UØØ1	A%	
FLUIDE FERM. RAPIDE SS-FLUESSIGKEIT	< 2,5 BAR				

LOGIQUE		DESIGNATION	REGLAGE	REPERE	
<AR> F5Ø2 - Ø1					
54 délai d'attente / contrôle / ordre %Q0.6	1	DECL. F. RAP. PAR CONT. P. ARB. PD ESSAI	LIBERÉ	SO11	U1Ø1
		SS-AUSL. D. WLW. W.P.	FREIGEGEBEN		
contrôle Ø,4S — %Q0.7	2	DECL. F. RAP. PAR CONT. P. ARB. PD ESSAI	LIBERÉ	SO11	U1Ø2
		SS-AUSL. D. WLW. W.P.	FREIGEGEBEN		
SO11U1Ø1 / F2Ø1 %I3.7		DECL. F. RAP. PAR CONT. P. ARB. PD ESSAI	LIBERÉ	SO11	U1Ø1
		SS-AUSL. D. WLW. W.P.	FREIGEGEBEN		
SO11U1Ø2 / F2Ø1 %I4.0		DECL. F. RAP. PAR CONT. P. ARB. PD ESSAI	LIBERÉ	SO11	U1Ø2
		SS-AUSL. D. WLW. W.P.	FREIGEGEBEN		
&					
55 délai d'attente / contrôle / ordre %Q1.0	1	DISTRIBUTEUR D'ESSAI	POS. DE SERVICE	SC11	S242
		PRUEFSCHALTSCH.	BETR. STELLG.		
délai d'attente 6S — contrôle 6S — %Q1.1	2	SELECTION	ANNULER	SO11	UØØ1
		ANWAHL	LOESCHEN		
%M10.7					
%I3.5		DISTRIBUTEUR D'ESSAI	POS. DE SERVICE	SC14	S2Ø1
		PRUEFSCHALTSCHIEBER	BETR. STELLG.		
3" 0					
%M11.0		DISTRIBUTEUR D'ESSAI	POS. DE SERVICE		
		PRUEFSCHALTSCHIEBER	BETR. STELLG.		
&					
56 délai d'attente / contrôle / ordre %Q1.2	1	T. DECL. F. RAP. ELECTROV. 1 PD ESSAI	ARRÊT	SO11	U1Ø1
		MV. SS-FERNAUSL. 1 W.P.	AUS		
contrôle 2S — %Q1.3	2	T. DECL. F. RAP. ELECTROV. 2 PD ESSAI	ARRÊT	SO11	U2Ø1
		MV. SS-FERNAUSL. 2 W.P.	AUS		
<U> F5Ø3 %M12.6					
<U> F5Ø2					
%I4.3		PRES. AMONT DISTRIB. D'ESSAI	< 2 BAR	SC11	P232
		DRUCK V. PRUEFSCH.			
%I4.4		PENTRE INST. FERM. RAP. PD ESSAI	< 2 BAR	SC11	P234
		DR. ZW. SS-FERN. W.P.			
&					
<R> SO11UØØ1 / F5Ø1-Ø1, F5Ø5 %M3.2		DEPASSEMENT DURÉE MARCHE	BLOQUER	SO11	UØØ1
		PROGRAMME	FIN	SO11	UØØ1
		LAUFZEITUEBERSCHR.	SPERREN		
		PROGRAMM	ENDE		

APPENDIX E:

The Detailed Software Solution

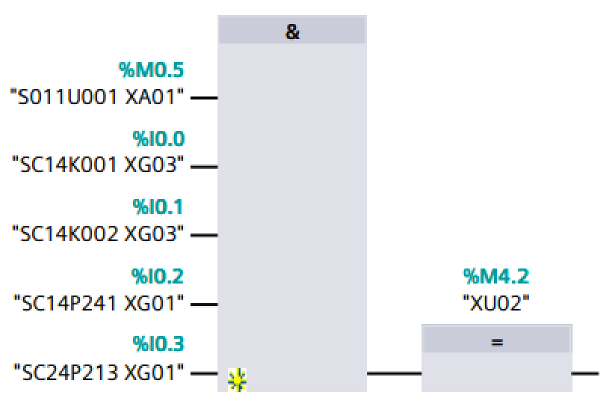
TURBINE PROTECTION PROGRAM / PLC_1 [CPU 412-1] / Program blocks

Main [OB1]

Main Properties								
General								
Name	Main	**Number**	1	**Type**	OB	**Language**	FBD	
Numbering	automatic							
Information								
Title	"Main Program Sweep (Cy- cle)"	**Author**		**Comment**		**Family**		
Version	0.1	**User-defined ID**						

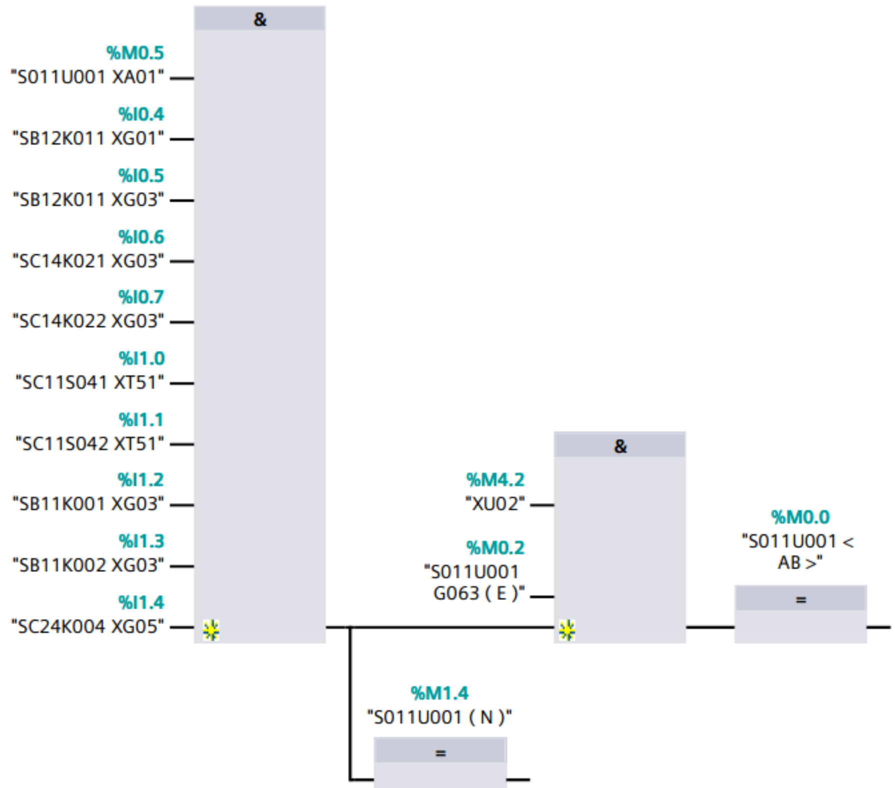
Main				
Name	**Data type**	**Offset**	**Default**	**Comment**
Temp				
OB1_EV_CLASS	Byte	0.0		Bits 0-3 = 1 (Coming event), Bits 4-7 = 1 (Event class 1)
OB1_SCAN_1	Byte	1.0		1 (Cold restart scan 1 of OB 1), 3 (Scan 2-n of OB 1)
OB1_PRIORITY	Byte	2.0		Priority of OB Execution
OB1_OB_NUMBR	Byte	3.0		1 (Organization block 1, OB1)
OB1_RESERVED_1	Byte	4.0		Reserved for system
OB1_RESERVED_2	Byte	5.0		Reserved for system
OB1_PREV_CYCLE	Int	6.0		Cycle time of previous OB1 scan (milliseconds)
OB1_MIN_CYCLE	Int	8.0		Minimum cycle time of OB1 (milliseconds)
OB1_MAX_CYCLE	Int	10.0		Maximum cycle time of OB1 (milliseconds)
OB1_DATE_TIME	Date_And_Time	12.0		Date and time OB1 started
Constant				

Network 1 : INST.FERMETURE RAPIDE POS DE SERVICE(%M4.2)



Symbol	Address	Type	Comment
"S011U001 XA01"	%M0.5	Bool	BASCULE VER AUTO MARCH
"SC14K001 XG03"	%I0.0	Bool	INST .FERM .RAPIDE .1 NON DECLENCHEE
"SC14K002 XG03"	%I0.1	Bool	INST .FERM .RAPIDE 2 NON DECLENCHEE
"SC14P241 XG01"	%I0.2	Bool	PRESSION FLUIDE FERM RAP > 5 BAR
"SC24P213 XG01"	%I0.3	Bool	PRESSION FLUIDE AUX FERM RAP > 5 BAR
"XU02"	%M4.2	Bool	INST.FERMETURE RAPIDE POS DE SERVICE

Network 2: S011U001<AB>(%M0.0)/S011U001<N>(%M1.4)

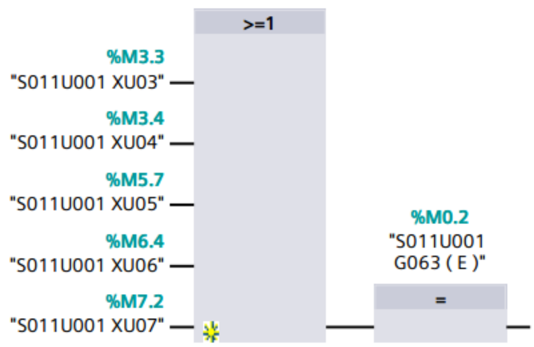


Symbol	Address	Type	Comment
"S011U001 (N)"	%M1.4	Bool	TOUS LES CONTROLEURS POS DE SERVICE
"S011U001 < AB >"	%M0.0	Bool	PAGE S011U001...F501-01
"S011U001 G063 (E)"	%M0.2	Bool	UNE LIBERATION EXISTANTE PAGE S011U001 F502 E
"S011U001 XA01"	%M0.5	Bool	BASCULE VER AUTO MARCH
"SB11K001 XG03"	%I1.2	Bool	CONTROLEUR DE SURVITESSE 1 POS SERVICE
"SB11K002 XG03"	%I1.3	Bool	CONTROLEUR DE SURVITESSE 2 POS DE SERVICE
"SB12K011 XG01"	%I0.4	Bool	CONTROLEUR POS .ARBRE POS DE SERVICE
"SB12K011 XG03"	%I0.5	Bool	CONTROLEUR POS D'ARBRE POS DE SERVICE
"SC11S041 XT51"	%I1.0	Bool	TELEDECLENCH.FERM.RAP.1 ARRET
"SC11S042 XT51"	%I1.1	Bool	TELEDEDECLENCH.FERM.RAP 2 ARRET
"SC14K021 XG03"	%I0.6	Bool	DECLENCH .MANUEL FERM .RAP POS DE SERVICE
"SC14K022 XG03"	%I0.7	Bool	DECLENCH MANUEL FERM.RAP POS DE SERVICE
"SC24K004 XG05"	%I1.4	Bool	PROTECTION HYDR CONDENSEUR POS DE SERVICE
"XU02"	%M4.2	Bool	INST.FERMETURE RAPIDE POS DE SERVICE

