Document Title:	Functional Analysis of the cryogenic distribution system for FAIR
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V 0.1	W. Bach		02.02.2021	First design of the document
V 0.2				
V 1.0				

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1. INTRODUCTION

About this template document:

- *Instructions are in cursive (Italics)*
- Example are highlighted in yellow
- The text to be kept is normal
- To Do

Please be aware that the examples shown are not connected together as a common example for a complete system!

*An industrial plant, as far as the process control is concerned, can be defined as an hierarchy of **units**. The global requirements are then categorised into requirements applicable to the plant-wide control and requirements applicable to the control of a particular plant unit. Thisdecomposition is based on the approach defined in IEC 61512-1 or ANSI/ISA S88 [1].*

The tags identifying sensors and actuators in this document must be the ones referenced on the P&I Diagrams of the controlled plant.

1.1 Terminology

Actuator: defined as *control module* in IEC 61512-1:

- A piece of equipment controlling the plant
- Acts as a single entity from a control standpoint
- Is the direct connection to the process and can embed sensors
- Cannot execute procedural sequences
- Examples: valves, motors, pumps, fans etc.

Unit: defined as unit and equipment module in IEC 61512-1:

- Collection of actuators and/or other units
- Can carry out a finite number of minor processing activities
- Contains all the necessary processing equipment to carry out these activities
- Can execute procedural sequences
- Examples:
  - Compression station: 3 compressors + 4 valves
  - Compressor: 1 motor + 1 valve

Controller: Regulation algorithm able to control a process variable (ex: PID controller)

Object: Unit,Actuator or Controller

Operational State: Each unit can be setup in different operational states (e.g: Cooling, Heating).

Interlock: Asynchronous condition preventing or stopping an actuator or a unitfrom starting for security reasons. An interlock must not be used during normal operation but only duration abnormal conditions. Software interlocks do not guarantee adequate personnel security.

The possible interlocks for a complete unit or for an actuator are:

- **Full stop interlock (FS):** Stop the unit/actuator (all dependent units/actuators are set to their fail-safe positions) and requires manual acknowledgement before restarting.
- **Temporary Stop Interlock (TS):** Stop the unit/actuator (all dependent units/actuators are set to their fail-safe positions) and will restart automatically when the interlock is acknowledged.
-
- .
- **Start Interlock (SI):** Prevents the unit from starting (all dependent units/actuators remain in their fail-safe position).
- **Alarm (AL):** It is an indication of a potential problem. In this case, there is no action.

Digital Alarm (DA): This type of alarm is triggered through a Boolean. This can be a digital input as well as a computed variable.

Analog Alarm (AA): This type of alarm is triggered through a Real value. This can be an analog input as well as a computed variable. For each AA there is the possibility to define 4 threshold limits. They have following meaning:

THRESHOLD LIMIT	ACTION
HH	High High limit violation, defined interlock will be triggered
H	High limit violation, warning message will be triggered
L	Low limit violation, warning message will be triggered
LL	Low Low limit violation, defined interlock will be triggered

User Command: Specific operator order to specify a particular action.

Computed-Variable: Value calculated during PLC cycle from a set of I/O signals, constants, computed variables or parameters.

Please add project related terminology

1.2 Abbreviations

ABBREVIATION	DESCRIPTION
DI	Digital Input
DO	Digital Output
AI	Analog Input
AO	Analog Output
AL	Alarm/Warning without reaction
FS	Full Stop Interlock
TS	Temporary Stop Interlock
SI	Start Interlock
ONOFF	Actuators which are switched between on and off or open and close, like solenoid valves
DA	Digital Alarm
AA	Analog Alarm
SP	Set point value
MV	Actual value
CV	Computed Variable or controlled valve (inside actuator names)
GSI	GSI Helmholtzzentrum für Schwerionenforschung GmbH, Darmstadt, Germany
FAIR	International Facility for Antiproton and Ion Research
SIS100	Schwerionensynchrotron (en. Heavy ion synchrotron) 100 Tm
Super-FRS	Superconducting Fragment Separator
CBM	Compressed Baryonic Matter (experimental setup)
HEBT300	High energy beam transfer for SIS300
R3B	Reactions with Relativistic Radioactive Beams
LEB	Low energy branch of the Super-FRS
DB	Distribution box
BB	Branch box
FB	Transfer line
NW	Northwest
SW	Southwest
SE	Southeast
MLI	Multi-layer insulation

Please add project related abbreviations

2. PROCESS DESCRIPTION

2.1 General capabilities

At the GSI, a new accelerator facility called FAIR will be built within the next years. The civil construction has started and the first superconducting magnets for the SIS100 as well as the cryogenics infrastructure for the testing of these magnets have already been ordered and delivered. There will be two major machines with superconducting magnets: the SIS100, a ring accelerator with a circumference of about 1,100 m, and the Super-FRS, a fragment separator for rare isotope beams with a length of about 410 m. Figure 1 shows an overview of the topology of the cryogenic infrastructure and distribution system at FAIR.

The distribution system is required to supply cold helium to all users and to return the helium back to the refrigerators. In Figure 2, a schematic overview of the distribution system is given. [1]

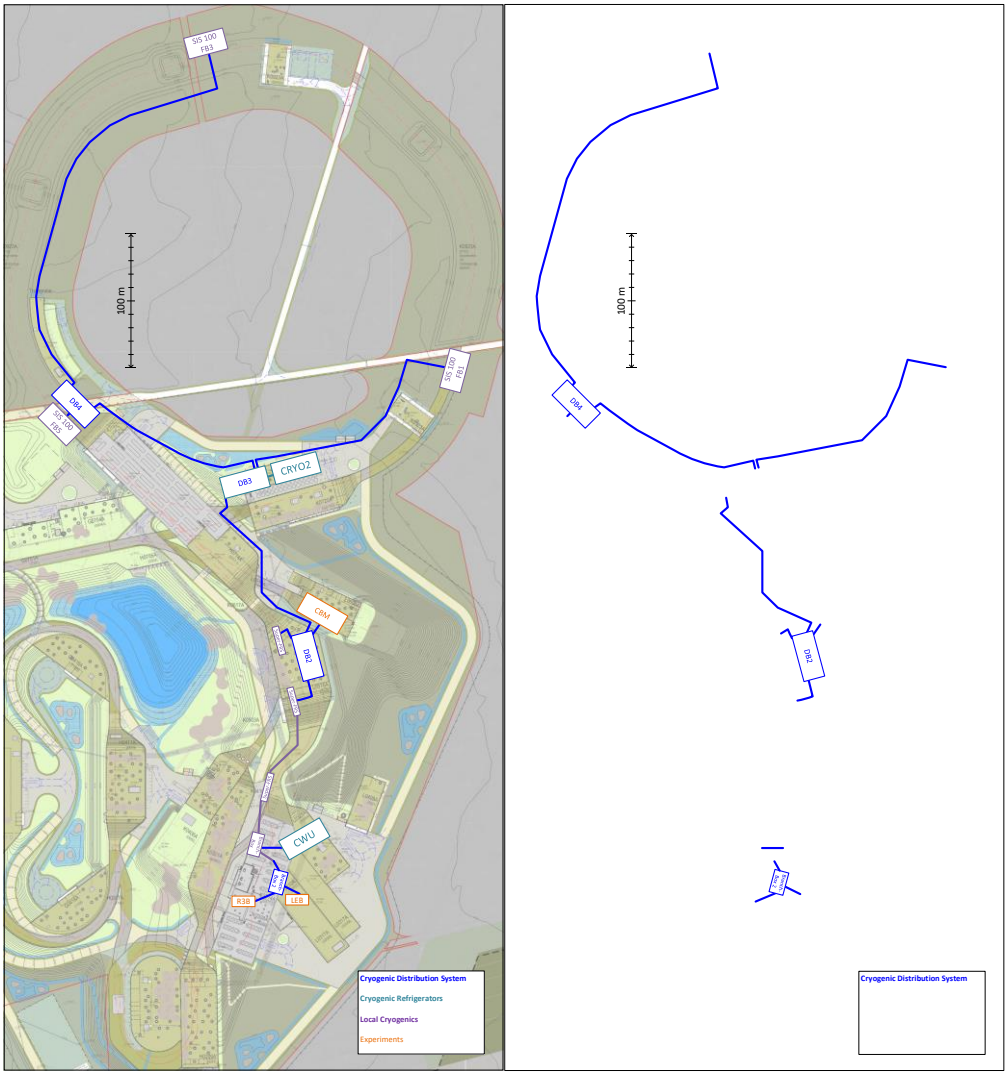

Figure 1: Topology of the cryogenic system of FAIR

[1] \\campus\groups\cryo\Projects\DistributionSystem\Planung\F-CS-CRY-en-K_NNNN_Cryogenic_Distributionsystem_FAIR-V001(Comments YX 16102018).pdf

