Photovoltaic Panel Emulator for DC converters (PV Emulator) (Optional)

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1. GENERAL 4
2. PV Emulator 6
    2.1. Tabs and Control 7
    2.2. Parameters 8
    2.3. Runtime View 11
    2.4. Example 12
3. FILE EXAMPLES 13

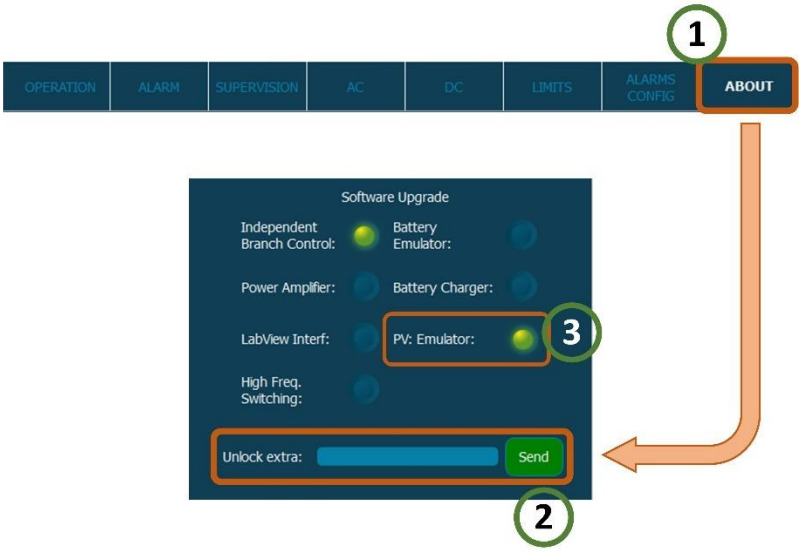
1. GENERAL

Cinergia equipment with DC output can be used as a constant voltage or current source, but they can also behave as a battery charger, battery emulator or as a photovoltaic panel emulator. This document provides the necessary information to control the DC converter behaving as a **Photovoltaic Panel Emulator**.

The converter must be in DC unipolar mode to emulate a photovoltaic panel. But the equipment can be in independent mode (emulates 3 independent panels) or in parallel (emulates only 1 panel).

To activate this optional, contact Cinergia to get the upgrade code. Upgrading it has an additional cost.

The delivered code must be introduced in the *Unlock extra* reserved space and, afterwards, press the button *Send* (number **2** in the figure below) in the *About* tab. When the PV Emulator is activated, the LED beside the option (**3** in the figure below) is shining:



It is important for the user to have this manual nearby and familiarize with it to operate efficiently with the converter.

This document tries to be easy to understand, created with schematics of the equipment and the interface with parts marked with letters and numbers which you can find the explanation just below the picture.

Cinergia is in constant development to deliver always the best service to you, so it is possible to find some discrepancy between this manual and the real converter itself. Don't hesitate to contact us and ask for the latest version of the documentation.

This manual is valid for the following versions of interface:

1.511, 1.512, 1.512x, 1.06xx 2.00xx

2. PV Emulator

The PV Emulator option can be only activated in DC units or AC/DC units in DC mode. The channel/s configured in PV emulator mode will work as a Constant Current source where the current setpoint is calculated by a Simplified PV Panel model as described by the function below:

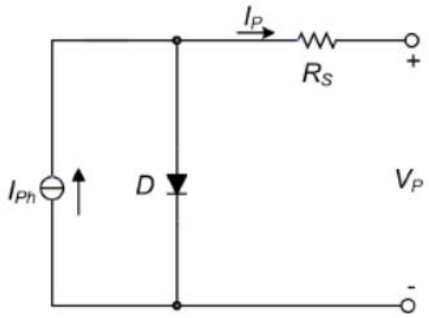


Fig. 1 – Single-diode equivalent circuit of a PV module.

$$I_P = I_{SC} \cdot \left[1 - C_1 \cdot \left(e^{\left(\frac{V_P}{C_2 \cdot V_{OC}}\right)} - 1\right)\right] \quad (1)$$

where

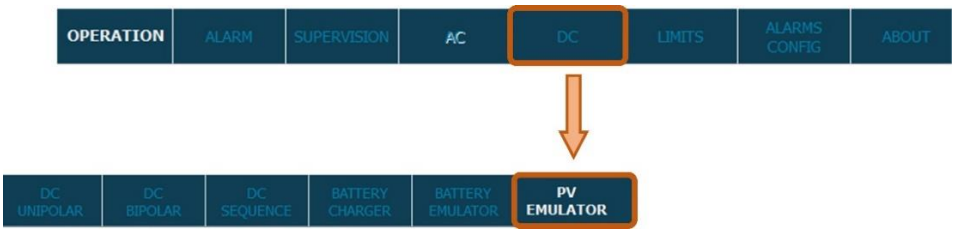
$$C_1 = \left(1 - \frac{I_{MPP}}{I_{SC}}\right) \cdot e^{\left(\frac{-V_{MPP}}{C_2 \cdot V_{OC}}\right)} \quad (2)$$

$$C_2 = \frac{\left(\frac{V_{MPP}}{V_{OC}} - 1\right)}{\ln\left(1 - \frac{I_{MPP}}{I_{SC}}\right)} \quad (3)$$

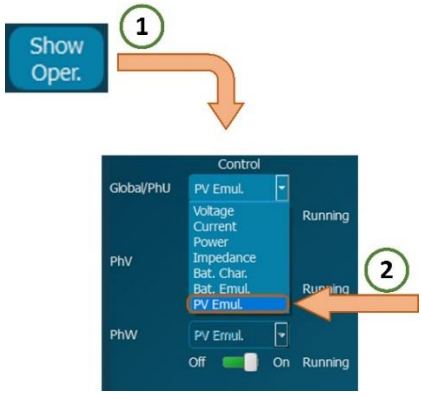
Model and expressions above are from: A. Bellini, S. Bifaretty, V. Iacovone, C. Cornaro, "Simplified Model of a Photovoltaic Module"

2.1. Tabs and Control

In this function mode, the power converter can emulate any kind of battery by introducing the parameters in the corresponding tab, which is in the DC part:

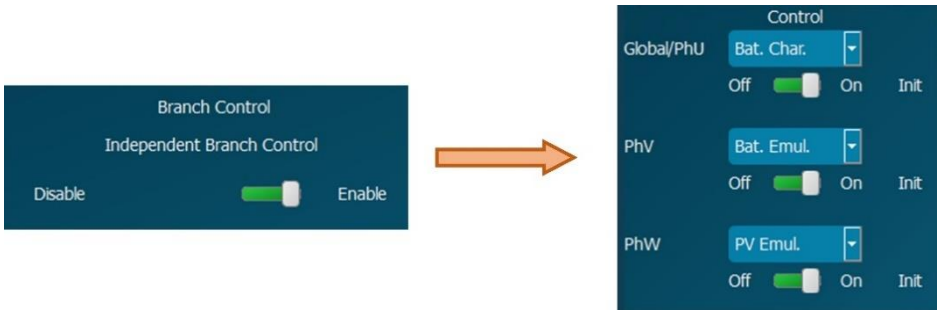


First, the user needs to select the Photovoltaic mode in the Control part of the interface. To do so, click to the button Show Operational on the left top part of the interface and find the PV control:



Once the user is in the PV Emulator tab and the control of the equipment is PV Emul, all is ready to proceed and emulate any kind of a photovoltaic panel by introducing all the parameters.

Having the equipment with the *Multichannel or Separated Branch Control* enabled, each channel can be in a different control mode:

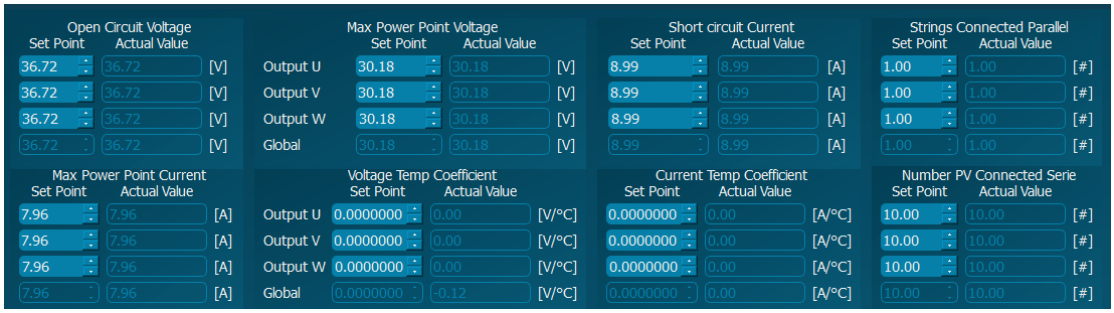


It is very important to be aware of the control configuration and the values of each channel before making the equipment go to *Run* state.

2.2. Parameters

Please be sure that the photovoltaic panel to be emulated fills in the voltage and current limits of the Cinergia converter.

Before the *Run* of the Cinergia converter, all the parameters must be configured and sent to the converter, otherwise, the equipment will start with the default values. These default values are the ones represented in the following picture:



These parameters can be modified in any state of the equipment, even in *Run*. Be sure, before sending any parameter, that the EUT and the Cinergia converter will accept the changes.

Depending of the connection of the equipment (independent or parallel), the windows setpoints and parameters to be introduced will be frozen or not showing only the ones where the user can introduce values.

The limits of the equipment in the *Limits* tab can also be configured for more security.

The following image details the parts of the interface with the parameters of the Battery with the corresponding description below:

- **A:** In this part there are all the parameters to be introduced in the equipment that will describe its behaviour as a photovoltaic panel. All of them are normally given by the manufacturer.
  1. **Open Circuit Voltage.** It is the output voltage of one panel when there is no voltage from the Equipment Under Test (EUT). If there are several panels in series, this voltage will be multiplied by the number of panels (configurable in **B**).
  2. **Max Power Point Current.** It is the current that makes the maximum power. Please see example below the description of this tab.
  3. **Max Power Point Voltage.** It is the voltage that makes the maximum power. Please see example below the description of this tab.
  4. **Short Circuit Current.** Current that the converter will reach with voltage zero (short circuit).
  5. **Voltage Temperature Coefficient.** Datasheet parameter. It is negative.
  6. **Current Temperature Coefficient.** Datasheet parameter.

- **B:** These two parameters are the multipliers because they simulate how many panels are in series or in parallel. So, the *Strings Connected Parallel* is the multiplier of the current and the *Number PV Connected Serie*.

- **C:** Using these buttons, the user will save or load the parameters of **A** and **B**, making it easier to work with one standardized photovoltaic panel:
  - **Save as CSV:** all the parameters in **A** and **B** are saved in a csv file in the folder that the user selects.
  - **Load CSV file:** to recover parameters from a csv file and introduce them to the converter, press this button and search the csv where the parameters are saved.
  - **Send PV Parameters:** it is always necessary to send the parameters. If the user loads a csv file and does not press this send button, the parameters will not be introduced to the converter. To know if the parameters are introduced properly, compare in **A** and **B** if the setpoints and the actual values are the same.
  - **Runtime View:** this button shows a table where the user will be able to introduce the parameters to create an evolution simulation of temperature and radiation. To know more about it, go to the *Runtime View* Chapter of this manual.

The csv file that can be saved and loaded can also be created by the user with a program such as Excel and loaded in the converter, but it must have the following structure:

First Column	U	V	W	Global
Open Circuit Voltage	36.72	36.72	36.72	36.72
Max Power Point Voltage	30.18	30.18	30.18	30.18
Short circuit Current	8.99	8.99	8.99	8.99
Max Power Point Current	5	7	8	7.96
Voltage Temperature Coefficient	0.01	0.02	0	0
Current Temperature Coefficient	0.004	0.005	0	0
Number PV Connected Serie	10	10	10	10
Strings Connected Parallel	1	2	2	1

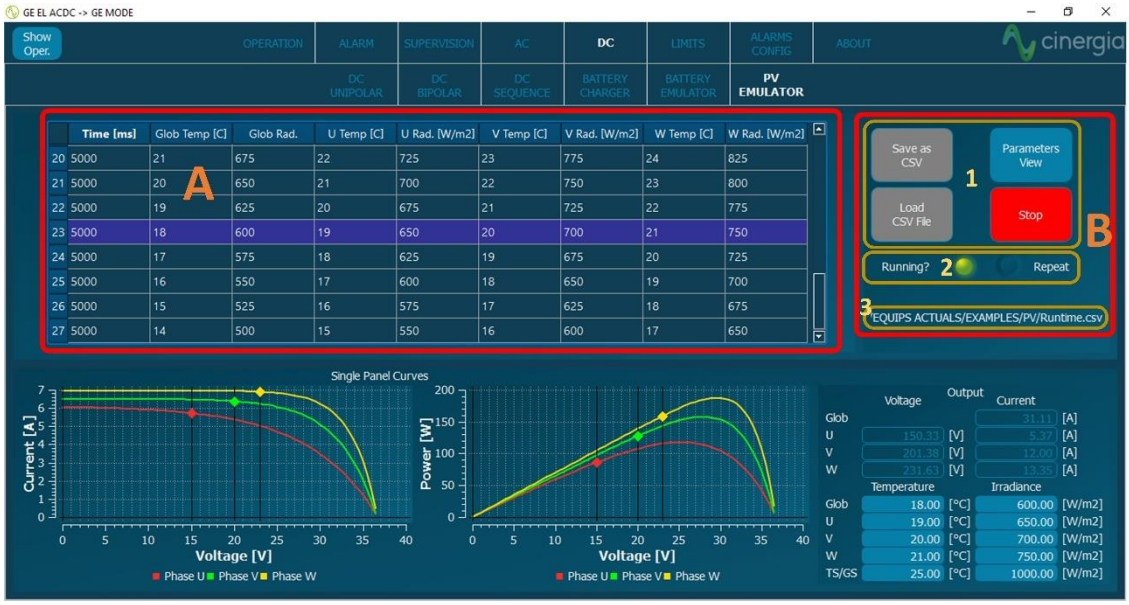
This csv file can only contain numbers.

- **D:** The curves display the behave of the photovoltaic panels of each channel showing which is the real-time point where the voltage-current is. Please note that these graphs are for a single panel and the multipliers explained in **B** are the responsible to adjust the calculations.

- **E:** These output real-time values show the voltage and current, but also the *Temperature* and the *Irradiance*, which these two last are modifiable on-line.
  The first column is for temperature and the second for irradiance, whereas the rows are for global (parallel mode), phase U, V and W and the last for the temperature and the irradiance standard.

2.3. Runtime View

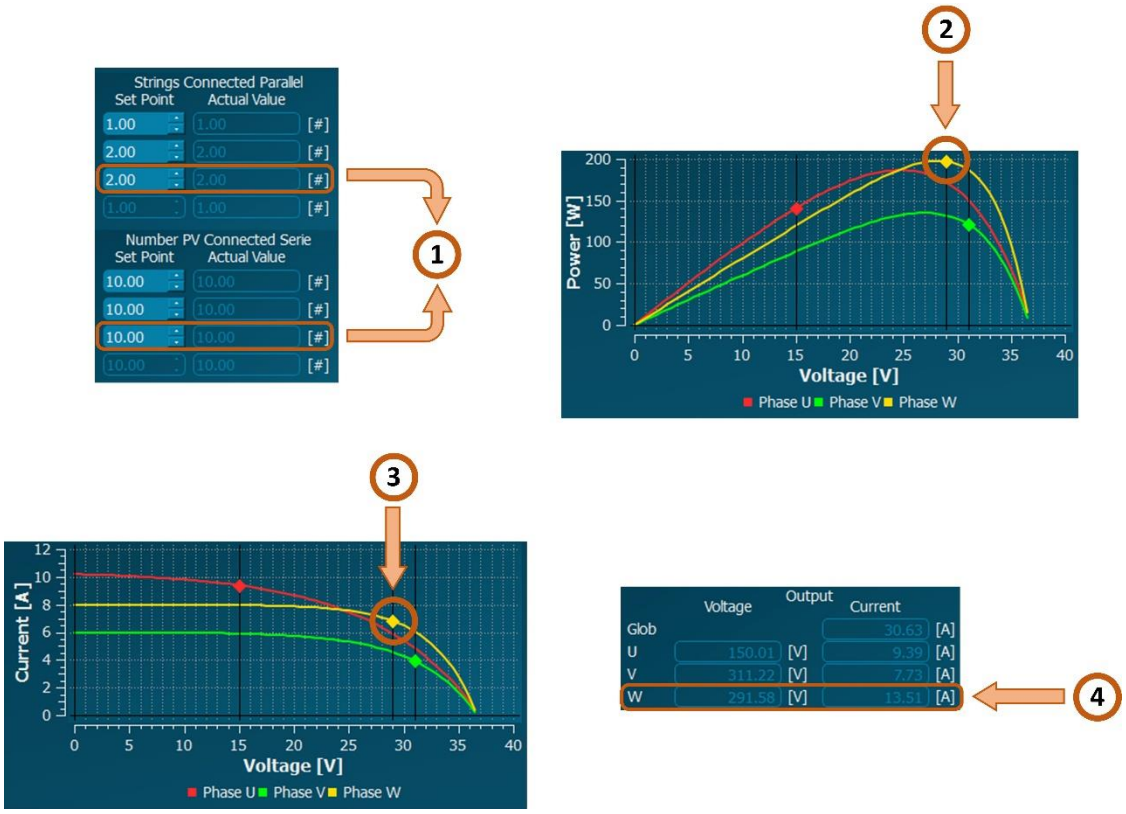
The converter allows to emulate different temperatures and radiation within a sequence:



- **A:** The table contains all the parameters, which are time (in milliseconds), global temperature, global radiation and temperature and radiation for all three channels as the first row explains.
- **B:** this part is used to execute the sequence and save or load the parameters from a csv file.
  1. Use the buttons *Save as CSV* and *Load CSV File* to save and recuperate parameters of the **A** table. It is useful to create a sequence and recuperate it later. The button *Run Table* or *Stop* starts or stops the sequence.
  2. The LED shows if the sequence is running or not.
  3. The location of the csv file is displayed in this zone.

2.4. Example

To make it easier to understand, the following example shows a specific point of the graphs and the values behind it:



1. First of all, it is important to watch at the panels in series and parallel: there are 2 strings in parallel and 10 in series. It means that the current will be multiplied by 2 (strings in parallel) and the voltage by 10 (strings in series).
2. The maximum power is delivered in the peak of the curve. This is reached with a voltage between 29 and 30V. But this voltage will be multiplied by 10 due to the panels in series.
3. With this voltage of 29V approximately, the current is 7A approximately. But this current will have to be multiplied by 2 due to the strings in parallel seen in **1**.
4. So, there is a voltage of 291.58V (29V · 10 panels in series) and a current of 13.51A (7Aapprox · 2panels in parallel).

3. FILE EXAMPLES

Cinergia provides, in the delivered USB stick, the CSV (Coma Separated Value) files detailed in the previous chapters.

In case of using these CSV examples, be sure that the EUT admits the voltage and the current loaded in the Cinergia converter with the CSV file.

The PV Emulator has 2 different CSV files to be loaded with the Cinergia interface: one is for the parameters explained in the chapter *2.2. Parameters* part A and B, whereas the other CSV file is for the values detailed in chapter *2.3. Runtime View* part A.