

NRG EtherCAT® User Manual

Operating instructions

Manuale d’istruzioni

Betriebsanleitung

Manuel d’instructions

Manual de instrucciones

Brugervejledning

操作说明

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1. Introduction

1.1. Foreword

The NRG described hereafter is a sub-system made up of a number of solid state relays intended for the switching of heaters in a machine. The solid state relays in this system are able to communicate with the main controller through an NRG controller that facilitates communication between the solid state relays and the main controller. The NRG controller is available with various communication interfaces including PROFINET, EtherNet/IP™, EtherCAT and Modbus RTU. Through this communication, it is possible for the main controller to control each solid state relay, read measurements related to each specific solid state relay and to identify specific failure modes related to the solid state relay or its associated heater load.

1.2. Scope

This manual is intended to provide information about the functionalities that are provided by the NRG system, explains set-up and configuration procedures, provides recommendations for use and gives a troubleshooting guide.

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 NRG system features dangerous voltages and consequently failure to observe the instructions contained in this user manual may cause serious harm to people and damage to property.

1.6. Abbreviations and acronyms

Acronym	Description
RG..N **RG..CM..N** **End-device**	NRG solid state relays
RGx1A..CM..N	NRG zero cross switching solid state relay
RGx1P..CM..N	NRG proportional switching solid state relay
RGC2/3P..N	NRG 2/3 pole proportional switching solid state relay
RGC2P..N	NRG 2-pole proportional switching solid state relay
RGC3P..N	NRG 3-pole proportional switching solid state relay
NRGC..	NRG Controller
COM	Common
PLC	Programmable Logic Controller
SSR	Solid State Relay

1.7. Other documentation

Datasheets, installation guide, certificates and other relevant documentation can be found online at www.gavazziautomation.com.

1.8. Disposal

Information for user 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 equipment may have negative effects on human health and on the environment
- The symbol (crossed-out wheelie bin) shown on the product or on the packaging and on the instruction sheet indicates that the equipment has been introduced onto the market after 13th 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 NRG is a sub-system that consists of one or more BUS chains that interact with the main controller or PLC in the machine through an EtherCAT communication interface. The communication link in the NRG systems can either be used to control the solid state relay, monitor various parameters, and diagnose faults in real time.

An NRG BUS chain is made up of a minimum 1x NRG controller and a minimum of 1 x NRG solid state relay (also referred to as end-device). The NRG bus chain can have a maximum of 32 switched poles (1-pole device = 1 switched pole, 2-pole device = 2 switched poles, 3-pole device = 3 switched poles. The 1-pole, 2-pole and 3-pole end-devices can be mixed on one bus chain as long as the 32 switched poles limit is not exceeded.

When more solid state relays are needed in a system, multiple BUS chains can be utilised. Each BUS chain connects to another BUS chain in a line topology via the NRG controllers of the respective BUS chains or in a star topology via an Ethernet switch.

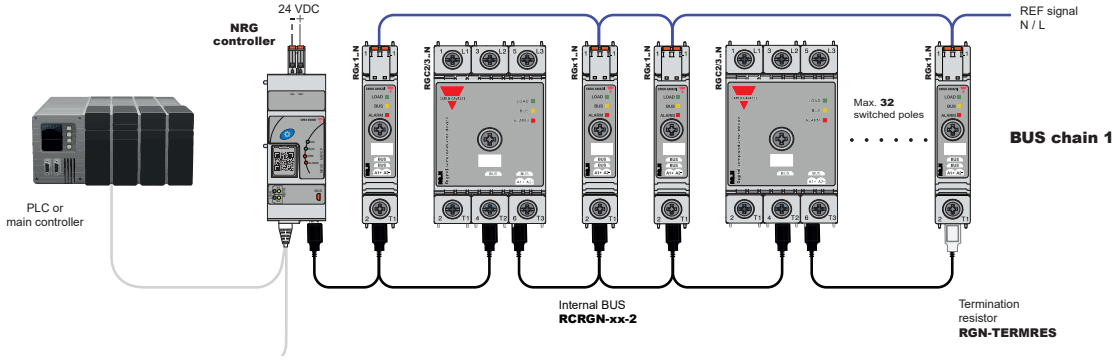


Fig. 1 - NRG bus chain

2.2. System components

The following system components are required for an NRG bus chain:

Description	Part Number	Notes
NRG Controller	NRGC..	**NRGC** NRG Controller with Modbus RTU. **NRGC-PN** NRG controller with PROFINET. **NRGC-EIP** NRG controller with Ethernet/IP™. **NRGC-ECAT** NRG controller with EtherCAT. **NRGC-MBTCP** NRG controller with Modbus TCP. 1x RGN-TERMRES is included in the NRGC.. packaging. The RGN-TERMRES is to be plugged into the last RG..N on the bus chain.

NRG Solid State Relays	RG..CM..N	**RGx1A..CM..N** NRG 1-pole zero cross switching solid state relay **RGx1P..CM..N** NRG 1-pole proportional switching solid state relay **RGC2P..CM..N** NRG 2-pole proportional switching solid state relay **RGC3P..CM..N** NRG 3-pole proportional switching solid state relay
NRG Internal Bus Cables	RCRGN-xx	Proprietary cables terminated at both ends with micro USB connector

NRG Controller



The NRG controller handles the communication with the higher-level controller and with the NRG solid state relays. It has to be supplied with a 24VDC supply and provides the power supply to the connected NRG solid state relays via the internal bus cables. A termination resistor (RGN-TERMRES) provided with every NRG controller has to be fitted on the last solid state relay of the NRG bus chain. The NRG controller is also capable of performing internal operations to setup and maintain the internal bus.

Various NRG Controller variants are available which facilitate communication via different communication protocols. These are identified via the part numbers. The NRG controller with an EtherCAT communication interface is the **NRGC-ECAT.**

NRG solid state relays



The RGx1..N solid state relays are the switching components in the NRG system. They are available with and without heatsink. For a reference of the variants available refer to the RGx1..N datasheet. There are 2 variants of the RGx1..N, the RGx1A..N is the zero cross relay including various switching modes such as ON/OFF, Burst, Distributed full cycle and Advanced full cycle modes. The RGx1P..N is the proportional control variant which on top of the aforementioned switching modes includes also phase angle switching and soft starting features. The NRG family includes also 2-pole and 3-pole proportional control solid state relays RGC2/3P..N capable of switching loads in different configurations including start, delta, star with neutral, a 1-pole load between phases and 1-pole load between phase and neutral.

The RG..CM..N utilises the communication system for switching, measurement and diagnostic thus minimising the number of components required in the system. For more information on the functions of each variant refer to Section 6.

Through the internal BUS, the main controller can read measurements, parameters and diagnostics information related to the RG..N and its load. The RG..N is also capable of detecting certain fault conditions. A fault condition is indicated through a red LED available on the facade of the RG..N. The type of fault can be identified through a specific flash rate of the red LED and identified via the communication system.

Since the main controller needs to address each specific RG..N individually, each RG..N needs to be uniquely identifiable. It is not required to physically set the ID for each RG..N. This can be done through an auto-

addressing function which occurs automatically on the first start up; whereby each RG..N on the bus chain will automatically be assigned an ID with respect to its physical placement on the internal bus.

NRG internal cables

The RCRGN-xxx-2 is a 5-way proprietary cable used for the internal BUS, i.e., between the NRG controller and the first RG..N on the BUS chain and between respective RG..Ns on the BUS. This internal BUS cable though terminated with a micro-USB plug is not a standard USB cable. Apart from the data and supply lines, the RCRGN-xxx-2 are equipped with an additional wire utilised for the auto-addressing of the RG..Ns on the NRG bus chain. These cables are available in various lengths from Carlo Gavazzi.



For further technical information on each NRG system component please refer to the respective product datasheets:

System component	Datasheet	QR code
NRGC-ECAT	https://www.gavazziautomation.com/fileadmin/images/PIM/DATASHEET/ENG/SSR_NRGC_ECAT.pdf	
RGx1..CM..N	https://www.gavazziautomation.com/fileadmin/images/PIM/DATASHEET/ENG/SSR_RG_CM_N.pdf	
RGC2/3P..N	https://www.gavazziautomation.com/fileadmin/images/PIM/DATASHEET/ENG/SSR_RGC_2_3_N.pdf	
RCRGN-xxx-2	https://www.gavazziautomation.com/fileadmin/images/PIM/DATASHEET/ENG/SSR_Accessories.pdf	

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 devices to direct sunlight and the elements in general.

3.1. System configuration

The NRG bus chain can consist of 1 x NRG controller and up to 32 x 1-pole NRG SSRs (RGx1...N). When 2-pole/3-pole NRG SSRs (RGC2/3P..N) are utilised, a maximum of 32 switched poles can be connected to each NRG controller. RGx1..N and RGC2/3P..N SSRs can be mixed on the same bus chain as long as the RGC2/3P..N relays are placed as first devices on the bus chain.

The NRG controller is the interface to the main controller via the 2 x RJ45 shielded communication ports. The connection between the NRG controller and the solid state relays is through the internal bus cables. Each RG..N is equipped with 2 x micro USB ports to allow looping between one RG..N and another using the RCRGN-xxx-2 bus cables from Carlo Gavazzi. The RGN-TERMRES supplied with each NRG controller has to be connected to the last RG..N on the NRG bus chain.

The NRG controller has to be supplied with a 24VDC supply via the supply input plug (Us-, Us+). Power to the RG..N SSRs on the bus chain is provided via the internal bus cables through the NRG controller.

The RGx1..N SSRs require a mains reference connection with respect to the load (neutral or another phase) through the 'Ref' connector to provide voltage and power measurements. The Ref connector has 2 x internally shorted terminals to allow for looping of the mains reference onto various RG..Ns. Refer to the 'Load connection diagrams' section (Section 3.3) for more information. This is not applicable for RGC2/3P..N SSRs.

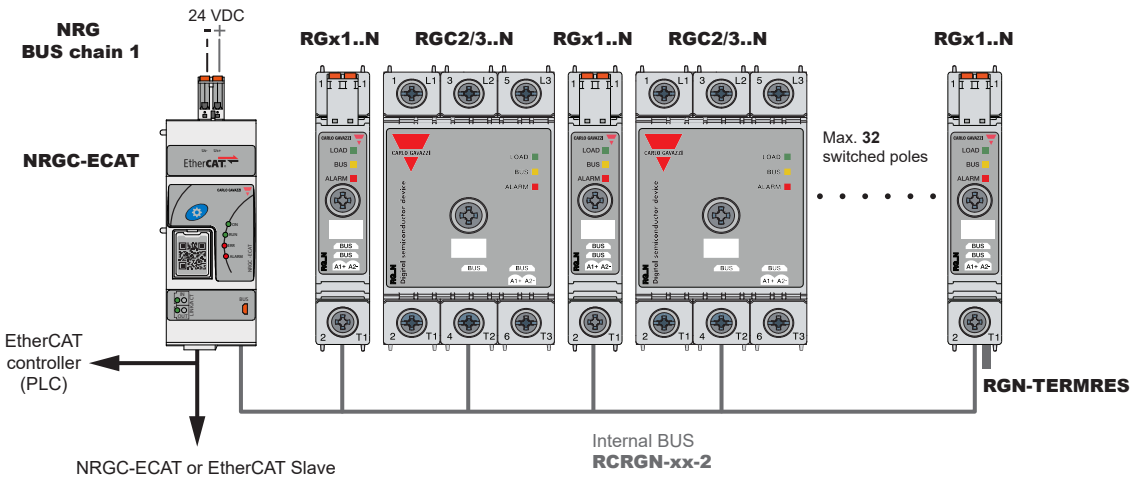


Fig. 2 - NRG bus chain configuration

3.2. Connection diagrams

The NRG bus chain can be connected to the Ethernet network via the pair of RJ45 connectors located on the NRG controller. The NRG can be configured in any network topology. If more than the maximum number of switched poles per bus chain (32) are required in an application, multiple bus chains can be utilised. These can be configured in a line or star topology as deemed fit for the application. The most favourable topologies for an EtherCAT network are line and ring. Wiring between EtherCAT devices should follow the standard EtherCAT cabling guidelines (max. 100m).

