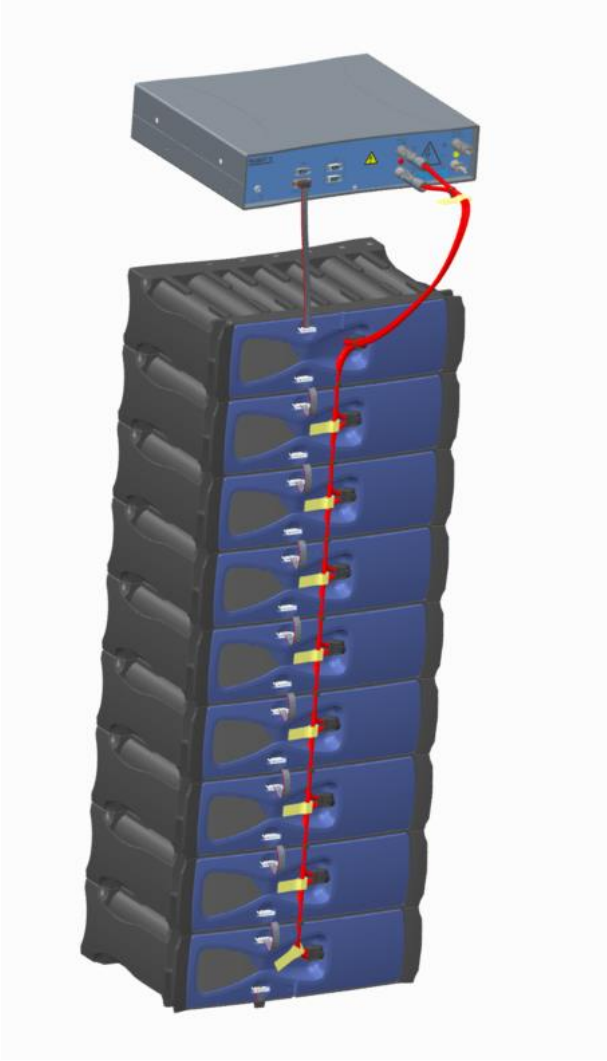
Lithium-ion Stationary Battery System
P/N 777308-00
BTR-0504V-VL45E-NCA-009M
504V / 45Ah



DOCUMENT REVISION

Version	Date	Changes
1	04/12/2015	First issue 9 Synerion modules version based on the ED2014-0210_UM_10 Syn48E battery_rev2

It is mandatory to read the user and the maintenance manuals prior to any use, installation or maintenance of a Saft battery. All instructions must be carefully complied with. In case any of the instructions contained in the user and the maintenance manuals are not applied, Saft's warranty on the battery is no longer applicable and Saft disclaim any liability for any and all direct, indirect or consequential damages or losses resulting thereof.

To highlight important points, the following symbols will be used:

 **Indicates a possibility of injury or serious equipment damage if instructions are not followed**

 **Indicates helpful information**

SAFETY RULES

All the recommendations contained in this document must be applied and respected.

(1) Always use the batteries with restrictive access. Battery must remain accessible only to trained service personnel.

(2) Install in a location that could be easily ventilated in case of misuse of batteries such as described below.

(3) Misusing the batteries may cause them to overheat or ignite and cause serious injuries. Make sure to follow the safety rules listed below:

- Never short-circuit the battery terminals
- Do not reverse the polarity
- Do not overcharge or over-discharge
- Respect the voltage range given in this manual.
- Do not open the battery or modules
- Do not disassemble the unit
- Do not use the unit without its electronic management system
- Do not subject to excessive mechanical stress
- Do not expose the unit to water or condensation
- Install the batteries in an area compatible with pollution level 2 according to EN 60664-1 (typical of office or laboratory environments).

(4) Do not place the batteries on or near fires or other high-temperature locations (> 70°C). Doing so may cause the batteries to overheat or ignite. Using the batteries in this manner may also result in a loss of performance and a shortened life expectancy.

(5) Immediately disconnect the batteries if, during operation, they emit an unusual smell, feel hot, change shape, or appear abnormal in any other way. Contact SAFT if any of these problems are observed.

(6) Prior to use the batteries, read carefully the Material Safety Data Sheet supplied with the batteries.

(7) The battery systems must be used with the Synerion 48E modules described in paragraph 2. Saft does not assure the behavior and the safety of the battery system if another module is used.

(8) In case of contactor stuck closed (Alarm 18 rising), stop immediately the battery charge or discharge.

TABLE OF CONTENTS

LIST OF FIGURES

1. INTRODUCTION

This document contains the operating rules of the SAFT Lithium-Ion battery unit model for Stationary Batteries 9 modules 504V max with limitation at 486V P/N 777308-00.

1.1. Applicability

This document describes functionalities and behaviour implemented in the BMM software version **0.65 revH.**

1.2. Acronyms

Acronym	Definition
Application	Equipment connected to the battery and consuming current from or feeding current to the battery
BMM	Battery Module Management
BMU	Battery Management Unit
CAN	Controlled Area Network
EDU	Electro-technical Device Unit
EMS	Energy Management System
EOL	End Of Life
HMI	Human to Machine Interface
HVIL	High Voltage Interlock Loop
I/O	Input / output signal
IMD	Maximum current allowed in discharge
IMR	Maximum current allowed in charge
Li-ion	Lithium Ion
MBMM	Master Battery Monitoring Module
N/A	Not Applicable
N/U	Not Used
PBIT	Power on Built In self Test
PoffBIT	Power off Built In self Test
P/N	Part Number
SMU	Safety Monitoring Unit
SOC	State Of Charge (Battery)
SOH	State Of Health (Battery)
TBC	To Be Confirmed

1.3. Symbols

Direct current

Caution

Caution, possibility of electric shocks

Li-ion recycling

1.4. Referenced documents

A reference document is used as a basis of work. Its strict application cannot be required.

🕮 : Document title	Emitter	Reference	Rev
[RD1] CAN OPEN dictionary for BMS	SAFT	SDU/SEL/DH 09-0974	L
[RD2] Diagnostic WinBMS Software User Manual	SAFT	User_Manual_WinBMS_11-1093	7
[RD3] Uninterruptible power systems Electromagnetic compatibility (EMC) requirements	-	CEI_62040_2 EN61000-6-2 EN61000-6-3	2006_06 2006_01 2007_03
[RD4] Electronic equipment for use in power installations	-	NF_EN_50178	1999_10
[RD5] Transport of Lithium batteries	-	UN 3480	-

2. UNPACKING AND INSPECTION

Each module is packed separately. The BMM, connection kit and documentation are packed together.
Check the packing material for any damages before accepting delivery from the carrier. If there is any sign of damage, report it to the carrier and to SAFT and make a “certified letter with acknowledgement” to the transporter.

