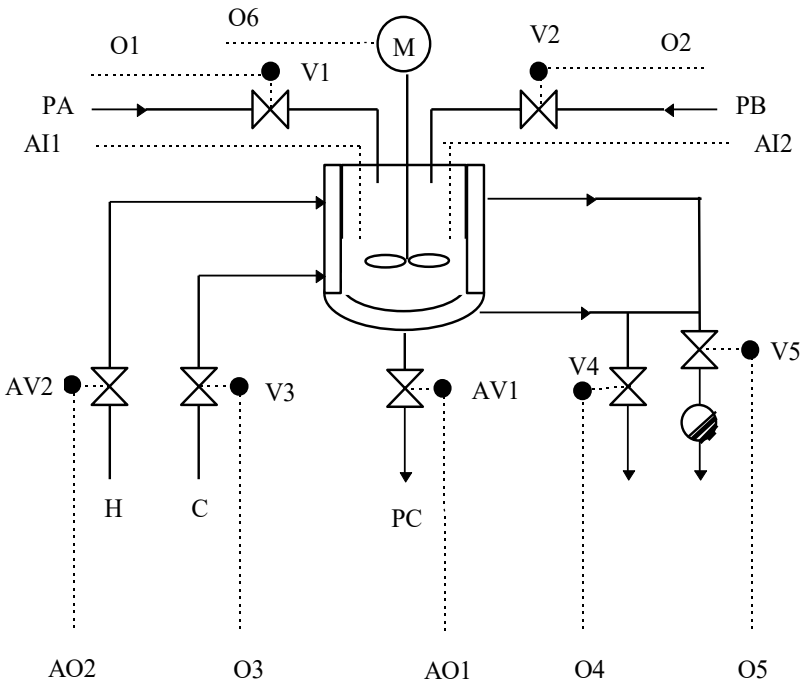
CONTROL OF A BATCH REACTOR

The reaction vessel is equipped with a double-walled jacket. The heating and cooling medium can be pumped through the vessel jacket. Two sensors (product temperature and feed level) and a paddle stirrer are installed inside the vessel.



DESCRIPTION OF SIGNALS

V1, V2 – electrovalves (solenoid valves) on the inlet for products A and B, respectively, controlled by digital outputs O1 and O2, respectively

V3, V4 – electrovalves to control the cooling water flow, controlled by digital outputs O3 and O4, respectively

V5 – an electrovalve on the outlet of the hot water, controlled by the digital output O5

M – mixer, controlled by the digital output O6

AI1 – analog input connected to the level sensor

AI2 – analog input connected to the temperature sensor

AV1 – analog valve AV1 on the outlet controlled by the first analog output AO1

AV2 – analog valve AV2 on the hot water inlet to the jacket controlled by the second analog output AO2

PROCESS DESCRIPTION

The process is started by the operator pushing the button connected to the first digital input I1 and it consists of 5 phases:

1) Feeding the vessel.

   Open V1 until level AI1 reaches 3/4 of the set level given in MW2.

   Next, switch on the mixer M and open V2 until level AI1 reaches the set level.

2) Heating - started immediately after completing phase 1.

   Store the initial value of AI2 in MW6, then open V5 and fully open AV2 by setting AO2:=26000.

3) Stabilizing the product temperature - started immediately after AI2 reaches the set temperature stored in MW4.

   Control the hot water flow according to the formula:

   AO2 = gain * (MW4 – AI2),

   where gain is a proportional coefficient in a P controller, stored in MW8.

   MW4 is a set point for the temperature, and AI2 is a measured temperature (both are INT).

   This phase lasts 5 minutes. (Remark – during testing you can assume 1 minute to save your time).

4) Cooling the product – started as soon as phase 3 is finished.

   Open V3 and V4 until the temperature AI2 drops to the initial temperature stored in MW6.

5) Draining of the vessel – commenced after completion of phase 4.

   Fully open AV1 by setting AO1:=26000.