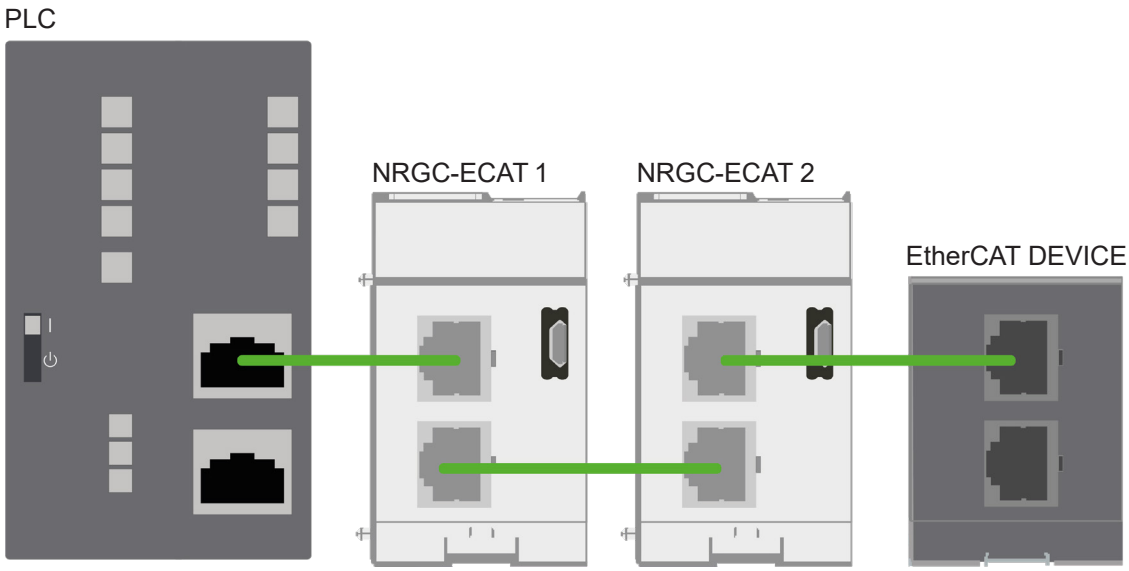


Fig. 3 - NRG bus chains connected in an EtherCAT topology

3.3. Load connection diagrams

RGx1..N load connection diagrams

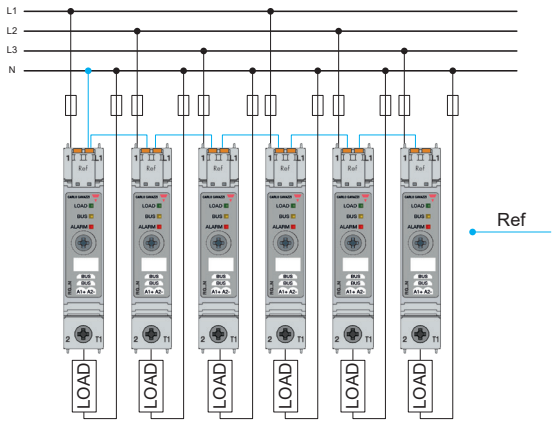


Fig. 4 - Loads connected between phase and neutral. The Ref connections can be looped from one RG..CM..N to another since all the loads have the same return path

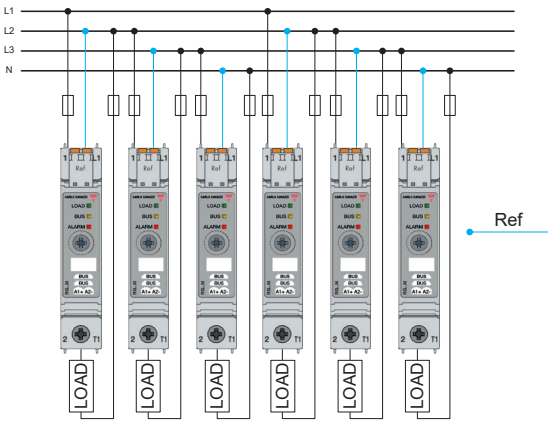


Fig. 5 - Loads connected between phases. Reference connection (Ref) should always follow the return path of the load

RGC2/3P..N load connection diagrams

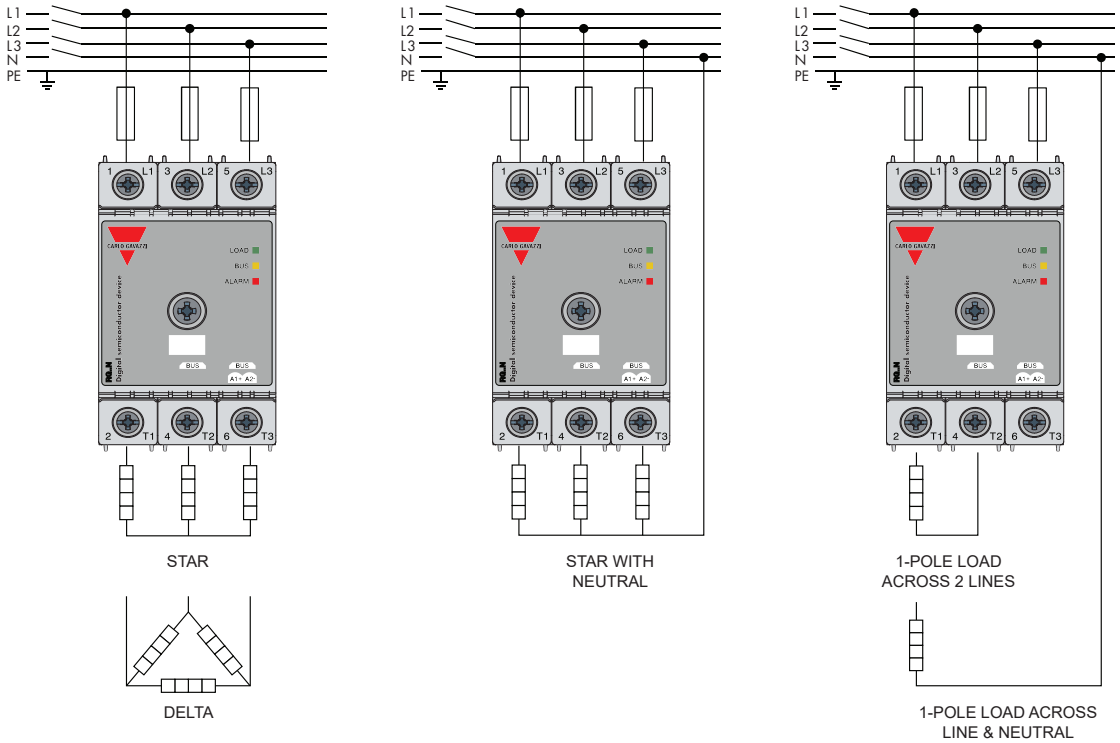


Fig. 6 - Possible load configurations for the RGC2/3P..N including star, delta, star with neutral, 1-pole load across L1- L2, 1-pole load across L2 - L3, 1-pole load across L1 - L3, 1-pole load across L1 - N, 1-pole load across L2 - N, and 1-pole load across L3 - N

3.4. Auto-addressing

The RG..Ns on the bus chain are automatically addressed upon the initial start-up of the system. The RG..Ns are addressed based on their position on the bus chain. The maximum number of devices on the bus chain (n) depends on the number of switched poles (**32 max**) which derives from the mix of **RGx1..N (1 switched pole)**, **RGC2P..N (2 switched poles)** and **RGC3P..N (3 switched poles)** devices on the same bus chain.

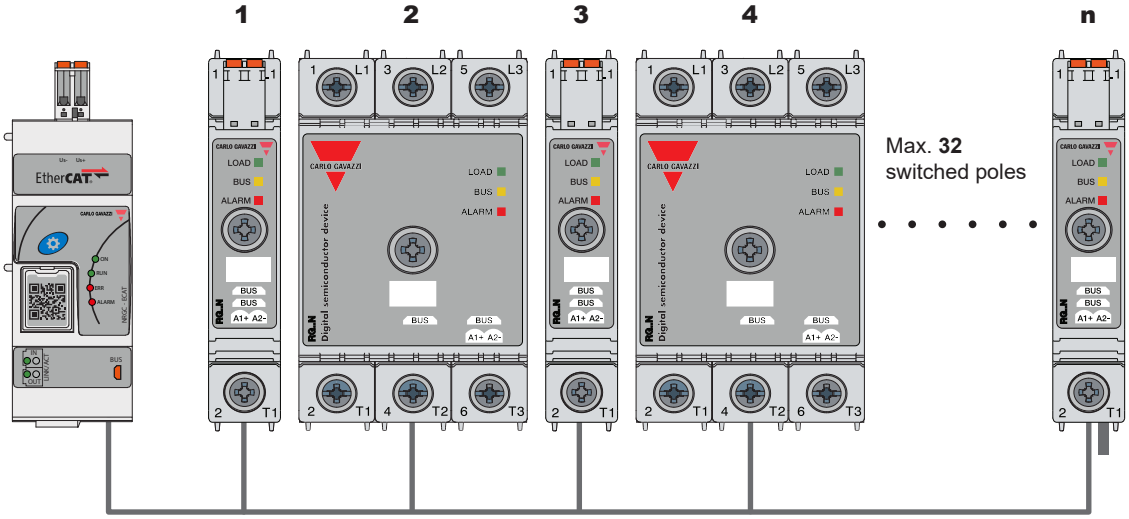


Fig. 7 - SSRs in NRG bus chain are automatically addressed based on their position on the bus

In case of an RG..N replacement, or any changes to the NRG bus chain, the RG..Ns have to be readdressed. Follow the procedure below (Figure 8) to readdress the RG..Ns on the NRG bus chain manually. Alternatively, auto-addressing can also be performed digitally, check 'Communication' section (Section 5) for further information.

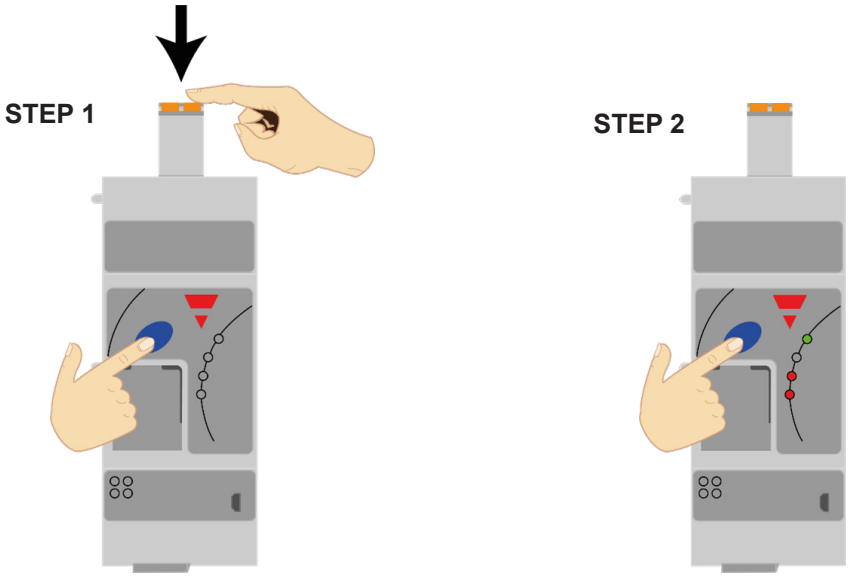


Fig. 8 - Manual Auto-addressing procedure

STEP 1: Hold the blue button while inserting the power supply plug of the NRGC-ECAT

STEP 2: Release the blue button once the Alarm LED turns ON

3.5. Grounding

Connecting the protective ground for the NRG Controller

The NRG controller is equipped with a metal contact clip at the back of the product to provide functional grounding via the Din Rail. The Din Rail must be conductive and grounded. Shielded Cat 5e cables fitted with an outer metallic shell should be used. The shell should be connected to the wire screen of the cable.

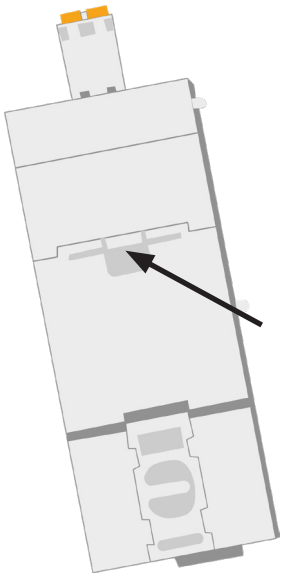


Fig. 9 - Metal DIN clip on NRG controller for functional grounding

Connecting the protective earth for the NRG solid state relays

The heatsink of the RGC..Ns has to be earthed. This can be done either via the metal DIN clip if the DIN rail is earthed, or through the connection provided using an M5 screw. Note that the M5 Protective Earth (PE) screw is not provided with the RG..N.

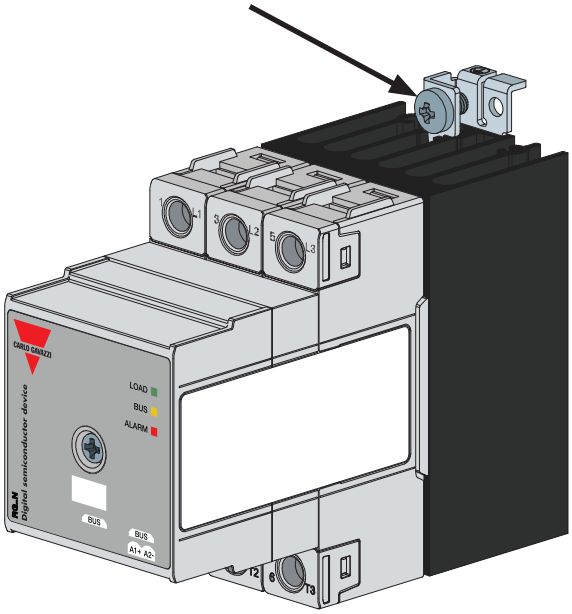


Fig. 10 - RG..N connection for Protective Earth (PE)

4. EtherCAT Configuration

EN

4.1. Installing the ESI file in TwinCAT

The ESI file is required for the configuration of the NRGC-ECAT. Obtain the xml file from:

https://www.gavazziautomation.com/fileadmin/images/PIM/OTHERSTUFF/ESI/ESI_NRGC-ECAT.zip

and relocate it in the TwinCAT default directory C:\TwinCAT\3.1\Config\Io\EtherCAT.

4.2. Integrating the NRG in TwinCAT

Launch TwinCAT in configuration mode and reload device descriptions as shown in Figure 11.

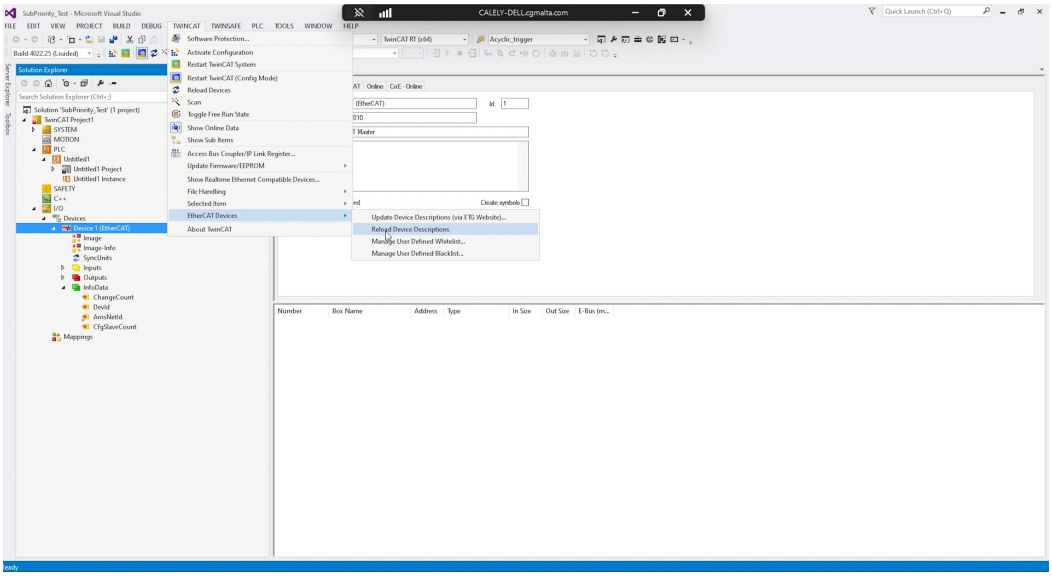


Fig. 11 - Reload Device Descriptions

Right-click on the EtherCAT Master and click ‘Add New Item...’