For each battery system, ensure that the following parts are delivered:

- **9 Synerion 48E modules / 48V nominal / 45Ah: P/N 774842-00**

Figure 1: Synerion 48E module

- **1 BMM: P/N 776354-01**

Figure 2: Battery Management System

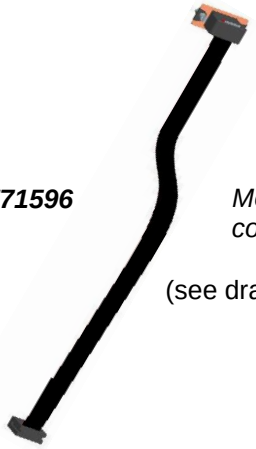
- **Connection Kit:**
  - Power cable to connect modules and BMM (see drawing on Appendix III):

Figure 3: Power cable connection for 9 modules battery

  - Communication ribbon cables kit to connect modules and BMM:

Termination connection: ***P/N 771611***
- 1 per battery
(see drawing on Appendix IV)

Inter-module connection: ***P/N 771596***
- 8 for 532V battery
(see drawing on Appendix V)



Module to BMM connection: ***P/N 772872***
- 1 per battery
(see drawing on Appendix VI)

Figure 4: Communication ribbon cables

- **1 CDROM or USB key with SAFT diagnostic software (DiagWinBMS) and its User Manual**

It is advised to save the original packaging for reuse in case of later shipment.

2.1. Battery characteristics

The table below gives the main characteristics of the battery and BMM:

Battery electrical characteristics	**9 modules**	**Unit**
Nominal voltage	432	V
Maximum voltage	486	V
Minimum voltage	378	V
Minimum capacity (C/3, 25°C)	31.5	Ah
Maximum continuous charge current allowed (normal charge)		-
@ +35°C	29	A
@ +20°C	20	A
@ 0°C	11	A
@ -20°C	5	A
Maximum discharge current		
- Continuous	50	A
- 30s pulse	60	A
Insulation:	Compliant with EN 50178:	-
- pollution degree	- Overvoltage category I, pollution d°2	-
- insulation resistor @1000Vdc	- > 1	MOhm
- dielectric	- 1350Veff_AC / 50Hz	Vrms
BMM electrical characteristics		
Power supply characteristics	TBTS compliant with CEI_60950-1	
- touch current	< 0.25	mA
- voltage	24 $^{+}/_{-}$ 5	Vdc
- maximum current	1	A
- maximum power	24	W
- ripple	< 100	mV
- inrush current	700	mA
Insulation:	Compliant with EN 50178:	-
- pollution degree	Overvoltage category I, pollution d°2	-
- insulation resistor @1000Vdc	> 1	MOhm
- dielectric	1350Veff_AC / 50Hz	Vrms
Maximum current		
- Continuous	50	A
- 30s pulse (circuit opened after 30s)	60	A
Mechanical characteristics		
Unit battery module Width	445	mm
Unit battery module Depth	293	mm
Unit battery module Height	131	mm
Unit battery module Weight	18.5	kg
BMM Width	420	mm
BMM Depth	372	mm
BMM Height	92	mm
BMM Weight	4.01	kg
Protection Index	IP 20	-
General characteristics		
Operating battery temperature range (derating between 50°C and	-20 to +60	°C

60°C)		
Storage battery temperature range	-20 to +75	°C
Recommended storage battery temperature range (to preserve lifetime)	< +40	°C
Recommended storage BMM temperature range (to preserve lifetime)	-20 to +65	°C
Maximum altitude	2000	m
Environmental conditions	Interior without air conditioning, not condensing: B type following EN50178-1:1997	-
- Environment temperature	+5 to +40	°C
- Environment humidity	5 to 85	%
EMC	Following EN 62040-2: C3 for immunity, C1 for emissions	-
- Electrostatic discharge	$^{+}/_{-}$ 4kV contact - $^{+}/_{-}$ 8kV air	-
- Fast transient-Burst	2kV - 5kHz - Capacitive clamp	-
- Magnetic field	30A/m - 50Hz	-
- Radiated immunity	10V/m from 80 to 1000MHz - 80% AM (1kHz)	-
- Radiated emission	30 dBµV/m from 30 to 230MHz at 10m 37 dBµV/m from 230 to 1000MHz at 10m	-
Vibration	IEC 62093: 2g from 10hz to 150Hz	-
Shocks	IEC 62093: 15g, 11ms	-
Transport of Lithium batteries	UN 3480	-

3. GENERAL DESCRIPTION OF THE BATTERY SYSTEM

3.1. Synoptic

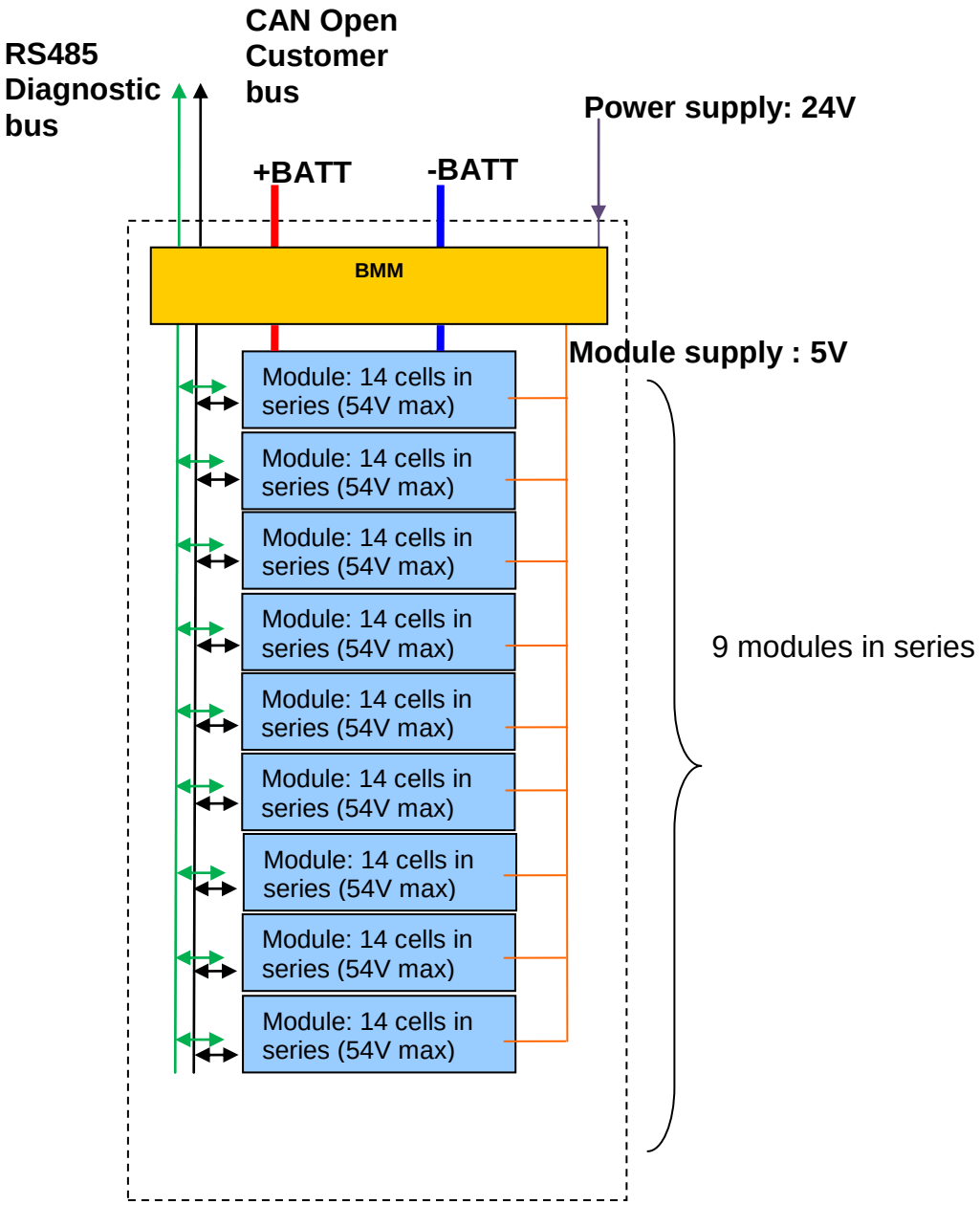


Figure 5: Battery synoptic

3.2. Battery system

Li-ion battery is made of:

- An assembly of Li-ion modules connected in series.
- A Battery Management Module (BMM) which is the interface between battery and customer application.

