CARLO GAVAZZI
Automation Components

CARLO GAVAZZI

WT3-BC

48V Battery Charger for Wind Turbine

Stand Alone System

User Manual

EcoEnergy
equipment

WT3–BC

User Manual

Version	Date	Author	Description
1.0	10-06-2011	Stefano Fusetti	First release
1.2	21-06-2011	Stefano Fusetti	Anemometer description
1.3	05-09-2011	Stefano Fusetti	Battery charging process & braking system updated.
1.4	24-11-2011	Stefano Fusetti	Wind turbine connection updated
1.5	13-12-2011	Stefano Fusetti	Thermal compensation updated
1.6	06-02-2012	Stefano Fusetti	Communication interface pinout and TEMPSOL1000 connection
1.7	13-03-2012	Stefano Fusetti	Hysteresis threshold and graph addition
1.8	26-03-2012	Stefano Fusetti	Wind turbine addition and communication
1.9	03-05-2012	Stefano Fusetti	EMI filter added

Intended use

This manual must be read and used by both the installer and the end user.
The aim of this technical documentation is to provide the necessary information required to install and use the battery charger WT3-BC, as well to define the function, usage and command modes.

Safety precautions and notes

The assembly, installation, wiring and commissioning operations of the WT3-BC battery charger must be strictly executed by skilled, trained and qualified electrical personnel.

NOTE: in case of power loss, some electrical components may still be at high voltage, which may cause electrical shock or injuries if touched.

The safety precautions and instructions listed in this manual must be strictly followed at all times during both installation and operation of WT3-BC.

Safety symbols

To reduce the risk of injury and to ensure the continued safe operation of this product, the safety related information contained in this manual is clearly marked with the following listed symbols:

Caution
This information is provided to prevent damage to the battery charger.

Warning: risk of electric shocks
The information marked by this symbol is provided to prevent the risk of serious injuries or death.

Electrical earth symbol.

General safety instructions

- ✓ Only trained and qualified personnel are authorised to mount, reconfigure and repair this battery charger;
- ✓ Only licensed electricians are entitled to permanently install wired equipment;
- ✓ All safety instructions and information contained in the present manual must be carefully read and followed;
- ✓ The WT3-BC must be provided with an earthing wire, which must be connected in accordance with the local norms regarding safety in electrical installations;
- ✓ The installation of the battery charger must be executed in accordance with local norms regarding electrical safety and protection.

Battery charger wiring

Warning
All electrical installations and wiring procedures must be carried out/used in accordance with the relevant national or local electrical regulations and should follow the safety instructions of this manual.

Warning
Make sure that you are using suitable connecting cables for both AC and DC wiring. The cables must be of adequate dimensions and resistant to temperature variations, UV radiation and other possible hazards.

Warning
Reconfirm that all the connections have been carried out properly and all screws are adequately tightened.

Connection to the wind turbine (AC)

The connection between the battery charger and the wind turbine must be made using insulated (PVC) copper cables. The cable section must be at least 2.5mm^2.
In order to ensure the quality of electrical wiring, please use the wire size recommended in this manual in accordance with the wiring standards of local electrical regulations.

Warning
Before connecting the wind turbine to the battery charger make sure there is no voltage on the turbine terminal block. The connection should be made only when no voltage is present in order to avoid electrical shocks.

Important
The GREEN wire of the turbine is the neutral wiring output from the generator, intended for special applications. Please leave the GREEN wire isolated: do not wire it to any conductive part.

Connection to the battery (DC)

The connection between the battery and the WT3-BC must be made using insulated (PVC) copper cables. The cable section must be at least 16mm^2, or a pair of cables (two for every battery pole) of 8mm^2 minimum section.

Warning
When connecting the battery to the WT3-BC extreme care should be taken in order to avoid a short circuit between the positive and negative poles of the battery.

Connecting the temperature sensor (Carlo Gavazzi Tempsol 1000)

The temperature sensor (recommended Carlo Gavazzi Tempsol 1000) must be placed directly onto the battery. Connect the two pins of the Tempsol 1000 to the terminal board of the battery charger. Tempsol 1000 has no polarity, so one pin must be connected to the mass terminal block – labelled TPM – and the other one to the “Temperature probe” – labelled TP – terminal block. **For more details on the connection please refer to the chapter on “Battery charger wiring”**.

NB the temperature probe is an optional device, which allows the battery charger to adapt the battery voltage charging threshold depending on the battery temperature. If you do not connect the temperature probe the BC will implement a charging process optimized for a battery temperature of 20°C (which is used as default value).

Repair and Maintenance

Only Carlo Gavazzi Logistics S.p.A. personnel are authorized to repair this unit.

Warning
Never try to alter or modify the assembly of the battery charger: you may incur an electric shock.

Caution
Attempted repairs carried out by unauthorized people may permanently damage the product and will in any case void the warranty.

Contents

Product overview

The WT3-BC is a battery charger designed for stand-alone wind power plants.
Figure 1 shows the required connections of the battery charger in order to commission the plant. The battery charger is connected to the wind turbine, and delivers the energy, converted into DC, to the battery to keep it charged.
The charging is performed using the I.C.C. technique, which will be described in detail in a later chapter.
The WT3-BC not only manages the battery charging but also monitors the wind turbine operation and the wind speed and actuates the resistive braking in order to protect the turbine in the event of prohibitive wind conditions.

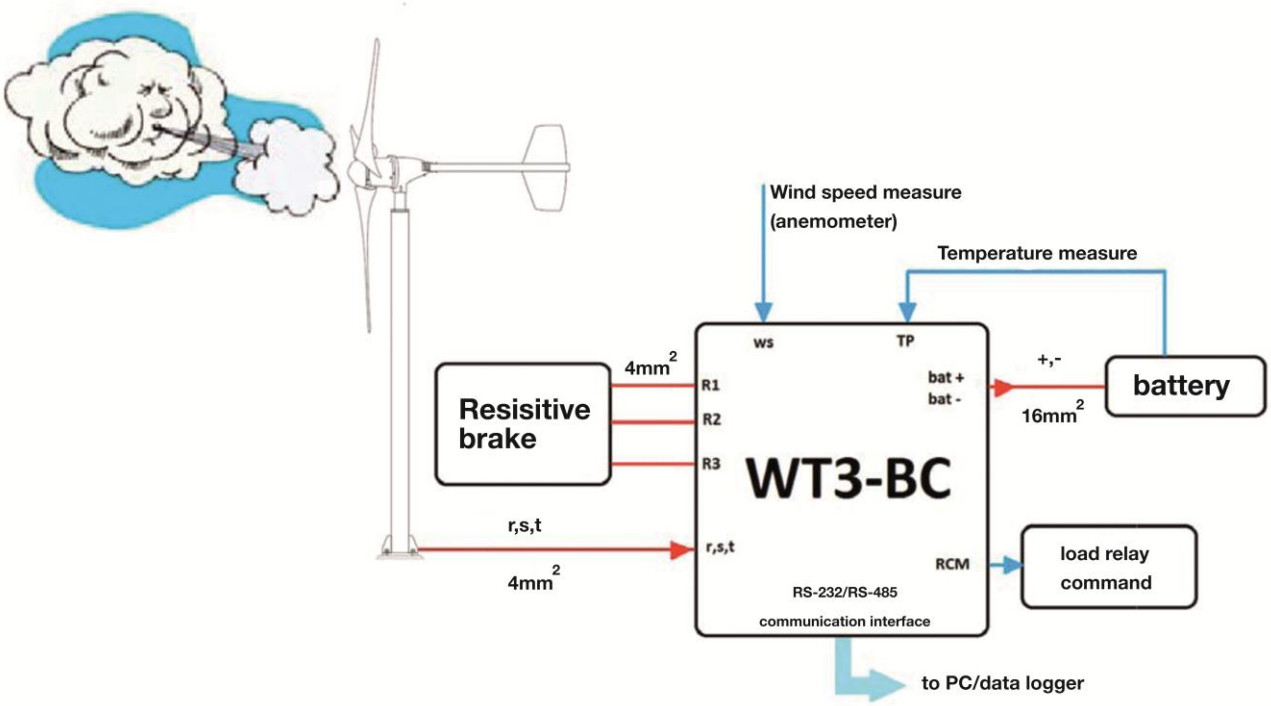


Figure 1: WT3-BC functional block diagram.