   This phase is finished when the tank is empty, i.e. AI1 <= 20. Finally, close AV1 (AO1:=0).

The next phase can only be started if the previous one has been completed!

The project should contain:

- Hardware configuration printout
- Printout of variable declaration
- Program printout with comments

PROJECT_PC_SUT / PLC_2 [CPU 1513-1 PN] / PLC tags

Tag_Table [74]

PLC tags

	Name	Data type	Address	Retain	Accessible from HMI/OPC UA/Web API	Writable from HMI/OPC UA/Web API	Visible in HMI engineering	Supervision	Comment
	start	Bool	%I0.1	False	True	True	True		
	AI1_level_sensor	Int	%IW1	False	True	True	True		
	AI2_temp_sensor	Int	%IW3	False	True	True	True		
	set_temperature_MW4	Int	%MW4	False	True	True	True		
	initial_temperature_MW6	Int	%MW6	False	True	True	True		
	set_level_MW2	Int	%MW2	False	True	True	True		
	gain	Int	%MW8	False	True	True	True		
	valve1	Bool	%Q0.1	False	True	True	True		
	valve2	Bool	%Q0.2	False	True	True	True		
	valve3	Bool	%Q0.3	False	True	True	True		
	valve4	Bool	%Q0.4	False	True	True	True		
	valve5	Bool	%Q0.5	False	True	True	True		
	mixer_motor	Bool	%Q0.6	False	True	True	True		
	AV1	Word	%QW2	False	True	True	True		
	AV2	Int	%QW4	False	True	True	True		
	compare_level	Real	%MD10	False	True	True	True		
	flag1	Bool	%M22.0	False	True	True	True		
	compare_bit_for_heating	Bool	%M22.1	False	True	True	True		
	set_heating	Bool	%M22.2	False	True	True	True		
	flag2	Bool	%M22.3	False	True	True	True		

	Name	Data type	Address	Retain	Accessible from HMI/OPC UA/Web API	Writable from HMI/OPC UA/Web API	Visible in HMI engineering	Supervision	Comment
	flag3	Bool	%M22.4	False	True	True	True		
	set_cooling	Bool	%M22.5	False	True	True	True		
	flag0	Bool	%M22.6	False	True	True	True		
	compare_bit_reset	Bool	%M22.7	False	True	True	True		
	compare_drain_bit_1	Bool	%M23.0	False	True	True	True		
	compare_drain_bit_2	Bool	%M23.1	False	True	True	True		
	drain_activation_bit	Bool	%M23.2	False	True	True	True		

PROJECT_PC_SUT / PLC_2 [CPU 1513-1 PN] / Program blocks

Main [OB1]

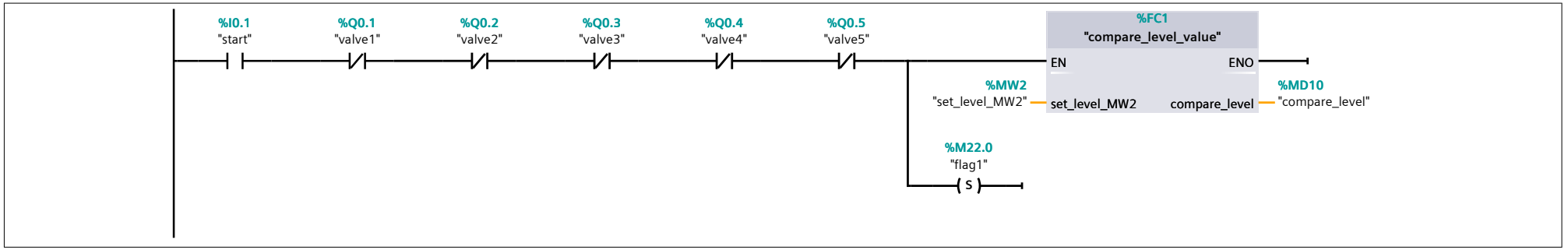
Main Properties							
General							
Name	Main	**Number**	1	**Type**	OB	**Language**	LAD
Numbering	Automatic						
Information							
Title	"Main Program Sweep (Cycle)"	**Author**		**Comment**		**Family**	
Version	0.1	**User-defined ID**					