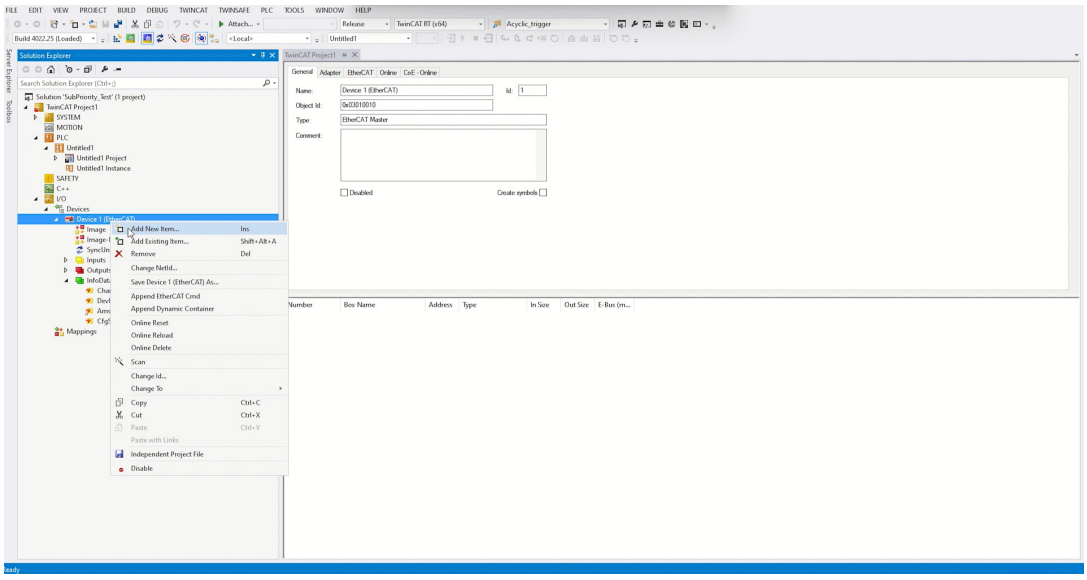


Fig. 12 - Add New Item

Find the ‘NRGC-ECAT’ in the EtherCAT device list under ‘Carlo Gavazzi Ltd’, ‘NRG Controller with EtherCAT’.

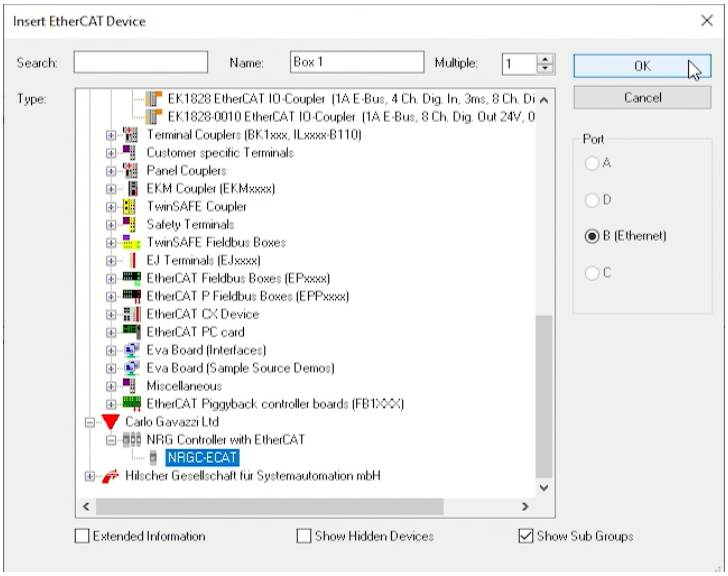
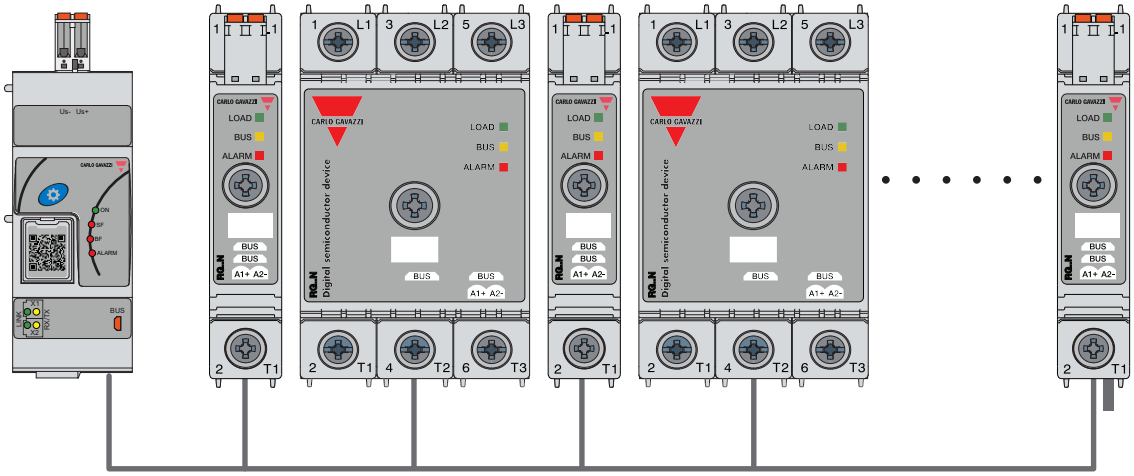


Fig. 13 - Find the NRGC-ECAT in the EtherCAT device list

4.3. Configuration of the NRG bus chain in TwinCAT

The NRG bus chain configuration must be mirrored in TwinCAT device configuration. Each RG..N on the bus chain shall occupy a slot according to its position on the NRG bus chain.



SLOT	1	2	3	4	...	n

SLOTS 1 - n: the maximum number of solid state relays connected to 1 x NRGC-ECAT depends on the ratio of RGx1..N (1 switched pole), RGC2P..N (2 switched poles) and RGC3P..N (3 switched poles) with a max. allowance of 32 switched poles.

In the ‘Slots’ tab, populate the modules depending on which variant of the RG..N solid state relays will be installed in the relevant slot (depending on its position on the NRG bus chain). For more information regarding the technical specifications of the different variants of the RG..N solid state relay please refer to the RG..CM..N datasheet.

Note: ‘Download SlotCfg’ should always be ticked.

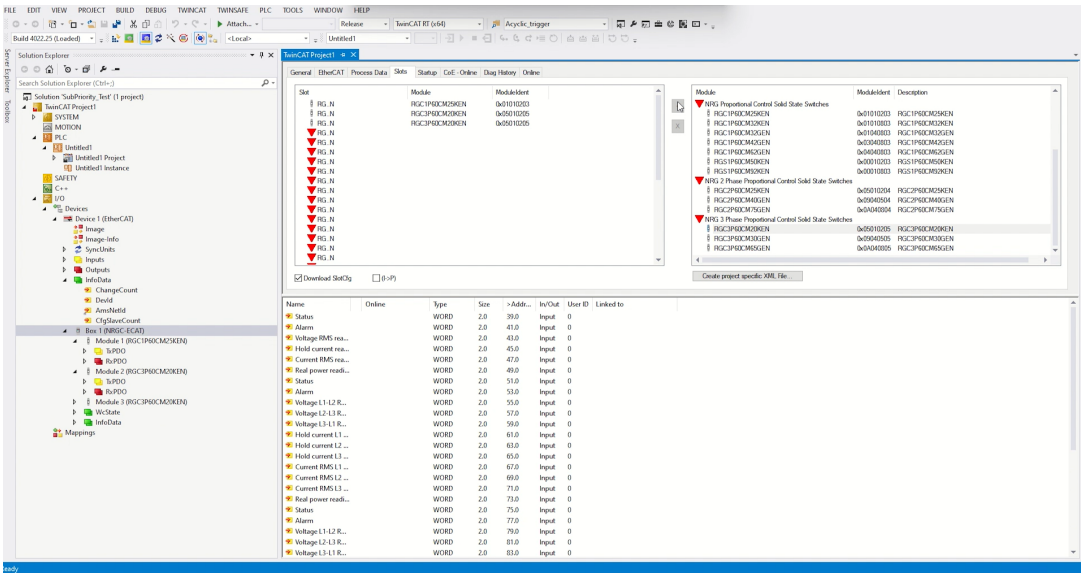


Fig. 14 - Slot configuration for the NRG bus chain in TwinCAT

4.4. Start-up Parameters

The start-up parameters are directly assigned to the respective slots (RG..Ns) and are set during device configuration. They are transferred automatically on start-up and during re-parametrisation. The service data objects with a write access in the object dictionary can be used during the start-up sequence. This is done by adding the required objects as start-up parameters in the “Startup” tab of the device in TwinCAT.

Note: start-up parameters are not added automatically.

The value of the start-up parameters should be written in a little-endian format, i.e. if for example a value of 660 DEC (02 94 HEX) is required to be written, the value written should be 94 02.

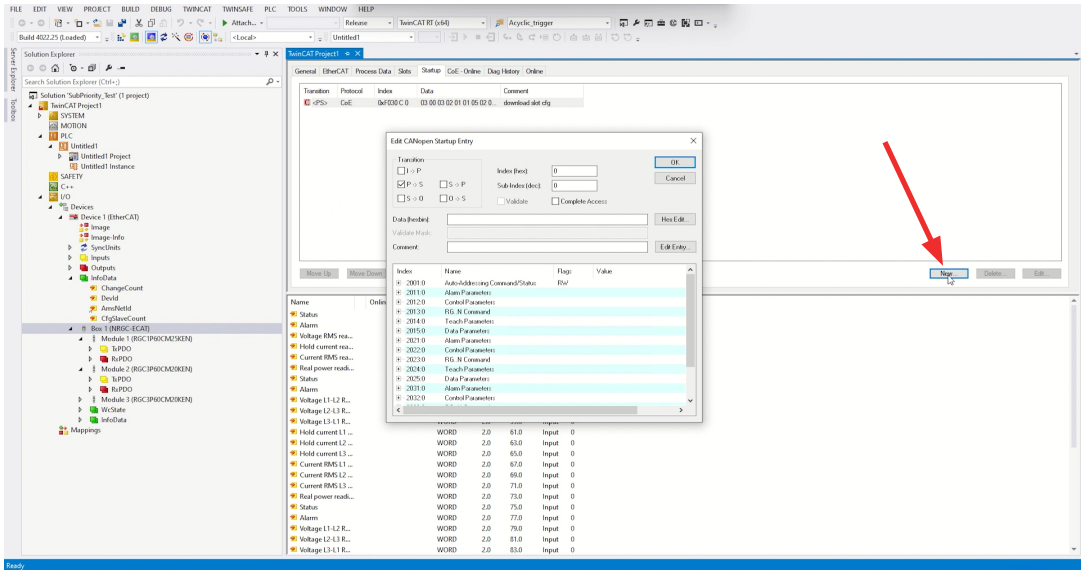


Fig. 15 - Click ‘New’ to add parameters (and their values) to the start-up sequence

The initialisation time of the NRGC-ECAT (from Pre-OP to OP) increases with the number of objects added to the start-up sequence. Alternatively, all parameters can be assigned or re-assigned via a service data object (SDO). Check ‘Communication’ section (Section 5) for further information. If start-up parameters are left blank, the values saved internally in the RG..Ns will be loaded.

The below parameters are available for all RG..Ns on the bus chain. The **xx** in the index represents the position (in HEX) of the solid state relay (RG..N) on the bus chain:

e.g 0x2**01**1 - 1st RG..N on the bus chain
0x2**02**1 - 2nd RG..N on the bus chain
0x2**0A**1 - 10th RG..N on the bus chain
0x2**20**1 - 32nd RG..N on the bus chain
0x2**xx**1 - xx RG..N on the bus chain

Note: ‘TEACH Parameters’ and **‘Load Running Hours reset’** should **NOT** be included as part of start-up sequence.