WT3-BC Main Functions

The WT3-BC is designed to perform the following tasks:

- Battery charging with energy produced by the wind turbine;
- Controlling the condition of the wind turbine;
- Maximizing energy harvesting, in any working situation;
- Optimizing the battery charging process;
- Measuring and recording the production data in order to monitor the plant performance.

To perform all the above functions the battery charger is provided with a microcontroller which also implements the MPPT and battery charging algorithm.
The WT3-BC is also equipped with two communication ports; RS-232 and RS-485, enabling the unit to be connected to a remote data logger or any other data acquisition system.

Package Content

The package contains:

- battery charger 1 pc;
- resistor box 1 pc;
- communication cable 1 pc;
- user manual 1 pc.

Battery charger location

The WT3-BC is designed for vertical mounting, and is suitable for either indoor or outdoor installation. As it is IP54 protection class, it should be placed in a place sheltered from the rain in the case of outdoor installation.
The wall or the support used for the battery charger placement must be adequately robust to solidly and safely hold the weight of the WT3-BC: it must be able to carry 25 kg or more.
The battery charger should not be exposed to direct sunlight, in order to maintain its internal temperature within the specified operational range (see technical specifications).

Warning
Some components of the battery charger may reach high temperatures: for this reason this device must not be used in explosive or flammable atmospheres and/or environments. Use of the battery charger near flammable or explosive substances must also be avoided.

Warning
Do not put the battery charger in contact with explosive liquids and/or gases.

Battery charger wiring

All the connections to the unit must be made using the terminal board shown in figure 3:

Clamp label	ID	Element to be connected
L1	-	*Turbine phase*
L2	-	*Turbine phase*
L3	-	*Turbine phase*
PE	*1*	*Ground cable*
R1	*2*	*Braking resistor*
R2	*3*	*Braking resistor*
R3	*4*	*Braking resistor*
BAT +	*5*	*Positive battery terminal*
BAT -	*6*	*Negative battery terminal*
CV	*7*	*External fan command*
24V	*8*	*Power supply +24 Vdc*
RMC	*9*	*Load relay command*
TP	*10*	*Temperature probe (signal)*
TPM	*11*	*Temperature probe and anemometer mass*
WS	*12*	*Anemometer signal*

Table 1: battery charger terminal labelling.

Wind turbine connection

The WT3-BC4800 accepts a maximum input power of 3 kW. Do not connect any turbine that exceeds this value. The connection to the terminal board must be made using PVC insulated, stranded copper wires with a section of at least 2.5 mm^2 (see figure 3).

Resistive brake connection

The resistor box is shown in the following pictures:

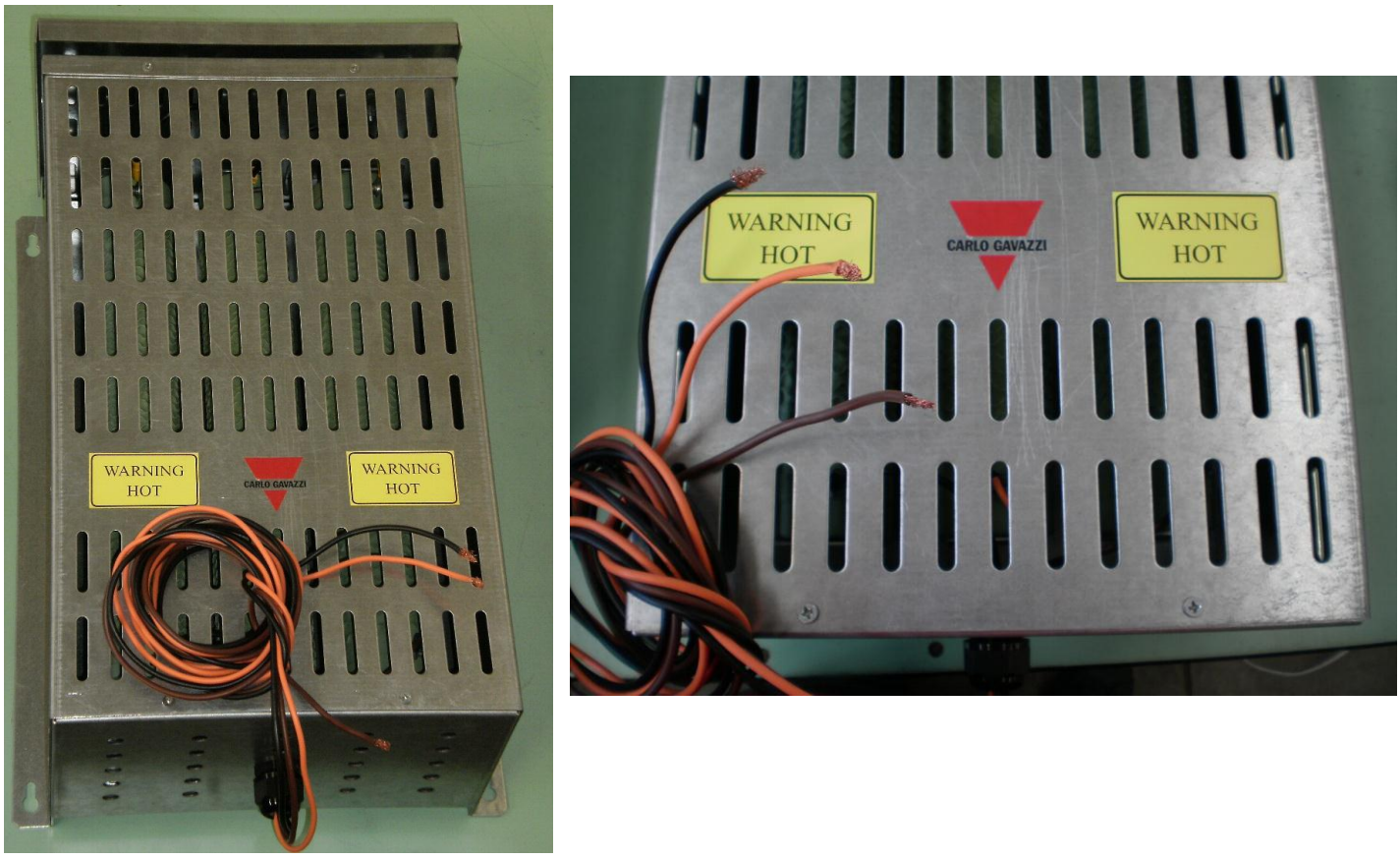


Figure 2: battery charger resistor box.