Network 3: S011U001<AA>(%M1.5)

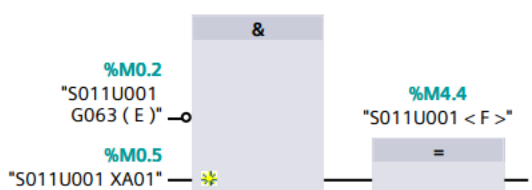
Symbol	Address	Type	Comment
"S011U001 < AA >"	%M1.5	Bool	AUTOM MARCHE/ARRET CONFIRM
"S011U001 XA11"	%I4.2	Bool	EIN / AUS .AUTOMATISME MARCHE / ARRET (XA11)
"SORTIE SR < R >"	%M4.3	Bool	

Network 4: S011U001<E>(%M0.2)



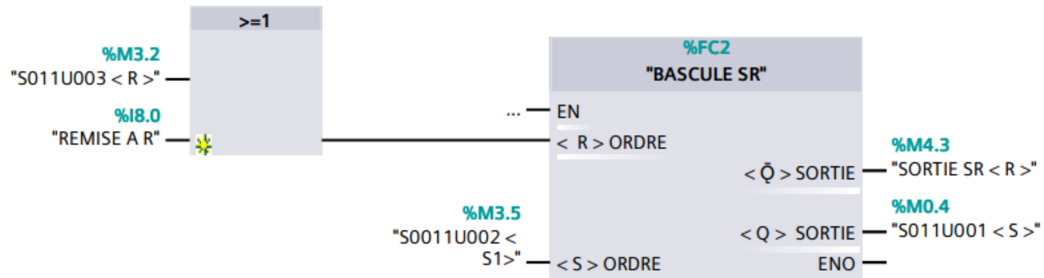
Symbol	Address	Type	Comment
"S011U001 G063 (E)"	%M0.2	Bool	UNE LIBERATION EXISTANTE PAGE S011U001 F502 E
"S011U001 XU03"	%M3.3	Bool	TELEDECLENCH FERM.RAP .1 LIBERE
"S011U001 XU04"	%M3.4	Bool	TELEDECLENCH.FERM.RAP.2 LIBERE
"S011U001 XU05"	%M5.7	Bool	CONTROLEUR DE SURVITESSE LIBERE
"S011U001 XU06"	%M6.4	Bool	PROTECTION HYDR .CONDENS LIBERE
"S011U001 XU07"	%M7.2	Bool	CONTROLEUR POS .ARBRE LIBEREE

Network 5: S011U001<F>(%M4.4)



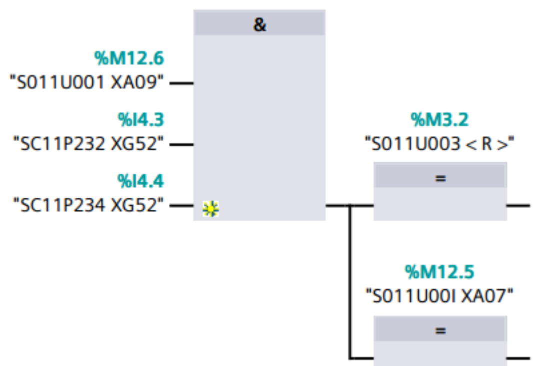
Symbol	Address	Type	Comment
"S011U001 < F >"	%M4.4	Bool	LIBERATION SELECTION
"S011U001 G063 (E)"	%M0.2	Bool	UNE LIBERATION EXISTANTE PAGE S011U001 F502 E
"S011U001 XA01"	%M0.5	Bool	BASCULE VER AUTO MARCH

Network 6: SR FLIP-FLOP (%M4.3 and %M0.4)



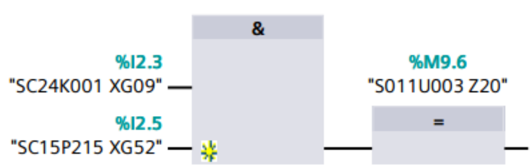
Symbol	Address	Type	Comment
"REMISE A R"	%I8.0	Bool	
"S0011U002 < S1>"	%M3.5	Bool	PHASE 1 ACTIVE
"S011U001 < S >"	%M0.4	Bool	PROGRAMME DE CONTROLE MARCHE
"S011U003 < R >"	%M3.2	Bool	DEPASSEMENT DUREE MARCHE BLOQUER PROGRAM
"SORTIE SR < R >"	%M4.3	Bool	

Network 7: (%M3.2)



Symbol	Address	Type	Comment
"S011U001 XA07"	%M12.5	Bool	RETRO SIGNAL PROGRISSIN REGIME ARRET
"S011U001 XA09"	%M12.6	Bool	PROGRAMME ARRET MARCHE
"S011U003 < R >"	%M3.2	Bool	DEPASSEMENT DUREE MARCHE BLOQUER PROGRAM
"SC11P232 XG52"	%I4.3	Bool	PRES AMONT DISTRIB D'ESSAI < 2 BAR
"SC11P234 XG52"	%I4.4	Bool	PENTRE INST FERM RAP PJ ESSAI < 2 BAR

Network 08: TRANSITION 51'S011U003 F501.1'(%M9.6)

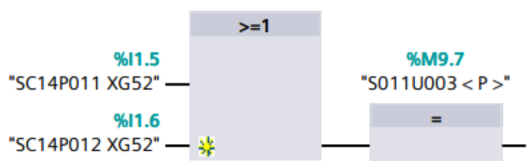


Symbol	Address	Type	Comment
"S011U003 Z20"	%M9.6	Bool	
"SC15P215 XG52"	%I2.5	Bool	PRESSION HUILE D'ESSAI < 0.1 BAR
"SC24K001 XG09"	%I2.3	Bool	DISP.ESSAI CONTROL.VITESSE 0%

Network 09: TRANSITION 51<P>'S011U003 F501.1'(%M9.7)

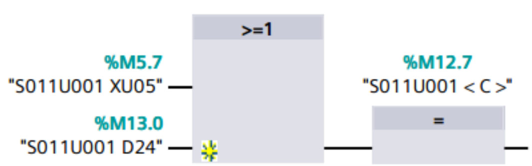
Symbol	Address	Type	Comment
"S011U003 < P >"	%M9.7	Bool	PRESSION FLUIDE .FERM.RAP < 2 BAR
"SC14P011 XG52"	%I1.5	Bool	PRESSION FLUIDE FERM .RAP < 2.5 BAR
"SC14P012 XG52"	%I1.6	Bool	PRESSION FLUIDE FERM.RAP.<2.5 BAR

Network 10: S011U003 TRANSITION 56 OF STEP S55



Symbol	Address	Type	Comment
"SC14S201 XG09"	%I3.5	Bool	DISTRIBUTEUR D'ESSAI POS.DE SERVICE
"SORTIE.TP.S55.ACTIVE"	%M11.0	Bool	DISTRIBUTER D'ESSAI POS .DE SERVICE XU07

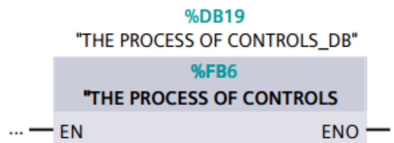
Network 11: S011U001 <C>(%M12.7)



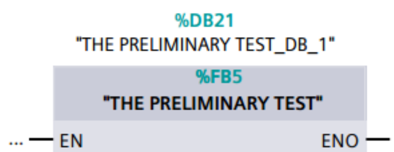
Symbol	Address	Type	Comment
"S011U001 < C >"	%M12.7	Bool	
"S011U001 D24"	%M13.0	Bool	
"S011U001 XU05"	%M5.7	Bool	CONTROLEUR DE SURVITESSE LIBERE

Network 12: CALLING THE RESET PROGRAM [FB3]

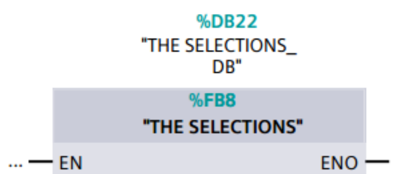
Network 13: CALLING THE PROCESS OF CONTROL [FB6]



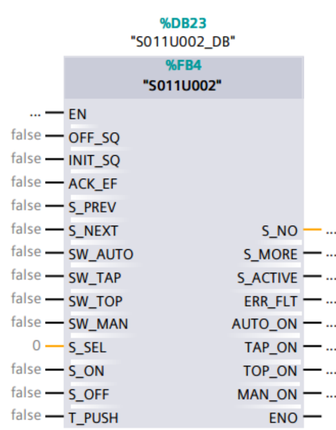
Network 14: CALLING THE PRELIMINARY TEST [FB5]



Network 15: CALLING THE SELECTIONS [FB8]



Network 16: CALLING [FB4]



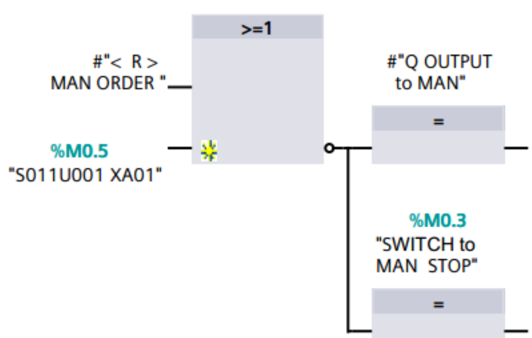
TURBINE PROTECTION PROGRAM / PLC_1 [CPU 412-1] / Program blocks

Switching AUTO/MAN [FC1]

Switching AUTO/MAN Properties							
General							
Name	Switching AUTO/MAN	**Number**	1	**Type**	FC	**Language**	FBD
Numbering	automatic						
Information							
Title		**Author**		**Comment**		**Family**	
Version	0.1	**User-defined ID**					

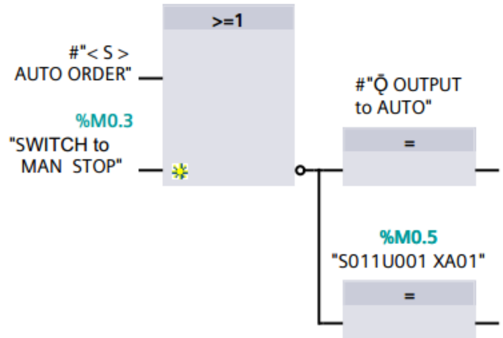
Switching AUTO/MAN				
Name	**Data type**	**Offset**	**Default value**	**Comment**
Input				
< S > OUTPUT AUTO	Bool			
< R > OUTPUT MAN	Bool			
Output				
Q OUTPUT to MAN	Bool			
Q̄ OUTPUT to AUTO	Bool			
InOut				
Temp				
Constant				
Return				
SWITCHING MAN /ARRET	Void			

Network 1: SWITCHING TO MANUAL STOP



Symbol	Address	Type	Comment
"SWITCHING MAN	%M0.3	Bool	
"S011U001 XA01"	%M0.5	Bool	SWITCHING MAN. STOP
#"< R > ORDER MAN"		Bool	
#"Q OUTPUT to MAN"		Bool	