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

Network 1: INITIAL STATE OF THE REACTOR

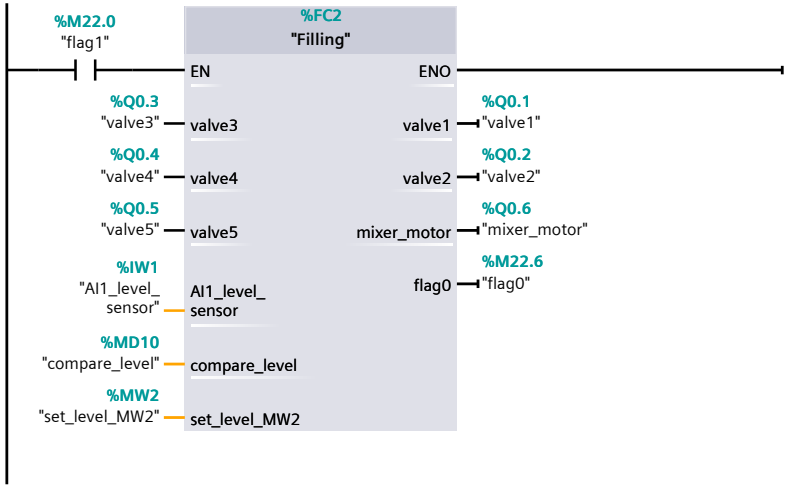
In this block, the compare function is called. This compare function is used to control the mixer and filling processes by comparing the level at which the mixer will be turned on and off, and also when the filling valves will be turned on and off.

Also, we set flag1 in this Network, Flag1 will be used to start the filling phase of the process.



