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U/AB

Universitat Autònoma
de Barcelona

TECHNICAL NOTE 95. 32

MELISSA Pilot Plant Higher Plants Chamber: Testing of the HPC Control

Prepared by/Préparé par	Gerbi, O.
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TECHNICAL NOTE 95.32

APPROVAL

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Prepared by *Auteur*	Gerbi, O.	Date *Date*	15/02/08

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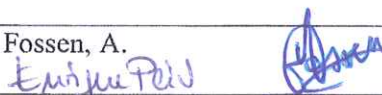|	**SHERPA ENGINEERING**
SHERPA ENGINEERING	269-287, rue de la Garenne - 92024 Nanterre Cedex
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	SA au capital de 412.400 €- APE : 7112 B- SIRET : 413 367 228 00017

SECTION 1

MELISSA Pilot Plant Higher Plants Chamber: Testing of the HPC Control

Prepared by/Préparé par	Olivier Gerbi
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1. Introduction

The first High Plant Compartment (HPC) is being constructed at the University of Guelph, one of the members of the MELISSA consortium.

Before its final transfer to the Melissa Pilot Plant (MPP) located at the premises of Universitat Autònoma de Barcelona (UAB), the HPC will be functionally tested with its own Control System, Argus, in Guelph.

According to a harmonization approach, same systems should be used in all the compartments. Black Box HPC control will be replaced with a White Box control system.

The main objective of the control is to pilot the light, CO_2 concentration, temperature, humidity, conductivity and pH in the plant compartment.

The first objective of the study was to develop the control laws in simulation, implement them in Schneider PLC Quantum with its electric hardware and do the validation at Guelph site.

During the project, the validation in Guelph was abandoned. The validation and implementation will be done in Barcelona, Spain.

Sherpa (France) with the partnership of NTE (Spain) perform this work, in addition of UAB as Prime Contractor

This Technical Note is the
- description of the test plan strategy,
- validation of the implementation of the code into the PLC HW

The tests were performed from January 29th to February 1st.

Reference documents for the elaboration of this technical note are
TN95.1: Technical requirement of the control system.
TN95.2 : Elaboration of the control system on simulator
TN95.31 : HPC Control hardware design
NTE-HPC-VCD-004 ; Verification Control Document for the Cabinet Melissa CIVb HPC1
NTE-HPC-PR-006 : Functional Test Procedure
NTE-HPC-RP-007 : Functional Test Report

2. HIL Description

Let's consider 3 parts in the HW description:
- the control cabinet, including
  - the PLC with its cards :
    - Ethernet
    - I/O, Digital and Analog
- The Data Acquisition Hardware
  - National Instrument NI 6229
  - National Instrument NI 0472
- The Laptop computer including
  - HPC simulation. In Matlab/Simulink with real-time connection to the National Instrument (NI) Hardware
  - Concept Program, connected to the PLC, via Ethernet link

    - Concept software is the programming environment designed for the Schneider Quantum PLC

The Laptop is physically connected to the PLC via an Ethernet Link, in order to connect the Concept program to the PLC in Real Time.
The Laptop is physically connected to the NI hardware with USB wires.

The PLC I/O cards are connected to
Terminal Blocks (see TN95.31, chapter 5.4 for the complete description of the Phoenix connector interface module.

When the Process (HPC-1) is into the MPP, each sensor and actuator will be connected to the Terminal Block.
To test the programming of the PLC, we can connect the PLC to a "fake" process. The process is simulated in a computer (the laptop) and the way to connect the computer to the PLC is to use NI HW.

There is the following correspondence between the inputs and outputs for the computer and for the PLC

Computer, NI type	NI Hardware	PLC Card	Comment
AI	6229	AVI	Analog Voltage Input
AI	6229	ACI	Analog Current Input
AO	6229	ACO	Analog Current Output
DO	9472	DI	Digital Input
DI	6229	DO	Digital Output
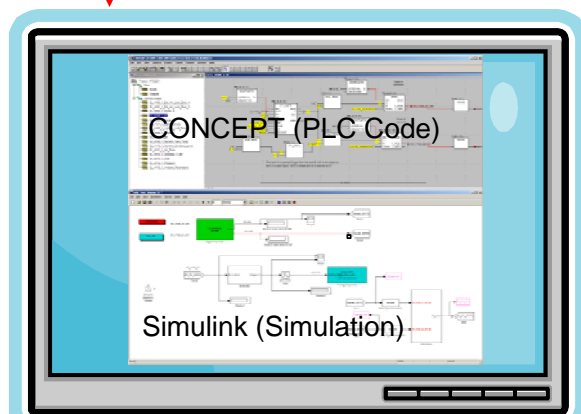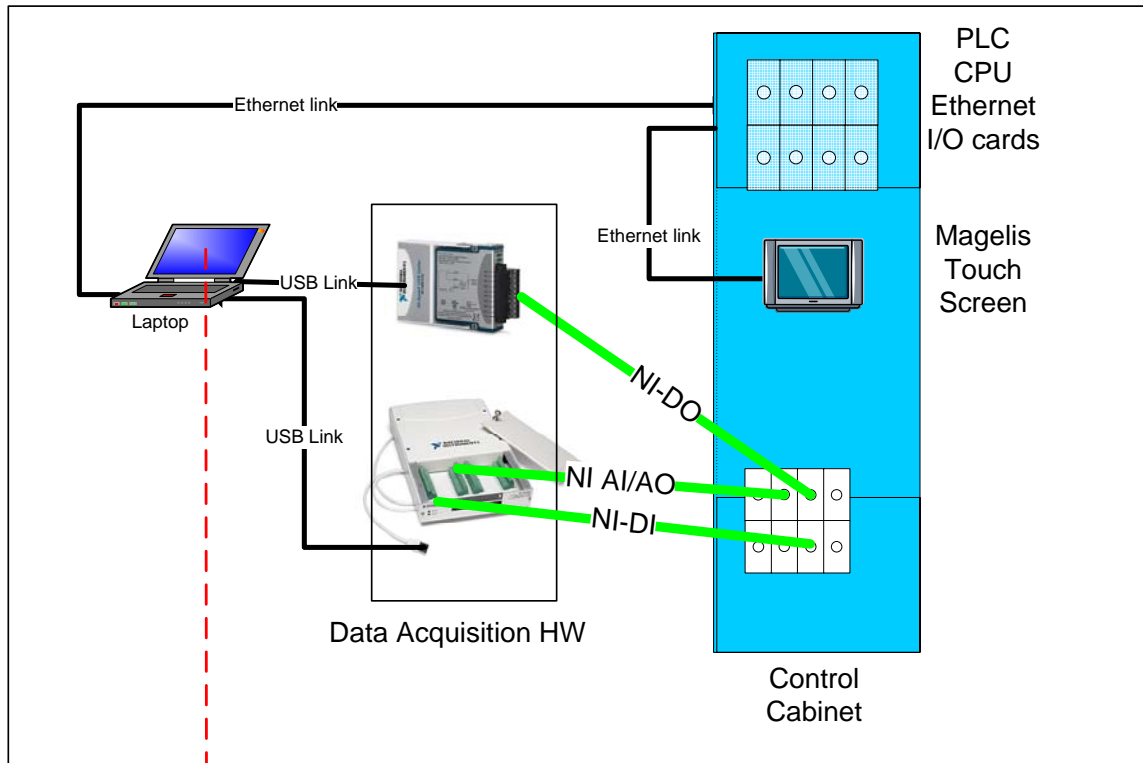
Figure 1 : tests schema

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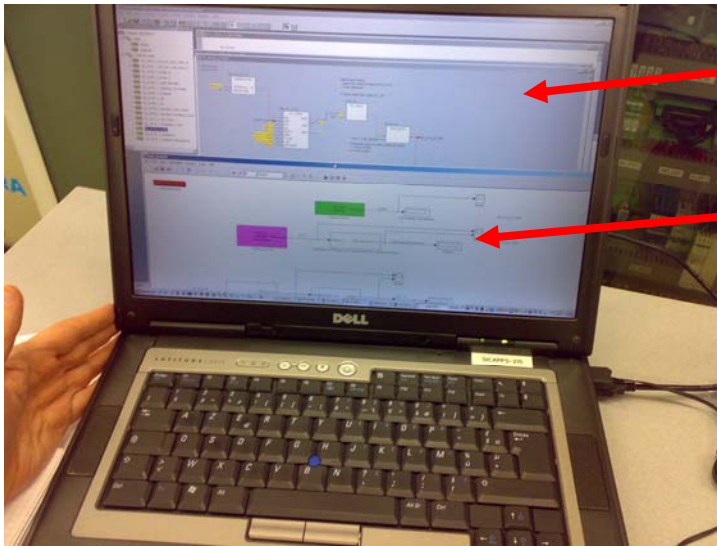
Concept – PLC programming (Top)

