CARLO GAVAZZI

RVPM

User Manual

Contents

1. Introduction

1.1 Foreword

The RVPM is a variable frequency drive specifically designed to control:

- Permanent Magnet A.C. (PMAC)
- Brushless D.C. (BLDC) and
- Induction motor (IM) compressors

Configuration, programming as well as Run/Stop commands and speed reference are managed via any controller through an RS485 serial connection using the Modbus® protocol in master mode or through a dedicated PC software that is provided by Carlo Gavazzi.

1.2 Scope

This document is intended to provide information on the RVPM frequency drive and the *Carlo Gavazzi Studio* software. For electrical connections and other detailed information, refer to the product datasheet.

Should there be any problems that cannot be solved with the information provided in this guide, contact your Carlo Gavazzi sales representative for further assistance.

1.3 Disclaimer

Carlo Gavazzi accepts no liability for any consequence resulting from inappropriate, negligent, incorrect installation or adjustment of parameters of the equipment. Nor can Carlo Gavazzi assume liability for recommendations that appear or are implied in the following description. The information in this document is not considered binding on any product warranty.

The contents of this guide are believed to be correct at the time of publishing. In the interests of commitment to a policy of continuous development and improvement, Carlo Gavazzi reserves the right to change the specification of the product or its performance, or the contents of this guide without prior notice.

1.4 Warning notice system

The symbols indicated below are used throughout this guide to indicate a particularly important subject or information on safety instructions, configuration and installation of the products covered by this guide.
It is strongly recommended that this guide is read thoroughly before using the products and that safety related recommendations are followed.

Danger
Indicates that death, severe personal injury or property damage will result if proper precautions are not taken.

Warning
Indicates actions that if not observed may lead to damage of the products.

Information
Indicates general information related to the proper use of the products.

1.5 Qualified personnel

The product / system described in this documentation may be operated only by personnel qualified for the specific task that are also capable of identifying risks and avoid potential hazards when working with these products.
The RVPM features dangerous voltages and consequently failure to observe the instructions contend in this user manual may cause serious harm to people and damage to property.

1.6 Basic safety requirements

Always disconnect RVPM and external control circuits from the power supply before performing any maintenance activity.
After removal of power, allow enough time (typically 5 minutes) before touching any terminal on the RVPM as dangerous voltages might still be present.

As a rule, always check, using suitable equipment, that there is no dangerous voltage across the RVPM terminals.
Always make sure that the motor has reached a complete stop before doing any maintenance on the RVPM. Motor that are still rotating may produce dangerous voltages at the RVPM terminals even when RVPM is not connected to the power supply.
Some parts of the RVPM (such as the heatsink and/or back plate) may be hot. Coming in contact with such surfaces may cause burns.

1.7 Abbreviations and acronyms

Acronyms	
VFD	**V**ariable **F**requency **D**rive
PMAC	**P**ermanent **M**agnet **AC**
BLDC	**B**rushless **DC**
IM	**I**nduction **M**otor

1.8 Conformity

Standards

The RVPM series complies with the following standards:-
* LVD: IEC / EN 61800-5-1
* EMC: IEC / EN 61800-3: 2004+A1:2011 (IEC / EN 61800-3: 2004+A1:2012)

Refer to the product datasheet for more details.

Degree of protection

The RVPM VFDs degree of protection is IP00.

> ⚠ **Danger**
>
> **Hazardous voltage.**
> **Will cause death or serious injury.**
>
> To ensure protection against electric shock hazard, always remove power supply when performing maintenance on the RVPM.

1.9 Disposal

> ⚠ **Information for users on the correct handling of waste of electrical and electronic equipment (WEEE)**
>
> With reference to European Union directive 2002/96/EC issued on 27 January 2003 and the related national legislation, please note that:
> * WEEE cannot be disposed of as municipal waste and such waste must be collected and disposed of separately
> * The public or private waste collection systems defined by local legislation must be used. In addition, the equipment can be returned to the distributor at the end of its working life when buying new equipment
> * The equipment may contain hazardous substances: the improper use or incorrect disposal of such may have negative effects on human health and on the environment
> * The symbol (crossed-out wheelie bin) shown on the packaging and on the instruction sheet, indicates that the equipment has been introduced onto the market after 13 August 2005 and that it must be disposed of separately
> * In the event of illegal disposal of electrical and electronic waste, the penalties are specified by local waste disposal legislation.

2. Description

2.1 System overview

The RVPM is a variable frequency drive (VFD) designed to control BLDC, PM and IM compressors. The RVPM comes in both single phase (RVPM1200500FP.) and three phase input (RVPM3400800FP.) versions. All models of RVPM come with cold-plate (Version: RVPM…FP) or heatsink (Version: RVPM…FPF) mounting.

The control method used for PMAC, BLDC compressors is sensor-less vector (SLV) whereas V/f control method is used when Induction motor compressor is selected.

RVPM single phase models are suitable for compressors up to 4.5 kW and RVPM three phase models are suitable for compressors up to 8.0 kW. More detailed specifications are available on the product datasheet.

The interface for configuring and controlling the RVPM is via a Modbus RTU serial port.

In addition to the RVPM VFD, additional accessories are provided to improve the EMC performance. These components are:

- RVDC0500 – PFC reactor for the RVPM1200500FP. models
- RVDC0800 – DC choke for the RVPM3400800FP. models

2.2 System components

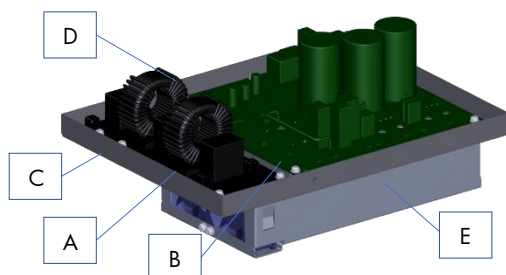The RVPM structure consists of the following elements.

Figure 1: RVPM structure

Element	Component	Function
A	EMC board	EMC filter board
B	Main drive board	Inverter board
C	Metal frame	Support frame for main drive and EMC filter board
D	Modbus port	Communication (read/write) to PLC
E	Aluminium plate or heatsink	Cooling medium

Note: for the RVPM with heatsink version, fans need to be powered via an external 24 VDC supply. Fans must be ON when RVPM is running.

To operate correctly, the RVPM requires the PFC reactor or the DC choke according to the model being used.

Description	Part number	Notes
RVPM, 1-phase i/p 230 V, 4.5 kW (cold-plate)	RVPM1200500FP	Cold-plate version – requires additional cooling interface to be provided by customer.
RVPM, 3-phase i/p 400 V, 8.0 kW (cold-plate)	RVPM3400800FP	
RVPM, 1-phase i/p 230 V, 4.5 kW (heatsink)	RVPM1200500FPF	Heatsink version. No additional cooling interfaces are required. Fans must be powered ON when RVPM is running.
RVPM, 3-phase i/p 400 V, 8.0 kW (heatsink)	RVPM3400800FPF	
DC choke for 3-phase RVPM	RVDC0080	Must be connected to RVPM before start.
PFC reactor for 1-phase RVPM	RVDC0050	

For further technical information on RVPM and the accessories please refer to the respective product datasheets:

3. Installation

⚠️	Installation general requirements

Avoid installing the device in environments with the following characteristics:

- relative humidity higher than 95% or with condensation;
- strong vibrations or shocks;
- exposure to water sprays;
- exposure to aggressive and polluting atmospheres (e.g.: sulphur and ammonia fumes, saline mist, smoke) to avoid corrosion and/or oxidation
- strong magnetic and/or radio frequency interference (thus avoid installation near transmitting antennae)
- exposure of the drive to direct sunlight and the elements in general

Additionally, general good practice for electrical wiring should be followed as outlined in the list below:

- use shielded cables. The cable shield must be connected to ground
- separate as much as possible the probe and digital input signal cables from the cables carrying inductive loads and power cables to avoid possible electromagnetic disturbance
- never run power cables (including the electrical panel wiring) and signal cables in the same conduits

Connection diagram (Modbus RTU)

The Modbus RTU serial port shall be connected as shown in figure 7. A three-wire shielded cable should be used. For multiple networks installation, a ¼ W 120 Ω resistor should be connected between B+ and A- terminals on the last device on the network to avoid potential problems with communication.
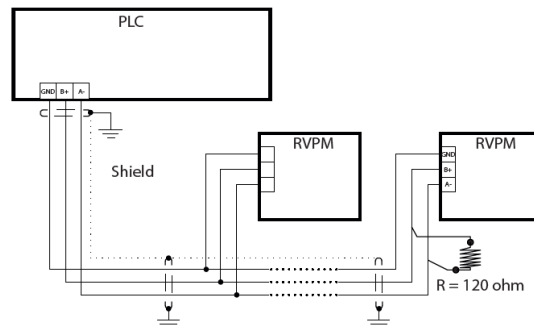

Figure 2: Modbus RTU connection diagram

3.1 Software installation

The RVPM parameters must be configured before the first start-up. For the configuration of the RVPM, Carlo Gavazzi provides a PC software that is compatible with Windows operating systems – *RVPM Configuration Software*.