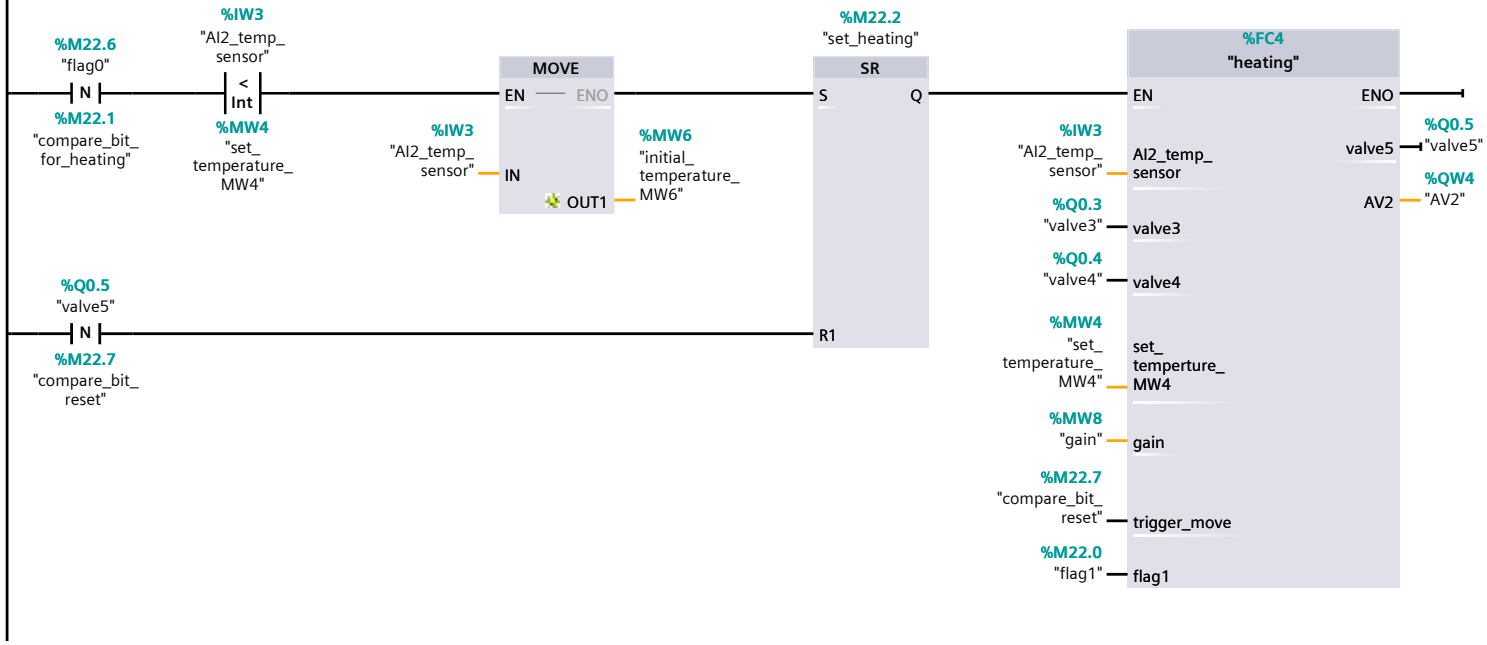
Network 2: FILLING

In this Network, Filling function is called.
Flag0 is activated and it is used to start the Heating phase when negative edge is detected on flag0, also valve1, valve2 and mixer are activated and deactivated in this phase.



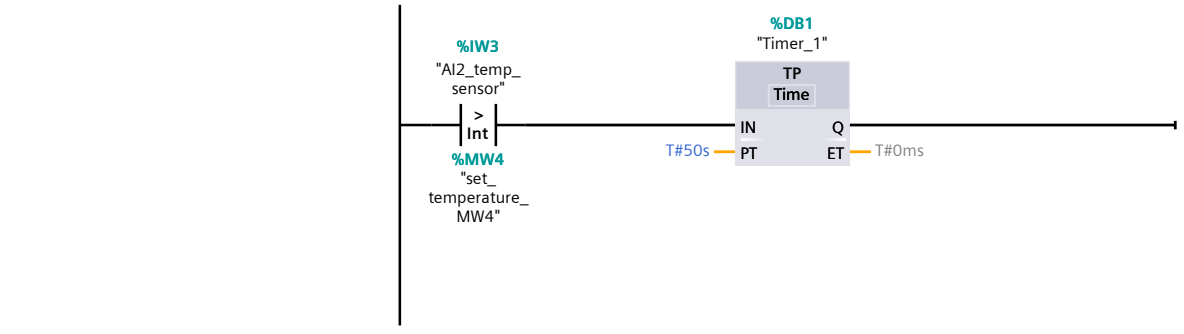
Network 3: HEATING

The heating is accomplished with an analog valve and a digital valve. Before the heating starts, we move the initial temperature value red by the "AI2_temp_sensor" to MW6 "Initial_temperature_MW6". For this network to be activated, "flag0" will experience a 1 to 0 bit change value and the "AI2_temp_sensor" temperature value must be lower than that of the "set_temperature_MW4".