The WT3-BC also implements the turbine electromechanical braking, which is controlled by connecting or disconnecting three braking resistors (to the turbine terminals), in a star connection (each resistor is able to dissipate an electrical power of 1 kW).
The Carlo Gavazzi resistors are placed in a specific box, called a *braking box* (part number WT3RB12), which must be connected to the battery charger via the terminal board using PVC insulated, stranded copper wires, of at least 4 mm^2 section.
Each resistor box must be connected to the battery charger using the terminal blocks (labelled as 2, 3 and 4 on the battery charger terminal block: see figure 3).

Temperature probe and anemometer

Temperature probe

A temperature probe should be used to control the upper charging threshold voltage of the battery. The upper voltage is 56.4V at 25°C and drift with a slope of -4mV/°C over the whole range between 0°C and 40°C. A thermo-resistant probe should be used: Pt1000 (Carlo Gavazzi TEMPSOL1000).

When using the Temperature probe it is important to note that:

- the temperature probe (Carlo Gavazzi TEMPSOL1000) must be glued onto one cell of the battery, or into the outer part of the battery pack;
- if you do not install the temperature probe, the control system will use as default the upper charging voltage of 56.4V assuming a temperature of 25°C;
- the temperature probe must be connected using the dedicated terminal block (labelled 10 and 11), located on the battery charger terminal board;
- At a battery (or ambient) temperature greater than 45°C the battery charger disconnects the charging current in order to protect itself.

Anemometer sensor

An anemometer sensor can be connected to the battery charger - using terminals labelled 14 (mass) and 15 (signal) - for measuring the wind speed. The wind speed measure is used to verify the performance of the battery charger. Several kinds of anemometers can be used: the battery charger can read signals such as those of the Carlo Gavazzi DWS-V-DBC05 anemometer, which has the following characteristics:

- square wave output signal;
- amplitude: 12.5 mA on 1Kohm resistor;
- frequency: 10 Hz per m/s.

With the WT3-BC you must use only an anemometer with a compatible output signal. If you use a DWS-V-DBC05 anemometer the connections must be:

Connection	Anemometer cable	Battery charger terminal block
+ 24 V	Brown	8
Ground	Blue	11
Signal (PNP output)	Beige	12

Table 2: Carlo Gavazzi DWS-V-DBC05 anemometer connection.

Battery connection

The battery charger has been optimized for a battery charging capacity of 1000 Ah, but also ensures high performance with battery capacities in the range of 500 - 1200 Ah.
For this connection you must use the dedicated terminal board: the wires to be used should have a section of at least 16 mm^2 if only one cable for each pole is used.Two cables of 8 mm^2 each in parallel can also be used.
If you program – using the dedicated programming software - the amp-value of the battery (the default value is 1000 Ah) the control system will never deliver to the battery a current higher than 1/20 of the nominal battery capacity.

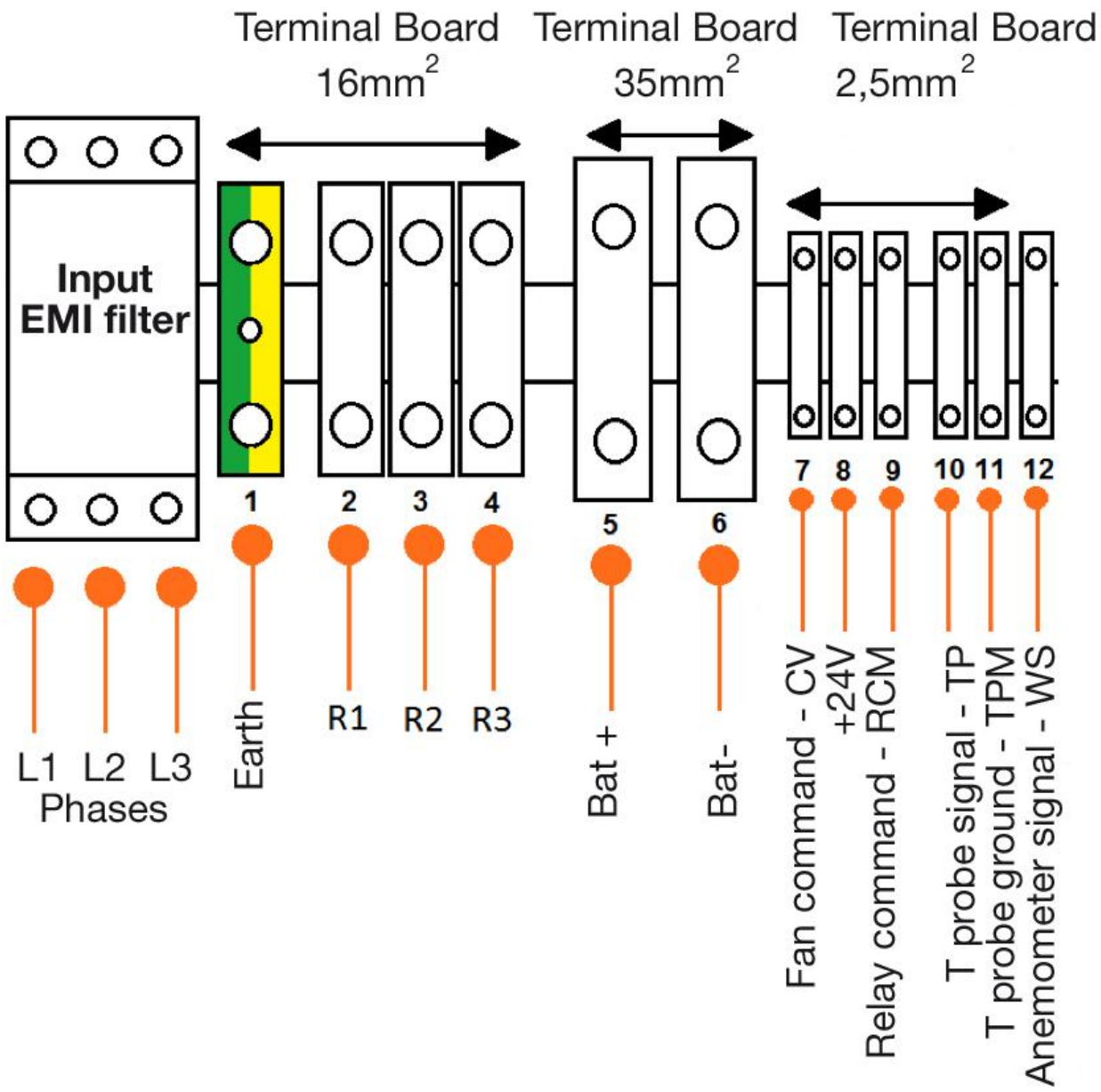


Figure 3: WT3-BC terminal board.

Warning

All electrical work must be carried out in accordance with the local and national electrical norms, and should follow all the safety precautions contained in this manual.

Warning

Make sure suitable cables are used for both AC and DC connections. The cables must be of the correct size (see the connections paragraphs) and must be resistant to temperature fluctuations, to UV radiation and other possible hazards.

Warning

When the turbine is turning, high voltage is present on the turbine terminals. When making the cable connection between the Turbine and the WT3-BC, make sure the turbine is blocked and/or have a breaker in between with the contacts open. Failing to follow this procedure may result in a fatal electric shock.

MPPT algorithm

The MPPT (Maximum Power Point Tracking) algorithm maximizes the energy conversion in all working conditions of the wind turbine.
This is implemented by continuously adapting the current load on the turbine and verifying the voltage stability.
The optimal curve – the ideal V/I operating curve is stored in the unit memory and provides the microcontroller with a set of points to be followed in order to provide maximum output power with any wind and turbine speed combination.