An external power supply (24V) is needed to supply the BMM (see §2.1 for characteristics).

3.2.1. Li-ion Modules

Li-ion modules contain 14 cells connected in series.
A 200A fuse protects the module against short-circuit (**fuse not replaceable**).

Each module contains an electronic board (named SMU) which monitors and sends the following information to the BMM:

- 1 temperature measurement
- 14 cell voltages measurement
- 1 emergency signal (digital line) driven by redundant hardware channel. This signal is active in case of:
    - Cell over charge
    - Cell over discharge
    - Module over temperature
    - Module switched OFF

The electronic board manages also the cells balancing and the data timestamp.

3.2.2. BMM

The Battery Management Module (BMM) optimizes the battery performances and protects the battery against extreme situations (over charge, over discharge, over temperature). The BMM monitors all modules and communicates with the customer application to manage battery cycles (charge and discharge).

The BMM functions are:

- Management of SMU boards (calculation of the data from the modules)
- Measurement of the battery current
- Battery over current protection (by 50A fuse)
- Protection of the battery unit
- Communication with the EMS via CAN Open bus
- Diagnostic functions using a RS485 bus

3.3. HMI

The figure below shows the BMM interface:

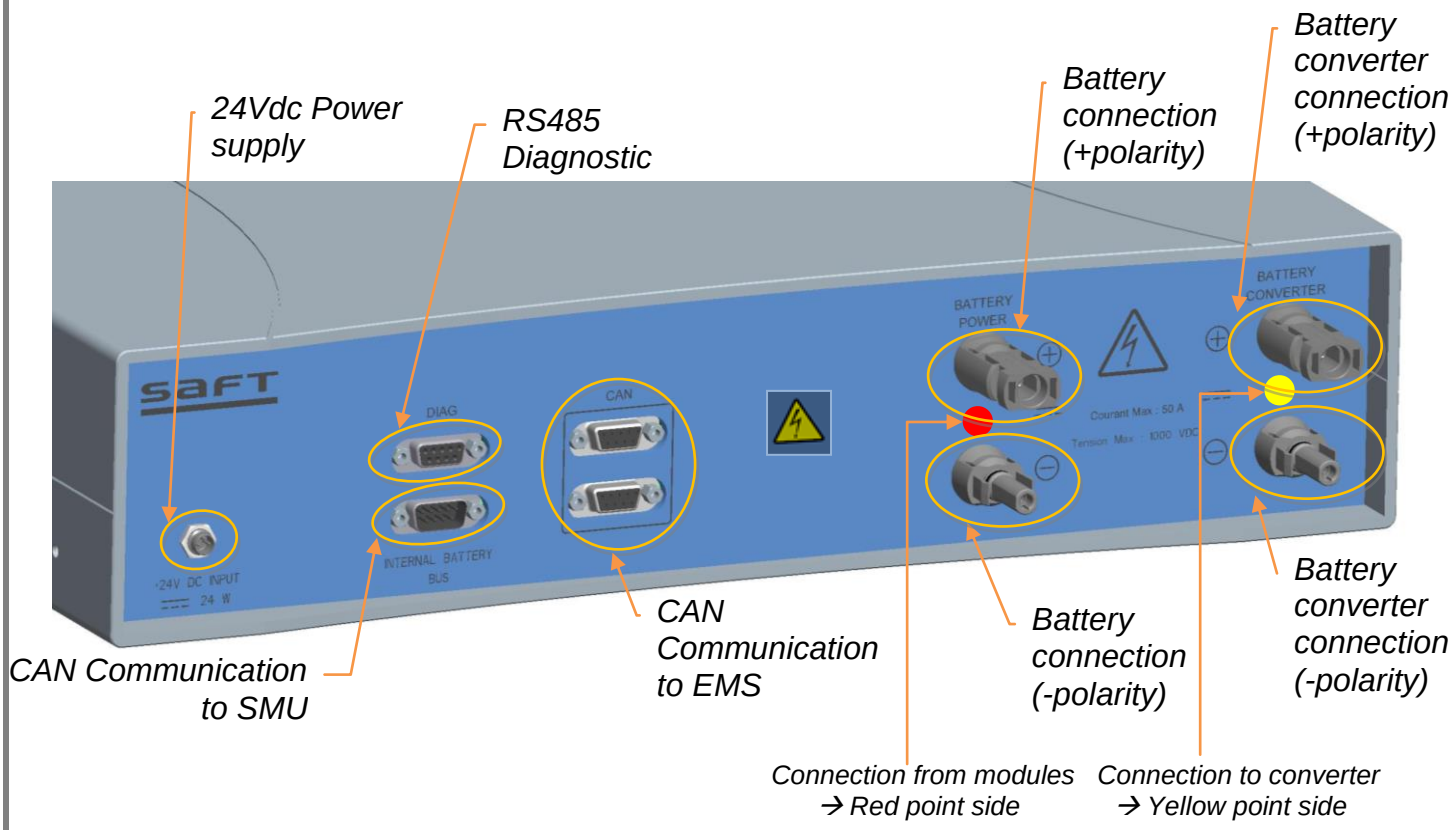


Figure 6: BMM HMI

Installation
The cabinet in which the battery will be installed must be in closed electrical enclosure according to chapter 5.2.7 of EN50178-1:1999 standard.

If the product is brought to the installation location from a cold environment, condensation may form and this may lead to damage the electronic equipment. Before commissioning, the product must be dry. Wait 2 hours after transportation before installing the product.

3.4. Assembly installation

The modules must be stacked horizontally. They must be protect against external aggression (shock, piercing, short-circuit, water, falling of objects, pollution dust,…).

If the battery is not installed inside a closed cabinet, no flammable material must be stored near the battery (2 meters radius).

3.5. Battery start-up

The start-up is done by supplying the BMM with 24VDC. The BMM immediately proceeds to its self-test by testing its internal functions.

 During self-test, the battery will be connected. Beware of high voltage**.**

The battery communicates by CAN-Open protocol. At start-up, the CAN-Open node is in *Pre-operational State*: the BMM waits for a *Start_Remote_Node* frame (with CAN-Open NMT service) to go to *Operational State*. After that, the BMM is operational and sends continuously messages on CAN Open bus.
Then the EMS must authorize the contactor closing by sending a command by CAN (CAN Open Object 2055 on RPDO2): at this stage, EMS can use the battery properly.

3.6. Battery shutdown

To shut-down the battery, disconnect the 24VDC supply voltage (battery contactor opens within 5s and the connections has no voltage anymore). Before opening, be sure that there is no current to prevent damage to the contactor.

3.7. Gas exhaust

In case of abusive situations, electrochemical cells may open and dissipate hot gases under pressure. Battery must be located in a room, where people are not staying permanently (with ventilation if the room volume is less than $25m^3$).