Parameter	Index	Description	Values
Alarm Recovery Mode	**0x2xx1:01**	Set the alarm recovery mode.	0: Automatic 1: Manual **Default: 0 (Automatic)**

Over Voltage limit (OVL)	**0x2xx1:02**	Set the over and under voltage limit if desired, which will trigger an alarm if the voltage reading is beyond the range.	0 - 660V but > UVL value **Default: 660**
Under Voltage limit (UVL)	**0x2xx1:03**		0 - 660V but < OVL value **Default: 0**
Over current limit (OCL)	**0x2xx1:04**	Set the over and under current limit if desired, which will trigger an alarm if the current reading is beyond the range. This parameter is in steps of 0.01, therefore a value of 1745 = 17.45A. Check 'Measurements' section (Section 6.3) for more information.	0 - RG..N model dependent but > UCL value **Default: RG..N model dependent**
Under current limit (UCL)	**0x2xx1:05**		0 - RG..N model dependent but < OCL value **Default: 0**
Over Frequency limit (OFL)	**0x2xx1:06**	Set the over and under frequency limit if desired, which will trigger an alarm if the frequency reading is beyond the range.	44 - 66Hz but > UFL value **Default: 66**
Under Frequency limit (UFL)	**0x2xx1:07**		44 - 66Hz but < OFL value **Default: 44**
Over-temperature pre-warning	**0x2xx1:08**	Δ temperature from max at which the RG..N will issue an alarm.	0 - 50°C **Default: 0**
Over current limit L1 (OCL-L1)	**0x2xx1:09**	Set the over and under current limit if desired, which will trigger an alarm if the current reading is beyond the range. This parameter is in steps of 0.01, therefore a value of 1745 = 17.45A. Check 'Measurements' section (Section 6.3) for more information.	0 - RG..N model dependent but > UCL-L1 value **Default: RG..N model dependent**
Under current limit L1 (UCL-L1)	**0x2xx1:10**		0 - RG..N model dependent but < OCL-L1 value **Default: 0**
Over current limit L2 (OCL-L2)	**0x2xx1:11**	Set the over and under current limit if desired, which will trigger an alarm if the current reading is beyond the range. This parameter is in steps of 0.01, therefore a value of 1745 = 17.45A. Check 'Measurements' section (Section 6.3) for more information.	0 - RG..N model dependent but > UCL-L2 value **Default: RG..N model dependent**
Under current limit L2 (UCL-L2)	**0x2xx1:12**		0 - RG..N model dependent but < OCL-L2 value **Default: 0**

Over current limit L3 (OCL-L3)	**0x2xx1:13**	Set the over and under current limit if desired, which will trigger an alarm if the current reading is beyond the range. This parameter is in steps of 0.01, therefore a value of 1745 = 17.45A. Check 'Measurements' section (Section 6.3) for more information.	0 - RG..N model dependent but > UCL-L3 value **Default: RG..N model dependent**
Under current limit L3 (UCL-L3)	**0x2xx1:14**		0 - RG..N model dependent but < OCL-L3 value **Default: 0**
Soft start ramping time *(only available for RGx1P..N and RGC2/3P..N)* **Note:** soft start with time and soft start with current limit are mutually exclusive	**0x2xx2:01**	Activate soft start with time whereby ramping will vary linearly with the set time **0:** soft start with time is disabled **0.1 – 25.5s:** soft start with time is enabled with the set time This parameter is in steps of 0.1, therefore a value of 11 = 1.1s	0 - 255 (0 - 25.5s) **Default: 0 (disabled)**
OFF time to soft start *(only available for RGx1P..N and RGC2/3P..N)*	**0x2xx2:02**	Set the non-firing time before soft start is reactivated **0:** soft start with occur on every start-up **0.1 - 25.5s:** non firing time for soft start to be reactivated This parameter is in steps of 0.1, therefore a value of 11 = 1.1s	0 - 255 (0 - 25.5s) **Default: 50 (5s)**
Soft start current limit *(only available for RGx1P..N and RGC2/3P..N)* **Note:** soft start with time and soft start with current limit are mutually exclusive	**0x2xx2:03**	Set the current limit to be utilised with Soft start with current limit mode **0:** soft start with current limit is disabled **0.1 - RG..N model dependent:** soft start with current limit is enabled with the set current limit. *(Recommended 1.2 – 1.5 times the nominal current)* This parameter is in steps of 0.01, therefore a value of 6600 = 66A	0 - RG..N model dependent **Default: 0 (disabled)**
Output substitute mode	**0x2xx2:04**	Set the output mode to be used in case of a communication timeout	0: Clear output 1: Hold output 2: Set value **Default: 1 (Hold output)**

Output substitute value *(Only applicable for 'Set Value option' for Output substitute mode)*	**0x2xx2:05**	Set the % control level to be used in case of a communication timeout.	0– 100% **Default: 0 (OFF)**
Switching modes	**0x2xx2:06**	Set the switching mode that the RG..N shall use at the output	0: External (only available with RGx1A..N & RGC2/3P..N) 1: ON/OFF 2: Burst 3: Advanced full cycle 4: Distributed full cycle 5: Phase Angle (only available with RGx1P..N/RGC3P..N) **RGx1A..N default: ON/OFF** **RGx1P..N default: Phase Angle** **RGC2/3P..N default: ON/OFF**
Timebase *(only applicable for Burst firing mode)*	**0x2xx2:07**	Set the desired timebase for Burst firing This parameter is in steps of 0.1, therefore a value of 11 = 1.1s	1 - 100 (0.1 – 10s) **Default: 1 (0.1s)**
Voltage compensation *(only available for RGx1P..N and RGC2/3P..N)*	**0x2xx2:08**	Set the reference voltage used to compensate for deviations in voltage when Voltage Compensation is activated **0:** Voltage compensation is disabled **42 - 600:** reference voltage for voltage compensation	0, 42 - 600V **Default: 0 (disabled)**
True power compensation *(only available for RGC2/3P..N)*	**0x2xx2:09**	Set the reference power used to compensate for deviations in voltage and current when True power compensation is active	TBD
Load configuration type	**0x2xx2:10**	Set the load configuration connected to the RGC2/3P..N	0: Star with Neutral 1: Star without Neutral 2: Delta 3: 1-P Load between L1& L2 4: 1-P Load between L2 & L3 5: 1-P Load between L3 & L1 6: 1-P Load between L1 & N 7: 1-P Load between L2 & N 8: 1-P Load between L3 & N
RG..N Commands	**0x2xx3:01**	Insert value to indicate the command that shall be executed by the RG..N	1: start a TEACH operation 4: store parameters permanently in RG..N 8: clear Latched Alarms in case latching of alarms is activated 99: factory reset of RG..N

In order for the values in the start-up parameters to be saved permanently in the RG..CM..N, a ‘Store permanently command’ is required. This is done by including the ‘RG..N Commands’ (**0x2xx3:01**) at the end of the start-up sequence and assigning a value of **‘4’**.

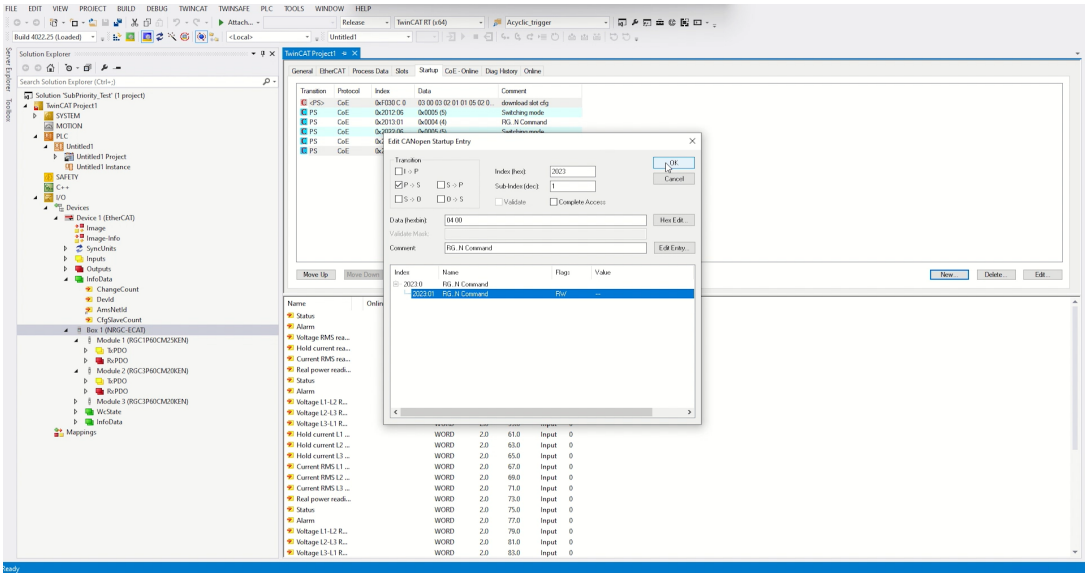


Fig. 16 - Add RG..N Commands to the end of the start-up sequence and assign the value ‘4’

5. Communication

5.1. Process data (PDO)

Process data is the transmission of real time data between an EtherCAT slave and an EtherCAT controller. In the NRG system, process data is exchanged between the EtherCAT Controller and the RG..N solid state relays. The data includes parameters and diagnostics measured by each NRG solid state relay as well as the control level from the PLC to control each solid state relay. Values are stored in a big endian format.

TxPDO - Input Process Data (RGx1..N)
]

Data	Data Type
Status	uint16
Alarm	uint16
Voltage RMS Reading	uint16
Hold Current Reading	uint16
Current RMS Reading	uint16
Real Power Reading	uint16

TxPDO - Input Process Data (RGC2/3P..N)

Data	Data Type
Status	uint16
Alarm	uint16
Voltage L1-L2 RMS Reading	uint16
Voltage L2-L3 RMS Reading	uint16
Voltage L3-L1 RMS Reading	uint16
Hold Current L1 Reading	uint16
Hold Current L2 Reading	uint16
Hold Current L3 Reading	uint16
Current RMS L1 Reading	uint16
Current RMS L2 Reading	uint16
Current RMS L3 Reading	uint16
Real Power Reading	uint16

The current measurements (Current RMS & Hold Current) are returned as scaled integers. Therefore, a current value of 16.81A will be received as 1681. The PLC program has to convert the numbers into floating point values. For further information regarding the scaling of each measurement, refer to the ‘Measurements’ section (Section 6.3) in this User Manual.

The bits in the Alarms and Status WORDs represent alarms and status flags present on the respective solid state relay.

RGx1..N

Name	Description
Alarms	Bit 0 - Mains loss alarm Flag Bit 1 - Load loss/SSR open circuit alarm Flag Bit 2 - RG..N short circuit alarm Flag Bit 3 - Voltage out of range alarm Flag Bit 4 - Current out of range alarm Flag Bit 5 - Frequency out of range alarm Flag Bit 6 - Over-temperature pre warning alarm Flag Bit 7 - Temperature out of range alarm Flag Bit 8 - Load deviation alarm Flag Bit 9 - Soft Start current limit reached Flag Bit 10 - Voltage Compensation not possible Flag Bits 11:15 - Not used. *(shall be 0)*
Status	Bit 0 - Device reset Flag Bit 1 - Autoconfiguration Flag *(for internal use)* Bit 2 - Internal Error Alarm Flag Bit 3 Communication Error Flag Bits 4:7 - Not used Bit 8 - Alarm Status Flag Bit 9 - TEACH busy Flag Bit 10 - TEACH successful Flag Bit 11 - Ramping Flag Bit 12 - Voltage Compensation Active Flag Bits 13:15 - Not used. (*shall be 0*)

RGC2/3P..N

Name	Description
Alarms	Bit 0 - Mains loss alarm Flag Bit 1 - Load loss/SSR open circuit alarm Flag Bit 2 - RG..N short circuit alarm Flag Bit 3 - Voltage out of range alarm Flag Bit 4 - Current out of range alarm Flag Bit 5 - Frequency out of range alarm Flag Bit 6 - Over-temperature pre warning alarm Flag Bit 7 - Temperature out of range alarm Flag Bit 8 - Load deviation alarm Flag Bit 9 - Soft Start current limit reached Flag Bit 10 - Voltage compensation not possible Flag Bit 11 - True Power compensation not possible Flag Bits 12:15 - Not used. (*shall be 0*)
Status	Bit 0 - Device reset Flag Bit 1 - *Autoconfiguration Flag (for internal use)* Bit 2 - Internal Error Alarm Flag Bit 3 - Communication Error Flag Bits 4:6 - Not used Bit 7 - Phase Sequence not identified Flag Bit 8 - Alarm Status Flag Bit 9 - TEACH busy Flag Bit 10 - TEACH successful Flag Bit 11 - Ramping Flag Bit 12 - Voltage Compensation active Flag Bit 13 - True Power Control active Flag Bits 14:15 - *Not used. (shall be 0)*

Note: ‘Ref’ terminal connection is required for Voltage, Apparent Power and Real Power readings. Otherwise the readings of these parameters will be 0. This does not apply for RGC2/3P..N solid state relays.

RxPDO – Output Process Data (RGx1..N & RGC2/3P..N)

Data	Data Type
Control level (0 -100%)	uint8

In case of **ON/OFF** control mode, a control level **< 100%** shall indicate SSR output **OFF** and a control level of **100%** shall indicate SSR output **ON**.

For the **Power control** firing modes (Burst, Distributed full cycle, Advanced full cycle and Phase Angle) the **% control** value shall be translate to **% power** of the SSR output. Refer to Section 6.2 for more information on Switching Modes.

5.2. Object Dictionary (SDO)

Service Data Object (SDO) is used to transfer data that does not require continuous updates or is not critical to the ongoing process. Any NRG parameter can be set via an SDO even if this is included in the start-up parameters.

Reading and writing is possible for all variables except for variables related the SSR history as indicated in the tables below. The datatype of each index is uint16. The indexes are in a big endian format.

