Application Guidelines

PeC Solution Controllers for Commercial Comfort Applications

EMERSON

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About these guidelines

The purpose of these guidelines is to provide guidance in the application of the Emerson PeC controller in users' systems. They are intended to answer the questions raised while designing, assembling, starting and operating a system with this product.

Besides the support they provide, the instructions listed herein are also critical for the proper and safe functioning of the system. The performance and reliability of the system may be impacted if the product is not used according to these guidelines or is misused.

These guidelines cover stationary applications only. For mobile applications, please contact the Application Engineering department at Emerson as other considerations may apply.

1 Safety instructions

Emerson PeC controllers are manufactured according to the latest European safety standards. Particular emphasis has been placed on the user's safety.

The PeC controllers are intended for installation in systems in accordance with the European Machinery Directive MD 2006/42/EC, the Low Voltage Directive LVD 2014/35/EU and the Electromagnetic Compatibility Directive EMC 2014/30/EU. They may be put to service only if they have been installed in these systems according to instructions and conform to the corresponding provisions of legislation. For relevant standards please refer to the Manufacturer's Declaration, available on request or at www.climate.emerson.com/en-gb.

These guidelines form part of the product and must always be kept near the controller for easy and quick reference. They should be retained throughout the lifetime of the controller.

You are strongly advised to follow these safety instructions.

1.1 Icon explanation

	**WARNING** This icon alerts the user of important instructions to avoid personal injury and material damage.		**CAUTION** This icon alerts the user of instructions to avoid material damage and possible personal injury.
	**WARNING** **High voltage!** This icon alerts the user of non-insulated "dangerous voltage" within the product area that is sufficiently high to constitute a risk of electric shock to persons.		**IMPORTANT** This icon alerts the user of important operating and maintenance or assistance instructions.
	**Danger of explosive atmosphere** This icon indicates a risk of explosive atmosphere.	***NOTE***	This word indicates a recommendation for easier operation.

1.2 Safety statements

- **This product can only be used for purposes specified by the manufacturer.**
- **This product is designed to be used in HVAC/R systems and can only be installed, operated or maintained by qualified electrical personnel with additional system-related expertise. Please immediately contact the manufacturer for support if the user is uncertain with any safety-related issue.**
- **Electrical connections must be made by qualified electrical personnel with additional system-related expertise.**
- **All valid standards and local electrical regulations for connecting electrical and refrigeration equipment must be observed.**
- **The national legislation and regulations regarding personnel protection must be observed.**

Use personal safety equipment. Safety goggles, gloves, protective clothing, safety boots and hard hats should be worn where necessary.

1.3 General warnings

WARNING
Conductor cables! Electrical shock hazard! This product operates at hazardous voltages which can cause severe personal injury or equipment damage. Extreme care and precautions must be taken when handling the product. Electrical connections must be made by qualified electrical personnel. Use a grounded system only. Moulded electrical plugs must be used in all applications. Refer to original equipment wiring diagrams.
Disconnect all voltages from system before installation or service. Do not operate system before all cable connections are completed. Allow drive components to electrically discharge for a minimum of two minutes before servicing.

WARNING
Conductor cables! Electrical shock hazard! The controller must always be inserted inside an electrical panel that can only be accessed by authorised personnel. The keyboard must be the only part that can be reached. The device must never be hand-held while being used.

CAUTION
The controller cannot be used as a safety device. Verify the limits of application before using the device.

IMPORTANT
Transit damage! Controller dysfonctions! Use original packaging.

1.4 Use with flammable refrigerants

WARNING
The PeC controller is not designed or qualified based on the ATEX directive!
The PeC controller fulfils the requirements of the mentioned system standard with the usage of flammable refrigerants.

Usage with flammable refrigerants is limited to systems which are based on the IEC 60335-2-40 standard. For systems using flammable refrigerants A2L and A3 the following points must be considered:

- The controller mounting area must be in **Zone 2** or outside any ATEX zone and in line with "**Pollution Degree 2**" classification.
- No airstream guided over the electronics.
- No condensation under normal operation.
- The IP class of the controller mounting area must be in line with the system standard.
- The standard differentiates between A2L and A3 refrigerants.
- Part 22.116 considers electrical components with flammable refrigerants.
- Components which are in line with Part 16...22 of the EN 60079-15 are not considered as a source of ignition.
- Components in A2L systems which are in line with Annex JJ are also not considered as a source of ignition (use of gastight relays).
- Creepage and clearance distances are not considered as source of ignition as long the pollution degree stays 2.
- The varistors (MOVs) could be a source of ignition but not under normal conditions, therefore they do not need a flame-retardant housing or an integrated fuse.
- Part 22.117 considers "Hot surfaces" which can be a source of ignition:
    - Max. allowable surface temperature: R32 / 700 °C, R452B / 700 °C

EN60079-15	Parts of EN 60079-15 which have to be considered	*EN 60335-2-34*	*EN 60335-2-89*	*EN 60335-2-40*	IEC 60335-2-40 2018-05	A2LSolution on the SEC Mono controller
4	General	-	-	-	-	N/A: Sparking and ignition sources are considered in part 16..20!
5	Temperatures – Max. surface temperatures	-	-	-	-	N/A: The max. surface temperature for A3 (Propane) of 370 °C will be considered!
6	General requirements on electrical appliances *IP54, IP44, IP4X / Creepage and clearance distances*	-	-	-	-	N/A: The electrical appliances, ie, chillers, heat pump, will be qualified based on EN 60335-2-40 and "**not"** based on EN 60079-0! The clearance and creepage distances are based on EN 60335-1 and EN 60730-1 respectively.
7	Connector and connecting rooms	-	-	-	-	N/A
8	Additional requests on non-sparking electrical machines	-	-	-	-	N/A
9	Fuses	-	-	X	-	Fuse soldered on PCB
10	Terminals	-	-	X	-	Pull-out force higher than 15 N on connector terminals. Connector types used with locking latch.
11	Luminairs	-	X	X	-	N/A
12	Cells / Batteries	-	-	X	-	N/A
13	Low power devices	-	-	X	-	N/A
14	Current transformer	-	-	X	-	N/A
15	Other non-ignitable components	-	-	X	-	Varistors w/o flame-retardant housing! Considered as a non-ignition source during normal operation! (Low risk: 2 conditions to be fulfilled: flammable concentration + overvoltage)
16	General additional requirements on components	X	X	X	X	Requests a solution based on part 17, 18, 19 or 20
17	Enclosed switching devices / Non-ignitable components	X	X	X	X	N/A
18	Hermetically sealed devices	X	X	X	X	N/A (qualified varistors)
19	Sealed devices (➔ Type test based on part 22.5)	X	X	X	X	Use of gas-tight relays
20	Restricted breathing housing	X	X	X	X	N/A
21	General advices related to verifications and tests	-	-	X	X	Requested type tests (see 22.x)
22	Type tests	-	X	X	X	Applicable relay test procedure approved with notified body
23	Verifications and routine tests	-	-	X	-	
24	Marking	-	-	X	-	
25	Documentation	-	-	X	-	
26	Operation manual	-	-	X	-	

Table 1

1.5 General recommendations

The customer shall bear full responsibility and risk for product configuration in order to achieve the results pertaining to installation and/or final equipment/system. Upon customer's request and following a specific agreement, Emerson. may be present during the start-up of the final machine/application, as a consultant. However, under no circumstances can Emerson be held responsible for the correct operation of the final equipment/system.

Since Emerson products form part of a very high level of technology, a qualification/configuration/ programming/commissioning stage is required to use them as best as possible. Otherwise, these products may malfunction, and Emerson cannot be held responsible.

It is good practice to bear the following in mind for all Emerson products:

- Prevent the electronic circuits from getting wet as contact made with water, humidity or any other type of liquid can damage them. Comply with the temperature and humidity limits specified in the guidelines to store the product correctly.
- The device must not be installed in particularly hot environments as high temperatures can cause damage, eg, to electronic circuits and/or plastic components forming part of the casing. Comply with the temperature and humidity limits specified in the guidelines to store the product correctly.
- Under no circumstances is the device to be opened – the user does not require the internal components. Please contact qualified service personnel for any assistance.
- Prevent the device from being dropped, knocked or shaken as either can cause irreparable damage.
- Do not clean the device with corrosive chemical products, solvents or aggressive detergents.
- The device must not be used in applications that differ from those specified in these guidelines.

1.6 Communication with Application Engineering and Development teams

When communicating with Application Engineering and/or development teams at Emerson during the development and testing phases of programs using the PeC, please include:

1. log file
2. description file
3. configuration file

These will help them give you more precise and complete answers to your questions.

2 Product description

2.1 General information about the Emerson PeC controller

The PeC (Performance Controller) controller has been specifically developed for Copeland™ scroll compressors using R410A and R32 refrigerants in heating and cooling applications such as reversible heat pumps, in both air-to-water and brine-to-water configurations.

PeC was developed to run and protect the refrigerant cycle with low control effort for the system controller but also to provide detailed information around the refrigerant cycle.

Figure 1: PeC external view

Figure 2: Internal view

The external dimensions of the PeC controller are 185 x 130 x 60 mm.

Figure 3: Top side view

Figure 4: Bottom side view

2.2 Refrigerants

The PeC controller operates with refrigerant systems using:

- R410A
- R32
- *R290 (for future use)*

2.3 Available PeC configurations

The following tables show the hardware and software capabilities with PeC C100 and C200.

PeC C100	Circuit 1				
	VS compressor + EV3 drive	Fixed speed	Temperature probe min-max	Pressure	EXV (bipolar)
	1-3 (1 can be a variable speed)		5-7	2	1

Table 2

PeC C200	Circuit 1					Circuit 2				
	VS compressor + EV3 drive	Fixed speed	Temperature .probe min-max	Pressure	EXV (bipolar)	VS compressor + EV3 drive	Fixed speed	Temperature . Probe min-max	Pressure	EXV (bipolar)
	1-3 (1 can be a variable speed)		5-7	2	1	0	0-3	4-6	2	1

Table 3

***NOTE:* The PeC factory default is unconfigured (-1) so configuration is needed. Invalid or unconfigured compressor package selection will cause an alarm.**

2.4 Main components and parts

For components and parts ordering please contact the Application Engineering or Sales Department at Emerson.

2.4.1 Supported compressor range

The PeC controller has been specifically developed for Copeland scroll variable-speed compressors using R410A and R32 refrigerants. It is currently qualified for the following ranges:

	R32	
	Fixed-speed compressor	**Variable-speed compressor**
	YP137	YPV066
	YP154	YPV096
	YP182	
	YP232	
	YP292	

Table 4: Qualified compressors for use with R32

	R410A	
	Fixed-speed compressor	**Variable-speed compressor**
	ZP104	ZPV066
	ZP122	ZPV096
	ZP154	
	ZP182	
	ZP232	
	ZP292	

Table 5: Qualified compressors for use with R410A

***NOTE:* Additional fixed-speed compressors may be supported based on customer request.**

2.4.2 Supported variable speed drive

	EV3150	EV3185	Compatible compressor model
	1		YPV066
	1		ZPV066
		1	YPV096
		1	ZPV096

Table 6: Compatible compressor models

NOTE: **The Emerson EV3 inverter drive is compliant with CAT 3 of EMC homologations.**

2.4.3 PeC accessories

Plug-in connector

	PeC C100	Screw terminals and/or cage clamp female connectors
	PeC C200	Screw terminals and/or cage clamp female connectors

Table 7

USB adapter

	XJ485-USB converter

Table 8

2.4.4 Supported electronic expansion valve range

	Alco EX4
	Alco EX5
	Alco EX6
EXV-M30 (wires)	3.0 m

Table 9: Qualified expansion valves

NOTE: **Additional expansion valves may be supported based on customer request.**

2.4.5 Supported pressure transmitters

	Alco PT5N-7 (7 bar max)	Low side
	Alco PT5N-10 (10 bar max)	
	Alco PT5N-18 (18 bar max)	
	Alco PT5N-30 (30 bar max)	High side
	Alco PT5N-50 (50 bar max)	
Cable for PT5N	PT4-M30	3.0 m

Table 10: Qualified pressure transmitters

NOTE: **Additional pressure transducers may be supported based on customer request.**

2.4.6 Supported temperature sensors

	TP1 series
	100K (high temperature) *(for future use)*

Table 11: Qualified temperature sensors

NOTE: **Additional temperature sensors may be supported based on customer request.**

2.5 PeC system functionalities

The PeC controller controls and manages the refrigerant system comprising the Copeland scroll variable-speed compressor (ZPV066 or ZPV096 & YPV066 or YPV096), the drive, the electronic expansion valves (EX range) and the 4-way valves. It is not a main system controller: it does not control or manage the full unit (chiller / heat pump / others).

The OEM system controller and the PeC communicate via Modbus serial communication, in order to exchange the fundamental parameters and information to provide an optimised combined control of compressor and expansion devices for maximum performance and reliability.

Table 12 below gives an overview of the PeC features and benefits.