3.8. Electrical interfaces

3.8.1. Power connection

Power connectors used for Battery and Inverter (-polarity) connections: PV-ADBP4/6 from Multi-contact.

Figure 7: -polarity power connector

Power connectors used for Battery and Inverter (+polarity) connections: PV-ADSP4/6 from Multi-contact.

Figure 8: +polarity power connector

3.8.2. Electrical connection

The modules must be connected only after their installation: connect them together and to the BMM, as shown in the drawing below, with the red power cable delivered with module.

Then, connect the modules together and to the BMM with the three kinds of cables delivered with the battery (see §2):

- Inter-module ribbon cables
- Module to BMM ribbon cable
- Termination connector ribbon cable

Then, connect inverter to the BMM “Battery converter” connectors.

Never start the battery system without connecting battery cables and inverter cables to the BMM.
Never connect a charger with a voltage below the battery voltage.

Note: the following picture represents the battery connection (only 5 on 9 modules are represented).

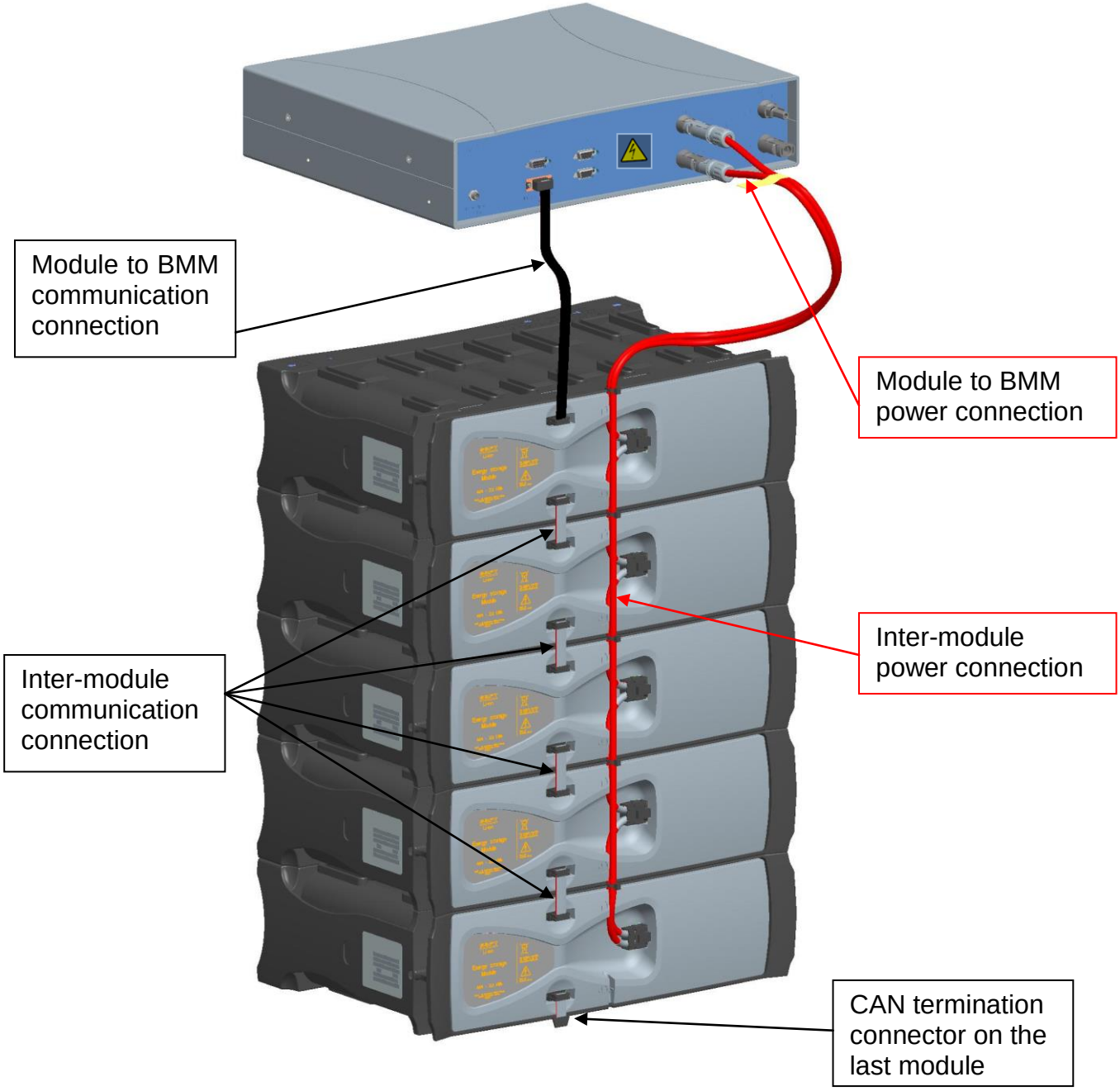


Figure 9: Battery connection

⚠ Don’t short-circuit the module terminals.

⚠ The battery circuit must be kept insulated from the ground. Battery polarities must **NOT** be connected to any part of the chassis or other conductive part.

⚠ Never disconnect power connections under load.

3.8.3. Communication connector

Two Sub-D9 female connectors are used for CAN Open communication bus: one or the other connector could be used (both connectors are pin to pin connected).

We recommend using a cable less than 3 meters length for CAN communication with BMM (cable shielded with 120Ω adaptation).

These connectors are insulated from High voltage by a protective separation.

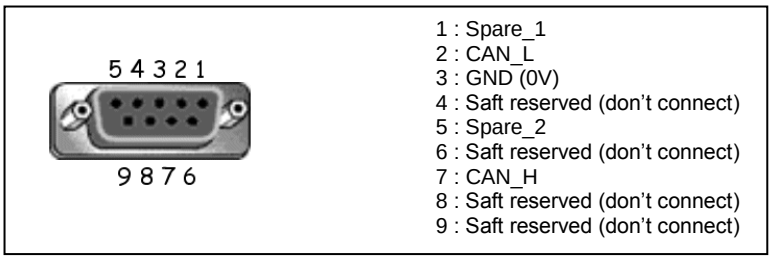


Figure 10: CAN connector

Nota: Spare_1 and Spare_2 pins are used for power supply gateway. The maximum current must be 1A.

3.8.4. Power supply connector

A three contacts male connector (ref. 1440070 from Phoenix Contact) is used to supply the BMM. See §2.1 for BMM power supply characteristics.

Compatible with ref. 1681172 or 1506888 from Phoenix Contact.

This connector is insulated from High voltage by a protective separation.

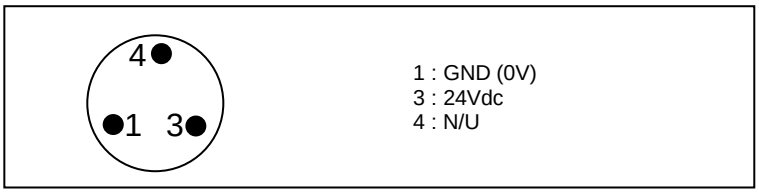


Figure 11: Power Supply connector

The 24V external power supply must be protected against overcurrent higher than 2A.