Network 2: SWITCHING TO AUTOMATIC RUN



Symbol	Address	Type	Comment
"SWITCHING MAN	%M0.3	Bool	
"S011U001 XA01"	%M0.5	Bool	SWITCHING AUTO. RUN
#"< S > ORDER AUTO"		Bool	
#"Q̄ OUTPUT to AUTO"		Bool	

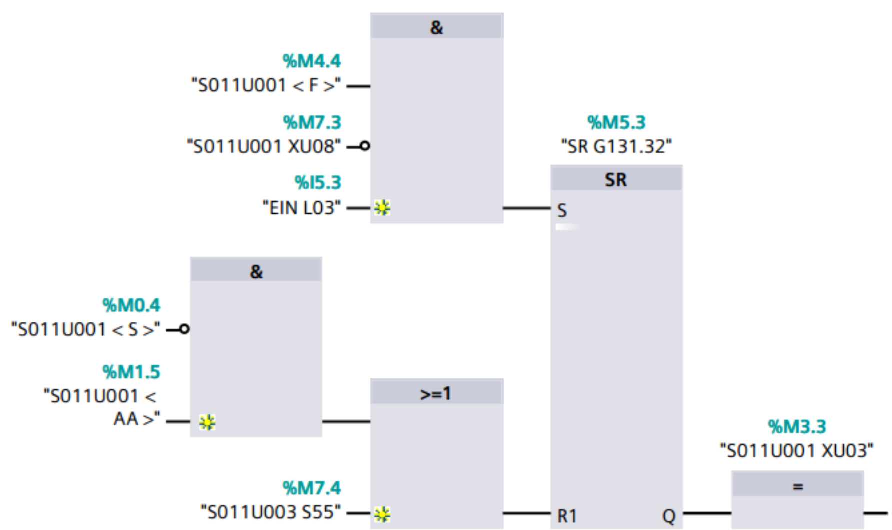
TURBINE PROTECTION PROGRAM / PLC_1 [CPU 412-1] / Program blocks

The selections [FB8]

THE SELECTIONS Properties							
General							
Name	THE SELECTIONS	**Number**	8	**Type**	FB	**Language**	FBD
Numbering	automatic						
Information							
Title		**Author**		**Comment**		**Family**	
Version	0.1	**User-defined ID**					

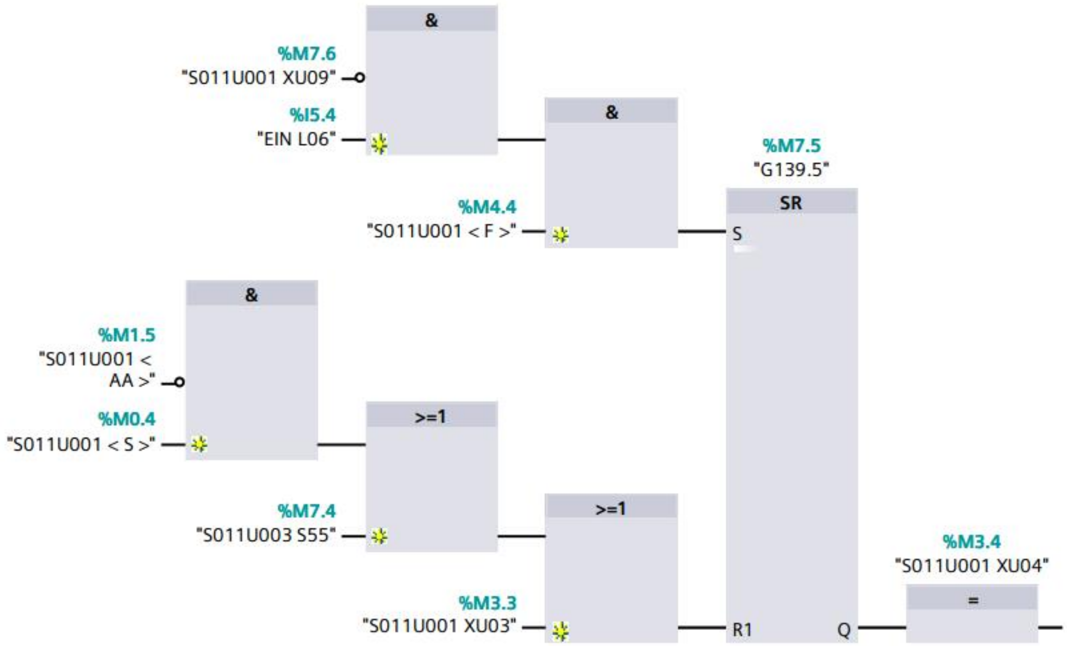
THE SELECTIONS							
Name	**Data type**	**Offset**	**Default value**	**Accessible from HMI**	**Visible in HMI**	**Set point**	**Comment**
Input							
Output							
InOut							
Static							
Temp							
Constant							

Network 1: S011U001 XU03(%M3.3)



Symbol	Address	Type	Comment
"EIN L03"	%I5.3	Bool	TELEDECLENCH.FERM.RAP.1 MARCHE
"S011U001 < AA >"	%M1.5	Bool	AUTOM MARCHE/ARRET CONFIRM
"S011U001 < F >"	%M4.4	Bool	LIBERATION SELECTION
"S011U001 < S >"	%M0.4	Bool	PROGRAMME DE CONTROLE MARCHE
"S011U001 XU03"	%M3.3	Bool	TELEDECLENCH FERM.RAP .1 LIBERE
"S011U001 XU08"	%M7.3	Bool	ESSAI TELEDECL.FERM.RAP.1 FIN
"S011U003 S55"	%M7.4	Bool	ORDRE PHASE 55 ACTIVE
"SR G131.32"	%M5.3	Bool	S011U001 G131.5--------> S508-------->JD08

Network 2: S011U001 XU04(%M3.4)

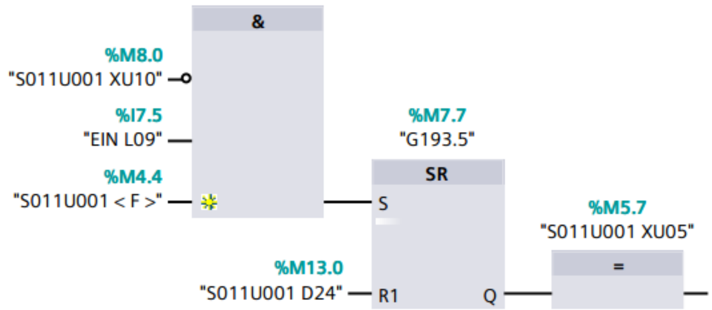


Symbol	Address	Type	Comment
"EIN L06"	%I5.4	Bool	TELEDECLENCH.FERM.RAP.2 MARCHE
"G139.5"	%M7.5	Bool	
"S011U001 < AA >"	%M1.5	Bool	AUTOM MARCHE/ARRET CONFIRM
"S011U001 < F >"	%M4.4	Bool	LIBERATION SELECTION
"S011U001 < S >"	%M0.4	Bool	PROGRAMME DE CONTROLE MARCHE
"S011U001 XU03"	%M3.3	Bool	TELEDECLENCH FERM.RAP .1 LIBERE
"S011U001 XU04"	%M3.4	Bool	TELEDECLENCH.FERM.RAP.2 LIBERE
"S011U001 XU09"	%M7.6	Bool	ESSAI TELEDECL.FERM.RAP.2 FIN
"S011U003 S55"	%M7.4	Bool	ORDRE PHASE 55 ACTIVE

Network 3: S011UOO1 D24(%M13.0)

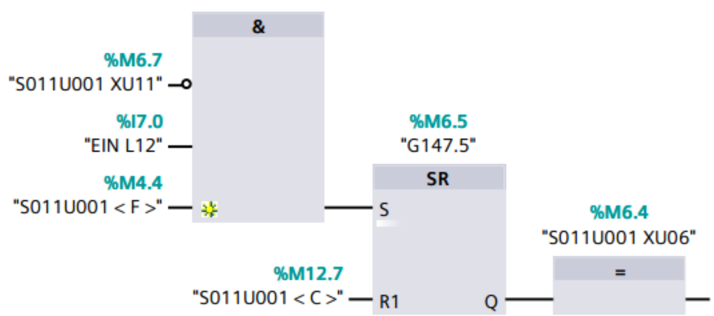
Symbol	Address	Type	Comment
"S011U001 < AA >"	%M1.5	Bool	AUTOM MARCHE/ARRET CONFIRM
"S011U001 < S >"	%M0.4	Bool	PROGRAMME DE CONTROLE MARCHE
"S011U001 D24"	%M13.0	Bool	
"S011U001 XU03"	%M3.3	Bool	TELEDECLENCH FERM.RAP .1 LIBERE
"S011U001 XU04"	%M3.4	Bool	TELEDECLENCH.FERM.RAP.2 LIBERE
"S011U003 S55"	%M7.4	Bool	ORDRE PHASE 55 ACTIVE

Network 4: S011U001 XU05(%M5.7)



Symbol	Address	Type	Comment
"EIN L09"	%I7.5	Bool	CONTROLEUR DE SURVITESSE MARCHE
"G193.5"	%M7.7	Bool	
"S011U001 < F >"	%M4.4	Bool	LIBERATION SELECTION
"S011U001 D24"	%M13.0	Bool	
"S011U001 XU05"	%M5.7	Bool	CONTROLEUR DE SURVITESSE LIBERE
"S011U001 XU10"	%M8.0	Bool	ESSAI CONTROLEUR SURVITESSE FIN

Network 5: S011U001 XU06(%M6.4)



	Address	Type	Comment
"EIN L12"	%I7.0	Bool	PROTECTION HYD.CONDENSEUR MARCHE
"G147.5"	%M6.5	Bool	
"S011U001 < C >"	%M12.7	Bool	
"S011U001 < F >"	%M4.4	Bool	LIBERATION SELECTION
"S011U001 XU06"	%M6.4	Bool	PROTECTION HYDR .CONDENS LIBERE
"S011U001 XU11"	%M6.7	Bool	ESSAI PROTECT.HYD.CONDENS FIN

Network 6: S011U001 XU07(%M7.2)

Symbol	Address	Type	Comment
"EIN L15"	%I7.6	Bool	CONTROLEUR POSITION ARBRE MARCHE
"G147.5.1"	%M8.1	Bool	
"S011U001 < C >"	%M12.7	Bool	
"S011U001 < F >"	%M4.4	Bool	LIBERATION SELECTION
"S011U001 XU06"	%M6.4	Bool	PROTECTION HYDR .CONDENS LIBERE
"S011U001 XU07"	%M7.2	Bool	CONTROLEUR POS .ARBRE LIBEREE
"S011U001 XU12"	%M8.2	Bool	ESSAI CONTROLEUR POS .ARBRE FIN