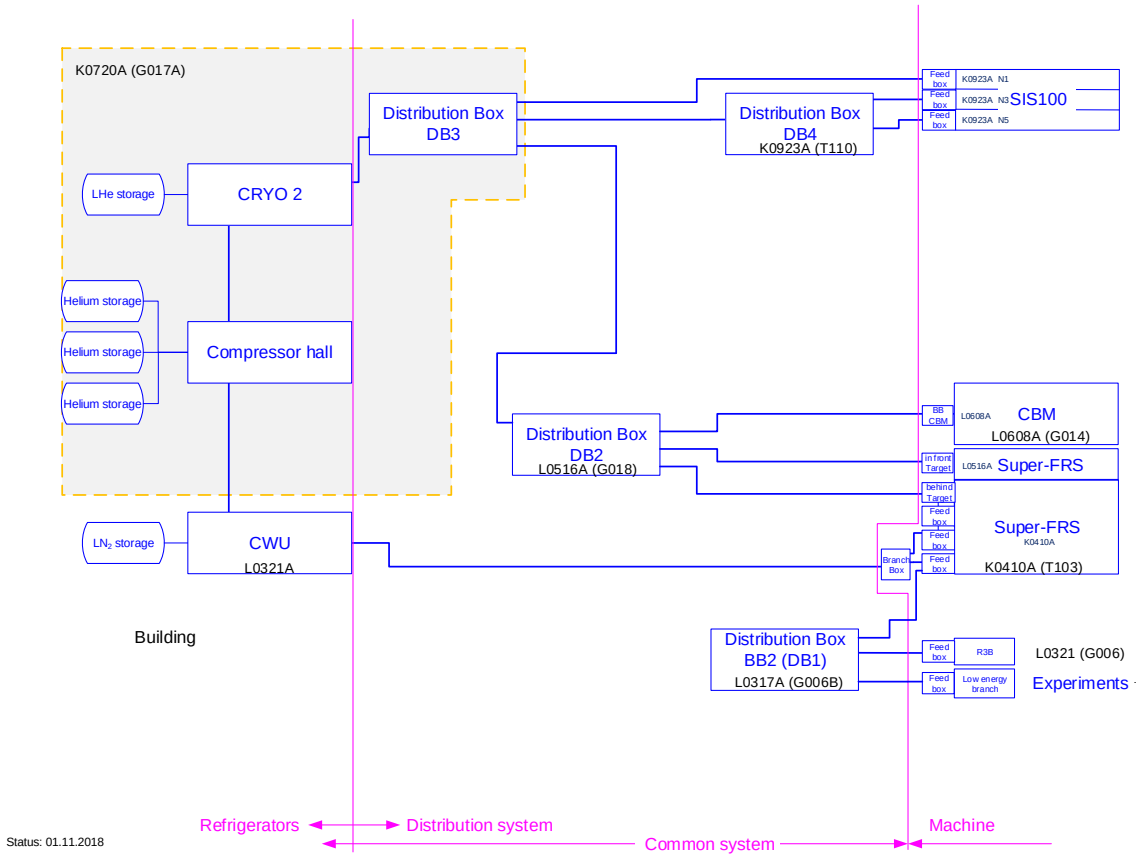

Figure 2: Schematic view of the cryogenic system with its main components

2.2 Process decomposition

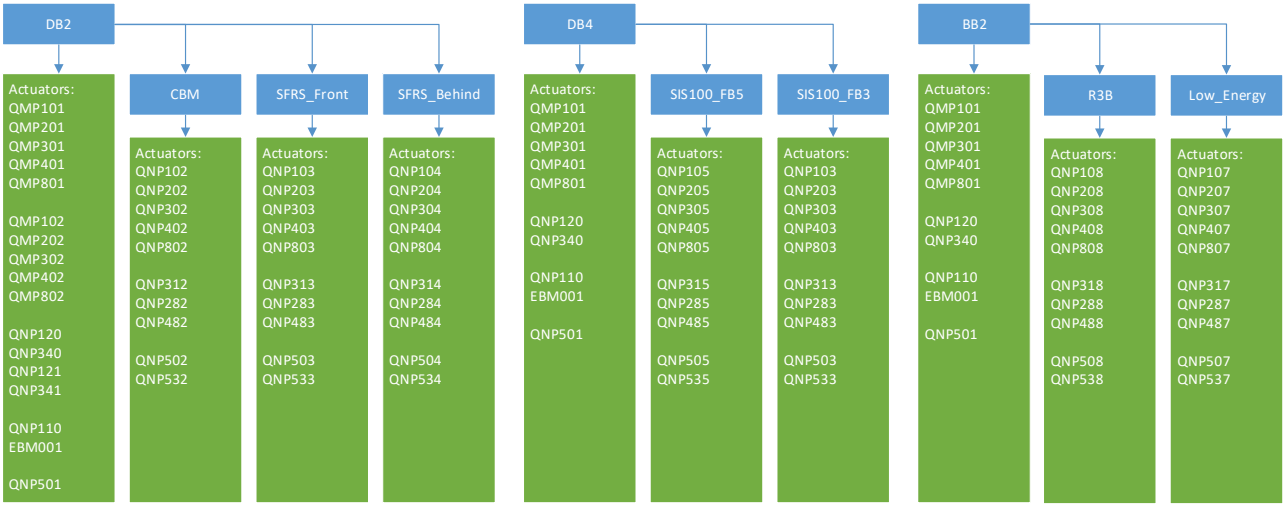

Figure 3: Hierarchy of the distribution system

2.3 Emergency stop procedure

The global safety (emergency stop button status) chain tripped only by pressing the emergency stop or a power failure/ shutdown. When this happen, the control system switch off the power to the cabinet. The PLC would shut off and the valves moves to the fail-safe position.

3. DB4

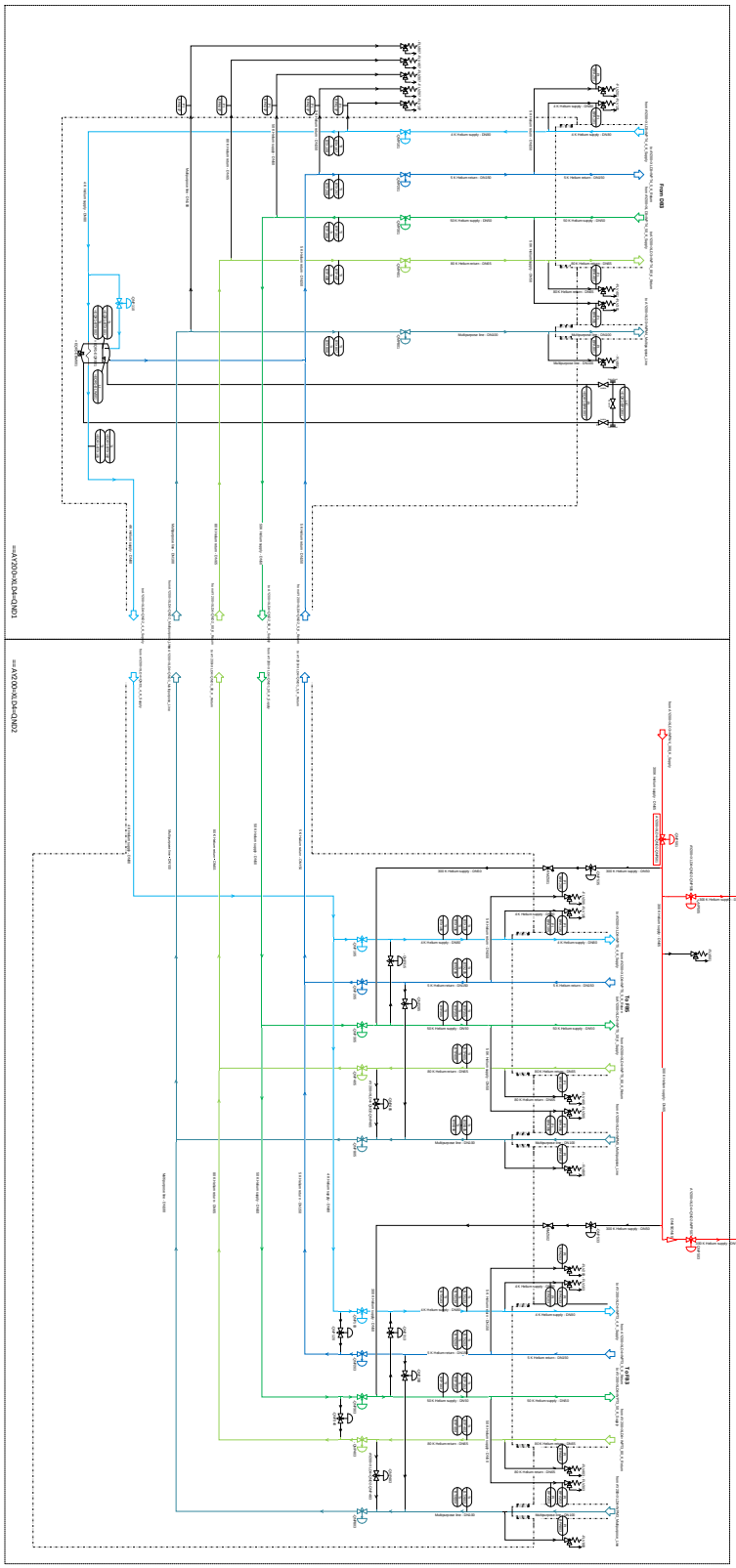

Figure 4: P&ID of distribution box 4[2]

[2] \\campus\groups\ACOGroup\Projects\IC\projects\Cryo\DS\docs\AY200=XLD4=QND0_Diag_V01.pdf

3.1 Controlled objects

3.1.1 Controlled units

- **SIS100_FB3**
- **SIS100_FB5**

3.1.2 Controlled actuators

- **QMP101:** On/Off 4 K Helium supply valve
- **QMP201:** On/Off 5 K Helium return valve
- **QMP301:** On/Off 50 K Helium supply valve
- **QMP401:** On/Off 80 K Helium return valve
- **QNP501:** Analog 300 K Helium supply valve
- **QMP801:** On/Off Multipurpose line valve

- **QNP110:** Analog Helium vessel valve
- **EBM001:** Helium vessel heater

- **QNP120:** Analog Bypass from 4 K supply to 5 K return
- **QNP340:** Analog Bypass from 50 K supply to 5 K return
-
- **QNP501:** Analog 300 K Helium supply valve

3.1.3 Controllers

- **QNP110_PID:** Joule Thomson valve controller of Helium Vessel
- **QNP340_PID:** Controller of Bypass from 50 K supply to 5 K return

3.1.4 Safety valve

- **FLV101**
- **FLV103**
- **FLV105**
- **FLV107**
- **FLV201**
- **FLV203**
- **FLV205**
- **FLV207**
- **FLV301**
- **FLV303**
- **FLV305**
- **FLV307**
- **FLV401**
- **FLV403**
- **FLV405**
- **FLV407**
- **FLV501**
- **FLV801**
- **FLV803**
- **FLV805**

- **FLV807**

3.2 Operational States

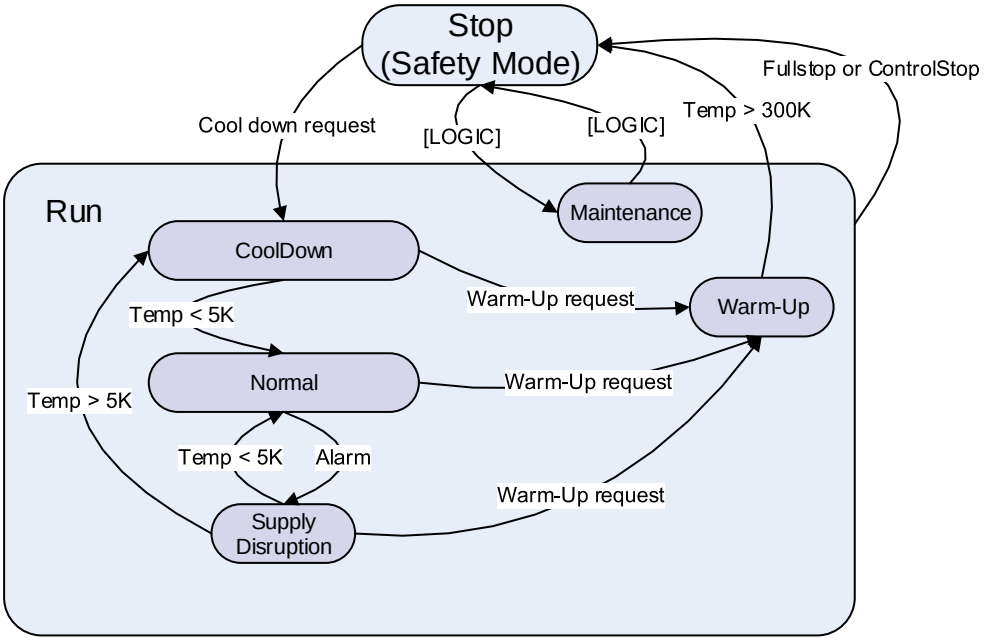

Figure 5: Process Control Diagram (State Diagram) of the distrubution box 4

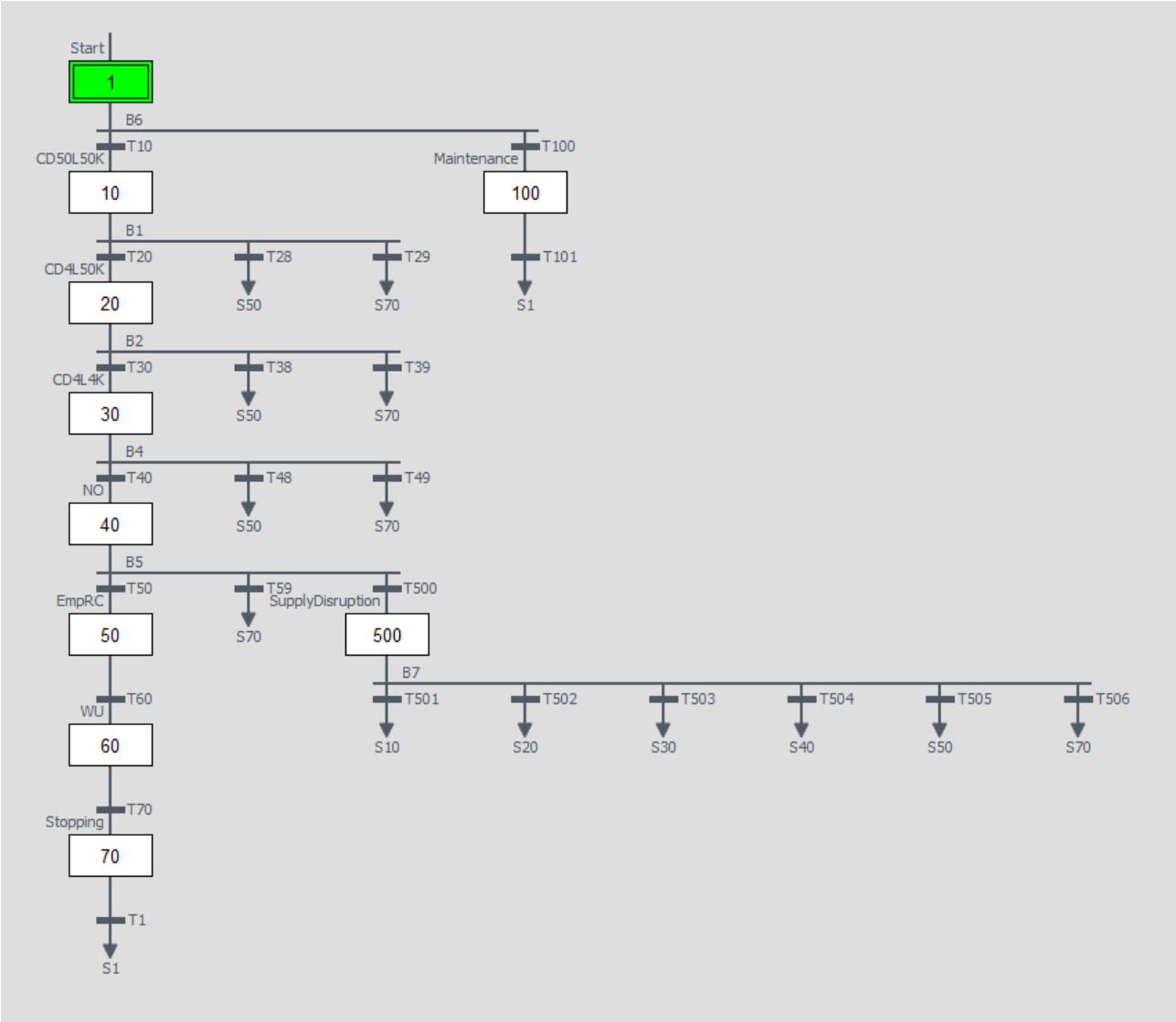

Figure 6: GRAFCET sequencer of the distribution box 4

3.2.1 Operational State definitions

Stop (Safety): The plant is stopped with all actuators in their fail-safe position.