A description of each parameter with an indication of the possible values is listed in the table below:

Index	Sub-Index	Description	Size	Valid Values
0x2001	**0x2001:01**	**Auto-addressing Command/Status**	2 bytes	1: Trigger an auto-addressing of the NRG bus chain on the next NRGC-ECAT powerup.
0x2002	**0x2002:01**	**NRG Controller Status**	2 bytes	Bit 0 - NRG Controller reset Flag Bit 1 - Not used Bit 2 - Internal error alarm Flag Bit 3 - Not used Bit 4 - Bus error Flag Bit 5 - Device limit error Flag Bit 6 - Device conflict error Flag Bit 7 - Termination error Flag Bit 8 - Device position error Flag Bit 9 - Supply out of range error Flag Bit 10 - Device Unconfigured error Flag Bit 11 - Device Incompatible error Flag Bits 12:15 - Not used (*shall be 0*)
0xF100	**0xF100:xx** **xx - RG..N position on bus chain (in HEX)**	**Device Status**	1 byte	Bit 0 - Substitute submodule (Module type does not match the installed RG..N variant, but communication is not interrupted) Bit 1 - Wrong submodule (Module type does not match the installed RG..N variant, but communication is interrupted) Bit 2 - Not used Bit 3 - Device not reachable Bit 4 - Device position error Bit 5 - Empty slot Bit 6 - Device incompatible error, Bit 7 - Not used

SDO – RG..N

The below parameters are available for all RG..Ns on the bus chain. The **xx** in the index represents the position (in hex) of the solid state relay (RG..N) on the bus chain:

e.g 0x2**01**1 - 1st RG..N on the bus chain
0x2**02**1 - 2nd RG..N on the bus chain
0x2**0A**1 - 10th RG..N on the bus chain
0x2**20**1 - 32nd RG..N on the bus chain
0x2**xx**1 - xx RG..N on the bus chain

Index	Description	Size	Parameters
0x2xx1	**Alarm Parameters**	16 bytes	Alarm recovery mode Over voltage limit Under voltage limit Over current limit *(for RGx1..N)* Under current limit *(for RGx1..N)* Over frequency limit Under frequency limit Over-temperature pre-warning Over current limit L1 *(for RGC2/3P..N)* Under current limit L1 *(for RGC2/3P..N)* Over current limit L2 *(for RGC2/3P..N)* Under current limit L2 *(for RGC2/3P..N)* Over current limit L3 *(for RGC2/3P..N)* Under current limit L3 *(for RGC2/3P..N)*
0x2xx2	**Control Parameters**	16 bytes	Soft start ramping time *(for RGx1P..N/RGC3P..N)* OFF time to soft start *(for RGx1P..N/RGC3P..N)* Soft start current limit mode *(for RGx1P..N/RGC3P..N)* Output substitute mode Output substitute value Switching mode Time base (for Burst firing mode) Voltage compensation *(for RGx1P..N & RGC2/3P..N)* True power compensation *(for RGx1P..N & RGC2/3P..N)* Load connection configuration *(for RGC2/3P..N)*
0x2xx3	**RG..N Commands**	2 bytes	RG..N command
0x2xx4	**TEACH Parameters**	6 bytes	TEACH voltage reference *(for RGx1..N)* TEACH current reference *(for RGx1..N)* TEACH % load deviation TEACH voltage reference L1-L2 *(for RGC2/3P..N)* TEACH current reference L1 *(for RGC2/3P..N)* TEACH voltage reference L2-L3 *(for RGC2/3P..N)* TEACH current reference L2 *(for RG2c/3P..N)* TEACH voltage reference L3-L1 *(for RGC2/3P..N)* TEACH current reference L3 *(for RGC2/3P..N)*
0x2xx5	**Load Running Hours**	6 bytes	Load Running hours Frequency reading Apparent power reading
0x2xx6	**SSR History** *(read only)*	6 bytes	Energy Reading (low) Energy Reading (high) SSR ON time
0x2xx7	**Status** *(read only)*	4 bytes (RGx1/2/3P..N) 2 bytes (RGx1A..N)	Control level feedback (only for RGx1P..N & RGC2/3P..N) General Status

A description of each parameter with an indication of the possible values is listed in the table below

Parameter	Index	Description	Values
Alarm Recovery Mode	**0x2xx1:01**	Set the alarm recovery mode.	0: Automatic 1: Manual **Default: 0 (Automatic)**
Over Voltage limit (OVL)	**0x2xx1:02**	Set the over and under voltage limit if desired, which will trigger an alarm if the voltage reading is beyond the range.	0 - 660V but > UVL value **Default: 660**
Under Voltage limit (UVL)	**0x2xx1:03**		0 - 660V but < OVL value **Default: 0**
Over current limit (OCL)	**0x2xx1:04**	Set the over and under current limit if desired, which will trigger an alarm if the current reading is beyond the range. This parameter is in steps of 0.01, therefore a value of 1745 = 17.45A. Check 'Current out of range' alarm in 'Alarms - RG..N' section (Section 7.4) for more information.	0 - RG..N model dependent but > UCL value **Default: RG..N model dependent**
Under current limit (UCL)	**0x2xx1:05**		0 - RG..N model dependent but < OCL value **Default: 0**
Over Frequency limit (OFL)	**0x2xx1:06**	Set the over and under frequency limit if desired, which will trigger an alarm if the frequency reading is beyond the range.	44 - 66Hz but > UFL value **Default: 66**
Under Frequency limit (UFL)	**0x2xx1:07**		44 - 66Hz but < OFL value **Default: 44**
Over-temperature pre-warning	**0x2xx1:08**	Δ temperature from max at which the RG..N will issue an alarm.	0 - 50°C **Default: 0**
Over current limit L1 (OCL-L1)	**0x2xx1:09**	Set the over and under current limit if desired, which will trigger an alarm if the current reading is beyond the range. This parameter is in steps of 0.01, therefore a value of 1745 = 17.45A. Check 'Current out of range' alarm in 'Alarms - RG..N' section (Section 7.4) for more information.	0 - RG..N model dependent but > UCL-L1 value **Default: RG..N model dependent**
Under current limit L1 (UCL-L1)	**0x2xx1:10**		0 - RG..N model dependent but < OCL-L1 value **Default: 0**

Over current limit L2 (OCL-L2)	**0x2xx1:11**	Set the over and under current limit if desired, which will trigger an alarm if the current reading is beyond the range. This parameter is in steps of 0.01, therefore a value of 1745 = 17.45A. Check 'Current out of range' alarm in 'Alarms - RG..N' section (Section 7.4) for more information.	0 - RG..N model dependent but > UCL-L2 value **Default: RG..N model dependent**
Under current limit L2 (UCL-L2)	**0x2xx1:12**		0 - RG..N model dependent but < OCL-L2 value **Default: 0**
Over current limit L3 (OCL-L3)	**0x2xx1:13**	Set the over and under current limit if desired, which will trigger an alarm if the current reading is beyond the range. This parameter is in steps of 0.01, therefore a value of 1745 = 17.45A. Check 'Current out of range' alarm in 'Alarms - RG..N' section (Section 7.4) for more information.	0 - RG..N model dependent but > UCL-L3 value **Default: RG..N model dependent**
Under current limit L3 (UCL-L3)	**0x2xx1:14**		0 - RG..N model dependent but < OCL-L3 value **Default: 0**
Soft start ramping time *(only available for RGx1P..N and RGC3P..N)* **Note:** soft start with time and soft start with current limit are mutually exclusive	**0x2xx2:01**	Activate soft start with time whereby ramping will vary linearly with the set time **0:** soft start with time is disabled **0.1 – 25.5s:** soft start with time is enabled with the set time This parameter is in steps of 0.1, therefore a value of 11 = 1.1s	0 - 255 (0 - 25.5s) **Default: 0 (disabled)**
OFF time to soft start *(only available for RGx1P..N and RGC3P..N)*	**0x2xx2:02**	Set the non-firing time before soft start is reactivated **0:** soft start with occur on every start-up **0.1 - 25.5s:** non firing time for soft start to be reactivated This parameter is in steps of 0.1, therefore a value of 11 = 1.1s	0 - 255 (0 - 25.5s) **Default: 50 (5s)**

Soft start current limit *(only available for RGx1P..N and RGC3P..N)* **Note:** soft start with time and soft start with current limit are mutually exclusive	**0x2xx2:03**	Set the current limit to be utilised with Soft start with current limit mode **0:** soft start with current limit is disabled **0.1 - RG..N model dependent:** soft start with current limit is enabled with the set current limit. *(Recommended 1.2 – 1.5 times the nominal current)* This parameter is in steps of 0.01, therefore a value of 6600 = 66A	0 - RG..N model dependent **Default: 0 (disabled)**
Output substitute mode	**0x2xx2:04**	Set the output mode to be used in case of a communication timeout	0: Clear output 1: Hold output 2: Set value **Default: 1 (Hold output)**
Output substitute value *(Only applicable for 'Set Value option' for Output substitute mode)*	**0x2xx2:05**	Set the % control level to be used in case of a communication timeout.	0– 100% **Default: 0 (OFF)**
Switching modes	**0x2xx2:06**	Set the switching mode that the RG..N shall use at the output	0: External (only available with RGx1A..N & RGC2/3P..N) 1: ON/OFF 2: Burst 3: Advanced full cycle 4: Distributed full cycle 5: Phase Angle (only available with RGx1P..N & RGC3P..N) **RGx1A..N default: ON/OFF** **RGx1P..N default: Phase Angle** **RGC2/3P..N default: ON/OFF**
Timebase *(only applicable for Burst firing mode)*	**0x2xx2:07**	Set the desired timebase for Burst firing This parameter is in steps of 0.1, therefore a value of 11 = 1.1s	1 - 100 (0.1 – 10s) **Default: 1 (0.1s)**
Voltage compensation *(only available for RGx1P..N and RGC2/3P..N)*	**0x2xx2:08**	Set the reference voltage used to compensate for deviations in voltage when Voltage Compensation is activated **0:** Voltage compensation is disabled **42 - 600:** reference voltage for voltage compensation	0, 42 - 600V **Default: 0 (disabled)**
True power compensation *(only available for RGC2/3P..N)*	**0x2xx2:09**	Set the reference power used to compensate for deviations in voltage and current when True power compensation is active	TBD

Load configuration type	**0x2xx2:10**	Set the load configuration connected to the RGC2/3P..N	0: Star with Neutral 1: Star without Neutral 2: Delta 3: 1-P Load between L1& L2 4: 1-P Load between L2 & L3 5: 1-P Load between L3 & L1 6: 1-P Load between L1 & N 7: 1-P Load between L2 & N 8: 1-P Load between L3 & N
RG..N Commands	**0x2xx3:01**	Insert value to indicate the command that shall be executed by the RG..N	1: start a TEACH operation 4: store parameters permanently in RG..N 8: clear Latched Alarms in case latching of alarms is activated 99: factory reset of RG..N
TEACH voltage reference	**0x2xx4:01**	Holds the reference voltage to be used for the load deviation alarm. Value is updated automatically with a TEACH command or manually. If TEACH is not successful value will reset to 0	0, 42 - 660 VAC **Default: 0**
TEACH current reference	**0x2xx4:02**	Holds the reference current to be used for the load deviation alarm. Value is updated automatically with a TEACH command or manually. If TEACH is not successful value will reset to 0 This parameter is in steps of 0.01, therefore a value of 1745 = 17.45A.	0, min. - max. current limit (RG..N model dependent) **Default: 0** Check Load deviation alarm in 'Alarms - RG..N' section (Section 7.4) for the current ranges of the full list of RG..N models.
TEACH % load deviation	**0x2xx4:03**	Holds the percentage load deviation used for the load deviation alarm.	5 - 100% **Default: 10**
TEACH voltage reference L1-L2	**0x2xx4:04**	Holds the reference voltage between L1-L2 for RGC2/3P..N and L1-REF for RGx1..N to be used for the load deviation alarm. Value is updated automatically with a TEACH command or can be done manually. If TEACH is not successful value will reset to 0	0, 42 - 660VAC **Default: 0**

TEACH current reference L1	**0x2xx4:05**	Holds the reference current on L1 to be used for the load deviation alarm. Can be updated automatically with a TEACH command or done manually. If TEACH is not successful value will reset to 0 This parameter is in steps of 0.01, therefore a value of 1745 = 17.45A	0, min. - max. current limit (RG..N model dependent) **Default: 0** Check Load deviation alarm in 'Alarms - RG..N' section (Section 7.4) for the current ranges of the full list of RG..N models.
TEACH voltage reference L2-L3	**0x2xx4:06**	Holds the reference voltage between L2-L3 for RGC2/3P..N to be used for the load deviation alarm. Value is updated automatically with a TEACH command or can be done manually. If TEACH is not successful value will reset to 0	0, 42 - 660VAC **Default: 0**
TEACH current reference L2	**0x2xx4:07**	Holds the reference current on L2 to be used for the load deviation alarm. Can be updated automatically with a TEACH command or done manually. If TEACH is not successful value will reset to 0 This parameter is in steps of 0.01, therefore a value of 1745 = 17.45A	0, min. - max. current limit (RG..N model dependent) **Default: 0** Check Load deviation alarm in 'Alarms - RG..N' section (Section 7.4) for the current ranges of the full list of RG..N models.
TEACH voltage reference L3-L1	**0x2xx4:08**	Holds the reference voltage between L3-L1 for RGC2/3P..N to be used for the load deviation alarm. Value is updated automatically with a TEACH command or can be done manually. If TEACH is not successful value will reset to 0	0, 42 - 660VAC **Default: 0**

TEACH current reference L3	**0x2xx4:09**	Holds the reference current on L3 to be used for the load deviation alarm. Can be updated automatically with a TEACH command or done manually. If TEACH is not successful value will reset to 0 This parameter is in steps of 0.01, therefore a value of 1745 = 17.45A	0, min. - max. current limit (RG..N model dependent) **Default: 0** Check Load deviation alarm in 'Alarms - RG..N' section (Section 7.4) for the current ranges of the full list of RG..N models.
Load running hours reset	**0x2xx5:01**	Use this index to reset the load running hours reading in case of load or SSR replacement in hours	0 hrs - **Default: 0**
Frequency *(read only)*	**0x2xx5:02**	Holds the frequency reading in Hz	0 Hz - **Default: 0**
Apparent Power *(read only)*	**0x2xx5:03**	Holds the apparent power reading in VA	0 VA - **Default: 0**
Energy Reading (low) *(read only)*	**0x2xx6:01**	The energy reading is split into 2 indexes. This index holds the lower value.	0 - **Default: 0**
Energy Reading (high) *(read only)*	**0x2xx6:02**	This index holds the upper value of the energy reading.	0 - **Default: 0**
SSR ON time *(read only)*	**0x2xx6:03**	Holds the accumulated time in hours that the output of the RG..N was switched ON.	0 hrs - **Default: 0**
Control level feedback *(read only)*	**0x2xx7:01**	Holds the actual control level of the output firing (0-100%). In the case of ON/OFF mode it shall give 0 or 100. In the case of the other firing modes, it shall reflect the control level. If voltage compensation is active then it shall contain the result of the voltage compensation algorithm	0 - 100% **Default: 0**
Status *(read only)*	**0x2xx7:02**	Holds flags related to general status data of the solid state relay. Each bit represents a specific flag	Bit 0 - Device reset Flag Bit 1 - Autoconfiguration Flag *(for internal use)* Bit 2 - Internal Error Alarm Flag Bit 3 - Communication Error Flag Bits 4:7 - Not used Bit 8 - Alarm Status Flag Bit 9 - TEACH busy Flag Bit 10 - TEACH successful Flag Bit 11 - Ramping Flag Bit 12 - Voltage Compensation Active Flag Bits 13:15 - Not used. (*shall be 0*)

Note: Reading the Energy (low) and Energy (high) readings as a uint32 will give the actual energy measurement

6. Functions

6.1. Functions Overview

The NRG solid state relays are equipped with a range of functionality within one device. For a list of some of the features refer to the table below.