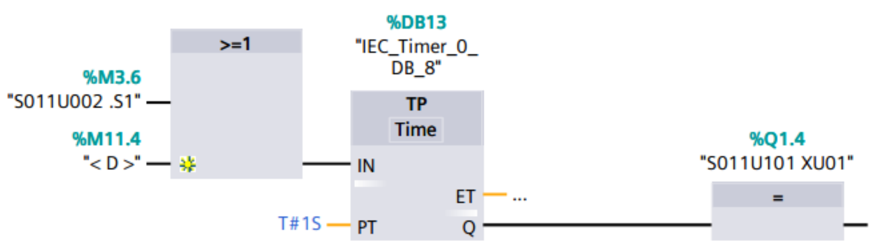
TURBINE PROTECTION PROGRAM / PLC_1 [CPU 412-1] / Program blocks

THE PRELIMINARY TEST [FB5]

THE PRELIMINARY TEST Properties							
General							
Name	THE PRELIMINARY TEST	**Number**	5	**Type**	FB	**Language**	FBD
Numbering	automatic						
Information							
Title		**Author**		**Comment**		**Family**	
Version	0.1	**User-defined ID**					

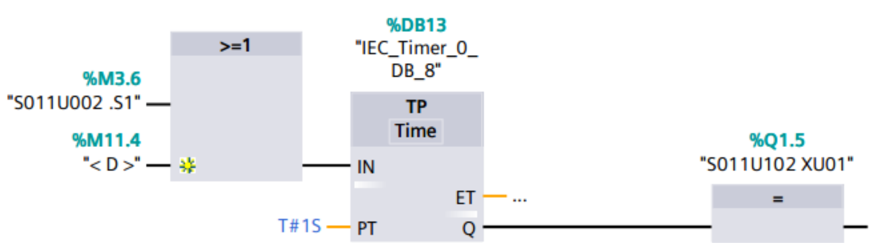
THE PRELIMINARY TEST							
Name	**Data type**	**Offset**	**Default value**	**Accessible from HMI**	**Visible in HMI**	**Setpoint**	**Comment**
Input							
Output							
InOut							
Static							
Temp							
Constant							

Network 1: S011U002 S1 'S011U101 XU01' (%Q1.4)



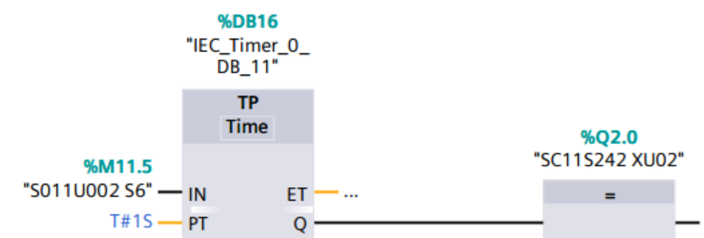
Symbol	Address	Type	Comment
"< D >"	%M11.4	Bool	S502.3---->G099 : d18
"S011U002 .S1"	%M3.6	Bool	PHASE N°1 ACTIVEE
"S011U101 XU01"	%Q1.4	Bool	TELEDECL.FERM.RAP.1 ELECT.PD ESSAI

Network 2: S011U002 S1 'S011U102 XU01' (%Q1.5)



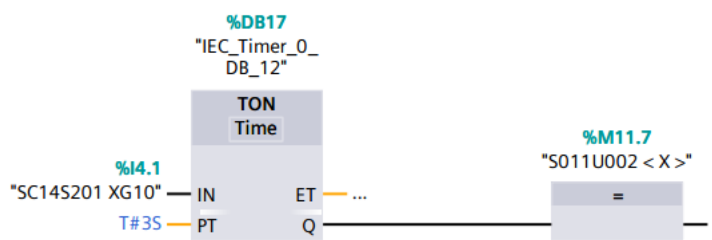
Symbol	Address	Type	Comment
"< D >"	%M11.4	Bool	S502.3---->G099 : d18
"S011U002 .S1"	%M3.6	Bool	PHASE N°1 ACTIVEE
"S011U102 XU01"	%Q1.5	Bool	TELEDECL.FERM.RAP.2 ELECT.PD ESSAI

Network 3: S011U002 S6 'SC11S242 XU02' (%Q2.0)



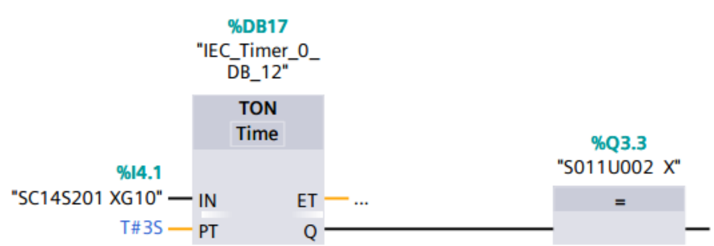
Symbol	Address	Type	Comment
"S011U002 S6"	%M11.5	Bool	ETAPE 6 ACTIVEE
"SC11S242 XU02"	%Q2.0	Bool	DISTRIBUTEUR D'ESSAI POS.D'ESSAI

Network 4: S011U002 < X > (%M11.7)



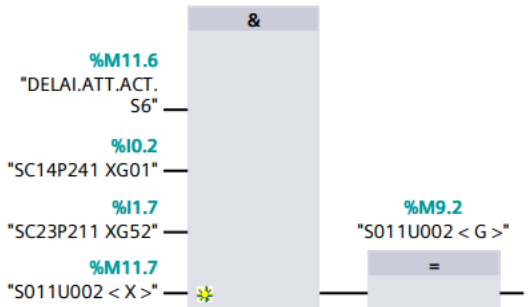
Symbol	Address	Type	Comment
"S011U002 < X >"	%M11.7	Bool	DISTRIBUTEUR D'ESSAI POS .D'ESSAI
"SC14S201 XG10"	%I4.1	Bool	DISTRIBUTEUR D'ESSAI POS.D'ESSAI

Network 5: SC11S243 XS0 <X> (%Q3.3)



Symbol	Address	Type	Comment
"S011U002 X"	%Q3.3	Bool	LAMPE INDIC POS ESSAI
"SC14S201 XG10"	%I4.1	Bool	DISTRIBUTEUR D'ESSAI POS.D'ESSAI

Network 6: S011U002 < G > (%M9.2)



Symbol	Address	Type	Comment
"DELAI.ATT.ACT.S6"	%M11.6	Bool	
"S011U002 < G >"	%M9.2	Bool	ESSAI PRELIMINAIRE FIN
"S011U002 < X >"	%M11.7	Bool	DISTRIBUTEUR D'ESSAI POS .D'ESSAI
"SC14P241 XG01"	%I0.2	Bool	PRESSION FLUIDE FERM RAP > 5 BAR
"SC23P211 XG52"	%I1.7	Bool	PRESS.FL.AUX..DEMARRAGE < 2 BAR

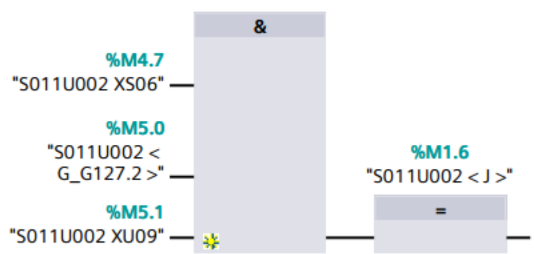
TURBINE PROTECTION PROGRAM / PLC_1 [CPU 412-1] / Program blocks

THE PROCESS OF CONTROLS [FB6]

THE PROCESS OF CONTROLS Properties							
General							
Name	THE PROCESS OF CONTROLS	**Number**	6	**Type**	FB	**Language**	FBD
Numbering	automatic						
Information							
Title		**Author**		**Comment**		**Family**	
Version	0.1	**User-defined ID**					

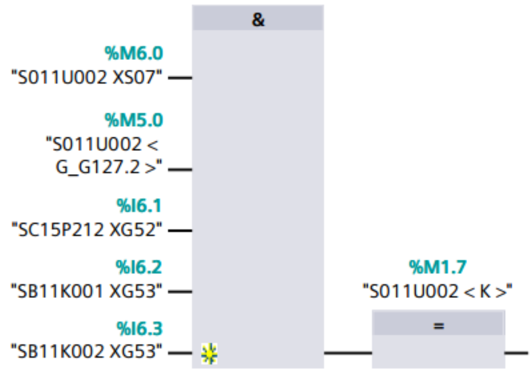
THE PROCESS OF CONTROLS							
Name	**Data type**	**Offset**	**Default value**	**Accessible from HMI**	**Visible in HMI**	**Setpoint**	**Comment**
Input							
Output							
InOut							
Static							
Temp							
Constant							

Network 1: S011U002 < J > (%M1.6)



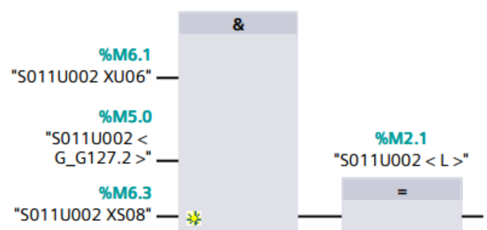
Symbol	Address	Type	Comment
"S011U002 <	%M5.0	Bool	S011U002------>S508----->JD08
"S011U002 < J >"	%M1.6	Bool	S011U002 J------>S508----->JD08
"S011U002 XS06"	%M4.7	Bool	STEP S6 <7>. ACTIVEE
"S011U002 XU09"	%M5.1	Bool	FLUIDE DE COMMANDE < 2 BAR

Network 2: S011U002 < K >%M1.7



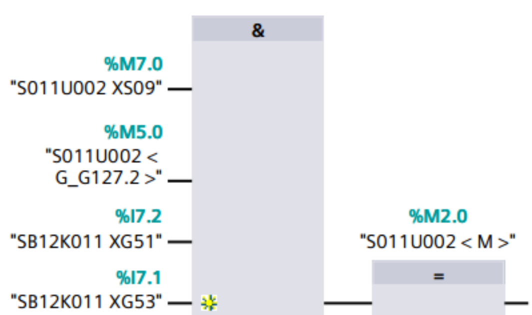
Symbol	Address	Type	Comment
"S011U002 <	%M5.0	Bool	S011U002------>S508----->JD08
"S011U002 < K >"	%M1.7	Bool	S011U002 < K >------->S509----->JD08
"S011U002 XS07"	%M6.0	Bool	INTERN ORDER STEP 7
"SB11K001 XG53"	%I6.2	Bool	CONTROLEUR SURVITESSE.1 DECLENCHE
"SB11K002 XG53"	%I6.3	Bool	CONTROLEUR SURVITESSE 2 DECLENCHEE
"SC15P212 XG52"	%I6.1	Bool	PRESSION HUILE D'ESSAI < 4.8 BAR