In the following sections the document shows the steps that users should follow to: -

- Install the *RVPM Configuration Software*
- Establish communication with the RVPM
- Modify parameters
- Start and stop the compressor
- Modify the output frequency

3.1.1 Installing the CG Drive Studio Software

To install the *Carlo Gavazzi Drives Studio,* follow the following steps:

Software installation

1. Double click on the *CG Drives Studio.exe* file
2. A pop-up window will appear. Click *Yes* to proceed with the installation
3. A new pop-up window will show up as shown in Figure 3
4. Click *Next* and then click *Install* (Figure 4)
5. The installation process will start and this might take a few seconds to complete
6. After the installation is ready, click *Finish*
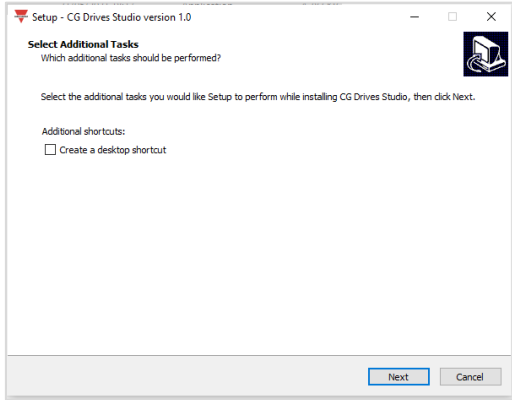7. The software will launch automatically and a shortcut will be available on the PC desktop
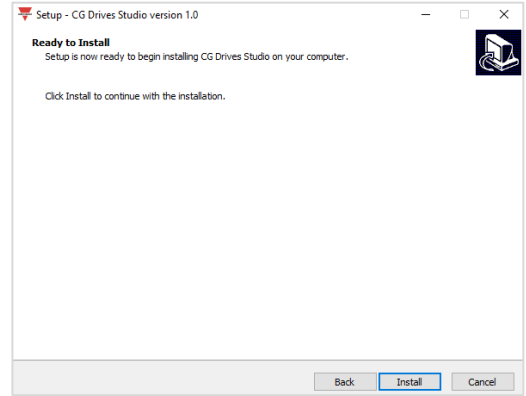
Figure 3: Software installation (1)

Figure 4: Software installation (2)

4. Operation

RVPM is a variable frequency drive that can control various types of 3-phase compressors with permanent magnet (PM) or brushless (BLDC) motors using the sensorless vector control algorithm (SLV). This algorithm is highly dependent on the compressor's electric data of the compressor (i.e. resistance and inductances). The RVPM have been tested with a number of compressor models, therefore, to speed up the commissioning period, Carlo Gavazzi has several configuration setups which can be provided to you upon request.

4.1 RVPM configuration

In order to start up the compressor and keep it running, you first need to configure the drive choosing one from the following two options:

Option 1: *Carlo Gavazzi Drive Studio* software (refer to section 6)

The *Carlo Gavazzi Drive Studio* is designed to offer the following benefits:

A. Quick set-up and easy commissioning
This feature incorporates a list of compressor models that can be selected by the user to minimise configuration time.

B. List of programmable parameters
This feature incorporates a list of programmable parameters that the user can modify to customise the drive setup according to the application. For more detail on the parameters refer to Section 4.2.

Option 2: Modbus RTU communication tool/system controller (e.g. PLC) (refer to section 4)

To configure the different registers in the drive, read through Section 4.2 that gives all the information related to the registers and the respective functionality. The section is organised in such a way to guide the user through the various steps required to configure the drive.

A. Modbus communication
B. Compressor start-up
C. Sensorless vector control algorithm
D. Performance control
E. Protection functions to prevent overtemperature alarm

4.2 Programmable configuration parameters

4.2.1 Modbus communication

The RVPM can be interfaced either to a PC or to a PLC using 3-wire RS485 serial connection with Modbus RTU protocol.
In order to establish communication, you need to set:
a. Baud rate – the transmission speed in bit/s
b. Parity and stop bit – Modbus error detecting code
c. Device address – device identifier

Modbus address	Parameter	Default value	Range	Function	
				Read	Write
1Eh	Baud rate	19200 bit/s	0: 9600 bit/s	✓	✓
			1: 19200 bit/s		
1Fh	Parity and stop bit	None (2 stop bits)	0: None (2 stop bits)	✓	✓
			1: Even (1 stop bit)		
			2: Odd (1 stop bit)		
20h	Device address	1	1… 247	✓	✓

If the communication parameters were updated, they will become effective after rebooting the drive (i.e. supply to the drive is cycled OFF and ON). Alternatively, a command can be sent to register (65h) *Update Modbus Communication Parameters.*

Any Modbus communication errors can be viewed through Modbus Communication Error Definition (7Ah).

4.2.2 Compressor start-up

When the RVPM receives a Start Command (64h), the sensorless vector control algorithm gets into action after the following steps are executed:
a. Alignment of motor rotor
The drive aligns the motor rotor to a known start position before starting the compressor. During this step the output frequency is equal to 0Hz while the output current is equal to Align Current I_{align} (this current is determined by the drive).

b. Open loop current limit control
The drive then generates a fixed starting current $I_{starting}$ to start-up the compressor for a certain time period t_0 until the starting frequency f_{start} is reached.

The value of the starting current is determined by the formula below and the time period is determined by the Open Loop Control Acceleration (B6h)

$$Starting\ current = Open\ loop\ starting\ current\ (39h) \times Compressor\ rated\ current\ (03h)$$

1: Alignment of motor rotor
2: Open loop current limit control
3: Sensorless vector control
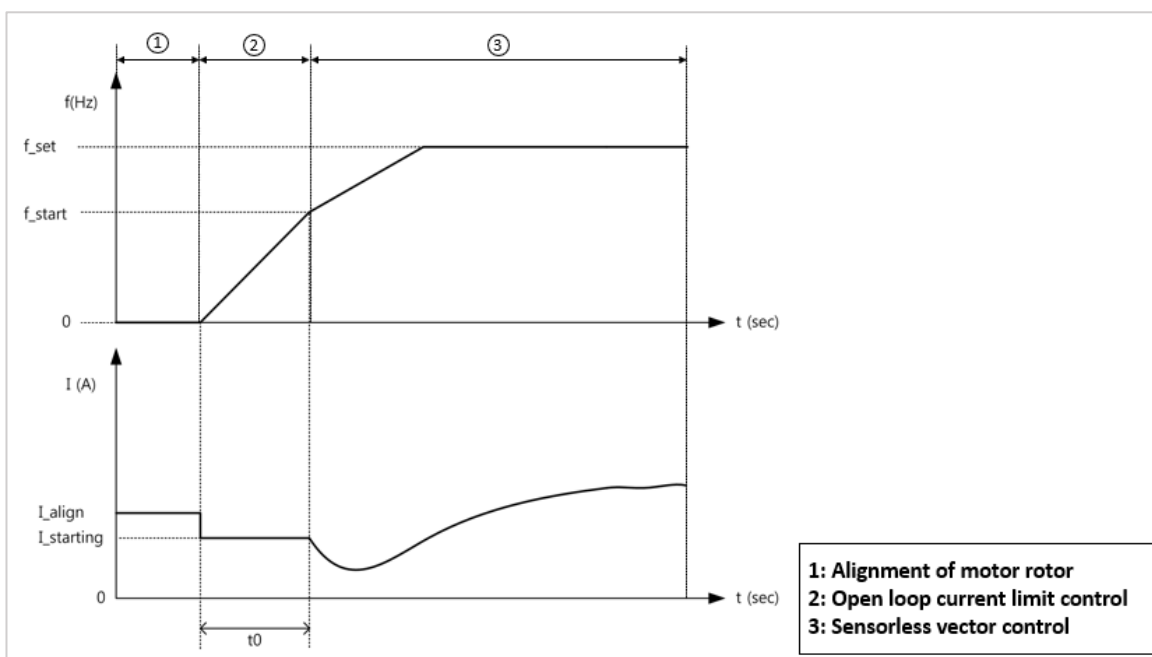
Modbus address	Parameter	Default value	Range	Function	
				Read	Write
39h	Open loop starting current	75.0 %	0.0 … 100.0 %	✓	✓
B6h	Open loop acceleration	6.0 Hz/s	0.0 … 50.0 Hz/s	✓	✓

4.2.3 Sensorless vector control algorithm

The sensorless vector control algorithm requires the following compressor information:
 a. Compressor rated frequency – complies with the rated speed
 b. Compressor rated voltage – the phase-to-phase voltage that the drive needs to apply the compressor at the rated frequency
 c. Compressor rated current – the compressor current at full load. This current should be set equal to the maximum compressor current corresponding to maximum compressor frequency.