Feature	RGx1A..CM..N	RGx1P..CM..N	RGC2/3P..CM..N
External Control	●	-	●
Control over BUS	●	●	●
ON/OFF mode	●	●	●
Burst Firing mode	●	●	●
Distributed full cycle Firing mode	●	●	●
Advanced full cycle Firing mode	●	●	●
Phase angle Firing mode	-	●	●
Soft start with time mode	-	●	●
Soft start with current limit mode	-	●	●
Voltage compensation	-	●	●
True power compensation	-	-	●
Monitoring of system parameters	●	●	●
SSR diagnostics	●	●	●
Load diagnostics	●	●	●
Over-temperature protection	●	●	●

6.2. Switching Modes

ON/OFF mode

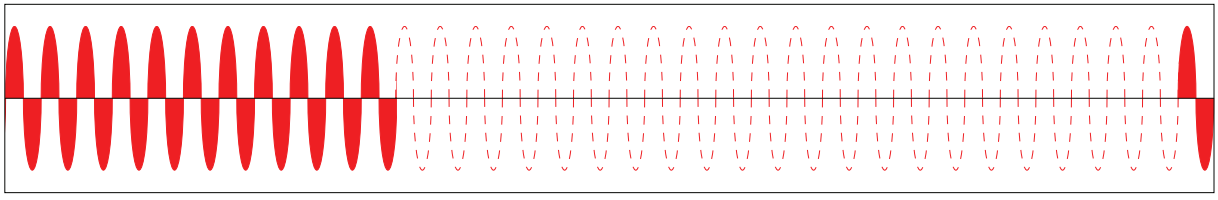
The ON/OFF mode controls the solid state relays at the user's command. Through an I/O output message, the RG..N can be controlled using the control level. A control level of 0% indicates SSR output OFF and a control level of 100% indicates SSR output ON.
The advantages of this mode are:

- It is effectively a direct replacement of the A1-A2 signal and the control algorithm within the PLC can be left relatively untouched, with the output being controlled via the communication interface.
- All RG..Ns on the bus chain can be controlled within 10ms.

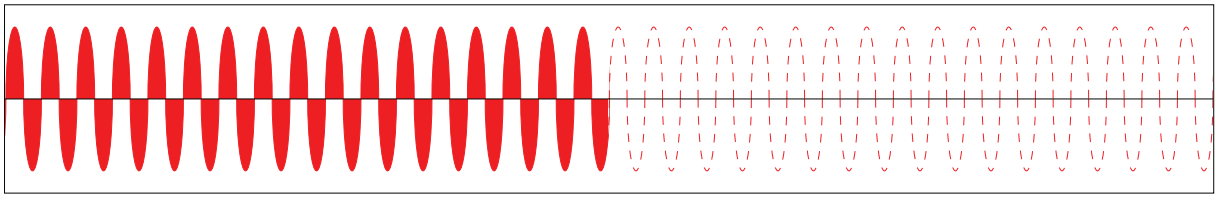
Burst Firing mode

The Burst firing mode works with the control level and a time-base parameter which can be varied from 0.1 seconds to 10 seconds. The percentage ON time is then determined by the control level via an I/O output command. Therefore, with a control level of 10% ;10% of the time-base will be ON and 90% will be OFF. The figures below show example waveforms of this firing mode at different control levels. In this example, the time base was set to 1 second. The percentage control resolution depends on the time base set by the user. To achieve a 1% resolution, the time base has to be a minimum of 2 sec for 50Hz and 1.7 sec for 60Hz.

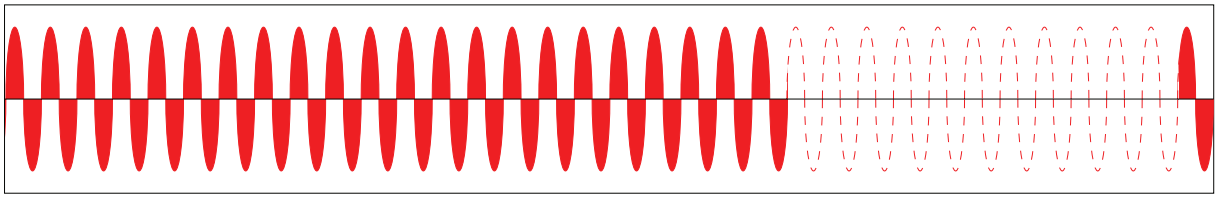
Output with Burst firing mode @ 33% control level



Output with Burst firing mode @ 50% control level



Output with Burst firing mode @ 66% control level

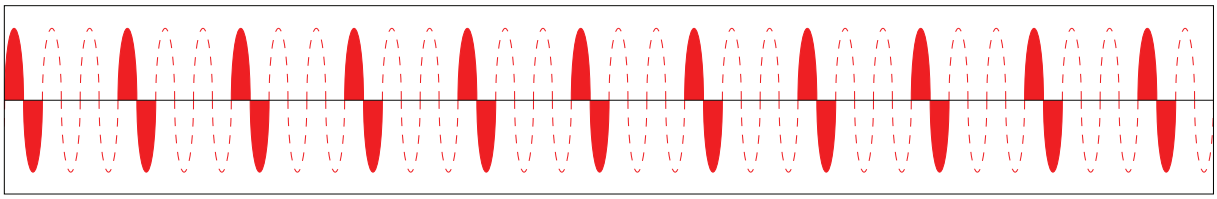


Distributed full cycle Firing mode (1x full cycle switching)

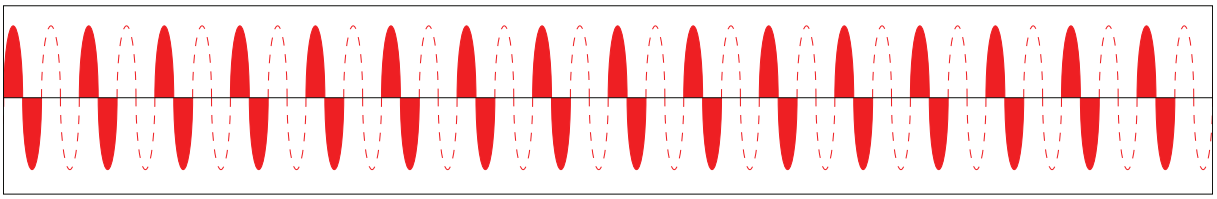
The Distributed firing mode works with a control level and a fixed time-base of 100 full cycles (2 seconds for 50 Hz). This mode operates with full cycles and it distributes the ON cycles as evenly as possible over the time base. In this mode, since the resolution is 1% and the time base is of 100 full cycles, the control level is equal to the number of full cycles over the whole time base.

1% = 1 full cycle every 100 cycles
2% = 2 full cycles every 100 cycles = 1 full cycle every 50 cycles

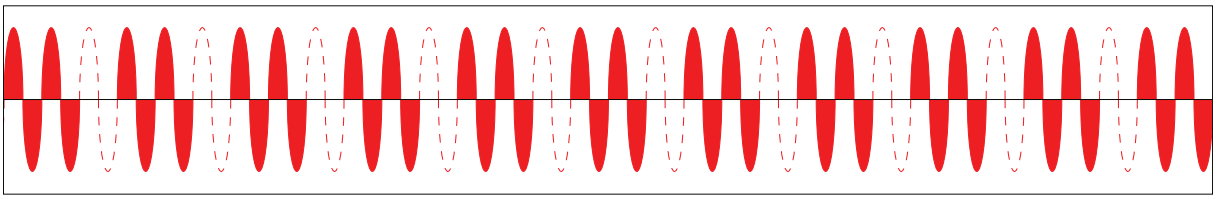
Output with Distributed firing mode @ 33% control level



Output with Distributed firing mode @ 50% control level



Output with Distributed firing mode @ 66% control level

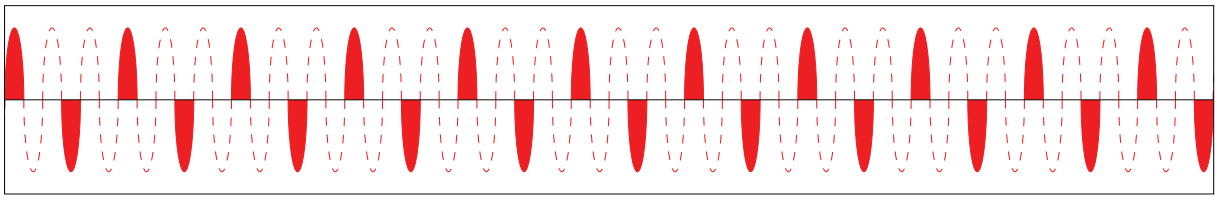


The advantage of Distributed firing over Burst firing is the reduction in thermal cycling. On the other hand, the Distributed firing mode suffers from worse harmonics/emissions than the Burst firing mode.

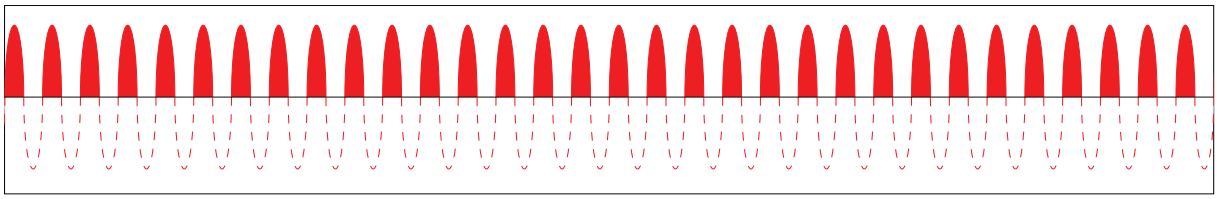
Advanced full cycle Firing mode

Advanced Full Cycle (AFC) firing works on the same concept as Distributed firing, but rather than distributing full cycles, it distributes half cycles. This mode also works over a time base of 100 full cycles (200 half cycles). In this mode, since the resolution is 1% and the time base is of 100 full cycles, the control level is equal to the number of full cycles over the whole time base. 1% = 2 half cycles every 200 half cycles = 1 half cycle every 100 half cycles, 2% = 4 half cycles every 200 half cycles = 1 half cycle every 50 half cycles.

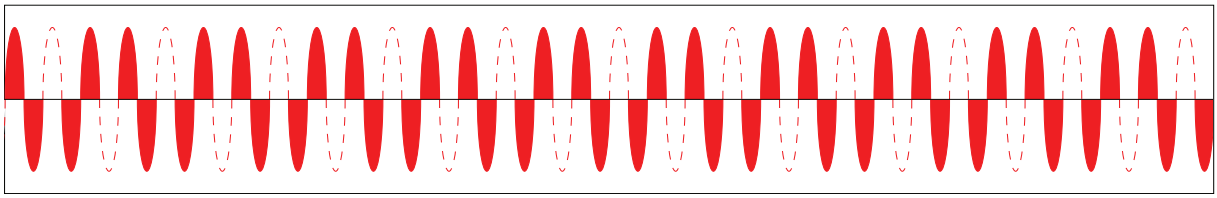
Output with Advanced full cycle firing mode @ 33% control level



Output with Advanced full cycle firing mode @ 50% control level



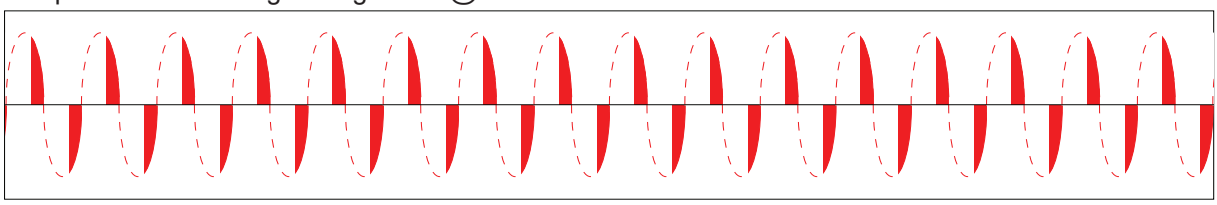
Output with Advanced full cycle firing mode @ 66% control level



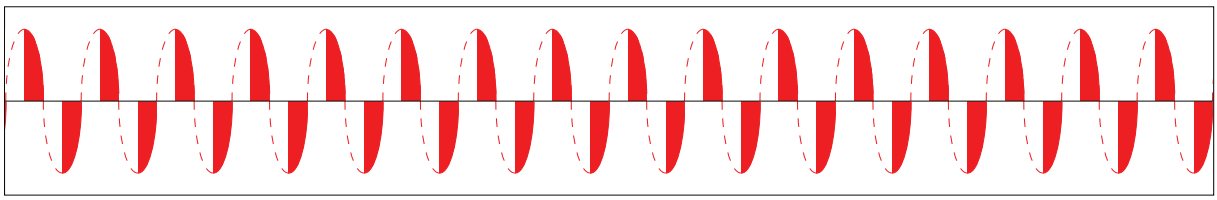
Phase Angle Firing mode

The Phase angle switching mode is available on the RGx1/3P..N solid state relays and works in accordance with the phase angle control principle. The power delivered to the load is controlled by the firing of the thyristors over each half mains cycle. The firing angle depends on the control level that determines the output power to be delivered to the load. The power to the load is varied linearly with the control level.