Network 3: S011U002 < L >%M2.1



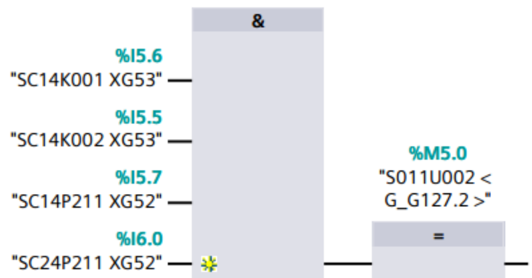
Symbol	Address	Type	Comment
"S011U002 <	%M5.0	Bool	S011U002------>S508----->JD08
"S011U002 < L >"	%M2.1	Bool	ESSAI PROT.HYD.CONDENSEUR FIN
"S011U002 XS08"	%M6.3	Bool	ORDER STEP 8
"S011U002 XU06"	%M6.1	Bool	PROTECTION HYD CONDENSEUR DECLENCHEE

Network 4: S011U002 < M >%M2.0



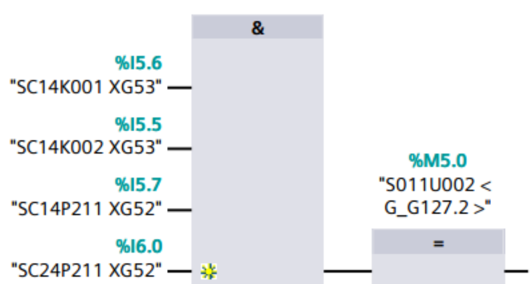
Symbol	Address	Type	Comment
"S011U002 <	%M5.0	Bool	S011U002------>S508----->JD08
"S011U002 < M >"	%M2.0	Bool	ESSAI CONTROLEUR POS.ARBRE FIN
"S011U002 XS09"	%M7.0	Bool	CONTROLEUR POS.ARBRE TESTER
"SB12K011 XG51"	%I7.2	Bool	CONTROLEUR POSITION ARBRE DECLENCHEE
"SB12K011 XG53"	%I7.1	Bool	CONTRROLEURPOSITION ARBRE DECLENCHEE

Network 5: S011U002 < G >%M5.0



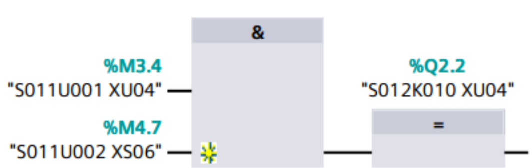
Symbol	Address	Type	Comment
"S011U002 <	%M5.0	Bool	S011U002------>S508----->JD08
"SC14K001 XG53"	%I5.6	Bool	INST.FERMETEUR RAPIDE DECLENCHEE
"SC14K002 XG53"	%I5.5	Bool	INST.FERMETURE RAPIDE DECLENCHEE
"SC14P211 XG52"	%I5.7	Bool	PRESSION FLUIDE FERM.RAP. < 2 BAR
"SC24P211 XG52"	%I6.0	Bool	PRESSION FLUIDE.AUX.FERM.RAP. < 2 BAR

Network 6: S011U002 S7(S011K010 XU03%Q2.1)



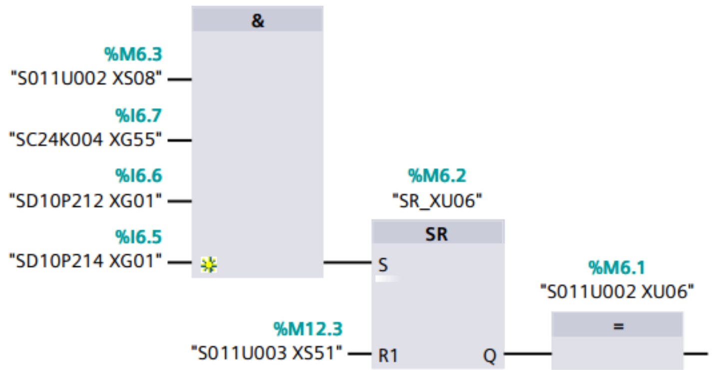
	Address	Type	Comment
"S011K010 XU03"	%Q2.1	Bool	TELEDECLENCH.FERM.RAP.1 TESTER
"S011U001 XU03"	%M3.3	Bool	TELEDECLENCH FERM.RAP .1 LIBERE
"S011U002 XS06"	%M4.7	Bool	STEP S6 <7>. ACTIVEE

Network 7: S011U002 S7(S011K010 XU04%Q2.2)



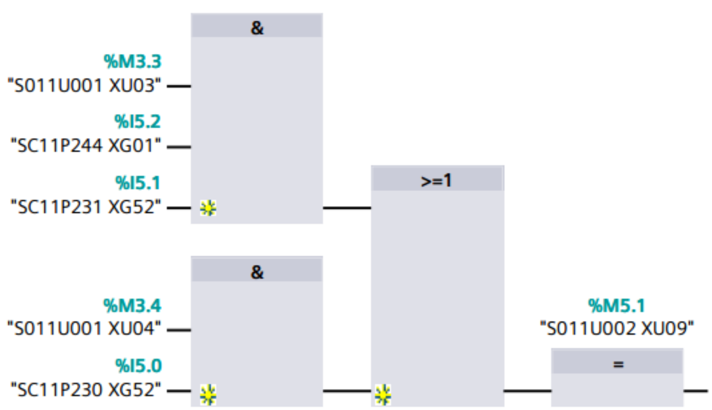
	Address	Type	Comment
"S011U001 XU04"	%M3.4	Bool	TELEDECLENCH.FERM.RAP.2 LIBERE
"S011U002 XS06"	%M4.7	Bool	STEP S6 <7>. ACTIVEE
"S012K010 XU04"	%Q2.2	Bool	TELEDECLENCH.FERM.RAP.1 TESTER

Network 8: (%M6.1)



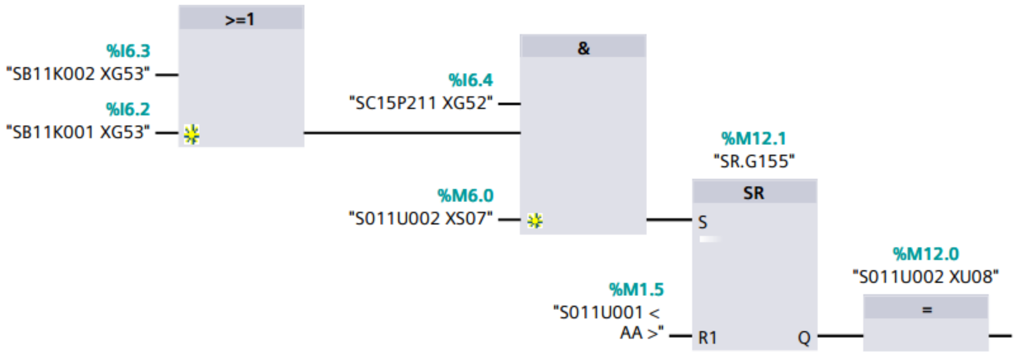
Symbol	Address	Type	Comment
"S011U002 XS08"	%M6.3	Bool	ORDRE PAS 8
"S011U002 XU06"	%M6.1	Bool	PROTECTION HYD CONDENSEUR DECLENCHEE
"S011U003 XS51"	%M12.3	Bool	ORDRE INTERNE PAS 51
"SC24K004 XG55"	%I6.7	Bool	PROTECTION HYD.CONDENSEUR DECLENCHEE
"SD10P212 XG01"	%I6.6	Bool	PRESSION ABS.AV CONDENSEUR > 0.35 BAR
"SD10P214 XG01"	%I6.5	Bool	PRESSION ABS .AU CONDENSEUR > 035 BAR
"SR_XU06"	%M6.2	Bool	

Network 9: S011U002 XU09(%M5.1)



Symbol	Address	Type	Comment
"S011U001 XU03"	%M3.3	Bool	TELEDECLENCH FERM.RAP .1 LIBERE
"S011U001 XU04"	%M3.4	Bool	TELEDECLENCH.FERM.RAP.2 LIBERE
"S011U002 XU09"	%M5.1	Bool	FLUIDE DE COMMANDE < 2 BAR
"SC11P230 XG52"	%I5.0	Bool	FL.DE COMM .ENTRE ELECTROV < 2 BAR
"SC11P231 XG52"	%I5.1	Bool	FL DE COMM. AMONT INST .F .RAP < 2 BAR
"SC11P244 XG01"	%I5.2	Bool	FL.DE.COMM.ENTRE ELECTROV > 5 BAR

Network 10: S011U002 XU08(%M12.0)



Symbol	Address	Type	Comment
"S011U001 < AA >"	%M1.5	Bool	AUTOM MARCHE/ARRET CONFIRM
"S011U002 XS07"	%M6.0	Bool	ORDRE INTERNE PAS 7
"S011U002 XU08"	%M12.0	Bool	DECL.CONTROLEUR SURVIT TROP TOT
"SB11K001 XG53"	%I6.2	Bool	CONTROLEUR SURVITESSE.1 DECLENCHE
"SB11K002 XG53"	%I6.3	Bool	CONTROLEUR SURVITESSE 2 DECLENCHEE
"SC15P211 XG52"	%I6.4	Bool	PRESSION HUILE D'ESSAI < 4.5 BAR
"SR.G155"	%M12.1	Bool	

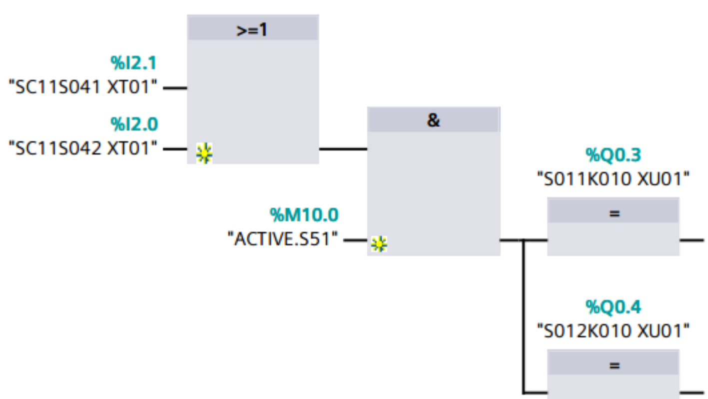
TURBINE PROTECTION PROGRAM / PLC_1 [CPU 412-1] / Program blocks

THE RESET PROGRAM [FB3]

THE RESET PROGRAM Properties							
General							
Name	THE RESET PROGRAM	**Number**	3	**Type**	FB	**Language**	FBD
Numbering	automatic						
Information							
Title		**Author**		**Comment**		**Family**	
Version	0.1	**User-defined ID**					

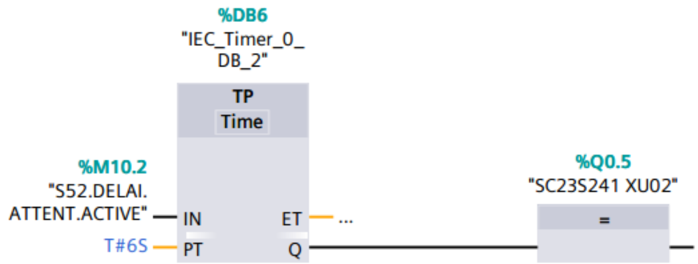
THE RESET PROGRAM							
Name	**Data type**	**Offset**	**Default value**	**Accessible from HMI**	**Visible in HMI**	**Setpoint**	**Comment**
Input							
Output							
InOut							
Static							
Temp							
Constant							