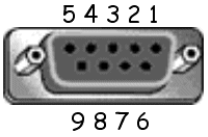
3.8.5. Earth connection

The 24V power supply of the BMM circuit must be earthed.

3.8.6. Diagnostic interface

One Sub-D9 female connectors is used for RS485 diagnostic bus.

This connector is insulated from High voltage by a protective separation.



1 : RS-485_A (+)
2 : RS-485_B (-)
3 : CAN_L
4 : CAN_H
5 : GND (0V)
6 : 24Vdc (Power Supply)
7 : N/U
8 : CAN_L_SMU (Saft only)
9 : CAN_H_SMU (Saft only)

Figure 12: Diagnostic connector

4. BATTERY MANAGEMENT AND OPERATING INSTRUCTIONS

4.1. General principle

Charge and discharge of the Li-ion battery must be monitored and managed with respect to physical parameters such as cell voltages, battery current and module temperature. This management is performed by the BMU board inside the BMM, which runs algorithms and monitors the battery.

The concept is to use the features of the converter to perform the battery management. The application will receive data from the battery via CAN Open bus and must take the appropriate actions.

Safety functions will still be ensured by the BMM.

During the use of the battery, if one critical physical parameter goes out of the acceptable range, the battery contactor is opened and the battery goes in *SAFE* mode (see §4.5 for mode description), the battery will go back in *STANDBY* mode if critical fault is reset (software reset or hardware reset). If the customer continue to send the authorization bit to close the contactor at 1, the battery system will go directly in *NOMINAL* mode (see §5.14.2).

Critical physical parameters are:

- Module temperature
- Cell voltage
- Current versus over current protection

The determination of the acceptable ranges of values for the temperature and the cell voltages is explained below at §4.2.2, §4.2.3 and §4.2.4.

4.2. Safety functions

4.2.1. Over charge protection

Two kinds of protection are used to prevent over charge: regarding cells voltage, BMM could open the contactor.

The two kinds of protection are:

- Cell over voltage first level: one cell voltage > 3,86V
- Cell over voltage second level (redundant): one cell voltage > 4,23V

4.2.2. Over-discharge protection

Two kinds of protection are used to prevent over discharge: regarding cells voltage, BMM could open the contactor.

The two kinds of protection are:

- Cell under voltage first level: one cell voltage < 2.5V
- Cell under voltage second level (redundant): one cell voltage < 2V

4.2.3. Over temperature protection

Two kinds of protection are used to prevent over temperature: regarding module temperature, BMM could open the contactor.

The two kinds of protection are:

- Module over temperature first level: one module temperature > 60°C
- Module over temperature second level (redundant): one module temperature > 70°C

4.2.4. Over current protection

Some kinds of protection are used to protect battery against over current and to prevent cells ageing by optimizing charge and discharge current.

The protections are:

- A 50A fuse inside BMM will protect battery in case of short-circuit
- A software over current protection will open contactor if current is > 55A during 40s.
- A software protection will open contactor if current is > MAX(1.1 x IMD ; 55A) during 30s.
- A software protection will open contactor if current is > MAX(1.6 x IMR ; 55A) during 30s.

To prevent cells ageing, charge and discharge current must be optimized following IMD_C and IMR_C values. These values are calculated depending on SOC, cell voltage, module temperature and instantaneous current. The values are given by the BMM on CAN-open bus.

4.3. Communication

CAN Open communication bus:

- Baud rate: 250kBd
- Standard CAN (11 bits identifier)
- 120Ω resistor terminal not connected inside the BMM
- For objects dictionary, see document [RD2].

Nota: as the 120Ω resistor terminal is not connected inside the BMM, it is the responsibility of user to integrate it in the CAN bus.

RS485 diagnostic bus:

- Use “DiagWinBMS” software (at least revision 2.9.5).
- Refer to document [RD2] and §4.6.8.

One dedicated software (DiagWinBMS) installed on a computer (compatible using an external USB/RS485 converter) is used to:

- Monitor the battery
- Configure battery parameters

4.4. Operation during storage & maintenance

During storage SMU in each module will wake-up periodically (every 1 hour) to measure cells voltage and temperature.

SMU board will also calculate SOC and will update the static SOH. Static SOH is calculated depending on the time the module spent at different SOC and at different temperature.

4.5. Operational states

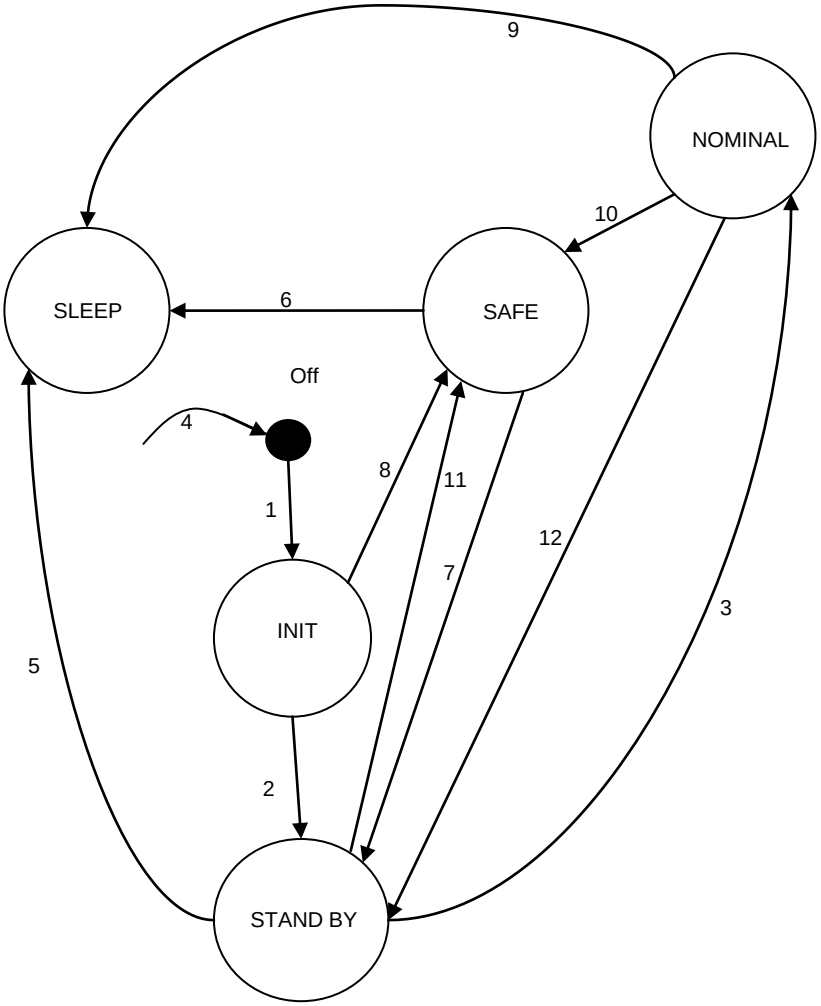


Figure 13: Battery modes

Off: in this mode, BMU is not supplied. Thus, the battery is not supervised by the BMM.

Init: in this mode, the battery is unavailable, meaning it is disconnected from the overall system. The BMU proceeds to its internal tests:

- PBIT self-test (BMU memory Read/Write, …)
- Software initialization
- Contactor test

If the self-test is ok, the BMM will go in *STANDBY* state.
If the self-test is not ok, the BMM will go in *SAFE* state.

The self-test duration is roughly 6 seconds.