Simulink (HPC Simulation) (Bottom)

Figure 2 : Laptop connected to the PLC

Control Cabinet

Laptop

NI HW
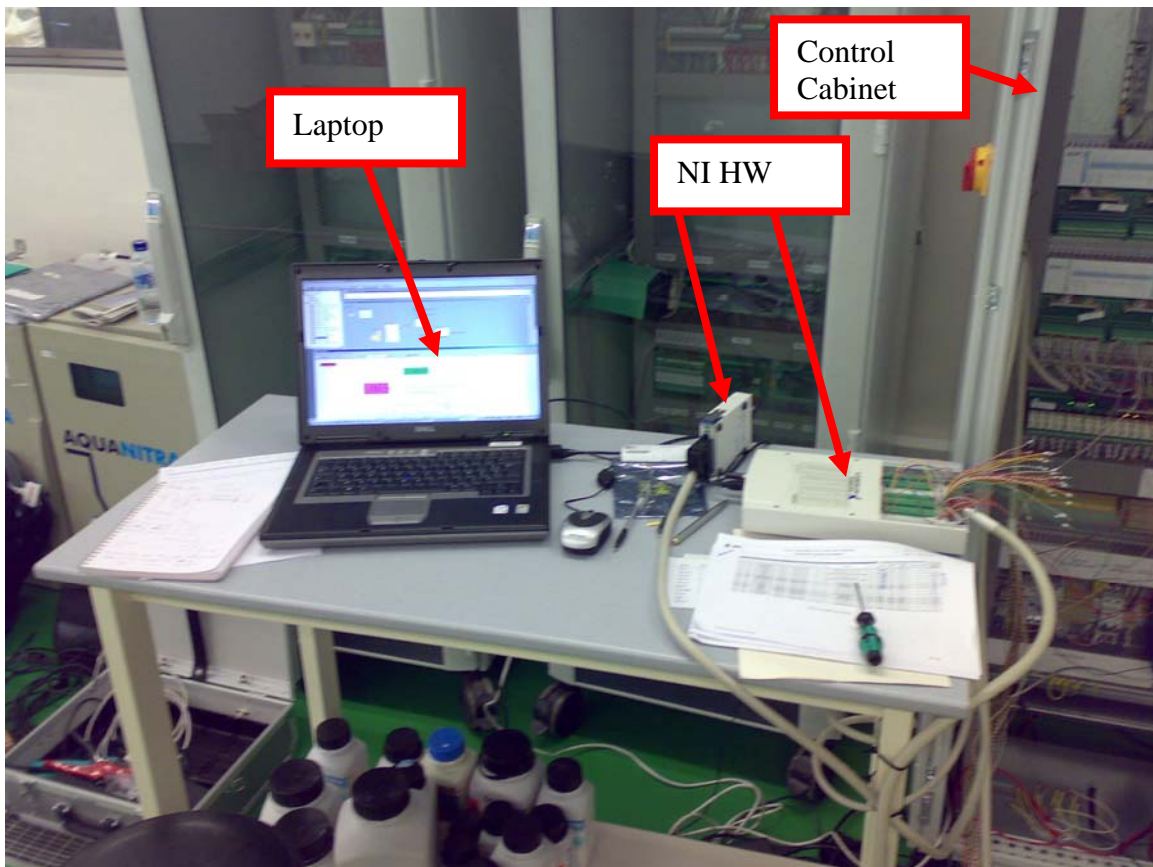
Figure 3 : HW for the tests

3. Test Plan & Results

Two kinds of tests have been applied:
- Static Tests, to check the good connection of the wires and localizatiuon of the signals into the Phoenix Terminal blocks
- Dynamic tests. They have been designed to check the control strategy designed and implemented into the PLC.

For dynamic tests, two types of tests have been performed.
- When programming the PLC with Concept. In Concept, when no connected to a PLC, it is possible to use Concept-PLCSIM32. This program simulates the PLC unit and its signal states.
- Connect the PLC to a "simulated process" via the NI HW equipment and a simple simulation done in Matlab Simulink.

The first test was done when programming the PLC in concept

The second one was performed at MPP premises when testing the PLC.

3.1. Static Tests

The following tables describe, for each control section of the PLC:
- the **Variable Tag** (in accordance with the normative list defined befine UAB and Sherpa and sent to UoG)
- the National Instrument (**NI**) **type** of signal,
- the National Instrument (**NI**) **Card** name
- the **NI location** and **Pin** number of the signal into the specified hardware
- The **Wire Color** chosen during the test (between the NI hardware and PLC Phoenix Bloc Terminal)
- the **PLC** signal **type** (DI = Digital Input, …) which identify the terminal into the cabinet
- the **Phoenix Terminal** Pin number to connect the wire

The figure associated represents the Simulink program used to "simulated" the process, read and write Input and Output to the PLC, via NI Hardware.

3.1.1.CL4100 and CL 4101 (detailed explanations for connections)

Each Tag of the Control Loop is associated with its PLC connection and connected to the computer via the NI Hardware.

For instance, The ZS_4100_01, which is the Upper Exterior Air Lock Door Switch (Side A) is for the PLC, a Digital Input (DI), connected in the PLC card DI_1 and to the Phoenix Terminal number 1.
It is a DI, so for Simulink it is a Digital Output (DO). Simulink will send the value (true or false, open or close) to the PLC. For that, the NI card 9472 is used, at NI Pin 0, which is a DO type.
During the test, a BLUE Wire was used to connect the signal.

Variable Tag	NI Type	NI Card	NI location	NI Pin	Wire Color	PLC Type	Phoenix Terminal
ZS_4100_01	DO	9472	DO0	0	BLUE	DI_1	1
ZS_4100_02	DO	9472	DO1	1	YELLOW	DI_1	2
ZS_4100_01	DO	9472	DO2	2	GREEN	DI_1	5
ZS_4100_02	DO	9472	DO3	3	WHITE	DI_1	6
			VSUP	8	RED	24+ VDC	4
			COM	9	BLACK	GROUND	3

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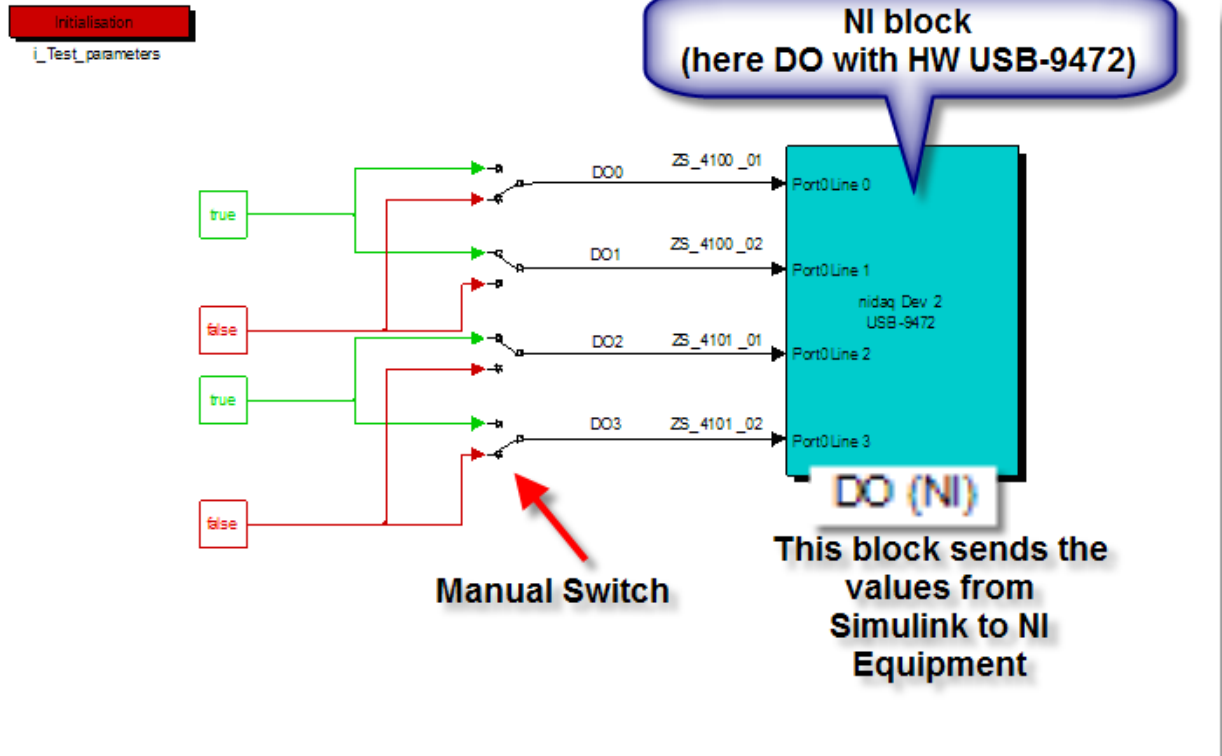
Figure 4 : CL4100 & CL4100 Simulink Test