Network 1: S011U003 S51 ORDRE01 (Q0.3+Q0.4)



Symbol	Address	Type	Comment
"ACTIVE.S51"	%M10.0	Bool	
"S011K010 XU01"	%Q0.3	Bool	RELAIS D'INTERRUPTION 1.MARCHE
"S012K010 XU01"	%Q0.4	Bool	RELAIS D'INTERRUPTION 2 MARCHE
"SC11S041 XT01"	%I2.1	Bool	CONTACTEUR DS AIR FERM .RAP.1 MARCHE
"SC11S042 XT01"	%I2.0	Bool	CONTACTEUR DS AIR FERM.RAP.2 MARCHE

Network 2: S011U003 S52 ORDRE02 (Q0.5)

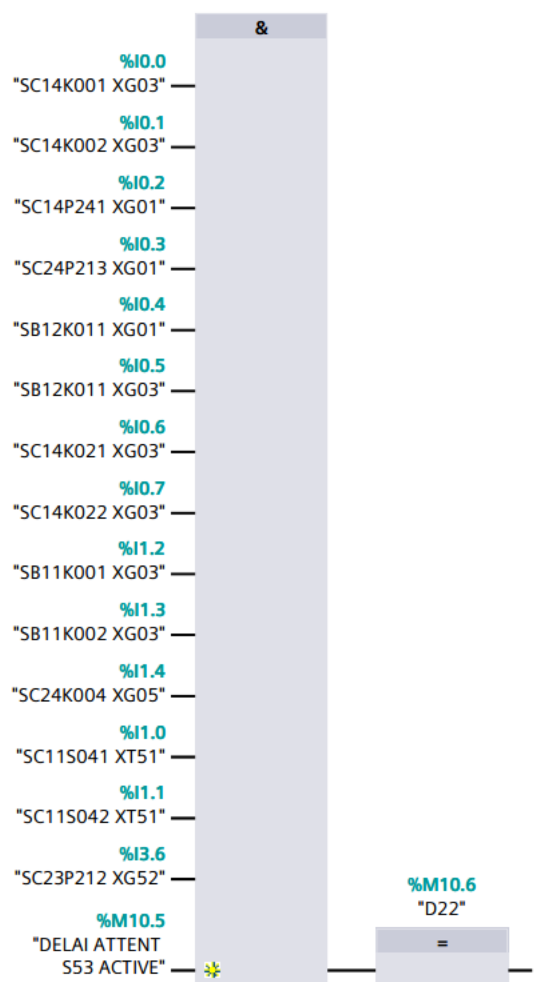


Symbol	Address	Type	Comment
"S52.DELAI.ATTENT.ACTIVE"	%M10.2	Bool	
"SC23S241 XU02"	%Q0.5	Bool	ELECTROVANNE DE REMISE 1.MARCHE

Network 3: S011U003<T>(%M10.3)

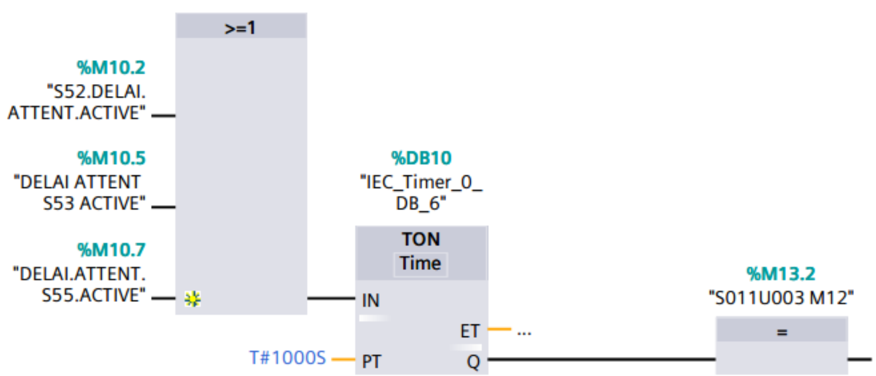
Symbol	Address	Type	Comment
"S011U003 < T >"	%M10.3	Bool	
"S52.DELAI.ATTENT.ACTIVE"	%M10.2	Bool	
"SB11K001 XG03"	%I1.2	Bool	CONTROLEUR DE SURVITESSE 1 POS SERVICE
"SB11K002 XG03"	%I1.3	Bool	CONTROLEUR DE SURVITESSE 2 POS DE
"SB12K011 XG01"	%I0.4	Bool	CONTROLEUR POS .ARBRE POS DE SERVICE
"SB12K011 XG03"	%I0.5	Bool	CONTROLEUR POS D'ARBRE POS DE SERVICE
"SC11S041 XT51"	%I1.0	Bool	TELEDECLENCH.FERM.RAP.1 ARRET
"SC11S042 XT51"	%I1.1	Bool	TELEDEDECLENCH.FERM.RAP 2 ARRET
"SC14K001 XG03"	%I0.0	Bool	INST .FERM .RAPIDE .1 NON DECLENCHEE
"SC14K002 XG03"	%I0.1	Bool	INST .FERM .RAPIDE 2 NON DECLENCHEE
"SC14K021 XG03"	%I0.6	Bool	DECLENCH .MANUEL FERM .RAP POS DE
"SC14K022 XG03"	%I0.7	Bool	DECLENCH MANUEL FERM.RAP POS DE
"SC14P241 XG01"	%I0.2	Bool	PRESSION FLUIDE FERM RAP > 5 BAR
"SC23P211 XG52"	%I1.7	Bool	PRESS.FL.AUX..DEMARRAGE < 2 BAR
"SC24K004 XG05"	%I1.4	Bool	PROTECTION HYDR CONDENSEUR POS DE
"SC24P213 XG01"	%I0.3	Bool	PRESSION FLUIDE AUX FERM RAP > 5 BAR

Network 4: S011U003 D22(%M10.6)



Symbol	Address	Type	Comment
"D22"	%M10.6	Bool	
"DELAI ATTENT S53	%M10.5	Bool	
"SB11K001 XG03"	%I1.2	Bool	CONTROLEUR DE SURVITESSE 1 POS SERVICE
"SB11K002 XG03"	%I1.3	Bool	CONTROLEUR DE SURVITESSE 2 POS DE
"SB12K011 XG01"	%I0.4	Bool	CONTROLEUR POS .ARBRE POS DE SERVICE
"SB12K011 XG03"	%I0.5	Bool	CONTROLEUR POS D'ARBRE POS DE SERVICE
"SC11S041 XT51"	%I1.0	Bool	TELEDECLENCH.FERM.RAP.1 ARRET
"SC11S042 XT51"	%I1.1	Bool	TELEDEDECLENCH.FERM.RAP 2 ARRET
"SC14K001 XG03"	%I0.0	Bool	INST .FERM .RAPIDE .1 NON DECLENCHEE
"SC14K002 XG03"	%I0.1	Bool	INST .FERM .RAPIDE 2 NON DECLENCHEE
"SC14K021 XG03"	%I0.6	Bool	DECLENCH .MANUEL FERM .RAP POS DE
"SC14K022 XG03"	%I0.7	Bool	DECLENCH MANUEL FERM.RAP POS DE SERVICE
"SC14P241 XG01"	%I0.2	Bool	PRESSION FLUIDE FERM RAP > 5 BAR
"SC23P212 XG52"	%I3.6	Bool	PRESSION FL.DEMARRAGE < 2BAR
"SC24K004 XG05"	%I1.4	Bool	PROTECTION HYDR CONDENSEUR POS DE
"SC24P213 XG01"	%I0.3	Bool	PRESSION FLUIDE AUX FERM RAP > 5 BAR

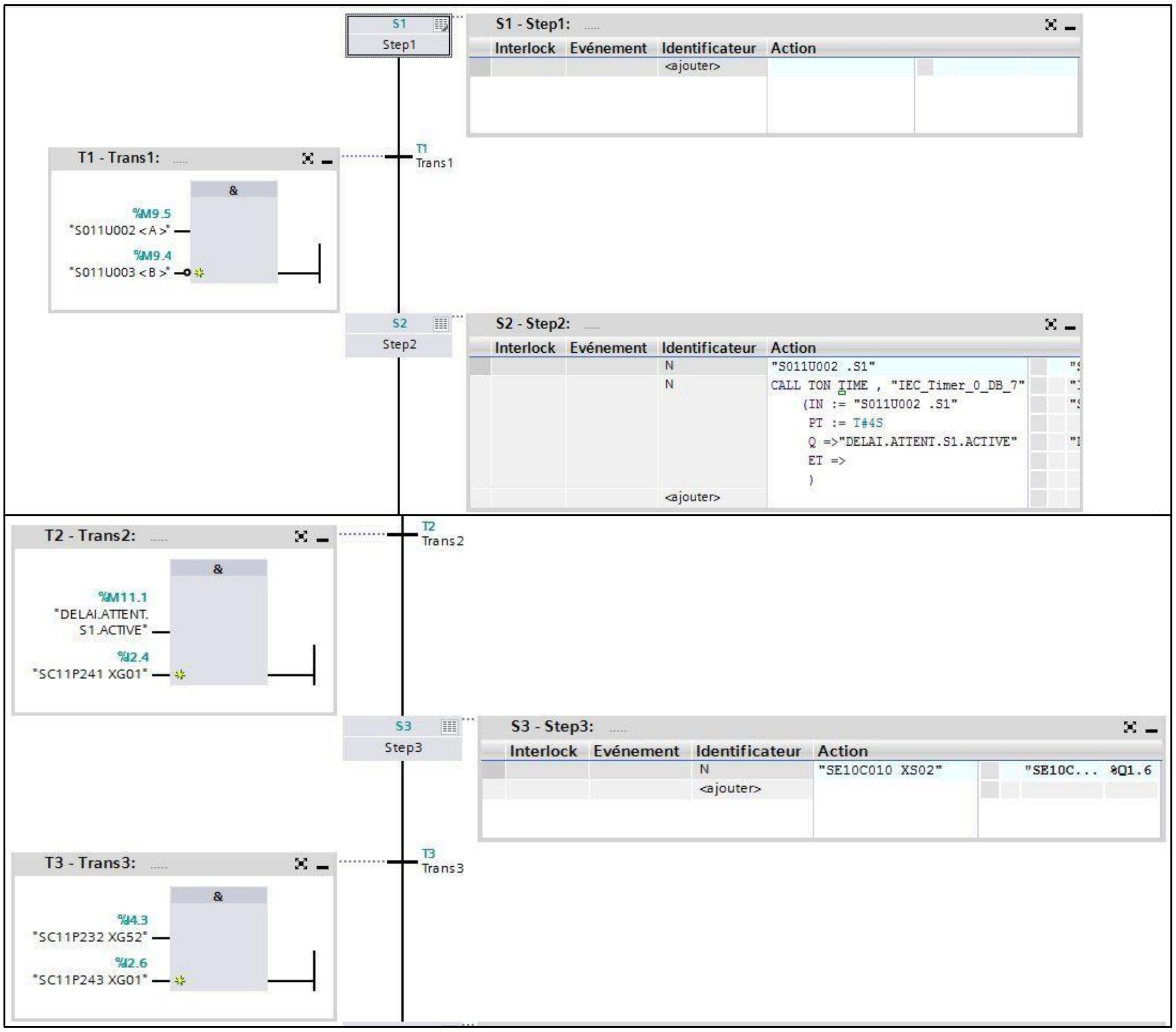
Network 5: Waiting time S011U003 M12(%M13.2)