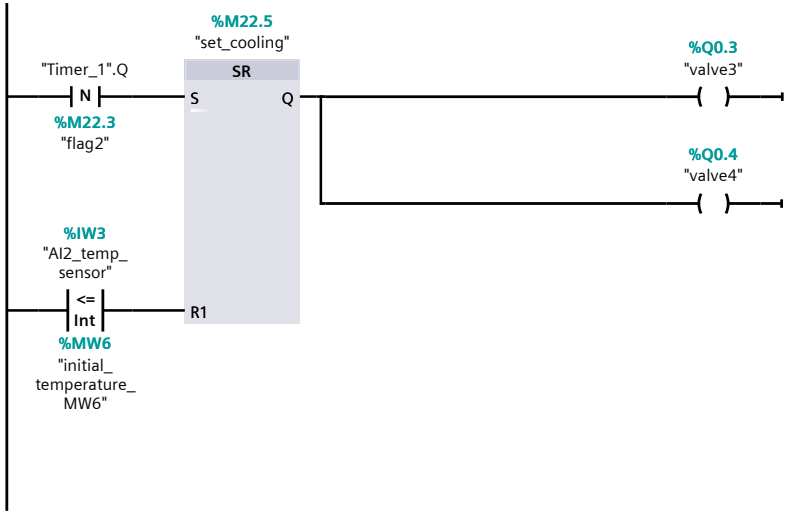
Network 4: STABILIZATION

The stabilization phase starts when the temperature sensor reads a temperature higher than the maximum set temperature of the process, before this phase starts, the heating phase is stopped on the same condition that the maximum set temperature is less than the temperature read by the temperature sensor.



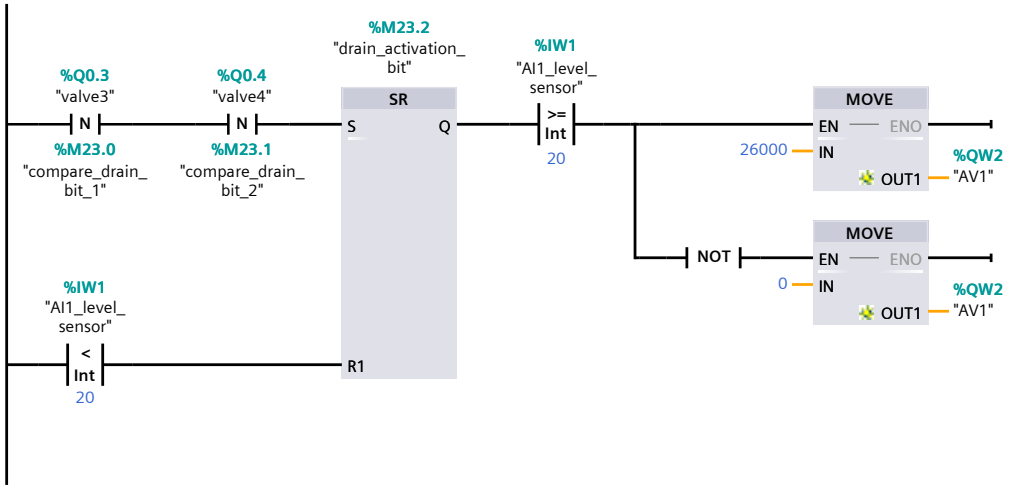
Network 5: COOLING

Negative edge detection on the Timer output of the stabilization phase starts the cooling phase. The cooling Phase is stopped when the temperature sensor "AI_temp_sensor" reads a temperature less than or equal to the initial temperature before the process was started.



Network 6: DRAINING

This phase is started when the cooling valves experiences a 1 to 0 bit change and the level sensor reads a level above 20litres.


%Q0.3
"valve3"
N
%M23.0
"compare_drain_
bit_1"
%Q0.4
"valve4"
N
%M23.1
"compare_drain_
bit_2"
%M23.2
"drain_activation_
bit"
SR
S
Q
R1
%IW1
"AI1_level_
sensor"
< Int
20
%IW1
"AI1_level_
sensor"
>= Int
20
MOVE
EN
ENO
26000
IN
OUT1
%QW2
"AV1"
NOT
MOVE
EN
ENO
0
IN
OUT1
%QW2
"AV1"

PROJECT_PC_SUT / PLC_2 [CPU 1513-1 PN] / Program blocks

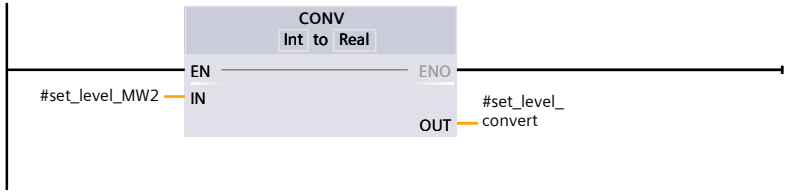
compare_level_value [FC1]

compare_level_value Properties							
General							
Name	compare_level_value	**Number**	1	**Type**	FC	**Language**	LAD
Numbering	Automatic						
Information							
Title		**Author**		**Comment**		**Family**	
Version	0.1	**User-defined ID**					

compare_level_value			
Name	**Data type**	**Default value**	**Comment**
▼ Input			
set_level_MW2	Int		
▼ Output			
compare_level	Real		
InOut			
▼ Temp			
hold	Real		
set_level_convert	Real		
Constant			
▼ Return			
compare_level_value	Void		