Procedure :

For each Variable :
- when changing the value in Simulink, check that the value is changed in the PLC

Results

- All signals checked OK
- The LED indicators (on the door) is correct

3.1.2. CL4102

Variable Tag	NI Type	NI Card	NI location	NI Pin	Wire Color	PLC Type	Phoenix Terminal
PT_4103_01	AO	6229	AO0	15	RED	ACI_1	5+
			AO GND	16	BROWN	ACI_1	6-
PS_4103_01	DO	9472	DO	5	DO_GREY	DI_1	12
SV_4103_01_MV	DI	6229	P0.0	65	BLUE	DO	54
SV_4103_02_MV	DI	6229	P0.1	66	YELLOW	DO	64
		9472	VSUP	8	DO_RED	24+ VDC	4
		9472	COM	9	DO_BLACK	GROUND	3
		6229	DGround	82	BLACK		5-VDC (PLC)

Figure 5 : CL4102 Simulink Test

3.1.3.CL4103

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Variable Tag	NI Type	NI Card	NI location	NI Pin	Wire Color	PLC Type	Phoenix Terminal
PT_4103_01	AO	6229	AO0	15	RED	ACI_1	5+
			AO GND	16	BROWN	ACI_1	6-
PS_4103_01	DO	9472	DO	5	DO_GREY	DI_1	12
SV_4103_01_MV	DI	6229	P0.0	65	BLUE	DO	54
SV_4103_02_MV	DI	6229	P0.1	66	YELLOW	DO	64
		9472	VSUP	8	DO_RED	24+ VDC	4
		9472	COM	9	DO_BLACK	GROUND	3
		6229	DGround	82	BLACK		5-VDC (PLC)

Figure 6 : CL4103 Simulink Test

3.1.4.CL4104

Variable Tag	NI Type	NI Card	NI location	NI Pin	Wire Color	PLC Type	Phoenix Terminal
RT_4104_01	AO	6229	AO0	15	RED	AVI_1	1+
			AO GND	16	BROWN	AVI_1	2-
RT_4104_02	AO	6229	AO0	31	GREEN	AVI_1	5+
			AO GND	32	PURPLE	AVI_1	6-
RT_4104_03	AO	6229	AO0	47	WHITE	AVI_1	11+
			AO GND	48	GREY	AVI_1	12-
IY_4104_01	DI	6229	P0.0	65	BLUE	DO	74
IY_4104_02	DI	6229	P0.1	66	YELLOW	DO	84
IY_4104_03	DI	6229	P0.1	67	PINK	DO	94
		9472	VSUP	8	DO_RED	24+ VDC	4
		9472	COM	9	DO_BLACK	GROUND	3
		6229	DGround	82	BLACK		5-VDC (PLC)
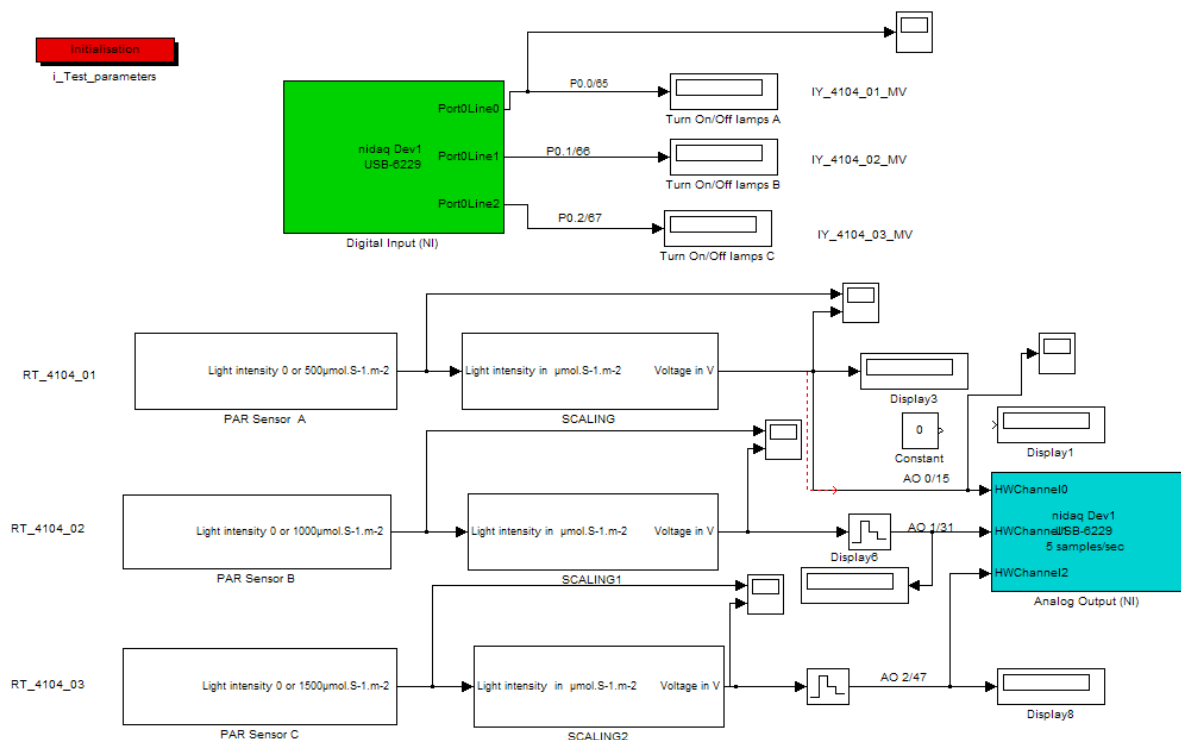
Figure 7 : CL4104 Simulink Test

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3.1.5.CL4105

Variable Tag	NI Type	NI Card	NI location	NI Pin	Wire Color	PLC Type	I/O number	Phoenix Terminal
TT_4105_01	AO	6229	AO0	15	RED	AVI_1		15+
			AO GND	16	BROWN	AVI_1		16-
TT_4105_02	AO	6229	AO0	31	GREEN	AVI_1		21+
			AO GND	32	PURPLE	AVI_1		22-
TT_4105_03	AO	6229	AO0	47	WHITE	AVI_1		25+
			AO GND	48	GREY	AVI_1		26-
FAN_4105_01_MV	DI	6229	P0.0	65	BLUE	DO		104
FAN_4105_01_MV	DI	6229	P0.1	66	YELLOW	DO		114
FAN_4105_01_MV	DI	6229	P0.1	67	PINK	DO		124
FSL_4105_01	DO	9472	DO	6	DO_PURPLE	DI_1	7	15
FSL_4105_02	DO	9472	DO	7	DO_PINK	DI_1	8	16
FSL_4105_03	DO	9472	DO	0	DO_BLUE	DI_1	9	21
			9472	VSUP	8	DO_RED	24+ VDC		4
			9472	COM	9	DO_BLACK	GROUND		3
			6229	DGround	82	BLACK			5-VDC (PLC)