PeC	Features	Benefits
Smart refrigerant circuit management	▪ Variable speed & fixed speed ▪ Tandem/Trio capacity management ▪ Smart superheat control & EXV management ▪ Dynamic compressor operating maps management ▪ Reverse cycle management	High efficiency & reduced time-to-market
Protection & diagnostics	▪ Active compressor envelope protection ▪ Active floodback protection ▪ Oil recovery management ▪ Performance monitoring	Improved protection & increased reliability
Communication	▪ RS485 Modbus OR analog interface communication with system controller ▪ Pre-programmed Modbus communication with CSD100 and alarms/parameters transfer	Modularity

Table 12

2.6 System configuration

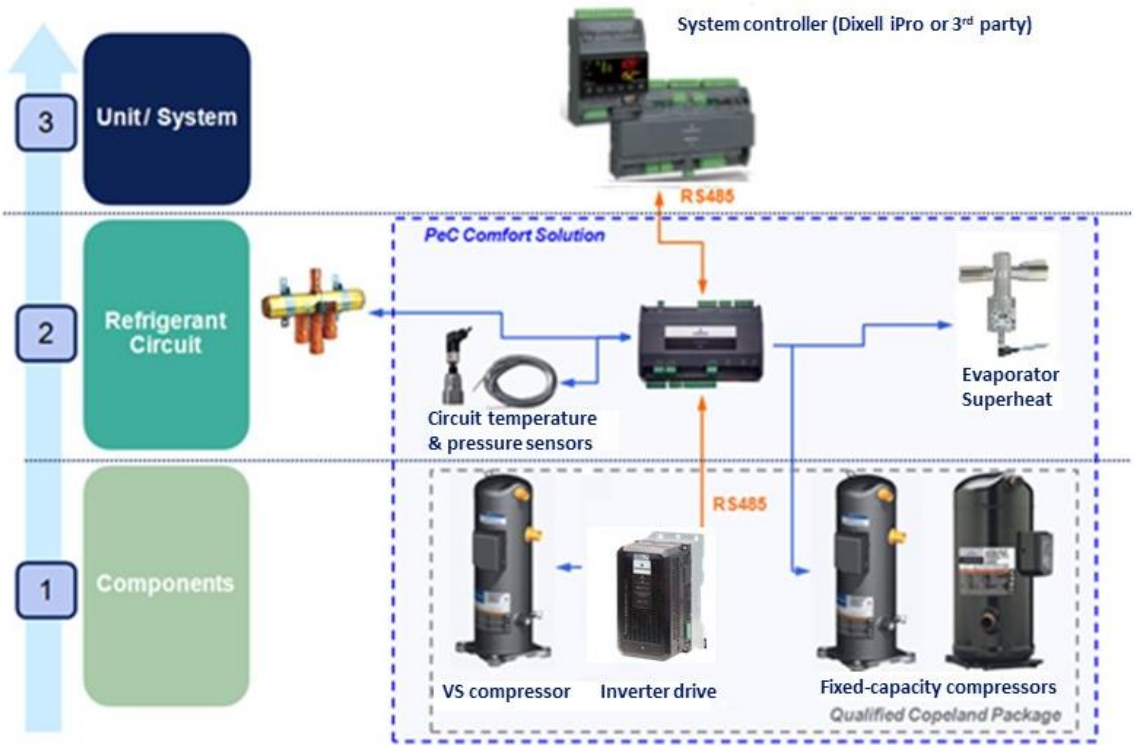


Figure 5

3 Hardware configuration

3.1 PeC Hardware configuration options

The controller board owns digital inputs and outputs that can provide customized use to the OEM. Configuration can be set via Modbus using "Configuration Parameters".

Factory default	Description	Type	Status on
DI1	Input for high-pressure switch signal	Fixed function	Modbus [280]
DI2	*Input for demand On/Off selection*	*Future use*	Modbus [280]
DI3	*Input for heating or cooling mode selection*	*Future use*	Modbus [280]
DO1	Relay for 4-way valve switching	Fixed function	Modbus [281]
DO2	Relay for fixed-speed compressor start/stop	Fixed function	Modbus [281]
DO3	Relay for fixed-speed compressor start/stop	Fixed function	Modbus [281]
DO4	Relay for fixed-speed compressor start/stop	See below	Modbus [281]

Table 13

Configuration parameter options on DO1 (4-way valve): Register [94] if reversible systems:

0 = Mainly cooling: rest position of 4-way valve in cooling = coil de-energized
rest position of 4-way valve in heating = coil energized

1 = Mainly Heating: rest position of 4-way valve in heating = coil de-energized
rest position of 4-way valve in cooling = coil energized

Configuration parameter options on DO4: Register [150] if compressors C1#3 installed (refer to index 86 bit 3) then relay can be used to indicate PeC status:

0 = Alarm negative logic (Alarm = Relay contact open)
1 = Alarm positive logic (Alarm = Relay contact closed)
2 = Drive active positive logic (speed > 0 = Relay closed)

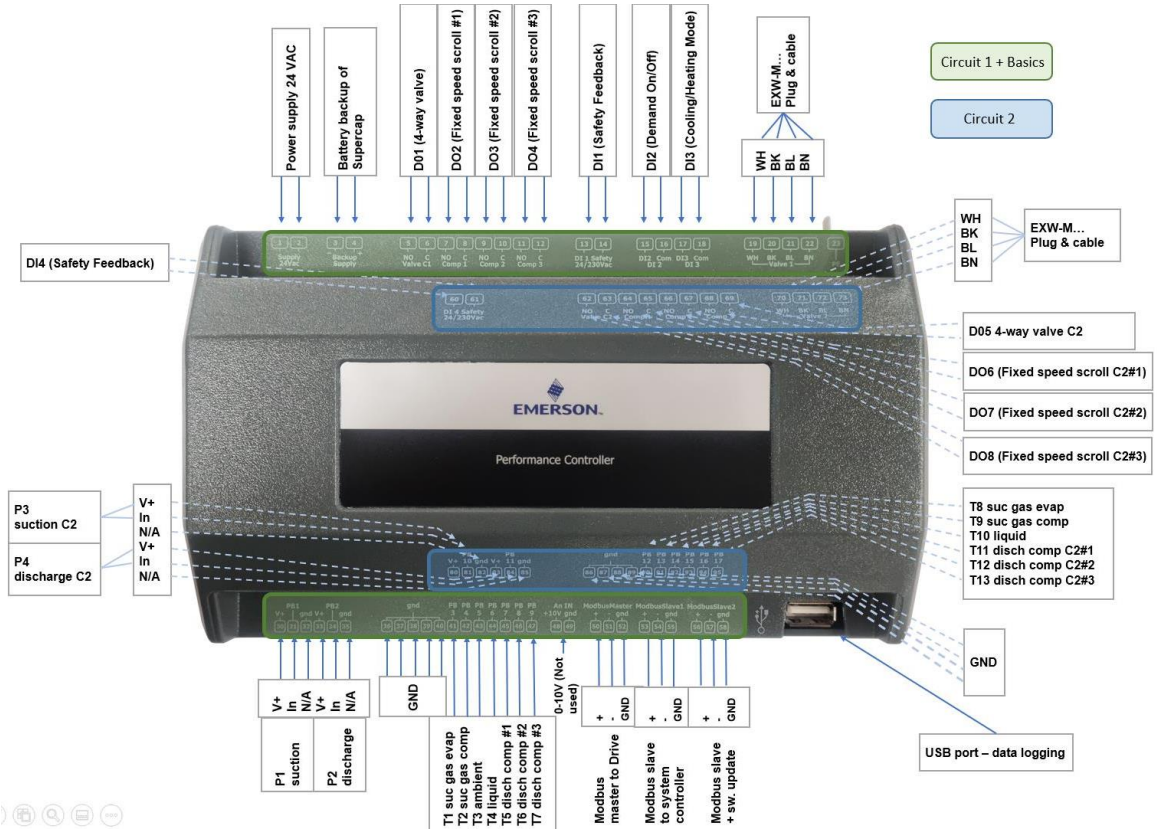


Figure 6: PeC controller top side – Power supply, digital outputs & inputs & EXV connections

NOTE: **For more information please refer to Application Guidelines AGL_Sol_PEC_01 "PeC Solution Controllers for commercial Comfort Applications – PeC C100 & PeC C200" or contact your local Application Engineering representative at Emerson.**

3.2 Examples of application

3.2.1 Monoblock reversible air-to-water heat pump system scheme with variable-speed & fixed-speed compressors and 1 electronic expansion valve in 1 circuit

Basic PeC C100 controller Circuit 1					
I/O	**Type**	**Function**	**Comments**		**PeC connectors**
P1	PT5N-7-10-18	Suction pressure for superheat (SH) control, high SH protection and envelope management	Configurable	Mandatory	30, 31
P2	PT5N-30-50	Discharge pressure for envelope management	Configurable	Mandatory	33, 34
T1	TP1	Evaporator outlet gas temperature for SH control and high SH protection	Configurable	Optional	36–40(GND), 41
T2	TP1	Compressor suction gas temperature for SH control and high SH protection	Configurable	Mandatory	36–40(GND), 42
T3	TP1	Ambient temperature	Configurable	Mandatory	36–40(GND), 43
T4	TP1	Liquid temperature before main EXV for energy counter function & EXV management	Configurable	Mandatory	36–40(GND), 44
T5	TP1	Variable-speed compressor discharge temperature	Configurable	Mandatory	36–40(GND), 45
T6	TP1	Fixed-speed compressor discharge temperature	Configurable	Mandatory	36–40(GND), 46
T7	TP1	Fixed-speed compressor discharge temperature	Configurable	Mandatory	36–40(GND), 47
	24 VAC	Power supply	Fixed		1, 2
	24 VDC	Supercap XEC mono valve	Optional		3(-), 4(+)
DO1	Relay	4-way valve	Fixed	Not needed	5, 6
DO2	Relay	Fixed-speed compressor #1 command	Configurable*		7, 8
DO3	Relay	Fixed-speed compressor #2 command	Configurable*		9, 10
DO4	Relay	Fixed-speed compressor #3 command	Configurable*		11, 12
DI1	Digital input	Safety feedback	Fixed		13, 14
DI2	Digital input	*Not used*	State readable by Modbus	Optional	15, 16
DI3	Digital input	*Not used*	State readable by Modbus	Optional	17, 18
EXV/BIP	Stepper output bipolar	EXV control	Fixed		19, 20, 21, 22 WH, BK, BL, BN
An. In.	0-10 V analog input	*Not used*	State readable by Modbus	Optional	48, 49
Bus Inverter	Modbus RS485	Modbus Master Communication with EV3 inverter	Fixed		50, 51, 52 +, -, GND
Bus Ctrl	Modbus RS485	Modbus Slave Communication with system controller	Fixed		53, 54, 55 +, -, GND
Bus Slave	Modbus RS485	Modbus Slave (for monitoring and/or flashing)	Fixed		56, 57, 58 +, -, GND
PE		PE connection for grounding	Fixed		23

** If no fixed-speed compressor is attached, optional use as alarm in positive or negative logic or drive active*

Table 14: Circuit 1 connections, power supply & communication for PeC C100

The type and number of compressors is selectable / scalable.

Circuit 1 can handle up to 1 variable-speed and up to 3 fixed-speed compressors.

In case of heating or cooling only application, the 4-way valve is not needed.

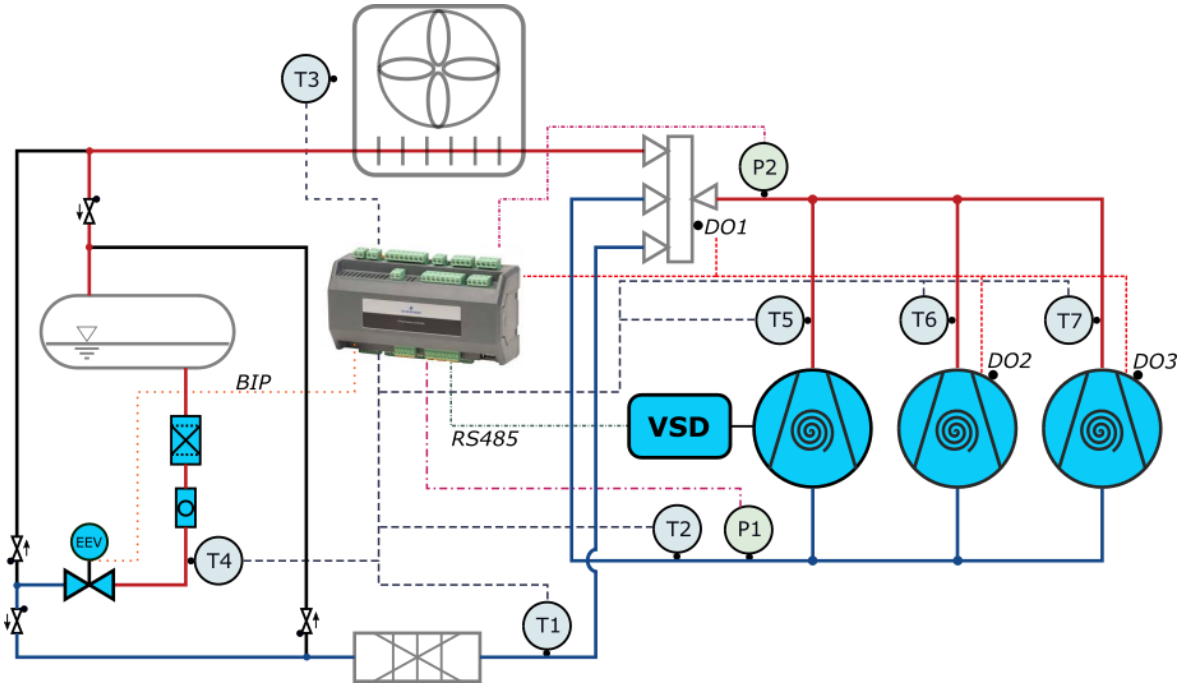


Figure 7: PeC system setup with 1 circuit (PeC C100) in maximum configuration with VSS

NOTE: **For more information please refer to Application Guidelines AGL_Sol_PEC_01 "PeC Solution Controllers for commercial Comfort Applications – PeC C100 & PeC C200" or contact your local Application Engineering representative at Emerson.**

3.2.2 *Monoblock reversible air-to-water heat pump system scheme with variable-speed & fixed-speed compressors and 2 electronic expansion valves in 2 circuits*

Circuit 1 connections, power supply and communication as for PeC C100 in **Table 14**.

Additional PeC C200 circuit 2 connections					
I/O	**Type**	**Function**	**Comments**		**PeC connectors**
P3	PT5N-7-10-18	Suction pressure for superheat (SH) control, high SH protection and envelope management	Configurable	Mandatory	80, 81
P4	PT5N-30-50	Discharge pressure for envelope management	Configurable	Mandatory	83, 84
T8	TP1	Evaporator outlet gas temperature for SH control and high SH protection	Configurable	Optional	86–89(GND), 90
T9	TP1	Compressor suction gas temperature for SH control and high SH protection	Configurable	Mandatory	86–89(GND), 91
T10	TP1	Liquid temperature before main EXV for energy counter function & EXV management	Configurable	Mandatory	86–89(GND), 92
T11	TP1	Fixed-speed compressor C2#1 discharge temperature	Configurable	Mandatory	86–89(GND), 93
T12	TP1	Fixed-speed compressor C2#2 discharge temperature	Configurable	Mandatory	86–89(GND), 94
T13	TP1	Fixed-speed compressor C2#3 discharge temperature	Configurable	Mandatory	86–89(GND), 95
DO5	Relay	4-way valve	Fixed	Optional	62, 63
DO6	Relay	Fixed-speed compressor C2#1 command	Configurable		64, 65
DO7	Relay	Fixed-speed compressor C2#2 command	Configurable		66, 67
DO8	Relay	Fixed-speed compressor C2#3 command	Configurable		68, 69
DI4	Digital input	Safety feedback	Fixed		60, 61
EXV/BIP	Stepper output bipolar	EXV control	Fixed		70, 71, 72, 73 WH, BK, BL, BN

Table 15: Additional circuit 2 connections

The type and number of compressors is selectable / scalable.

Circuit 1 can handle up to 1 variable-speed and up to 3 fixed-speed compressors.

Circuit 2 can only handle fixed-speed compressors.