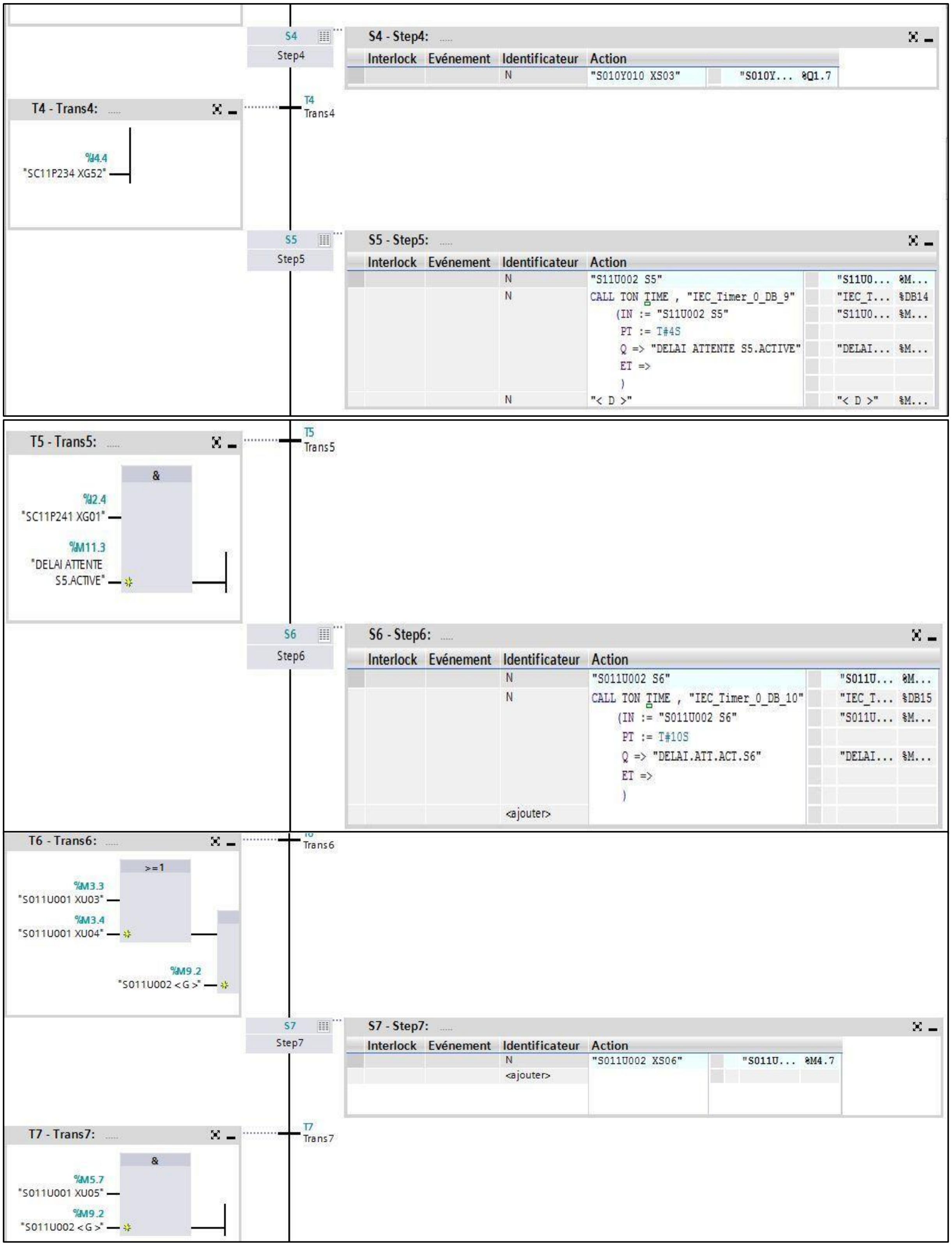


Symbol	Address	Type	Comment
"DELAI ATTENT S53 ACTIVE"	%M10.5	Bool	
"DELAI.ATTENT.S55.ACTIVE"	%M10.7	Bool	
"S011U003 M12"	%M13.2	Bool	DEPASSEMENT DUREE
"S52.DELAI.ATTENT.ACTIVE"	%M10.2	Bool	

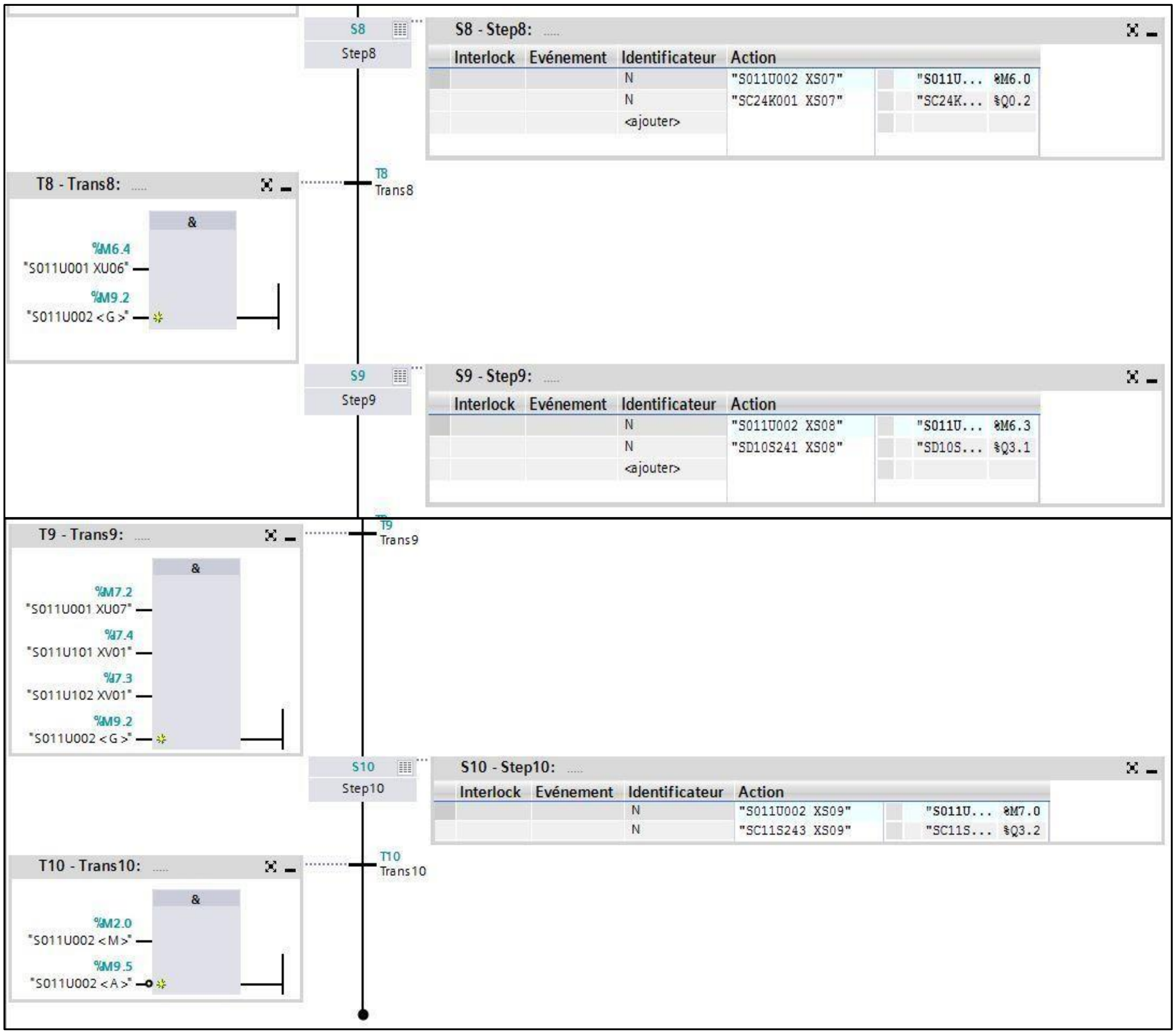
TURBINE PROTECTION PROGRAM / PLC_1 [CPU 412-1] / Program blocks

S011U002 [FB4]