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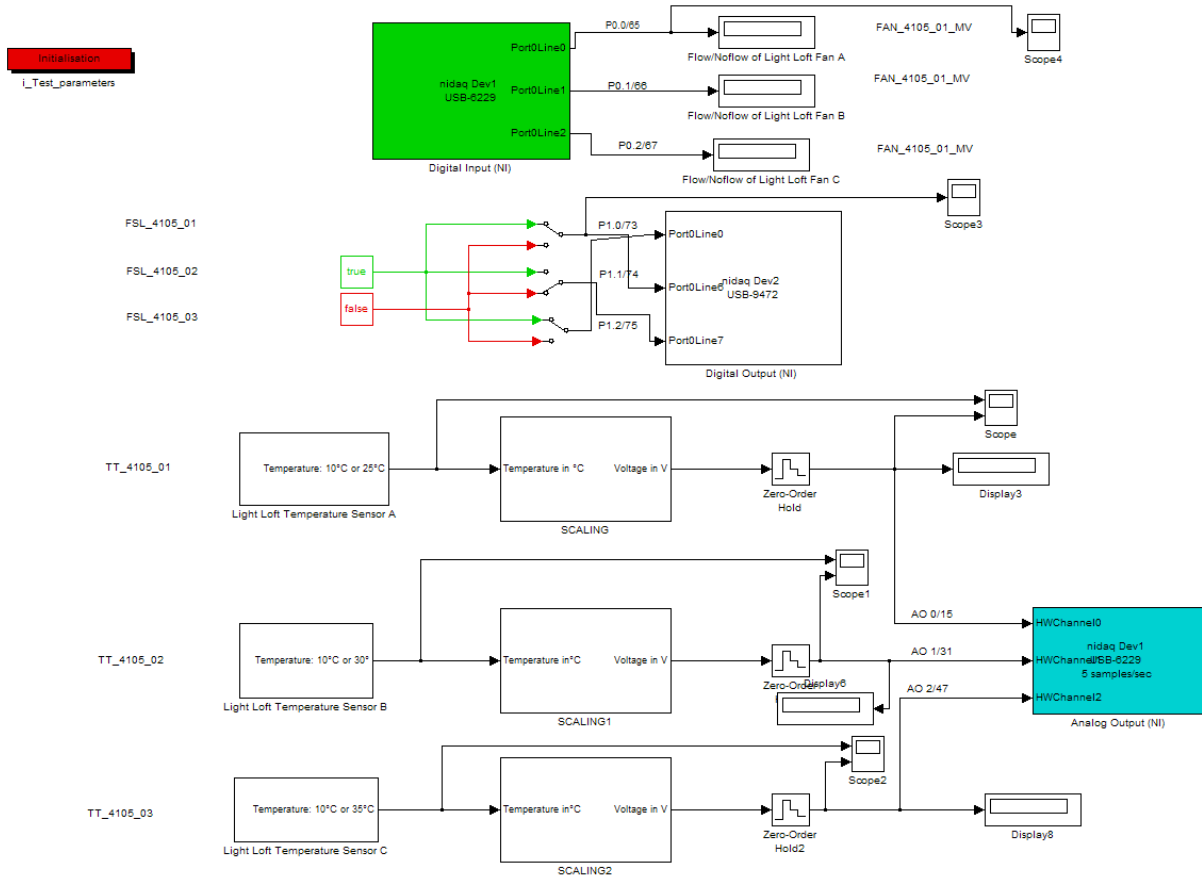
Figure 8 : CL4105 Simulink Test

3.1.6.CL4106

Variable Tag	NI Type	NI Card	NI location	NI Pin	Wire Color	PLC Type	I/O number	Phoenix Terminal
FT_4106_01	AO	6229	AO0	15	RED	ACI_1		11+
			AO GND	16	BROWN	ACI_1		12-
GP_4106_01_MV	DI	6229	P0.0	65	BLUE	DO		134
		9472	VSUP	8	DO_RED	24+ VDC		4
		9472	COM	9	DO_BLACK	GROUND		3
		6229	DGround	82	BLACK			5-VDC (PLC)
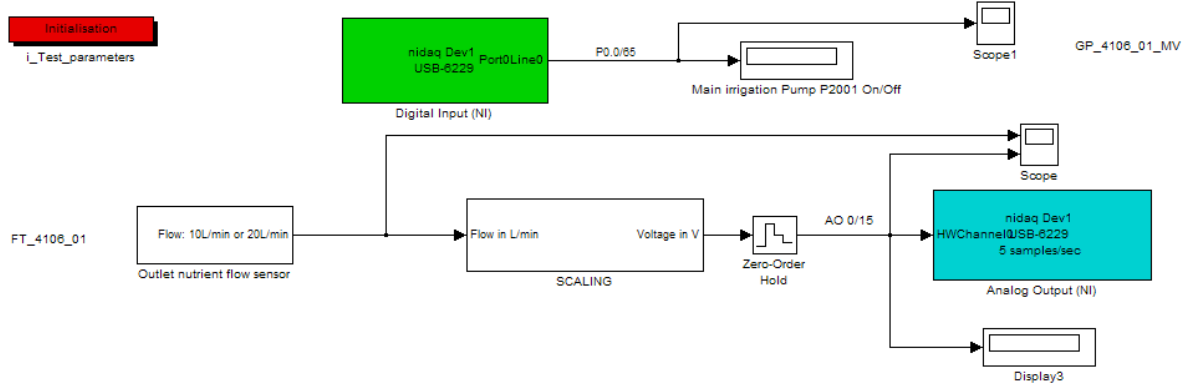
Figure 9 : CL4106 Simulink Test

3.1.7.CL4107

Variable Tag	NI Type	NI Card	NI location	NI Pin	Wire Color	PLC Type	I/O number	Phoenix Terminal
AT_4107_01	AO	6229	AO0	15	RED	ACI_1		15+
			AO GND	16	BROWN	ACI_1		16-
SV_4107_01_MV	DI	6229	P0.0	65	BLUE	DO	14	144
SV_4107_01_MV	DI	6229	P0.1	66	YELLOW	DO	15	154
LSL_4107_01	DO	9472	DO	0	DO_BLUE	DI_1	10	22
LSL_4107_02	DO	9472	DO	1	DO_YELLOW	DI_1	11	25
		9472	VSUP	8	DO_RED	24+ VDC		4
		9472	COM	9	DO_BLACK	GROUND		3
		6229	DGround	82	BLACK			5-VDC (PLC)
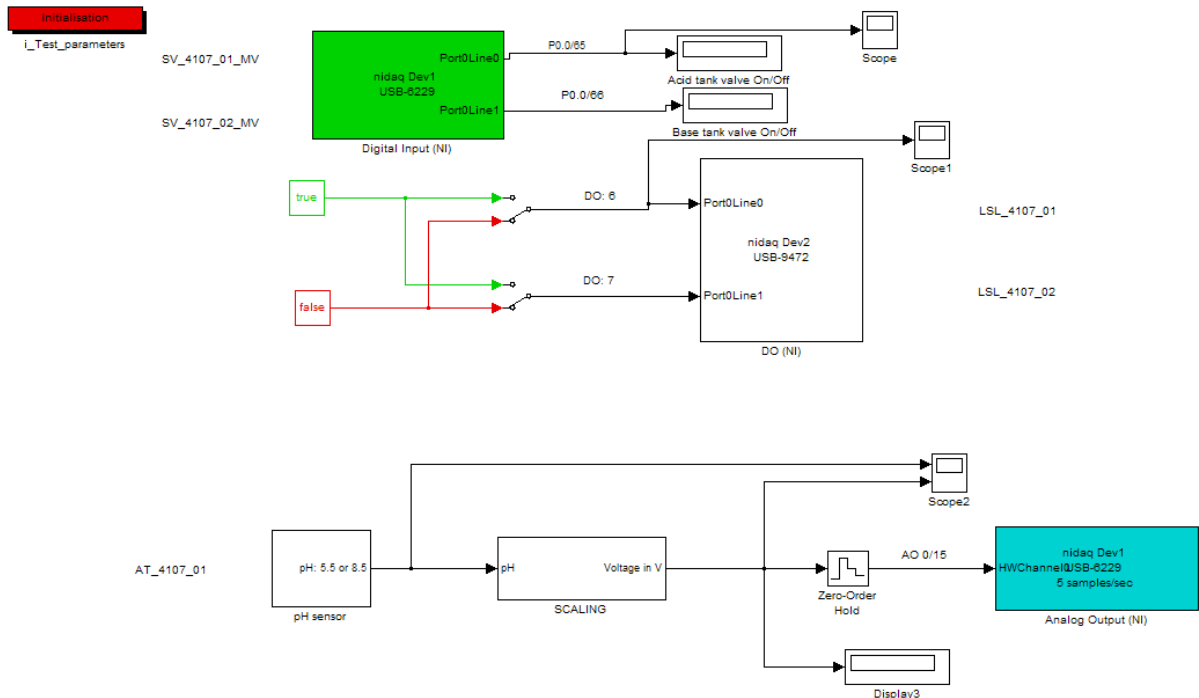
Figure 10 : CL4107 Simulink Test