Wind turbine braking control system

The battery charger is able to brake the wind turbine in two ways:

- using a resistive brake;
- using a short circuit brake.

Resistive brake

The resistive braking system consists of three resistors in a star connection: when at least one of the following conditions is reached, the resistive brakes the wind turbine by means of the control unit, in order to slow down its rotor:

- The battery is fully charged: it is useless to produce energy that will be wasted when it cannot be delivered to the battery. Turbine durability is increased as a result;
- There is a very strong wind (ie: the wind speed is very high). In this condition, if the turbine is not braked the angular speed of the rotor may reach very high (dangerous) levels, causing possible mechanical damage to the turbine;
- The battery charging process is in ICC phase, and the battery is in the discharging sub-phase: the resistive brake is activated in order to give an electrical load to the wind turbine, so it will not be in a no-load condition, transferring the electrical power generated to the resistive brake.

The electrical power of every braking resistance must be 1 kW, and its electrical resistance value must be 12 Ω.

Please note that when the resistive brake is activated, the CV signal – which is the command for an eventual fan-cooling of the brake – is at ground potential (0 V): if the resistive brake is off, CV is floating.

Short circuit brake

The short circuit brake is a safety brake: it is activated when the turbine is wired to the battery charger (see relevant chapter), the general AC three-phase breaker is in ON position and the battery charger is OFF. In this way the maximum electrical load (is applied to the wind turbine), which is the maximum braking.
This brake is activated every time one of the following conditions is reached:

- the turbine is braked manually, switching off he battery charger;
- event of power loss, and the input AC 3-phase breaker is ON.

The following table explains the conditions for the short circuit brake status:

AC 3-phase breaker status	Battery charger status	**Short circuit brake status**	Wind turbine status
OFF (open)	OFF	Not active	Free (no mechanical/electrical load connected)
OFF (open)	ON	Not active	Free (no mechanical/electrical load connected)
ON (closed)	OFF	ACTIVE	Short circuited (braked)
ON (closed)	ON	Not active	Loaded by the battery charger (depending on wind speed and battery voltage)

Table 3: short circuit brake activation.

The short circuit is automatically deactivated when the battery charger is switched ON, and could be manually excluded by opening the AC three phase input breaker (N.B. not recommended).

Wind Turbine Manual braking

The wind turbine can be braked manually by using the brake to short circuit. This is done by turning off the battery charger using the button on / off General, leaving in the "on" position the switch three-phase input (leaving the wind turbine connected to the battery charger).
The brake can be switched off in two different ways:
- turning on the battery charger using the on / off button, to activate the control system which is responsible for managing the braking of the turbine;
- turning off the three-phase input circuit breaker, to disconnect the battery charger from the wind turbine (the wind turbine is not connected to other loads and it will turn freely without loads).

Pay attention if using the manual braking: it is designed for use only in the event of **maintenance and inspection**, not for frequent use.

Battery charging process

Control of the battery charging, in order to extend the battery lifetime above the average, is performed using the *I.C.C. (Interrupted Charge Control)* technique, which avoids gas evaporation.
The I.C.C. technique charging process is performed in two phases: the bulk charge and the interrupted charge.
In the first phase the battery is charged by applying to it a constant current I_{bulk}: the battery voltage increases with a ramp. This stage stops when a voltage threshold is reached. The threshold is not fixed but changes with temperature: if the temperature increases the voltage threshold decreases and vice versa. When the threshold is reached, the second charging phase starts.
In the second phase the battery is partially discharged and charged cyclically: just after the bulk phase, with no charging applied to the battery, no current flow, the battery discharges due to self-consumption. When the battery voltage reaches a minimum threshold the charging process is restarted by applying a constant current value I_{icc}.
During the discharging phase the wind turbine generator is automatically braked using the resistive brake.
The Diagram below shows the behaviour of the battery current and voltage during the charging process:

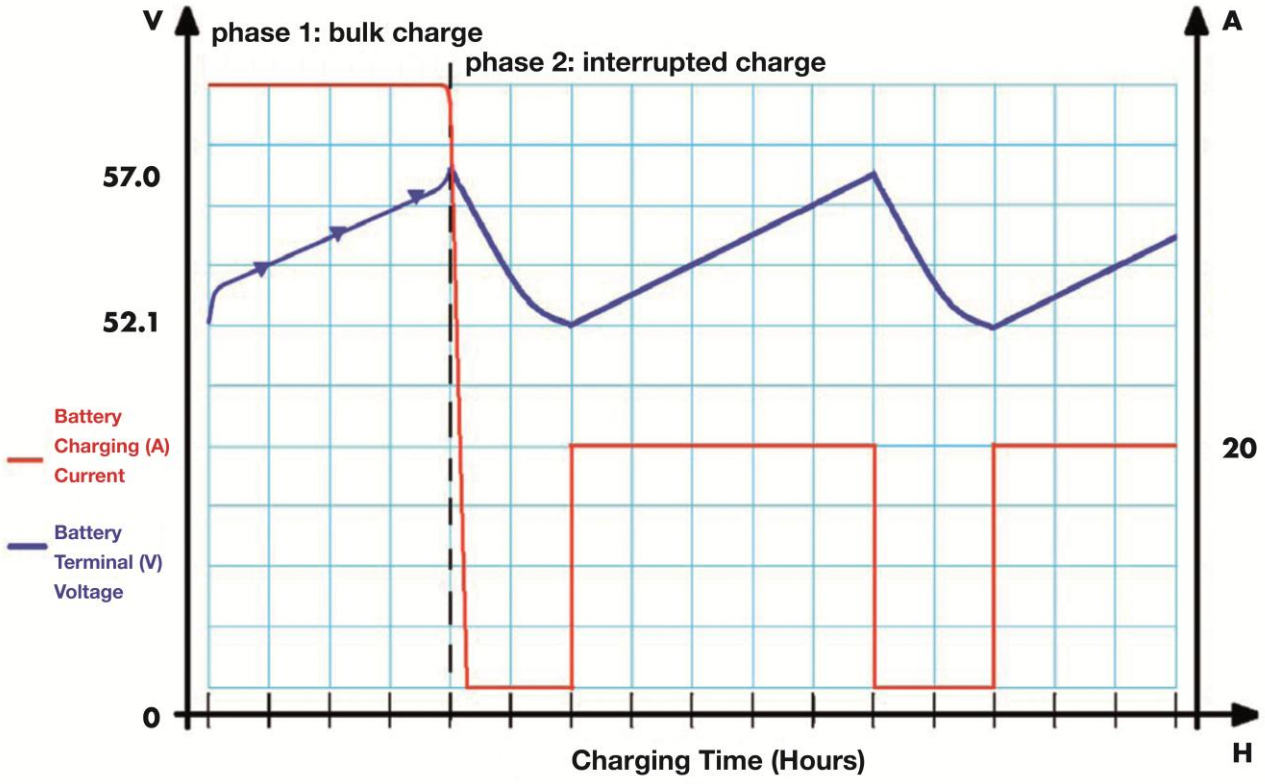


Figure 4: battery voltage and current during the charging process.

Braking, load relay command, overcharging and AC overvoltage protection thresholds

Resistive braking thresholds

The braking control system activates or deactivates the resistive brake depending on the value of the rectified voltage, which is connected to the thresholds listed in table 4:

Threshold	Rectified voltage [V]	AC voltage [V]
Braking activation (OFF → ON)	340	250
Braking deactivation (ON → OFF)	200	148

Table 4: resistive braking control thresholds.