In case of heating or cooling only application, the 4-way valve is not needed.

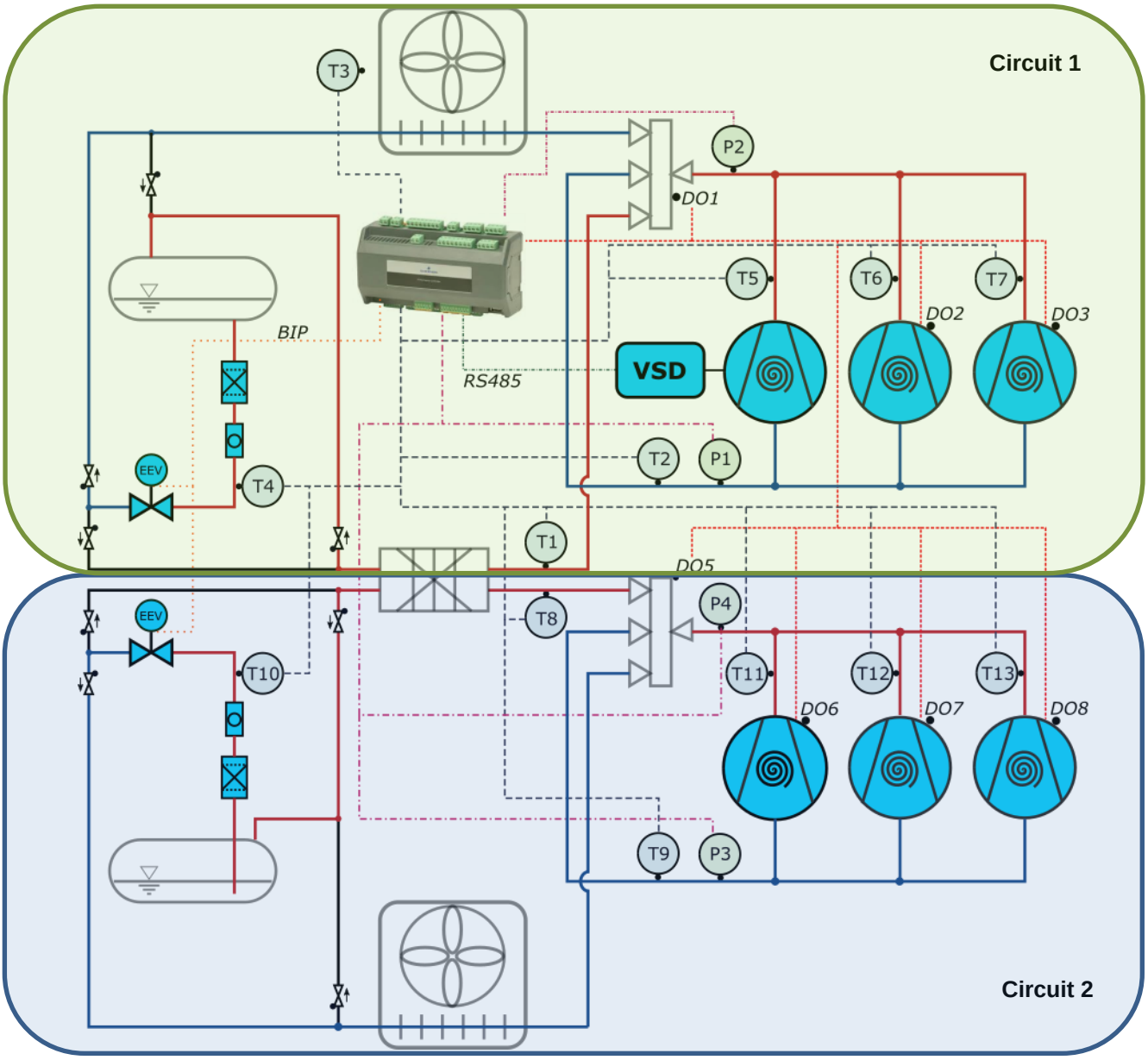


Figure 8: PeC system setup with 2 circuits (PeC C200) in maximum configuration with VSS

3.3 DLT sensor installation

The DLT sensor assembly improves the accuracy and response time of the temperature management.

The high-pressure safety input was designed to fulfil the requirements of standard EN 378.

Please follow the recommendations below for sensor assembly:

- The temperature sensor must be installed along the straight or bended pipe at a distance of 120 mm from the compressor shell.
- The discharge pipe including the sensor must be insulated to reduce the impact of ambient temperature.
- Use thermal compound to improve heat transfer to the sensor. The thermal compound must be approved for maximum system operating temperatures (usually 150 °C for R32).
- Protect the sensor from being moved or removed from its position by transport, vibration or any other incident.
- The sensor must be installed in a copper sleeve to improve response time and to reduce setoff. The copper sleeve must be brazed on the surface of the discharge pipe. Use thermal compound to improve the heat transfer from the sleeve to the sensor.

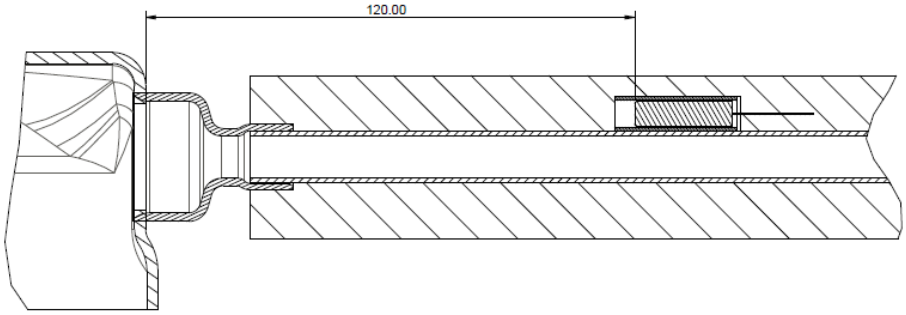


Figure 9: Discharge temperature sensor mounting

4 OEM control strategy on PeC

4.1 System controller with Modbus communication

OEM system controller with Modbus RS485 RTU					
Bus					
↓	↓	↓	↑……↑	↑……↑	↓……↓
Operating mode Heating/Cooling Standby/Off	**Capacity**	**Defrost** Start/Stop	**Refrigerant cycle info** Measured & calculated values	**Alarms and warnings** Hardware & software	**Manual control** 2 EXV's & speed & 6 relays 4-way valves
↓	↓	↓	↑……↑	↑……↑	↓……↓
PeC					

Table 16

The PeC was developed to run and protect the refrigerant cycle with low control effort for the system controller but also to provide detailed information around the refrigerant cycle.

The system controller must provide operating mode and capacity request to run the system.

- PeC operating modes can be Off, Heating, Cooling, Standby or Manual.
- Modbus communication also gives the possibility of enhanced use of all PeC functions shown above.
- Accessories (pumps, fan, etc.) have to be controlled directly by the OEM controller to ensure problem-free conditions for running the refrigerant cycle, eg, water flow on condenser around compressor activity, water flow management in the evaporator as a function of compressor speed, fan control during a defrost etc.

***NOTE:* It is important to synchronize the system controller with the PEC by its application state [338]. This guarantees a mature and smooth cooperation between the system controller and the PEC particularly if customized control strategies are used by the OEM controller.**

The OEM is responsible for developing a mitigation strategy in response to the occurrence of alarms and warnings on the PeC.

There are different alarm conditions: "Alarm", "Warning" and "Alarm State". Alarms and warnings may not lead to direct system shutdown. The system controller can monitor these and take preventive action with the capacity request to avoid system shutdown by an "Alarm State". The occurrence of an "Alarm State" will force immediate system shutdown.

When not acting on the PeC during an "Alarm State" phase, the PeC will recover, if possible, after a recommended waiting phase (Alarm Pause).

The OEM has to consider the best response to specified alarms, eg, deactivate the system or let the system run, lock the system to protect it against damage, demand a defrost, etc.

An advantage of Modbus communication is that it provides full PeC functionality such as:

1) Operation control
   - Gives precise control on operating mode and capacity request given %.
2) Monitoring all sensor values and system status
   - Gives opportunity to use these data for OEM processing the system by the system controller and for data logging. This provides valuable information to analyse the system operation.
3) Explicit warning and alarm information
   - The OEM controller can get explicit fault and warning information for preventive actions on the system, as well for service and maintenance.
4) Manual control options
   - For customized individual control strategy, the OEM controller can take control on the compressor speed, the EXV's and the 4-way valve instead of PeC internal control function.
5) Additional hardware functionality
   - 1 Digital input + 2 potential free relays can be used by the system controller via Modbus or internal pre-defined function.

4.2 OEM capacity demand strategy

The OEM controller should adapt the capacity demand signal to variable speed operation. Common P, PI or PID control strategy should be used to avoid strong setpoint exceeding. This will enhance the system efficiency and reduce useless high speeds, temperatures and sound on the system. An optimal strategy has to be figured out via OEM system qualification process.

Detailed information is provided in **section 5.2 "Main functionalities"**.

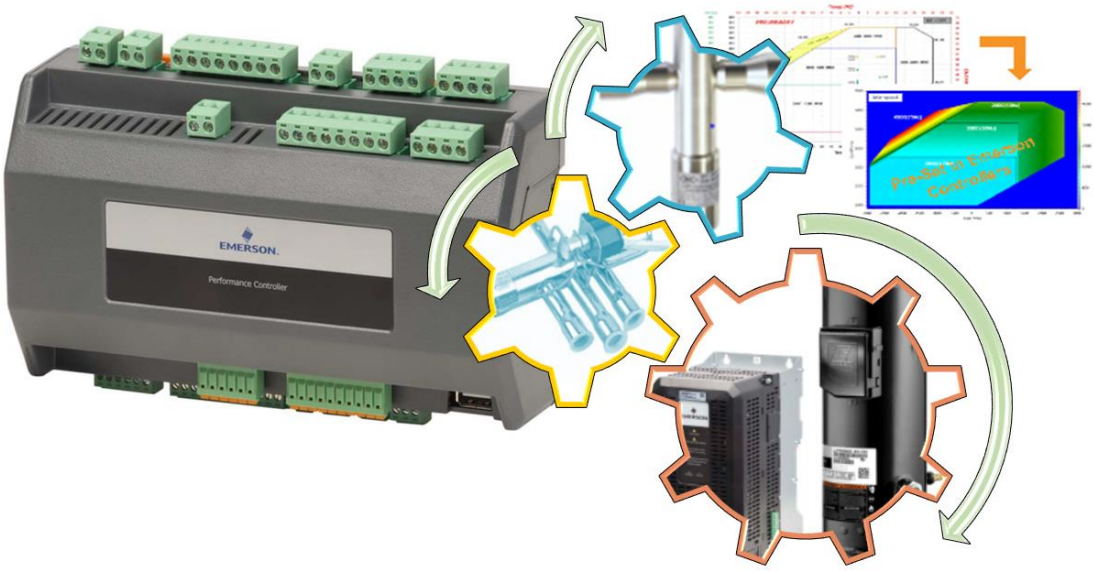


Figure 10

4.3 System controller with analog 0-10 V demand signal + 1 digital signal

Currently unused –Option available in future.

5 PeC functionalities

5.1 Operating modes

The application is governed by a state machine of which the various states are summarized in **Table 17**.

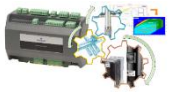
State machine	Loads to manage			
	**EXV** 	**Compressor pack – Variable speed** 	**Compressor pack – Fixed speed** 	**4-way valve** 
Off	After shutdown all valves are closed, the 4-way valve switches to cooling position			
Start-up	Normal start-up with predefined opening (function of ambient temperature)	Normal start-up with predefined speed and duration	Normal start-up with configurable duration	Swappable Heating or Cooling active
Shutdown	Function of suction pressure (and of compressor speed for variable speed pack)	The compressor speed is ramped down and the valve closes	Sequential compressor shutdown	
Standby		Stator heater	Migration status is available via Modbus	
Cooling	Normal operation (dynamic setpoint graph)	Normal capacity matching	Normal capacity matching	
	Low superheat operation (IP-sensitive)	Exceptions (protection, prevention)	Exceptions (protection, prevention)	
	Floodback operation	Exceptions (protection, prevention)	Exceptions (protection, prevention)	
Heating	Normal operation (dynamic setpoint graph)	Normal capacity matching	Normal capacity matching	
	Discharge temperature protection			
	Floodback operation	Exceptions (protection, prevention)	Exceptions (protection, prevention)	
Transition to Cooling / Defrost	With unit stop: close valves in relation with capacity	With unit stop: all compressors shut down regularly	With unit stop: all compressors shut down regularly	With unit stop: wait for pressure band to swap
	Without unit stop: proceed to cooling start-up opening	Without unit stop: ramp down to defined capacity on each circuit	Without unit stop: ramp down to defined capacity on each circuit	Without unit stop: wait for defined capacity to swap Low delta pressure protection
Transition to Heating	With unit stop: close valves in relation with capacity	With unit stop: all compressors shut down regularly	With unit stop: all compressors shut down regularly	With unit stop: wait for pressure band to swap
	Without unit stop: proceed to cooling start-up opening	Without unit stop: ramp down to defined capacity on each circuit	Without unit stop: ramp down to defined capacity on each circuit	Without unit stop: wait for defined capacity to swap Low delta pressure protection
Defrost	Suction pressure regulation	Suction pressure regulated capacity band	Suction pressure regulated capacity band	
Manual	Full manual mode	Full manual mode	Full manual mode	Full manual mode
Emergency shutdown	Valve closing by capacity	Fast capacity shutdown	Fast capacity shutdown	No action
Alarm	Valve closing by capacity	Fast capacity shutdown	Fast capacity shutdown	No action

Table 17: State machine matrix

5.1.1 Off

The compressor shutdown procedure is executed. After shutdown, all valves are closed and the 4-way valve switches to cooling position.

The stator heater function is active for both variable- and fixed-speed scrolls.

- **EXV management:**

  During the Off state, all EXV's on all circuits are held in the fully closed position.

- **Compressor management:**

  During the Off state, all compressors on all circuits are switched off, ie, all compressor relays are open.

- **4-way valve management:**

  During the Off state, the 4-way valve is held in the position, ie, cooling or heating, which it was in before the unit was turned off (relay could be powered or unpowered). Any required change in the position of the 4-way valve is initiated only during the next run cycle.