3.1.8. CL4108

Variable Tag	NI Type	NI Card	NI location	NI Pin	Wire Color	PLC Type	I/O number	Phoenix Terminal
AT_4108_01	AO	6229	AO0	15	RED	ACI_1		21+
			AO GND	16	BROWN	ACI_1		22-
SV_4108_01_MV	DI	6229	P0.0	65	BLUE	DO	16	164
SV_4108_01_MV	DI	6229	P0.1	66	YELLOW	DO	17	174
LSL_4108_01	DO	9472	DO	0	DO_BLUE	DI_1	12	26
LSL_4108_01	DO	9472	DO	1	DO_YELLOW	DI_1	13	31
		9472	VSUP	8	DO_RED	24+ VDC		4
		9472	COM	9	DO_BLACK	GROUND		3
		6229	DGround	82	BLACK			5-VDC (PLC)
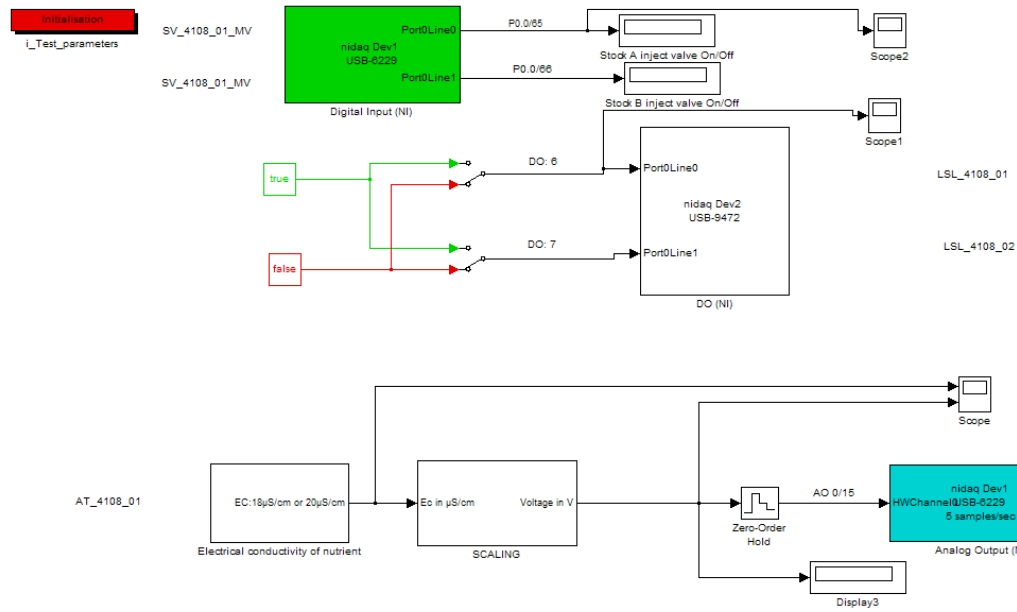
Figure 11 : CL4108 Simulink Test

3.1.9.CL4109

Variable Tag	NI Type	NI Card	NI location	NI Pin	Wire Color	PLC Type	I/O number	Phoenix Terminal
TT_4109_01	AO	6229	AO0	15	RED	AVI_1		31+
			AO GND	16	BROWN	AVI_1		32-
SV_4109_01_MV	DI	6229	P0.0	65	BLUE	DO	18	184
		9472	VSUP	8	DO_RED	24+ VDC		4
		9472	COM	9	DO_BLACK	GROUND		3
		6229	DGround	82	BLACK			5-VDC (PLC)
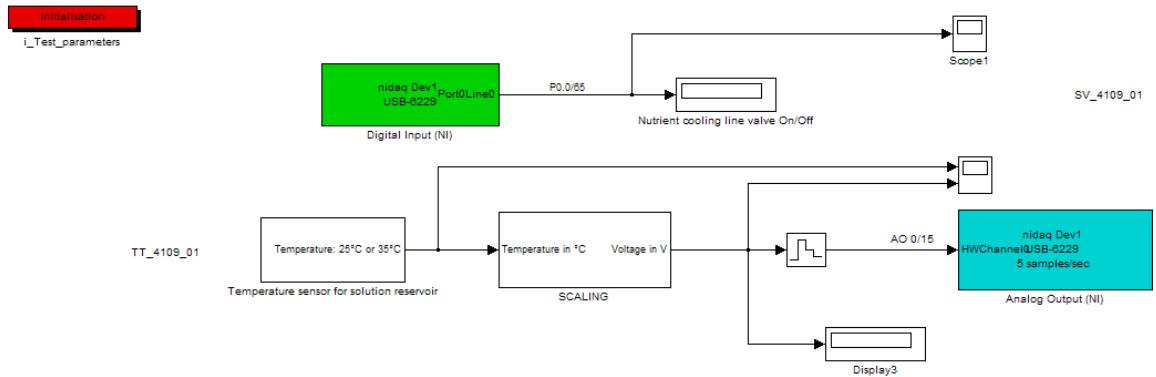
Figure 12 : CL4109 Simulink Test

3.1.10.CL4110

NI Type	NI Card	NI location	NI Pin	Wire Color	PLC Type	I/O number	Phoenix Terminal
DI	6229	P0.1	65	BLUE	DO	19	194
DO	9472	DO		DO_BLUE	DI_1	14	32
DO	9472	DO		DO_YELLOW	DI_1	15	35
DO	9472	DO		DO_GREEN	DI_1	16	36
DO	9472	DO		DO_WHITE	DI_2	17	1
	9472	VSUP	8	DO_RED	24+ VDC		4
	9472	COM	9	DO_BLACK	GROUND		3
	6229	DGround	82	BLACK			5-VDC (PLC)
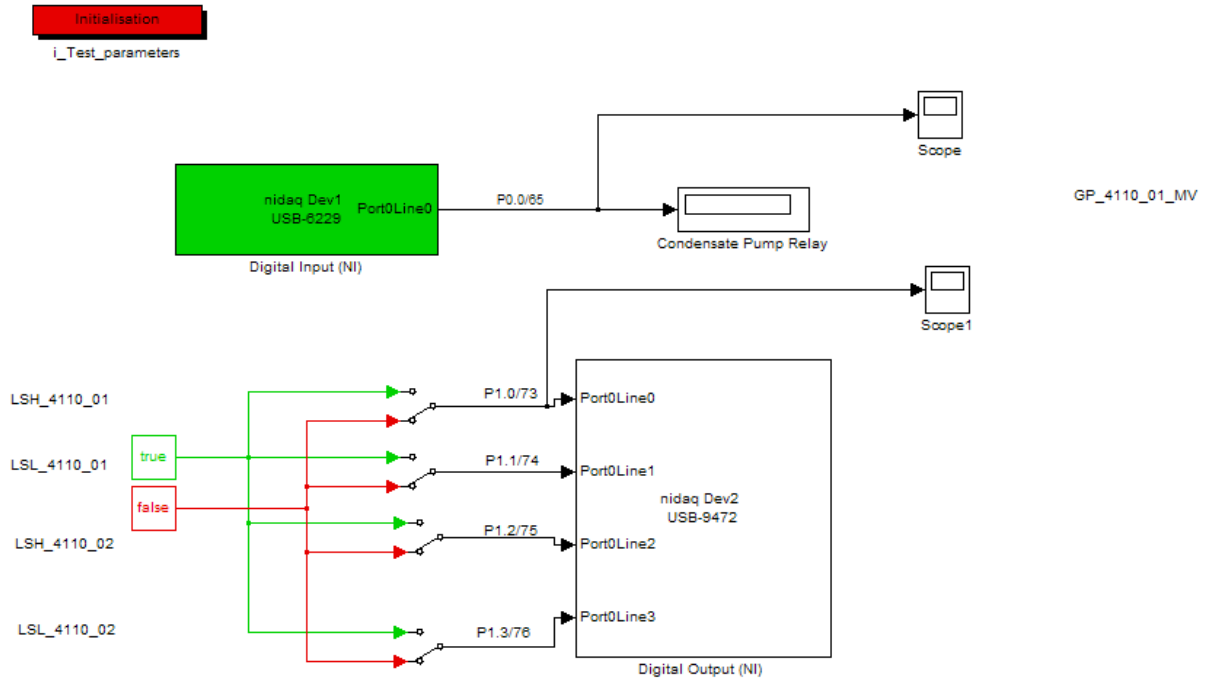
Figure 13 : CL4110 Simulink Test