Modbus address	Parameter	Default value	Range	Function	
				Read	Write
01h	Compressor rated frequency	50.0 Hz	25.0 … 400.0 Hz	✓	✓
02h	Compressor rated voltage	230 V_{rms} (1φ models) 400 V_{rms} (3φ models)	25 … 250 V_{rms} (1φ models) 25 … 500 V_{rms} (3φ models)	✓	✓
03h	Compressor rated current	14.0 A_{rms} (1φ models) 18.0 A_{rms} (3φ models)	0.1 * Drive rated output current … Drive rated output current	✓	✓

The aforementioned data can be typically found on the compressor nameplate or in the compressor manufacturer's datasheet. It is suggested to contact your nearest Carlo Gavazzi distributor or our sales representatives to support you in setting the correct value to achieve the optimum performance from the compressor.

The compressor rated current is also used as reference for motor overload protection.

Furthermore, the sensorless vector control algorithm requires the electrical data of the compressor's motor. Typically, this information is found in the compressor manufacturer's datasheet.
 a. Line-to-line stator resistance (Rs) – the phase-to-phase resistance of the stator winding
 b. d-axis inductance (Ld) – Required for the SLV algorithm
 c. q-axis inductance (Lq) – Required for the SLV algorithm
 d. Number of poles – Determines the motor synchronous speed. The value must always be an even number.

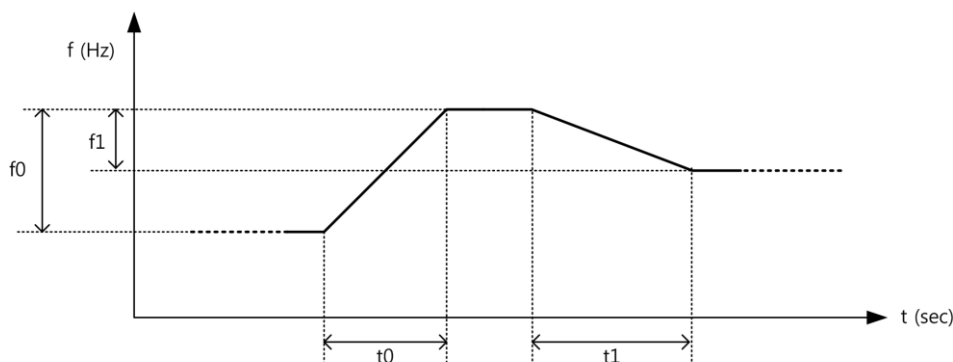| Modbus address	Parameter	Default value	Range	Function	
				Read	Write
2Eh	Line-to-line stator resistance (Rs)	550 mΩ (1φ models) 1020 mΩ (3φ models)	0 … 30000 mΩ	✓	✓
30h	d-axis inductance (Ld)	2.5 mH (1φ models) 5.1 mH (3φ models)	0.0 … 600.0 mH	✓	✓
32h	q-axis inductance (Lq)	5.0 mH (1φ models) 9.5 mH (3φ models)	0.0 … 600.0 mH	✓	✓
B4h	Number of poles	6	6 … 20	✓	✓

A. Operable frequency range

These two parameters allow you to set the operable frequency range of the compressor. The range is determined by setting the lower and upper limits of the drive output frequency. The frequency setpoint must always be within the operable frequency range and the frequency lower limit is configured to be less than the frequency upper limit, else RVPM will not accept it and a Modbus exception code 03 is send to the Modbus Master device.

Modbus address	Parameter	Default value	Range	Function Read	Function Write
06h	Frequency upper limit	0.0 Hz	Frequency lower limit (07h) … 400.0Hz	✓	✓
07h	Frequency lower limit	0.0 Hz	0.0 … Frequency upper limit (06h)	✓	✓

B. Ramping

Use these two parameters to define the acceleration and deceleration rate of the drive output frequency; hence directly both affect the compressor speed and acceleration/deceleration time. Preferably, the values of these parameters are set according to the datasheet of the compressor to ensure system stability.

key

f0/t0: acceleration rate   f: motor electrical frequency
f1/t1: deceleration rate   t: time

Modbus address	Parameter	Default value	Range	Function Read	Function Write
12h	Acceleration rate	6.0 Hz/s	0.0 … 50.0 Hz/s	✓	✓
17h	Deceleration rate	6.0 Hz/s	0.0 … 50.0 Hz/s	✓	✓

If the Stop Mode (21h) parameter is set to ramp (i.e. 0) and RVPM receives a Stop Command (64h), the drive output frequency starts to reduce according to the configured Deceleration Rate (17h) until it reaches the Frequency Lower Limit (07h).

C. Stop mode

RVPM has been designed with a programmable stop mode to implement the required procedure when stopping the compressor:
- Deceleration-to-stop
  When the Stop Command (64h) is requested; the RVPM will reduce the drive output frequency (hence the compressor speed will also reduce) until it is equal to the Frequency Lower Limit (07h). The time it takes the drive to reach the frequency lower limit is determined by the Deceleration rate (17h).

- Coast-to-stop
  When the Stop Command (64h) is requested, the RVPM stops controlling the output frequency and the latter will coast (i.e. free-run) to stop. The time it takes for the compressor to stop depends on the compressor's inertia.

Modbus address	Parameter	Default value	Range	Function Read	Function Write
21h	Stop mode	Coast-to-stop	0: Deceleration-to-stop 1: Coast-to-stop	✓	✓

D. Modbus communication monitoring (related to Alarm 13)

The Modbus Communication Loss alarm (Alarm 13) is enabled by setting the Refresh Interval (1Dh) at a value greater than zero. RVPM excepts a Refresh Command (65h) within the refresh interval during RUN state. If the refresh command is not sent during this period, then the RVPM assumes that communication has been lost and will trigger Alarm 13.

Modbus address	Parameter	Default value	Range	Function	
				Read	Write
1Dh	Refresh interval	0	0 … 600 s	✓	✓

Preferably, Modbus Communication Loss alarm is enabled, because if a communication fault occurs when the drive is in RUN state, the RVPM drive (hence also the compressor) cannot be stopped.

E. Switching frequency

This parameter allows you to configure the switching frequency of the RVPM drive. The switching frequency is the frequency at which the drive's power module operates. If you set a high switching frequency, the audible noise in compressor decreases but the drive's temperature increases and vice versa if you set a low switching frequency. Typically, for compressors the switching frequency should be set to 4kHz.

Modbus address	Parameter	Default value	Range	Function	
				Read	Write
18h	Switching frequency	4 kHz	0: 4 kHz	✓	✓
			1: 5 kHz		
			2: 6 kHz		

The RVPM has been designed to reduce the switching frequency in cases when the temperature starts to reach the maximum limits in order to avoid tripping from overheating. For more information regarding Switching Frequency Auto-reduction Protection function.

F. Compressor temperature regulation

Compressors are typically installed inside outdoor heat pump units. Due to outside temperature variations, it may be necessary that the compressor's temperature is regulated to prevent scenarios such as oil freezing or oil and refrigerant mix together. Crankcase heater controllers are usually used to regulate the compressor's temperature; however, thanks to the RVPM's compressor temperature regulation function you can avoid in buying a crankcase heater. When preheating is required, RVPM must receive a Compressor Temperature Regulation Command (64h) and the latter injects a DC current as a percentage of the Compressor Rated Current (03h) into the compressor stator windings to warm it up.

$$Injected\ DC\ current = Compressor\ temperature\ reglation\ current\ setting\ (41h) \times Compressor\ rated\ current\ (03h)$$

The compressor temperature regulation function can be activated if the following conditions are true:
- RVPM is not in run or alarm status (68h)
- Compressor temperature regulation current setting (41h) is greater than zero

The RVPM ignores any Compressor Temperature Regulation Command (64h) while it is in Run status since the latter has a higher priority.

Modbus address	Parameter	Default value	Range	Function	
				Read	Write
41h	Compressor temperature regulation current setting	0.0 %	0.0 … 100.0 %	✓	✓

Compressor temperature regulation current setting must be properly set in order to avoid damaging the compressor's stator winding.

If during the compressor temperature regulation process, any of the phases of the compressor becomes disconnected, the RVPM does not trigger Compressor Phase Loss Alarm (i.e. Alarm 17).

G. Supply voltage detection levels (related to Alarms 3 & 4)

The power supply voltage is directly proportional to the DC Link Voltage (71h) measurement as shown below.

$$Supply\ voltage = \frac{DC\ link\ voltage}{\sqrt{2}}$$

By setting these two parameters you are defining the under voltage and over voltage detection levels of the DC link voltage; hence indirectly you are also defining the supply voltage limits. Furthermore, these parameters define Overvoltage alarm (Alarm 3) and Undervoltage alarm (Alarm 4).