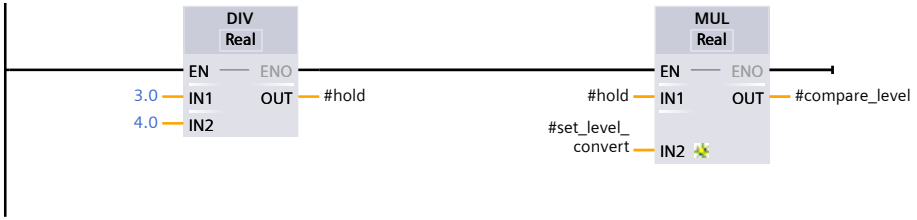
Network 1: Data type conversion

covert set_level_MW2 from INT to REAL



Network 2: Calculates the 3/4 of the level

The maximum level sensor value is multiplied by 3/4 for use in implementing the project.



PROJECT_PC_SUT / PLC_2 [CPU 1513-1 PN] / Program blocks

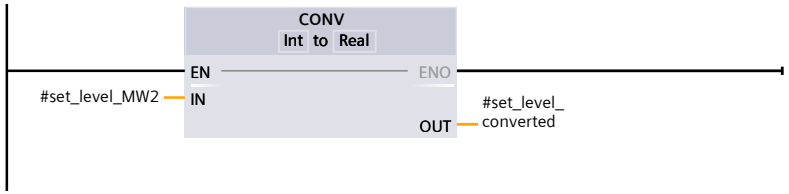
Filling [FC2]

Filling Properties							
General							
Name	Filling	**Number**	2	**Type**	FC	**Language**	LAD
Numbering	Automatic						
Information							
Title		**Author**		**Comment**		**Family**	
Version	0.1	**User-defined ID**					

Filling			
Name	**Data type**	**Default value**	**Comment**
▼ Input			
valve3	Bool		
valve4	Bool		
valve5	Bool		
AI1_level_sensor	Int		
compare_level	Real		
set_level_MW2	Int		
▼ Output			
valve1	Bool		
valve2	Bool		
mixer_motor	Bool		
flag0	Bool		
InOut			
▼ Temp			
level_sensor_conv	Real		
set_level_converted	Real		
Constant			
▼ Return			
Filling	Void		

Network 2:

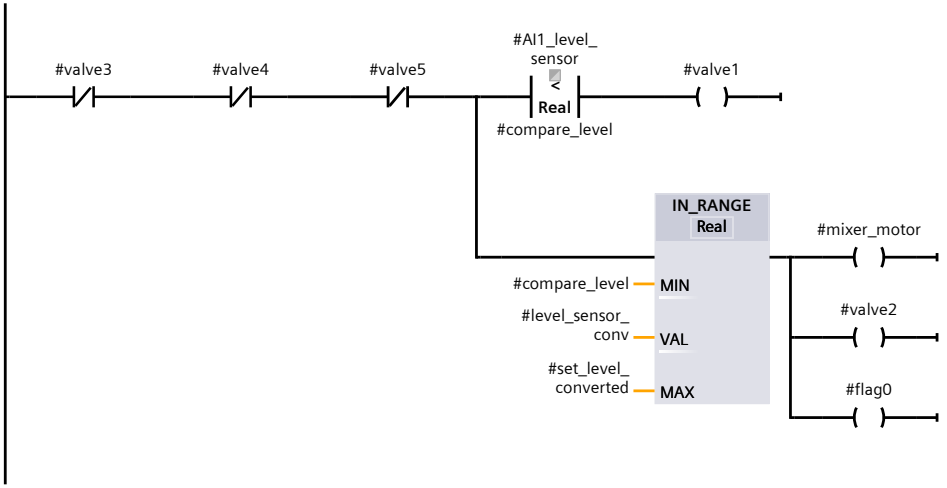
set_level_MW2 is coverted fron Int to Real.