5.1.2 Start-up

- **EXV management:**

  During the Off state, all EXV's on all circuits are held in the fully closed position. Once a capacity request is received from the system controller, the state machine moves into the Start-up state. In this state, the EXV opens to a predefined value, which is a linear relation based on the ambient temperature. The relevant configurable values are "Cooling start-up opening" in Cooling mode (cfg 159 and cfg 160 for circuit 1, cfg 163 and cfg 164 for circuit 2), or "Heating start-up opening" in Heating mode (cfg 157 and cfg 158 for circuit 1, cfg 161 and cfg 162 for circuit 2). The start-up opening is respected for a predefined period of time ("Cooling control start-up opening duration" (cfg 88 for circuit 1, cfg 121 for circuit 2) or "Heating control start-up opening duration" (cfg 26 for circuit1, cfg 123 for circuit 2)). These may be tuned as per unit requirements, in order to have steady behaviour. Once the start-up opening duration has passed, the valve behaviour is transitioned to normal regulation where the automatic adaptive PID guides the valve.

  Note that the EXV opens a few seconds after the compressor starts, once the compressor has hit a certain speed threshold. This is because there is often a delay (of a few seconds) between a speed command given to the drive, and the actual drive ramp up. During this time, the EXV is held closed in order to prevent compressor floodback. In the case of fixed-speed compressors, the valve is held closed unit the relay is activated.

- **Compressor management:**

  During the Off state, all compressors on all circuits are switched off, ie, all compressor relays are closed. Once a capacity request is received from the system controller, the state machine moves into the Start-up state. In the case of variable-speed units, the variable-speed compressor ramps to a predefined value – the "Cooling start-up speed" in Cooling mode [cfg 90], or "Heating start-up speed" in Heating mode [cfg 31] – for a predefined period of time ("Cooling start-up speed duration" [cfg 32] or "Heating start-up speed duration" [cfg 30]). These may be tuned as per unit requirements, in order to have steady behaviour. After start-up speed duration is satisfied, the controller will modulate the speed of the compressor in order to meet the capacity requirements of the system. Note that the variable-speed compressor is always the first compressor to be switched on, and the last to be switched off.

  In the case of a fixed-speed unit, the start-up speed and duration are redundant. The first fixed-speed compressor is switched on immediately, and subsequent compressors (if any) are activated according to capacity requirements after a certain add delay - the "Pack control add delay" [cfg 99].

- **4-way valve management:**

  During the Off state, the 4-way valve is held in the position, ie, cooling or heating, which it was before the unit was turned off (relay could be powered or unpowered). Any required change in position of the 4-way valve is initiated only during the next run cycle.

  If the 4-way valve is indeed required to change position immediately after a start-up, eg, the unit starts in Cooling mode, but heating is desired, the 4-way valve is switched once the difference between the suction and discharge pressures are within a certain configured range, ie, between the "Four-way switch min delta P" [cfg 109] and the "Four-way switch max delta P" [cfg 188]. Note that the 4-way valve may be switched before the start-up speed and start-up duration are reached.

5.1.3 Shutdown

The compressor speed is reduced gradually and the valve is closing.

- **EXV management:**

  Once a "unit off" request is received from the system controller, the state machine moves into the Shutdown state. In this state, the fixed-speed compressor(s) is (are) switched off first, and the EXV closes to a calculated value (scaled according to the capacity of each fixed-speed compressor). The variable-speed compressor is the last to switch off, and the EXV closing follows the profile of the speed ramp-down.

- **Compressor management:**

  Once the state machine moves into the Shutdown state, the fixed-speed compressors on all circuits are switched off sequentially. The fixed compressors are switched off according to the "Packing Remove Delay" criterion [cfg 100]. Note that all compressors must also have respected the "minimum on-time". The variable-speed compressor is the last to be switched off and follows a prescribed ramp-down rate - "Variable Speed Shutdown Rate" [cfg 202].

- **4-way valve management:**

  In the Shutdown phase, there is no change in the 4-way valve position. Any required change in the position of the 4-way valve is initiated only during the next run cycle.

5.1.4 Standby

The compressor shutdown procedure is executed. After shutdown all valves are closed and the 4-way valve switches to cooling position.

The stator heater function is active.

- **EXV management:**

  In the Standby state, all EXV's on all circuits are held in the fully closed position.

- **Compressor management:**

  In the Standby state, the PeC controller can use a stator heating function to prevent the risk of liquid migration (in units that use a single variable-speed compressor only). It keeps the scroll temperature in a temperature band of 5-10 K above the evaporating temperature. The heater function is only active in Standby mode and not in Off mode. The power of the stator heater can be configured - "Stator heater power" [cfg 48].

- **4-way valve management:**

  In the Standby state, there is no change in the 4-way valve position. Any required change in the position of the 4-way valve is initiated only during the next run cycle.

5.1.5 Cooling

The compressor is running, the expansion valve is active and the 4-way valve is in cooling position.

- **EXV management:**

  In the Cooling state, all EXV's on all circuits are in normal regulation where the automatic adaptive PID guides the valve in order to achieve the target superheat setpoint. Please note that in the case of any addition of a compressor to a circuit (for example, in order to achieve a higher capacity), the EXV will open according to the proportion of the calculated capacity as it changes ("Nominal Capacity Change Scaling" [cfg 81]). The PID will then adjust the EXV opening in order to achieve the configured setpoint.

  Low Superheat operation: Please note that in order to enter into Low Superheat operating mode, the unit must be in Cooling mode, the superheat setpoint must be lower than 5 K ([cfg 21] for circuit 1 and [cfg 68] for circuit 2), and the operating conditions must be stable. If these criterion are met, the valve is steadily opened, and superheat is gradually reduced to the setpoint value. Note that the minimum superheat value is 0 K.

  Floodback Prevention operation: In order to anticipate and prevent a floodback event, an algorithm that manages the EXV in a proactive manner has been implemented. This normally occurs in transition modes, eg, into or out of Defrost mode, changes between Cooling and Heating modes. The Floodback Prevention algorithm is activated when the superheat value, discharge temperatures and slope of discharge temperatures are below a threshold value ("Superheat lower limit" [cfg 16418], "Superheat upper limit" [cfg 16421], "Unsafe band lower limit" [cfg 16415], "Unsafe band upper limit" [cfg 16416], "Discharge trend lower limit" [cfg 16417], "Discharge trend

upper limit" [cfg 16420]). Note that these do not apply when in low superheat operating mode. If these criterion are met, the EXV is closed, with the speed of closing proportional to the "degree of flooding", ie, difference between actual and expected discharge temperatures.

- **Compressor management:**

  In the Cooling state, the variable-speed compressor matches the capacity request from the system following the "VS Drive Control Rate" [cfg 123]. Please note that there is also a capacity tolerance, below which there is no change in the speed of the compressor ("Under capacity tolerance" [cfg 125], "Over capacity tolerance" [cfg 85]). In the case of fixed-speed only units, the control is identical.

  Exceptions (protection, prevention): The envelope prevention and protection zones are defined to take action before the compressor(s) leave(s) their respective envelopes.

  In the defined Envelope Prevention zone, the compressor speed control rates differ from the normal rates and the addition of compressors is prevented (however compressor removal is allowed).

  In the defined Envelope Protection zone, the variable-speed compressor is set to the minimum speed. Note that compressor speed control rates differ from the normal rates. In the case of fixed-speed only units, the control is set to demand only one fixed-speed compressor running.

  Please note that the unit may leave the envelope prevention and/or protection zones before all the above criterion are fulfilled, in which case the PeC will return to normal Cooling control.

- **4-way valve management:**

  In the Cooling state, the 4-way valve is held in the cooling position. Any required change in the position of the 4-way valve is initiated only with a change in operating state.

5.1.6 Heating

The compressor is running, the expansion valve is active and the 4-way valve is in heating position.

- **Dynamic setpoint:**

  According to a stability algorithm, the superheat setpoint is dynamically adjusted to between 0 and 6 K above the actual user-configured superheat setpoint.

- **EXV management:**

  In the Heating state, all EXV's on all circuits are in normal regulation where the automatic adaptive PID guides the valve in order to achieve the target superheat setpoint. Please note that in the case of any addition of a compressor in a circuit (for example, in order to achieve a higher capacity), the EXV will open according to the proportion of the calculated capacity as it changes ("Nominal Capacity Change Scaling" [cfg 81]). The PID will then adjust the EXV opening in order to achieve the configured setpoint.

  Low Superheat operation: Not available in Heating mode.

  Floodback Prevention operation: Please see Floodback Prevention operation in Cooling mode (the behaviour is identical in Heating mode).

- **Compressor management:**

  In the Heating state, the variable-speed compressor matches the capacity request from the system following the "VS Drive Control Rate" [cfg 123]. Please note that there is also a capacity tolerance, below which there is no change in the speed of the compressor ("Under capacity tolerance" [cfg 125], "Over capacity tolerance" [cfg 85]). In the case of fixed-speed only units, the control is identical.

  Exceptions (protection, prevention): Please see the exceptions in the Cooling mode (the behaviour is identical in Heating mode). Note, however, that the protection and prevention limits are different between Cooling and Heating modes.

- **4-way valve management:**

  In the Heating state, the 4-way valve is held in the heating position. Any required change in the position of the 4-way valve is initiated only with a change in operating state.

5.1.7 Transition from Heating to Cooling mode

The normal shutdown procedure is applied to switch off the compressors then restart the system to Cooling mode.

The transition to Cooling mode is activated when switching between Heating and Cooling modes.

5.1.7.1 Transition to Cooling mode WITHOUT a stop

- **EXV management:**

  Once the mode transition from Heating to Transition to Cooling mode has been instigated, all EXV's on all circuits are in normal regulation where the automatic adaptive PID guides the expansion valve. Note that in this case, the expansion valve continues to be controlled as in the Heating mode. Also note that the switching off of fixed-speed compressors is still anticipated by the EXVs, ie, the valve closes concurrently with the opening of the compressor relay.

- **Compressor management:**

  In the Transition to Cooling mode, all circuits are set to the minimum capacity. This means that in a variable-speed circuit, the fixed-speed compressors are sequentially switched off while respecting the remove delays and minimum compressor runtime. The variable-speed compressor is set to the "Cooling start-up speed" [cfg 90] and is steadily ramped down to that speed.

  In the case of a fixed-speed only circuit, the fixed-speed compressors are sequentially switched off until only 1 compressor is running. Note that if a circuit is not active, no action is taken, ie, no compressor is switched on.

  Note that, if required for unit management purposes, a stabilisation delay can be configured after all circuits have reached the minimum capacity ("Transition to Cooling stabilization delay" [cfg 193]).

- **4-way valve management:**

  The change of position of the 4-way valve is initiated at the end of the Transition to Cooling mode. Note that the 4-way valve will change position when the difference between the suction and discharge pressures are within the configured range ("Four way switching min delta P" [cfg 109] and "Four way switching max delta P" [cfg 188]).

  If a circuit is below the minimum pressure difference, the unit is stopped. There is then a delay of 30 seconds, after which the unit is restarted. On restart, once the circuit pressure is above the minimum pressure difference, the position of the 4-way valve is switched immediately.

  In case a circuit is above the maximum pressure difference, the 4-way valve will be switched immediately (due to no other feasible alternative). A different mitigation strategy is applied when there is a transition to Cooling with a stop.

5.1.7.2 Transition to Cooling mode WITH a stop

- **EXV management:**

  Once the mode transition from Heating to Transition to Cooling mode has been instigated, all EXV's on all circuits are in a special regulation mode. In this case, the expansion valve is controlled on suction pressure, rather than superheat. Also note that the switching off of a fixed-speed compressor is anticipated by the EXV's, ie, the valve closes concurrently with the opening of the compressor relay.

- **Compressor management:**

  In the Transition to Cooling state, the fixed-speed compressors are sequentially switched off, ie, all compressor relays are opened, while respecting the remove delays and minimum compressor runtime. The variable-speed compressor is switched off last. All compressors will remain switched off for the time period prescribed by the "Before Cooling Delay" [cfg 130], before being allowed to be switched on again.

  Note that if a circuit is not active, no action is taken, ie, no compressor is switched on.

- **4-way valve management:**

  The change of position of the 4-way valve is initiated at the end of the Transition to Cooling mode (after the "Before Cooling Delay" has elapsed). Note that the 4-way valve will only change position when the difference between the suction and discharge pressures are within the configured range ("Four-way switching min delta P" [cfg 109] and "Four-way switching max delta P" [cfg 188]).

If a circuit is above the maximum pressure difference, the expansion valve is opened in order to reduce the difference between suction and discharge pressures. Once this is within range, the first compressor is immediately started (and others are switched on sequentially).

If a circuit is below the minimum pressure difference, the first compressor is restarted, and the position of the 4-way valve is switched only once the circuit is above the minimum pressure difference.

5.1.8 Transition from Cooling to Heating mode

The normal shutdown procedure is applied to switch off the compressors then restart the system to Heating mode.

The transition to Heating mode is activated when switching between Cooling and Heating modes.

5.1.8.1 Transition to Heating mode WITHOUT a stop

- **EXV management:**

  Once the mode transition from Cooling mode to Transition to Heating mode has been instigated, all EXV's on all circuits are in normal regulation where the automatic adaptive PID guides the expansion valve. Note that in this case, the expansion valve continues to be controlled as in the Cooling mode. Also note that the switching off of a fixed-speed compressor is anticipated by the EXVs, ie, the valve closes concurrently with the opening of the compressor relay.

- **Compressor management:**

  In the Transition to Heating state, all circuits are set to the minimum capacity. This means that the fixed-speed compressors are sequentially switched off, ie, all compressor relays are opened, in the variable-speed circuit, while respecting the remove delays and minimum compressor runtime. The variable-speed compressor is set to the "Heating start-up speed" [cfg 31] and is steadily ramped down to that speed.

  In the case of a fixed-speed only circuit, the fixed-speed compressors are sequentially switched off until only 1 compressor is running. Note that if a circuit is not active, no action is taken, ie, no compressor is switched on.

  Note that, if required for unit management purposes, a stabilisation delay can be configured after all circuits have reached the minimum capacity ("Transition to Heating stabilization delay" [cfg 194]).

- **4-way valve management:**

  The change of position of the 4-way valve is initiated at the end of the Transition to Heating mode (after the "Before Heating Delay" has elapsed). Note that the 4-way valve will only change position when the difference between the suction and discharge pressures are within the configured range ("Four-way switching min delta P" [cfg 109] and "Four-way switching max delta P" [cfg 188]).

  If a circuit is below the minimum pressure difference, the unit is stopped. There is then a delay of 30 seconds, after which the unit is restarted. On restart, once the circuit pressure is above the minimum pressure difference, the position of the 4-way valve is switched immediately.

  In case a circuit is above the maximum pressure difference, the 4-way valve will be switched immediately (due to no other feasible alternative). A different mitigation strategy is applied when there is a transition to heating with a stop.