3.1.11.CL4111

Variable Tag	NI Type	NI Card	NI location	NI Pin	Wire Color	PLC Type	I/O number	Phoenix Terminal
FT_4111_01	AO	6229	AO0	15	RED	AVI_1		35+
			AO GND	16	BROWN	AVI_1		36-
MVFD_4111_01_MV	AI	6229	AI	1	RED/BLUE	ACO		4+
			AI GND	3	BROWN/BLUE	ACO		6-
		9472	VSUP	8	DO_RED	24+ VDC		4
		9472	COM	9	DO_BLACK	GROUND		3
		6229	DGround	82	BLACK			5-VDC (PLC)
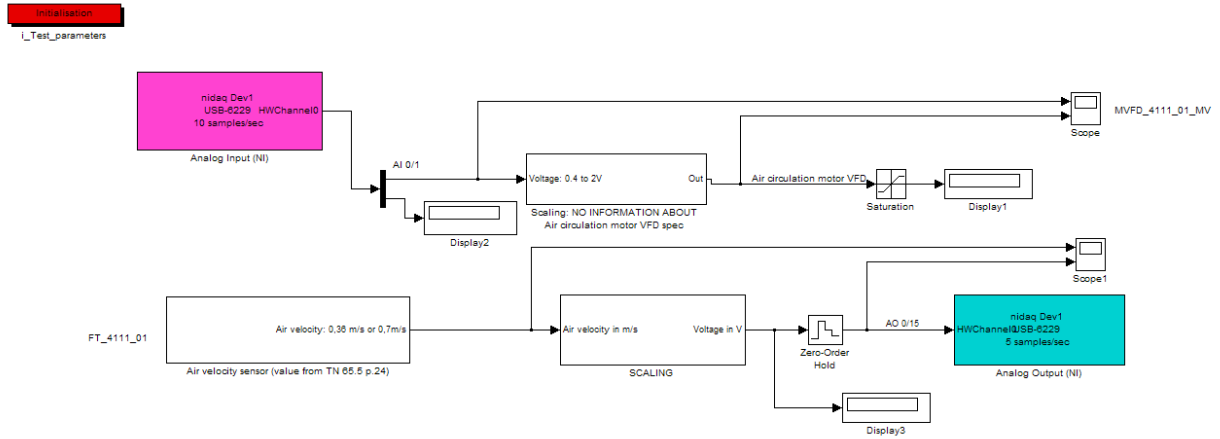
Figure 14 : CL4111 Simulink Test

3.1.12.CL4112

3.1.12.1. *CL4112_1*

Variable Tag	NI Type	NI Card	NI location	NI Pin	Wire Color	PLC Type	I/O number	Phoenix Terminal
TT_4112_01	AO	6229	AO0	15	RED	ACI_1		25+
			AO GND	16	BROWN	ACI_1		26-
AT_4112_01	AO	6229	AO2	31	GREEN	ACI_2		31+
			AO GND	32	PURPLE	ACI_2		32_
TT_4112_02	AO	6229	AO3	47	WHITE	ACI_1		31+
			AO GND	48	GREY	ACI_1		32-

Figure 16 : CL4112_2 Simulink Test

3.1.12.3. *CL4112_3*

Variable Tag	NI Type	NI Card	NI location	NI Pin	Wire Color	PLC Type	I/O number	Phoenix Terminal
TT_4112_04	AO	6229	AO0	15	RED	AVI_2		1+
			AO GND	16	BROWN	AVI_2		2-
TT_4112_05	AO	6229	AO2	31	GREEN	AVI_2		5+
			AO GND	32	PURPLE	AVI_2		6-
TT_4112_06	AO	6229	AO3	47	WHITE	AVI_2		11+
			AO GND	48	GREY	AVI_2		12-
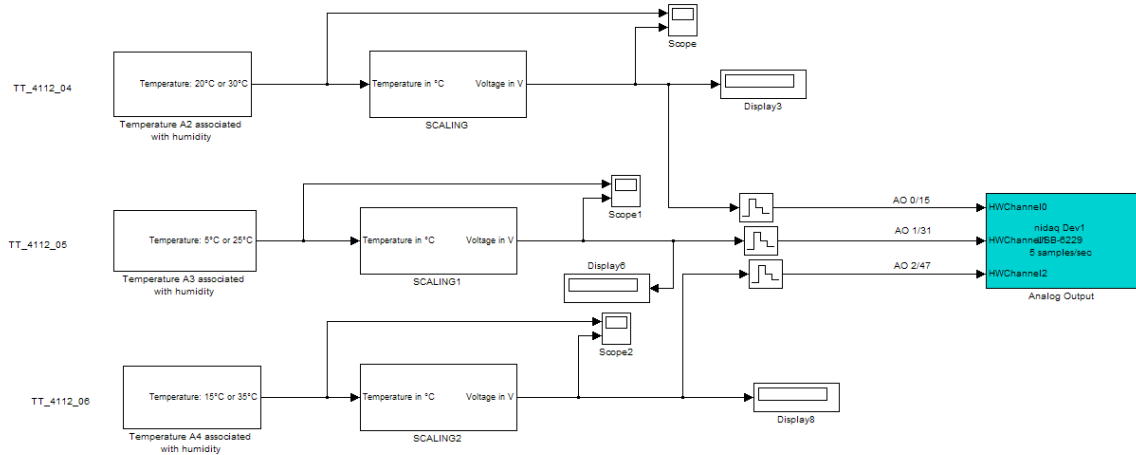
Figure 17 : CL4112_3 Simulink Test

3.1.12.4. *CL4112_4*

Variable Tag	NI Type	NI Card	NI location	NI Pin	Wire Color	PLC Type	I/O number	Phoenix Terminal
TT_4112_07	AO	6229	AO0	15	RED	AVI_2		15+
			AO GND	16	BROWN	AVI_2		16-
TT_4112_08	AO	6229	AO2	31	GREEN	AVI_2		21+
			AO GND	32	PURPLE	AVI_2		22-
TT_4112_09	AO	6229	AO3	47	WHITE	AVI_2		25+
			AO GND	48	GREY	AVI_2		26-
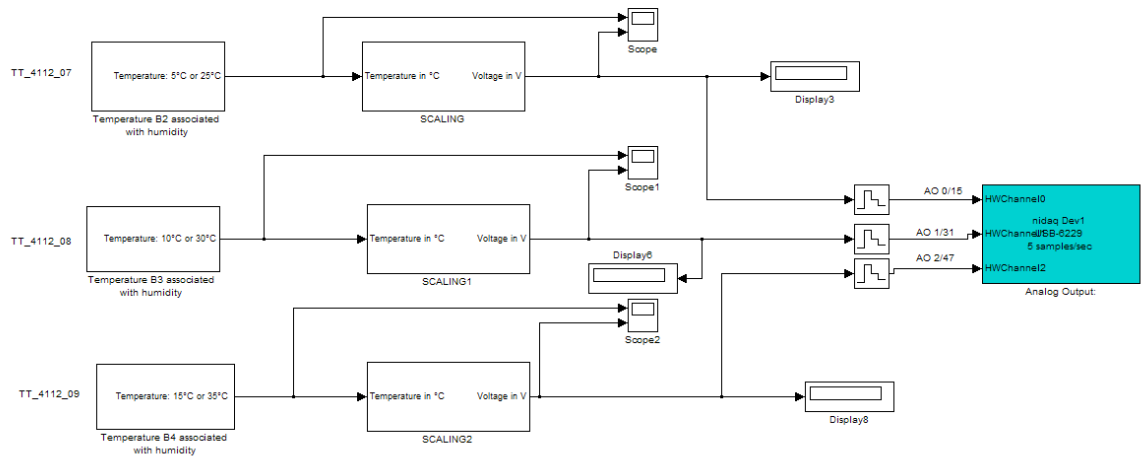
Figure 18 : CL4112_4 Simulink Test

3.1.12.5. *CL4112_5*

Variable Tag	NI Type	NI Card	NI location	NI Pin	Wire Color	PLC Type	I/O number	Phoenix Terminal
TT_4112_10	AO	6229	AO0	15	RED	AVI_2		31+
			AO GND	16	BROWN	AVI_2		32-
TT_4112_11	AO	6229	AO2	31	GREEN	AVI_2		35+
			AO GND	32	PURPLE	AVI_2		36-
TT_4112_12	AO	6229	AO3	47	WHITE	AVI_3		1+
			AO GND	48	GREY	AVI_3		2-
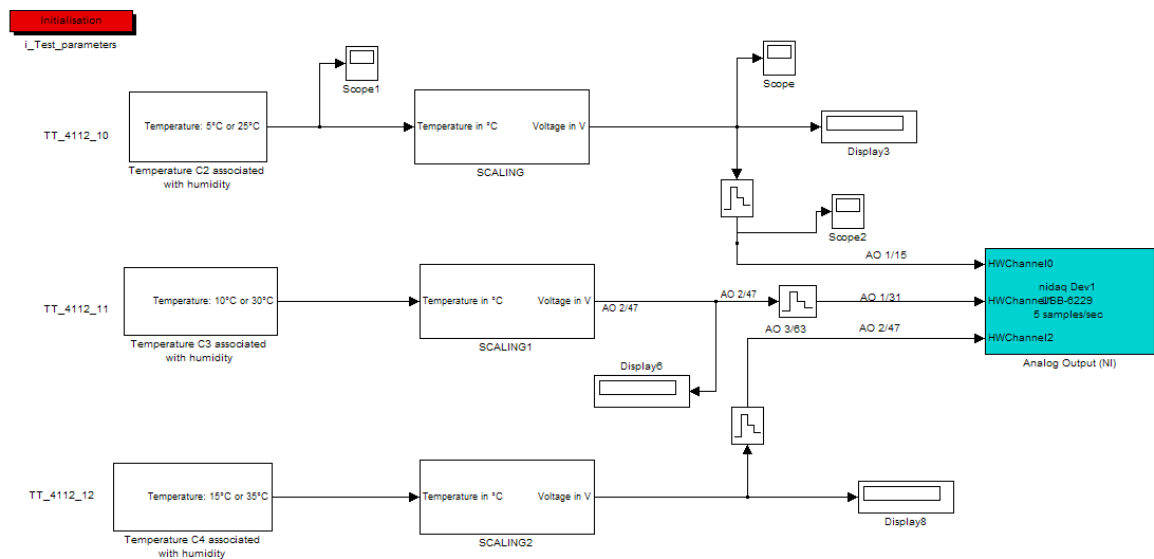
Figure 19 : CL4112_5 Simulink Test

