Grid Emulator (GE)
Installation and operation manual
4.2.2. Standby ........................................................................... 25
4.2.3. Precharge ....................................................................... 25
4.2.4. Ready ............................................................................. 25
4.2.5. Run ................................................................................. 25
4.2.6. Alarm ............................................................................. 26

4.3. Operation modes .................................................................. 26
4.3.1. Constant Voltage (CV) ......................................................... 28
4.3.2. Faults Generation (FG) ......................................................... 30

4.4. Connection modes ................................................................. 34

4.5. Working with the equipment .................................................. 34
4.5.1. Start-up .......................................................................... 35
4.5.2. Stop ................................................................................. 36
4.5.2.1. Full stop .................................................................... 36
4.5.2.2. Standby stop ................................................................. 36
4.5.2.3. Ready ......................................................................... 36
4.5.3. Emergency stop ................................................................. 37
4.5.4. Accidental shut down ......................................................... 37
4.5.5. Alarms ............................................................................ 38
4.5.6. Alarms reset ................................................................. 40

5. Control Mode ........................................................................ 41

5.1. LOCAL TOUCHSCREEN CONTROL PANEL ................................... 41
5.1.1. Basic functions ................................................................. 41
5.1.2. Menus and submenus ....................................................... 41

Supervision ........................................................................ 42

5.2. CONSOLE CONTROL ............................................................... 44

5.3. REMOTE COMMUNICATIONS .................................................. 45
5.3.1. IQ MANAGEMENT ............................................................ 45

5.4. HUMAN MACHINE INTERFACE .............................................. 48
5.4.1. Operation .................................................................... 48
5.4.2. Alarm ........................................................................... 50
5.4.3. Supervision .................................................................... 51
5.4.4. Harmonic .................................................................... 52
5.4.5. Faults ......................................................................... 53

6. WARRANTY AND MAINTENANCE ............................................. 56
5.5. Replacing the input fuses.................................................................................. 56
5.6. Fans .................................................................................................................. 56
5.7. DC bus capacitors ............................................................................................ 56
5.8. Warranty .......................................................................................................... 56
5.9. Claim procedure .............................................................................................. 57
1. INTRODUCTION

Dear customer, on behalf of CINERGIA team, thank you for the confidence placed in our company and for the purchase of this product. Please, read carefully this manual before using the equipment to get familiarized with it and to obtain the maximum performance from it.

This document is intended for appropriately qualified personnel. Only personnel with the appropriate skills are allowed to perform the electrical connection and commissioning of the equipment.

The information in this documentation is not binding. CINERGIA reserves the right to make changes in part or in the whole at any time and without prior notice due to technical advance or product improvement.

1.1. Symbols used

DANGER: Indicates a hazardous situation which can result in death or serious injury and can cause important damage or destruction of the equipment or the property.

WARNING: Indicates important information that must be taken into account to operate the equipment. Take the appropriate prevention measures.

INFORMATION: Information that is important but is not safety-relevant.

1.2. Safety notes

Improper use of this equipment can cause both important personal injury and physical damage to the electrical power grid and the loads connected to it. Read this document carefully and follow all safety precautions at all times.

1.3. Quality and regulations

The equipment is based on a hardware designed, manufactured and commercialized in accordance with the standard EN ISO 9001 of Quality Management Systems. The marking shows conformity to the EEC Directive by means of application of the following standards:

• 2006/95/EC Low voltage directive.

• 2004/108/EC Electromagnetic Compatibility directive (EMC)

In accordance with the specifications of the harmonized standards:
• EN-IEC 62040-1. Uninterruptible power supply (UPS). Part 1-1: General and safety requirements for UPS’s used in accessible areas by end users.

• EN-IEC 60950-1. IT equipments. Safety. Part 1: General requirements.


The manufacturer responsibility is excluded in the event of any modification or intervention in the product by the customer’s side.
2. PRESENTATION

2.1. Introduction

As a grid emulator, the GE an AC programmable power supply specially designed to emulate grid disturbances. Its programmable parameters will allow the generation of different type of grids and its common faults and disturbances. The main functionalities of the GE are the following:

- It converts the AC input, of the main grid, in a controlled programmable AC (optionally also DC) output by using an IGBT-based switching topology and DSP-based state-of-the-art digital control.

- It can generate different types of grids:
  - Three phase power grid (3F+N) from 0 to 480 Vac (270Vrms f-n)
  - Power grid with variable frequency from 10 to 400 Hz
  - DC voltage source from -750 to 750 Vdc (optional)
  - HF Voltage Source from 360 to 880Hz (optional)

- Faults that GE can generate are:
  - Power grid with voltage harmonics control up to 15th (13th if f0=60Hz)
  - Flickers (programmable amplitude and frequency) and overvoltage
  - Interruptions and voltage dips (types A, B,C,D)
  - Three phase power grids with programmable variations in frequency
  - Variable Z impedance of grid

- As a bidirectional power supply, energy can flow from the grid to the equipment under test (EUT) or viceversa. It allows energy saving during the tests by returning energy to the power grid.

- The AC current consumed from the grid is sinusoidal (THDi < 2%).

- The user can define the reactive power to be injected by the GE and also choose between capacitive or inductive.

The power range covered by the GE grid emulators goes from 7.5 to 200kVA (6.75-160kW). The parallelization of GEs is possible to increase power.
<table>
<thead>
<tr>
<th>Reference</th>
<th>Rated</th>
<th>Rated Current</th>
<th>DC (per channel)</th>
<th>DC (per channel)</th>
<th>Dimensions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>kVA</td>
<td>kW</td>
<td>AC rms</td>
<td>(optional)</td>
<td>DxWxH</td>
</tr>
<tr>
<td><strong>GE7.5</strong></td>
<td>7.5</td>
<td>6.75</td>
<td>10A</td>
<td>10A</td>
<td>±750V</td>
</tr>
<tr>
<td><strong>GE10</strong></td>
<td>10</td>
<td>9</td>
<td>15A</td>
<td>15A</td>
<td>±750V</td>
</tr>
<tr>
<td><strong>GE15</strong></td>
<td>15</td>
<td>13.5</td>
<td>20A</td>
<td>20A</td>
<td>±750V</td>
</tr>
<tr>
<td><strong>GE20</strong></td>
<td>20</td>
<td>18</td>
<td>30A</td>
<td>25A</td>
<td>±750V</td>
</tr>
<tr>
<td><strong>GE30</strong></td>
<td>30</td>
<td>27</td>
<td>40A</td>
<td>40A</td>
<td>±750V</td>
</tr>
<tr>
<td><strong>GE40</strong></td>
<td>40</td>
<td>36</td>
<td>55A</td>
<td>50A</td>
<td>±750V</td>
</tr>
<tr>
<td><strong>GE50</strong></td>
<td>50</td>
<td>45</td>
<td>70A</td>
<td>65A</td>
<td>±750V</td>
</tr>
<tr>
<td><strong>GE60</strong></td>
<td>60</td>
<td>54</td>
<td>85A</td>
<td>80A</td>
<td>±750V</td>
</tr>
<tr>
<td><strong>GE80</strong></td>
<td>80</td>
<td>72</td>
<td>115A</td>
<td>105A</td>
<td>±750V</td>
</tr>
<tr>
<td><strong>GE100</strong></td>
<td>100</td>
<td>90</td>
<td>145A</td>
<td>130A</td>
<td>±750V</td>
</tr>
<tr>
<td><strong>GE120</strong></td>
<td>120</td>
<td>108</td>
<td>175A</td>
<td>155A</td>
<td>±750V</td>
</tr>
<tr>
<td><strong>GE160</strong></td>
<td>160</td>
<td>128</td>
<td>230A</td>
<td>185A</td>
<td>±750V</td>
</tr>
<tr>
<td><strong>GE200</strong></td>
<td>200</td>
<td>160</td>
<td>290A</td>
<td>230A</td>
<td>±750V</td>
</tr>
</tbody>
</table>
2.2. Power supply features