Depending on the threshold the resistive brake is switched on or off: the resistive braking curve is shown in figure 5:

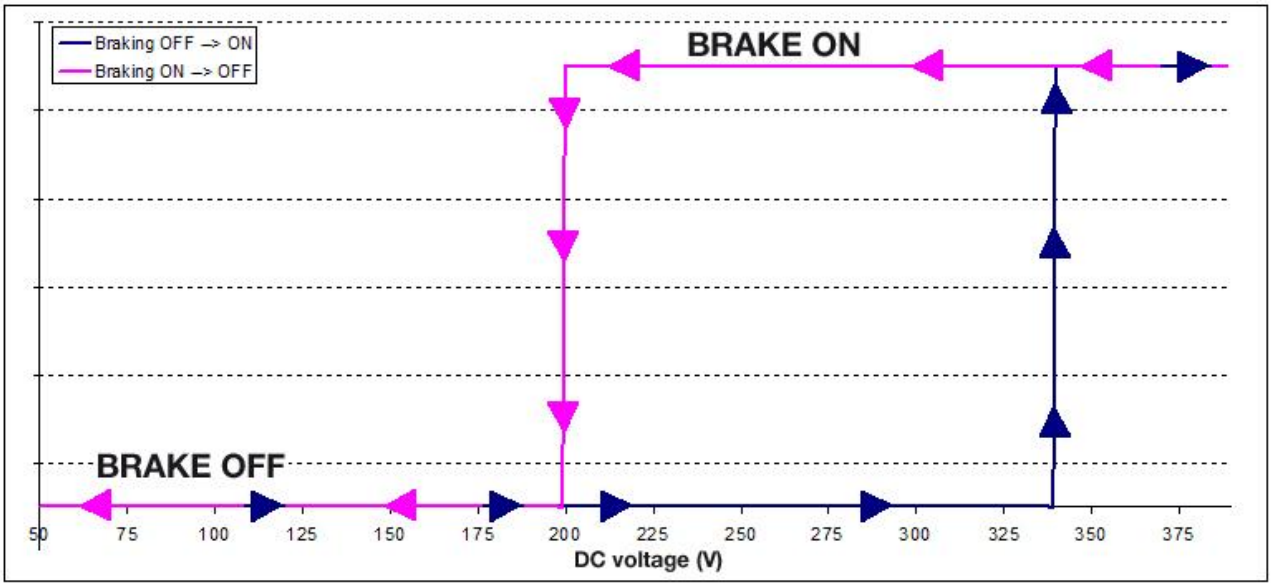


Figure 5: braking control system curve.

Local load control relay (RCM) thresholds

The status of the command for the local load relay depends on the battery voltage:

Threshold	Battery voltage [V]
Load activation (OFF → ON)	50.4
Load deactivation (ON → OFF)	45.6

Table 5: load relay command thresholds.

The control unit sets the local load relay command according to the value of the battery voltage, which is connected to the thresholds listed in table 5. The logic implemented by the control system is shown in figure 6:

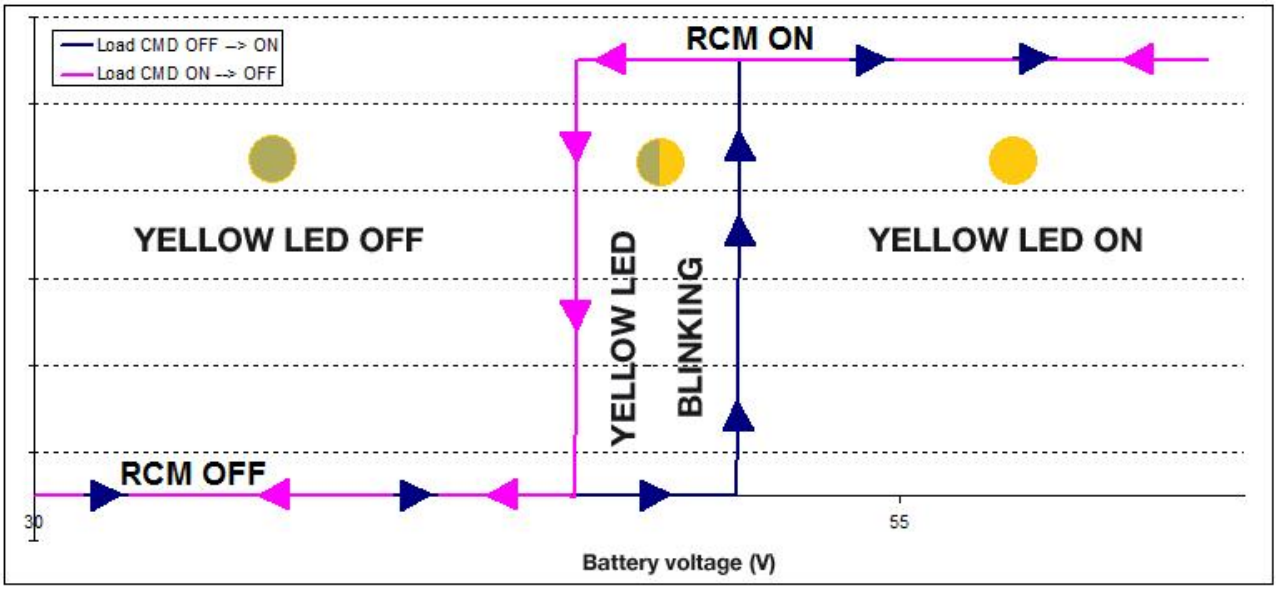


Figure 6: local load relay command curve.

Battery overcharging protection thresholds

To avoid overcharging of the battery, when the battery voltage exceeds a defined threshold the resistive brake is switched on, in order to deliver the power coming from the wind turbine to the brake; in this way the battery charging process is interrupted.
When the battery voltage drops below a reactivation voltage the resistive brake is switched off and the battery charging process is restarted.

Threshold	Battery voltage [V]
Battery OC protection (OFF → ON)	57.0
Battery OC protection (ON → OFF)	52.1

Table 6: battery overcharging protection thresholds.

NB the values in table 6 are not fixed, but depend on the temperature, which is continuously measured by the temperature probe (TEMPSOL1000). **If the temperature probe is not connected to the battery charger the control system uses the default value, corresponding to 20°C**. The following table describes the connection between temperature and overcharging threshold values:

Temperature [°C]	Activation threshold [V]	Deactivation threshold [V]
0	59.4	53.5
10	58.2	52.8
20	57.0	52.1
30	55.9	51.4
40	55.2	51.0

Table 7: thermal compensation.