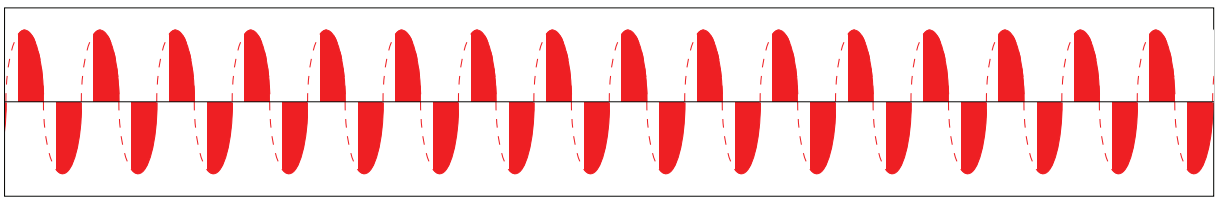
Output with Phase angle firing mode @ 33% control level



Output with Phase angle firing mode @ 50% control level



Output with Phase angle firing mode @ 66% control level

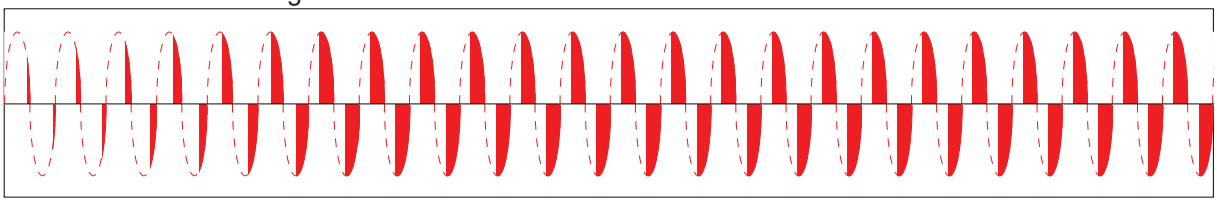


The advantage of Phase angle over the other switching modes is its precise resolution of power. However, Phase angle generates excessive harmonics vs other switching modes. With Phase angle control, the flickering of IR heaters is eliminated completely.

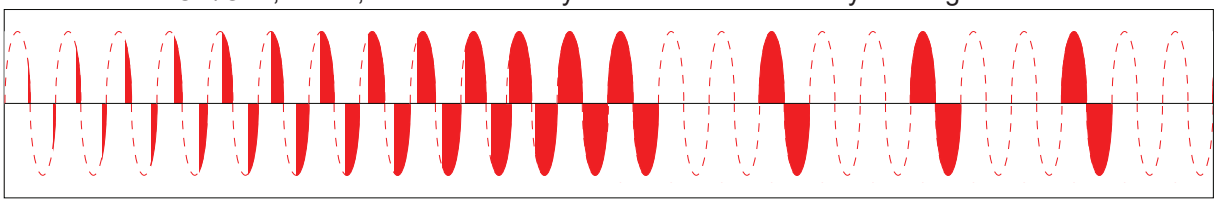
Soft Starting

Soft starting is utilised to reduce the start-up current of loads having a high cold-to-hot resistance ratio such as short wave infrared heaters. The thyristor firing angle is gradually increased in order to apply the power to the load smoothly. Soft start can be applied with all the other available switching modes: ON/OFF, Burst, Distributed full cycle, Advanced full cycle and Phase angle. When applied with phase angle, the soft start will stop at the set control level whereas for the other switching mode the soft start will stop when fully ON. Soft start shall be applied upon power up (i.e. on first application of the control signal) and after a number of non-firing cycles settable by the user (i.e. re-applying the control signal after the output is switched OFF for a period of time > OFF time to soft start setting).

Soft start with Phase angle



Soft start with ON/OFF, Burst , Distributed full cycle and Advanced full cycle firing modes



There are two type of soft start modes:

Soft start with time mode
The soft start will apply the power smoothly to the load over a time period of maximum 25.5s. This is settable via the communication system (Soft start ramping time setting).

Soft start with current limit mode
This soft start mode works with a current limit set by the user via the communication. The soft start time will adapt such that the set current limit is not exceeded, and the soft start occurs in the shortest amount of time. The recommended setting for the current limit is 1.2 - 1.5 times the nominal current. The maximum settable current limit is 2 times the rated current of the RG..CM..N variant used. If the current limit is set too low and the current limit is reached, a warning message will be triggered (Soft start current limit reached).

Voltage compensation

When voltage compensation is utilised, the output power on the output of the solid state relay will remain balanced despite any voltage deviations from normal readings. The algorithm uses a reference voltage set by the user via the communication (Voltage compensation setting) to compute the compensation factor. A new control level is calculated by applying the compensation factor on the control level from the main controller.

The compensation factor (C.F.) applied on the control level is calculated as follows:

$$\text{C.F.} = \left(\frac{\text{Reference Voltage}}{\text{Measured Voltage}} \right)^2$$

If the calculated control level, after the compensation factor is applied, is beyond the control level limits (0 & 100%), the absolute limit will be applied (0 or 100%) and a warning message will be triggered (Voltage compensation not possible).

External Firing mode

The RG..N can also be controlled externally via the A1,A2 terminal behind the blanking cover. For further information on the technical specifications of the input terminal, please refer to the product datasheet. External firing is only available on the RGx1A..CM..N and RGC2/3P..N solid state relays.

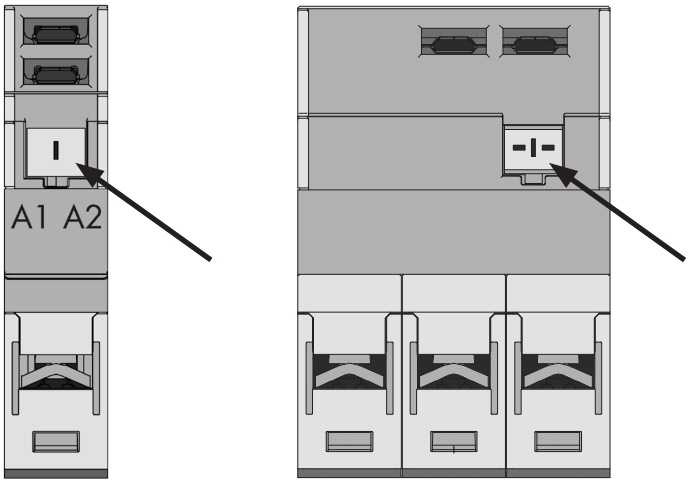


Fig. 17 - Blanking cover at the bottom of RG..N to be removed for external control (RGM25 plug is required - not included in packaging)

Note: For percentage power control switching modes (Burst, Distributed Full cycle, Advanced Full cycle and Phase Angle), the response time for each RG..N on the bus chain shall increment by a half mains cycle with each device. Therefore:
- with 32 x RGx1..N devices on the bus chain (max); all RG..Ns are controlled within 267ms (60Hz) or 320ms (50Hz) depending on the cycle time.
- with 16 x RGC2P..N devices on the bus chain (max); all RG..Ns are controlled within 133ms (60Hz) or 160ms (50Hz) depending on the cycle time.
- with 10 x RGC3P..N devices on the bus chain (max); all RG..Ns are controlled within 83ms (60Hz) or 100ms (50Hz) depending on the cycle time.
- with any combination of N x RGx1/2/3..N devices on the bus chain, all RG..Ns are controlled within N x 8.3ms (60Hz) or N x 10ms (50Hz).

6.3. Measurements

Voltage RMS / Voltage L1-L2 RMS / Voltage L2-L3 RMS / Voltage L3-L1 RMS

The last reading of the RMS voltage is recorded. The value of the reading is in 1V steps hence a value of 50 means 50V, a value of 600 means 600V. If a fault occurs in the system such that it is not possible to measure the voltage, the reading is 0. The reading is updated every half cycle based on the average of the last 16 half cycles.
For RGx1..N, this reading requires the 'Ref' terminal to be connected. If the Ref terminal is not connected this register reads the on-state voltage of the RG..N when the output is ON.
For RGC2/3P..N, three line-to-line voltages are measured (L1-L2, L2-L3, L3-L1) and no Ref connections are required.

Current RMS / Current L1 RMS/ Current L2 RMS / Current L3 RMS

The last reading of the RMS current is recorded. This reading is in steps of 0.01A hence a value of 50 means 0.5A and a value of 1747 means 17.47A. If a fault occurs in the system such that it is not possible to measure the current, this value is 0. This reading is updated every half cycle but is based on the average of the last 16 half cycles.
For RGC2/3P..N, three RMS current measurements are available (L1, L2, L3). The values are either line or phase currents depending on the load configurations

Frequency RMS

The last reading of the frequency is recorded. The value is in steps of 1 Hz. If a fault occurs in the system such that it is not possible to measure the frequency, this register gives a value of 0. This value Is updated every half cycle but is based on the averaged value of the last 15 cycles.

Hold Current / Hold Current L1 / Hold Current L2 / Hold Current L3

The average current of the last 16 ON half cycles. This value is in steps of 0.01A hence a value of 50 means 0.5A and a value of 1747 means 17.47A.
For the RGC2/3P..N, three hold current measurements are available for each phase (L1, L2, L3) for all switching modes except Advanced Full Cycle.

This measurement can be used as feedback current for an I^2 control feedback loop.

Apparent Power

The apparent power reading is recorded in VA. This reading is in steps of 1VA for RGC1..N and 10VA for RGC2/3P..N. This value is updated every half cycle and is a multiplication of the Voltage RMS value and Current RMS value determined in the last half cycle.
For RGC1..N, this reading requires the 'Ref' terminal to be connected, otherwise the value will be 0.
For RGC2/3P..N, the measurement is calculated by accumulating the individual phase power values.

Real Power

The real power reading is recorded in W. This reading is in steps of 1W for RGC1..N and 10W for RGC2/3P..N. This value is updated every half cycle and is a multiplication of the Voltage RMS value and Current RMS value determined in the last half cycle.
For RGC1..N, this reading requires the 'Ref' terminal to be connected, otherwise the value will be 0.
For RGC2/3P..N, the measurement is calculated by accumulating the individual phase power values.

Note that for resistive loads with power factor = 1, the real power and the apparent power will be the same.

Energy

The initial value of this register at power-up is the last reading recording before switch OFF of the NRG controller. In case of a new device this value starts from 0. This reading is the addition of the initial energy value at power-up and the kWh consumed during this power up. This reading is updated in steps of 1 kWh hence a value of 1034 would mean 1034kWh.

SSR Running Hours

This reading records the accumulated time in hours that the output of the RG..N was switched ON. The value is updated every half cycle. The initial reading at power-up is the last reading recorded before switch OFF of the NRG controller. In case of a new device this value starts from 0. This reading is the addition of the initial running-hours value at power-up and the running hours during this power-up. The reading is updated in steps of 1 hour, thus a value of 1034 would mean 1034h that the output was ON during its lifetime. In the event that the counter reaches its maximum value, the counter shall roll back to 0 and start counting up again.

Load Running Hours

This reading records the accumulated time in hours that the output of the RG..N was switched ON. The value of this register is updated every half cycle. The initial value of this register at power-up is the last reading recording before switch OFF of the NRG control. This reading is updated in steps of 1 hour, thus a value of 1034 means 1034h that the output was ON during its lifetime. In case of a new SSR this value starts from 0. This reading can be reset in case of a load or SSR replacement via the Load Running Hours reset setting. A ‘Store Permanently’ command shall be executed after modifying the value.

7. Alarms and Diagnostics

The NRG bus chain is equipped with on-board diagnostics to facilitate troubleshooting. The status of each component can be
identified via the status LEDs on the facade of the product as well as via the communication system.
The errors identified by the NRG controller indicate any identified issues relating to the status of the NRG internal bus. On the other
hand, the alarms on the NRG solid state relay indicate any alarms relating to the SSR or the process.

7.1. LED indications - NRG Controller

ON	Green	ON	US is present at terminals Us+ Us-
		OFF	US is not present at terminals Us+ Us-
LINK / ACT	Green	ON	The NRG controller is linked to Ethernet
		OFF	The NRG controller has no link to Ethernet
BUS	Yellow	ON	Transmission of messages from NRG Controller to RG..Ns
		OFF	Internal bus is idle
RUN	Green	ON	**Operational:** The device is in OPERATIONAL state
		Flickering	**Pre-Operational:** The device is in PRE-OPERATIONAL state
		Single Flash	**Safe-Operational:** The device is in SAFE-OPERATIONAL state
		OFF	**INIT:** The device is in INIT state
ERR	Red	Flickering	**Invalid configuration:** General Configuration error *Possible reason: State change commanded by master is impossible due to register or object settings.*
		Double Flash	**Application watchdog timeout:** An application watchdog timeout has occurred. *Possible reason: Sync Manager Watchdog timeout.*
		Single Flash	**Local error:** Slave device application has changed the EtherCAT state autonomously. *Possible reason 1: A host watchdog timeout has occurred.* *Possible reason 2: Synchronization error, device enters Safe-Operational automatically.*
		OFF	**No error:** The EtherCAT communication of the device is in working condition.
Alarm	Red	2 Flashes	Configuration error *(Device limit error, Device conflict error, Device unconfigured error, Device position error)*
		4 Flashes	Supply error
		8 Flashes	Communication error
		9 Flashes	Internal error
		10 Flashes	Termination error

7.2. LED indications - RG..N

LOAD	Green	ON	SSR output is ON
		OFF	SSR output is OFF
BUS	Yellow	ON	Communication ongoing between NRG controller and RG..Ns
		OFF	Communication between NRG controller and RG..Ns is idle
Alarm	Red	100% ON	SSR over-temperature
		1 Flash	Load deviation
		2 Flashes	Mains loss
		3 Flashes	Load loss / SSR open circuit
		4 Flashes	SSR short circuit
		5 Flashes	Frequency out of range
		6 Flashes	Current out of range
		7 Flashes	Voltage out of range
		8 Flashes	Communication error (BUS)
		9 Flashes	Internal error

7.3. Alarms - NRG Controller

Internal Error	
Description	This alarm is issued when a problem arises within the internal circuitry of the NRG controller. In the presence of this alarm, the NRG controller will try as much as possible to proceed with normal operation. It is up to the user to detect the presence of errors reported by the NRGC and take action accordingly. When continuing operation with NRGCs reporting an internal error there is a risk that communication may not work correctly or may not be possible, damage may occur to the RG..N devices on the BUS if the internal error is caused by an overvoltage on the supply lines.
Diagnose	Consider replacing the NRG Controller.

Bus Error	
Description	This error is issued in case of wrong messages exchanged between the NRG Controller and the RG..Ns.
Diagnose	Not applicable.

Device Limit Error	
Description	More than 32 switched poles are detected on the NRG bus chain.
Diagnose	Confirm that the number of RG..Ns/switched poles connected to one NRG Controller is < 32

Termination Error	
Description	This alarm is issued if the NRG controller detects that the BUS between the NRG controller and the RG..Ns is not correctly terminated. This can be due to: - An internal fault in the NRG controller (start of BUS termination) - RGN-TERMRES is faulty - An internal fault in the RG..N that affects the BUS This Alarm will clear (unless alarm latching is selected) when the termination of the BUS is found in order.
Diagnose	Make sure RGN-TERMRES is connected to the last RG..N on the NRG bus chain.