Modbus address	Parameter	Default value	Range	Function	
				Read	Write
BCh	Undervoltage fault level	220 V$_{rms}$ (1φ models) 400 V$_{rms}$ (3φ models)	220 … 350 V$_{rms}$ (1φ models) 400 … 600 V$_{rms}$ (3φ models)	✓	✓
BDh	Overvoltage fault level	420 V$_{rms}$ (1φ models) 810 V$_{rms}$ (3φ models)	390 … 420 V$_{rms}$ (1φ models) 650 … 810 V$_{rms}$ (3φ models)	✓	✓

H. Three phase output current balance monitoring (related to Alarm 17)

If any of the phases of the compressor becomes disconnected an unbalance in the three-phase output current occurs. The Compressor Phase Loss alarm (Alarm 17) is enabled by setting the Three Phase Output Current Balance Sensitivity (C3h) at a value greater than zero. This parameter sets the sensitivity of this alarm. For more information regarding Alarm 17.

Modbus address	Parameter	Default value	Range	Function	
				Read	Write
C3h	Three phase output current balance sensitivity	50 %	0 … 100 %	✓	✓

I. Power supply phase loss (related to Alarm 22)

The following three parameters apply only for 3-phase models.

If any of the phases of the power supply becomes disconnected, the drive does not operate as intended. The Power Supply Undervoltage or Input Phase Loss alarm (Alarm 22) is enabled by enabling the Power Supply Phase Loss Supervisor (C0h). The sensitivity of this function and the time to detect the phase loss are determined by Power Supply Phase Loss DC Voltage Ripple (C1h) and Power Supply Phase Loss Fault Time (C2h) respectively. For more information regarding Alarm 22.

Modbus address	Parameter	Default value	Range	Function	
				Read	Write
C0h	Power Supply Phase Loss Supervisor	Enable	0: Disable 1: Enable	✓	✓
C1h	Power Supply Phase Loss DC Voltage Ripple	100 VDC	0 … 200 VDC	✓	✓
C2h	Power Supply Phase Loss Fault Time	10 s	0 … 100 s	✓	✓

4.2.5 Protection functions to prevent overtemperature alarm

The RVPM has the two following integrated protection functions to prevent issuing Alarm 5 – Overtemperature when the drives' power module temperature exceeds the maximum temperature limit:
- Switching Frequency Auto-reduction
- Output Frequency Auto-reduction
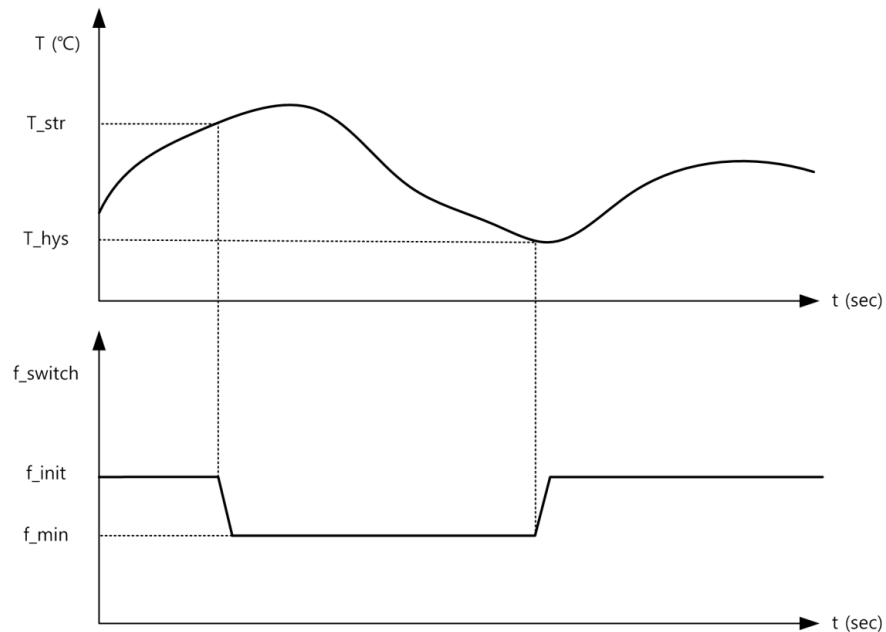
A. Switching Frequency Auto-reduction

The table below shows the benefits and drawbacks when configuring a low or a high switching frequency for your drive-in relation with the compressor. For more information on how to set the switching frequency of RVPM, refer to Section 4.2.4E.

The table clearly shows that when the drive's power module operates at high switching frequency there are more benefits. However, the temperature of the drive rises due to the fact that the switching rate of the power module increases resulting in higher heat dissipation.

	RVPM drive			Compressor	
Switching frequency	Heat losses	Voltage waveform distortion	Audible noise	Heat losses	
Low	↓	↑	↑	↑	
High	↑	↓	↓	↓	

Therefore, if the drive is set to operate at either 5kHz or 6kHz switching frequency and during running operation the drives' power module temperature exceeds the maximum temperature limit; the switching frequency auto-reduction protection function comes into action to prevent issuing the overtemperature alarm. This function reduces the switching frequency to 4kHz until the drives' power module temperature is within acceptable operating range; then it reverts back to the original setting switching frequency. Furthermore, this function is programmed to follow a temperature band called hysteresis to avoid frequent change of switching frequency. The switching frequency auto-reduction protection function can be easily enabled via Modbus communication.

Modbus address	Parameter	Default value	Range	Function	
				Read	Write
19h	Switching frequency auto-reduction	Disable	0: Disable 1: Enable	✓	✓

key
T_str: frequency derating start temperature
T_hys: frequency derating hysteresis temperature
f_init: initial switching frequency
f_min: minimum switching frequency
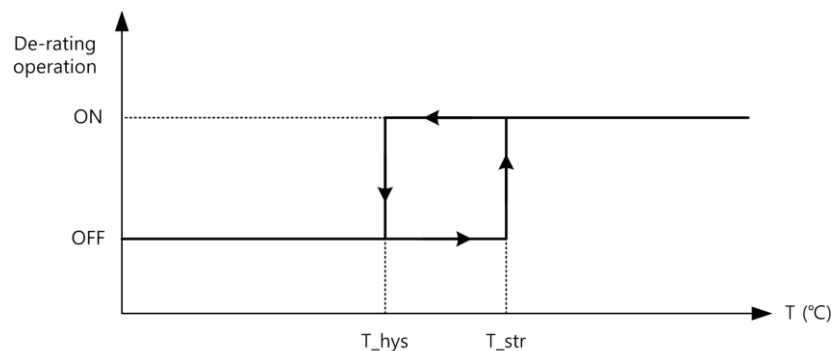
T: drive temperature
f_switch: drive switching frequency
t: time

key
T_str: frequency derating start temperature
T_hys: frequency derating hysteresis temperature
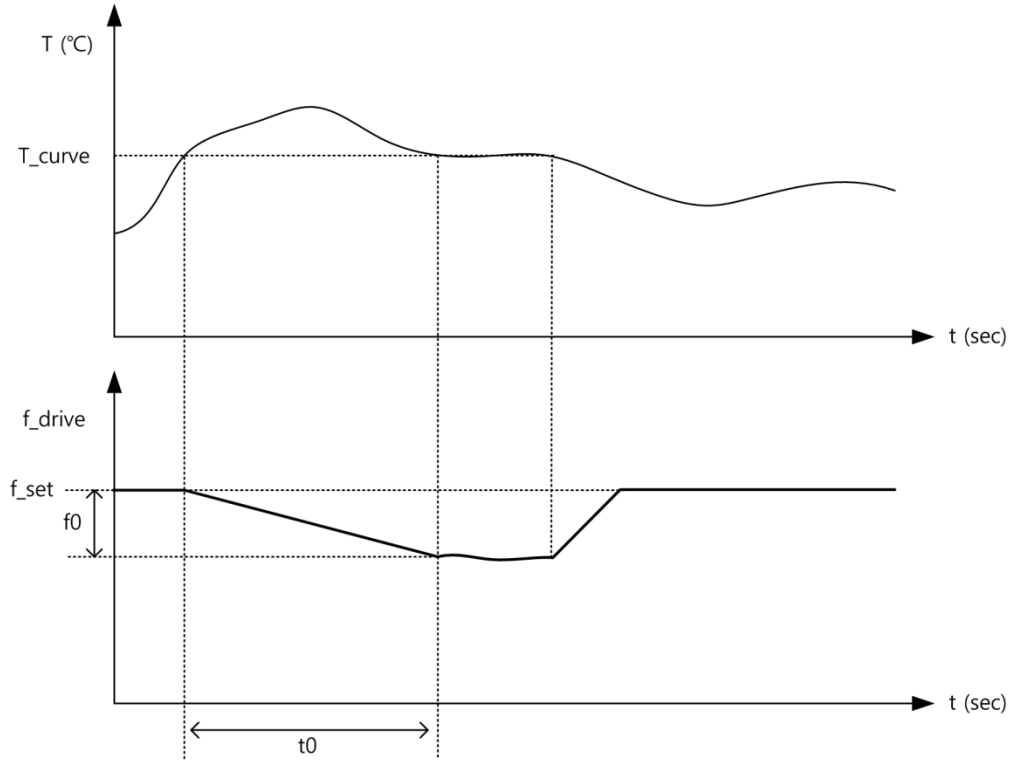T: drive temperature

The drive's power module temperature and the operating switching frequency can be easily accessed through Modbus communication using parameter 72h and 7Ch respectively. It is possible to check if the switching frequency auto-reduction is triggered or not through Parameter 6Ah.

B. Output Frequency Auto-reduction

The output frequency auto-reduction protection function is an alternative solution to prevent the drive from issuing an overtemperature alarm and stops the compressor from functioning. For example, if the RVPM drive is used to control a compressor in a heat pump unit regulating the temperature of a building and the end user requests a drastic change in temperature; the drive will increase its output frequency so that the compressor operates near its rated speed. Undoubtedly, this will increase the current demand from the drive resulting in higher heat dissipation inside it. Therefore, when the drives' power module temperature exceeds the maximum temperature limit, the output frequency auto-reduction protection function comes into action where it reduces the output frequency to the Frequency Lower Limit (07h) until the drives' power module temperature is within acceptable range. This will cause the compressor to operate at lower speed hence the current demand is lower but the system will take more time to reach the setpoint temperature. This scenario is more preferable rather than having a system shut down due to an overtemperature alarm. When the drives' power module temperature is lower than the rated drives' temperature (refer to the current derating curve), the output frequency reverts back to reach the setpoint frequency.

The output frequency auto-reduction protection function by default is always enabled but it can be disabled via Modbus communication. Furthermore, you can also configure the deceleration rate of the output frequency when this protection function is working.

Modbus address	Parameter	Default value	Range	Function	
				Read	Write
09h	Output frequency auto-reduction	Enable	0: Enable	✓	✓
			1: Disable		
C4h	Deceleration rate during output frequency auto-reduction	0.5Hz/s	0.0 ... 50.0 Hz/s	✓	✓

key

T_curve: temperature point on the derating curve T: drive temperature
f_set: frequency set point f_drive: drive frequency
f0/t0: deceleration rate in derating function t: time
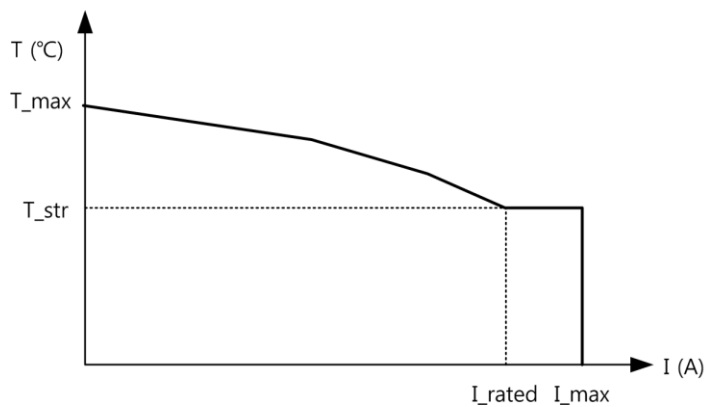
key
T_max: maximum drive temp. T_str: speed derating start temp.
I_max: maximum drive current T: drive temp.
I_rated: drive rated current I: drive output current

The drive's power module temperature and the output frequency can be easily accessed through Modbus communication using parameter 72h and 6Ch respectively. It is possible to check if the output frequency auto-reduction is triggered or not through Parameter 6Bh.

4.3 Control parameters

4.3.1 Start/Stop commands

The Start/Stop command should be used to turn ON and OFF the compressor.

Modbus address	Parameter	Default value	Range	Function	
				Read	Write
64h	Start/Stop command	Stop	0: Stop	✓	✓
			1: Start		

4.3.2 Compressor Temperature Regulation command

This command should be used to activate the compressor temperature regulation function where the RVPM injects a current as a percentage of the Compressor Rated Current (03h) into the compressor stator windings to warm it up. For more information refer to Section 4.2.4F.

Modbus address	Parameter	Default value	Range	Function	
				Read	Write
64h	Compressor temperature regulation command	Off	0: Off	✓	✓
			4: On		

The compressor temperature regulation function can be activated if the following conditions are true:
- RVPM is not in run or alarm status (68h)
- Compressor temperature regulation current setting (41h) is greater than zero

The RVPM ignores any Compressor Temperature Regulation Command (64h) while it is in Run status since the latter has a higher priority.

If during the compressor temperature regulation process, any of the phases of the compressor becomes disconnected, the RVPM does not trigger Compressor Phase Loss Alarm (i.e. Alarm 17).

4.3.3 Alarm Reset

If an alarm is triggered, the alarm reset can be used to reset the alarm.

Modbus address	Parameter	Default value	Range	Function	
				Read	Write
65h	Alarm reset	No action	0: No action	✓	✓
			1: Alarm reset		

4.3.4 Factory Reset

When factory reset is selected, the value of every programmable parameter of the RVPM mentioned in Section 4.2 is restored to its default values.

Modbus address	Parameter	Default value	Range	Function	
				Read	Write
65h	Factory reset	No action	0: No action	✓	✓
			2: Factory reset		

4.3.5 Update Modbus communication parameters command

If you updated the communication parameters and would like to become effective, it is necessary either to reboot the RVPM drive (i.e. supply to the drive is cycled OFF and ON) or send an Update Modbus Communication Parameters command (65h).

Modbus address	Parameter	Default value	Range	Function	
				Read	Write
65h	Update Modbus communication parameters command	No action	0: No action	✓	✓
			4: Update Modbus communication parameters		

4.3.6 Refresh command (a.k.a. heartbeat signal)

When Refresh Interval (1Dh) is set at a value greater than zero, the RVPM expects a refresh command to be sent within the refresh interval during RUN state. If this command is not sent, then RVPM assumes that communication has been lost and will trigger Alarm 13. For more information refer to Section 4.2.4D.

Modbus address	Parameter	Default value	Range	Function	
				Read	Write

			0: No action		
65h	Refresh command	No action	4: Refresh command	✓	✓

4.3.7 Frequency setpoint

This parameter defines the frequency at which the compressor should reach and operate at; after the Start command is triggered (64h).

Modbus address	Parameter	Default value	Range	Function	
				Read	**Write**
66h	Frequency setpoint	0.0 Hz	0.0 … Frequency upper limit (06h)	✓	✓

When frequency setpoint value is set to 40.0Hz or below, there is the possibility that the compressor experience vibrations which will lead to an output over current alarm.

4.4 Monitoring parameters

The monitoring parameters are read only holding (03h) and input (04h) Modbus registers. These parameters provide information related to RVPM drive and compressor to the Modbus master upon request:
   a.   Device status
   b.   Alarm definition
   c.   Electrical real-time variables
   d.   General counters
   e.   Variables related to communication
   f.   Identification codes

Modbus address	Parameter	Range	Function	
			Read	**Write**
68h	Drive status	0: Idle	✓	X
		1: Running		
		2: Alarm		
		3: Compressor temperature regulation		
69h	Alarm definition	0: No alarm	✓	X
		1: Output overcurrent		
		2: Compressor overload		
		3: Overvoltage		
		4: Undervoltage		
		5: Overtemperature		
		13: Modbus communication loss		
		14: Input overcurrent (1φ models only)		
		15: Power module faulty		
		16: Control power undervoltage (3φ models only)		
		17: Compressor phase loss		
		22: Power supply undervoltage or input phase loss (3φ models only)		
6Ah	Switching frequency auto-reduction status	0: Switching frequency is according to parameter 18h	✓	X
		32: Switching frequency reduced to 4kHz to prevent Alarm 5		
6Bh	Output frequency auto-reduction status	0: Output frequency is equal to Frequency Setpoint (66h)	✓	X
		2: Output frequency reduced to Frequency Lower Limit (07h) to prevent Alarm 5		
6Ch	Output frequency	0.0 … 400.0 Hz (depends on parameters 06h and 07h)	✓	X
6Dh	Output current	- AAC	✓	X
6Eh	Output power	- kW	✓	X
6Fh	Output voltage	- VAC	✓	X
71h	DC link voltage	- VDC	✓	X
72h	Drives' power module temperature	- °C	✓	X
		Conversion formula to convert temperatures below 0°C: *Temperature = Parameter data (72h) - 65536*	✓	X
73h	Drive switch-on time	- hours	✓	X
		When this parameter reaches 65536 hours, the value resets to zero.		
74h	Compressor running time	- hours	✓	X
		When this parameter reaches 65536 hours, the value resets to zero.		
75h		- hours		

			✓	X
	Drive running time from last alarm	When this parameter reaches 65536 hours, the value resets to zero.	✓	X
76h	kWh meter	- kWh	✓	X
		When this parameter reaches 1000.0kWh, the value resets to zero and parameter MWh meter (77h) increments by 1.		
77h	MWh meter	- MWh	✓	X
78h	Device address	1 … 247	✓	X
7Ah	Modbus communication error definition	0: No error	✓	X
		1: Illegal function		
		2: Illegal data address		
		3: Illegal data value		
		4: Illegal data size		
		6: RVPM drive busy		
7Bh	Modbus communication error counter	-	✓	X
		The value of this parameter resets when the drive is rebooted (i.e. supply to the drive is cycled OFF and ON		
7Ch	Switching frequency	0: 4 kHz	✓	X
		1: 5 kHz		
		2: 6 kHz		
89h	Alarm 1 variable	0 … 22 (Refer to Section 5.2)	✓	X
8Ah	Alarm 2 variable	0 … 22 (Refer to Section 5.2)	✓	X
8Bh	Alarm 3 variable	0 … 22 (Refer to Section 5.2)	✓	X
8Ch	Alarm 4 variable	0 … 22 (Refer to Section 5.2)	✓	X
8Eh	Firmware version	120: 1PH 200V 14A	✓	X
		130: 3PH 400V 18A		
95h	Hardware version	2016: 1PH 200V 14A	✓	X
		4018: 3PH 400V 18A		

5. Alarms

5.1 Outline

The RVPM drive includes a number of diagnostics and protection features each of which signalled either through Modbus communication or a flashing sequence on the RED LED as shown in the diagram below. Information on flashing sequence refer to Section 5.3.
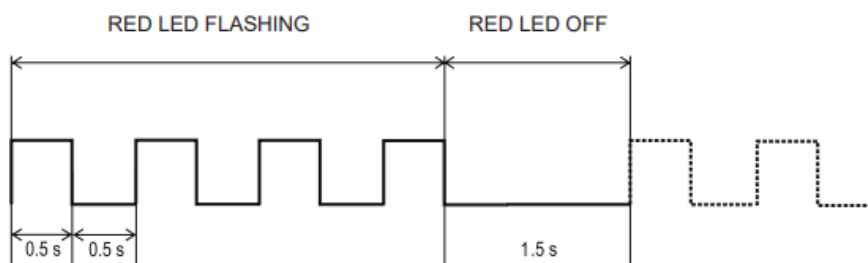
Any alarm that is triggered, will stop the RVPM drive from functioning and hence the overall system will shut down. In order to continue with the system operation, you must first reset the RVPM either through Modbus using register 65h as mentioned in Section 4.3.3 or switch off and on the drive's power supply.

5.2 Alarm logging

When an alarm is issued, the value of the Alarm Definition (69h) is equal to the number of LED flashes.

Modbus address	Parameter	Range	Function	
			Read	Write
69h	Alarm definition	0: No alarm 1: Output overcurrent 2: Compressor overload 3: Overvoltage 4: Undervoltage 5: Overtemperature 13: Modbus communication loss 14: Input overcurrent (1φ models only) 15: Power module faulty 16: Control power undervoltage (3φ models only) 17: Compressor phase loss 22: Power supply undervoltage or input phase loss (3φ models only)	✓	X

Furthermore, in order to facilitate the troubleshooting process, the RVPM logs the last four alarms in a FIFO (first-in, first-out) data structure. The last alarm that is triggered by RVPM is always logged in Alarm 1 Variable (89h).
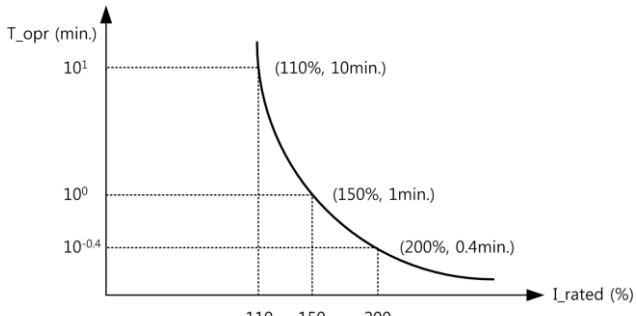
Modbus address	Parameter	Range	Function	
			Read	Write
89h	Alarm 1 variable	0 … 22	✓	X
8Ah	Alarm 2 variable	0 … 22	✓	X
8Bh	Alarm 3 variable	0 … 22	✓	X
8Ch	Alarm 4 variable	0 … 22	✓	X

5.3 Troubleshooting

5.5.1 Alarm 1 - Output Overcurrent

Number of LED flashes	1
Alarm	Output overcurrent
Alarm description	If a high instantaneous output current is detected, the RVPM will issue the output overcurrent alarm.
Cause	• The compressor withdraws a higher current than the power rating of the RVPM drive. • Compressor winding short circuit. • Transient load change. • Acceleration/Deceleration Rate (12h/17h) is set to high.
RVPM reaction	The RVPM will switch off the gate drivers and compressor will coast to stop.
Action to recover alarm	• Reset the alarm through Alarm Reset command (65h) as mentioned in Section 4.3.3. • Switch off and on the drive's power supply.
Troubleshooting	• Check that the Compressor Rated Current (03h) setting is not smaller than compressor name plate current. • Check that the RVPM model is suitably rated for the compressor. • Check compressor windings resistance to check if compressor is damaged. • Set a lower Acceleration/Deceleration Rate (12h/17h). • Check the programmable parameters related to the compressor mentioned in Section 4.2.3. • If the alarm is persistent, contact a Carlo Gavazzi representative.

5.5.2 Alarm 2 – Compressor overload

Number of LED flashes	2
Alarm	Compressor overload
Alarm description	If the RVPM time-current characteristic is violated, the RVPM will issue the compressor overload alarm. key T_opr: operating time I_rated: percentage of motor rated current *The Compressor Rated Current (03h) is the reference for the compressor overload protection*
Cause	The system current demand is large when compared to normal conditions.
RVPM reaction	The RVPM will switch off the gate drivers and compressor will coast to stop.
Action to recover alarm	• Reset the alarm through Alarm Reset command (65h) as mentioned in Section 4.3.3. • Switch off and on the drive's power supply.
Troubleshooting	• Check that the Compressor Rated Current (03h) setting is not smaller than compressor name plate current. • Check the programmable parameters related to the compressor mentioned in Section 4.2.3.

5.5.3 Alarm 3 – Overvoltage

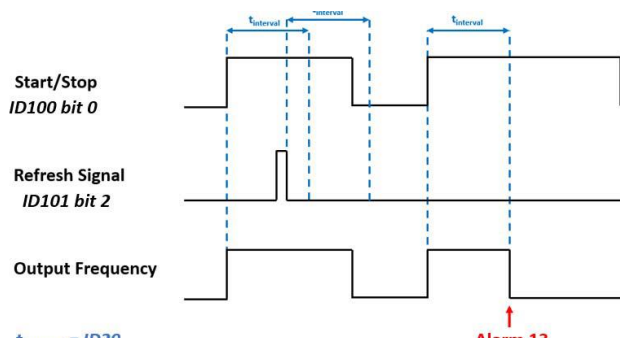|	
Number of LED flashes	3
Alarm	Overvoltage
Alarm description	If the DC Link Voltage (71h) exceeds the Overvoltage Fault Level (BDh) setting, the RVPM will issue an overvoltage alarm.
Cause	• Deceleration Rate (17h) is set to high. • Voltage fluctuation on the power supply network.
RVPM reaction	The RVPM will switch off the gate drivers and compressor will coast to stop.
Action to recover alarm	• Reset the alarm through Alarm Reset command (65h) as mentioned in Section 4.3.3 if the DC Link Voltage (71h) measurement is lower than the Overvoltage Fault Level (BDh) setting • Switch off and on the drive's power supply.
Troubleshooting	• Set a lower Deceleration Rate (17h).

5.5.4 Alarm 4 – Undervoltage

Number of LED flashes	4
Alarm	Undervoltage
Alarm description	If the DC Link Voltage (71h) is less than the Undervoltage Fault Level (BCh) setting, the RVPM will issue an undervoltage alarm.
Cause	• Voltage fluctuation on the power supply network. • The voltage detection circuit inside the drive is faulty.
RVPM reaction	The RVPM will switch off the gate drivers and compressor will coast to stop.
Action to recover alarm	• Reset the alarm through Alarm Reset command (65h) as mentioned in Section 4.3.3 if the DC Link Voltage (71h) measurement is above the Undervoltage Fault Level (BCh) setting • Switch off and on the drive's power supply.
Troubleshooting	• Set a lower Deceleration rate (17h). • If the alarm is persistent, contact a Carlo Gavazzi representative.

5.5.5 Alarm 5 – Overtemperature

Number of LED flashes	5
Alarm	Overtemperature
Alarm description	The RVPM constantly measures the power module (IGBTs) temperature. If the drives' power module temperature exceeds the maximum level allowed an overtemperature alarm is triggered.
Cause	• High surrounding temperature. • The power module is not properly cooled. • The temperature sensor or temperature sensing circuit inside the drive is faulty.
RVPM reaction	The RVPM will switch off the gate drivers and compressor will coast to stop.
Action to recover alarm	• Reset the alarm through Alarm Reset command (65h) as mentioned in Section 4.3.3 if the Drives' Power Module Temperature (72h) is lower than the maximum level allowed. The higher the surrounding temperature, the longer the cooling period. • Switch off and on the drive's power supply.
Troubleshooting	• Improve the cooling and ventilation system. • Consider to reduce the Switching Frequency (18h) setting. • Consider to enable either the Switching Frequency or Output Frequency Auto-reduction Protection Function (19h/09h). • If the alarm is persistent, contact a Carlo Gavazzi representative.

5.5.6 Alarm 13 – Modbus communication loss

Number of LED flashes	13
Alarm	Modbus communication loss
Alarm description	If Refresh Interval (1Dh) value is greater than zero, the RVPM excepts a Refresh Command (65h) within the refresh interval during RUN state. If the refresh command is not sent during this period, the RVPM assumes that communication has been lost and Modbus communication loss is triggered.
Cause	• RS485 serial disconnection between the RVPM drive and the Modbus master.
RVPM reaction	The RVPM will switch off the gate drivers and compressor will coast to stop.
Action to recover alarm	• Reset the alarm through Alarm Reset command (65h) as mentioned in Section 4.3.3. • Switch off and on the drive's power supply.
Troubleshooting	• Check the RS485 serial wiring.

5.5.7 Alarm 14 – Input overcurrent (single-phase models only)

Number of LED flashes	14
Alarm	Input overcurrent (single-phase models only)
Alarm description	If a high instantaneous input current is detected, the RVPM will issue the input overcurrent alarm.
Cause	• Transient load change. • Acceleration Rate (12h) is set to high.
RVPM reaction	The RVPM will switch off the gate drivers and compressor will coast to stop.
Action to recover alarm	• Reset the alarm through Alarm Reset command (65h) as mentioned in Section 4.3.3. • Switch off and on the drive's power supply.
Troubleshooting	• Check compressor windings resistance to check if compressor is damaged. • Set a lower Acceleration Rate (12h). • Check the programmable parameters related to the compressor mentioned in Section 4.2.3. • If the alarm is persistent, contact a Carlo Gavazzi representative.

5.5.8 Alarm 15 – Power module faulty

Number of LED flashes	15
Alarm	Power module faulty
Alarm description	In case the RVPM detects that the power module is damaged, the drive will trip.
Cause	Excessive load.
RVPM reaction	The RVPM will switch off the gate drivers and compressor will coast to stop.
Action to recover alarm	This alarm is not resettable and it is suggested to replace the unit and contact a Carlo Gavazzi representative should this alarm occur.
Troubleshooting	• Consider to replace the RVPM drive.

5.5.9 Alarm 16 – Control power undervoltage (3-phase models only)

Number of LED flashes	16
Alarm	Control power undervoltage (3-phase models only)
Alarm description	If the gate driver input voltage is lower than the voltage level required, the RVPM will issue the control power undervoltage.
Cause	• Insufficient power supply voltage. • The control circuit inside the drive is faulty.
RVPM reaction	The RVPM will switch off the gate drivers and compressor will coast to stop.
Action to recover alarm	• Reset the alarm through Alarm Reset command (65h) as mentioned in Section 4.3.3. • Switch off and on the drive's power supply.
Troubleshooting	• Check the power supply voltage. • If the alarm is persistent, contact a Carlo Gavazzi representative.

5.5.10 Alarm 17 – Compressor phase loss

Number of LED flashes	17
Alarm	Compressor phase loss
Alarm description	The RVPM will issue a compressor phase loss alarm if the following conditions are true: • the Three Phase Output Current Balance Sensitivity (C3h) value is greater than zero and; • an unbalance in the three phase output current is detected.
Cause	Any of the phases of the compressor cables become disconnected.
RVPM reaction	The RVPM will switch off the gate drivers and compressor will coast to stop.
Action to recover alarm	• Reset the alarm through Alarm Reset command (65h) as mentioned in Section 4.3.3; after checking the connections between the drive and compressor. • Switch off the drive's power supply, check the connections between the compressor and drive and then turn on again the latter.
Troubleshooting	• Check for any loose connections on the U, V, W side of the drive. • Check for any loose connections on the compressor terminals.

5.5.11 Alarm 22 – Power supply undervoltage or input phase loss (3-phase models only)

Number of LED flashes	22
Alarm	Power supply undervoltage or phase loss (3-phase models only)
Alarm description	If the power supply undervoltage or phase loss is detected, the RVPM will issue an alarm. This alarm is enabled by Power Supply Phase Loss Supervisor (C0h) and the sensitivity of this function and the time to detect the phase loss are determined by Power Supply Phase Loss DC Voltage Ripple (C1h) and Power Supply Phase Loss Fault time (C2h) respectively.
Cause	• Insufficient power supply voltage. • Power cable supplying the drive disconnects.
RVPM reaction	The RVPM will switch off the gate drivers and compressor will coast to stop.
Action to recover alarm	• Reset the alarm through Alarm Reset command (65h) as mentioned in Section 4.3.3; after checking the connections of the power cable

	• Switch off the drive's power supply, check the connections between the power supply and drive and then turn on again the latter.
Troubleshooting	• Check the power supply voltage. • If the alarm is persistent, contact a Carlo Gavazzi representative.

6. Software overview

6.1 User interface

The software user interface is shown in figure 3 below. The interface is organised in 6 main blocks:-

- PM/BLDC Compressor
- Advanced Configuration
- Control
- Waveforms
- Diagnostics
- Monitor

The additional two buttons on the leftmost column are related to the connection setup and device information.
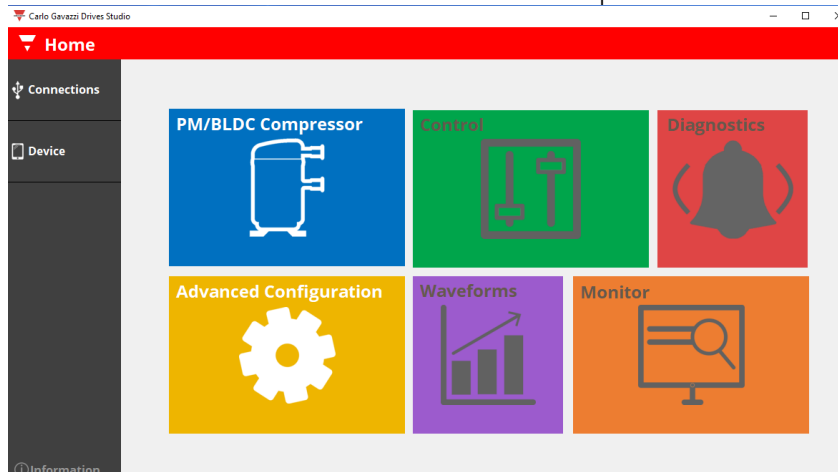
Figure 5: RVPM Configuration Software user interface

6.2 Establishing connection to RVPM

1. Click the "Connections" button to get to the connection configuration page

2. A new window will pop-up showing the two methods of connection

   a) *Automatic connection* – the software will loop through the various combinations of the communication settings until communication is established with the drive

   b) *Manual connection* – the user must enter the relevant communication parameters to communicate with the drive as shown in figure 6

3. Once communication is established the software will exit this screen and the user interface as shown in figure 4 will be displayed on the screen.

4. The text and icons on the blocks: *Control, Waveforms, Monitor and Diagnostics* will turn to white indicating that the blocks are now active.

5. If communication is not established, check that the proper parameters have been selected and that the correct COM port was chosen.
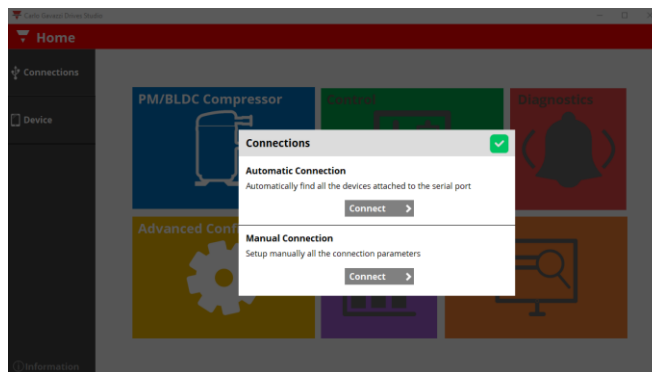
Figure 6: Manual or automatic connection page
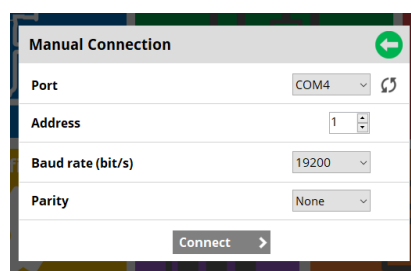
Figure 7: Manual connection parameters

6.3 Compressor configuration

Compressor configuration

PM/BLDC compressor configurator

The Carlo Gavazzi Drive Studio comes with a series of pre-configured compressor parameters. Note: This applies to PM/BLDC compressor models only.