Network 3:

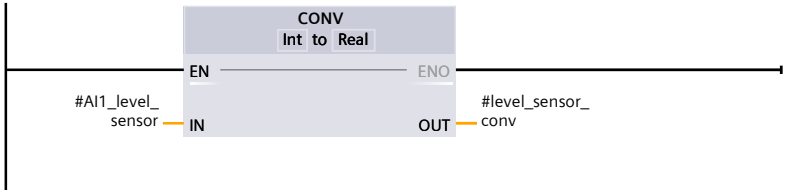
Open valve1 when level sensor value is less than 3/4 of the maximum sensor level value and close it when the level sensor value is equal or greater than 3/4 of maximum sensor value.

start mixer_motor and open valve2 when level sensor value equals or is greater than 3/4 of maximum level sensor value



Network 1: Data type convert

A1I_level_sensor data type is converted to Real


CONV
Int to Real
EN
ENO
#AI1_level_
sensor
IN
OUT
#level_sensor_
conv

PROJECT_PC_SUT / PLC_2 [CPU 1513-1 PN] / Program blocks

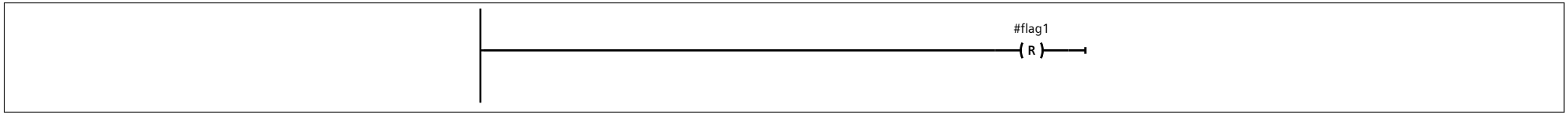
heating [FC4]

heating Properties							
General							
Name	heating	**Number**	4	**Type**	FC	**Language**	LAD
Numbering	Automatic						
Information							
Title		**Author**		**Comment**		**Family**	
Version	0.1	**User-defined ID**					

heating			
Name	**Data type**	**Default value**	**Comment**
▼ Input			
AI2_temp_sensor	Int		
valve3	Bool		
valve4	Bool		
set_temperture_MW4	Int		
gain	Int		
▼ Output			
valve5	Bool		
AV2	Int		
▼ InOut			
trigger_move	Bool		
flag1	Bool		
▼ Temp			
bit_operate	Bool		
Constant			
▼ Return			
heating	Void		

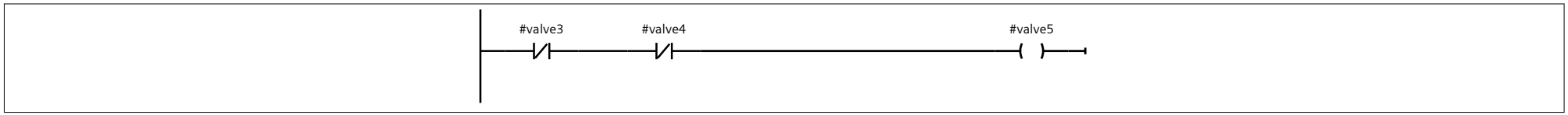
Network 1:

Reset flag1, which stops mixer_motor and closes valve2 when level sensor value is greater than the set_level sensor value.