Cool down: The plant is running and cool down all supply lines till normal operation reached.

Normal: The plant is supply FB3 and FB5 with helium. EBM001_PID is controlling to a vessel level.

Warm-Up: The plant warm up the supply lines to 300K.

SupplyDisruption: The plant is in an alarm step and waits for acknowledge.

Maintenance: The plant is in maintenance and operate only in force mode.

3.2.2 Transition conditions

T10: DB4 On Status AND

DB4 Run Order Status AND

DB4 Option Mode Status = 2 (Cool Down) AND

Interface DB3 cool-down shield to 50K (see interface table 1: Interface valve of DB3)

T20: BTX307 < 55K AND
BTX407 < 55K AND
Interface DB3 cool-down 4K line to 50K (see interface table 1: Interface valve of DB3)

T30: BTX107 < 55K AND
BTX207 < 55K AND
Interface DB3 cool-down 4K line to 4.5K (see interface table 1: Interface valve of DB3)

T40: Temperature of BTX107 < 5K AND
BTX207 < 5K AND
Interface DB3 normal operation (see interface table 1: Interface valve of DB3)

T50: DB4 Option Mode Status = 4 (Warm Up) AND
Interface DB3 warm up operation (see interface table 1: Interface valve of DB3)

T60: DB4 Option Mode Status = 4 (Warm Up) AND
EQR1BLW001_ML < 1%

T70: DB4 Control Stop Order Status OR
DB4 Automatic Control Stop Order Status OR
(BTX107 > 290K AND
BTX307 > 290K)

T1: DB4 Off Status AND
DB4 Option Mode Status = 1 (Stop)

T28, T38, T48, T455: DB4 Option Mode Status = 4 (Warm Up)
T29, T39, T49, T59, T506: DB4 Full Stop St OR
DB4 Control Stop Status

T500: DB4 Digital Alarm to Supply Disruption

T501: NOT DB4 Digital Alarm to Supply Disruption AND
BTX307 > 55K AND
BTX407 > 55K

T502: NOT DB4 Digital Alarm to Supply Disruption AND
BTX307 < 55K AND
BTX407 < 55K AND

BTX107 > 55K AND
BTX207 > 55K

T503: NOT DB4 Digital Alarm to Supply Disruption AND
BTX307 < 55K AND
BTX407 < 55K AND
BTX107 < 55K AND
BTX207 < 55K AND
BTX107 > 5K AND
BTX207 > 5K

T504: NOT DB4 Digital Alarm to Supply Disruption AND
BTX107 <= 5K AND
BTX207 <= 5K

3.2.3 Logical sequences

S1 (Stop):

All valves are in safety position.

S10 (Cool-Down 50K line (300K to 50K)):

Open valve QMP301, QMP401 and QMP340.

S20 (Cool-Down 4K line (300K to 50K)):

Open valve QMP101, QMP201 and QMP120.

S30 (Cool-Down 4K line (50K to 4K)):

Open valve QMP101, QMP201 and QMP120.

S40 (Normal operation):

Set PCO DB4 to Normal Mode. Control valve QNP110 to vessel level.

S50 (Empty re-cooler vessel):

Heater EBM001.

S60 (Warm-Up):

Controlled-Stop using warm gas from DB3.

S70 (Stopping):

Set DB4 PCO to Option Mode 1 (Stop) and turn off the PCO.

S500 (SupplyDisruption):

Hold DB4 after alarm to set back to the Steps S10, S20. S30, S40, S60 or S70.

S100 (Maintenance):

All valves are in fail-save position. Control only by force mode.

3.3 Actuators behaviour

Actuator	S1	S10	S20	S30	S40	S50	S60	S500	S100

QMP101	OFF		ON	ON	ON	ON	ON	ON	failsafe
QMP201	OFF		ON	ON	ON	ON	ON	ON	failsafe
QMP301	OFF	ON	ON	ON	ON	ON	ON	ON	failsafe
QMP401	OFF	ON	ON	ON	ON	ON	ON	ON	failsafe
QMP801	OFF				ON	ON	ON	ON	failsafe
QNP110	0%		100%	100%	Regulation: EQR1-BLD001 = 90%	0%	0%	10%	failsafe
EQR1-EBM001	0%				OFF	ON	0%	OFF	failsafe
QNP120	0%		100%	100%		100%	100%	10%	failsafe
QNP340	0%	100%	Regulation: BTX407 = 75K	100% (GGf mit Regulation = 75)		100%	100%	10%	failsafe
QNP501	0%	100%	100%	100%	100%	100%	100%	100%	failsafe

Table 1: Actuator behaviour of DB4

QMP101

- On Request If logical sequence S20, S30, S40, S50, S60, S500
- Off Request if DB4 = “Safety mode” AND S1

QMP201

- On Request If logical sequence S20, S30, S40, S50, S60, S500
- Off Request if DB4 = “Safety mode” AND S1

QMP301

- On Request If logical sequence S10, S20, S30, S40, S50, S500
- Off Request if DB4 = “Safety mode” AND S1

QMP401

- On Request If logical sequence S10, S20, S40, S50, S60, S500
- Off Request if DB4 = “Safety mode” AND S1

QMP801

- On Request If logical sequence S40, S50, S60, S500
- Off Request if DB4 = “Safety mode” AND S1

QNP110

- Position = 100% If logical sequence S20, S30
- Position = 10% If logical sequence S500
- Position = 0% if DB4 = “Safety mode” AND S1, S50, S60
- Regulated by QMP110_PID logical sequence S40

QNP120

- Position = 100% If logical sequence S10, S30, S50, S60
- Position = 10% If logical sequence S500
- Position = 0% if DB4 = “Safety mode” AND S1

QNP340

- Position = 100% If logical sequence S10, S20, S50, S60
- Position = 10% If logical sequence S500
- Position = 0% If “Safety mode” AND S1
- Regulated by QMP340_PID logical sequence S20

EQR1-EBM001

- Position = 100% If logical sequence S50
- Position = 0% if DB4 = “Safety mode” AND S1, S40, S500

QNP501

- Position = 100% If logical sequence NOT S1, S500
- Position = 0% If “Safety mode” AND S1

3.4 Regulation Loops

QNP110_PID

The controller is responsible to hold the level inside the cooler vessel.

- Controlled variable: EQR1-BLD001 (%)
- Controlled actuator: QNP110 (0-100%)
- Set-Point limits: 0 - 100 %
- Set-Point speed: 1 %/s
- Set-point = 90 % If S40 active, else tracking mode
- PID default parameters: Kc/Ti/Td = XX/XX s/0
- Split configuration: non
- Regulation mode: S40 active
- Output positioning mode: non

QNP340_PID

The controller is responsible to minimize the flow to shield while cooling down the 4K line to 50K.

- Controlled variable: BTX407 (K)
- Controlled actuator: QNP340 (0-100%)
- Set-Point limits: 50 – 80 K
- Set-Point speed: 1 K/s
- Set-point =75 K If S20 active, else tracking mode
- PID default parameters: Kc/Ti/Td = XX/XX s/0
- Split configuration: non
- Regulation mode: S20 active
- Output positioning mode: non

3.5 User commands

DB4 Cool down:
User decision to switch to use the PCO DB4 to cool down the plant
DB4 Warm-Up:
User decision to switch to use the PCO DB4 to warm-up the plant
DB4 Maintenance:
User decision to switch to use the PCO DB4 to warm-up the plant

3.6 Parameters

- **QNP110_AP:** AP of the PID QNP110_PID for the level set point
- **QNP340_AP:** AP of the PID QNP340_PID for the temperature set point

- **QNP501_DP:** DP of the analog object QNP510_Ana for 300K helium supply valve to switch the sensor from HART to 4 – 20mA

- **BTP407_DP:** DP of the BTP407 for temperature of PT100 to switch between main and redundant sensor
- **BTP807_DP:** DP of the BTP807 for temperature of PT100 to switch between main and redundant sensor

3.7 Interfaces

- **DB3:**
  - Valve positions:
    - ==AY200=XLD3=QND0-QNP140
    - ==AY200=XLD3=QND0-QNP240
    - ==AY200=XLD3=QND0-QNP340
    - ==AY200=XLD3=QND0-QNP440
    - ==AY200=XLD3=QND0-QNP840
    - ==AY200=XLD3=QND0-QNP341
    - ==AY200=XLD3=QND0-QNP241
    - ==AY200=XLD3=QND0-QNP441
    - ==AY200=XLD3=QND0-QNP842
  - Insolation vacuum:
    - Vacuum ok

Interface signal of the DB3 for the operation:

Standby	50K line to 50K	4K line to 50K	4K line to 4K	Normal operation	Warm up	Valve
			X	X		QNP140
				X		QNP240
	X	X	X	X		QNP340
		X	X	X		QNP440
			X			QNP840
		X			X	QNP341
		X	X		X	QNP241

	X				X	QNP441
	X	X		X	X	QNP845
					X	WarmGas

Table 2: : Interface valve of DB3

3.8 Computed Variables

Name, description	Type	Unit	Calculation
EQR1BLD001_ML Level in percent of the vessel EQR001	Real	%	EQR1-BLD001 := (Result of BPD001, BPA001)

QNP501_MGF_AS
Sensor of QNP501
	Real	%	IF QNP501_DP == FALSE THEN
			QNP501_MGF_AS := QNP501_MGF_HART
			ELSE
			QNP501_MGF_AS := QNP501_MGF_MEI

BTP407_AS
Sensor switch of BTP407 or BTP408
	Real	K	IF BTP407_DP == FALSE THEN
			BTP407_AS := BTP407_MT_K
			ELSE
			BTP407_AS := BTP408_MT_K

BTP807_AS
Sensor switch of BTP807 or BTP808
	Real	K	IF BTP807_DP == FALSE THEN
			BTP807_AS := BTP807_MT_K
			ELSE
			BTP807_AS := BTP808_MT_K

Table 3: Computed varables of DB4

3.9 Unit feedback

- **Feedback On =** PCO DB4 Run Order Status
- **Feedback Off =** NOT PCO DB4 Feedback On
- **Feedback Control Stop Fin =** DB4 sequence S1

3.10 Events

Name	Condition
Supply FB3	PCO SIS100_FB3 is in run
Supply FB5	PCO SIS100_FB5 is in run

Table 4: Events of DB4

3.11 Unit Alarms

Naming convention for alarms:

Description	Alarm name
Analog Alarms with a threshold on a sensor or computed-variable with relationship (reaction, alarm) to a Unit	Unitxxx_AA

	(Unit = name of Unit, xxx = type of AA)
Digital Alarm on DI or computed-variable with relationship to an Unit	Unitxxx_DA (Unit = name of Unit, xxx = type of DA)

Table 5: Naming convention for alarms of DB4

AA List for DB4:

NAME	MESSAGE	LOGIC FOR ALARM	LIMITS [HH;H;L;LL]	ACTION	DT [s]
EQR1BLW001_AA1	Level of EQR1 (SC) too low	Enable condition: DB4_Stp.NO.X OR DB4_Stp.SupplyDisruption.X	-,-,5,0 (in %)	AL(DB4),	
EQR1BLW001_AA2	Level of EQR1 (SC) too high	Enable condition: DB4_Stp.NO.X OR DB4_Stp.SupplyDisruption.X	90,80,-,- (in %)	AL(QNP110)	
EQR1BPA001_AA	Pressure of EQR1 too high	Enable condition: DB4_Stp.NO.X OR DB4_Stp.SupplyDisruption.X	2.2,2,-,- (in bar)	AL(QNP110),	
EQR1BPD001_AA	Diff.Pressure of EQR1 under low range		-,-,-,0 (in mbar)	AL(DB4)	
EQR1BLD001_AA1	Level of EQR1 (DP) too low	Enable condition: DB4_Stp.NO.X OR DB4_Stp.SupplyDisruption.X	-,-,5,0 (in %)	AL(DB4),	
EQR1BLD001_AA2	Level of EQR1 (DP) too high	Enable condition: DB4_Stp.NO.X OR DB4_Stp.SupplyDisruption.X	90,80,-,- (in %)	AL(QNP110)	
EQR1BTX001_AA	Temperature inside EQR1 too high	Enable condition: DB4_Stp.NO.X OR DB4_Stp.SupplyDisruption.X	5.2,5,-,- (in K)	AL(QNP110),	
EQR1BTX101_AA	Temperature after EQR1 too high	Enable condition: DB4_Stp.NO.X OR DB4_Stp.SupplyDisruption.X	5,4.8,-,- (in K)	AL(DB4)	
EQR1EBM001BTC_AA	Temperature of EQR1 heater too high		20,0,-,- (in C)	FS(EQR1EBM001)	
BPA101_AA	Pressure of 4K supply too high	Enable condition: DB4_Stp.NO.X OR DB4_Stp.SupplyDisruption.X	6,5,-,- (in bar)	AL(QMP101_OO)	
BPA107_AA	Pressure of 4K supply too high	Enable condition: DB4_Stp.NO.X OR	6,5,-,- (in bar)	AL(QMP101_OO)	

		DB4_Stp.SupplyDisruption.X			
BPA201_AA	Pressure of 5K return too high	Enable condition: DB4_Stp.NO.X OR DB4_Stp.SupplyDisruption.X	2,1.5,- (in bar)	AL(DB4)	
BPA207_AA	Pressure of 5K return too high	Enable condition: DB4_Stp.NO.X OR DB4_Stp.SupplyDisruption.X	2,1.5,- (in bar)	AL(DB4)	
BPA301_AA	Pressure of 50K supply too low	Enable condition: DB4_Stp.NO.X OR DB4_Stp.SupplyDisruption.X	-,-,12,10 (in bar)	AL(QMP301_OO)	
BPA307_AA	Pressure of 50K supply too low	Enable condition: DB4_Stp.NO.X OR DB4_Stp.SupplyDisruption.X	-,-,12,10 (in bar)	AL(QMP301_OO)	
BPA401_AA	Pressure of 80K return too low	Enable condition: DB4_Stp.NO.X OR DB4_Stp.SupplyDisruption.X	-,-,12,10 (in bar)	AL(DB4)	
BPA407_AA	Pressure of 80K return too low	Enable condition: DB4_Stp.NO.X OR DB4_Stp.SupplyDisruption.X	-,-,12,10 (in bar)	AL(DB4)	
BPA801_AA	Pressure of MPL	BPA801	,,,	-	
BPA807_AA	Pressure of MPL	BPA807	,,,	-	
BTX107_AA	Temperature of 4K supply to high	Enable condition: DB4_Stp.NO.X OR DB4_Stp.SupplyDisruption.X	5.5,5,-,- (in K)	AL(DB4)	
BTX207_AA	Temperature of 5K return to high	Enable condition: DB4_Stp.NO.X OR DB4_Stp.SupplyDisruption.X	5.5,5,-,- (in K)	AL(DB4)	
BTP307_AA	Temperature of 50K supply Info: High load for 4K supply -> close 4K supply	Enable condition: DB4_Stp.NO.X OR DB4_Stp.SupplyDisruption.X	60,55,-,- (in K)	AL(DB4)	
BTX407_AA	Temperature of 80K return Only info for the operator	Enable condition: DB4_Stp.NO.X OR DB4_Stp.SupplyDisruption.X	90,85,, (in K)	AL(DB4)	
BTX807_AA	Temperature of MPL	BTX807	,,,		

Table 6: AA list of DB4

**FS = Full Stop Interlock; TS = Temporary Stop Interlock; SI=Start Interlock; AL=Alarm*

DA List for DB4:

NAME	MESSAGE	LOGIC FOR ALARM	ACTION	DT [s]
VAC_Ok_DA	Insolation vacuum ok	VAC_Ok	FS(DB4)	
DB4_SupplyDisruption_DA	Matrix for the supply disruption of DB4	EQR1BLW001_AA1.ISt OR EQR1BPA001_AA.ISt OR EQR1BLD001_AA1.ISt OR EQR1BTX001_AA.ISt OR EQR1BTX101_AA.ISt OR BPA101_AA.ISt OR BPA107_AA.ISt OR BPA201_AA.ISt OR BPA207_AA.ISt OR BPA301_AA.ISt OR BPA307_AA.ISt OR BPA401_AA.ISt OR BPA407_AA.ISt OR BTX107_AA.ISt OR BTX207_AA.ISt OR BTP307_AA.ISt	AL(DB4)	
EQR1BLW001_DA1	Level of EQR1 (SC) too low	EQR1BLW001_AA1.ISt OR (EQR1BLW001_DA1.ISt AND EQR1BLW001_AA1.WSt)	AL(DB4),	
EQR1BLW001_DA2	Level of EQR1 (SC) too high	EQR1BLW001_AA2.ISt OR (EQR1BLW001_DA2.ISt AND EQR1BLW001_AA2.WSt)	FS(QNP110)	
EQR1BPA001_DA	Pressure of EQR1 too high	EQR1BPA001_AA.ISt OR (EQR1BPA001_DA.ISt AND EQR1BPA001_AA.WSt)	FS(QNP110) ,	
EQR1BPD001_DA	Diff.Pressure of EQR1 under low range	EQR1BPD001_AA.ISt OR (EQR1BPD001_DA.ISt AND EQR1BPD001_AA.WSt)	AL(DB4)	
EQR1BLD001_DA1	Level of EQR1 (DP) too low	EQR1BLD001_AA1.ISt OR (EQR1BLD001_DA1.ISt AND EQR1BLD001_AA1.WSt)	AL(DB4),	

EQR1BLD001_DA2	Level of EQR1 (DP) too high	EQR1BLD001_AA2.ISt OR (EQR1BLD001_DA2.ISt AND EQR1BLD001_AA2.WSt)	FS(QNP110)	
EQR1BTX001_DA	Temperature inside EQR1 too high	EQR1BTX001_AA.ISt OR (EQR1BTX001_DA.ISt AND EQR1BTX001_AA.WSt)	FS(QNP110) ,	
EQR1BTX101_DA	Temperature after EQR1 too high	EQR1BTX101_AA.ISt OR (EQR1BTX101_DA.ISt AND EQR1BTX101_AA.WSt)	AL(DB4)	
EQR1EBM001BTC_DA	Temperature of EQR1 heater too high	EQR1EBM001BTC _AA.ISt OR (EQR1EBM001BTC _DA.ISt AND EQR1EBM001BTC _AA.WSt)	FS(EQR1EBM001)	
BPA101_DA	Pressure of 4K supply too high	BPA101_AA.ISt OR (BPA101_DA.ISt AND BPA101_AA.WSt)	FS(QMP101_OO)	
BPA107_DA	Pressure of 4K supply too high	BPA107_DA_AA.ISt OR (E BPA107_DA_DA.ISt AND BPA107_DA_AA.WSt)	FS(QMP101_OO)	
BPA201_DA	Pressure of 5K return too high	BPA201_AA.ISt OR (BPA201_DA.ISt AND BPA201_AA.WSt)	AL(DB4)	
BPA207_DA	Pressure of 5K return too high	BPA207_AA.ISt OR (BPA207_DA.ISt AND BPA207_AA.WSt)	AL(DB4)	
BPA301_DA	Pressure of 50K supply too low	BPA301_AA.ISt OR (BPA301_DA.ISt AND BPA301_AA.WSt)	FS(QMP301_OO)	
BPA307_DA	Pressure of 50K supply too low	BPA307_AA.ISt OR (BPA307_DA.ISt AND BPA307_AA.WSt)	FS(QMP301_OO)	
BPA401_DA	Pressure of 80K return too low	BPA401_AA.ISt OR (BPA401_DA.ISt AND BPA401_AA.WSt)	AL(DB4)	
BPA407_DA	Pressure of 80K return too low	BPA407_AA.ISt OR (BPA407_DA.ISt AND BPA407_AA.WSt)	AL(DB4)	
BPA801_DA	Pressure of MPL	BPA801_AA.ISt OR (BPA801_DA.ISt AND BPA801_AA.WSt)	-	

BPA807_DA	Pressure of MPL	BPA807_AA.ISt OR (BPA807_DA.ISt AND BPA807_AA.WSt)	-	
BTX107_DA	Temperature of 4K supply to high	BTX107.ISt OR (BTX107_DA.ISt AND BTX107_AA.WSt)	AL(DB4)	
BTX207_DA	Temperature of 5K return to high	BTX207_AA.ISt OR (E BTX207_DA.ISt AND BTX207_AA.WSt)	AL(DB4)	
BTP307_DA	Temperature of 50K supply Info: High load for 4K supply -> close 4K supply	BTP307_AA.ISt OR (E BTP307_DA.ISt AND BTP307_AA.WSt)	AL(DB4)	
BTX407_DA	Temperature of 80K return	BTX407_AA.ISt OR (BTX407_DA.ISt AND BTX407_AA.WSt)		
BTX807_DA	Temperature of MPL	BTX807_AA.ISt OR (BTX807_DA.ISt AND BTX807_AA.WSt)		

Table 7: DA list of DB4

**FS = Full Stop Interlock; TS = Temporary Stop Interlock; SI=Start Interlock; AL=Alarm*

4. FB3

4.1 Controlled objects

4.1.1 Controlled actuators

- **QNP103:** Analog 4 K Helium supply valve
- **QNP203:** Analog 5 K Helium return valve
- **QNP303:** Analog 50 K Helium supply valve
- **QNP403:** Analog 80 K Helium return valve
- **QNP803:** Analog Multipurpose line valve

- **QNP313:** Analog Bypass from 4 K supply to 50 K supply
- **QNP283:** Analog Bypass from 5 K return to MPL
- **QNP483:** Analog Bypass from 80 K return to MPL

- **QNP503:** Analog 300 K Helium supply valve
- **QNP533:** Analog 300 K Helium supply valve