<table>
<thead>
<tr>
<th>Magnitude</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power</td>
<td>7.5kVA-200kVA</td>
</tr>
<tr>
<td>Input side</td>
<td></td>
</tr>
<tr>
<td>AC Voltage</td>
<td>Rated 3x400V+Neutral+Earth</td>
</tr>
<tr>
<td>Voltage range</td>
<td>+15% / -20%</td>
</tr>
<tr>
<td>AC Current</td>
<td>10A-290Arms</td>
</tr>
<tr>
<td>Frequency</td>
<td>50/60Hz</td>
</tr>
<tr>
<td>Power Factor</td>
<td>Controllable -1/1 (capacitive/inductive)</td>
</tr>
<tr>
<td>Efficiency</td>
<td>At full load &gt;92%</td>
</tr>
<tr>
<td>Overload</td>
<td>125% for 10 min / 150% for 60 s</td>
</tr>
<tr>
<td>Output side</td>
<td></td>
</tr>
<tr>
<td>AC Voltage</td>
<td>Phase-phase 0-480Vrms</td>
</tr>
<tr>
<td>AC Current</td>
<td>Single-phase 10-230Arms</td>
</tr>
<tr>
<td>Frequency</td>
<td>10-400Hz (360-880Hz optional)</td>
</tr>
<tr>
<td>Harmonic content</td>
<td>1st – 15th at 50Hz, 1st – 13th at 60Hz (only 1st harmonic for 400Hz)</td>
</tr>
<tr>
<td>DC Current</td>
<td>(Optional) ±10 to ±230Arms</td>
</tr>
<tr>
<td>DC Voltage</td>
<td>(Optional) ±750V</td>
</tr>
<tr>
<td>Modes of operation</td>
<td>Range Resolution Ripple</td>
</tr>
<tr>
<td>Constant Voltage</td>
<td>0-100% &lt;±0.1% &lt;1%</td>
</tr>
<tr>
<td>Faults Generation</td>
<td>Voltage dip Over and Undervoltage</td>
</tr>
<tr>
<td></td>
<td>Frequency variation Flicker</td>
</tr>
<tr>
<td></td>
<td>Harmonic sequence</td>
</tr>
<tr>
<td>GENERAL</td>
<td></td>
</tr>
<tr>
<td>Measurements</td>
<td>Input Voltage (Vrms) and Current (I rms)</td>
</tr>
<tr>
<td></td>
<td>Input Power</td>
</tr>
<tr>
<td></td>
<td>Output Voltage and Current</td>
</tr>
<tr>
<td></td>
<td>Output Power</td>
</tr>
<tr>
<td></td>
<td>Temperatures</td>
</tr>
<tr>
<td>User interface</td>
<td>3.2” Touchscreen</td>
</tr>
<tr>
<td>Control port:</td>
<td>3 analog inputs, 3 analog outputs, 4 inputs, 3 relay outputs</td>
</tr>
<tr>
<td>Communication Ports:</td>
<td>Ethernet, RS485 (optional)</td>
</tr>
<tr>
<td>Communication Protocol:</td>
<td>Modbus/TCP</td>
</tr>
<tr>
<td>Customized communications for IEC61850, ERP or MATLAB® (optional)</td>
<td></td>
</tr>
<tr>
<td>Humidity</td>
<td>10-90% (Absolute maximum, without condensation)</td>
</tr>
<tr>
<td>Temperature</td>
<td>5-40°C (Absolute maximum)</td>
</tr>
<tr>
<td>Refrigeration</td>
<td>Forced air</td>
</tr>
<tr>
<td>Protections</td>
<td>Over Current, Over Voltage, Shortcircuit, Overtemperature</td>
</tr>
<tr>
<td>Standards</td>
<td></td>
</tr>
<tr>
<td>Safety</td>
<td>EN-62040-1-2, EN-60950-1</td>
</tr>
<tr>
<td>EMC</td>
<td>EMC: EN-62040-2</td>
</tr>
</tbody>
</table>

Please note that items marked as optional shall be requested specifically for quotation.
2.3. Operation and connection modes

The output of the power supply is formed by three phases referenced to the neutral point of the system (N).

For the GE there is only one possible connection mode:

- **Independent phases:** each phase (U,V,W) is controlled independently. The voltage setpoint can be different in angle and magnitude for each of the three phases.

However, two operation modes are allowed:

- **Constant Voltage (CV):** the output voltage is controlled to the setpoint value.
- **Faults generation (FG):** the chosen kind of fault is applied to the output voltage.

2.4. Configuration and control of the power supply

The power supply can be interfaced by three means:

- **Local touchscreen:** a 3.2” colour local touchscreen panel can be used to configure, monitor and operate the grid emulator. See section Local Touchscreen Control Panel for further information.
- **Analog inputs:** the power supply owns three isolated analog inputs (0-10V) to control output rms voltage of the fundamental frequency.
- **Remote interface:** an Ethernet communication interface with protocol MODBUS/TCP can be used to configure, monitor and operate the grid emulator. By using HMI software application provided by CINERGIA, downloading of excel files is also possible.

2.5. Functional diagram

The diagram below is the conceptual functions blocks diagram of the power supply:

![Functional diagram](image)

The main components of the diagram are the following (from grid side to load side):

- **Isolation transformer:** a 50/60Hz isolation transformer can be provided optionally in order to isolate the output phases. In this case, an isolation monitor can be integrated in the power supply to detect isolation faults too.

- **Input protections:** these protections include a thermal-magnetic circuit breaker and fuses. The connection of the power supply input with the grid is done by screw terminals. Please follow safety instructions in Installation section to connect the grid emulator.

- **Input EMI filter:** an electromagnetic filter is integrated to fulfil electromagnetic compatibility regulations. The structure of the filter in question is the same as the one of the output EMI filter.
- **Input LCL filter:** the purpose of this filter is to reduce the current distortion at frequencies equal to or higher than switching frequency and thus reduce THD.

- **Active Rectifier:** a three-branch IGBT active front end is integrated in the equipment to consume/inject a sinusoidal current from/to the grid. The DC link voltage is set to 850V providing a regulation margin for fast transients at the output of the grid emulator. The active rectifier has bidirectional power flow capability and the injected reactive power (grid side) can be defined by the customer.

- **DC/AC output power supply:** it is a three-branch IGBT converter. Its topology is the three phase inverter and allows the conversion from the DC bus to each of the output AC phases. Each phase is controlled independently.

- **Output LC filter:** the filter in question reduces voltage distortion (caused by switching) at the output of the grid emulator.

- **Output EMI filter:** a high frequency common mode LC filter is used to reduce electromagnetic disturbances at the output of the grid emulator.

- **Output protections:** a disconnector is provided to isolate the output from the EUT. Screw terminals are also integrated to connect the EUT. Please, follow safety instructions in Installation section to connect them.

### 2.6. Principle of operation

Below, a technical diagram of the power supply is shown:

(Please note that earth protection cable is only connected to the cabinet chassis).
State-of-the-art digital control is used in all CINERGIA products. In the GE case, the control system algorithms are computed in a dual core DSP-based hardware, designed by CINERGIA, allowing a multitask execution of the regulation systems for the Active Rectifier and the Inverter output. This produces a fast transient response and a high performance against EUT changes. A 12 bits analog to digital conversion, with digital processing, allows a high resolution output up to 0.1% with high stability too.

**Resonant control**

Control algorithms based on Resonant Control are used in both AC sides; i.e. Resonant Control is always used in grid side but it is used in EUT side only when AC output option is chosen for the grid emulator.

The algorithms regulation is structured in blocks resonating at a given frequency. Within the resonant frequency each block allows the suppression of gain and phase errors of the voltage. Thanks to this, each harmonic can be controlled independently and thus it can be generated or suppressed, as needed.

The following diagram illustrates how the mentioned algorithms operate:

![Diagram of resonant control algorithms](image)

Therefore, the main characteristics of the Resonant Control applied are the ones listed below:

- Control loop rate of 7.5 kHz.
- Harmonics controlled up to 800Hz (1-15\textsuperscript{th} with f\textsubscript{0}=50Hz, 1-13\textsuperscript{th} with f\textsubscript{0}=60Hz, only fundamental for 400Hz)
- 15 control loops executed per phase.
- 45 control loops executed in total (for the 3 phases).
- Each control loop controls independently magnitude and angle of one harmonic.
- Any kind of grid can be implemented in the EUT side.
- All harmonics can be suppressed in the grid side.
* It should be noted that the equipment bandwidth is 800 Hz. Therefore, the harmonic content will be determined by the bandwidth as well as by the fundamental frequency specified by the user. Even harmonics 10, 12 and 14 cannot be configured by user.

Finally, the following picture is an example of how the GE Resonant Control manages to control harmonics:

![GE Resonant Control Example](image)

Where:

- **A**: EUT current (EUT is connected to the phase W of GE)
- **B**: GE output voltage $U_{U-N}$
- **C**: GE output voltage $U_{V-N}$
- **D**: GE output voltage $U_{W-N}$
- **E**: Instant at which the EUT is started.
- **F**: Fundamental harmonic of $U_{W-N}$ (shown in the FFT)
- **G**: 15th harmonic of $U_{W-N}$ (shown in the FFT)

**PID control**

For those cases in which DC output option is chosen for the grid emulator, the EUT side control algorithm is based on a traditional PID controller.
3. INSTALLATION

3.1. Important safety instructions

As a device with class I protection against electric shocks, it is essential to install a protective earth wire (connect earth \( \Delta \)). Connect the protection earth wire to the terminal (X5) before connecting the grid to the grid emulator input.

All the electrical connections, including those for control (interface, remote control...etc.), shall be done with all the switches in OFF position and with the mains supply disconnected (thermal-magnetic circuit breaker in OFF position too).

⚠️ **It must never be forgotten that the GE is a power supply, so users must take all necessary precautions against direct or indirect contact.**

Warning labels should be placed on all primary power switches installed in places far from the device to alert the electrical maintenance personnel of the presence of a voltage in the circuit up to 10 minutes after stopping the device.

⚠️ **In devices without isolation transformer, precautions must be taken as they are not isolated from the alternating input line, and there might be dangerous voltage between the output phases and the ground.**

3.2. Equipment views

Electrical connections:

Local front panel:
Front view (with the door open):

![Front view of equipment]

Q1a
Q2
Q3

Detailed view of the signal connectors:

![Detailed view of signal connectors]

X11
X12
X13
X14
X15
X16
X17
General view (with the front door closed):

**Protection elements (Q*):**

- **(Q1a)** Input thermal-magnetic circuit breaker or disconnector according to power of the equipment.
- **(Q2)** Output disconnector.
- **(Q3)** Output fuses (only in DC output option).

**Connection elements (X*):**

- **(X1)** Phase input terminal R.
- **(X2)** Phase input terminal S.
- **(X3)** Phase input terminal T.
- **(X4)** Neutral input terminal N.
- **(X5)** Earth connection terminal for main supply input (⚠️).
- **(X6)** Phase output terminal W.
- **(X7)** Phase output terminal V.
- **(X8)** Phase output terminal U.
- **(X9)** Neutral output terminal N.
- **(X10)** Earth connection terminal for EUT (⚠️).
- **(X11)** DB9 connector for RS485 communications.
- **(X12)** Terminals for external Emergency Power Off (EPO) button.
- **(X13)** DB9 connector for CAN communications (input).
- **(X14)** DB9 connector for CAN communications (output).
- **(X15)** RJ45 connector for MODBUS interface.
- **(X16)** DE15 connector for digital inputs and outputs.
- **(X17)** DE15 connector for analogic inputs and outputs.

### 3.3. Equipment reception

#### 3.3.1. Unpacking and checking the content

On receiving the device, make sure that the power supply has not suffered any damage during the transportation. Otherwise, make all pertinent claims to the supplier or to CINERGIA.

The packing of the device consists of a wooden palette, a cardboard or wooden packaging (depending on the case), expanded polystyrene corner pieces, a polyethylene sleeve and bands; all recyclable materials. Therefore they should be disposed of according to current regulations. We recommend to keep the packaging in case its use is necessary in the future.

In order to unpack, cut the bands and remove the cardboard packaging with a vertical movement. In case of wooden packaging, remove it with the appropriate tools. Afterwards, remove the corner pieces and the plastic sleeve. At this point the equipment will be unpacked on the pallet. Please, use suitable tools to lower the power supply from the pallet.

After unpacking the equipment, check that the data in the nameplate (stuck on the inner part of the front door) correspond to those specified in the purchase order. Contact the supplier or CINERGIA in case of disconformity.

Keep the equipment in the original package if it will not be used in order to protect it from any possible mechanical damages, dust, dirt, etc...

#### 3.3.2. Storage

The equipment shall be stored in a dry, ventilated place and protected against rain, water jets or chemical agents. It is advisable to keep the power supply into its original package, which has been designed to assure the maximum protection during the transport and storage.

**⚠️ Do not store the unit where the ambient temperature exceeds 40ºC or falls below -20ºC**
3.3.3. Transport to location

The equipment includes castors to facilitate its transport to its final location.

It is important to check previously if the weight of the power supply is appropriate for the site where it will be located.

It is also important to consider the most suitable means to place the power supply in its final location (floor, hoist, lift, stairs, etc...).

3.3.4. Location

It is necessary to leave a minimum of 25 cm in the contour of the equipment for its ventilation. If possible, as shown in following figures, it is recommended to leave additional 75 cm to facilitate the operations of maintenance of the equipment or the interventions of the technical service in case of breakdown.
The equipment may be installed in any place as long as the safety and ventilation requirements are fulfilled.

The power supply includes 2 levelling elements located near the front castors, which serve to immobilize the unit once it is in place.

To adjust the level, open the front door of the cabinet and proceed as follows:

- By hand, loosen the levelling elements by turning them anticlockwise until they touch the floor, and then, using a spanner, continue loosening until the castors are raised off the floor 0.5 cm maximum.
- Close the door once more.
3.4. Connection

3.4.1. Earth protection

As a device with class I protection against electric shocks, it is essential to install a protective earth wire (connect earth △). Connect the protection earth wire to the terminal (X5) before connecting the grid to the grid emulator input.

On the other hand, connect the protection earth wire to the terminal (X10) before connecting the EUT to the grid emulator output.

3.4.2. Input connection, terminals (X1 to X5).

Connect the grid cables R, S, T and N to the terminals (X1), (X2), (X3) and (X4) respectively. This connection must always be done according to the label placed under the input screw terminals.

In case of isolation transformer, connect grid cables (R, S, T without neutral) to the primary of the transformer (U1, V1, W1) and secondary of the transformer (U2, V2, W2, N2) to the input terminals (X1), (X2), (X3) and (X4) of GE.

![Image of connection terminals]

The ground cable (PE) of the main grid must be connected to ground transformer terminal (yellow-green) and ground GE terminal (X5) in all cases.

In case of discrepancies between labelling and this manual instructions, the label information will always prevail.

3.4.3. Output connection, terminals (X6 to X10)

The equipment has 3 output phases (U, V and W) which are referenced to the neutral point of the system (N). Therefore, the EUT must be connected between one of the phases and the neutral point (phase-N) or between two phases (phase-phase):

- Output phase U (X8)
- Output phase V (X7)
3.4.4. Emergency Power Off terminals (X12)

The equipment owns two terminals dedicated to external Emergency Power Off (EPO).

The EPO must act as a normally closed contact, and thus, there are two possible options for connection:

a) Connecting an external Emergency pushbutton to X12
b) Installing a cable bridge to close the circuit in terminal X12 (in case EPO is not desired)

If option a) is chosen, the procedure is as follows:

1. **Emergency shutdown activation**: the Emergency pushbutton must be set in the position in which it forces to open the circuit between the two terminals of X12.
2. **Normal mode restoration**: the Emergency pushbutton position must be inverted in order to close the circuit again between the two terminals of X12.

3.4.5. Communications

There are several connectors dedicated to communications, which are listed below:

- **Connector for RS485 communications (X11) (Optional)**: DB9 connector to be used when Modbus RS485 option is chosen.

- **Connectors for CAN communications (X13, X14) (Optional)**: DB9 connectors to be used when parallelization of grid emulators is needed (X13 works as input and X14 works as output).

- **Connector for MODBUS interface (X15)**: RJ45 connector. A standard Ethernet cable must be connected between X15 and PC to communicate a remote PC with the grid
emulator. Alternatively a standard Ethernet cable can be connected between X15 and a Hub or a Router to communicate a remote PC with the grid emulator.

3.4.6. Digital inputs and outputs

Is it possible controls the basic operation of GE with digital input/output signals.

![Digital inputs and outputs diagram]

The acceptable voltage of the input digital signals is 12Vdc.

The output digital signals are Normally Open relay contact. The maximum electrical values are: 24V, 12A.

3.4.6.1. Functionalities

<table>
<thead>
<tr>
<th>I/O pin</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>DIG_IN_1</td>
<td>Console select control</td>
</tr>
<tr>
<td>DIG_IN_2</td>
<td>RUN</td>
</tr>
<tr>
<td>DIG_IN_3</td>
<td>STOP</td>
</tr>
<tr>
<td>DIG_IN_4</td>
<td>Reset Alarm/Go Ready</td>
</tr>
<tr>
<td>DIG_OUT_1</td>
<td>RUN Output signal</td>
</tr>
<tr>
<td>DIG_OUT_2</td>
<td>ALARM Output signal</td>
</tr>
<tr>
<td>DIG_OUT_3</td>
<td>READY Output signal</td>
</tr>
</tbody>
</table>

3.4.7. Analog inputs and outputs

Analog inputs and outputs are gathered in X17.

The analog inputs of GE are isolated and accept a voltage range from 0 to 10Vdc. There are 3 analog inputs and each one corresponds to the voltage setpoint of one different output phase.
3.4.7.1. Functionalities

<table>
<thead>
<tr>
<th>I/O pin</th>
<th>Function</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>ANALOG_IN_1</td>
<td>Voltage U Set point</td>
<td>10Vdc = 270Vrms</td>
</tr>
<tr>
<td>ANALOG_IN_2</td>
<td>Voltage V Set point</td>
<td>10Vdc = 270Vrms</td>
</tr>
<tr>
<td>ANALOG_IN_3</td>
<td>Voltage W Set point</td>
<td>10Vdc = 270Vrms</td>
</tr>
<tr>
<td>ANALOG_OUT_1</td>
<td>DC Link Voltage</td>
<td>10Vdc = 900Vdc link</td>
</tr>
<tr>
<td>ANALOG_OUT_2</td>
<td>Total Output Power</td>
<td>10Vdc = 20kW</td>
</tr>
</tbody>
</table>

Please note that the voltage envelope magnitude of an output phase is proportional to the voltage of the respective analog input. For example, for a 10 V analog input, the voltage envelope magnitude of the corresponding output phase will be the maximum that the GE withstands (270Vrms).
4. OPERATION

4.1. Safety

Before operating the equipment, check that the Protective Earth is properly connected.

Check out the electrical installation in both sides (input and output) of the cabinet. All wires shall be connected and secured before proceeding to the power supply start-up.

4.2. State Machine

The operation of the power supply is based on 6 different states (rectangles) and 6 transitions (rhombus). Each state defines the behaviour and possible actions of the power supply:
4.2.1. Initialization

During the initialization, the power supply control system checks the presence of all internal components and the embedded PC loads the operating system.

No voltage is present at the DC bus and the IGBTs PWMs are completely stopped.

The transition from Initialization state brings the power supply to the Standby state as long as the emergency stop is deactivated (equipment armed).

4.2.2. Standby

The Standby state keeps the power supply in low power mode until an Enable signal is received. While the power supply is in standby only the internal power supplies are energized. In particular, this means that there is no voltage in the DC link and no voltage/current is applied to the output of the power supply.

The transition from the Standby state is the Enable signal or, in case of errors, a Fault signal. The Enable signal will bring the State Machine to Precharge and eventually to the Ready state. If an error is detected the power supply will go into Alarm state.

4.2.3. Precharge

The Precharge is an internal transition state between Standby and Ready. During this state the DC link is gradually charged through resistors until the rated DC link voltage is reached. The transition will finish successfully as long as, in less than 10 seconds of precharge, the DC link has reached the specified voltage. Otherwise, the next state will be Alarm.

The Precharge state is only applicable to the grid side converter.

4.2.4. Ready

In the Ready state the power supply is ready to operate but no PWM signal is sent to IGBTs. The DC bus is charged to the rectified voltage and there is no voltage/current applied to the outputs.

The transition from Ready state can be the Run signal, the Not enable signal or, in case of errors, a Fault signal. When a Run signal is received the State Machine will evolve to the Run state. When a Not enable signal is received the State Machine puts the power supply on standby, thus discharging the DC link capacitors. If a fault is detected the power supply goes to Alarm state.

4.2.5. Run

In this state, the power supply is completely operational. Due to the power supply architecture, the grid side converter (Active Rectifier) will make the transition first while stabilizes the DC link voltage. After that, the inverter will start the control algorithms and PWM.
This state can evolve to Standby state when a Not enable signal is received, to Ready state when a Not run signal is received or to Alarm state if an error condition is detected.

### 4.2.6. Alarm

In this state, the power supply is stopped and kept in a safe condition: the DC link is discharged and the PWM signals are stopped.

The Alarm state can be reached by any fault detected during the normal operation of the power supply, for instance, an emergency stop activation (see Alarms chapter for further detail).

The only possible transition from Alarm state is to Initialization state. Once in Alarm state a Reset signal is required from the customer after clearing the fault condition. If the fault condition has not been cleared the power supply state will be kept in Alarm (for example, when heatsink overheating has occurred and the temperature is still high).

### 4.3. Operation modes

The GE has two operation modes:

- **Constant Voltage (CV):** the power supply regulates the output voltage to the setpoint defined by the user.
- **Faults generation (FG):** the user defines the type of fault to be applied at the output voltage.

In the following diagram, the relations between operation modes, interfaces and states of the GE are reflected:
Parameters according to interface

**LCD**
- **Interface selector**: Modbus by default
- **Alarms**: Display and Reset
- **Control**: Reset, Rearm, Enable, Run

**Parameters**:
- Constant voltage mode: Freq, |V| mm, φ, Req (Fundamental)
- Faults generation mode: Soft, Trigger

**PC**
- All of them except the interface selector

**Console**
- **Analog inputs**: x3 voltages (ph-n)

**Constant Voltage Mode**
- **Parameters**:
  - Freq (|V| mm, φ, Req, R_emulated grid (Fundamental))
  - U% (x3 U%, φ (harmonics))

**Faults Generation Mode**
- **Parameters**:
  - Voltage dips: U% of each phase
  - Over/Under Voltage: U% of all phases
  - Freq Variations: Final Freq of all phases
  - Flicker: U% Voltage envelope amplitude, Freq of voltage envelopes
  - Harmonic Sequence: Parameters
4.3.1. Constant Voltage (CV)

This mode allows the user to define and generate a specific grid.

**Parameters and limits**

In CV mode, the user can modify the value of the following emulated grid parameters as long as it is within the specified range:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Allowed range of values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grid frequency</td>
<td>10-400 Hz</td>
</tr>
<tr>
<td>$V_{\text{peak, phase-neutral}}$</td>
<td>400V</td>
</tr>
<tr>
<td>$V_{\text{rms, max, p-n}}$</td>
<td>280Vrms (if $f_0 \leq 200Hz$) / 120Vrms (if $f_0 &gt; 200Hz$)*</td>
</tr>
<tr>
<td>$V_{\text{rms, max, p-p}}$</td>
<td>480Vrms (if $f_0 \leq 200Hz$) / 210Vrms (if $f_0 &gt; 200Hz$)*</td>
</tr>
<tr>
<td>Grid virtual resistance</td>
<td>0 - 0.5 $\Omega$</td>
</tr>
<tr>
<td>Fundamental harmonic angle</td>
<td>0 - 360 °</td>
</tr>
<tr>
<td>(respect the 120° delay of each phase)</td>
<td></td>
</tr>
<tr>
<td>Fundamental harmonic voltage</td>
<td>0-280 Vrms</td>
</tr>
<tr>
<td>(phase-N)</td>
<td></td>
</tr>
</tbody>
</table>

* $f_0$ is the frequency of fundamental wave.

**Harmonic control**

The bandwidth of the harmonic control is fixed to 800Hz. Depending on the fundamental frequency the high harmonics must be disabled because exceed the 800Hz (p.e. 15th harmonic of 60Hz fundamental grid becomes 900Hz).

The enabled harmonic controls can enable or disable on different conditions:

- $f_0 \leq 51Hz$: 1,2,3,4,5,6,7,8,9,11,13,15
- $51Hz < f_0 \leq 66Hz$: 1,2,3,4,5,6,7,8,9,11,13
- $f_0 > 66Hz$: 1 (only fundamental wave)

- Harmonics from 15th to 11th are **automatically** disabled if the output is unstable.
- Harmonics from 15th to 2nd can be **manually** disabled
- During faults (voltage dips, flicker, ...) the harmonic control is automatically disabled. Thus, the harmonic content during the fault is basically the same as before the fault (with some phase delay and minor magnitude variation)
Harmonic set point

It should be noted that no $V_{\text{peak}}$ of any phase can exceed the 400 V, i.e., after adding harmonics to the fundamental voltage, the resultant wave cannot exceed 400 $V_{\text{peak}}$.

The maximum set point value can see below:

<table>
<thead>
<tr>
<th>Harmonic</th>
<th>% of set point</th>
<th>Harmonic</th>
<th>% of set point</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>100</td>
<td>9</td>
<td>100</td>
</tr>
<tr>
<td>2</td>
<td>100</td>
<td>11</td>
<td>50</td>
</tr>
<tr>
<td>3</td>
<td>100</td>
<td>13</td>
<td>10</td>
</tr>
<tr>
<td>4</td>
<td>100</td>
<td>15</td>
<td>10</td>
</tr>
<tr>
<td>5</td>
<td>100</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>100</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>100</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>100</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The values of harmonics can be set with .xls archive or editing directly from PC interface. Note that PC software interface calculates the maximum voltage and maximum voltage RMS of the resulting wave and will not send it to the GE if exceeds the maximum values of the unit.

Analog inputs

When analog input control is enabled, through DIG_1 console input, the output voltage is a sinusoidal voltage with the frequency and phase configured in the LCD and the rms magnitude configured by 3 analog values in (X17) connector.

$10V$ (input) $\rightarrow$ $270V_{\text{rms}}$ (output)
4.3.2. Faults Generation (FG)

This mode allows the user to define and apply faults in the grid previously generated with the CV mode.

Parameters and limits

In FG mode, the user can modify the value of the following fault general parameters as long as it is within the specified range:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Allowed range of values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fault duration</td>
<td>1ms – 24h</td>
</tr>
<tr>
<td>Fault repetition</td>
<td>Minimum 1s</td>
</tr>
<tr>
<td>Fault delay (β)</td>
<td>0 - 360 °</td>
</tr>
</tbody>
</table>

The specified fault will start when the trigger is activated.

The procedure is as follows:
That is, when the trigger is activated, the GE will wait until phase U voltage reaches 0 V. Once 0\(V_U\) are reached, then GE will wait until phase U reaches angle \(\beta\) (Fault delay). At this point, the specified fault will start.

At the same time the fault starts, one digital output generates a signal that will remain activated until the fault finishes.

Additionally, in the FG mode, each kind of fault has its own particular parameters to be modified by the user. These parameters are listed below:

<table>
<thead>
<tr>
<th>Parameters of Voltage Dip*</th>
<th>Allowed range of values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Voltage of fundamental harmonics of phases U,V,W</td>
<td>0-100%</td>
</tr>
<tr>
<td></td>
<td>0% means 0V</td>
</tr>
<tr>
<td>Angle of fundamental harmonics of phases U,V,W</td>
<td>0-360°</td>
</tr>
</tbody>
</table>

*The harmonic content during the voltage dip is the same as the content before the voltage dip but there is no harmonic control while the voltage dip is taking place, so harmonic phase delay may change.

Example Voltage Dip: U%=100, V%=50, W%=50; U°=0, V°=60, W°=300
### Parameters of Over/Under Voltage

<table>
<thead>
<tr>
<th>Voltage of fundamental harmonics of phases U,V,W</th>
<th>Allowed range of values</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-120%</td>
<td>0% means 0V</td>
</tr>
</tbody>
</table>

### Example Overvoltage 120%

### Parameters of Frequency variation

<table>
<thead>
<tr>
<th>Fundamental frequency of phases U,V,W</th>
<th>Allowed range of values</th>
</tr>
</thead>
<tbody>
<tr>
<td>10-66 Hz</td>
<td></td>
</tr>
<tr>
<td>Frequency ramp</td>
<td>0.01-0.5Hz/s</td>
</tr>
</tbody>
</table>

### Parameters of Flicker

<table>
<thead>
<tr>
<th>Voltage of fundamental harmonics of phases U,V,W</th>
<th>Allowed range of values</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-120 %</td>
<td></td>
</tr>
<tr>
<td>Frequency of flicker</td>
<td>1-10 Hz</td>
</tr>
</tbody>
</table>
Example Flicker 120% 10Hz

<table>
<thead>
<tr>
<th>Parameters of Harmonic sequence</th>
<th>Allowed range of values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Application time</td>
<td>Minimum 1s</td>
</tr>
</tbody>
</table>

Set point limits:

<table>
<thead>
<tr>
<th>Harmonic</th>
<th>% of set point</th>
<th>Harmonic</th>
<th>% of set point</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>100</td>
<td>9</td>
<td>100</td>
</tr>
<tr>
<td>2</td>
<td>100</td>
<td>11</td>
<td>50</td>
</tr>
<tr>
<td>3</td>
<td>100</td>
<td>13</td>
<td>10</td>
</tr>
<tr>
<td>4</td>
<td>100</td>
<td>15</td>
<td>10</td>
</tr>
<tr>
<td>5</td>
<td>100</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>100</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>100</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>100</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*It should be noted that no $U_{peak}$ of any phase can exceed the 400 V, i.e., after adding harmonics to the fundamental voltage, the resultant wave cannot exceed 400 $V_{peak}$.

Example Harmonic content Phase U harmonic 3 and 5
4.4. Connection modes

As it has been previously mentioned, for the GE there is only one possible connection mode:

- **Independent phases**: each phase (U,V,W) is controlled independently. The voltage setpoint can be different in angle, magnitude and harmonics for each of the three phases.

It must be remembered that the equipment has 3 output phases (U, V and W) which are referenced to the neutral point of the system (N). Therefore, the EUT must be connected between one of the phases and the neutral point (phase-N) or between two phases (phase-phase). In this way, the power supply could, for instance, feed three independent single-phase loads at the same time and with different capacities, voltages, currents, etc.

Please be sure that no electrical connection between the phases exists. Keep in mind that, if two phases are actually interconnected, a shortcircuit may appear in voltage based modes.

Please remember to disconnect the equipment before modifying the connection mode.

4.5. Working with the equipment

Before powering the cabinet check step by step the following items:

- The power supply output must be disconnected:

- The grid side of the power supply is protected by a thermal-magnetic circuit breaker. Be sure that this breaker is switched off:
• Check that all wires are connected and secured before proceeding to the power supply start-up.

If these steps are validated the power supply is ready to be started.

4.5.1. Start-up

Switch on the thermal-magnetic circuit breaker of the grid side of the power supply. After switching it on, the power supply will initiate the start-up sequence. This sequence will activate the cabinet fans for one second.

At this point the power supply will start the initialization process, as described previously. During this time the embedded PC will load the operating system and the communications program. The power supply will ignore any command during this process.

The Initialization state can last up to 15 seconds. If every step is completed successfully the power supply will move automatically to Standby state.

Summarizing, to put the equipment in Run state the user should follow step by step the next checklist:

1. Connect the mains.
2. Turn on the thermal-magnetic circuit breaker.
3. Activate the cabinet output by switching the disconnector.
4. Deactivate the emergency stop (pull out the button). (Initialization \(\rightarrow\) Standby)
5. Send the Enable signal. (Standby \(\rightarrow\) Precharge \(\rightarrow\) Ready)
6. Select the connection mode (in the GE case, there is only one connection mode available). This option cannot be undone while the power supply is running.
7. Select the operation mode. Please keep in mind that not all EUTs are compatible with all operation modes. For example, if the power supply is acting like a voltage source, do not connect any other voltage sources at the output.
8. Send the Run signal (Ready \(\rightarrow\) Run)

Please keep in mind that not all EUTs are compatible with all operation modes. If the power supply is operated as a voltage source, please do not connect any other voltage sources at the output.
4.5.2. Stop

Once the equipment is running (Run state) it may be stopped in three ways:

4.5.2.1. Full stop

This type of stop is recommended if the electrical connections are to be modified or the power supply will be stopped for a long time.

When the power supply is running, special care must be taken. It is strongly recommended to follow the next steps:

1. Send the Not enable signal to the power supply (*Run* → *Ready* → *Standby*)
2. Press the emergency stop button (*Standby* → *Alarm*)
3. Disconnect the output disconnector.
4. **Wait at least 60 seconds** (time to get discharged the internal DC link capacitors)
5. Disconnect the input thermal-magnetic circuit breaker

*Before manipulating the cables in the cabinet terminals, please check the voltages with a voltmeter to assure no voltage is present. The grid cable and the EUT must be completely unpowered before connecting or disconnecting the cables. The user must be sure that the input and output switches are both in OFF position.*

4.5.2.2. Standby stop

This type of stop is recommended if the power supply will be stopped during some hours. The DC link is discharged and therefore aging of the DC bus capacitors is prevented.

Send the Not enable signal to the power supply. If the user wants to lock the power supply in order to avoid an accidental start-up, press the emergency stop button, and keep it pressed.

For restarting operation, release the emergency stop button and send the Reset signal. After doing this, proceed as a standard start-up sending the Enable signal.

**NEVER connect or disconnect the cables while the power supply is in this state.**

4.5.2.3. Ready

This type of stop is recommended if the power supply will be stopped for a short time. The DC link is kept charged and the power supply is ready to run.

When the power supply is running, the user may send the Not run signal at any time. This will stop the IGBT PWM signals but all internal parts will be kept powered. To restart operation, send the Run signal.

**NEVER connect or disconnect the cables while the power supply is in this state.**
4.5.3. Emergency stop

The emergency stop button may be pressed at any time bringing the power supply to the Alarm state. The emergency stop shall be only used when an emergency is detected. Please, avoid to stop the equipment with the emergency button as a “normal practice” since it will contribute to premature component aging. To lock the power supply and bring it to the Alarm state, follow the Full stop procedure.

The emergency stop unpowers all the electromechanical devices in the cabinet so the power supply is stopped by hardware assuring a full stop. The internal contactors will be open so no power will be present at the DC link or at the output of the power supply. Only the control boards, the embedded PC and the local touchscreen remain powered.

4.5.4. Accidental shut down

When the power supply is suddenly disconnected from the mains special care must be taken for restarting it. When the power supply is shut down with a charged DC link, some thermal protections of the internal power supplies will prevent its start-up.

When an accidental shutdown happens disconnect the mains and wait for at least 2 minutes for powering the cabinet again.
4.5.5. Alarms

There are different sources of alarm in the power supply. The following table describes them and offers possible causes and solutions to the user.

<table>
<thead>
<tr>
<th>Code</th>
<th>Name</th>
<th>Cause</th>
<th>Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Watchdog</td>
<td>Internal microcontroller error.</td>
<td>If this alarm persists, contact Cinergia's technical support.</td>
</tr>
<tr>
<td>1</td>
<td>Emergency sequence</td>
<td>The emergency stop button is activated or the EPO wire in no longer connected.</td>
<td>Unpress the emergency stop button or reconnect the EPO wire.</td>
</tr>
<tr>
<td>2</td>
<td>Drivers</td>
<td>IGBTs saturation protection has been activated. This alarm is triggered when there is a sudden overcurrent in the power supply output.</td>
<td>Contact Cinergia for technical support if this alarm persists. Check the equipment under test before restarting the power supply.</td>
</tr>
<tr>
<td>3</td>
<td>Precharge timeout</td>
<td>Internal error caused by a low voltage in mains.</td>
<td>Check the grid voltage.</td>
</tr>
<tr>
<td>4</td>
<td>Overload in precharge</td>
<td>Internal alarm caused by a shortcircuit. Or short time between take off the Emergency Stop and Enable the GE</td>
<td>Repeat the Enable action with 5 seconds between take off the Emergency Stop and Enable</td>
</tr>
<tr>
<td>5</td>
<td>Overvoltage in the DC link</td>
<td>The DC link voltage has exceeded its maximum value.</td>
<td>Reduce the output step transition time. Contact Cinergia for technical support if this alarm persists.</td>
</tr>
<tr>
<td>6</td>
<td>Undervoltage in the DC link</td>
<td>Undervoltage in the DC link caused by fast output transient.</td>
<td>Reduce the output step transition time. Contact Cinergia for technical support if this alarm persists.</td>
</tr>
<tr>
<td>7</td>
<td>Output overvoltage</td>
<td>The voltage in the emulated grid is too high.</td>
<td>Check the emulated grid voltage. Can be activated due to connection/disconnection load transition.</td>
</tr>
<tr>
<td>8</td>
<td>Output overcurrent</td>
<td>The output current has exceeded the configured limitation.</td>
<td>Check the output load.</td>
</tr>
<tr>
<td>9</td>
<td>Heatsink overtemperature</td>
<td>Overtemperature in the heatsink.</td>
<td>Check enough space exists between the power supply and the wall. There is insufficient air flow inside the power supply. Check</td>
</tr>
<tr>
<td>No.</td>
<td>Condition</td>
<td>Description</td>
<td>Action/Resolution</td>
</tr>
<tr>
<td>-----</td>
<td>----------------------------</td>
<td>------------------------------------------------------------------------------</td>
<td>-----------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>10</td>
<td>Room overtemperature</td>
<td>Overtemperature in the room.</td>
<td>Check that room temperature does not exceed 50°C.</td>
</tr>
<tr>
<td>11</td>
<td>Sensor offset</td>
<td>Error caused by transducers malfunction.</td>
<td>Turn off the equipment, wait one minute, and turn it on again. This alarm can occur when the power supply is switched off accidentally under load. Otherwise, contact Cinergia for technical support.</td>
</tr>
<tr>
<td>12</td>
<td>PID Saturation</td>
<td>The PID controller is saturated.</td>
<td>Reset the equipment. Contact Cinergia for technical support if this alarm persists.</td>
</tr>
<tr>
<td>13</td>
<td>Node alarm</td>
<td>One of the two control boards is alarmed.</td>
<td>Reset alarms.</td>
</tr>
<tr>
<td>14</td>
<td>Node without Heart Beat</td>
<td>Communication cable broken or control board without response.</td>
<td>Contact Cinergia in order to isolate the problem.</td>
</tr>
<tr>
<td>15</td>
<td>Enquiry timeout</td>
<td>Control board without response or with very slow response.</td>
<td>Reset the equipment. Contact Cinergia for technical support if this alarm persists.</td>
</tr>
<tr>
<td>16</td>
<td>Bus HW error</td>
<td>Communication cable broken.</td>
<td>Contact Cinergia in order to isolate the problem.</td>
</tr>
<tr>
<td>17</td>
<td>PLL error</td>
<td>The frequency of the grid is too high or low.</td>
<td>Check the grid frequency.</td>
</tr>
<tr>
<td>18</td>
<td>CANopen Reset Message</td>
<td>One of the control elements has sent a Reset Message to the CAN bus.</td>
<td>Reset the equipment. Contact Cinergia for technical support if this alarm persists.</td>
</tr>
<tr>
<td>19</td>
<td>Output Shortcircuit</td>
<td>The power supply has detected a shortcircuit in the equipment under test.</td>
<td>Check the equipment under test impedance.</td>
</tr>
<tr>
<td>20</td>
<td>Isolation</td>
<td>The isolator detector detects less than 10kOhm between any phases and ground</td>
<td>Check the output and input electrical connections. Chec the EUT to isolator faults.</td>
</tr>
<tr>
<td>21</td>
<td>Overload</td>
<td>The output power exceeds 150% during 60s or 120% during 10 minutes.</td>
<td>Reduce de EUT power.</td>
</tr>
</tbody>
</table>
4.5.6. Alarms reset

The user shall follow the next steps for resetting the alarms:

1. Send a Reset signal to the power supply.
2. Send a Not enable and Not run signals (note: this step is done automatically when the user is interfacing the power supply by the LCD or by the software provided by Cinergia).
3. Proceed as a standard start-up process by deactivating the emergency stop (pull out the button).

A Reset will be performed only in the case that the alarm source has been cleared. If the problem persists after resetting the power supply, a new alarm will be triggered.
5. Control Mode

5.1. LOCAL TOUCHSCREEN CONTROL PANEL

5.1.1. Basic functions

The LCD touchscreen main purpose is to provide the user with the necessary information about the power supply principal variables. Besides, the touchscreen allows the user to interact with the power converter and control some of these variables.

By means of the black bar in the upper side of the touchscreen, the user is constantly aware of the following variables:

- Control
- Mode
- State of the power supply

The rest of information can be found throughout the menus and submenus.

5.1.2. Menus and submenus

General
There are four main menus: Operational, Supervision, Configuration and Alarms. A description of each one can be found in the following points.
Operational
The main purpose of the Operational menu is allowing the user to introduce set-points as well as manage the power supply State Machine (as long as the Local control is activated).

State Machine
By means of the ENABLE and RUN buttons the user can manage the power supply State Machine.

- **ENABLE**: the function of this button depends on the power supply state:
  - **Standby State**: the ENABLE button is released. By pressing the ENABLE button the user orders the system to move to the Ready state.
  - **Ready & Run States**: the ENABLE button is pressed. By pressing the ENABLE button the user orders the system to disable the power supply.

The ENABLE button has no effect in every other state.

- **RUN**: the function of this button also depends on the power supply state:
  - **Ready State**: the RUN button is released. By pressing the RUN button the user orders the system to move to Run State.
  - **Run State**: the RUN button is pressed. By pressing the RUN button the user orders the system to return to Ready State.

The RUN button has no effect in every other State.

Commands
The user may introduce voltage, phase and frequency set-points by means of the following buttons:

- **Set Voltage**: allows the user to enter phase voltage RMS set-points.
- **Set Phase and Frequency**: allows the user to enter both frequency and phase set-points.

The power supply State Machine must be in either READY or RUN for the user to introduce these set-points. If it was the case that the analog input is activated, then the voltage set-point button would no longer be activated.

Supervision
The Supervision window is exclusively informative.
**Configuration**

By means of this menu, the user can decide whether to control the power supply through the LCD or the PC interface.

**Alarms**

The Alarms window displays information about the power supply alarms. Any existing alarm will appear in this window. In case the user is willing to reset the system, the RESET button permits him to do so.
5.2. CONSOLE CONTROL

The GE can be controlled using Digital and Analog Inputs and Outputs.

<table>
<thead>
<tr>
<th>I/O pin</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>DIG_IN_1</td>
<td>Console select control</td>
</tr>
<tr>
<td>DIG_IN_2</td>
<td>RUN</td>
</tr>
<tr>
<td>DIG_IN_3</td>
<td>STOP</td>
</tr>
<tr>
<td>DIG_IN_4</td>
<td>Reset Alarm/Go Ready</td>
</tr>
<tr>
<td>DIG_OUT_1</td>
<td>RUN Output signal</td>
</tr>
<tr>
<td>DIG_OUT_2</td>
<td>ALARM Output signal</td>
</tr>
<tr>
<td>DIG_OUT_3</td>
<td>READY Output signal</td>
</tr>
</tbody>
</table>

Digital Outputs according to the Machine State:

<table>
<thead>
<tr>
<th>Machine State</th>
<th>DIG_OUT_1 (Run)</th>
<th>DIG_OUT_2 (Alarm)</th>
<th>DIG_OUT_3 (Ready)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initialization</td>
<td>ON</td>
<td>ON</td>
<td>ON</td>
</tr>
<tr>
<td>Standby</td>
<td>OFF</td>
<td>OFF</td>
<td>OFF</td>
</tr>
<tr>
<td>Pre Charge</td>
<td>OFF</td>
<td>OFF</td>
<td>ON intermittent</td>
</tr>
<tr>
<td>Ready</td>
<td>OFF</td>
<td>OFF</td>
<td>ON</td>
</tr>
<tr>
<td>Run</td>
<td>ON</td>
<td>OFF</td>
<td>ON</td>
</tr>
<tr>
<td>Alarm</td>
<td>OFF</td>
<td>ON</td>
<td>OFF</td>
</tr>
</tbody>
</table>

To control the GE through the Console it is necessary to activate the DIG_IN_1 signal continuously. The Control Mode can only be changed in the Standby and Alarm State.

<table>
<thead>
<tr>
<th>Machine State Transition</th>
<th>DIG_IN_2 (Run)</th>
<th>DIG_IN_3 (STOP)</th>
<th>DIG_OUT_3 (Reset)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre Charge (go to Ready)</td>
<td>ON</td>
<td>OFF</td>
<td>ON</td>
</tr>
<tr>
<td>Go to Run</td>
<td>ON</td>
<td>OFF</td>
<td>OFF</td>
</tr>
<tr>
<td>Stop (go to Ready)</td>
<td>OFF</td>
<td>ON</td>
<td>OFF</td>
</tr>
<tr>
<td>Go to Standby</td>
<td>OFF</td>
<td>ON (2 seconds)</td>
<td>OFF</td>
</tr>
<tr>
<td>Reset Alarm</td>
<td>OFF</td>
<td>ON</td>
<td>ON</td>
</tr>
</tbody>
</table>

In Console control mode the Fault and harmonic generation are disabled. Only Constant Voltage is active. In other words, only fundamental frequency is applied.

It must be noted that when Console Control mode is activated, then the GE offers the power amplifier characteristic. That is, each analog input corresponds to the voltage set-point of each output phase respectively. The voltage envelope magnitude of an output phase is proportional to the voltage of the respective analog input. For example, for a 10 V analog input, the voltage envelope magnitude of the corresponding output phase will be the maximum that the GE withstands (i.e., 270 Vrms).

The frequency and angle between voltage phases can be configured using LCD touch panel, the Modbus interface is disabled in this option.
5.3. REMOTE COMMUNICATIONS

CINERGIA’s power supplies can be operated and supervised remotely through an Ethernet communications bus. An internal embedded PC, with CINERGIA’s proprietary software, allows the exchange of information between the internal CAN bus and the external Modbus TCP/IP (Ethernet). In this way, the customer can build specific HMI client software application while CINERGIA’s power supply acts as a Modbus TCP/IP server.

This Modbus TCP slave has the following properties:

<table>
<thead>
<tr>
<th>Property</th>
<th>Implementation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Function Codes:</strong></td>
<td></td>
</tr>
<tr>
<td>0x04: READ_INPUT_REGISTER</td>
<td></td>
</tr>
<tr>
<td>0x03: READ_HOLDING_REGISTER</td>
<td></td>
</tr>
<tr>
<td>0x10: WRITE_MULTIPLE_REGISTER</td>
<td></td>
</tr>
<tr>
<td><strong>CRC</strong></td>
<td>Not used. Included in the TCP stack.</td>
</tr>
<tr>
<td><strong>Multiple connections</strong></td>
<td>Only one master at one time allowed. Additional connection requests might be delayed or even rejected.</td>
</tr>
<tr>
<td><strong>Idle connections</strong></td>
<td>Idle connections might be closed by the slave. However, the listen socket will force the master to keep the connection active, even when there is no active connection at all.</td>
</tr>
<tr>
<td><strong>Other</strong></td>
<td>All variables are 32 bit long (2 registers). Their MODBUS addresses are 1 register long each one. All Read operations must start at the beginning of one variable, and must read an even number of registers. As for Write operations, ONLY 1 WRITE OPERATION OF 1 VARIABLE IS ALLOWED AT ONE TIME.</td>
</tr>
</tbody>
</table>
5.3.1. IQ MANAGEMENT

Many of the parameters of this equipment are defined as IQ (Texas Instruments nomenclature). An IQ number refers to a 32 bit signed integer and in its name it is specified in which bit the decimal number begins. As an example, IQ21 means that the decimal part has 21 bits, the integer part 10 and the first one is for the sign.

For the representation of the negative numbers:

\[ X_{iq} = X_{float} \cdot 2^n + 2^{32} \]

And for the positive numbers:

\[ X_{iq} = X_{float} \cdot 2^n \]

As an example, 1.4142 in IQ10 representation:

\[ 1.4142 \cdot 2^{10} = 1448.155 \]

Below there is a C# sample code for the representation:

**IQ10 functions:**

```csharp
public double IQ10toFloat(double Var)
{
    if (Var > 2147483648) //if the value is bigger than 2^31 (positive)
    {
        Var = Var - 4294967296; // Var - 2^32
        Var = Var / (1024); // Var/(2^10)
    }
    else
    {
        Var = Var / (1024);
    }
    return Var;
}

public UInt32 FloatToIQ10(double Var)
{
    UInt32 Retorn=0;
    if (Var < 0) // if negative
    {
        Var = (1024*Var) + 4294967296; // x*2^10 + 2^32
    }
    else
    {
        Var = Var * (1024);
    }
    Retorn = Convert.ToUInt32(Var);
    return Retorn;
}
```
IQ21 functions:

```csharp
public double IQ21toFloat(double Var)
{
    if (Var > 2147483648) // if the value is bigger than 2^31 (positive)
    {
        Var = Var - 4294967296; // Var - 2^32
        Var = Var / (2097152); // Var / (2^21)
    }
    else
    {
        Var = Var / (2097152); // Var/(2^21)
    }
    return Var;
}

public UInt32 FloatToIQ21(double Var)
{
    UInt32 Retorn = 0;
    if (Var < 0) // if negative
    {
        Var = (2097152 * Var) + 4294967296; // Var*2^21 + 2^32
    }
    else
    {
        Var = Var * (2097152); // Var*2^21
    }
    Retorn = Convert.ToUInt32(Var);
    return Retorn;
}
```
5.4. HUMAN MACHINE INTERFACE

CINERGIA delivers, within the scope of the supply, a Human Machine Interface software that communicates with the equipment using MODBUS protocol. This application is based on Windows 7/Windows XP. The software can be installed by executing Setup.exe file in Administrator Mode and following the instructions of the application.

The software is based on a Tab Dialog, in which each tab has one of the following purposes:

- OPERATION
- ALARM
- SUPERVISION
- HARMONIC
- FAULTS

Further information of each tab can be found in the following sections.

5.4.1. Operation

A) Information about the status of the equipment and buttons to control it:

- **Enable / Disable**: the corresponding led shows whether the equipment is enabled or disabled.
- **Run / Ready**: the corresponding led shows whether the equipment is running or is ready for operation.
- **Reset**: it allows the user to reset all the alarms that have occurred and that have been previously announced.

Note when start up power supply and Emergency Stop is enabled the state is Initialization and cannot Enable the GE. Please turn off the Emergency Stop.
B) Emulated grid main parameters:

- Grid frequency
- Grid resistance
- Fundamental harmonic angle
- Fundamental harmonic voltage
- Reset Harmonics

The Grid frequency only can be changed in Ready State, not in the Run state.

When the GE generate a grid with harmonic content you can push Reset Harmonic button and all harmonic set points reaches to zero and generates a standard grid.

C) MODBUS configuration (IP settings).

D) Active Rectifier and Inverter Status.

E) Harmonics from 15th to 11th are automatically disabled if the output is unstable. Harmonics from 15th to 2nd can be manually disabled. Only applies the order when puts GE in Ready state and Run again.