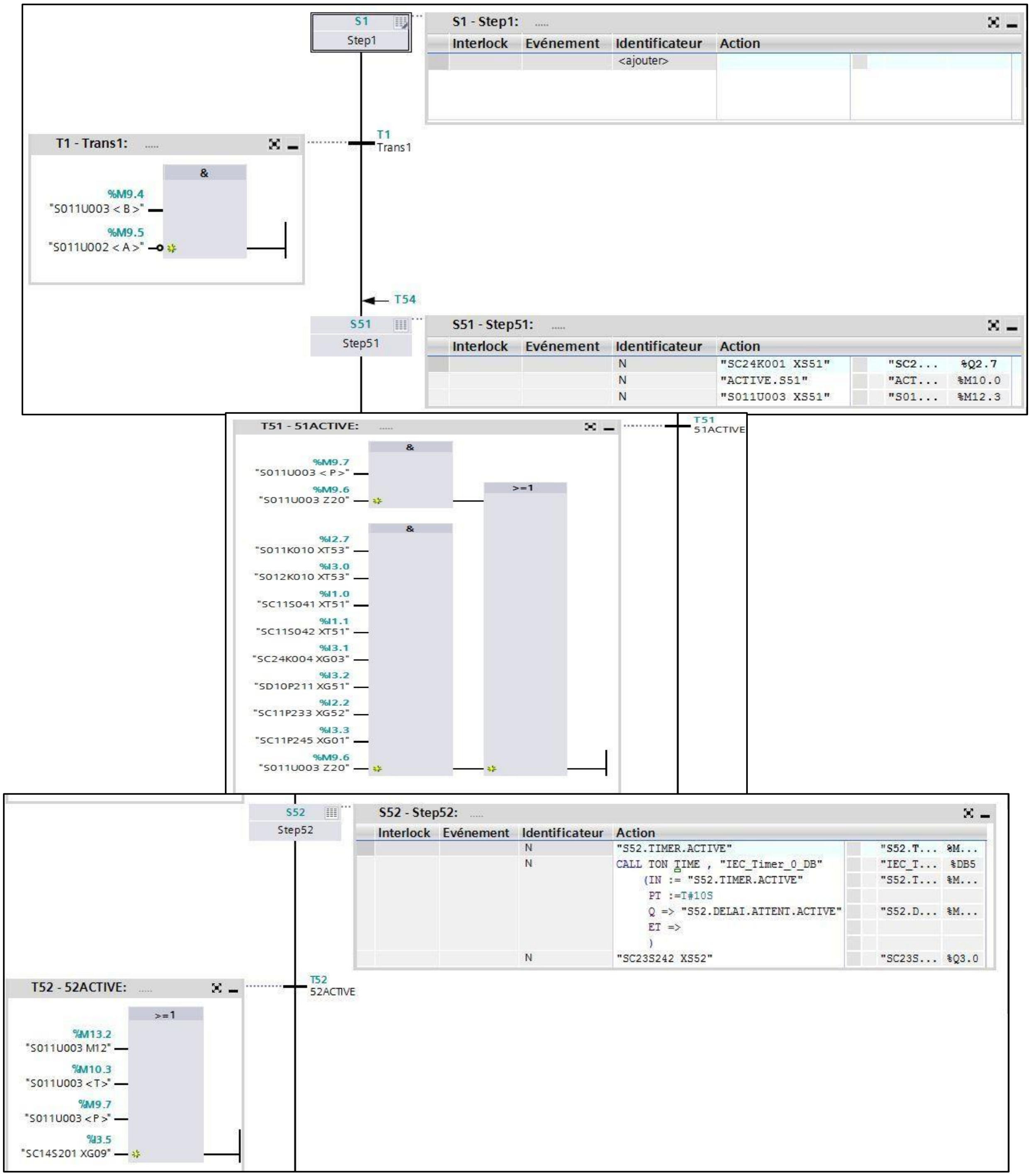


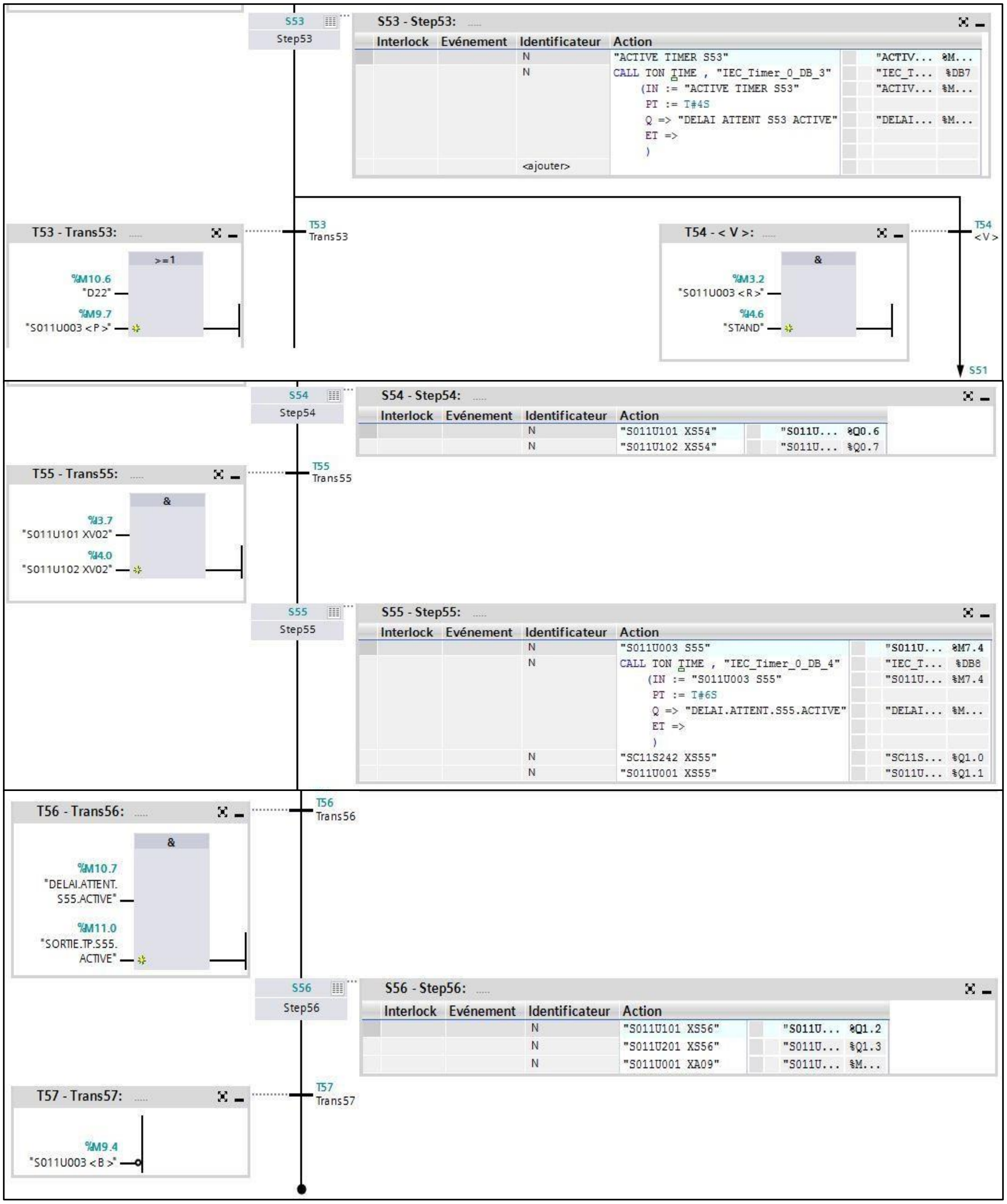
S4
Step4
S4 - Step4:
Interlock Evénement Identificateur Action
N "S010Y010 XS03" "S010Y... %Q1.7
T4 - Trans4:
%I4.4
"SC11P234 XG52"
T4
Trans4
S5
Step5
S5 - Step5:
Interlock Evénement Identificateur Action
N "S11U002 S5" "S11U0... %M...
N CALL TON TIME , "IEC_Timer_0_DB_9" "IEC_T... %DB14
(IN := "S11U002 S5" "S11U0... %M...
PT := T#4S
Q => "DELAI ATTENTE S5.ACTIVE" "DELAI... %M...
ET =>
)
N "< D >" "< D >" %M...
T5 - Trans5:
&
%I2.4
"SC11P241 XG01"
%M11.3
"DELAI ATTENTE S5.ACTIVE"
T5
Trans5
S6
Step6
S6 - Step6:
Interlock Evénement Identificateur Action
N "S011U002 S6" "S011U... %M...
N CALL TON TIME , "IEC_Timer_0_DB_10" "IEC_T... %DB15
(IN := "S011U002 S6" "S011U... %M...
PT := T#10S
Q => "DELAI.ATT.ACT.S6" "DELAI... %M...
ET =>
)
<ajouter>
T6 - Trans6:
>=1
%M3.3
"S011U001 XU03"
%M3.4
"S011U001 XU04"
%M9.2
"S011U002 <G>"
Trans6
S7
Step7
S7 - Step7:
Interlock Evénement Identificateur Action
N "S011U002 XS06" "S011U... %M4.7
<ajouter>
T7 - Trans7:
&
%M5.7
"S011U001 XU05"
%M9.2
"S011U002 <G>"
T7
Trans7


S8
Step8
S8 - Step8:
Interlock
Evénement
Identificateur
Action
N
"S011U002 XS07"
"S011U... %M6.0
N
"SC24K001 XS07"
"SC24K... %Q0.2
<ajouter>
T8 - Trans8:
&
%M6.4
"S011U001 XU06"
%M9.2
"S011U002 <G>"
T8
Trans8
S9
Step9
S9 - Step9:
Interlock
Evénement
Identificateur
Action
N
"S011U002 XS08"
"S011U... %M6.3
N
"SD10S241 XS08"
"SD10S... %Q3.1
<ajouter>
T9 - Trans9:
&
%M7.2
"S011U001 XU07"
%I7.4
"S011U101 XV01"
%I7.3
"S011U102 XV01"
%M9.2
"S011U002 <G>"
T9
Trans9
S10
Step10
S10 - Step10:
Interlock
Evénement
Identificateur
Action
N
"S011U002 XS09"
"S011U... %M7.0
N
"SC11S243 XS09"
"SC11S... %Q3.2
T10 - Trans10:
&
%M2.0
"S011U002 <M>"
%M9.5
"S011U002 <A>"
T10
Trans10

TURBINE PROTECTION PROGRAM / PLC_1 [CPU 412-1] / Program blocks

S011U003 [FB2]




S53
Step53
S53 - Step53:
Interlock Evénement Identificateur Action
N "ACTIVE TIMER S53" "ACTIV... %M...
N CALL TON TIME , "IEC_Timer_0_DB_3" "IEC_T... %DB7
(IN := "ACTIVE TIMER S53" "ACTIV... %M...
PT := T#4S
Q => "DELAI ATTENT S53 ACTIVE" "DELAI... %M...
ET =>
)
<ajouter>
T53 - Trans53:
>=1
%M10.6
"D22"
%M9.7
"S011U003 <P>"
T53
Trans53
T54 - < V >:
&
%M3.2
"S011U003 <R>"
%I4.6
"STAND"
T54
<V>
S51
S54
Step54
S54 - Step54:
Interlock Evénement Identificateur Action
N "S011U101 XS54" "S011U... %Q0.6
N "S011U102 XS54" "S011U... %Q0.7
T55 - Trans55:
&
%I3.7
"S011U101 XV02"
%I4.0
"S011U102 XV02"
T55
Trans55
S55
Step55
S55 - Step55:
Interlock Evénement Identificateur Action
N "S011U003 S55" "S011U... %M7.4
N CALL TON TIME , "IEC_Timer_0_DB_4" "IEC_T... %DB8
(IN := "S011U003 S55" "S011U... %M7.4
PT := T#6S
Q => "DELAI.ATTENT.S55.ACTIVE" "DELAI... %M...
ET =>
)
N "SC11S242 XS55" "SC11S... %Q1.0
N "S011U001 XS55" "S011U... %Q1.1
T56 - Trans56:
&
%M10.7
"DELAI.ATTENT.S55.ACTIVE"
%M11.0
"SORTIE.TP.S55.ACTIVE"
T56
Trans56
S56
Step56
S56 - Step56:
Interlock Evénement Identificateur Action
N "S011U101 XS56" "S011U... %Q1.2
N "S011U201 XS56" "S011U... %Q1.3
N "S011U001 XA09" "S011U... %M...
T57 - Trans57:
%M9.4
"S011U003 <B>"
T57
Trans57

People's Democratic Republic of Algeria
Ministry of Higher Education and Scientific Research

University M'Hamed BOUGARA - Boumerdes

Institute of Electrical and Electronic Engineering

Department of Power and Control

Authorization for Final Year Project Defense

Academic year: 2019/2020

The undersigned supervisor: **OUADI Abderrahmane**
Authorizes the students:

SELLAMI Abdelmoumen ………………………… Option ……… Control ………………………

……………………………………………………………… Option ………………………………………

……………………………………………………………… Option ………………………………………

to defend their final year Master program project entitled:
Control and protection Simulation of steam turbine, in Cap Djinet power plant, using S7-400 PLC

during the session of: ☐ June ■ September.

Date: 16 / 11 / 2020

The Supervisor: A. Ouadi

The Department Head