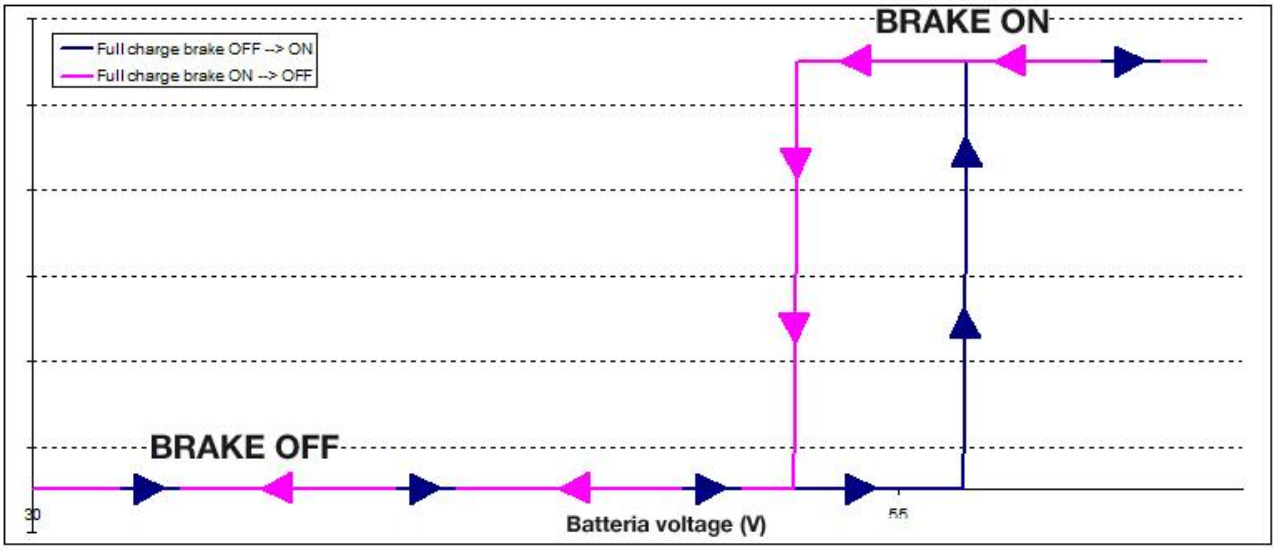


Figure 7: battery overcharging protection curve.

Wind turbine overvoltage protection

To avoid overvoltage from the wind turbine, a protection system disconnects the battery charger from the wind turbine if the AC voltage exceeds a fixed value, and is reconnected only when the AC voltage drops below a safety threshold (see table 8):

Threshold	WT AC voltage [V] (phase-phase)
WT overvoltage protection (OFF → ON)	267
WT overcharging protection (ON → OFF)	200

Table 8: Wind turbine overvoltage protection thresholds.

The overvoltage protection curve is shown as follows:

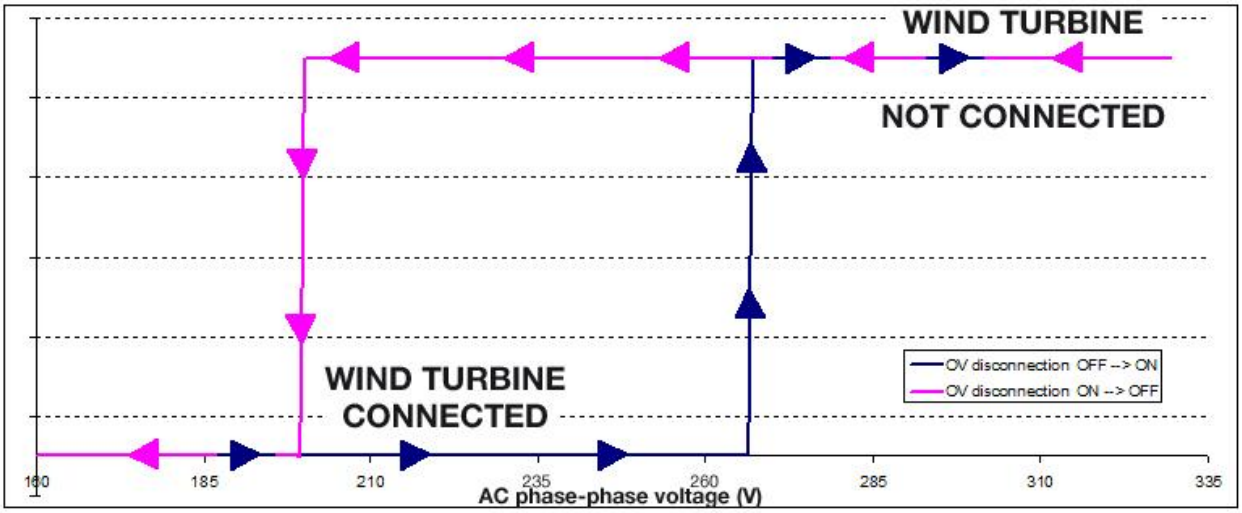


Figure 8: wind turbine overvoltage protection curve.

Wind turbine curve

The battery charger is supplied with a pre-charged wind turbine curve.
This is the curve of the Carlo Gavazzi Mistral wind turbine, a 3 kW wind turbine, as shown in the next figure:

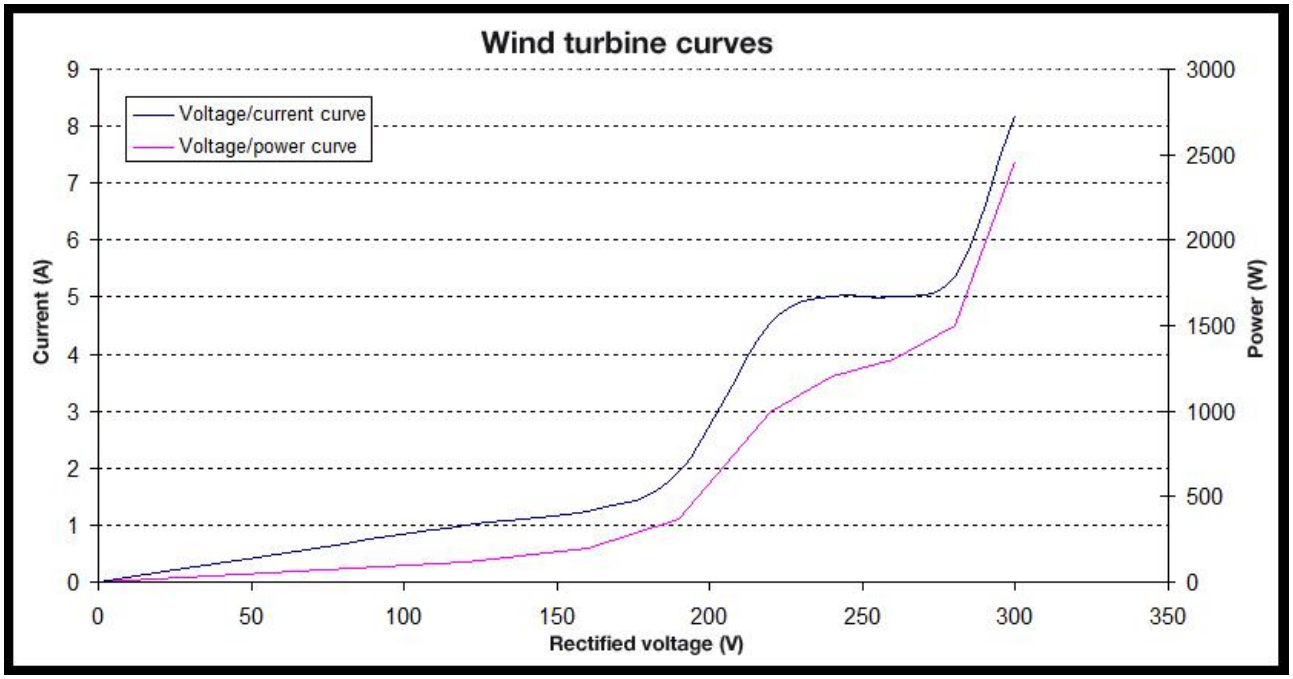


Figure 9: wind turbine curves.