Stand-by: in this mode, the battery pack is not yet operating. BMU is waiting from EMS for the permission to close the contactor (via the CAN Open Bus).

Nominal: system is running. The battery is available for discharge and recharge according to the IMD, IMR, VMD and VMR values. Under these conditions, the BMU performs several functions (such as monitoring and protection of the battery modules, communication with the various modules, managing the contactors and managing battery cell balancing).

Sleep: this state places the electronic devices inside modules (SMU) and BMM in low power consumption: the contactor is open and there is no possibility to charge and discharge battery. However, CAN communication is still available with BMM.

Safe: two kinds of faults can occur: warnings and alarms. At warning level, the battery system stays in nominal mode and only informs about the fault code. If a fault occurs with an alarm level, the BMM will open the contactor.

Thus, the battery is isolated from the customer application because it has gone out of the safety perimeter. The charging and discharging operation are not permitted. However, the BMM remains operational (powered up and awake).

A “hardware reset” or a “software reset” implies the BMU going into Nominal mode again (assuming the fault is no more present). Hardware reset corresponds to ON/OFF/ON of the 24V power supply that reset the alarm. Software reset corresponds either to client reset by CAN Open (alarms status are sent to client who can or not reset them) or if the fault condition is no more present for some kind of alarms.

Transition between modes:

#	States transition	Conditions
1	Off -> Init	BMM is supplied with 24Vdc
2	Init -> Stand-by	Initialization ends successfully
3	Stand-by -> Nominal	Contactor closing demand by EMS (CAN Open request)
4	Any states -> Off	Power supply is switched Off
5	Stand-by -> Sleep	One Cell voltage < 3.35V during 2 hours
6	Safe -> Sleep	One Cell voltage < 3.35V during 2 hours
7	Safe -> Stand-by	Critical fault condition reset occurred
8	Init -> Safe	Failure of BMU PBIT
9	Nominal -> Sleep	One Cell voltage < 3.35V during 2 hours
10	Nominal -> Safe	Critical fault condition appears
11	Stand-by -> Safe	Critical fault condition appears
12	Nominal -> Stand-by	Contactor opening demand by EMS (CAN Open request)

4.6. Precharge

The battery system does not implement a precharge function. If a precharge function is needed from customer side to charge capacitors, this precharge has to be activated before closing the battery contactor. Then, the customer has to allow the closing of the battery contactor within 300 seconds after the start-up of the precharge. Otherwise, the alarm 18 « Main contactor status not expected (closed) » may appear.

4.7. Battery charging

The BMM sends to the application via the CAN Open bus the maximum continuous charge current allowed (IMR_C) and the instantaneous charge current allowed (IMR). Exceeding IMR value might lead to preliminary aging.

During charge, the BMM controls the battery physical parameters (cell voltages, current and temperature) and informs the application about some warning first and alarms then.
IMR / IMR_C depend on 2 parameters:

- Battery temperature
- Battery SOC: IMR_C is decreased to 50% between 85% SOC to 100% SOC

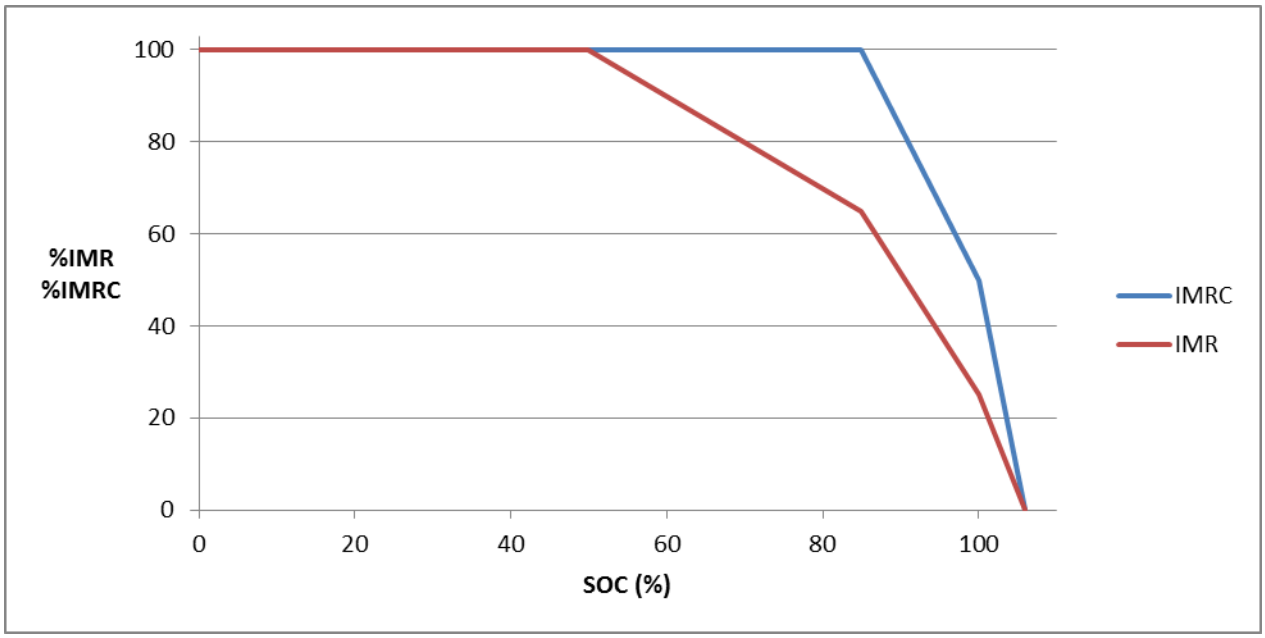


Figure 14: IMR & IMR_C versus SOC profile

4.8. Charge profile description

The charge consists in a CC/CV (Constant Current / Constant Voltage) charge type.

The maximum continuous charge current **IMR_C** and the maximum dynamic charge current **IMR** depend on the temperature. Both of them are sent on CAN bus.

The maximum charge voltage **VMR** is sent on CAN bus by the BMM. Nevertheless, it is possible to charge the module with a lower value; the available capacity will be therefore smaller.

The battery can be let in “floating” charge during phase 3.

