Battery Emulator for DC converters (Optional)

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V1	Creation	November 17
V2	Upgrade chapter	January 18
V3	Add chapter	February 18
V4	New document format	March 18
V5	Upgrade chapter	April 18
V6	Add and upgraded chapter	June 18

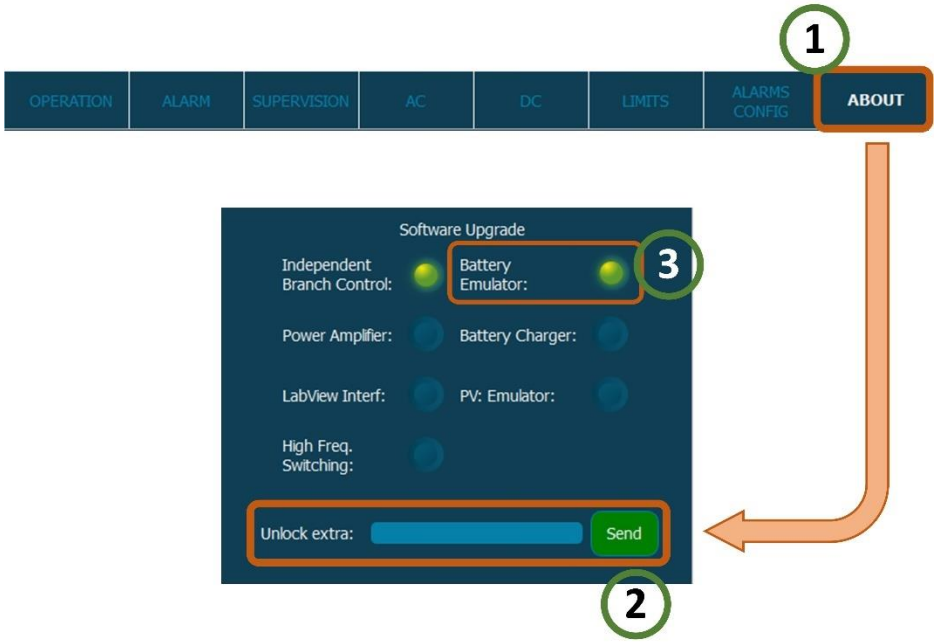
1. GENERAL

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 **Battery Emulator**.

The converter must be in DC UNIPOLAR mode to emulate a battery. But the equipment can be in INDEPENDENT (3 independent batteries) or in PARALLEL (only one battery).

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 Battery 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.

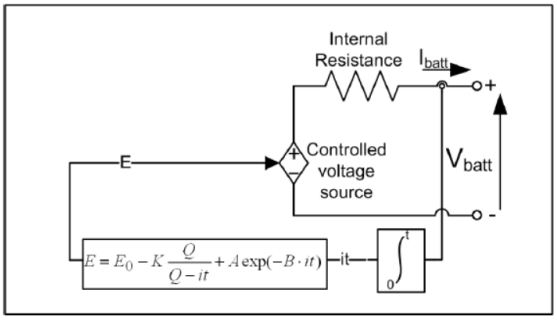
Cinergia is in constant development to deliver always the best service to you, so it is possible to find some discrepancy between this manual and the real converter itself. Don't hesitate to contact us and ask for the latest version of the documentation.

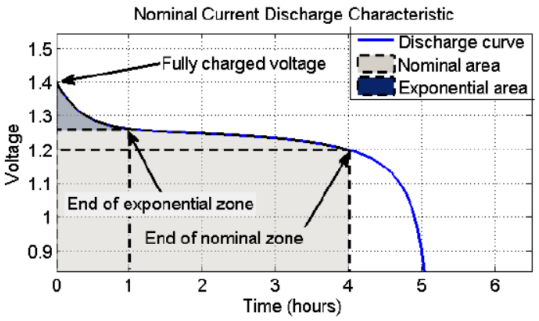
This manual is valid for the following versions of interface:

1.511, 1.512, 1.512x, 1.06xx 2.00xx

2. BATTERY EMULATOR

The Battery Emulator option can be only activated in DC units or AC/DC units in DC mode. The channel/s configured in battery emulator mode will work as a Constant Voltage source where the voltage is a function of a battery model as described by the function below:





Model and picture above are from: O. Tremblay, L.-A. Dessaint, A.-I. Dekkiche, "A Generic Battery Model for the Dynamic Simulation of Hybrid Electric Vehicles", 2007 IEEE® Vehicle Power and Propulsion Conference, September 9-13, 2007, Arlington/Texas, USA

The mathematical model is saved and executed in the firmware of the DSP so it warrants precise and deterministic behaviour, but the model cannot be changed. The user can emulate different batteries by adjusting the parameters of the model and the parameters of the battery (cells in series/parallel, capacity of the cell, etc…).

The model allows the emulation of different technologies of battery as shown in the following table:

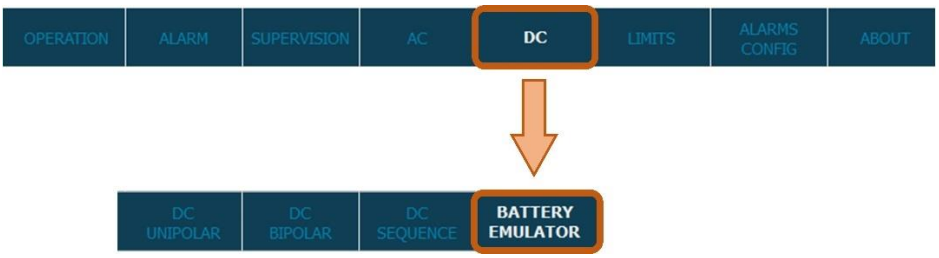
BATTERY PARAMETERS

Type Parameters	Lead-Acid 12V 1.2Ah	Nickel-Cadmium 1.2V 1.3Ah	Lithium--Ion 3.6V 1Ah	Nickel-Metal-Hydrid 1.2V 6.5Ah
$E_0(V)$	12.6463	1.2505	3.7348	1.2848
R (Ω)	0.25	0.023	0.09	0.0046
K (V)	0.33	0.00852	0.00876	0.01875
A (V)	0.66	0.144	0.468	0.144
B $(Ah)^{-1}$	2884.61	5.7692	3.5294	2.3077

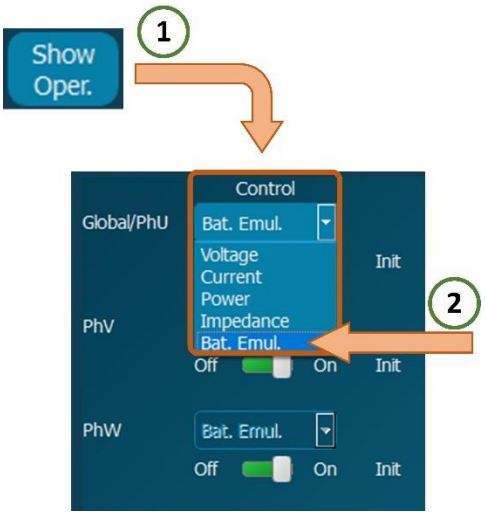
Table above is from the article: O. Tremblay, L.-A. Dessaint, A.-I. Dekkiche, "A Generic Battery Model for the Dynamic Simulation of Hybrid Electric Vehicles"

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:

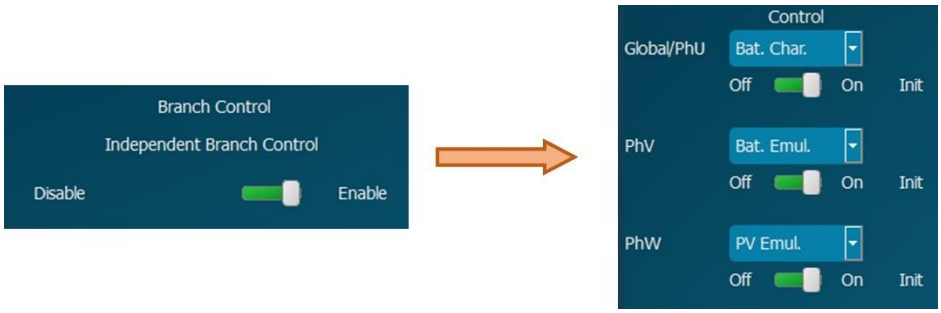


First, the user needs to select the Battery Emulator mode in the Control part of the interface. To do so, click to the button Show Operational on the left top part of the interface and find the Battery control:



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

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

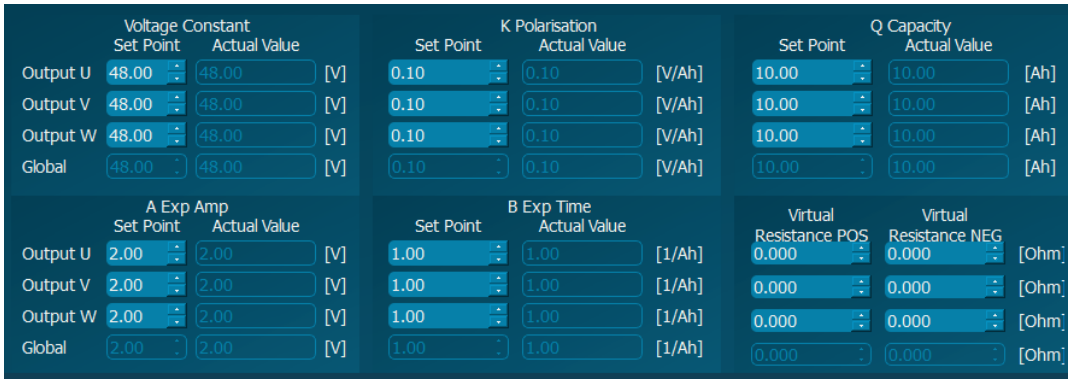


It is very important to be aware of the control configuration and the values of each channel before making the equipment go to *Run* state.

2.2. Parameters

Please be sure that the battery 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:

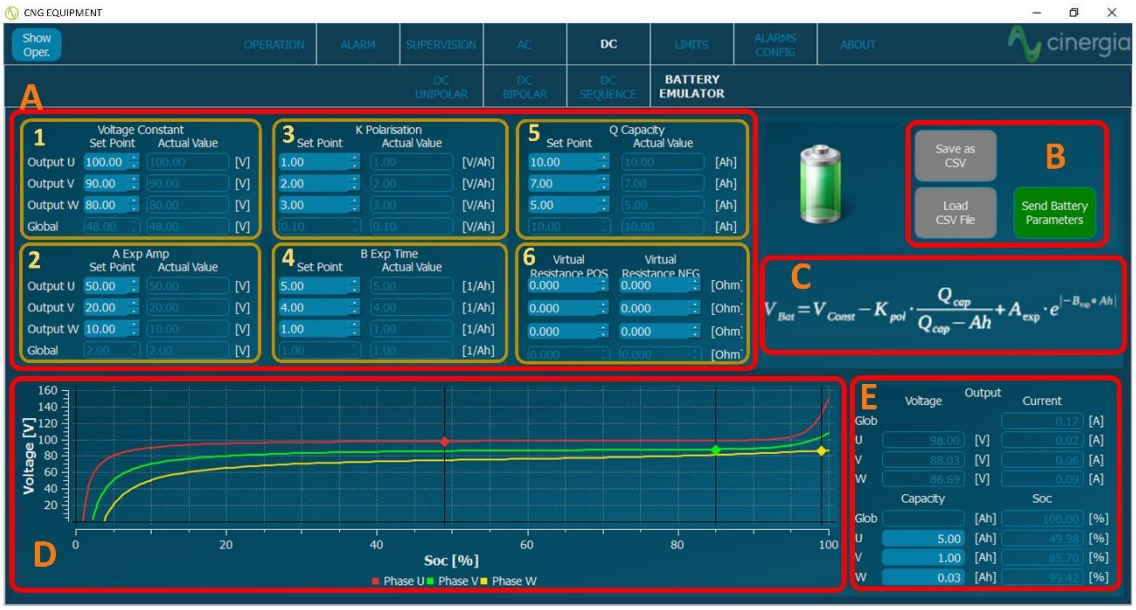


These parameters can be modified in any state of the equipment, even in *Run*. Be sure, before sending any parameter, that the EUT and the Cinergia converter will accept the changes.

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:



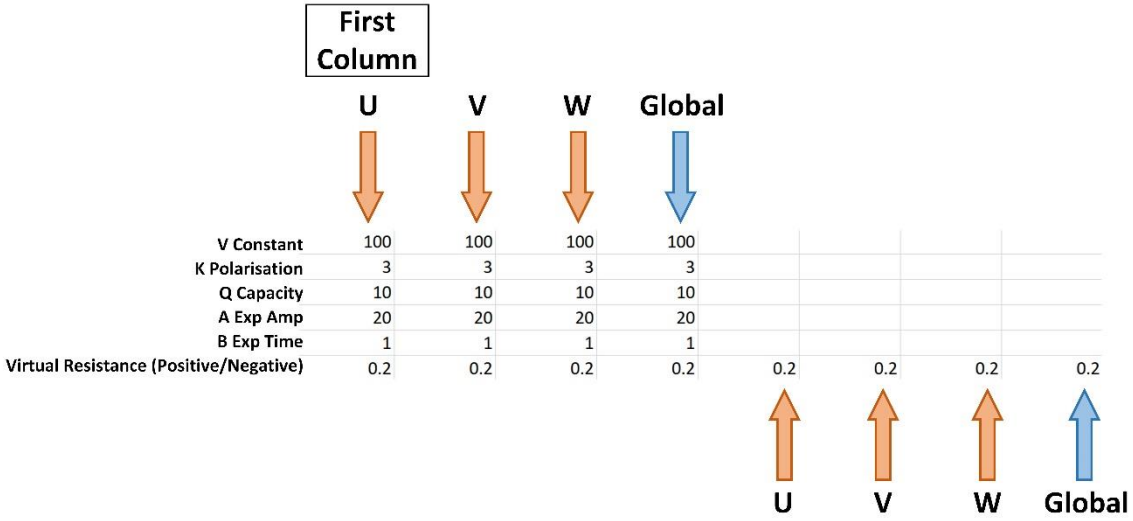
- **A:** In this part there are all the parameters to be introduced in the equipment that will describe its behaviour as a battery.
  1. **Voltage Constant.** This voltage is normally given by the manufacturer of the battery. It is where the two exponentials are found in the graph, so it is, approximately, the voltage in the middle of the graph.
  2. **A Exp Amp.** It is the voltage that will be increased from the *Voltage Constant* depending on the technology of the battery. If the *Ah* (explained in part E) is 0, which means that the battery is fully charged, the maximum voltage will be *Voltage Constant* + *A Exp Amp*. This parameter describes the slope of the right in the graph (the one that makes the voltage go to the maximum).
  3. **K Polarisation.** This parameter describes the slope of the left (the one that makes the voltage go to 0).
  4. **B Exp Time.** It describes how long will be the horizontal part of the line in the graph.
  5. **Q Capacity.** Capacity of the battery in *Ah*.
  6. **Virtual Resistance.** This resistance is also delivered by the manufacturer of the battery, and it is the parameter that sets the voltage drop depending on the current flowing through each channel. So, for example, if the voltage is 100V, the resistance is 1Ω and the current is 10A, the voltage drop will be of 10V, so the voltage in the output will be of 90V instead of 100V. When the current is positive, the virtual resistance that will affect is the positive one, whereas if the current is negative, the virtual resistance will be the negative.

If these virtual resistance (*POS* and *NEG*) are 0, it can introduce resonances in the system.

From 1 to 5, there are 2 columns: the first one is the set point to be introduced and the second is the actual value that the equipment has and is applying.

- **B:** these 3 buttons are used to operate with the parameters described above:
  - **Save as CSV:** all the parameters in **A** 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 Battery 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** if the setpoints and the actual values are the same.

  This 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:



This csv file can only contain numbers.

- **C:** The formula that the equipment uses to calculate the output voltage is the following:

$$V_{Bat} = V_{const} - K_{pol} \cdot \frac{Q_{cap}}{Q_{cap} - Ah} + A_{exp} \cdot e^{(-B_{exp} \cdot Ah)}$$

- **D:** The graph Voltage-SOC represents in real time the state of the battery for each channel. There is a point represented in each line that shows the exact point of the charge.

- **E:** The output parameters show the values in the output of the converter such as voltage and current. The *SOC [%]* also shows in real time the state of the battery and it can be seen in the graph in **D**.

In this part there is also the *Capacity [Ah]* which can be modified online while the converter is in Run state. It will be useful to make a battery go to any part of the line and do not have to wait until it reaches the desired part. So, for example, if the capacity (*Q Capacity*) of the battery (introduced in part **A5**) is 10Ah and the user sets a *Capacity* of 5Ah in the **E** part, the *SOC* of the battery will go to 50%.

3. FILE EXAMPLES

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

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.