3.1.12.6. *CL4112_6*

Variable Tag	NI Type	NI Card	NI location	NI Pin	Wire Color	PLC Type	I/O number	Phoenix Terminal
TT_4112_13	AO	6229	AO0	15	RED	ACI_2		1+
			AO GND	16	BROWN	ACI_2		2-
TT_4112_14	AO	6229	AO2	31	GREEN	ACI_2		5+
			AO GND	32	PURPLE	ACI_2		6-
TT_4112_15	AO	6229	AO3	47	WHITE	ACI_2		11+
			AO GND	48	GREY	ACI_2		12-

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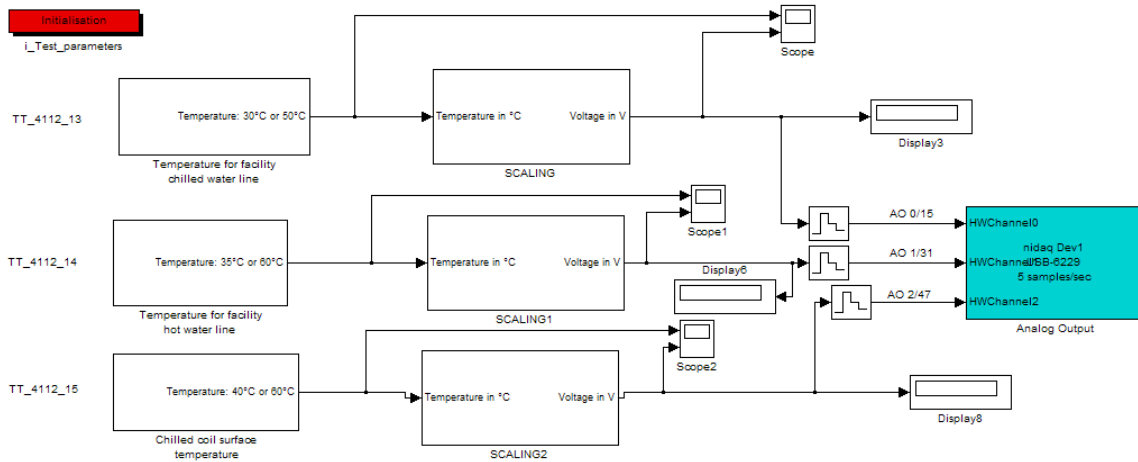
Figure 20 : CL4112_6 Simulink Test

3.1.12.7. *CL4112_7*

Variable Tag	NI Type	NI Card	NI location	NI Pin	Wire Color	PLC Type	I/O number	Phoenix Terminal
TT_4112_16	AO	6229	AO0	15	RED	ACI_2		15+
			AO GND	16	BROWN	ACI_2		16-
TT_4112_17	AO	6229	AO2	31	GREEN	ACI_2		21+
			AO GND	32	PURPLE	ACI_2		22-
TT_4112_18	AO	6229	AO3	47	WHITE	ACI_2		25+
			AO GND	48	GREY	ACI_2		26-
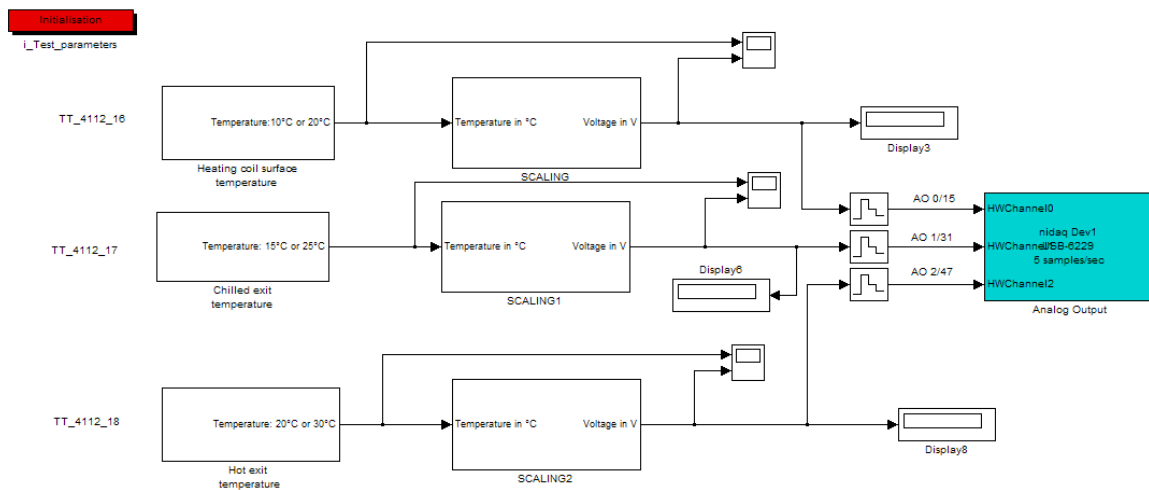
Figure 21 : CL4112_7 Simulink Test

3.1.12.8. *CL4112_8*

Variable Tag	NI Type	NI Card	NI location	NI Pin	Wire Color	PLC Type	I/O number	Phoenix Terminal
S3CV_4112_01_MV	AO	6229	AI0	1		ACO		8+. Monitor 5
			AI GND	3		ACO		
S3CV_4112_02_MV	AO	6229	AI1	4		ACO		14+ Monitor 11
			AI GND	6		ACO		
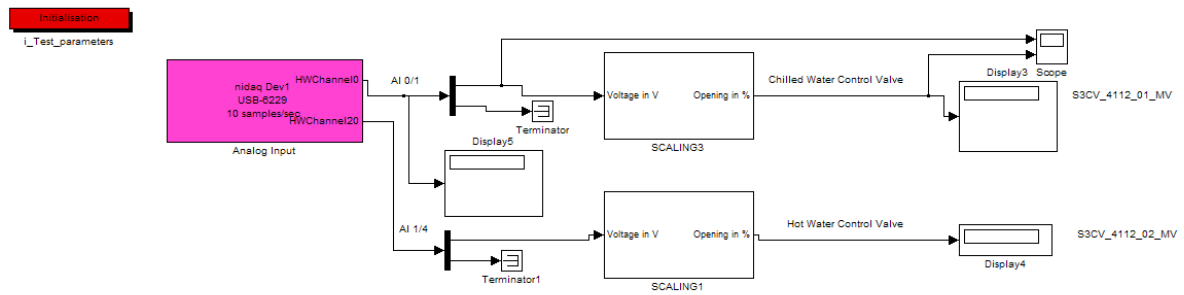
Figure 22 : CL4112_8 Simulink Test