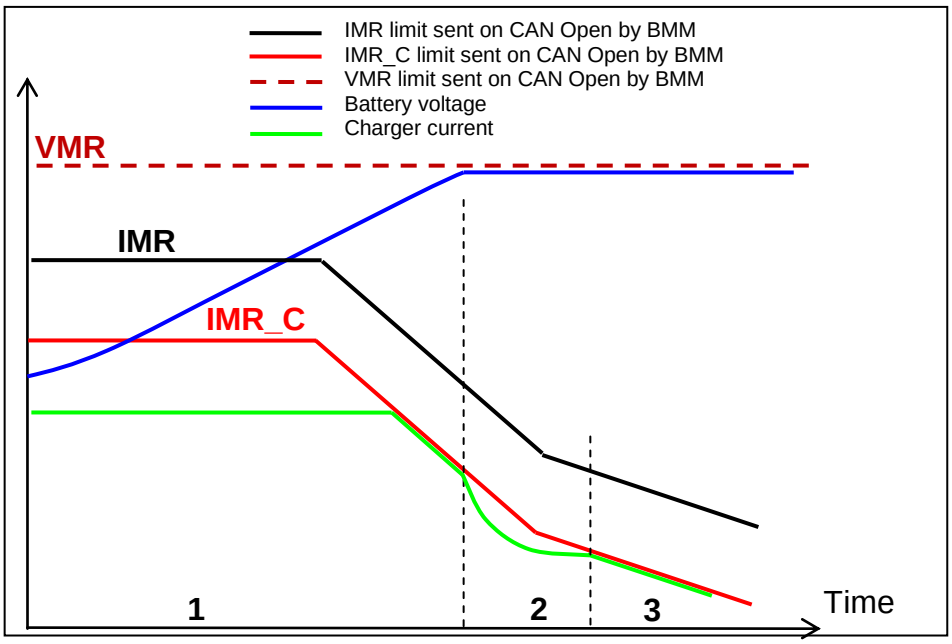


Figure 15: Battery charge profile

The following profile gives the recommended maximum currents for the normal charging profile as a function of temperature, for a VL45E cell. If the charge current is above IMR_C and below IMR, an algorithm is running and decreases the IMR current until IMR_C value (the slope will depend on the current value and the time above the limit; about 30s for high current). The contactor will open if the current is upper the MAX (IMR x 1.6 ; 55A) during 30s.

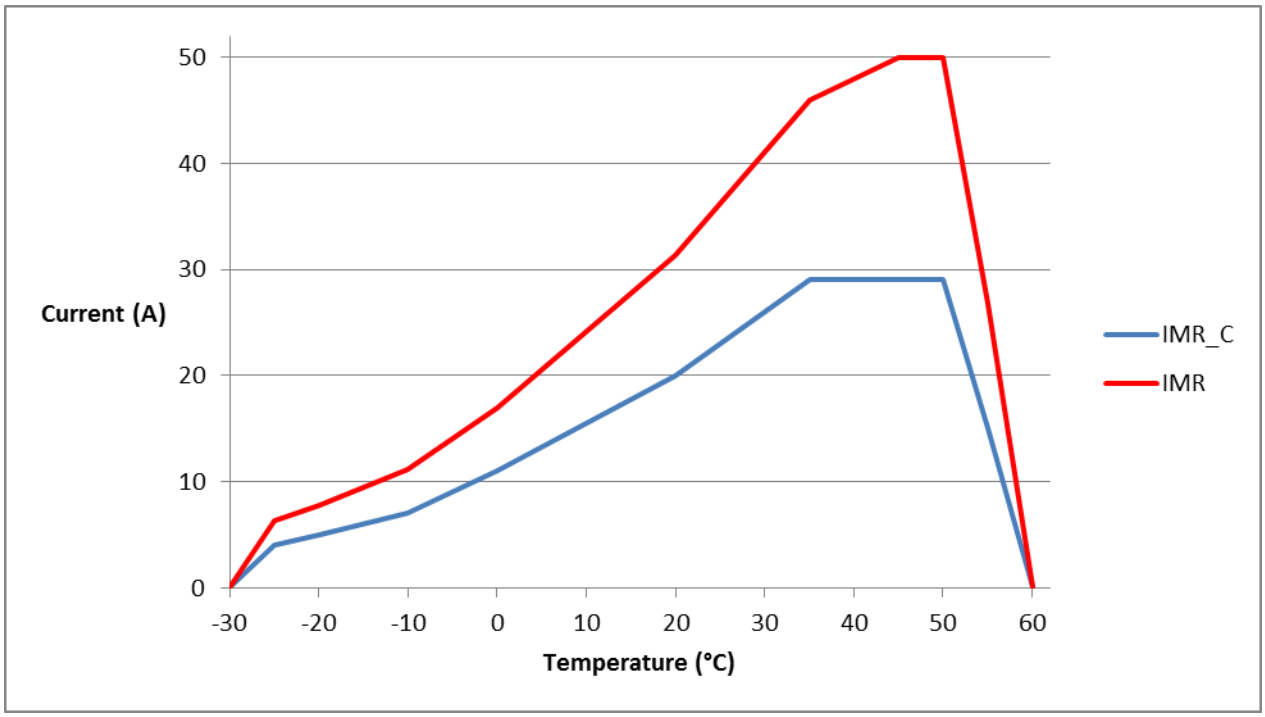


Figure 16: VL45E normal rate charge profile (IMR & IMR_C vs T°C)

4.9. Battery discharging

During discharge, the BMU monitors the battery physical parameters (cell voltages, current and temperature) and informs the application via the CAN Open bus about the maximum current authorized for discharge (IMD) and the minimum voltage allowed for discharged (VMD), warning and alarms.
The BMU sends the IMD and VMD values on the CAN Open bus in real time.

IMD depends on 2 parameters:

- Battery temperature
- Battery SOC

It is important to note that this dependency is only made to ramp down the power in order to avoid a sudden opening of the battery contactor (see alarms description in in §16, Appendix III).

Nota: IMD will never exceed 50A continuous.

4.10. Complete discharge & sleep mode

When a full discharge has been performed, it is recommended to charge the battery immediately or, if not possible, to switch OFF the 24VDC supply in order to stop the internal consumption of battery electronics.

If the system is not switched OFF and if one cell voltage is below 3.325V during 2 hours (see §4.5), the BMM will automatically put the system in *SLEEP* state. To restart the system when it is in *SLEEP* state, send a RESET frame by CAN bus which is still alive.

In usage conditions, the discharge is limited to 2.7V on the first cell voltage reached: the BMM sends the corresponding warning fault code. If the discharge continues and if one cell voltage goes below 2.5V, a critical fault is sent and the battery contactor is opened (see §4.2.2).

If one cell is over-discharged (< 2V), the battery is out of order and SAFT shall be contacted. For lithium-ion technology, when the cell voltage reaches a very low value, the battery may be no longer operational. The alarm value includes tolerance, but under this limit the battery life cannot be guaranteed.

4.11. Alarms and warnings

The BMM sends on the CAN Open bus the code faults (warnings or alarms) to the application (see alarms description in §16, Appendix III).

For example, during a discharge if one cell reaches 2.7V, the BMM will send code fault and the converter has to stop the discharge. If the discharge continues and one cell reaches 2.5V, the BMU will open the battery contactor.

4.12. Balancing

The balancing of the cells consists in keeping the cell voltages homogeneous in all the system. The resistive balancing management circuit is integrated into the SMU module: it partially discharges any cells that exceed the specified voltage discrepancy with respect to their neighbours via bypass resistors.

The balancing is done only if the cells are unbalanced (voltage difference more than 30mV) and if their voltage is above 3.5V.

- When the battery system is working, the balancing is done at battery level by SMUs following BMM settings (overall cells voltages target) transmitted permanently via the internal CAN bus. Balancing operates in all states when the BMM is power supplied.
- During storage without BMM connected or with BMM powered-off, the balancing between cells is ensured at module level by the SMU board. After long storage, there might inter-module unbalanced that will be reduced as soon as the system is working.

4.13. Displayed information

N/A

4.14. Communication with application

For details, see document [RD1].

4.14.1. Data sent by BMM to EMS

All data objects are readable by EMS using SDO management protocol (client / server).
But some of data objects are also transmitted periodically by BMM inside TPDO CAN open frames (see document [RD1]).
TPDO frame interval is set at:

- TPDO1 = 100ms
- TPDO2 = 100ms
- TPDO3 = 100ms
- TPDO4 = 100ms

4.14.2. Data received by BMM from EMS

To work properly, BMM needs to receive data from EMS.