5.1.8.2 Transition to Heating mode WITH a stop

- **EXV management:**

  Once the mode transition from Cooling mode to Transition to Heating mode has been instigated, all EXV's on all circuits are in a special regulation mode. In this case, the expansion valve is controlled on suction pressure, rather than superheat. Also note that the switching off of fixed-speed compressors is anticipated by the EXVs, ie, the valve closes concurrently with the opening of the compressor relay.

- **Compressor management:**

  In the Transition to Heating state, the fixed-speed compressors are sequentially switched off, ie, all compressor relays are opened, while respecting the remove delays and minimum compressor runtime. The variable-speed compressor is switched off last. All compressors will remain switched off for the time period prescribed by the "Before Heating Delay" [cfg 126], before being allowed to be switched on again.

Note that if a circuit is not active, no action is taken, ie, no compressor is switched on.

- **4-way valve management:**

  The change of position of the 4-way valve is initiated at the end of the Transition to Heating mode (after the "Before Heating Delay" has elapsed). Note that the 4-way valve will only change position when the difference between the suction and discharge pressures are within the configured range ("Four-way switching min delta P" [cfg 109] and "Four-way switching max delta P" [cfg 188]).

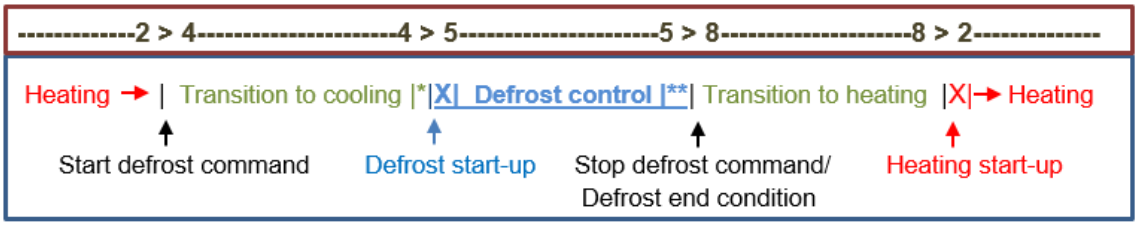
  If a circuit is above the maximum pressure difference, the expansion valve is opened in order to reduce the difference between suction and discharge pressures. Once this is within range, the first compressor is immediately started (and others are switched on sequentially).

  If a circuit is below the minimum pressure difference, the first compressor is restarted, and the position of the 4-way valve is switched only once the circuit is above the minimum pressure difference.

5.1.9 Defrost

The compressor is running, the expansion valve is active, the 4-way valve is in cooling position.

In the Defrost mode, the compressor speed and the cooling valve are controlled by PeC fuzzy logic to optimize compressor sound due to scroll unloading and to avoid low evaporating temperatures. The control strategy is balanced between plate heat exchanger protection against freezing and defrost duration. Heat exchanger design and selection will also impact defrost behaviour. Defrost start-up parameters and max. and min. speed during Defrost are available to optimize defrost control behaviour according to the system design.



* with optional compressor stop [99]

** with optional low capacity defrost end above dedicated condensing temp. [91, 92] and optional compressor stop [118]

Figure 11: Defrost operation flow and application state sequence

The OEM system controller can monitor the system and evaluate the need for a defrost cycle. It can send the Defrost command via digital 230 V signal or bus communication to the PeC controller. The PeC controller will actuate the defrost, taking care to reverse the 4-way valve respecting the proper compressor timings. When no "Defrost stop" signal is given by the system controller, the PeC will stop defrost after exceeding the "Defrost maximum time" or when "Defrost end temperature" has been reached.

***NOTE:* Defrost can be handled independently for each circuit or synchronized depending on how it is configured [cfg 29].**

5.1.10 Transition to Defrost from Heating mode (transition to Cooling)

- **EXV management:**

  EXV management from Heating mode to Defrost is identical to that from Heating to Cooling mode. This applies to both Defrost with a stop and Defrost without a stop (analogous to "Transition to Cooling with a stop" and "Transition to Cooling without a stop", respectively).

- **Compressor management:**

  Compressor management from Heating mode to Defrost is largely identical to that from Heating to Cooling mode (with or without a stop). The sole exception is that if a circuit is not active, action is taken to ensure that at least 1 compressor on each circuit is activated before the 4-way valve position is switched.

- **4-way valve management:**

  4-way valve management from Heating mode to Defrost is identical to that from Heating to Cooling mode (with or without a stop).

5.1.11 Defrost operation

- **EXV management:**

  In Defrost mode, all EXV's on all circuits are in a special regulation mode. In this case, the expansion valve is controlled based on suction pressure, rather than superheat. Note that this continues until the unit is back into Heating mode.

- **Compressor management:**

  Compressor management in Defrost mode is based on the following principle: until a circuit is completely defrosted, the maximum capacity on each circuit is applied, ie, all fixed-speed compressors are activated, and the variable-speed compressor is commanded to the maximum speed (depending on the operating conditions). Please note that there are specific Add Delays ("Defrost Control Add Delay" [cfg 103]) in Defrost mode, and the minimum off times to activate compressors are not respected. Also note that there is a minimum speed during defrost that is configurable ("Defrost Minimum Speed" [cfg 54]). Finally, the control rates, ie, the acceleration of the drive, are different in Defrost mode and are more aggressive than in normal operation in order to achieve an efficient defrost.

  Once the circuit is completely defrosted, the minimum capacity on each circuit is applied, ie, all fixed-speed compressors on the circuit with a variable-speed compressor are removed, the variable-speed compressor is commanded to the "Heating start-up speed" [cfg 31], and only 1 compressor on the fixed-speed only circuit is running. Please note that the remove delays are the same as in normal operation, and the minimum runtimes of the compressors are not respected.

- **4-way valve management:**

  The 4-way valve in Defrost mode is held in the cooling position.

5.1.12 Transition to Heating mode from Defrost (transition to Heating)

- **EXV management:**

  EXV management from Defrost to Heating mode is identical to that from Cooling to Heating mode. This applies to both Defrost with a stop and Defrost without a stop (analogous to Transition to Heating with a stop and without a stop, respectively).

- **Compressor management:**

  Compressor management from Defrost to Heating mode is largely identical to that from Cooling to Heating mode (with or without a stop). Note that all circuits are in the minimum capacity in the transition from Defrost to Heating mode (see above for explanation of minimum capacity). However, the minimum running times of the compressors are not respected in this transition state.

- **4-way valve management:**

  4-way valve management from Defrost to Heating mode is identical to that from Cooling to Heating mode (with or without a stop).

5.1.13 Manual

The user takes control of every component individually.

Please note that use in Manual mode removes all protections embedded in the PeC. The unit will respond only to specific user / controller commands. Note, however, that if an alarm condition is reached, the unit will shut down.

- **EXV management:**

  EXV management in Manual mode is completely determined by the user / controller input. This means that the EXV will retain and hold the previous prescribed value until commanded to change position.

- **Compressor management:**

  Compressor management in Manual mode is completely determined by the user using the digital output write variable. The speed of the variable-speed compressor is also determined by the user. Note that the speed and compressor commands are respected immediately, using the control rates specified by the user. Also note that compressor envelope speed limits are not respected.

- **4-way valve management:**

  4-way valve management in Manual mode is set by the digital output write variable and is executed without regard to any other criterion.

5.1.14 Emergency shutdown

- **EXV management:**

  Once an Emergency shutdown is requested, the EXV is effectively set to close completely (0 % opening).

- **Compressor management:**

  In an Emergency shutdown, all compressors on all circuits are switched off immediately. The variable-speed compressor is ramped down to zero at the fastest rate possible. Please note that Remove Delay or minimum runtimes are respected.

- **4-way valve management:**

  There is no action on the 4-way valve during an Emergency shutdown.

5.1.15 Alarm

The unit has encountered a problem and stopped. When the PeC enters this state, it shadows and clears the alarms. To avoid immediate restart, the unit is moved into waiting state for a configurable amount of time.

5.1.16 Waiting

The unit is in delayed restart after an alarm occurred during operating mode.

5.1.17 Compressor start

The unit has a heating request but the 4-way valve is in Cooling mode, so the unit starts in Cooling mode to build up the necessary pressure to switch the 4-way valve. Duration: 10 seconds at 2700 rpm.

5.2 Main functionalities

5.2.1 Smart compressor operating map management

The operating envelopes of the variable-speed scroll (VSS) are stored in the controller.

Based on measurements of suction and discharge pressures the possible speed range is calculated for every operating point. Protection algorithms prevent the operating point from leaving the operating map by acting on compressor speed and expansion valve opening. Envelope alarm limits are defined in order to avoid operation outside the envelope.

Additional fallback protection is implemented as safety software function in the drive. Torque and discharge temperature limitation are the major protective features.

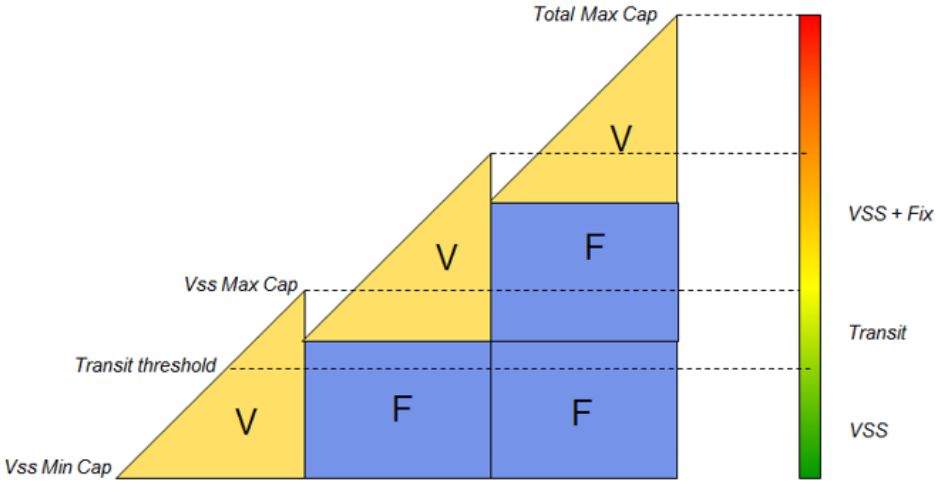


Figure 12

The system controller sends a request to the PeC controller for a certain heating capacity in kW or % of the maximum capacity. The mathematical compressor model and the R410A refrigerant properties are programmed in the PeC. Through this information, plus the measurement of the other system parameters, the PeC controller calculates the necessary compressor speed and need to operate the fixed-speed compressor in order to fulfill the system controller request.

The requested heating or cooling capacity is kept constant by the PeC, in a close control loop, by varying the compressor speed and operation within their application limits.

In multi-circuit applications, the multi-circuit capacity management function will be activated. In this system configuration, the methodology is to separate the total capacity requirement based on the capacity limits of the two circuits.

5.2.2 Speed control

The speed regulation algorithm is used in Heating and Cooling modes. The PeC calculates the speed that has to be applied to the compressor in order to match the requested capacity.

However, if the operating point reaches the lower limit of evaporating temperature, the compressor speed is decreased in order to stay inside the envelope.

When the condensing temperature reaches the upper limit of the envelope, the speed is also decreased.

5.2.3 Envelope limitations

To avoid overload of the compressor motor, the MOP function of the PeC limits the evaporating pressure to a pre-determined value, defined according to the safe operating envelope of the compressor(s). The evaporating temperature is limited by decreasing the main expansion valve opening causing higher superheat values.

The speed request has to respect the allowed envelopes according to the unit's operating point. This means that for the evaporating and condensing temperatures of the unit, the controller runs through all the envelopes of the compressor to find the lowest and highest envelopes containing the point.

The calculated envelope gives the minimum and maximum speeds allowed for the operating point. Note that for each limit, the controller progresses dichotomously to refine the envelope (up to a precision of 50 rpm).

If the evaporating temperature of the unit goes around the left side of the largest envelope allowed (equivalent to 4500 rpm) or if the condensing temperature goes around the top side of the largest envelope, a smart control algorithm is implemented to attempt to bring back the unit's operating point inside the allowed envelopes. The resulting speed is not filtered but it is still bound according to the allowed envelopes.

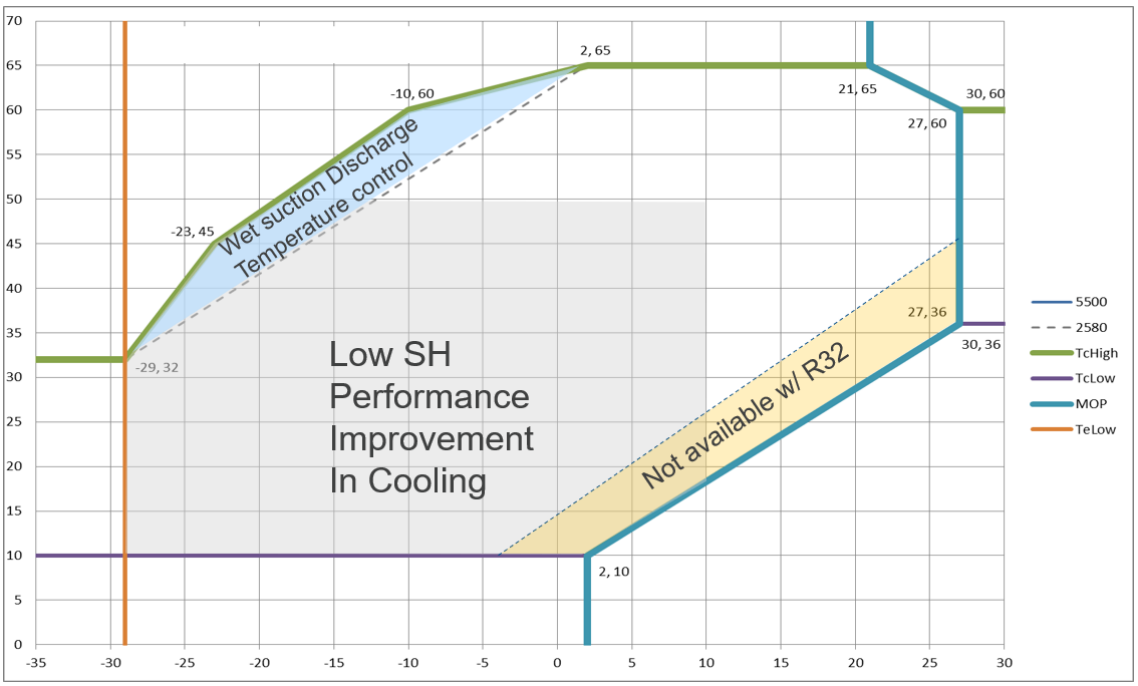


Figure 13

5.3 Additional features and functionalities

5.3.1 Energy metering

PeC provides information on system performance: power, COP, SCOP, SEER, heating and cooling capacity and minimum / maximum capacity.