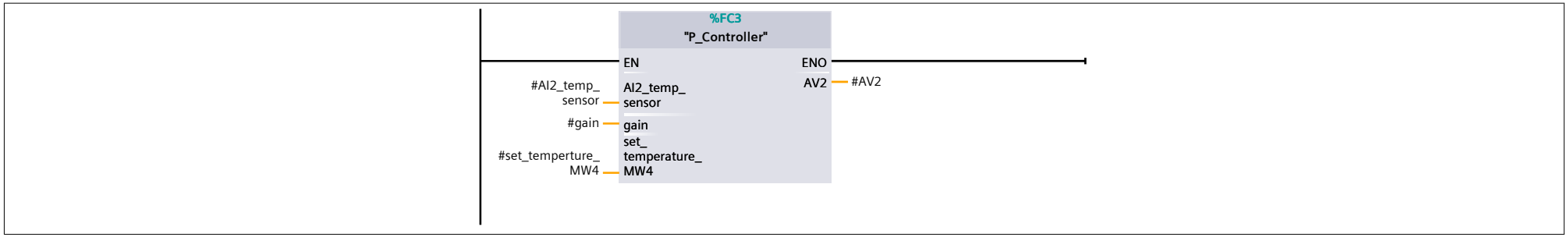
Network 2:

open valve5



Network 3:

Control of the analog valve2, AV2, starts when the leve; sensor value exceeds the set_level sensor value.



Network 4:

close valve5 when the temperature is greater than the set temperature value of the reaction process.


#AI2_temp_
sensor
>=
Int
#set_temperture_
MW4
#valve5
R

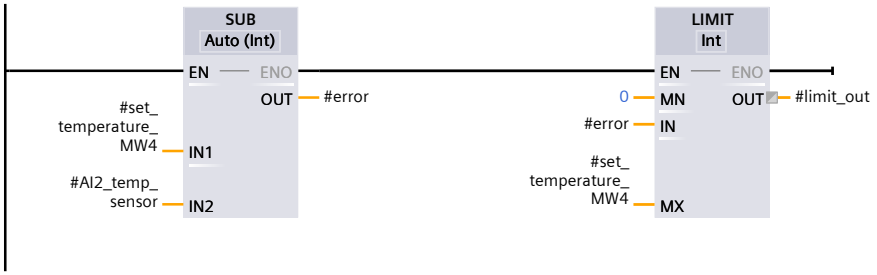
PROJECT_PC_SUT / PLC_2 [CPU 1513-1 PN] / Program blocks

P_Controller [FC3]

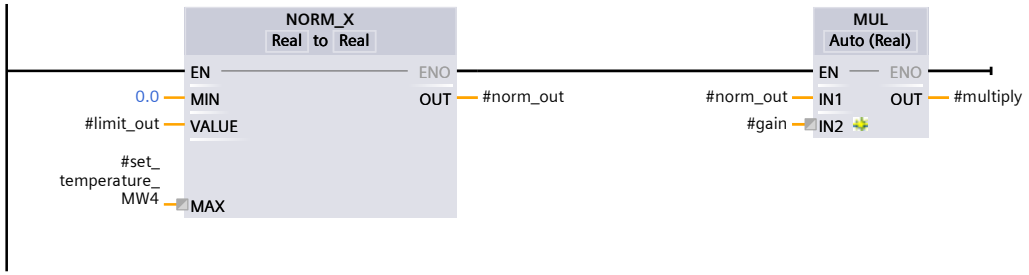
P_Controller Properties							
General							
Name	P_Controller	**Number**	3	**Type**	FC	**Language**	LAD
Numbering	Automatic						
Information							
Title		**Author**		**Comment**	Proportional controller for the system	**Family**	
Version	0.1	**User-defined ID**					

P_Controller			
Name	**Data type**	**Default value**	**Comment**
▼ Input			
AI2_temp_sensor	Int		
gain	Int		
set_temperature_MW4	Int		
▼ Output			
AV2	Int		
InOut			
▼ Temp			
error	Int		
multiply	Real		
norm_out	Real		
limit_out	Real		
Constant			
▼ Return			
P_Controller	Void		

Network 1:



Network 2:



Network 3: