Experimental Physics Department

CMS Cold Subdetector Gas PLC

This document describes the requirements on the CMS Cold subdetector Dry Gas PLC-based control system and their interfacing to the rest of the Cold subdetector control systems via DCS and directly (MASTER)

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1 Introduction

This document describes the requirements on the Dry Gas PLC systems operation and monitoring services for the CMS cold subdetectors (Tracker, BTL, HGCAL, ETL and ECAL Barrel).

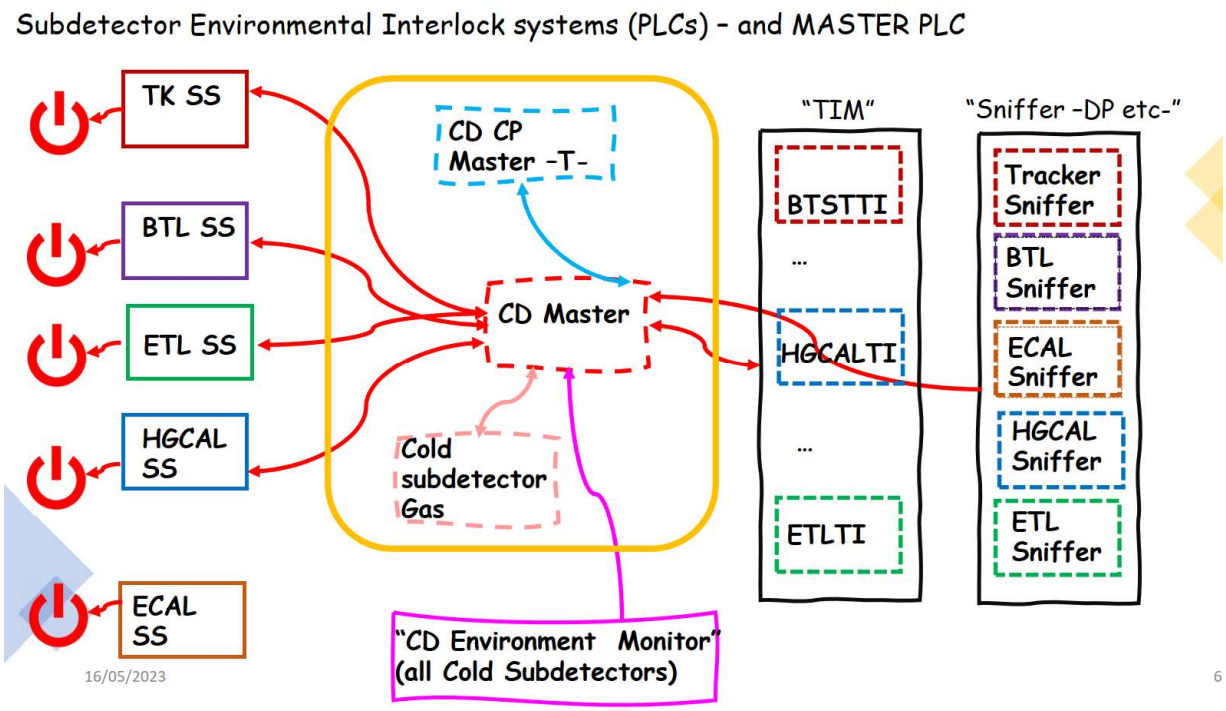
In what follows the above subdetectors will be referred to as "Cold Subdetectors". The adjective "Cold" is attributed because they will be kept at temperatures below the CMS cavern dewpoint (upper limit = 13^{0}C). The requirements on their Dry Gas control are modelled on the CMS Tracker Dry Gas PLC-based controls that has been running uninterruptedly for more than ten years without any problem and have been providing the functionalities described in this document.

The document covers both foreseen Dry gas installations at P5.

1. Surface buildings SX5 and SXA5 (first time installation, servicing detector testing facilities) and
2. At the "extended" gas room of USC comprising of the old gas room and the "mezzanine" room on top of it. The "mezzanine" will be a new installation while the gas room is already used for the Tracker and ECAL dry gas distribution that will be partially remade.

2 General description and specificities of the Dry Gas Controls for the CMS CS.

The CMS CS Dry gas system status and data will be a critical part in the implementation of interlocks and alarms as is currently the case for the Tracker. Any future implementation must integrate smoothly in the detector DCS as is currently the case so that the detector is operable. DCS alarms must be always reliably transmitted and configurable via DCS. For example, the Tracker DCS monitors the dead time between updates from the Tracker PLCs and generates alarms when the dead time exceeds a configurable limit. This functionality is mandatory for operation.



1 The Cold subdetector environmental safety system has the Dry Gas PLC system as integral part.

The Dry Gas control system status and monitored values are part of the CS Action Matrix. All the systems indicated in Fig. 1 (TK SS, BTL SS, ETL SS, HGCAL SS, ECAL SS -SS= Safety System, TIM (Thermal

Interface Master), Sniffer DewPoint, CS Environmental Monitor, CD CP Master, CD Gas and MASTER, the last three will collapse to one installation due to size at the Surface area) are PLC-based systems. They will be implemented using the SIEMENS S7 -1500 PLC family processors. The PLCs will use a secure power source (combination of a UPS backed input from EOD source and a standard EXD source).

The CMS Phase II Dry Gas control systems will be delivered at different times. While the Surface Dry Gas system should be operational starting in the beginning of 2024, the ones in the USC will be needed later. The Surface system is described in this document and will act as prototype for the USC system.

The Dry Gas sources are the SH5 Dry Air Compressor line (SH5), the (filtered) SU5 compressed Air line and Dry Air bottles installed in the vicinity of Bat. 3570. The sources are cycled based on the line pressure and the dewpoint acceptability in the order in which they are listed.

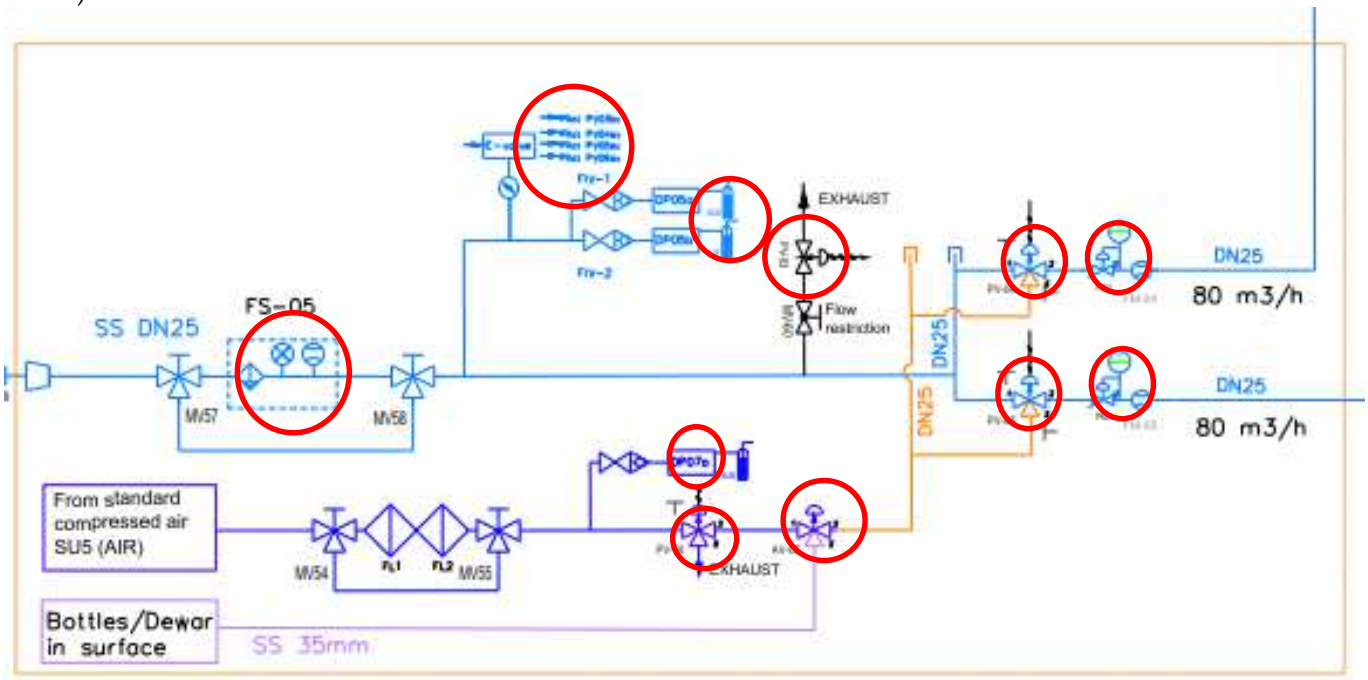
The primary line source is the outcome of the selection between the Dry Air and the Backup source. The backup line is the outcome of the selection between the SU5 compresses Air line and the Bottles. An additional line and valve combination allows to vent the humid air.

The basic switching element on the primary line is a three-way valve connecting one of the two inputs to the output towards the subdetector test facilities. The three-way valves are pneumaticaly driven. If the primary line pressure drops below the acceptable limit (set via hardware and upon agreement between the DT and the detector expert), the valve must switch to the other position (3->2, Backup as Dry Gas) and stay in this position while conditions persist and/or it is not reset. The reset is manual on a touch screen via a software implemented non-latching button. In addition:

1. Too high values of dewpoint (the threshold is user selected) trigger (via electropneumatic control) the opening the Dry Gas vent enabling the switchover to the backup line.

2. Too high pressure value (the threshold is user selected) triggers (via electropneumatic control) the opening the Dry Gas vent.

The same principles are valid for both Dry Gas systems attached to the SH5 Compressors (SX5 and SXA5).



2: The SX5 Dry Gas system PLC-controlled/monitored elements indicated by the red cycle (FS-05, DP05a, DP05b, DP07a, PV03sv, PV04sv, PV05sv, PV03, PV04, PV05, AV-05 and PV-06)

3 The SX5 Dry Air control system – inputs and outputs

The sensors and actuators in Fig.2 entering the Dry Gas process (states and transitions) and defined as PLC I/Os are the following:

	Analog inputs (for the PLC)			
Sensor		type	Model	Input type
Flow (FS-05 F)	FS5F	FESTO SFAM	SFAM-62-3000R-M-25A-M13	4...20mA 4-wire
Pressure (FS-05 P)	FS5P	FESTO SPAU	SPAU-P10R-H-G18FD-L-PNLK-PNVBA-M8U	4...20mA 4-wire
Dewpoint 05a	DP5x	VAISALA DMT143	DMT143 L2G1A1A310ASX	4...20mA 4-wire
Dewpoint 05b	DP5x	VAISALA DMT143	DMT143 L2G1A1A310ASX	4...20mA 4-wire
Dewpoint 07a	DP7a	VAISALA DMT143	DMT143 L2G1A1A310ASX	4...20mA 4-wire
Flow FM-04	FM04	FESTO SFAM	SFAM-62-3000R-M-25A-M13	4...20mA 4-wire
Flow FM-05	FM05	FESTO SFAM	SFAM-62-3000R-M-25A-M13	4...20mA 4-wire
Filter DP		Donaldson specific		4...20mA 2-wire

The analog input values are to be considered out of bounds if they exceed the acceptable range (modifiable by DCS) for at least a specified (fixed but on a per input basis) amount of time at which point the status of the input becomes out of bounds and remains such until a successful acknowledge command is executed.

For all valves the PLC transmits (over Dry contacts) a copy of its driving electrical outputs (where present) and all the state inputs from the valve to the MASTER.

PLC I/Os attached to the actuators		
	Gas system PLC value	To CMS MASTER system
PV-04	I0.0 1 On Primary I0.1 1 On secondary	1.Q0.Evalve status 2.Q0.1 Copy of On Primary status 3.Q0.2 Copy of On Secondary status
PV-05	I0.2 1 On Primary I0.3 1 On secondary	1.Q0.3 Evalve status 2. Q0.4 Copy of On Primary status 3. Q0.5 Copy of On Secondary status
PV-03	I0.4 1 Open vent I0.5 1 Not Open vent	1.Q0.6 Evalve status 2 Q0.7 Copy of Open Vent 3 Q1.0 Copy of Not Open Vent
AV-05	I0.6 1 Backup is Compressed air I0.7 1 Backup is Bottles	1 Q1.1 Copy of Backup is Compressed air 2 Q1.2 Copy of Backup is Bottles
PV-06	I1.0 1 Compressed Air OK I1.1 1 Compressed Air not OK	1. Q1.3Copy of Compressed Air OK 2. Q1.4 Copy of Compressed Air Not OK

Evalve status = Copy of value written to Evalve.

4 The SX5 Dry Air control system – states and I/Os

The SX5 system will be in any of the following 9 states each of which depends on the gas siurce in use, the pressure and dewpoints and the power status. We pack the states in a byte for ease. The states and are the following:

1. “Normal Operation”. (State 0000)

Primary source active PV-04(-05) 1->2

Vent closed

Secondary source is filtered compressed air

2. “Normal Operation No Compressed Air”. (State 0001)

Primary source active

Vent closed

Secondary source is Bottles

3. “Overpressure”. (State 0010)

Primary source active

Vent open

Secondary source is filtered compressed air

4. “Overpressure no compressed Air”. (State 0011)

Primary source active

Vent open

Secondary source is bottles

5. “Backup”. (State 0100) PV-04(-05) 3->2

Secondary source active

Vent closed

Secondary source is filtered compressed air

6. “Backup no compressed Air”. (State 0101)

Secondary source active

Vent closed

Secondary source is Bottles

7. “Backup Vent Open” . (State 0110)

Secondary source active

Vent open

Secondary source is filtered compressed air

8. “Backup Bottles Vent Open” . (State 0111)

Secondary source active

Vent open

Secondary source is Bottles

9. “Power off” . (State 1000)

5 The SX5 status of the valves as a function of the state

	State 1	State 2	State 3	State 4	State 5	State 6	State 7	State 8	State 9
PV-04	1(1->2)	1(1->2)	1(1->2)	1(1->2)	0(3->2)	0(3->2)	0(3->2)	0(3->2)	X
PV-05	0(3->2)	0(3->2)	0(3->2)	0(3->2)	1(1->2)	1(1->2)	1(1->2)	1(1->2)	1(1->2)
PV-03	1(1->2)	1(1->2)	1(1->2)	1(1->2)	0(3->2)	0(3->2)	0(3->2)	0(3->2)	1(1->2)
AV-05	1(1->2)	0(3->2)	1(1->2)	0(3->2)	1(1->2)	0(3->2)	1(1->2)	0(3->2)	0(3->2)
AV-06	1(1->2)	0(3->2)	1(1->2)	0(3->2)	1(1->2)	0(3->2)	1(1->2)	0(3->2)	0(3->2)

6 The SX5 Dry Air control system – state transitions

Go to	State 1	State 2	State 3	State 4	State 5	State 6	State 7	State 8	State 9
State 1	X	DP7a=1	FS5P=1	X	DP5x=1	X	X	X	PCUT
State 2	ACK	X	X	FS5P=1	X	DP5x=1	X	X	PCUT
State 3	ACK	X	X	DP7a=1	X	X	DP5x=1	X	PCUT
State 4	ACK	ACK	ACK	X	X	X	X	DP5x=1	PCUT
State 5	ACK	X	X	X	X	DP7a=1	FS5P=1	X	PCUT
State 6	ACK	ACK	X	X	ACK	X	X	FS5P=1	PCUT
State 7	ACK	X	ACK	X	X	X	X	DP7a=1	PCUT
State 8	ACK	ACK	ACK	ACK	ACK	ACK	ACK	X	PCUT
State 9	PCUT	PCUT	PCUT	PCUT	PCUT	PCUT	PCUT	PCUT	PCUT

7 The SX5 Dry Air control system – more signals

1. One DQ, The Watchdog

The Watchdog is a critical signal for the CS PLCs and its role is to inform the MASTER that the processis executing. If the signal is not present for a determinate amount of time (~1 min), the MASTER will take the foreseen actions. The Watchdg is the output of an external Timer relay with a countdown time of approximately one minute, to be reset by the execution of OB1 exclusively. Failure to reset the timer within the allocated time must result in the opening of the external timer relay contacts. The output of the relay (usually the last available output bit, in our case Q3.7) goes to the MASTER that takes appropriate actions.

2. Three DI inputs from the MASTER (dedicated to communication between DSS and MASTER)

8 The SX5 Dry Air control system – software commands

The systems must accept a set of commands from a CMS-like DCS and from an HMI and (at least in the case of DCS) they should return feedback showing that the command has been received and executed (or not). These commands are:

1. Acknowledge existing alarms: this command will cause the out-of-bound status for the analog measurements to be cleared, unless the values are still outside the permissible range.

2. Enter Manual Control Mode (HMI). When in Manual Control Mode, the PLC will set the outputs controlling the valves to values entered by the operator. The access to this mode must be protected by password.

9 HMI access and Operation

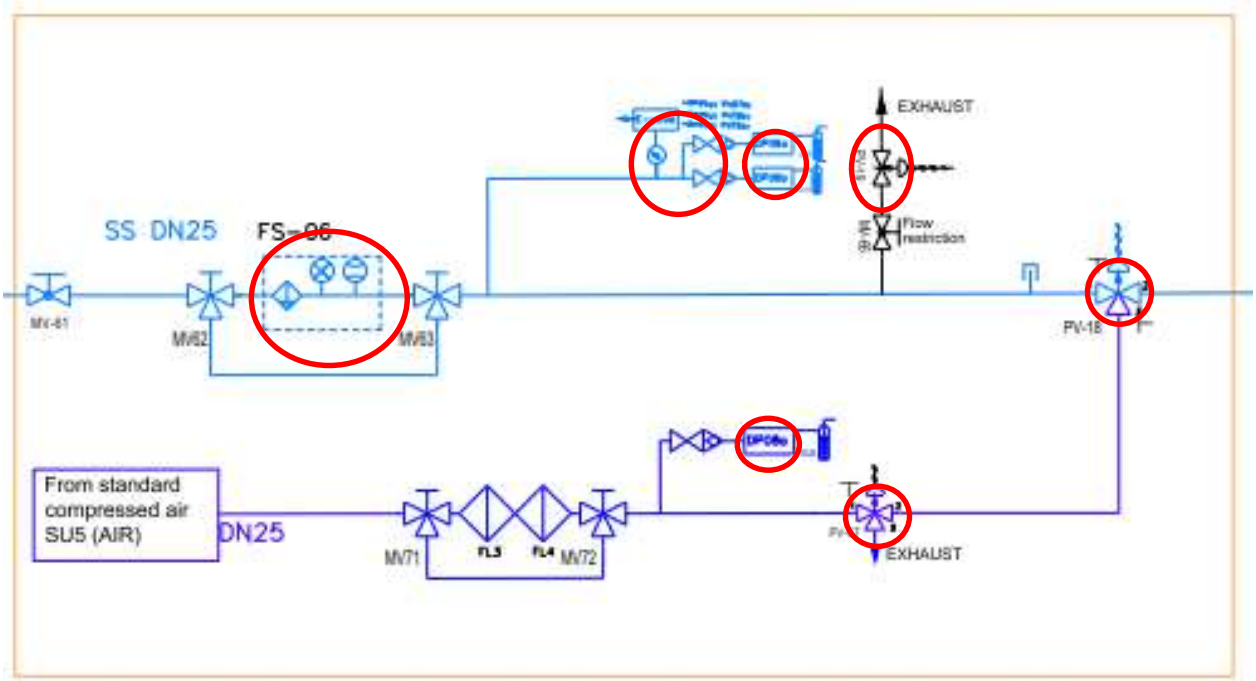
Both the SX5 and the SXA5 systems must also be accessible over a dedicated HMI (Touch Panel) both in order to visualize the current values and the time trends (over the 10 minutes or so) of the

monitored quantities and states and to send commands to the systems as already underlined above.

10 SX5 Loss of power

In case of power loss we will not have the dewpoint monitoring except in case we plan appropriate UPS installation. We think the state should be 6 ("Backup, secondary source is bottles"). The status of the valves is described in 5.

11 The SXA5 Dry Air control system



3:The SXA5 Dry Gas system PLC-controlled/monitored elements indicated by the red cycle (FS-06, DP06a, DP06b, DP08a, PV18, PV19, and PV-07)

12 The SXA5 Dry Air control system – inputs and outputs

The sensors and actuators in Fig.2 entering the Dry Gas process (states and transitions) and defined as PLC I/Os are the following:

	Analog inputs (for the PLC)			
Sensor		type	Model	Input type
Flow (FS-06 F)	FS6F	FESTO SFAM	SFAM-62-3000R-M-25A-M13	4...20mA 4-wire
Pressure (FS-06 P)	FS6P	FESTO SPAU	SPAU-P10R-H-G18FD-L-PNLK-PNVBA-M8U	4...20mA 4-wire
Dewpoint 06a	DP6x	VAISALA DMT143	DMT143 L2G1A1A310ASX	4...20mA 4-wire
Dewpoint 06b	DP6x	VAISALA DMT143	DMT143 L2G1A1A310ASX	4...20mA 4-wire
Dewpoint 08a	DP8a	VAISALA DMT143	DMT143 L2G1A1A310ASX	4...20mA 4-wire
Filter DP		Donaldson specific		4...20mA 2-wire

The analog input values are to be considered out of bounds if they exceed the acceptable range (modifiable by DCS) for at least a specified (fixed but on a per input basis) amount of time at which point the status of the input becomes out of bounds and remains such until a successful acknowledge command is executed.

PLC I/Os attached to the actuators		
	Gas system PLC value	To CMS MASTER system
PV-18	I0.0 0 On Primary I0.1 1 On secondary	1.Q2.0 Copy of Signal to Valve 2.Q2.1 Copy of On Primary 3.Q2.2 Copy of On Secondary
PV-19	I0.2 1 Open Vent I0.3 1 Not Open Vent	1.Q 2.3 Copy of signal to Valve 2. Q2.4 Copy of Open Vent 3. Q2.5 Copy of Not Open Vent
PV-07	I0.4 1 Compressed Air OK I0.5 1 Compressed Air not OK	1. Q 2.7 Copy of Compressed Air OK 2. Q 3.0 Copy of Compressed Air Not OK

For all valves the PLC transmits (over Dry contacts) a copy of its driving electrical outputs (where present) and all the state inputs from the valve to the MASTER.

13 The SXA5 Dry Air control system – states and I/Os

The SX5 system will be in any of the following 9 states each of which depends on the gas siurce in use, the pressure and dewpoints and the power status. We pack the states in a byte for ease. The states and are the following:

1. "Normal Operation". (State 0000)

Primary source active PV-18 1->2

Vent closed

Secondary source filtered compressed air present. (PV06 is not allowing the compressed air into AV-05)

2. "Normal Operation No Compressed Air". (State 0001)

Primary source active

Vent closed

Secondary source filtered compressed air not present (PV06 is not allowing the compressed air into AV-05)

3. "Overpressure". (State 0010)

Primary source active

Vent open

Secondary source is filtered compressed air

4. "Overpressure no compressed Air". (State 0011)

Primary source active

Vent open

Secondary source filtered compressed air not present

5. "Backup". (State 0100)

Secondary source active

Vent closed

Secondary source is filtered compressed air

6. "Backup no compressed Air". (State 0101)

Secondary source active

Vent closed

Secondary source filtered compressed air not present

7. "Backup Vent Open" . (State 0110)

Secondary source active

Vent open

Secondary source is filtered compressed air

8. "Backup Bottles Vent Open" . (State 0111)

Secondary source active

Vent open

Secondary source filtered compressed air not present

9. “Power off” . (State 1000) In power off we remain in what we were and open the vents

14 The SXA5 status of the valves as a function of the state

	State 1	State 2	State 3	State 4	State 5	State 6	State 7	State 8	State 9
PV-18	1(1->2)	1(1->2)	1(1->2)	1(1->2)	0(3->2)	0(3->2)	0(3->2)	0(3->2)	X
PV-19	0(3->2)	0(3->2)	0(3->2)	0(3->2)	1(1->2)	1(1->2)	1(1->2)	1(1->2)	1(1->2)
AV-07	1(1->2)	1(1->2)	1(1->2)	1(1->2)	0(3->2)	0(3->2)	0(3->2)	0(3->2)	1(1->2)

15 The SXA5 Dry Air control system – state transitions

Go to	State 1	State 2	State 3	State 4	State 5	State 6	State 7	State 8	State 9
State 1	X	DP8a=1	FS6P=1	X	DP6x=1	X	X	X	PCUT
State 2	ACK	X	X	FS5P=1	X	DP6x=1	X	X	PCUT
State 3	ACK	X	X	DP8a=1	X	X	DP6x=1	X	PCUT
State 4	ACK	ACK	ACK	X	X	X	X	DP6x=1	PCUT
State 5	ACK	X	X	X	X	DP8a=1	FS6P=1	X	PCUT
State 6	ACK	ACK	X	X	ACK	X	X	FS6P=1	PCUT
State 7	ACK	X	ACK	X	X	X	X	DP8a=1	PCUT
State 8	ACK	ACK	ACK	ACK	ACK	ACK	ACK	X	PCUT
State 9	PCUT	PCUT	PCUT	PCUT	PCUT	PCUT	PCUT	PCUT	PCUT

16 The SXA5 Dry Air control system – more signals – not necessary.

As the implementation will happen using one PLC connecting via two ProfiBus lines to the two installations (one for each), so the extra signals, Watchdog and MASTER-related should not be repeated.

17 The SXA5 Dry Air control system – software commands

The systems must accept a set of commands from a CMS-like DCS and from an HMI and (at least in the case of DCS) they should return feedback showing that the command has been received and executed (or not). These commands are:

1. Acknowledge existing alarms: this command will cause the out-of-bound status for the analog measurements to be cleared, unless the values are still outside the permissible range.

2. Enter Manual Control Mode (HMI). When in Manual Control Mode, the PLC will set the outputs controlling the valves to values entered by the operator. The access to this mode must be protected by password.

18 HMI access and Operation

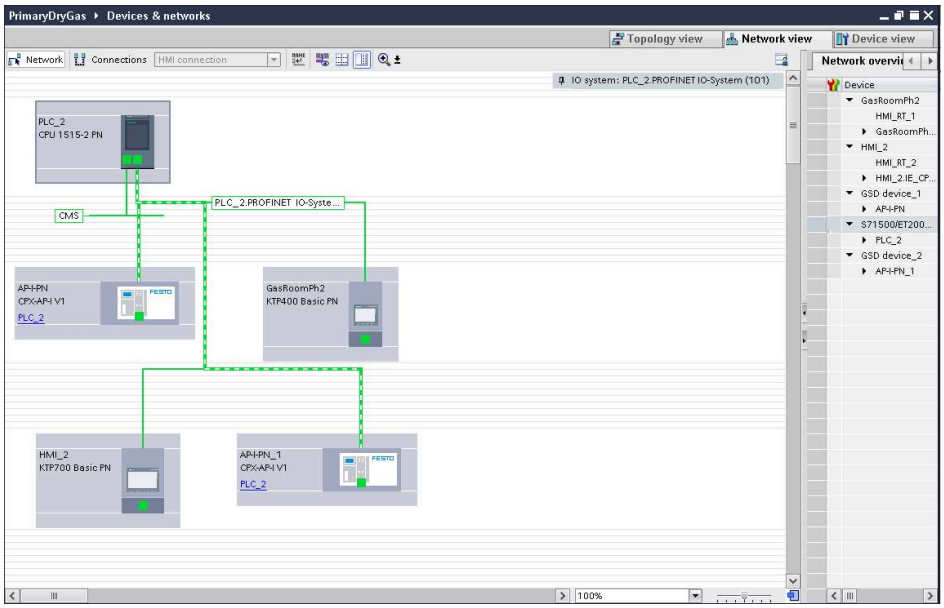
See Paragraph 10 of this document.

19 SXA5 Loss of power

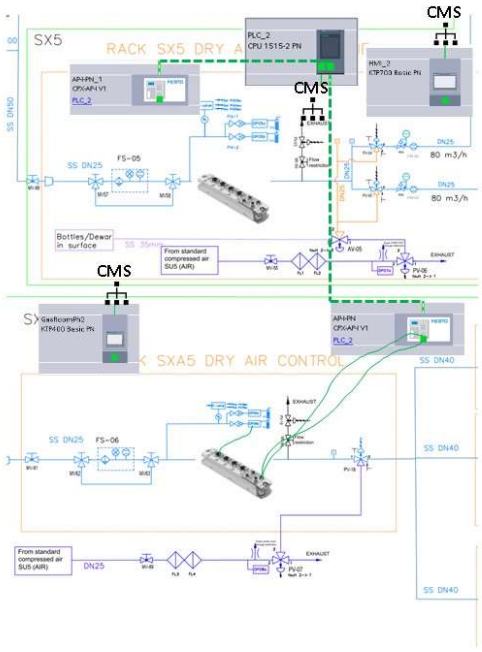
In case of power loss we will not have access to dewpoint monitoring except in case we plan for an appropriately sized UPS installation. We think the state should be 6 ("Backup, no compressed air"). The status of the valves is described in Section 14.

20 Possible hardware control implementation (combination of FESTO and SIEMENS hardware).

We opt for a distributed control system that will be flexible enough to incorporate some more sensors/actuators if necessary. The optimal solution both in functionality and cost we will be using as much as possible the distributed FESTO modules (for sensor inputs and actuator I/Os except for the case of connections with the MASTER). The distributed FESTO modules can be convenently positioned while connecting via Profinet Interface to the PLC CPU that will house the intelligence. The CPU will be one of the CERN "standard" Siemens PLC CPUs and will connect via a Profinet cable to each of the two interfaces. A Siemens touchpanel will provide HMI access to the user in each of the two installations (SX5 and SXA5).The topology of the system can be described as:



4: The distributed control system; the PLC CPU+DO module for the MASTER communications together with one FESTO Profinet Interface will be in SXA5 or SX5 depending on installation times together with a touch screen and the second Interface with the touchscreen will be in the second laboratory.



5: A more generalized view of the above

21 A cost estimate of the above

The cost of the hardware will be approximtely 5k (details available if somebody is interested).