The programmed points are as follows:

Rectified voltage [V]	120	160	190	220	240	260	280	300
Current [A]	1	1.25	1.95	4.55	5	5.01	5.36	8.2

Table 9: Voltage and current programmed points.

The battery charger is also programmable: using the dedicated software you can program the curve of each wind turbine: the only constraints are:

- the curve must be monotonic strictly crescent;
- the power of the wind turbine must be maximum 3kW.

User interface

The WT3-BC can interact with the operator in two ways: by means of the display and by the three LEDs placed on the top of the display.
The status (on, off or blinking) of the LEDs indicates the battery charging process status, whilst the display is used to visualize the different values of the plant or the active alarms.
On the right side below the display there are four pushbuttons, which are used for browsing the measurements and alarm menus.

Light indicators

On the top of the display there are three LEDs: green, red and yellow, which are used to indicate the device status.
Each LED can have one of three statuses: on, off or blinking. Each status indicates a particular condition of the device: this feature enables the user to read three pieces of information simultaneously.

LED Status reference table

LED	Status	Meaning
Red	On	Battery discharged or damaged
Red	Blinking	Low battery and turbine not connected
Red	Off	Battery OK
Yellow	On	Load relay on (possible to use local loads)
Yellow	Blinking	Load relay on (possible to use local loads) but turbine not connected or generating voltage lower than battery voltage
Yellow	Off	Load relay off (not possible to use local loads)
Green	On	Battery fully charged
Green	Blinking	Battery on charge
Green	Off	Battery not connected to the wind turbine

Table 10: LED indications.

Display

The WT3-BC has a display, which is used to visualize the measurements on the system and the active alarms.
In order to simplify the navigation of the information on the display, measurements and alarms are collected in two different sub-menus, which may be browsed by using the pushbuttons on the right side and below the display.
Each pushbutton provides a different function:

- *up* ➔ back to the previous item of the current menu
- *down* ➔ next item of the current menu
- *clear* ➔ back to the upper hierarchy level menu
- *enter* ➔ enter the inner hierarchy level menu

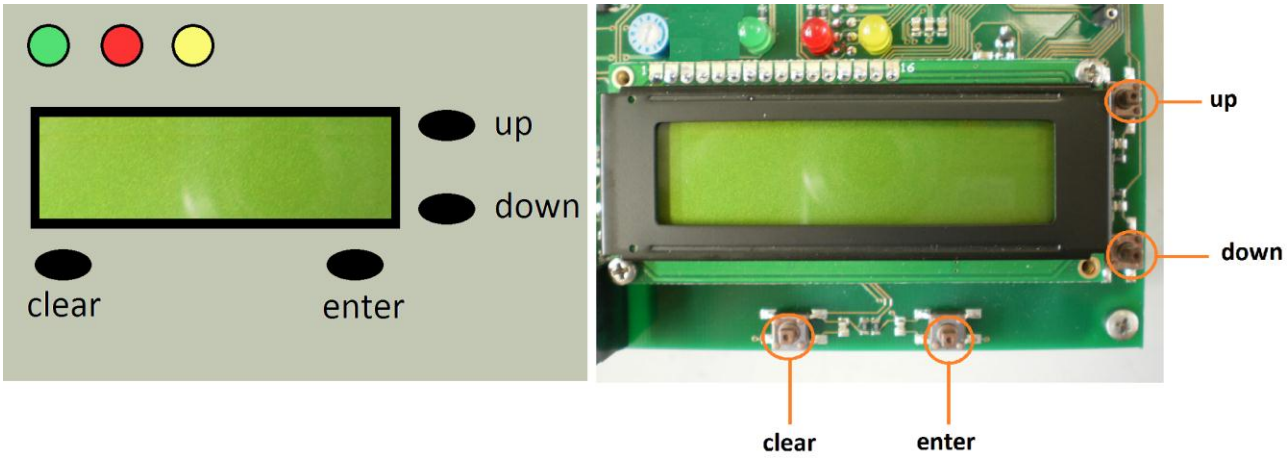


Figure 10 display and buttons of the WT3-BC.

When no keys are pressed the display shows the “home page” with the value of the power delivered to the battery.
If the “down” key is pressed the main menu appears: in this menu there are only two items, the “measurements” submenu and the “alarms” submenu.
The first is the menu that displays all the measurements in the system.
The second submenu displays all the active alarms. If there are no active alarms, the string “No active alarms” is visualized.
Fig. 11 shows the visualization order of the measurements and of the alarms in their respective submenus.

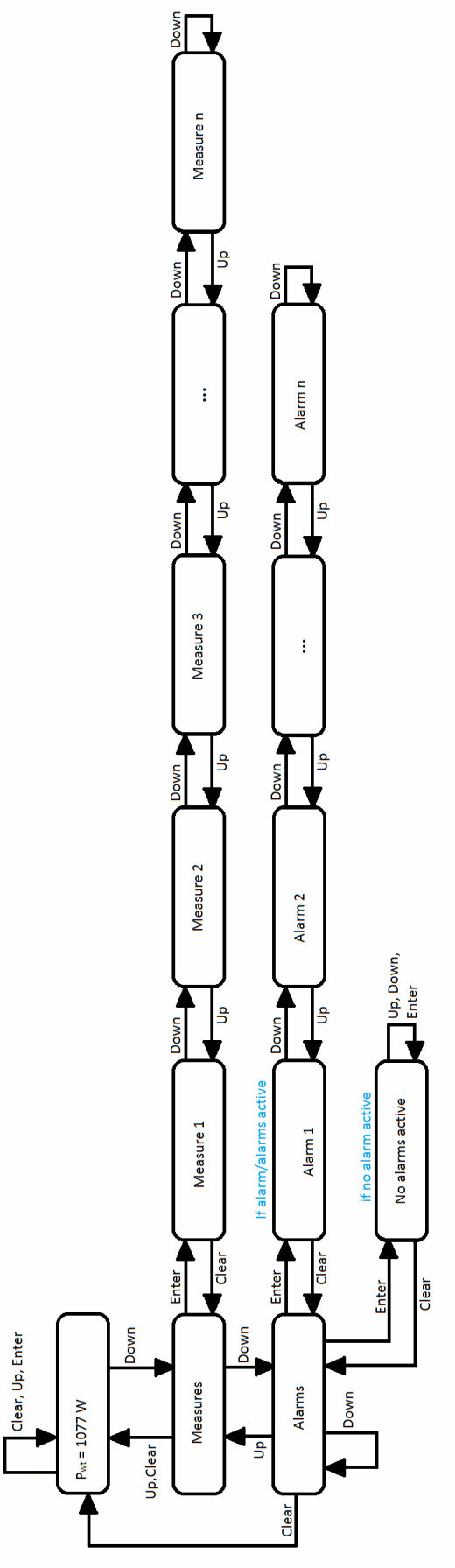


Figure 11: hierarchy and browsing of the menus.

Measurements

The table below shows the list of measurements that can be displayed on the device display:

Measure	Displayed message
Current from wind turbine [A]	WT input current
Rectified voltage from wind turbine [V]	WT input voltage
Electrical power from wind turbine [W]	WT input power
RMS voltage (ac) from the wind turbine [V]	WT ac voltage
Frequency of the produced AC voltage [Hz]	WT voltage frequency
Battery voltage [V]	Battery voltage
Current applied to battery [A]	Battery current
Electrical power applied to the battery [W]	Power in battery

Table 11: measures and messages visualized on the display.