After pressing the *PM/BLDC compressor* block on the main user interface, the page below will appear on screen.

The user can then select the specific compressor model available in the list provided. Once selected, the relevant compressor parameters are downloaded to the drive. The parameters downloaded in the drive can be viewed from the *Advanced Configuration* block.

Note: The ⌂ icon gets the user to the main (home) screen. This icon is available on every page except the main screen.
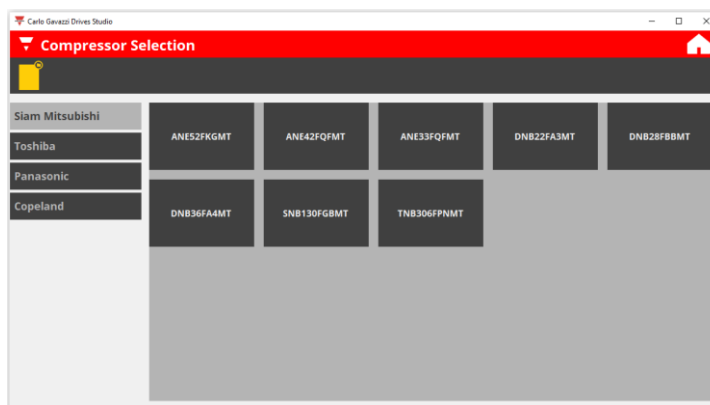

Figure 8: Compressor selection page

6.4 Advanced configuration

Advanced configuration

Advanced Configuration

The *Advanced Configuration* block allows the user to configure additional parameters within the drive. It is made up of 5 sections as shown in the figure below.

- Communication
- Compressor
- Start-up control
- Performance control
- Protection

In the menu bar there are also 4 icons that can be used to:

- Create a new configuration
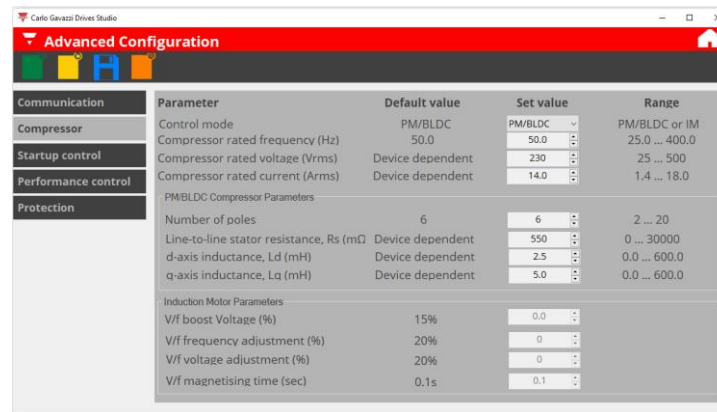- Open a configuration from file
- Save configuration
- Preview configuration

Figure 9: Compressor selection page

Main functions

The following table lists the main functions of the sections in the *Advanced Configuration* block:

| Section	Main function
Communication	Configuration of drive communication parameters (device address, baud rate, parity)
Compressor	Detailed configuration of compressor electrical parameters
Start-up control	Setting of the initial starting current and acceleration
Performance control	Setting of acceleration/deceleration, frequency limits, stop mode, crankcase heater function
Protection	Configuration of alarm limits and advanced protection functions

Table 1: Advanced configuration sections

Toolbar icons

Toolbar icons description		
Icon	**Definition**	**Description**
	New	Creates a new configuration by updating the Set Value of each parameter equal to the Default Value.
	Open	Loads a configuration file that is saved on the user's PC and updates the Set value of each parameter.
	Save	Saves a configuration file at any desirable location on the user's PC.
	Preview	Generates a configuration file report (in Portable Document Format (.pdf)) with respect to the user password protection level.
	Read	Reads the value of all programmable parameters. Note: This icon is activated only if communication exists between the PC and the drive.
	Write	Updates the value of all programmable parameters with respect to the user password protection level. Note: This icon

		is activated only if communication exists between the PC and the drive.

6.5 Control
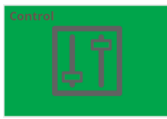
Control

Once all the configuration parameters are setup, the compressor can be controlled directly via the software.

The *Control* block allows the user to control and, at the same time, monitor the status of the drive through the *Device status, Alarm status and Frequency waveform* sections.

The drive can be started/stopped by clicking on the red button next to *start/Stop command*. As soon as this button is pressed, the drive will start accelerating the compressor up to the *frequency setpoint* value.

The *Compressor temperature regulation* button enables/disables the crankcase heater function.

In the case of any alarm, the icon in the *Alarm status* section will change colour to red and the fault will also be indicated below the icon. Should an alarm be present, go to the *Diagnostics* block to view the troubleshooting guide as shown in the next page.
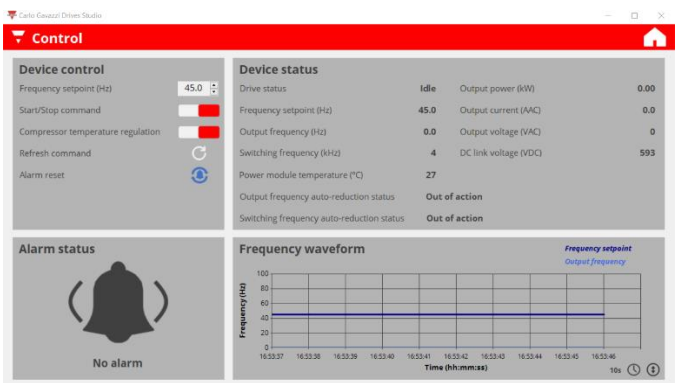
Figure 10: Control block

6.6 Diagnostics

Diagnostics

The *Diagnostics* block gives the information about the specific fault present on the drive. By clicking ⓘ the user can view a detailed troubleshooting section related to that specific alarm.
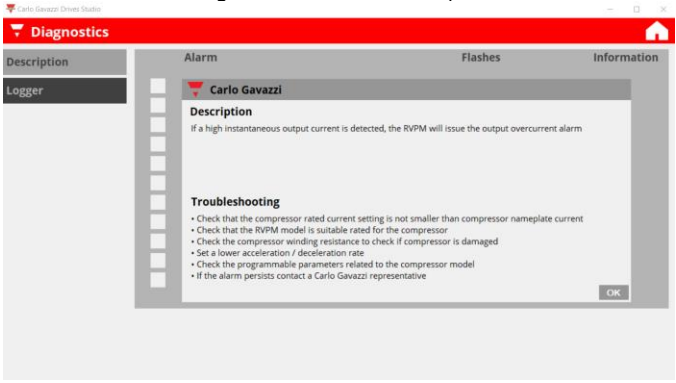

Figure 11: Diagnostics block (Troubleshooting)

6.7 Waveforms

Waveforms

The *Waveforms* block gives a more visual information related to specific real-time parameters such as voltage, output frequency, current and temperature.

The monitoring time base can be adjusted via the 🕐 and the user can also take a snapshot of the screen by pressing 👁.
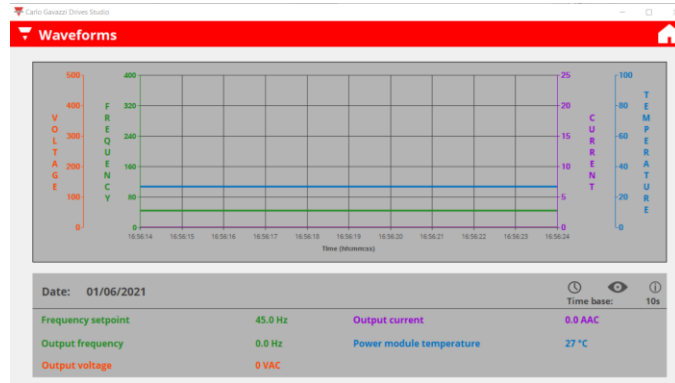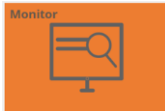

Figure 12: Waveforms block

6.8 Monitor

Monitor

The *Monitor* block displays both real-time variables as well as data that is stored in the internal memory of the drive.

Figure 13: Monitor block

7. RVPM Modbus RTU Protocol

7.1 Outline

Modbus RTU protocol is a messaging structure used to establish master-slave communication between devices in which only one device (called master) can initiate transactions (called queries); the other devices (called slaves) respond with the requested data to the master.

7.2 Modbus RTU function codes

The following Modbus functions are available on the RVPM drives:

- ➢ Read Holding Registers (code 03h)
- ➢ Read Input Registers (code 04h)
- ➢ Write Single Holding Register (code 06h)

The Modbus protocol states that Holding registers are those registers that can be read or written while Input registers are of read-only type. The RVPM Modbus RTU protocol does not distinguish between holding and input registers; hence either function code 03h or 04h can eb used when reading a register.