4.2 Operational States

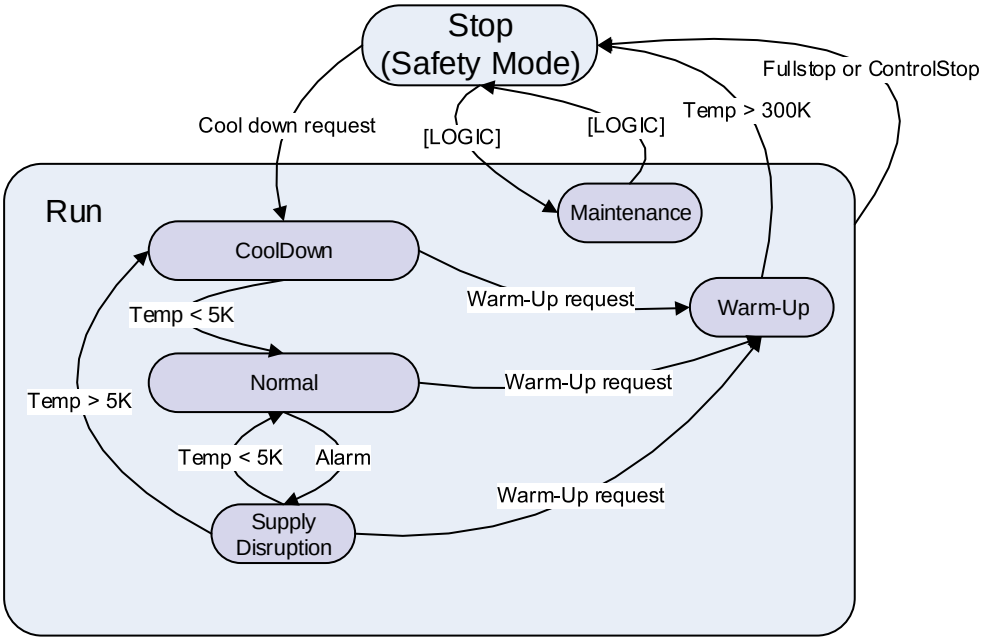

Figure 7: Process Control Diagram (State Diagram) of the FB3 of SIS100 supply

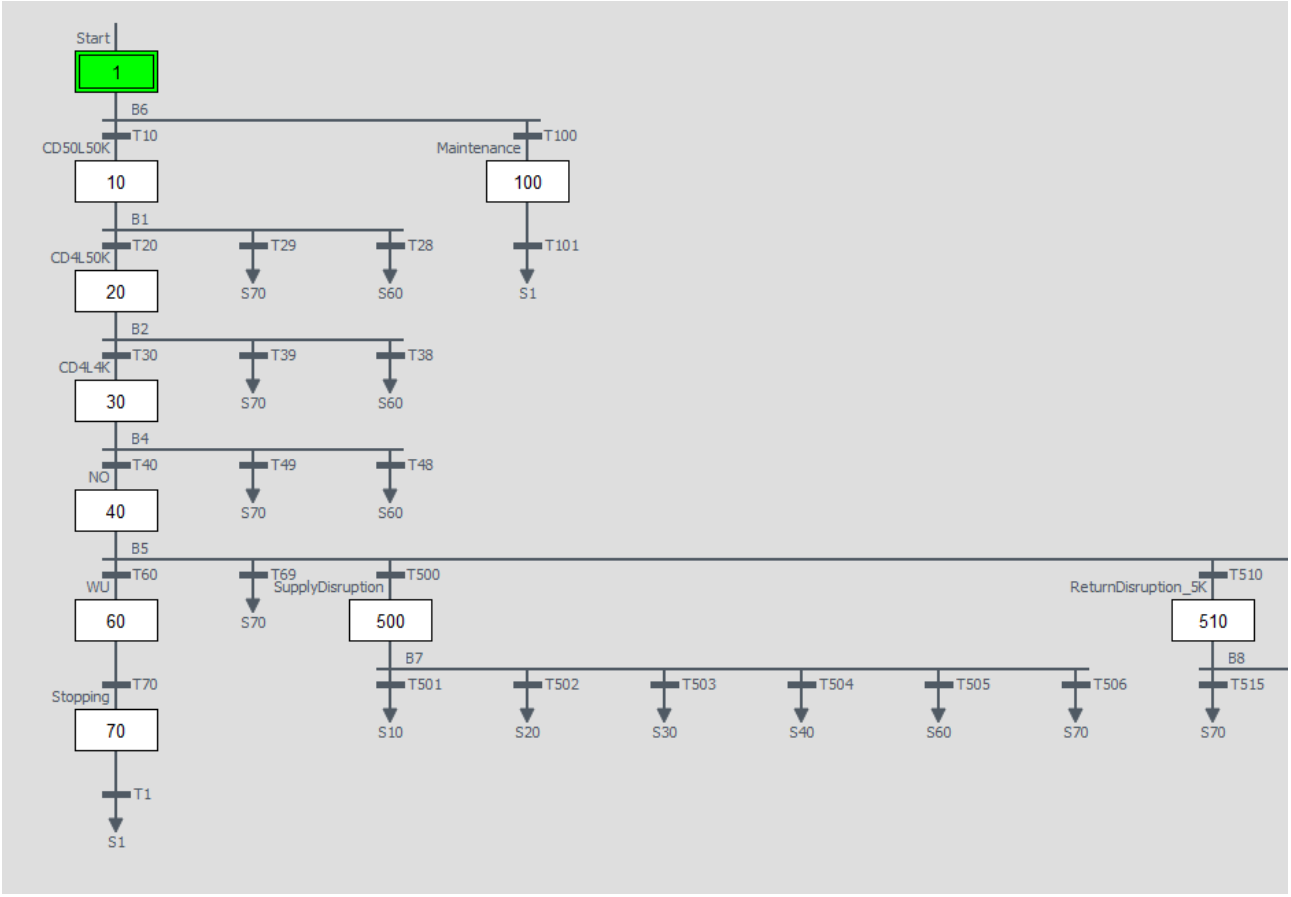

Figure 8: GRAFCET sequencer of the FB3 of SIS100 supply (1/2)

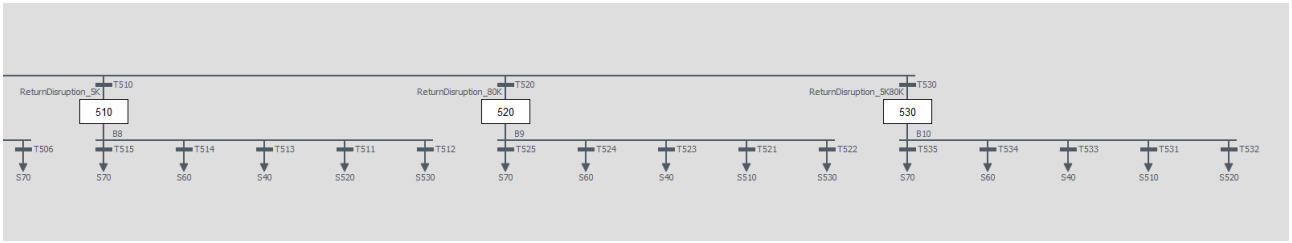

Figure 9: GRAFCET sequencer of the FB3 of SIS100 supply (2/2)

4.2.1 Operational State definitions

Stop (Safety): The plant is stopped with all actuators in their fail-safe position.
Cool down: The plant is running and cool down all supply lines till normal operation reached.

Normal: The plant is supply FB3 and FB5 with helium. EBM001_PID is controlling to a vessel level.

Warm-Up: The plant warm up the supply lines to 300K.

SupplyDisruption: The plant is in an alarm step and waits for acknowledge.

Maintenance: The plant is in maintenance and is con not be operate.

4.2.2 Transition conditions

T10: FB3 On Status AND

FB3 Option Mode Status = 2 (Cool Down) AND

DB4 Option Mode Status = 3 (Normal Operation)

T20: BTP403 < 55K

T30: BTX203 < 55K

T40: BTX203 < 5K

T50: FB3 Option Mode Status = 4 (Warm-Up)

T70: BTX203 > 290K AND
BTX403 > 290K

T28, T38, T48: FB3 Option Mode Status = 4 (Warm-Up)

T29, T39, T49, T59: FB3 Control Stop Order Status OR
FB3 Automatic Control Stop Order Status OR
DB4 Control Stop Order Status OR
DB4 Automatic Control Stop Order Status

T500: DB4SupplyDisruption_DA.Ist

(Should be discuss with SIS100){
T501: NOT DB4 Digital Alarm to Supply Disruption AND
BTX307 > 55K AND
BTX407 > 55K

T502: NOT DB4 Digital Alarm to Supply Disruption AND
BTX307 < 55K AND
BTX407 < 55K AND
BTX107 > 55K AND
BTX207 > 55K

T503: NOT DB4 Digital Alarm to Supply Disruption AND
BTX307 < 55K AND
BTX407 < 55K AND
BTX107 < 55K AND
BTX207 < 55K AND
BTX107 > 5K AND
BTX207 > 5K

T504: NOT DB4 Digital Alarm to Supply Disruption AND
BTX107 <= 5K AND
BTX207 <= 5K
}

T510: FB3ReturnDisruption_5K_DA.Ist
T520: FB3ReturnDisruption_80K_DA.Ist
T530: FB3ReturnDisruption_5K80K_DA.Ist

T511: NOT FB3ReturnDisruption_5K_DA.Ist AND
FB3ReturnDisruption_80K_DA.Ist
T512: FB3ReturnDisruption_5K_DA.Ist AND
FB3ReturnDisruption_80K_DA.Ist
T513: NOT FB3ReturnDisruption_5K_DA.Ist AND
NOT FB3ReturnDisruption_80K_DA.Ist
T514: FB3 Option Mode Status = 4 (Warm Up)
T515: FB3 Control Stop Order Status OR
FB3 Automatic Control Stop Order Status

T521: FB3ReturnDisruption_5K_DA.Ist AND
NOT FB3ReturnDisruption_80K_DA.Ist
T522: FB3ReturnDisruption_5K_DA.Ist AND
FB3ReturnDisruption_80K_DA.Ist
T523: NOT FB3ReturnDisruption_5K_DA.Ist AND
NOT FB3ReturnDisruption_80K_DA.Ist
T524: FB3 Option Mode Status = 4 (Warm Up)
T525: FB3 Control Stop Order Status OR
FB3 Automatic Control Stop Order Status

T531: FB3ReturnDisruption_5K_DA.Ist AND
NOT FB3ReturnDisruption_80K_DA.Ist
T532: NOT FB3ReturnDisruption_5K_DA.Ist AND
FB3ReturnDisruption_80K_DA.Ist
T533: NOT FB3ReturnDisruption_5K_DA.Ist AND
NOT FB3ReturnDisruption_80K_DA.Ist
T534: FB3 Option Mode Status = 4 (Warm Up)
T535: FB3 Control Stop Order Status OR
FB3 Automatic Control Stop Order Status

4.2.3 Logical sequences

S1 (Stop):

All valves are in safety position.

S10 (Cool-Down 50K line (300K to 50K)):

Open valve QNP303, QNP803 and QNP483.

S20 (Cool-Down 4K line (300K to 50K)):

Open valve QNP303, QNP403, QNP803 and QNP313.

Close valve QNP483.

S30 (Cool-Down 4K line (50K to 4K)):

Open valve QNP103, QNP303, QNP403, QNP803 and QNP283.

Close valve QNP203, QNP313 and QNP483.

S40 (Normal operation):

Set PCO FB3 to Normal Mode.

Open valve QNP103, QNP203, QNP303, QNP403, QNP803 and QNP503.

Close valve QNP313, QNP283 and QNP483.

S60 (Warm-Up):

Close QNP103, QNP203, QNP303 and QNP403 and QNP503.

Open QNP803, QNP313, QNP283, QNP483 and QNP533.

S100 (Maintenance):

All valves are in fail-save position. Control only by force mode.

S500 (SupplyDisruption):

Hold FB3 after alarm to set back to the Steps S10, S20. S30, S40, S60 or S70.

S510 (5K_Return_Disruption):

Hold FB3 after alarm for 5K return disruption.

S520 (80K_Return_Disruption):

Hold FB3 after alarm for 80K return disruption.

S530 (5K80K_Return_Disruption):

Hold FB3 after both alarm of return disruption is active.

4.3 Actuators behaviour

Actuator	S1	S10	S20	S30	S40	S60	S500	S100	S510	S520	S530
QNP103	OFF			ON	ON	OFF	OFF	failsafe	ON	ON	ON
QNP203	OFF			OFF	ON	OFF	OFF	failsafe	OFF	ON	OFF
QNP303	OFF	ON	ON	ON	ON	OFF	OFF	failsafe	ON	ON	ON
QNP403	OFF		ON	ON	ON	OFF	OFF	failsafe	ON	OFF	OFF
QNP803	OFF	ON	ON	ON	ON	ON	OFF	failsafe	ON	ON	ON
QNP313	OFF		ON	OFF	OFF	ON	OFF	failsafe	OFF	OFF	OFF
QNP283	OFF		ON	ON	OFF	ON	OFF	failsafe	ON	OFF	ON

QNP483	OFF	ON	OFF	OFF	OFF	ON	OFF	failsafe	OFF	ON	ON
QNP533	OFF					ON	OFF	failsafe	OFF	OFF	OFF
QNP503	OFF				ON	OFF	OFF	failsafe	ON	ON	ON

Table 8: Actuator behaviour of FB3

QNP103

Describe here the Analog actuator behaviour.

- Position = 100% If logical sequence S30, S40, S410, S420, S530
- Position = 0% if FB3 = “Safety mode” AND S1, S60, S500

QNP203

Describe here the Analog actuator behaviour.

- Position = 100% If logical sequence S40, S520
- Position = 0% if FB3 = “Safety mode” AND S1, S30, S60, S500, S510, S530

QNP303

Describe here the Analog actuator behaviour.

- Position = 100% If logical sequence S10, S20, S30, S40, S510, S520, S530
- Position = 0% if FB3 = “Safety mode” AND S1, S60, S500

QNP403

Describe here the Analog actuator behaviour.

- Position = 100% If logical sequence S20, S30, S40, S510
- Position = 0% if FB3 = “Safety mode” AND S1, S60, S500, S520, S530

QNP803

Describe here the Analog actuator behaviour.

- Position = 100% If logical sequence S10, S20, S30, S40, S60, S510, S520, S530
- Position = 0% if FB3 = “Safety mode” AND S1, S500

QNP313

Describe here the Analog actuator behaviour.

- Position = 100% If logical sequence S20, S60
- Position = 0% if FB3 = “Safety mode” AND S1, S30, S40, S500, S510, S520, S530

QNP283

Describe here the Analog actuator behaviour.