PeC calculates the energy from compressors performance maps and values measured from the refrigerant cycle:

- Heating energy + electrical energy in Heating mode
- Cooling energy + electrical energy in Cooling mode

These values can be read once per second (1/s) in Wh (2 x 16 bit).

Accumulated values for SCOP and SEER calculation are stored once every 24 hours in read-only registers. Resetting the PeC or a "power off" cycle will lead to a loss of non-stored information.

All these values can be accessed via Modbus communication.

For SCOP and SEER calculation, accessory power for fan, pump, etc. is included in the calculation (constant 150 W by default). Static accessory power can be pre-set, from 0 to 3000 W, on configuration parameter.

For greater accuracy, it is possible to give the actual accessory power consumption, eg, for variable fan, pump, etc. via Bus communication to the PeC, to be considered for SCOP and SEER calculation.

Variable accessory power has to be written to the "Accessory Power value" write register.

On PeC power up, the "Accessory Power" write register is initialized by the "Accessory Power" configuration parameter value.

5.3.2 FREMAR band protection (FREquency Management to Avoid Resonances)

Due to system-specific design and the wide speed range of the compressor, harmful or disturbing resonance vibrations can occur in the mechanical system. If such resonances are measured during the OEM system qualification process and cannot be avoided, the Fremar band protection can be used to cut out the critical speed range(s) by defining the Fremar bandwidth and up to 3 separate frequencies.

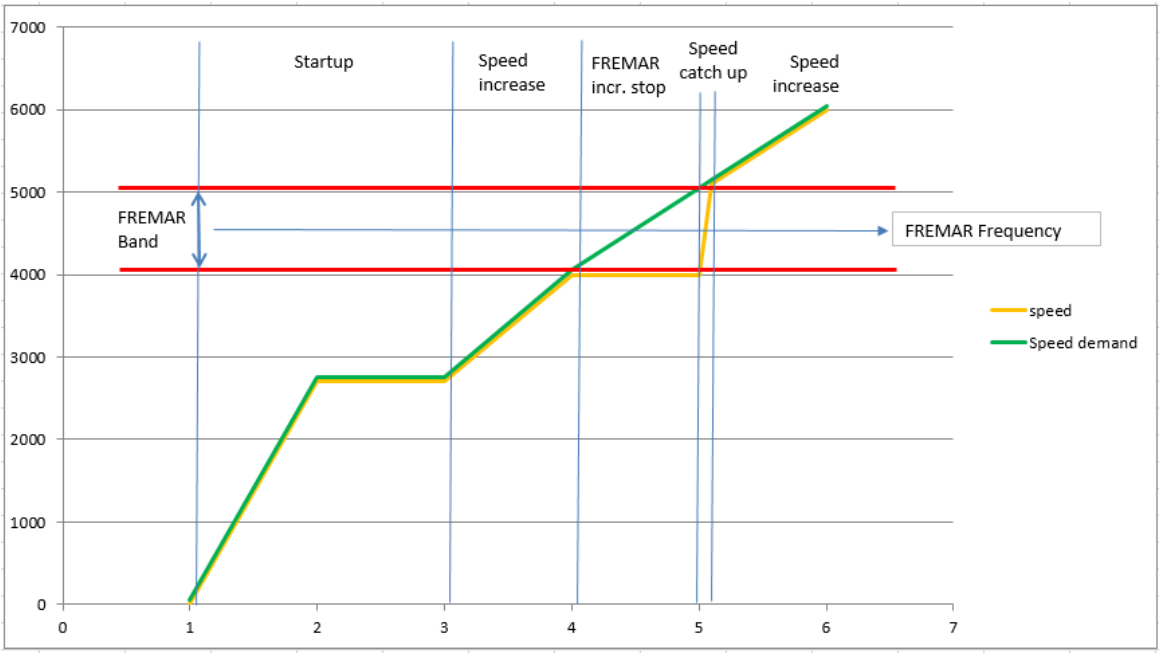


Figure 14

5.3.3 Oil return function

To ensure sufficient oil level in the compressor at all times, the system has to be properly designed and qualified by the OEM. By monitoring the oil level, the "oil return-threshold" and "oil return-threshold duration" parameters can be configured to facilitate the oil return to the compressor. These

parameters will trigger the oil return phase. In this phase, the system will run for a specific "oil return duration" time at a specific "oil return speed" to bring the oil back to the compressor.

To qualify the oil return performance of the system, Emerson can provide compressors with sight tubes.

If the system is in oil return mode, the "Speed control" state parameter is set to "Oil return".

During the oil return state, if a critical alarm is encountered, eg, envelope alarm, the alarm state and consequently the circuit management will supersede that of the oil return function.

All the parameters associated to the oil return function are configurable. If the compressor speed goes below a threshold value for a certain amount of time, the oil return function is triggered. This function forces the compressor to an "oil return" speed for a brief period.

5.3.4 DLT limitation control function with wet suction control

The PeC will monitor the discharge line temperature. In case the high DLT area is entered, superheat control will change into Discharge Temperature Protection control. The smart logic on the EXV control ensures that the portion of liquid refrigerant droplets at the inlet of the compressor is sufficient to keep the discharge line gas temperature below the allowed limit, while the COP is kept as good as possible, following the strategy "As much as needed and as little as possible".

The discharge gas temperature limitation is compressor-type dependent.

5.3.5 Main superheat control

One bipolar expansion valve per circuit can be controlled by PeC for Heating and Cooling modes.

The superheat control is based on pressure/temperature control strategy involving a self-adapting PID control algorithm so as to adapt to different operating conditions. The main superheat setpoint is being adapted in a pre-defined range in order to achieve stable and optimal operating conditions.

NOTE: **To test the control behaviour at special conditions, fixed and non-adaptive PID parameters can be used in the "Manual Control mode". Please contact the Application Engineering department at Emerson in case this functionality needs to be configured.**

5.3.6 External capacity request via Modbus

The capacity request for Heating and Cooling modes can be sent by the system controller via Modbus communication. In addition to the capacity, the operating mode has to be set separately.

The capacity input request, sent via Modbus communication, is an absolute value expressed in %.

The maximum available capacity for the current operating conditions is accessible by the system controller via Modbus communication.

5.3.7 Start-up configuration function

During variable-speed compressor start-up, the compressor will run to the start-up speed with a given ramp-up rate. When the 4-way valve position is correctly set, the compressor will go to the mode-based start-up speed. The compressor speed is stabilized at the start-up speed for a given time (start-up duration). After that, the controller will modulate the speed to meet the capacity requirement of the system.

5.3.8 Compressor shutdown

If the controller receives a compressor shutdown command, it will switch off the fixed-speed compressor(s) first if it is (they are) running. Then the variable-speed compressor will shut down according to a pre-determined procedure.

5.3.9 Maximum speed during heating

Maximum speed during heating restricts the speed of the compressor, to limit the load on it and the heating capacity of the system.

5.3.10 Variable-speed Scroll smart crankcase heater function

The PeC controller uses a smart crankcase heating function to prevent the risk of liquid migration. It keeps the scroll temperature in a temperature band of 5-10 K above the evaporating temperature. The heater function is only active in Standby mode of the PeC. By using Standby and Off modes, the heater can be switched on and off by the OEM system controller.

This function is available only when there is one variable-speed compressor on the circuit.

5.4 Alarm management

5.4.1 "Alarm State" during compressor operation

Exceeding hard-programmed or configured operating limits leads to an alarm or warning to the alarm registers. Depending on the delay time and the different alarms and warnings, the system may continue to run.

The PeC will react, on a delayed warning or alarm, by changing the speed and valve opening to avoid getting into an "Alarm State". The OEM system controller can also trigger preventive actions by, eg, reducing demanded capacity, increasing pump speed, fan speed, etc.

If there is no delay time on an alarm or if the delay time has expired, the PeC goes into "Alarm" state. "Alarm" state means:

1. Compressor is shut down as fast as possible and valves will close accordingly.
   a. Alarm registers are copied as a snapshot into shadow alarm registers and cleared.
   b. Hardware and software alarm words are written to the alarm history.
   c. The alarm relay is activated (the relay status can be monitored via Modbus communication, "Read parameter").
2. After the alarm cause has disappeared, the application state goes into "Waiting" state (alarm pause) before a restart is attempted.
3. When the alarm pause time has expired, all the alarms, alarm shadows and relay/bit are cleared and the PeC goes back to normal operating mode.

NOTE: **For more information please refer to Technical Information TI_Sol_PEC_01 "Performance Controller PeC – Modbus Interface Description" or contact your local Application Engineering representative at Emerson.**

5.4.2 Hardware alarms

On occurrence of any hardware alarm, the system will shut down immediately. If not mentioned specifically, all hardware alarms are self-resetting and the system will restart when the alarm disappears and the forced waiting time (Alarm Pause) has expired.

- **Valve alarms:** A complete valve check is performed at start-up. This test is repeated on a valve if it has been detected as faulty. Upon regular operation, at the end of each valve movement, the energized coils are checked.
- **Sensor failures:** These alarms are evaluated permanently regardless of application state.
- **VSS & bipolar drive communication:** Every second the PeC reads the variables available from the bipolar drive unit and the VSS drive. After 5 successive failed attempts, the associated alarm will be raised and the associated data will be invalidated. Note that during the first four failures, the old values are kept.
  During HP alarm or EVU lock, the VSS communication alarm is disabled (drive is unpowered).
- **High-pressure switch alarm:** This alarm is raised whenever the digital input 2 is released. During HP alarm, the VSS communication alarm is disabled (drive is unpowered).
- **Compressor alarm:** This alarm is raised if there are major or minor faults on the VSS drive. The details of the compressor alarm cause are reported in the VSS fault structures.
- **EEPROM failure:** The EEPROM memory holding configuration parameters and energy counter values are checked at reset. This alarm is resettable only by power off – power on.
- **COM timeout:** When the analog input is not used on the controller, the communication to the system controller has a timeout of 60 sec. When this timeout expires, the compressor shuts down. When communication resumes, the system restarts in the state present on the write variables.

These alarms are perpetually evaluated and are self-resetting.

On occurrence of an alarm, the system can react in different ways based on its state and the alarm severity:

- If it is in off mode, nothing will happen.
- If it is not off **but not running** and the severity is high, the system will be pushed into the alarm state. Upon alarm disappearance, control will start right away.

- If it is not off but running and the severity is high, the system will be pushed into the alarm state. Upon alarm disappearance, it will go in the alarm pause state and wait for the remaining alarm pause delay.
- If it is not off but running and the severity is medium or low, the system will start, and the relevant circuit and/or compressor will be pushed into alarm.

The tables below describe various types of hardware alarms, their origin, severity, action and reset conditions.

Discharge sensor failure 1, 2, 3, 4, 5, 6	
Origin	During normal running conditions when a sensor reads a value (resistance, current) which is considered to be abnormal, eg, short circuit or open circuit.
Severity	Low
Action	Depending upon the conditions, triggers a compressor or circuit or unit shutdown. See above for detailed shutdown behaviours.
Reset	When the sensor reads a value which is considered normal.

Ambient sensor failure	
Origin	During normal running conditions when a sensor reads a value (resistance, current) which is considered to be abnormal, eg, short circuit or open circuit.
Severity	High
Action	Triggers a unit shutdown. See above for detailed shutdown behaviour.
Reset	When the sensor reads a value which is considered normal.

Any other sensor failure	
Origin	During normal running conditions when a sensor reads a value (resistance, current) which is considered to be abnormal, eg, short circuit, open circuit.
Severity	Medium
Action	Depending upon the conditions, triggers a circuit or unit shutdown. See above for detailed shutdown behaviours.
Reset	When the sensor reads a value which is considered normal.

Inverter communication	
Origin	If communication is lost with the inverter (5-second delay).
Severity	Low
Action	Depending upon the conditions, triggers a compressor or circuit or unit shutdown. See above for detailed shutdown behaviours. If a circuit or unit shutdown is performed, valve close is deferred by 180 seconds. This safety delay guarantees that the drive reaches an alarm state and stops.
Reset	When communication is regained (10 seconds delay)

Permanent memory	
Origin	If permanent memory becomes unreachable or its data integrity is not guaranteed anymore.
Severity	None
Action	**No action**, flag is informative.
Reset	Never, flag is permanent until controller is power cycled.

Supervisor communication	
Origin	If communication activity from the supervisor is lost for 60 seconds on **both** the Modbus slave buses.
Severity	High
Action	**Graceful** shutdown with: - Regular ramp-down for variable-speed compressor. - Regular switch off-of the fixed-speed compressors. - Valve regulation while the compressors are stopping. The valve is closed when the compressors have stopped.
Reset	When supervisor communication activity is regained on **any** of the Modbus slave buses.

Compressor failures and/or configuration and/or lockdown	
Origin	- If the VS drive advertises faults on its interface. - If the VS drive configuration does not match the desired one. - If the VS drive advertises the locked-down signal on its interface.
Severity	Low
Action	Depending upon the conditions, triggers a compressor or circuit or unit shutdown. See above for detailed shutdown behaviours.
Reset	When the VS drive is (all satisfied): - faults free; - configured in the desired way; - and not in the locked down state.

Safety chain 1, 2	
Origin	If a safety chain's digital input is released.
Severity	Medium
Action	Depending upon the conditions, triggers a circuit or unit shutdown. See above for detailed shutdown behaviours.
Reset	When the safety chain's digital input is active again.

Power loss	
Origin	If controller supply voltage is lost.
Severity	High
Action	Triggers a unit shutdown. See above for unit shutdown behaviour.
Reset	Irrelevant, since the controller will at some point drain out the back-up power supply.

Valve configuration	
Origin	- If the valves to be used are not configured. - If the valves to be used are not compatible.
Severity	High
Action	No action, the valve types can only be changed while the unit is **not** running. However, any operating mode request will immediately push the unit in the alarm state.
Reset	When the valve types are configured and compatible.

Valve 1, 2	
Origin	If the measured currents (upon start-up or while the unit is running) reach abnormal values.
Severity	Medium
Action	If happening during start-up, no reaction. However, any operating mode request will immediately push the circuit and/or the unit in the alarm state. If happening while the unit is running, depending upon the conditions, circuit or unit shutdown. Note however that there is no valve regulation or close since the valve is in failure.
Reset	When the measured currents are back to normal values.

Drive start-up	
Origin	If the VS drive stays in the starting phase for more than 30 seconds.
Severity	Low
Action	Depending upon the conditions, triggers a compressor or circuit or unit shutdown. See above for detailed shutdown behaviours.
Reset	As soon as the drive enters the stopping phase due to its shutdown.

Pack configuration	
Origin	- If both variable-speed and fixed-speed compressors 1.1 are defined. - If no compressor is defined. - If the compressor definitions do not share the same refrigerant.
Severity	High
Action	No action, the pack configuration can only be changed while the unit is **not** running. However, any operating mode request will immediately push the unit in the alarm state.
Reset	When the pack configuration respects all the above mentioned rules.

Oil sensing controller 1, 2, 3, 4, 5, 6 communication	
Origin	If communication is lost with the device (3-second delay).
Severity	Low
Action	Depending upon the conditions, triggers a compressor or circuit or unit shutdown. See above for detailed shutdown behaviours.
Reset	When communication is regained (5-second delay).

Circuit 1 or 2 external emergency	
Origin	If a circuit’s emergency Modbus signal is on.
Severity	Medium
Action	Depending upon the conditions, triggers a circuit or unit shutdown. See above for detailed shutdown behaviours.
Reset	When the signal is off.

5.4.3 Software alarms

Delay counter triggers an "Alarm State" when configured delay time is exceeded			
Delay counter increases	Over limits	↓	Limit value
Delay counter stopped	Inside limits	Dead band	Limit value - Bandwidth
Delay counter cleared	Inside limits	↑	

Table 18: Dead band function on alarms

- **Low pressure alarm:** This alarm works in a dual fashion. If the pressure is above the threshold, the alarm is cleared.
- **Low superheat:** This alarm works in a dead band fashion with an incremental counter.
- **High superheat alarm:** This alarm works in a dead band fashion with an incremental counter and can indicate low refrigerant charge in the system.
- **Valve large opening:** Raised only as warning. This alarm works in a dead band fashion with an incremental counter and can indicate low refrigerant charge in the system.
- **High condensing pressure:** This pressure alarm is one of the system protection functions: when the maximum condensing pressure (adjustable) after a time delay (adjustable) is exceeded, the high condensing pressure alarm is triggered and the compressor is shut down to protect the system before the mandatory high-pressure switch triggers.
  This does not replace the high-pressure switch limiter imposed by EN 378.
- ***Freeze alarm:*** *This alarm is currently inactive. It will be implemented in future in order to protect the heat exchanger in cooling mode.*
- **Envelope Tc low:** Raised only as warning. This flag is raised if the condensing temperature is below the minimum allowed value. No preventive action is performed and the allowed time outside the envelope is 30 minutes.
- **Envelope Tc high**: Raised only as warning. This flag is raised if the condensing temperature is above the maximum allowed value. Compressor speed is decreased in order to stay inside the allowed application envelope.
- **Envelope Te low:** Raised only as warning. This flag is raised if the evaporating temperature is below the minimum allowed value. Compressor speed is decreased in order to stay inside the allowed application envelope.
- **Envelope Te high**: Raised only as warning. This flag is raised if the evaporating temperature is above the maximum allowed value. Valve opening is decreased in order to stay inside the allowed application envelope (MOP protection).
- **Envelope alarm:** The envelope alarm is triggered if one of Tc low, Tc high, Te low or Te high flags are raised for the respective durations. This alarm stops the system.
- **High discharge temperature:** This alarm is triggered immediately if the discharge temperature exceeds 130 ºC.

These alarms are evaluated only while the unit / circuit / compressor is running and are reset as soon as the unit / circuit / compressor enters an alarm state or when the unit enters the Off state.

The tables below describe the origin, severity and action for each type of software alarm.

Low pressure 1, 2		
Origin	**Suction pressure**	**Action**
	> [cfg 36] bar	✓ No action (alarm timer cleared)
	[cfg 36] – 0.5 to [cfg 36] bar	⚠ Alarm after [cfg 37] sec
	< [cfg 36] – 0.5 bar	⊘ Instantaneous alarm
Severity	Medium	
Action	Depending upon the conditions, triggers a circuit or unit shutdown. See above for detailed shutdown behaviours.	

Low superheat 1, 2 – Outside of the low superheat zone		
Origin	**Compressor superheat**	**Action**
	> [cfg 34] + 2 K	✓ No action (alarm timer cleared)
	[cfg 34] K to [cfg 34] + 2 K	⏸ Pause (alarm timer frozen)
	< [cfg 34] K	⚠ Alarm after [cfg 35] sec
Severity	Medium	
Action	Depending upon the conditions, triggers a circuit or unit shutdown. See above for detailed shutdown behaviours.	

High superheat 1, 2		
Origin	**Compressor superheat**	**Action**
	> [cfg 44]	⚠ Alarm after [cfg 45] sec
	[cfg 44] - 4.0 K	⏸ Pause (alarm timer frozen)
	< [cfg 44] - 4.0 K	✓ No action (alarm timer cleared)
Severity	Medium	
Action	Depending upon the conditions, triggers a circuit or unit shutdown. See above for detailed shutdown behaviours.	

Opening 1, 2		
Origin	**Valve opening**	**Action**
	> 95 %	⚠ Warning after 600 sec
	90 %	⏸ Pause (warning timer frozen)
	< 90 %	✓ No action (warning timer cleared)
Severity	None	
Action	No action, flag is purely informative.	

High pressure 1, 2		
Origin	**Discharge pressure**	**Action**
	> [cfg 39] bar	⚠ Alarm after [cfg 40] sec
	< [cfg 39] bar	✓ No action (alarm timer cleared)
	The high condensing pressure alarm is one of the system protection functions, it should be triggered before the mandatory high pressure switch triggers. This does not replace the high-pressure switch limiter imposed by EN 378.	
Severity	Medium	
Action	Depending upon the conditions, triggers a circuit or unit shutdown. See above for detailed shutdown behaviours.	

<table>
<tr><th colspan="2">Envelope alarm 1, 2</th></tr>
<tr><td>Origin</td><td>Considering the following diagram of the envelope definitions, 4 limits can be extracted: Te min., Te max., Tc min. and Tc max.
<table>
<tr><th>Evaporating temperature</th><th>Action</th></tr>
<tr><td>> Te max + 10.0 °C</td><td>⊘ Instantaneous alarm</td></tr>
<tr><td>Te max to Te max + 10 °C</td><td>⚠ Alarm after 10 sec</td></tr>
<tr><td>Te min to Te max °C</td><td>✓ No action (alarm timer cleared)</td></tr>
<tr><td>Te min to Te min - 5.0 °C</td><td>⚠ Alarm after 30 sec</td></tr>
<tr><td>< Te min - 5.0 °C</td><td>⊘ Instantaneous alarm</td></tr>
</table>
<table>
<tr><th>Condensing temperature</th><th>Action</th></tr>
<tr><td>> Tc max + 2.0 °C</td><td>⊘ Instantaneous alarm</td></tr>
<tr><td>Tc max to Tc max + 2 °C</td><td>⚠ Alarm after 10 sec</td></tr>
<tr><td>Tc min to Tc max °C</td><td>✓ No action (alarm timer cleared)</td></tr>
<tr><td>< Tc min °C</td><td>⚠ Alarm after 30 min</td></tr>
</table></td></tr>
<tr><td>Severity</td><td>Medium</td></tr>
<tr><td>Action</td><td>Depending upon the conditions, triggers a circuit or unit shutdown. See above for detailed shutdown behaviours.</td></tr>
</table>

Envelope evaporating temperature low 1, 2	
Origin	If the evaporating temperature goes below the minimum allowed evaporating temperature.
Severity	None
Action	As a protective measure, the PeC will: - slow down the variable-speed compressor; - switch off the fixed-speed compressors; - increase the valve opening (should the superheat level allow it).

Envelope evaporating temperature high 1, 2	
Origin	If the evaporating temperature goes above the maximum allowed evaporating temperature.
Severity	None
Action	As a protective measure, the PeC will: - decrease the valve opening (should the superheat level allow it).

Envelope condensing temperature low 1, 2	
Origin	If the condensing temperature goes below the minimum allowed condensing temperature.
Severity	None
Action	No action, flag is purely informative

Envelope condensing temperature high 1, 2	
Origin	If the condensing temperature goes above the maximum allowed condensing temperature.
Severity	None
Action	As a protective measure, the PeC will: - slow down the variable-speed compressor - switch off the fixed-speed compressors

Freeze alarm 1, 2		
Origin	**Evaporating temperature**	**Action**
	> [cfg 46] + 2.0 °C	✓ No action (alarm timer cleared)
	[cfg 46] to [cfg 46] + 2.0 °C	⏸ Pause (alarm timer frozen)
	< [cfg 46] °C	⚠ Alarm after [cfg 47] sec
	This alarm is only active in Cooling and after the Cooling start-up duration [cfg. 88].	
Severity	Medium	
Action	Depending upon the conditions, triggers a circuit or unit shutdown. See above for detailed shutdown behaviours.	

Defrost termination	
Origin	If the defrost runs for longer than [cfg 50] minutes.
Severity	High
Action	Triggers a unit shutdown. See above for detailed shutdown behaviour.

High discharge temperature 1, 2, 3, 4, 5, 6		
Origin	If the discharge temperature of a **running** compressor goes above the following limits:	
	Discharge temperature	**Action**
	> Maximum discharge	⊘ Instantaneous alarm
	Discharge to maximum discharge threshold	⚠ Alarm after 30 sec
	< Discharge threshold	✓ No action (alarm timer cleared)
	For R410A: Max. discharge = 140 °C, discharge threshold = 137.5 °C For R32: Max. discharge = 150 °C, discharge threshold = 147.5 °C *For R290: Max. discharge = 135 °C, discharge threshold = 132.5 °C (future use)*	
Severity	Low	
Action	Depending upon the conditions, triggers a compressor or circuit or unit shutdown. See above for detailed shutdown behaviours.	

Delta pressure alarm	
Origin	If after a circuit start-up (compressors activation), that circuit's controller (state machine) stays in an inactive state (Off, Pre-Opening or Ready/Waiting) for more than 300 seconds. This condition basically translates the fact that for whatever reason, the pressures of the installation are not separating when some compressors are running.
Severity	High
Action	Triggers a unit shutdown. See above for detailed shutdown behaviour.

5.4.4 Machine alarms summary

Alarm description	Alarm Status	Inverter speed	Circuit 1 fixed-speed comp.	Circuit 2 fixed-speed comp.	Valve 1	Valve 2	System controller action
Any sensor failure **Inverter communication** **Oil sensing controller communication** **Inverter alarms** **Circuit safety 1, 2** **Power loss** **Valve 1, 2** **High discharge temp. 1, 2, 3, 4, 5, 6** **Low pressure 1, 2** **Low superheat 1, 2** **High superheat 1, 2** **High pressure 1, 2** **Envelope 1, 2** **Freeze protection 1,2**	Alarm	Shut-down	Switch off	Switch off	Closing	Closing	Force immediate system shutdown
Supervisor communication	Alarm	OFF	OFF	OFF	OFF	OFF	Force graceful system shutdown
Valve large opening 1,2	Warning	Normal control	Normal control	Normal control	Normal control	Normal control	
Envelope Tc low 1, 2	Warning (for 30 min.)	Normal control	Normal control	Normal control	Normal control	Normal control	
Envelope Te high 1,2	Warning (for 10 s)	Normal control	Normal control	Normal control	MOP control	MOP control	
Envelope Tc high 1,2	Warning (for 10 s)	Speed reduction	OFF (after 5 s)	OFF (after 5 s)	Normal control	Normal control	Can monitor these and take preventive action (increase fan or pump speed)
Envelope Te low 1,2	Warning (for 10 s)	Speed reduction	OFF (after 5 s)	OFF (after 5 s)	LOP Control	LOP Control	

Table 19

5.5 USB log file management

The PeC can record the log file trough the USB port. The main functionalities are as follows:

- 40 signals are buffered every 3 seconds.
- Upon alarm occurrence (Application or Circuit 1 or Circuit 2), the last 3 minutes of data are backed up on the USB stick.
- All the shadow alarms of Application, Circuit 1 and Circuit 2 are backed up too.
- All the data are stored on a file as raw data.
- Each alarm file has its own distinctive 5-digit number code.
- The stick will always contain the last 100 alarms that have occurred. For any additional alarm, the oldest alarm file on the stick will be deleted to leave room for the latest one.

5.6 Modbus protocol specifications

NOTE: **Please read carefully Technical Information TI_Sol_PEC_01 "Performance Controller PeC – Modbus Interface Description" to avoid system-controller communication problems and to be able to use the latest PeC features. If further information is needed, please contact your local Application Engineering representative at Emerson.**

6 Laboratory testing

6.1 Semi-manual mode

For lab testing purposes and/or to achieve special running parameters or conditions, it is possible to activate the semi-manual mode in Heating or Cooling mode. It is possible to change the control mode from automatic to manual on the compressor speed or the expansion valves, to get manual control over the device(s).

Heating/cooling capacity, compressor speed or valve openings are set as absolute values of kW, rpm or % valve opening.

Defrost can be activated and deactivated via push button registers.

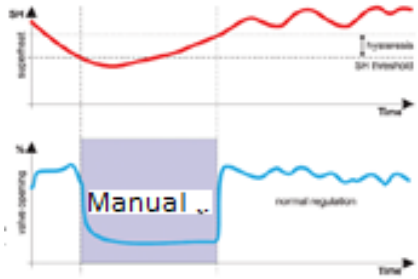


Figure 15

***NOTE:* The semi-manual mode is only available via Modbus communication and for experienced users.**

6.2 Manual mode

To test the system components attached to the PeC, it is possible to handle all active components manually.

No automatic function and no safety or alarm functions are active in this mode.

All components must be controlled manually, eg, for component function test.

***NOTE:* The manual mode is only available via Modbus communication and for experienced users.**

6.3 Starting lab testing with Modmonitoring software

To quick-start lab testing, Emerson provides a Modbus communication-based PC software with which all the PeC functionalities are available and the testing on the prototype can be performed.

***NOTE:* For more information please contact your local Application Engineering representative at Emerson**.

6.4 Software update on the PeC

For lab testing purposes or during the qualification process, an update of the PeC firmware may be needed. To this end, Emerson can supply a programming tool and an instruction sheet about how to flash the new firmware on the PeC controller.

The PeC software may be updated via a Modbus cable through the "Modbus Slave" port.

***NOTE:* For more information or to get the programming tool or instruction sheet, please contact your local Application Engineering representative at Emerson.**

7 Electrical connection

7.1 General recommendations

WARNING
Conductor cables! Electrical shock hazard! The controller operates at hazardous voltages which can cause severe personal injury or equipment damage. Extreme care and precautions must be taken when handling the product.
The controller must always be inserted inside an electrical panel that can only be accessed by authorised personnel. The keyboard must be the only part that can be reached. Insert the probe where it cannot be reached by the end-user.
Disconnect all the electric connections before performing any maintenance or servicing work.
The device must never be hand-held while being used.

CAUTION
Wrong supply voltage! Material damage! Verify that the power supply voltage is correct before connecting the controller.
Consider the maximum current that can be applied to each relay.

IMPORTANT
Make sure that the wires for the probes, the loads and the electrical power supply are separated and sufficiently distant from each other, without crossing or intertwining with each other.
Separate the power of the controller from the rest of the electrical devices connected inside the electrical panel. The secondary of the transformer must never be connected to the earth.
In the case of applications in industrial environments, it may be useful to use the main filters in parallel to the inductive loads.

During the installation process, follow the recommendations below to prevent the device from malfunctioning:

- Separate the cables of the analog inputs from those of the digital inputs, and the serial line cables from the power cables, to avoid malfunction due to electromagnetic interference.
- Separate the power of the device from that of other electrical components.
- Never connect the secondary of the supply transformer to the earth.
- Separate the signal cables from the power cables. It is recommended to follow the diagram in **Figure 16** below as far as possible.

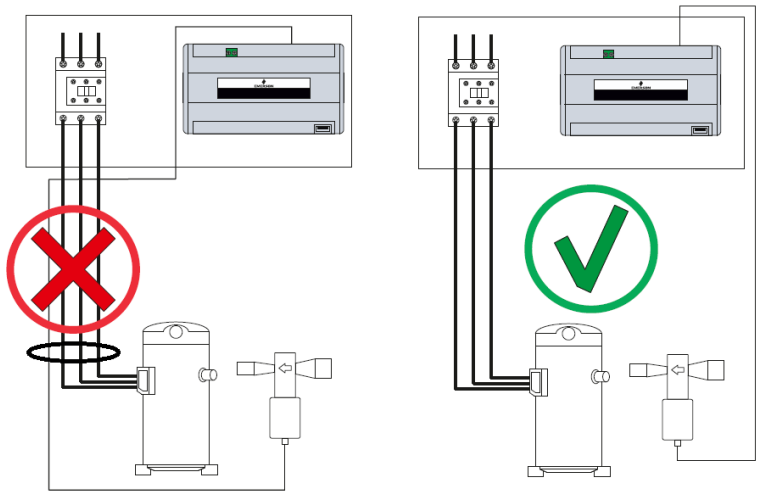


Figure 16: Example of wrong connection

The example in above diagram shows how improper connection can generate a wrong signal to the EXV valve and the possibility to lose steps.

7.1.1 EMC

- Separate drive-to-compressor supply from controls, sensor lines and communication lines.
- Keep a distance of 10 cm between clean and dirty lines and components if possible.
- Do not disable EMC measures by:
  - wrong mounting of components (position & orientation);
  - crossing or bringing together clean and dirty cables or components;
  - putting components too close together;
  - not keeping enough clearance distance.

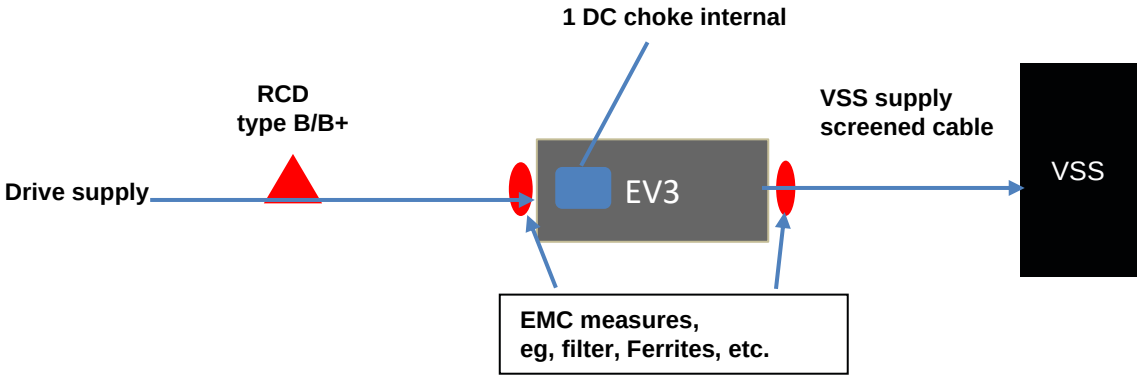


Figure 17

7.1.2 Ferrites

- Ferrites should be positioned close to input and output of the drive.
- Do not pass input and output wires which would make the ferrite useless.

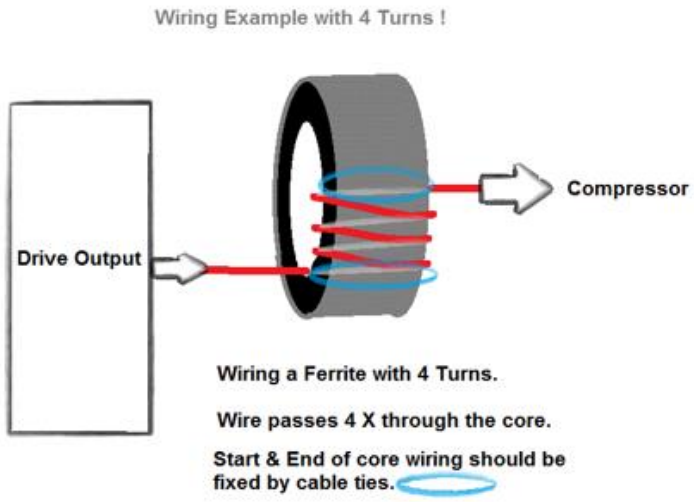


Figure 18: Example of good practice 4 turns with one ferrite

NOTE: **For more information, please refer to Application Guidelines AGL_Sol_EV3 "EV3 Inverter Drive for ZPV* Variable Speed Compressors" and AGL_AC_VS_YPV "Copeland Scroll Variable Speed Compressors for R32 Applications – YPV066* & YPV096*" or contact your local Application Engineering representative at Emerson.**

7.1.3 Digital inputs and outputs wiring

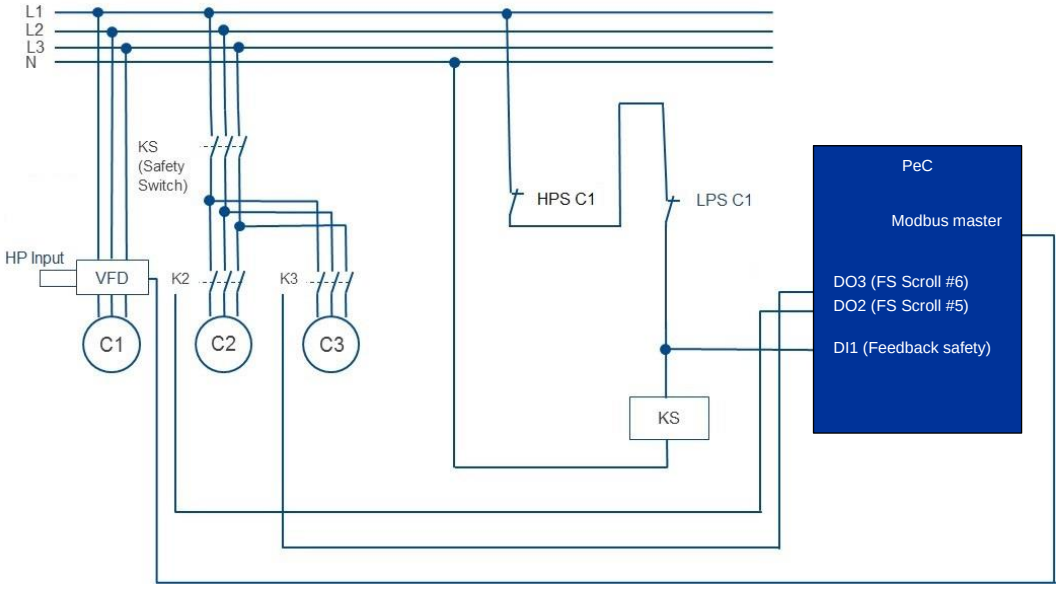


Figure 19: Digital inputs and outputs wiring for variable-speed circuit 1 (proposal)

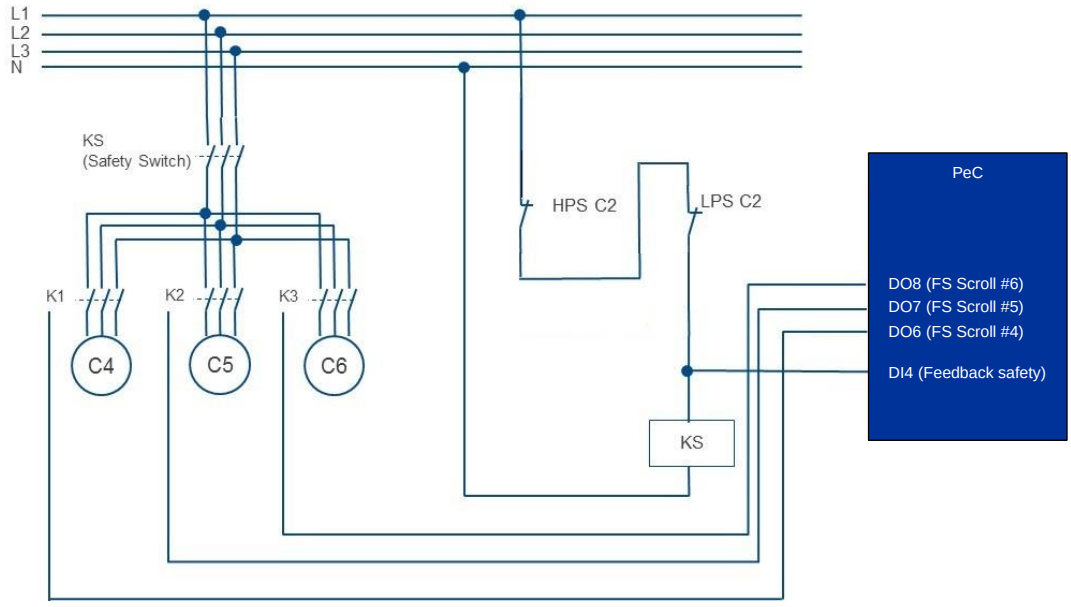
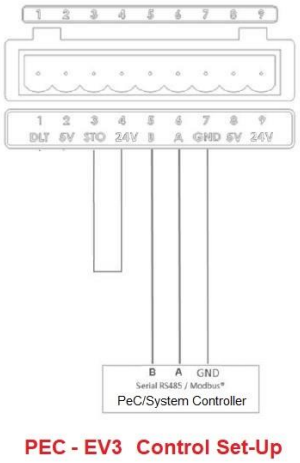


Figure 20: Digital inputs and outputs wiring for fixed-speed circuit 2

7.1.4 EV3 Drive control wiring



PEC - EV3 Control Set-Up

Figure 21: EV3 drive wiring

8 Items list for electronic solution package

Description	Type	Item number	
PeC series	PeC C100 (single circuit) PeC C200 (double circuit)	XAA004AA5 50-S00 XAA004AA5 60-S00	
Electronic expansion valves EX4 – 7 Bipolar stepper motor valves, uniflow	EX4-I21 EX5-U21 EX6-M21	800615 800618 800621	
Cable connector assembly	EXV-M60 (6-m cable)	804665	
Pressure transmitter Suction pressure 18 bar Discharge gas pressure 50 bar	PT5N-18M PT5N-18T PT5N-50M PT5N-50T *(Type: xxM = screwed, xxT = brazed)*	805351 805381 805353 805383	
Plugged cable assembly for pressure sensor	PT4-M15 (1.5-m cable) PT4-M30 (3-m cable) PT4-M60 (6-m cable)	804803 804804 804805	
Temperature sensor with cable	TP1 NP3 (3-m cable) TP1 NP6 (6-m cable) TP1 NP12 (12-m cable)	804489 804490 804491	
Accessories			
Connectors kit	PeC C100 PeC C200	DA000021 00 DA000021 10	
PeC – EV3 Drive Modbus connection	XJ485-USB converter	X0J7MXZZZ900-S00	

Table 20

9 Certification & approval

- The controllers PeC C100 and C200 comply with the Low Voltage Directive LVD 2014/35/EU. The applied harmonised standards are:
  - EN 60335-1:2012/A11:2014: Household and similar electrical appliances - Safety - Part 1: Part 1: General requirements;
  - EN 60335-2-40:2003/A13:2012: Household and similar electrical appliances - Safety - Part 2-40: Particular requirements for electrical heat pumps, air conditioners and dehumidifiers.

  Other applied standards:
  - DIN IEC 60335-2-40:2018-05: Household and similar electrical appliances - Safety - Part 2-40: Particular requirements for electrical heat pumps, air-conditioners and dehumidifiers;
  - EN 60079-15:2010: Explosive atmospheres - Part 15: Equipment protection by type of protection "n".
- The controllers PeC C100 and C200 comply with the Electromagnetic Compatibility Directive EMC 2014/30/EU. The applied harmonised standards are:
  - EN 55014-1:2006/A2:2011: Electromagnetic compatibility - Requirements for household appliances, electric tools and similar apparatus Part 1: Emission;
  - EN 55014-2: 1997/A2:2008: Electromagnetic compatibility - Requirements for household appliances, electric tools and similar apparatus Part 2: Immunity - Product family standard.

  Other applied standards:
  - DIN EN 55014-1:2018-08: Electromagnetic compatibility - Requirements for household appliances, electric tools and similar apparatus Part 1: Emission;
  - DIN EN 55014-2:2016-01: Electromagnetic compatibility - Requirements for household appliances, electric tools and similar apparatus Part 2: Immunity - Product family standard.
- The controllers PeC C100 and C200 comply with RoHS 2011/65/EU, (EU) 2015/863.

10 Dismantling & disposal

With reference to the Waste Electrical and Electronic Equipment (WEEE) Directive 2012/19/EU and to the relative national legislation, please note that:

- **There lies the obligation not to dispose of electrical and electronic waste as municipal waste but to separate the waste.**
- **Public or private collection points must be used to dispose of the goods in accordance with local laws. Furthermore, at the end of the product's life, it is also possible to return this to the retailer when a new purchase is made.**
- **This equipment may contain hazardous substances. Improper use or incorrect disposal can have adverse effects on human health and the environment.**
- **The symbol shown on the product or the package indicates that the product has been placed on the market after 13 August 2005 and must be disposed of as separated waste.**
- **Should the product be disposed of incorrectly, sanctions may be applied as stipulated in applicable local regulations regarding waste disposal.**

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