Device Conflict Error	
Description	Two RG..Ns on the same NRG bus chain have the same address.
Diagnose	Check internal bus connections. If bus connection is correct, do an auto addressing command. Otherwise re-connect the bus as required.

Device Unconfigured Error	
Description	An RG.N on the NRG bus chain does not have an address.
Diagnose	Perform an auto-addressing command.

Device Position Error	
Description	The position of some devices on the internal bus does not correspond to the stored address.
Diagnose	Check alarms on individual RG..Ns on the internal bus for more detail.

Power supply out of range	
Description	The internal supply voltage of the NRG controller is not within the specified range.
Diagnose	Check that supply on Us+, Us- is within the specified range.

Device Incompatible Error	
Description	An RG..N connected on the bus is not compatible.
Diagnose	New devices may not be compatible with old firmware of the NRG Controller. Check with Carlo Gavazzi personnel. To use RGC2/3P..N devices, the following firmware versions or above are required on the NRGC: - NRGC-ECAT: V2.0.0 - NRGC-EIP: V2.1.0 - NRGC-MBTCP: V2.0.0 - NRGC-PN: V2.0.0

7.4. Alarms - RG..N

SSR Over-temperature	
Description	This situation happens when the RG..N does not operate within the rated specifications causing the SSR to overheat. The output of the RG..N is switched OFF to prevent the RG..N from getting damaged due to overheating. When the RG..N cools down, the alarm automatically recovers (unless alarm latching is selected), the Alarm LED is switched OFF, and the RG..N output can be switched accordingly.
Diagnose	Confirm that the RG..N being used is operated within the rated specifications (current rating, spacing and surrounding temperature).

SSR Over-temperature Pre-warning	
Description	This is not an alarm condition and has no effect on the function of the RG..N. The Over-temperature Pre-warning alarm is activated when the pre-warning margin set on the RG..N is not respected. For example, the over-temperature pre-warning has been set to 40°C and the actual delta is 39°C. In this case, the over-temperature pre-warning alarm is activated. This alarm is re-set when the actual temperature reading is ≥ 40°C. This alarm does not trigger the Alarm LED on the RG..Ns.
Diagnose	Confirm that RG..N used is operated within the rated specifications (current rating, spacing and surrounding temperature.

Load deviation alarm		
Description	This alarm works in conjunction with the TEACH Voltage Reference, TEACH Current Reference and TEACH % load deviation settings. If the values of the TEACH Voltage and Current reference are > 0 either through a 'TEACH' command or updated manually; the load deviation alarm is activated. With a TEACH command the values of Vref and Iref registers will be updated by measuring the present current and voltage over a period of time. The TEACH command is refuted in case of alarms present on the system. If the TEACH is unsuccessful, the values of Vref and Iref will be cleared to 0. The TEACH command does not take control of the output of the SSR, it is up to the user to issue a TEACH command when the output is switched ON with a control percentage of > 20% (25% when using Phase Angle switching). The duration of the TEACH procedure shall take up to a maximum of 35s depending on the level of % control. A 'Store Permanently' command is required after a TEACH command for the values of the Vref and Iref to be saved permanently in the device for next power up. The load deviation alarm is issued when a change in resistance > the % load deviation setting is detected. The resistance is measured using the Voltage and Current measurements. The load deviation alarm is useful to detect changes in the load either due to load degradation or partial load failure when more than one load is connected to the SSR. For 3-phase load configurations with RGC2/3P..N, the load deviation of each line is monitored according to the set Vref, Iref and % deviation for each line respectively. If a 1-phase load is connected to the RGC2/3P..N, only the respective lines used for the load configuration will be checked. Unused lines will be ignored. It is important to select the correct load configuration for the RGC2/3P..N via the 'Load Configuration Type' parameter. For RGC2/3P..N, the load deviation alarm is not available with Advanced Full Cycle switching mode.	
Current range (RGx1..N)	RGC1x60CM25KEN	300 - 3300 (300 mA - 33 A)
	RGC1x60CM32KEN	500 - 3300 (500 mA - 33 A)
	RGC1x60CM32GEN	500 - 4700 (500 mA - 47 A)
	RGC1x60CM42GEN	500 - 6400 (500 mA - 64 A)
	RGC1x60CM62GEN	500 - 9300 (500 mA - 93 A)
	RGS1x60CM50KEN	300 - 5500 (300 mA - 55 A)
	RGS1x60CM92KEN	500 - 9900 (500 mA - 99 A)
	RGS1x60CM92GEN	500 - 9900 (500 mA - 99 A)
Current range (RGC2/3P..N)	RGC2P60CM25KEN	500 - 3000 (500 mA - 30 A)
	RGC2P60CM40GEN	1000 - 4400 (1 A - 44 A)
	RGC2P60CM75GEN	1000 - 8200 (1 A - 82 A)
	RGC3P60CM20KEN	500 - 2200 (500 mA - 22 A)
	RGC3P60CM30GEN	1000 - 3300 (1 A - 33 A)
	RGC3P60CM65GEN	1000 - 7300 (1 A - 73 A)
Diagnose	Check loads for degradation or partial load failure (in case of multiple loads with 1 x RGx1A..N). Take into consideration the load thermal coefficient when setting the percentage deviation in LDEVPR to avoid this alarm from being issued unnecessarily.	

Mains loss	
Description	Voltage and current signals are missing for more than 3 mains half cycles. The cause is a mains loss. For RGx1..N, the Ref terminal must be connected to identify this alarm otherwise the alarm can either be a mains loss or load loss. For RGC2/3P..N all 3 line-to-line voltages are monitored. The alarm will trigger if the voltage and current signals are missing from any one of the 3 lines.
Diagnose	Ensure mains supply is ON. Confirm that protection (fuses / miniature circuit breakers) have not tripped. Ensure L1 (RGx1..N) or L1 / L2 / L3 (RGC2/3..N) terminals of RG..N are properly connected.

Load loss / SSR Open Circuit	
Description	Load is not switching ON for more than 1 mains half cycle when control signal is present. The cause is either a load loss or an SSR open circuit condition. For 3-phase load configurations with RGC2/3P..N, each line is monitored and if the Load on one of the lines is not switching ON when control signal is present, the alarm will trigger. If a 1-phase load is connected to the RGC2/3P..N, only the respective lines used for the load configuration will be checked. Unused lines will be ignored. It is important to select the correct load configuration for the RGC2/3P..N via the 'Load Configuration Type' parameter.
Diagnose	Make sure that load is not faulty or check that the SSR is in an open circuit condition. If an RG..N is replaced, make sure to follow the re-addressing procedure.

SSR Short Circuit	
Description	This condition is identified when a current >300mA flows through the RG..N output when the control signal is OFF.
Diagnose	Make sure that the appropriate short circuit protection is utilised. If an RG..N is replaced, follow the re-addressing procedure at power-up. Check the load and protection devices (fuses or Miniature Circuit Breakers) status before re-starting.

Frequency out of range	
Description	This condition is identified when the frequency measured by the RG..N is not within the set range, i.e. it is > Over Frequency Limit or < Under Frequency Limit. This alarm is issued if this condition is present for >10 seconds. Though indicated as an alarm condition, this alarm has no effect on the function on the RG..N and it is up to the user to decide what to do when this alarm is activated.
Diagnose	Check the line frequency and ensure that the over and under frequency limits are set properly. Though the switching function of the RG…N is not affected by this alarm, care must be taken to make sure RG..N is operated within its rated specification.

Current out of range		
Description	This condition is identified when the current measured by the RG..N is not within the set range, i.e. the measured current is > Over Current Limit or < Under Current Limit. This alarm is issued if this condition is present for >10 seconds. Though indicated as an alarm condition, this alarm has no effect on the function on the RG..N and it is up to the user to decide what to do when this alarm is activated. The over current limit is bound by the maximum current for each NRG solid state relay variant. A list of the variants with their maximum current values is listed in the table below. The over current limit can be switched off by setting the value to 65535. For 3-phase load configurations with RGC2/3P..N, each line is monitored for any current fluctuations outside of the set limits. If a 1-phase load is connected to the RGC2/3P..N, only the respective lines used for the load configuration will be monitored. Unused lines will be ignored. It is important to select the correct load configuration for the RGC2/3P..N via the 'Load Configuration Type' parameter. For RGC2/3P..N, the current out of range alarm is not available with Advanced Full Cycle switching mode.	
Current limits (RGx1..N)	RGC1x60CM25KEN	3300 (33 A)
	RGC1x60CM32KEN	3300 (33 A)
	RGC1x60CM32GEN	4700 (47 A)
	RGC1x60CM42GEN	6400 (64 A)
	RGC1x60CM62GEN	9300 (93 A)
	RGS1x60CM50KEN	5500 (55 A)
	RGS1x60CM92KEN	9900 (99 A)
	RGS1x60CM92GEN	9900 (99 A)
Current limits (RGC2/3P..N)	RGC2P60CM25KEN	3000 (30 A)
	RGC2P60CM40GEN	4400 (44 A)
	RGC2P60CM75GEN	8200 (82 A)
	RGC3P60CM20KEN	2200 (22 A)
	RGC3P60CM30GEN	3300 (33 A)
	RGC3P60CM65GEN	7300 (73 A)
Diagnose	The over current limit is bound by the maximum current for each NRG solid state relay variant. A list of the variants with their maximum current values is listed in the table above. The over current limit can be switched off by setting the value to 65535.	

Voltage out of range	
Description	This condition is identified when the voltage measured by the RG..N is not within the set range, i.e. the measured voltage is > Over Voltage Limit or < Under Voltage Limit. This alarm is issued if this condition is present for >10 seconds. Though indicated as an alarm condition, this alarm has no effect on the function on the RG..N and it is up to the user to decide what to do when this alarm is activated. For RGC2/3P..N all 3 line-to-line voltages are monitored for any voltage fluctuations outside of the set limits.
Diagnose	Check mains and ensure that the over and under voltage limits are set properly. Though the switching function of the RG…N is not affected by this alarm, care must be taken to make sure RG..N is operated within its rated specification.

Communication (BUS) error	
Description	This alarm indicates that there is a communication problem between the NRGC-ECAT and the RG..N. It is only issued via the Alarm LED on the RG..N. This alarm should also trigger the BUS error alarm via the communication system.
Diagnose	Not applicable

Internal error	
Description	This alarm is issued when a problem arises within the internal circuit of the RG..N. In the presence of this alarm, the RG..N will try as much as possible to proceed with normal operation. It is up to the user to detect the presence of errors reported by the RG..N and take action accordingly. When continuing operation with RG..Ns reporting an internal error there is a risk that the messages are not correctly received by the RG..N and/or replies will not be correctly received by the NRGC and/or main controller.
Diagnose	Confirm presence of 24V supply voltage on the NRG Controller US terminals. Otherwise, replace the RG..N reporting an internal error.

Soft start current limit reached *(only available for RGx1P..N / RGC3P..N)*	
Description	The set current limit was reached during soft start
Diagnose	The set current limit may be too low for the nominal current. The recommended current limit value is 1.2 – 1.5 times the nominal current

Voltage compensation not possible *(only available for RGx1P..N / RGC2/3P..N)*	
Description	Mains voltage has deviated too much such that the control level after the correction factor has been applied is beyond the control limits (either < s0% or > 100%)
Diagnose	Not applicable

True power compensation not possible *(only available for RGx1P..N / RGC2/3P..N)*	
Description	Power has deviated too much such that the control level after the correction factor has been applied is beyond the control limits (either < 0% or > 100%)
Diagnose	Not applicable

8. Service and Maintenance

8.1. Internal Bus communication check

During the initial installation of the system, it may be useful to do a communications check before connecting the NRG controller to the PLC. A communications check will ensure that all RG..Ns connected on the bus chain are responding.

To perform a communications check, press the blue button on the facade of the NRG controller for 2 – 5 seconds. The NRG controller will ping each device sequentially. All communicating RG..Ns on the NRG bus chain will have their BUS LED flashing to indicate that communication was established.

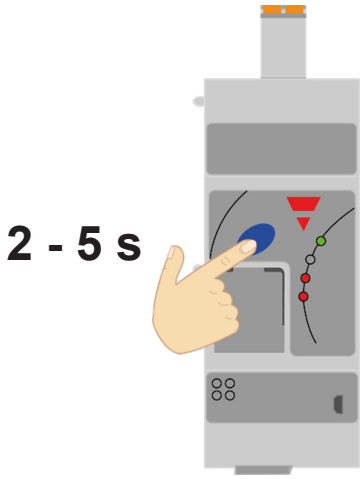


Fig. 18 - Press blue button for 2 - 5s to start / stop the communications check

After finishing with the communications check it is important to turn it off by pressing the blue button again (2-5 secs) otherwise the PLC cannot communicate with the NRG bus chain.

8.2. Replacing an RG..N

When an RG..N has to be replaced:

1. Connect the new RG..N to the bus chain.
2. Perform an auto-addressing procedure (Section 3.4) or via an SDO (Section 5.2).
3. If the same RG..N variant is used as the previous one (same part number), start-up parameters will be sent automatically upon start-up of the PLC and communication should initiate.
4. If a new part-number is used, the PLC will only initiate communication with the RG..N if the current rating of the new device is higher, otherwise the RG..N will not be found on the communication interface.
5. If step 2 is accidentally skipped, a ‘Device Unconfigured Error’ shall automatically be triggered which would indicate that an auto-addressing is required.

Note: RG..N replacements should be performed with the system turned OFF.

8.3 Using the NRG system without ‘REF’ terminal connection

The NRG system can be utilised without connecting the ‘REF’ terminal, however there will be some limitations as listed below:

1. The following readings are not available:
    - RMS Voltage
    - Real Power
    - Apparent Power
2. The ‘TEACH’ operation cannot be executed.
3. The Voltage out of range and Load deviation alarms are not available.
4. The mains loss alarm cannot be discriminated from a load loss. Therefore, a mains loss alarm will indicate either a mains loss or a load loss.

This does not apply for RGC2/3P..N. Voltage reference is not required for these relays.