3.1.13.CL4113

Variable Tag	NI Type	NI Card	NI location	NI Pin	Wire Color	PLC Type	I/O number	Phoenix Terminal
FC_4113_01	AO	6229	AO0	15	RED	ACI_3		5+
			AO GND	16	BROWN	ACI_3		6-
AT_4113_01	AO	6229	AO2	31	GREEN	ACI_3		11+
			AO GND	32	PURPLE	ACI_3		12-
AT_4113_02	AO	6229	AO3	47	WHITE	ACI_3		15+
			AO GND	48	GREY	ACI_3		16-
SV_4108_01_MV	DI	6229	P0.0	65	BLUE	DO	20	204
FC_4113_01_SP	AI	6229	AI	1	RED/BLUE	ACO		18+
			AI GND	3	BROWN/BLUE	ACO		6-
		9472	VSUP	8	DO_RED	24+ VDC		4
		9472	COM	9	DO_BLACK	GROUND		3
		6229	DGround	82	BLACK			5-VDC (PLC)
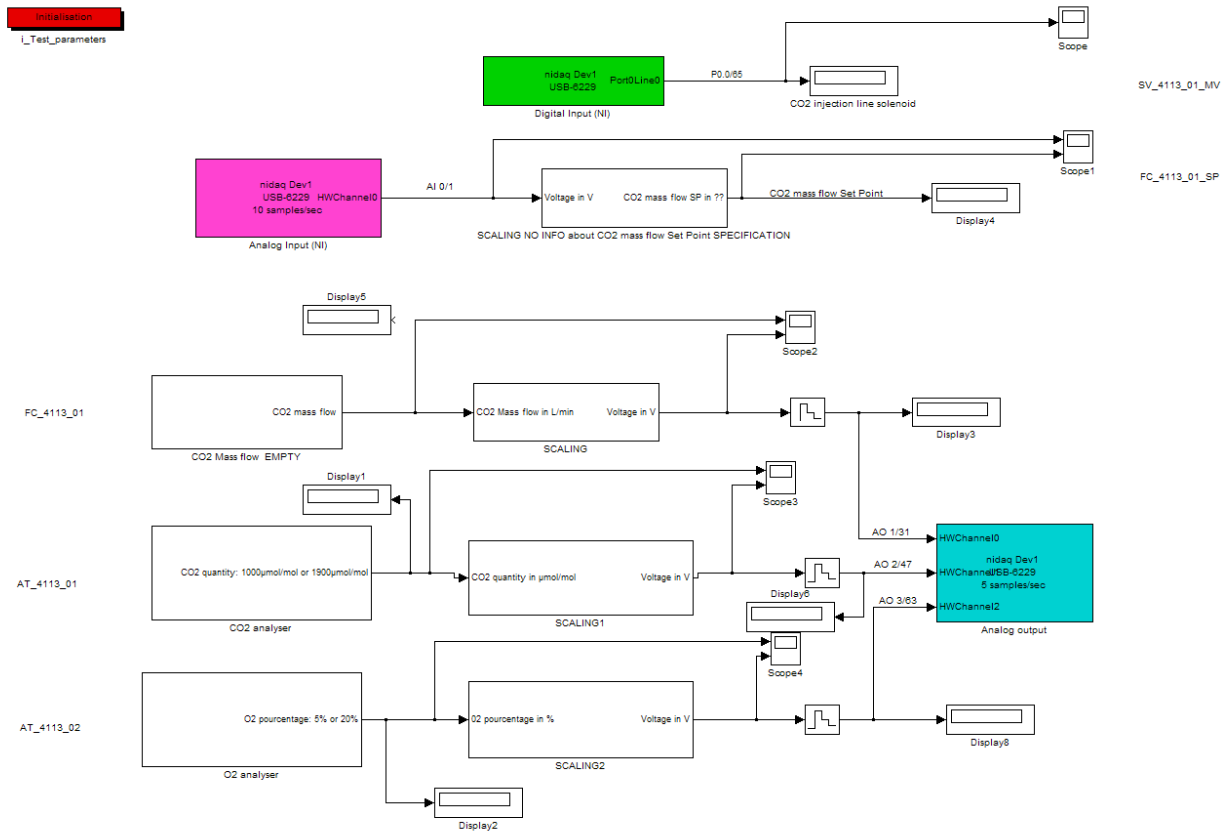
Figure 23 : CL4113 Simulink Test

3.1.14.CL4114 and CL4115

Variable Tag	NI Type	NI Card	NI location	NI Pin	Wire Color	PLC Type	I/O number	Phoenix Terminal
PT_4114_01	AO	6229	AO0	15	RED	AVI_3		5+
			AO GND	16	BROWN	AVI_3		6-
TT_4115_01	AO	6229	AO2	31	GREEN	AVI_3		11+
			AO GND	32	PURPLE	AVI_3		12-
PT_4115_01	AO	6229	AO3	47	WHITE	AVI_3		15+
			AO GND	48	GREY	AVI_3		16-
		9472	VSUP	8	DO_RED	24+ VDC		4
		9472	COM	9	DO_BLACK	GROUND		3
		6229	DGround	82	BLACK			5-VDC (PLC)

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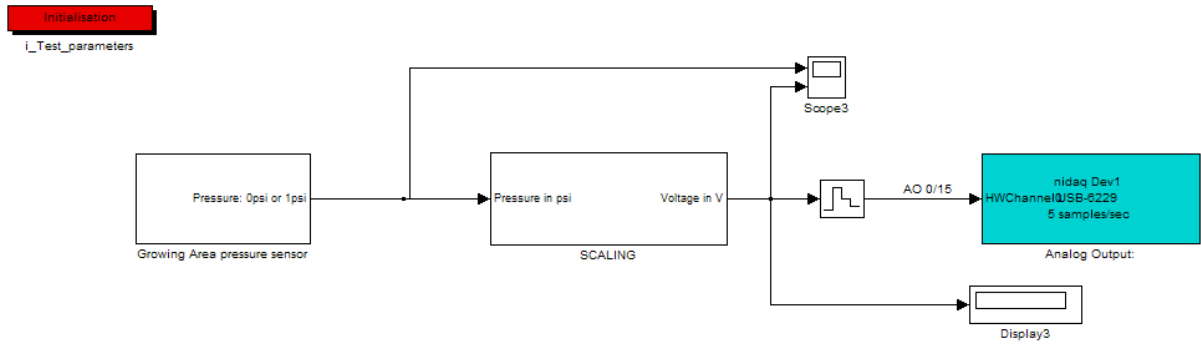Memorandum of Understanding 19071/05/NL/CP

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Figure 24 : CL4114 Simulink Test

3.2. Dynamic Tests

Variable Tag	NI Type	NI Card	NI location	NI Pin	Wire Color	PLC Type	I/O number	Phoenix Terminal
AT_4108_01	AO	6229	AO0	15	RED	ACI_1		21+
			AO GND	16	BROWN	ACI_1		22-
SV_4108_01_MV	DI	6229	P0.0	65	BLUE	DO	16	164
SV_4108_01_MV	DI	6229	P0.1	66	YELLOW	DO	17	174
LSL_4108_01	DO	9472	DO	0	DO_BLUE	DI_1	12	26
LSL_4108_02	DO	9472	DO	1	DO_YELLOW	DI_1	13	31
		9472	VSUP	8	DO_RED	24+ VDC		4
		9472	COM	9	DO_BLACK	GROUND		3
		6229	DGround	82	BLACK			5-VDC (PLC)

Variable Tag	NI Type	NI Card	NI location	NI Pin	Wire Color	PLC Type	I/O number	Phoenix Terminal
TT_4112_01	AO	6229	AO0	15	RED	ACI_1		25+
			AO GND	16	BROWN	ACI_1		26-
AT_4112_01	AO	6229	AO2	31	GREEN	ACI_2		31+
			AO GND	32	PURPLE	ACI_2		32_
TT_4112_15	AO	6229	AO3	47	WHITE	ACI_2		11+
			AO GND	48	GREY	ACI_2		12-

Variable Tag	NI Type	NI Card	NI location	NI Pin	Wire Color	PLC Type	I/O number	Phoenix Terminal
S3CV_4112_01_MV	AO	6229	AI20	49	White/Red	ACO		8+. Monitor 5
			AI GND	51	Grey/Red	ACO		
S3CV_4112_02_MV	AO	6229	AI0	1	Red/Blue	ACO		14+ Monitor 11
			AI GND	3	Brown/Blue	ACO		

TT_4112_13	Temp. Chilled water : fixed to 8.3 in Concept							
TT_4112_14	Temp. Hot water : fixed to 49 in Concept							
TT_4112_02	= TT_4112_01							
TT_4112_03	= TT_4112_01							
AT_4112_02	= AT_4112_01							
AT_4112_03	= AT_4112_01							

NOK for the tests due to the data acquisition which is not done between the computer and the PLC.
Synchroneous or Asynchroneous is possible when there is no PhiSim simulation. No possible otherwise.

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4. Conclusion

The performed tests demonstrate the validation of the implementation of the code into the PLC HW.

The Static tests have permitted to check the good connection of the wires and their localization into the Phoenix Terminal blocks.

Some dynamic tests have validated when possible the control strategy as designed and implemented into the PLC.

When HPC1 is available, final control strategies and tuning will be performed directly with the process.