- Position = 100% If logical sequence S30, S60, S510, S530
- Position = 0% if FB3 = “Safety mode” AND S1, S40, S500, S520

QNP483

Describe here the Analog actuator behaviour.

- Position = 100% If logical sequence S10, S60, S520, S530
- Position = 0% if FB3 = “Safety mode” AND S1, S20, S30, S40, S500, S510

QNP503

Describe here the Analog actuator behaviour.

- Position = 100% If logical sequence S40, S410, S420, S430
- Position = 0% if FB3 = “Safety mode” AND S1, S60, S500

QNP533

Describe here the Analog actuator behaviour.

- Position = 100% If logical sequence S60
- Position = 0% if FB3 = “Safety mode” AND S1, S500, S510, S520, S530

4.4 User commands

- **FB3 Stop:**
  Start/Safety position of the plant.
- **FB3 Cool down:**
  User decision to switch to use the PCO SIS100_FB3 to cool down the plant
- **FB3 Normal Operation:**
  Code control the PCO SIS100_FB3 from Cool down to Normal Mode
- **FB3 Warm-Up:**
  User decision to switch to use the PCO SIS100_FB3 to warm-up the plant

4.5 Unit feedback

- **Feedback On =** PCO SIS100_FB3 not in option mode Stop
- **Feedback Off =** All valves are in safety position
- **Feedback Control Stop Fin =** All valves are in safety position

4.6 Unit Alarms

Naming convention for alarms:

Description	Alarm name
Analog Alarms with a threshold on a sensor or computed-variable with relationship (reaction, alarm) to a Unit	Unitxxx_AA (Unit = name of Unit, xxx = type of AA)
Digital Alarm on DI or computed-variable with relationship to an Unit	Unitxxx_DA (Unit = name of Unit, xxx = type of DA)

Table 9: Naming convention for alarms of FB3

AA List for SIS100_FB3:

NAME	MESSAGE	LOGIC FOR ALARM	LIMITS [HH;H;L;LL]	ACTION	DT [s]
BPA103_AA	Pressure of 4K supply to high	Enable condition: FB3_Stp.NO.X OR	6,5,, (in bar)	AL (FB3)	1

		FB3_Stp.SupplyDisruption.X			
BPA133_AA	Pressure of 4K supply too high	Normal operation step or disruptions steps of FB3	6,5,, (in bar)	AL (FB3)	1
BPA203_AA	Pressure of 5K return too high	Normal operation step or disruptions steps of FB3	2,1.5,,	AL (FB3)	1
BPA303_AA	Pressure of 50K supply too low	Normal operation step or disruptions steps of FB3	-,-,12,10 (in bar)	AL(FB3)	1
BPA353_AA	Pressure of 50K supply too low	Normal operation step or disruptions steps of FB3	-,-,12,10 (in bar)	AL(FB3)	1
BPA403_AA	Pressure of 80K return too low	Normal operation step or disruptions steps of FB3	-,-,12,10 (in bar)	AL(FB3)	1
BPA803_AA	Pressure of MPL		,,,		
BTX103_AA	Temperature of 4K supply too high	Normal operation step or disruptions steps of FB3	5.5,5,-,- (in K)	AL(FB3)	1
BTX133_AA	Temperature of 4K supply too high	Normal operation step or disruptions steps of FB3	5.5,5,-,- (in K)	AL(FB3)	1
BTX203_AA	Temperature of 5K return too high	Normal operation step or disruptions steps of FB3	5.5,5,-,- (in K)	AL(FB3)	1
BTX303_AA	Temperature of 50K supply too high	Normal operation step or disruptions steps of FB3	60,55,-,- (in K)	AL(FB3)	1
BTX353_AA	Temperature of 50K supply too high	Normal operation step or disruptions steps of FB3	60,55,-,- (in K)	AL(FB3)	1
BTX403_AA	Temperature of 80K return too high	Normal operation step or disruptions steps of FB3	90,85,, (in K)	AL(FB3)	1
BTX803_AA	Temperature of MPL		,,,		

Table 10: AA list for FB3

**FS = Full Stop Interlock; TS = Temporary Stop Interlock; SI=Start Interlock; AL=Alarm*

DA List for DB4:

NAME	MESSAGE	LOGIC FOR ALARM	ACTION	DT [s]
FB3Interface_DA	Feedback from FB3		AL(FB3)	
FB3ReturnDisruption_5K_DA	Matrix for the return disruption of 5K for FB3	BPA203_AA.ISt OR BTX203_AA.ISt	AL(FB3)	
FB3ReturnDisruption_80K_DA	Matrix for the return disruption of 80K for FB3	BPA403_AA.ISt OR BTX403_AA.ISt	AL(FB3)	
FB3ReturnDisruption_5K80K_DA	Matrix for the return disruption of 5K and 80K for FB3	5K_ReturnDisruption_DA.ISt AND 80K_ReturnDisruption_DA.ISt	AL(FB3)	

Table 11: DA List for FB3

**FS = Full Stop Interlock; TS = Temporary Stop Interlock; SI=Start Interlock; AL=Alarm*

5. DB2

(Insert picture of DB2 here)

Figure 10: P&ID of distribution box 4[3]

5.1 Controlled objects

5.1.1 Controlled units

- **CBM**
- **SFRS_Front**
- **SFRS_Behind**

5.1.2 Controlled actuators

- **QMP101:** On/Off 4 K Helium supply valve
- **QMP201:** On/Off 5 K Helium return valve
- **QMP301:** On/Off 50 K Helium supply valve
- **QMP401:** On/Off 80 K Helium return valve
- **QMP801:** On/Off Multipurpose line valve
-
- **QMP102:** On/Off 4 K Helium supply valve
- **QMP202:** On/Off 5 K Helium return valve
- **QMP302:** On/Off 50 K Helium supply valve
- **QMP402:** On/Off 80 K Helium return valve
- **QMP802:** On/Off Multipurpose line valve
-
- **QNP110:** Analog Helium vessel valve
- **EBM001:** Helium vessel heater

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-
- **QNP120:** Analog Bypass from 4 K supply to 5 K return
- **QNP340:** Analog Bypass from 50 K supply to 5 K return
- **QNP121:** Analog Bypass from 4 K supply to 5 K return
- **QNP341:** Analog Bypass from 50 K supply to 5 K return
-
- **QNP501:** Analog 300 K Helium supply valve

5.1.3 Controllers

- **QNP110_PID:** Joule Thomson valve controller of Helium Vessel
- **QNP340_PID:** Joule Thomson valve controller of Bypass from 50 K supply to 5 K return
- **QNP341_PID:** Joule Thomson valve controller of Bypass from 50 K supply to 5 K return

5.1.4 Safety valve

- **????**

5.2 Operational States

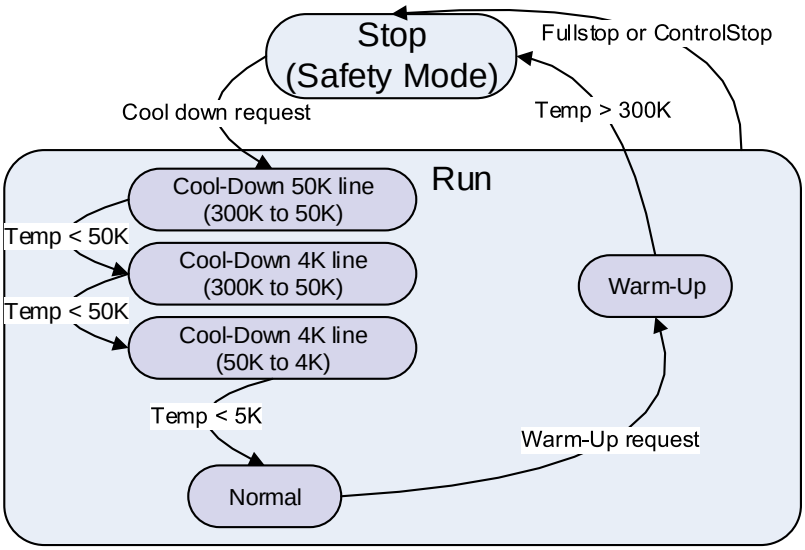

Figure 11: Process Control Diagram (State Diagram) of the distrubution box 4

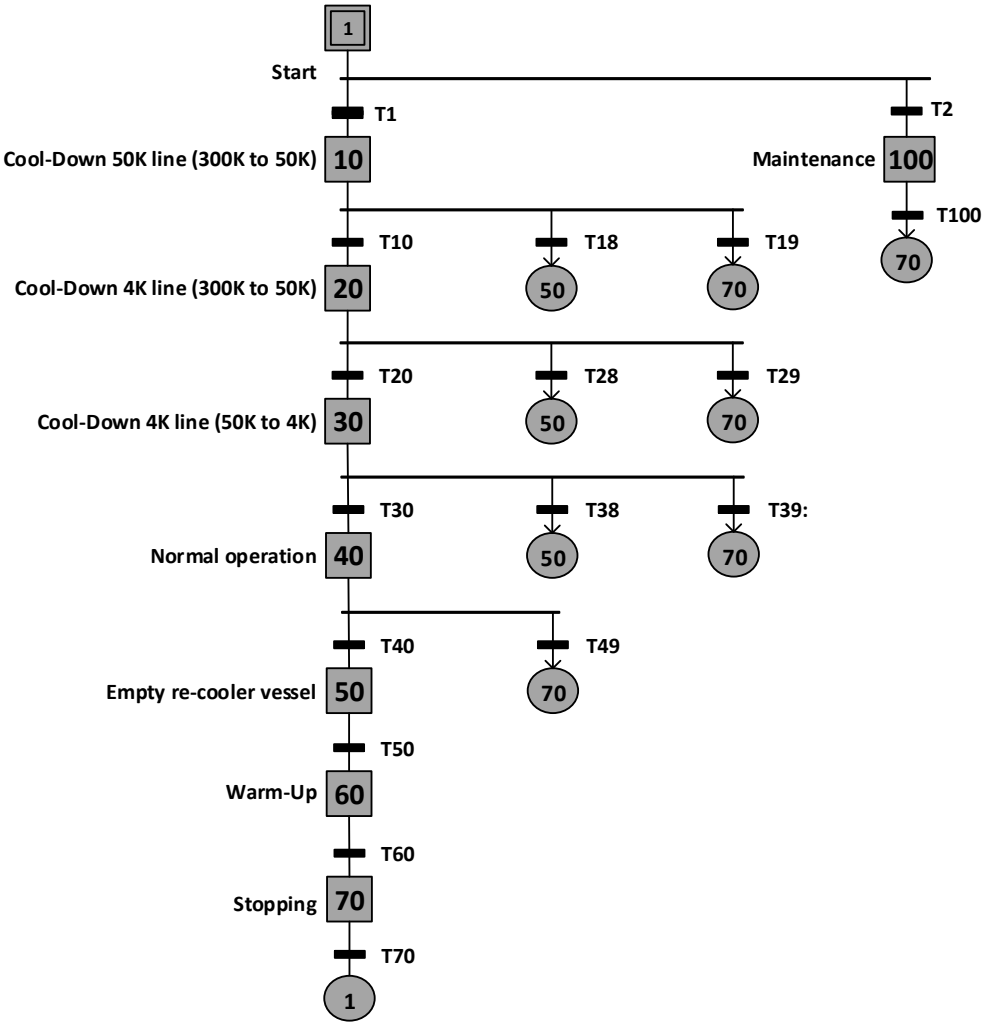

Figure 12: GRAFCET sequencer of the distribution box 4

5.2.1 Operational State definitions

Stop (Safety): The plant is stopped with all actuators in their fail-safe position.

Cool down: The plant is running and cool down all supply lines till normal operation reached.

Normal: The plant is supply CBM, SFRS_Front and SFRS_Behind with helium. EBM001_PID is controlling to a vessel level.

Warm-Up: The plant warm up the supply lines to 300K.

5.2.2 Transition conditions

T1: DB2.OnR = true AND

DB2.OpMoSt = 2 AND

Interface DB3 cool-down shield to 50K (see interface table 1: Interface valve of DB3).

T10: Temperature of BTX307 < 55K AND

BTX407 < 55K AND

Interface DB3 cool-down 4K line to 50K (see interface table 1: Interface valve of DB3).