F) Reactive power set point. You can control de reactive power, capacitive or inductive, consumed from the main grid by Active Rectifier. Note that the maximum available reactive power depends on output active power of EUT. It’s limited automatically when the apparent power exceeds the limits.
5.4.2. Alarm

In this tab, the alarm status of each converter is shown:
5.4.3. Supervision

A) Information about electrical parameters of both converters:

- Voltage
- Current
- Frequency
- Temperature
- Active power
- Reactive power

B) Voltage and current trend plots:

- Due to a long refreshing time, it is not possible to detect fast transients of the variable.
5.4.4. Harmonic

A) It allows opening a *.xls file in which the harmonic content of the output voltage is specified. User can save the changes in the excel file using the Update button.

B) It is the content of the *.xls file mentioned in the previous point, where:

- **Harm**: Harmonic number.
- **Frequency**: Frequency of the harmonic in question.
- **Phase X**: Harmonic amplitude of phase X (in parts per unit of fundamental harmonic voltage). The fundamental harmonic sets by real voltage in RMS (maximum 270V)
- **Desf Phase X**: Fundamental Harmonic Shift Angle (in °) of phase X.

C) Calculated theoretical values of $U_{rms}$, $U_{max}$ and $U_{Crest Factor}$ per output phase. These will be used as limiting values during the tests.

D) Graph of the harmonic distortion implemented.

E) Graph of the resultant voltage curves in output phases.

If the command exceeds the voltage limits of the equipment the the command is not send.

When harmonic set points (in per unit) exceed the limits of the equipment, the program automatically change the value to the maximum allowable.
5.4.5. Faults

A) Fault general parameters whose values can be modified by the user.

The ACTIVATE button allows the user to activate the software trigger for faults.

Repetition time: Time in seconds between repetition defaults if Repeat button is switched on.

Note $\beta$ is the Angle Start Defect.

To stop repetition sequence push Repeat button.

To interrupt fault generation, introduce a 0 in Defect Duration and push Activate button. The fault will stop immediately.

B) In this area, the desired fault can be chosen (the green led indicates which kind of fault is active at the moment). After activating the desired type of fault, the user can modify the value of the intrinsic parameters of the fault.

To send the parameters to GE, the Send button shall be pushed.
Harmonic Excel set point file

Find a below an example of harmonic set point file. The files in Harmonic menu are the same as in harmonic sequence.

<table>
<thead>
<tr>
<th>Harm</th>
<th>Frequency</th>
<th>Phase 1</th>
<th>Phase 2</th>
<th>Phase 3</th>
<th>Desf Phase 1</th>
<th>Desf Phase 2</th>
<th>Desf Phase 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>H1</td>
<td>50</td>
<td>110</td>
<td>110</td>
<td>110</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>H2</td>
<td>100</td>
<td>0</td>
<td>0</td>
<td>0,1</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>H3</td>
<td>150</td>
<td>0,1</td>
<td>0</td>
<td>0,1</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>H4</td>
<td>200</td>
<td>0</td>
<td>0</td>
<td>0,1</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>H5</td>
<td>250</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>H6</td>
<td>300</td>
<td>0,1</td>
<td>0</td>
<td>0,1</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>H7</td>
<td>350</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>H8</td>
<td>400</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>H9</td>
<td>450</td>
<td>0,1</td>
<td>0</td>
<td>0,1</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>H10</td>
<td>500</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>H11</td>
<td>550</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>H12</td>
<td>600</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>H13</td>
<td>650</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>H14</td>
<td>700</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>H15</td>
<td>750</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>H16</td>
<td>800</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>H17</td>
<td>850</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>H18</td>
<td>900</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>H19</td>
<td>950</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>H20</td>
<td>1000</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>HDC</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>TIME(s)</td>
<td>11</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: HDC and harmonics 12,14 and 16 to 20 cannot be configured

- Column 1: Harmonic index
- Column 2: Frequency of each harmonic. Note that the value is only a reference and is not used to program the harmonic to be generated. With the same excel set point file you can change the Grid frequency in the Operation menu and automatically all harmonics change the frequency.
- Columns 3, 4 and 5: Set point voltage of phase U, V, W. The H1 (fundamental) set point input in RMS absolute voltage (270Vrms maximum). The set point for the other harmonics is in per unit with respect the introduced fundamental voltage. Example: H1 = 110 and H3=0.1 means fundamental voltage 110Vrms and Harmonic 3 10% of 110V = 11Vrms.
- Columns 6, 7 and 8: Set point phase angle of each electric phase. Only fundamental phase can be modified (first row), the phase of other harmonic follows automatically the phase of the fundamental. Example: 100º of phase 2 means a resultant angle in to electrical phase V of 120º + 100º = 220º.
- **Time parameter:** Indicates the application time of each file when working in Harmonic Sequence functionality.

Note: When any resultant wave exceeds the maximum voltage RMS or the maximum allowable voltage peak of the equipment, an error message appears and the wave is not sent to the GE.

When any harmonic set point exceeds the limits, the program automatically changes the value to the limit. The maximum harmonic set point can be seen below:

<table>
<thead>
<tr>
<th>Harmonic</th>
<th>% of set point</th>
<th>Harmonic</th>
<th>% of set point</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>100</td>
<td>9</td>
<td>100</td>
</tr>
<tr>
<td>2</td>
<td>100</td>
<td>11</td>
<td>50</td>
</tr>
<tr>
<td>3</td>
<td>100</td>
<td>13</td>
<td>10</td>
</tr>
<tr>
<td>4</td>
<td>100</td>
<td>15</td>
<td>10</td>
</tr>
<tr>
<td>5</td>
<td>100</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>100</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>100</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>100</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
6. WARRANTY AND MAINTENANCE

Fans and capacitors must be replaced at the end of their useful lifetime.

Inside the equipment there are dangerous voltages and metallic parts at high temperatures even when the equipment is stopped. The direct contact can cause electrocutions and burns. All the operations must be done by authorized technical staff.

5.5. Replacing the input fuses

This operation must be performed by personnel experienced with electrical systems. The direct contact can cause electrocutions and burns.

In order to replace the input fuses follow procedure below:

1. Stop the power supply following the instructions of FULL STOP
2. Turn the output switch-disconnector (Q2) to the OFF position
3. Open the fuse holder and replace the fuses

These fuses can only be replaced by new ones of exactly the same model.

5.6. Fans

The useful lifetime of the fans used to cool the power circuits depends on the use and environment conditions. It is recommended their preventive replacement by authorized technical staff.

5.7. DC bus capacitors

The useful lifetime of the DC bus capacitors and those ones used in the input and output filtering depends on the use and the environment conditions. It is recommended their preventive replacement by authorized technical staff.

5.8. Warranty

CINERGIA warrants that the delivered equipment is free from any defect affecting the functioning thereof for a time period not exceeding one (1) year from the Ex Works delivery date. If a purchased CINERGIA product becomes defective because of a faulty component or manufacturing, at any time during its standard warranty period, CINERGIA shall provide one of the following solutions:

• On-site technical assistance;
• Product or component repair at CINERGIA’s premises.

• Replacement of the defective product or component;

The decision whether to perform the assistance on-site, to repair or replace the faulty product and/or component shall be taken in any case exclusively by CINERGIA.

5.9. Claim procedure

The warranty rights can be exercised during the validity of the warranty period and immediately upon detecting any abnormalities, except in the case of visible defects, in which case the claim shall be submitted within a maximum time of 7 days from the date of receipt of the equipment and always prior to its installation.

If defect of malfunction is detected, please proceed as follows:

• Immediately notify in writing CINERGIA by submitting a brief report describing the type of fault detected and all the data contained in the product data plate, attaching a copy of the purchase invoice/receipt. Such documentation shall be sent to the email address of the Sales Team (comercial@cinergia.coop).

• Upon receiving the documentation, CINERGIA will analyse it to decide whether the intervention required is covered by the warranty terms described herein.

• If the claim is covered by the warranty terms, CINERGIA shall provide on-site technical assistance or, alternatively, can request the shipping of the defective product and/or component to have it repaired at CINERGIA premises. At last, CINERGIA shall decide to send a replacement product and/or component. The faulty product and/or component shall be returned to CINERGIA. Any shipping damages attributable to improper packaging shall not be covered by warranty.

• Failure to return the replaced equipment within 10 (ten) standard days shall authorize CINERGIA to invoice the equipment supplied as replacement.

• In case the defect of the returned equipment is deemed not to be covered by the warranty, CINERGIA shall issue an invoice to the purchaser for the repair activity.

• If on arrival at CINERGIA’s premises the returned equipment is deemed to be in perfect operating conditions, CINERGIA shall be authorized to issue an invoice for all the costs resulting from its replacement (analysis and testing of the equipment and shipping costs).

• CINERGIA reserves the right to provide a different model of product and/or component to process the claims covered by the warranty terms, in case the original model and/or component is out of production.