Alarms

The list of Alarms and the related meaning are shown in the table below:

Alarm	Displayed message
Maximum voltage from the wind turbine, activation of the resistive brake.	RES braking ON
Over-voltage from wind turbine	WT overvoltage
Under-voltage from wind turbine	WT undervoltage
Over-current from wind turbine	WT overcurrent
Under-current from wind turbine	WT undercurrent
Fault at the chopper (DC/DC converter)	WT line faulty
Fault at the battery charger control unit (CU)	CU faulty
Battery low voltage	Battery low
Battery over-voltage	Battery high
Battery faulty or damaged	Battery faulty

Table 12: system alarms.

Communication interface

The WT3-BC is equipped with two serial RS232 / RS485 communication ports.
The cable must be a shielded communication cable EIA/TIA T568A (8 wires), as in the following picture:

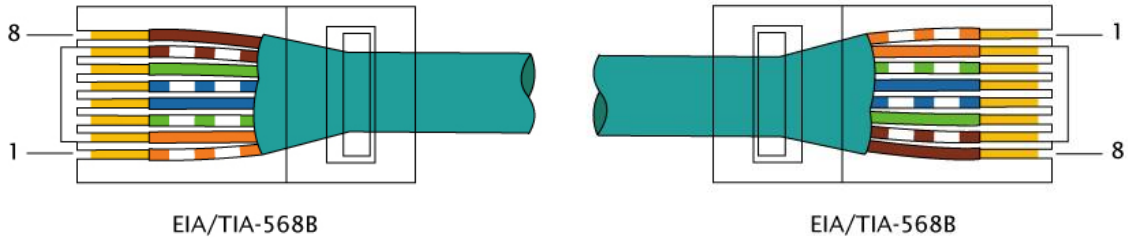


Figure 12: serial communication cable: PC (or converter) side (on the left) and battery charger side (on the right).

You must use communication cables with an RJ45 terminal (8 wire), referring to the pinout listed in the following table:

RJ45 pin	RS 232 / RS485	RS 485
1	Not used / Data+ (B)	Data+ (B)
2	Not used / Data- (A)	Data- (A)
3	Not used / Not used	Not used
4	Ground / Ground	Ground
5	Ground / Ground	Ground
6	Not used / Not used	Not used
7	Rx / Not used	Not used
8	Tx / Not used	Not used

Table 133: serial communication interface pinout.

For both RS232 and RS485 interface MODBUS communication protocol is implemented.

Technical specifications

AC input (wind turbine)

Voltage input range	55 – 300 V
Current input range	0 – 10 A
Maximum input electrical power	3.000 W
Voltage threshold for activating the resistive brake.	230 Vrms (phase to phase)
Input frequency range	20 – 180 Hz
Turbine over-voltage threshold	270 Vrms (phase to phase)

DC output

Battery current range	0 – 50 A
Battery voltage range	42 – 60 V
Maximum output power to the battery	3000 W

Protection devices

Turbine over-voltage relay	Present
Load relay	Command at the terminal block
Load relay command OFF → ON	50,5 V batt
Load relay command ON → OFF	45,5 V batt

Environmental data

Working temperature range	- 10 ÷ +50 °C
Working humidity range	10% – 93% non condensing
Protection class	IP54

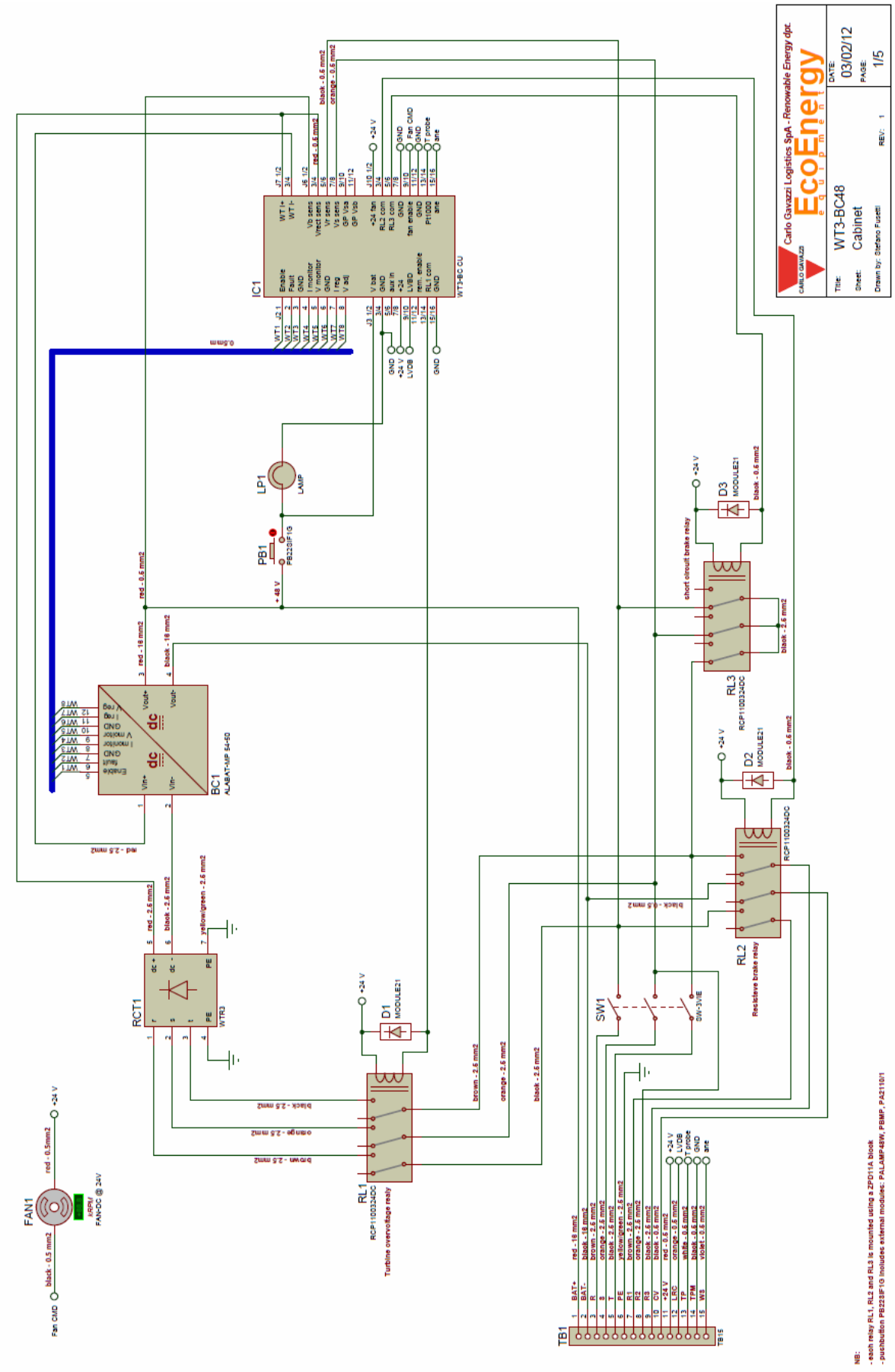
General data

Width x Height x Depth	500 x 400 x 200
Weight	25 kg
Self consumption	20 W
Cooling system	Forced ventilation

Equipment

CA connection	Screw terminal
CC connection	Screw terminal
User interface	LCD display, LED indicators
Communication interface	RS-232, RS-485

Device electrical wiring diagram



Note

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