T20: Temperature of BTX107 < 55K AND BTX207 < 55K AND
Interface DB3 cool-down 4K line to 4.5K (see interface table 1: Interface valve of DB3).
T30: Temperature of BTX107 < 5K AND
BTX207 < 5K AND
Interface DB3 normal operation (see interface table 1: Interface valve of DB3).
T40: Warm-Up request from PCO DB2 AND
Interface DB3 warm up operation (see interface table 1: Interface valve of DB3).
T50: Warm-Up request from PCO DB2 AND
EQR1BLW001_ML.PosSt < 1
T60: Temperature of BTX107 AND BTX307 > 300K.
T70: Temperature of BTX107 and BTX307 > 300K.
T18, T28, T38: Warm-Up request from PCO DB2.
T19, T29, T39, T49: Interlock or ControlStop of PCO DB2.

5.2.3 Logical sequences

S1 (Stop):

All valves are in safety position.

S10 (Cool-Down 50K line (300K to 50K)):

Open valve QMP301, QMP401 and QMP340.

S20 (Cool-Down 4K line (300K to 50K)):

Open valve QMP101, QMP201 and QMP120.

S30 (Cool-Down 4K line (50K to 4K)):

Open valve QMP101, QMP201 and QMP120.

S40 (Normal operation):

Set PCO DB4 to Normal Mode. Control valve QNP110 to vessel level.

S50 (Empty re-cooler vessel):

Heater EBM001.

S55 (Warm-Up):

Controlled-Stop using warm gas from DB3

5.3 Actuators behaviour

Actuator	S1	S10	S20	S30	S40	S50	S55
QMP101	OFF		ON	ON	ON	ON	ON
QMP201	OFF		ON	ON	ON	ON	ON
QMP301	OFF	ON	ON	ON	On	On	On
QMP401	OFF	ON	ON	ON	ON	ON	ON
QMP801	OFF				ON	ON	ON
QMP102	OFF		ON	ON	ON	ON	ON

QMP202	OFF		ON	ON	ON	ON	ON
QMP302	OFF	ON	ON	ON	On	On	On
QMP402	OFF	ON	ON	ON	ON	ON	ON
QMP802	OFF				ON	ON	ON
QNP110	0%		100%	100%	Regulation: EQR1-BLD001 = 90%	0%	0%
EQR1-EBM001	0%				OFF	ON	0%
QNP120	0%		ON100%	100%		100%	100%
QNP340	0%	100%	Regulation: BTX407 = 75K	100%		100%	100%
QNP121	0%		ON100%	100%		100%	100%
QNP341	0%	100%	Regulation: BTX407 = 75K	100%		100%	100%
QNP501	0%	100%	100%	100%	100%	100%	100%

QMP101

- On Request If logical sequence S20, S30, S40, S50, S55
- Off Request if DB4 = “Safety mode” AND S1

QMP201

- On Request If logical sequence S20, S30, S40, S50, S55
- Off Request if DB4 = “Safety mode” AND S1

QMP301

- On Request If logical sequence S10, S20, S30, S40, S50, S55
- Off Request if DB4 = “Safety mode” AND S1

QMP401

- On Request If logical sequence S10, S20, S40, S50, S55
- Off Request if DB4 = “Safety mode” AND S1

QMP801

- On Request If logical sequence S40, S50, S55
- Off Request if DB4 = “Safety mode” AND S1

QMP102

- On Request If logical sequence S20, S30, S40, S50, S55
- Off Request if DB4 = “Safety mode” AND S1

QMP202

- On Request If logical sequence S20, S30, S40, S50, S55
- Off Request if DB4 = “Safety mode” AND S1

QMP302

- On Request If logical sequence S10, S20, S30, S40, S50, S55
- Off Request if DB4 = “Safety mode” AND S1

QMP402

- On Request If logical sequence S10, S20, S40, S50, S55
- Off Request if DB4 = “Safety mode” AND S1

QMP802

- On Request If logical sequence S40, S50, S55
- Off Request if DB4 = “Safety mode” AND S1

QNP110

- Position = 100% If logical sequence S20, S30
- Position = 0% if DB4 = “Safety mode” AND S1, S50, S55
- Regulated by QMP110_PID logical sequence S40

QNP120

- Position = 100% If logical sequence S10, S30, S50, S55
- Position = 0% if DB4 = “Safety mode” AND S1

QNP340

- Position = 100% If logical sequence S10, S20, S50, S55
- Position = 0% If “Safety mode” AND S1
- Regulated by QMP340_PID logical sequence S20

QNP121

- Position = 100% If logical sequence S10, S30, S50, S55
- Position = 0% if DB4 = “Safety mode” AND S1

QNP341

- Position = 100% If logical sequence S10, S20, S50, S55
- Position = 0% If “Safety mode” AND S1
- Regulated by QMP340_PID logical sequence S20

EQR1-EBM001

- Position = 100% If logical sequence S50
- Position = 0% if DB4 = “Safety mode” AND S1, S40

QNP501

- Position = 100% If logical sequence NOT S1
- Position = 0% If “Safety mode” AND S1

5.4 Regulation Loops

QNP110_PID

The controller is responsible to hold the level inside the cooler vessel.

- Controlled variable: EQR1-BLD001 (%)
- Controlled actuator: QNP110 (0-100%)
- Set-Point limits: 0 - 100 %
- Set-Point speed: 1 %/s
- Set-point =90 % If S40 active, else tracking mode
- PID default parameters: Kc/Ti/Td = XX/XX s/0
- Split configuration: non
- Regulation mode: S40 active
- Output positioning mode: non

QNP340_PID

The controller is responsible to minimize the flow to shield while cooling down the 4K line to 50K.

- Controlled variable: BTX407 (K)
- Controlled actuator: QNP340 (0-100%)
- Set-Point limits: 50 – 80 K
- Set-Point speed: 1 K/s
- Set-point =75 K If S20 active, else tracking mode
- PID default parameters: Kc/Ti/Td = XX/XX s/0
- Split configuration: non
- Regulation mode: S20 active
- Output positioning mode: non

5.5 User commands

- **DB2 Stop:**
  Start/Safety position of the plant.
- **DB2 Cool down:**
  User decision to switch to use the PCO DB2 to cool down the plant
- **DB2 Normal Operation:**
  Code control the PCO DB2 from Cool down to Normal Mode
- **DB2 Warm-Up:**
  User decision to switch to use the PCO DB2 to warm-up the plant

5.6 Parameters

- **QNP110_AP:** AP of the PID QNP110_PID for the level set point
- **QNP340_AP:** AP of the PID QNP340_PID for the temperature set point

5.7 Interfaces

- **DB3:**
  - Valve positions:
    - ==AY200=XLD3=QND0-QNP140
    - ==AY200=XLD3=QND0-QNP240

- ==AY200=XLD3=QND0-QNP340
- ==AY200=XLD3=QND0-QNP440
- ==AY200=XLD3=QND0-QNP840
- ==AY200=XLD3=QND0-QNP341
- ==AY200=XLD3=QND0-QNP241
- ==AY200=XLD3=QND0-QNP441
- ==AY200=XLD3=QND0-QNP842

- Insolation vacuum:
  - Vacuum ok

Interface signal of the DB3 for the operation:

Standby	50K line to 50K	4K line to 50K	4K line to 4K	Normal operation	Warm up	Valve
			1	1		QNP140
				1		QNP240
	1	1	1	1		QNP340
		1	1	1		QNP440
			1			QNP840
		1			1	QNP341
		1	1		1	QNP241
	1				1	QNP441
	1	1		1	1	QNP845
					1	WarmGas

Table 12: : Interface valve of DB3

5.8 Computed Variables

Name, description	Type	Unit	Calculation
EQR1-BLD001 Level in percent of the vessel EQR001	Real	%	EQR1-BLD001 := (Result of BPD001, BPA001)

5.9 Unit feedback

- **Feedback On =** PCO DB2 in normal operation
- **Feedback Off =** All valves are in safety position AND S1
- **Feedback Control Stop Fin =** All valves are in safety position AND S1

5.10 Events

Name	Condition
Supply CBM	PCO CBM is in run
Supply SFRS_Front	PCO SFRS_Front is in run
Supply SFRS_Behind	PCO SFRS_Behind is in run

5.11 Unit Alarms

Naming convention for alarms:

Description	Alarm name
Analog Alarms with a threshold on a sensor or computed-variable with relationship (reaction, alarm) to a Unit	Unitxxx_AA (Unit = name of Unit, xxx = type of AA)
Digital Alarm on DI or computed-variable with relationship to an Unit	Unitxxx_DA (Unit = name of Unit, xxx = type of DA)

AA List for DB4:

NAME	MESSAGE	LOGIC FOR ALARM	LIMITS [HH;H;L;LL]	ACTION	DT [s]
EQR1BLW001_AA1	Level of EQR1 (SC) too low	Enable condition: If Normal Operation	-,-,5,0 (in %)	AL(DB4), TS(CBM), TS(SFRS_Front), TS(SFRS_Behind)	
EQR1BLW001_AA2	Level of EQR1 (SC) too high	Enable condition: If Normal Operation	90,80,-,- (in %)	FS(QNP110)	
EQR1BPA001_AA	Pressure of EQR1 too high	Enable condition: If Normal Operation	2.2,2,-,- (in bar)	FS(QNP110), TS(CBM), TS(SFRS_Front), TS(SFRS_Behind)	
EQR1BPD001_AA	Diff.Pressure of EQR1 under low range		-,-,-,0 (in mbar)	AL(DB4)	
EQR1BLD001_AA1	Level of EQR1 (DP) too low	Enable condition: If Normal Operation	-,-,5,0 (in %)	AL(DB4), TS(FB3), TS(FB5)	
EQR1BLD001_AA2	Level of EQR1 (DP) too high	Enable condition: If Normal Operation	90,80,-,- (in %)	FS(QNP110)	
EQR1BTX001_AA	Temperature inside EQR1 too high	Enable condition: If Normal Operation	5.2,5,-,- (in K)	FS(QNP110), TS(CBM), TS(SFRS_Front), TS(SFRS_Behind)	

EQR1BTX101_AA	Temperature after EQR1 too high	Enable condition: If Normal Operation	5,4.8,-,- (in K)	TS(CBM), TS(SFRS_Front), TS(SFRS_Behind)	
EQR1EBM001BTC_AA	Temperature of EQR1 heater too high		20,0,-,- (in C)	FS(EQR1EBM001)	
BPA101_AA	Pressure of 4K supply too high	Enable condition: If Normal Operation	6,5,-,- (in bar)	FS(QMP101_OO), TS(CBM), TS(SFRS_Front), TS(SFRS_Behind)	
BPA107_AA	Pressure of 4K supply too high	Enable condition: If Normal Operation	6,5,-,- (in bar)	FS(QMP101_OO), TS(CBM), TS(SFRS_Front), TS(SFRS_Behind)	
BPA201_AA	Pressure of 5K return too high	Enable condition: If Normal Operation	2,1.5,- (in bar)	TS(CBM), TS(SFRS_Front), TS(SFRS_Behind)	
BPA207_AA	Pressure of 5K return too high	Enable condition: If Normal Operation	2,1.5,- (in bar)	TS(CBM), TS(SFRS_Front), TS(SFRS_Behind)	
BPA301_AA	Pressure of 50K supply too low	Enable condition: If Normal Operation	-,-,12,10 (in bar)	FS(QMP301_OO), TS(CBM), TS(SFRS_Front), TS(SFRS_Behind)	
BPA307_AA	Pressure of 50K supply too low	Enable condition: If Normal Operation	-,-,12,10 (in bar)	FS(QMP301_OO), TS(CBM), TS(SFRS_Front), TS(SFRS_Behind)	
BPA401_AA	Pressure of 80K return too low	Enable condition: If Normal Operation	-,-,12,10 (in bar)	TS(CBM), TS(SFRS_Front), TS(SFRS_Behind)	

BPA407_AA	Pressure of 80K return too low	Enable condition: If Normal Operation	-,-,12,10 (in bar)	TS(CBM), TS(SFRS_Front), TS(SFRS_Behind)	
BPA801_AA	Pressure of MPL	BPA801	,,,	-	
BPA807_AA	Pressure of MPL	BPA807	,,,	-	
BTX107_AA	Temperature of 4K supply to high	Enable condition: If Normal Operation	5.5,5,-,- (in K)	FS(QMP101_OO), TS(CBM), TS(SFRS_Front), TS(SFRS_Behind)	
BTX207_AA	Temperature of 5K return to high	Enable condition: If Normal Operation	5.5,5,-,- (in K)	TS(CBM), TS(SFRS_Front), TS(SFRS_Behind)	
BTX307_AA	Temperature of 50K supply Info: High load for 4K supply -> close 4K supply	Enable condition: If Normal Operation	60,55,-,- (in K)	FS(QMP101_OO), TS(CBM), TS(SFRS_Front), TS(SFRS_Behind)	
BTX407_AA	Temperature of 80K return	BTX407	,,,		
BTX807_AA	Temperature of MPL	BTX807	,,,		

**FS = Full Stop Interlock; TS = Temporary Stop Interlock; SI=Start Interlock; AL=Alarm*

DA List for DB4:

NAME	MESSAGE	LOGIC FOR ALARM	ACTION	DT [s]
VAC_Ok_DA	Insolation vacuum ok	VAC_Ok	-	

**FS = Full Stop Interlock; TS = Temporary Stop Interlock; SI=Start Interlock; AL=Alarm*

6. Supervision

6.1 Synoptic Panels

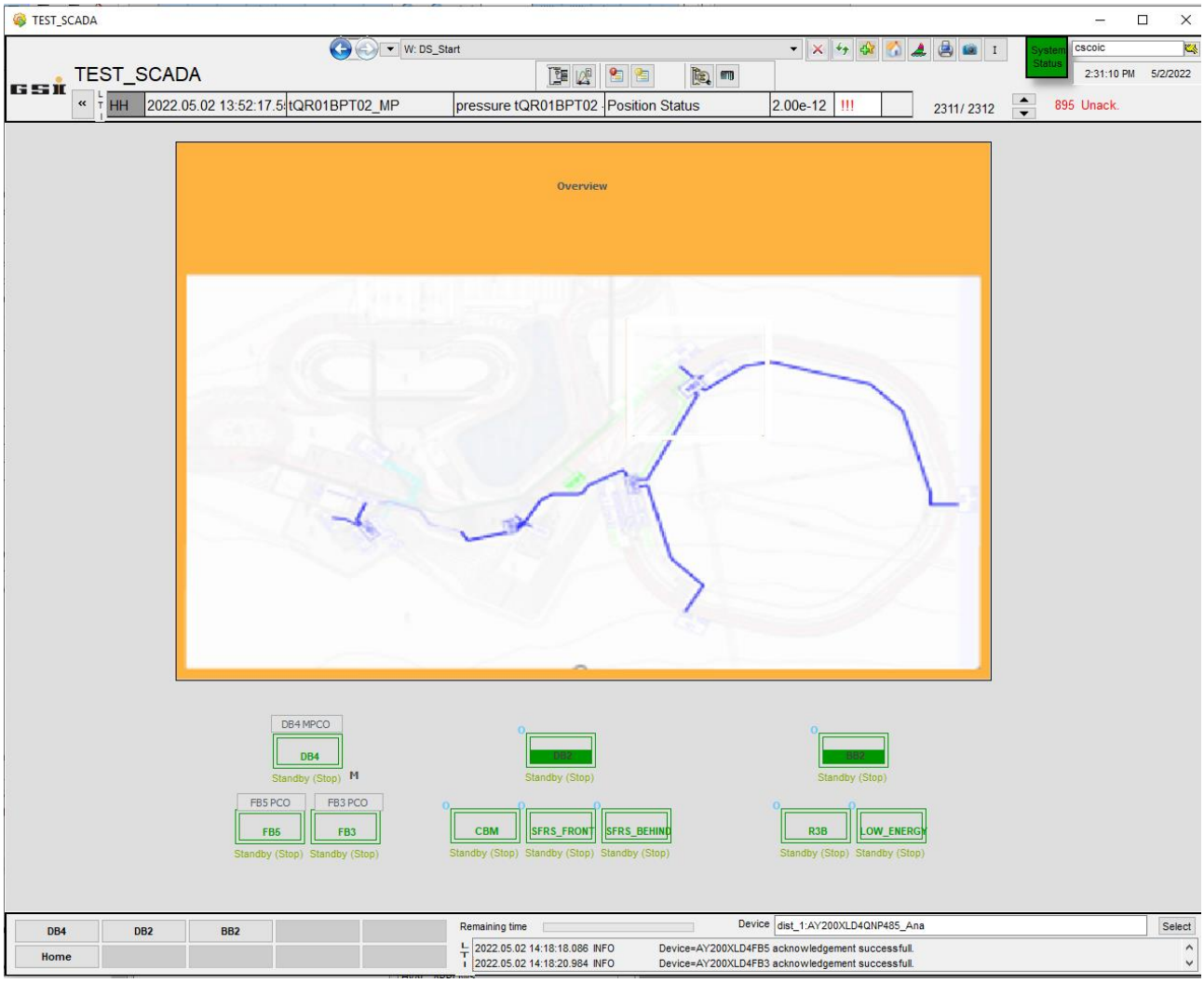

Figure 13: Main panel of the distribution system

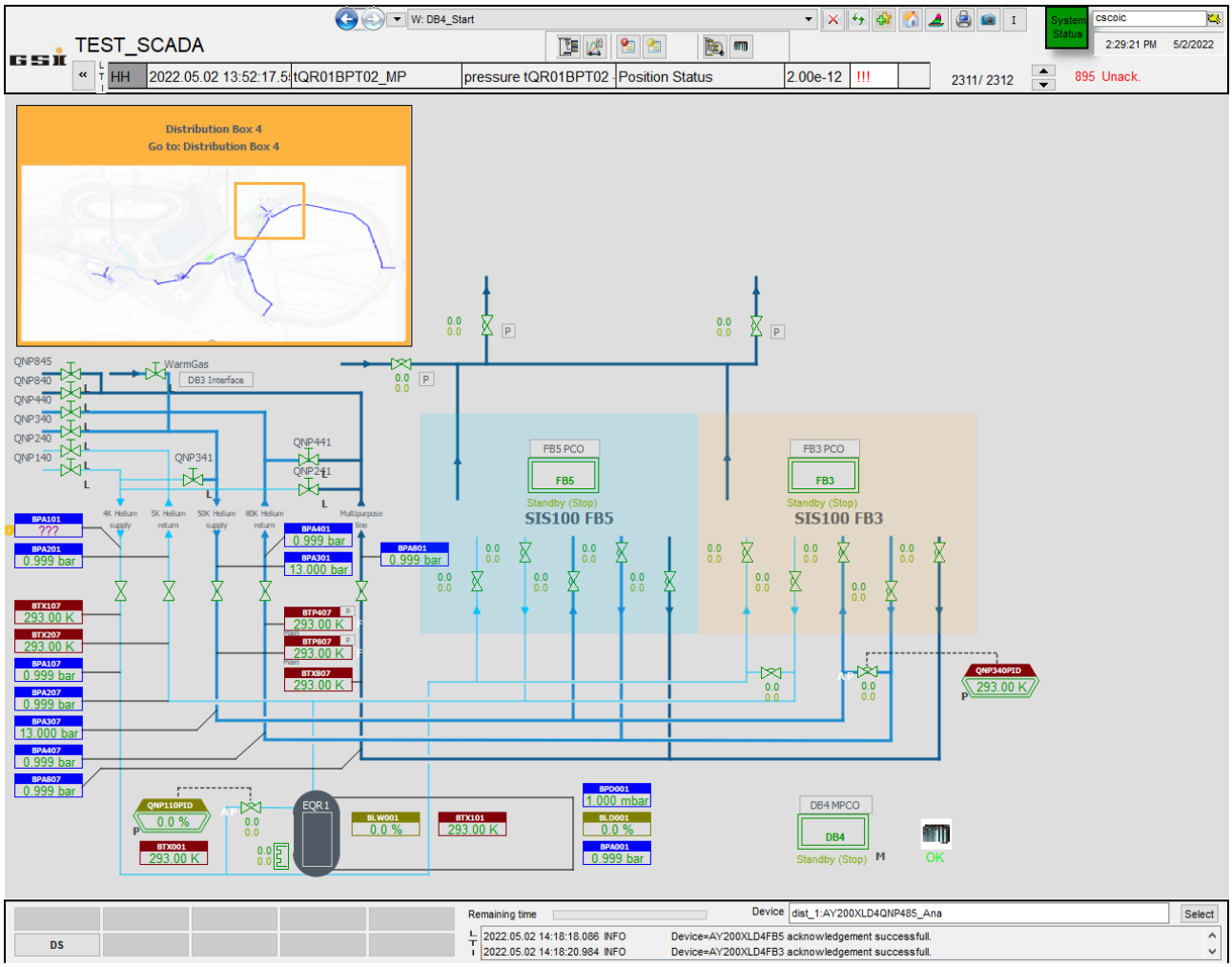

Figure 14: Main panel of the DB4

Units:

- **Name:** DB4, SIS100_FB5. SIS100_SB3

Content:

- All valves, temperatures, pressure and controller
- Navigation overview
- Navigation button
- Needed special information like:

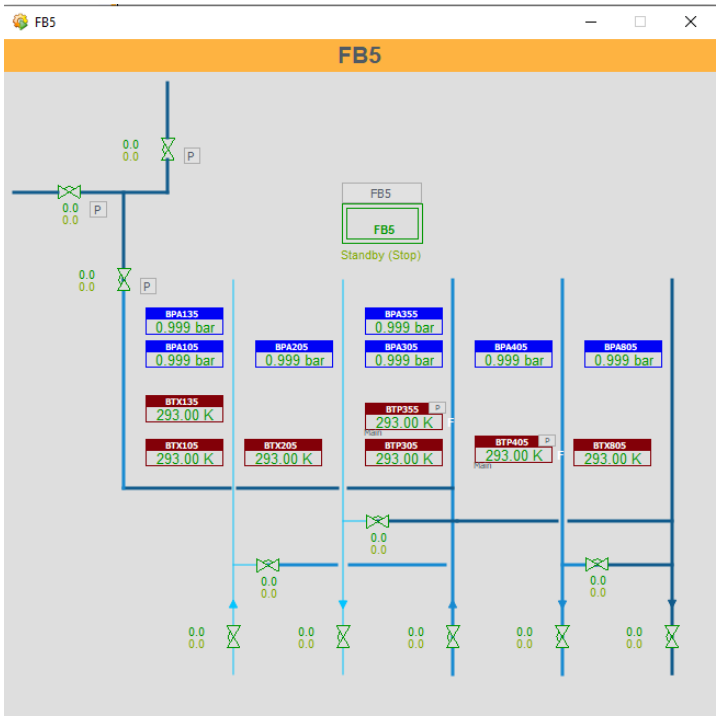

Figure 15: Child panel of a sub PCO

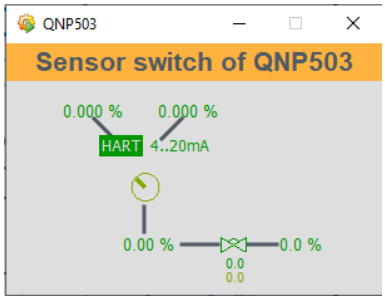

Figure 16: Child panel of warm valve to switch the sensor

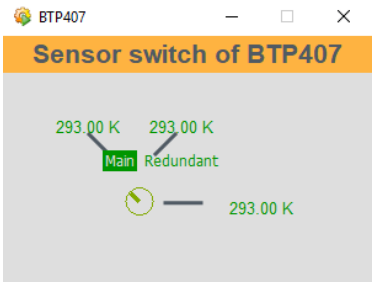

Figure 17: Child panel of temperature to switch the sensor (Main/Redundant)

6.2 Trends

Describe here all needed trends/plots with name and configuration

- **Name:** Temperature Unit A

Elements:

- DP: TT100, Legend Text: “Temperature Turbine Inlet”, Y Axis: OFF

- DP: TT101, Legend Text: “Temperature T2 Inlet”, Y Axis: ON
- DP: TT105, Legend Text: “Temperature Turbine Outlet”, Y Axis: OFF

6.3 Panel organisation

Window tree:

- FAIR:
  - DS:
    - DB2
      - Main panel
      - CBM
      - SFRS_FRONT
      - SFRS_BEHIND
    - DB4:
      - Main panel
      - SIS100_FB3
      - SIS100_FB5
    - BB2
      - Main panel
      - R3B
      - LOW_ENERGY

Trend tree:

- xxx:

Navigation between:

- SIS100
- SFRS

6.4 Access rights

CRY_admin:

CRY_expert:

CRY_operator:

7. REFERENCES

Add here any other documents which may be related to this functional analysis (e.g. user requirement, process functionalities, etc.).

[1] IEC 61512-1 or ANSI/ISA S88. Batch Control - Part 1: Models and terminology. 1995.