***Command to close the contactor*:**
At start-up, the battery is in *STANDBY* mode and is waiting for a RPDO CAN open message to go in *NOMINAL* mode (and close the contactor).
See above the RDPO2 CAN open frame to send:

	RPDO2 (ID: 0302_h)
Byte0	0 (N/U)
Byte1	0 (N/U)
Byte2	2055h: Battery contactors authorization
Byte3	0 (N/U)
Byte4	0 (N/U)
Byte5	0 (N/U)
Byte6	0 (N/U)
Byte7	0 (N/U)

Byte2 - Bit0: Authorization for Main+ contactor
- 0 = not authorized to close Main+ or command to open Main+ contactor
- 1 = authorized to close Main+ contactor

The 2055h object could also be written using SDO CAN open protocol.

 Authorization must be kept at 1 in order to keep the battery system in *NOMINAL* mode. If this bit is reset to 0, battery will open the contactor and go in *STANDBY* mode.

***Command to request a Self-test*:**
In order to authorize the battery contactor self-testing (opening / closing), EMS needs to send a command using SDO CAN open protocol. This command must be sent:

- Every 6 months or,
- When BMM requires a Self-test (object 2018: Byte6 – Bit0 of TPD03 set to 1).

When the BMM requires a Self-test via CAN, EMS has to request a Self-test in the following 24 hours. If not, BMM will set IMD and IMR values to 0 on CAN open bus (no charge or discharge authorized).
Then, if EMS always doesn't request a Self-test, 10 minutes after battery will open the contactor and go in *SAFE* mode with alarm 12 ("IBIT undone for 6 months"). The only way to restart the battery is to switch OFF and ON the battery power supply.

 Before requesting a Self-test, EMS must open the battery converter. After self-test completion, BMU will go in *STANDBY* mode and wait for contactor closing authorization.

To request a Self-test, Bit0 of object 2054h must be set to 1: the contactor self-test is starting on rising edge of this bit. After the test, don't forget to put this bit to 0 before a contactor closing request.

For details, see document [RD1].

***Time stamp object*:**
In order to time stamp data inside the black box, "Time stamp" object (1012h) need to be sent at least one time at each BMM start-up.

4.15. SOH and EOL definitions

SOH is the battery State Of Health in %.
EOL is the battery End Of Life.

For a new battery, SOH is equal to 100%.
The SOH is equal to 0% when the battery has reached its EOL criteria.
The end of life criteria is based on a capacity loss: it is set at 20% loss of initial capacity.
This value is given by CAN bus in the dedicated object 2036h as indication.
It is not taken in account in SOC and IMD/IMR calculations.

4.16. SOC definitions

"SOC" (CAN open object 2026h) is the battery state of charge calculated according to:

- Cells voltages
- Coulomb-metry
- Battery temperature

The value is smoothened to prevent from sudden jumps that may be caused by:

- A change of the temperature range
- Recalibration on open cell voltage a low current rate
- Cell voltage accuracy

The old SOC CAN open object 2025h (SOC_without_SOH) given in TPDO4 sub-index 5 is forced to 0 and no longer usable.

5. COMMISSIONING AFTER LONG STORAGE

During storage, the battery cells have a natural self-discharged that is heterogeneous. The balancing is ensured automatically by SMU boards, but only at a module level (not battery level).

An unbalanced battery affects its performance. Of course the battery system is operational but the autonomy is not at full performance during the first days. For example, a difference of 100mV between minimum and maximum cells' voltages minimizes by 15% its capacity. Battery performance is at its maximum when the balancing is done at a full charge (100% SOC).

The balancing duration is depending on the voltage difference between the cells: balancing efficiency is 25mV per day for VL45E, in average (depending on cell voltage). For example: if a battery is stored during one year, the battery balancing can take up to 20 days.

The balancing can be considered as finished when the voltage difference is lower than 30mV.

Perform a full charge for 24h every 3 month keeps modules balanced each other and avoid a long time of balancing.

Before assembling modules after a long period of storage, it is advised to charge modules separately at the same voltage level before battery assembling in order to minimize the inter-module cells equalizing.

6. HANDLING & STORAGE OF THE BATTERY MODULES

This paragraph describes the handling and the storage of the battery or its components.

6.1. Handling

N/A

6.2. Storage

6.2.1. Storage location

It is recommended to store the battery **indoors** in a dry, cool location, lower than **+40°C** on open shelves in order to preserve the lifetime of the cells.

Store the BMM in a dry place, between -20°C and +65°C. There is no particular procedure for maintaining the BMM during storage.

6.2.2. Battery state of charge checking

At the voltage sent, the modules can be stored at least **4 months**.

After this period, recharge the module with an adapted equipment (see §6.2.3).

6.2.3. Battery recharge in storage

Modules can be recharged individually only with equipment that have communication capability with the module and that can protect the modules against fear events.

In case of modules stored at negative temperature, they have to be stored 24h inside an area with a temperature > 0°C prior to recharge them.

If a cell voltage drops below 2V, do not try to recharge the module and contact SAFT. Charging an over discharged module may lead to an uncontrolled heating.

Failing to strictly comply with the storage and maintenance recommendations voids the warranty.

7. MAINTENANCE

Except the voltage control during storage, no maintenance (cleaning, electrolyte filling…) is required on the battery modules. In case of malfunctioning or if the modules have been exposed to abnormal conditions (crushes, short-circuit, overcharge, overheat, electrolyte leakages on cells…), contact SAFT. Do not open the modules and BMM.

It is the responsibility of the customer to ensure that maintenance people have the skills to operate on high voltage systems.

It is strictly forbidden to open the unit prior to Saft's formal approval.

8. PACKAGING AND TRANSPORT

The lithium-ion batteries are restricted for transport according to UN Recommendations of Dangerous Goods Transportation (UN 3480 when shipped alone and UN3481 when shipped inside equipment). Packaging preparation for transport and shipment must comply with the appropriate applicable regulations such as IATA (Air), IMDG Code (Maritime), ADR (Road in Europe) rules.

This chapter intends to give an overview of the procedure but it is the responsibility of the customer to follows and stay informed of the last regulation evolutions. In addition, countries that are not part of the ADR (European road transport), IATA (International air transport) or IMDG (Sea transport) could have their own requirements.

8.1. Battery classification

Shipment name: **Lithium-Ion batteries**
UN classification: **UN3480 Class 9**

8.2. Training

People engaged in the transport of dangerous goods shall receive training in the contents of dangerous goods requirements commensurate with their responsibilities. Refer to UN regulations for more details.

8.3. Battery packing

The batteries must be transported in a packaging conforming to the UN regulations.

A completed package must display a Class 9 hazard label in addition to markings that identify the applicable proper shipping name (Lithium ion batteries) and UN number (3480).

It is advised to save the original packaging for reuse in case of later shipment.

8.4. Charging state for transportation

N/A

8.5. Document used for transportation

The following documents must be prepared for transportation:

- A shipper's Declaration for Dangerous Goods
- Safety instructions (SAFT use the MSDS NS 710 051)
- If transport by air and weight exceeding 35kg a copy of the approval by the state of the origin must accompany the consignment.
- If transport by air of a prototype or small series a copy of the approval by the state of the origin must accompany the consignment.

9. DISPOSAL

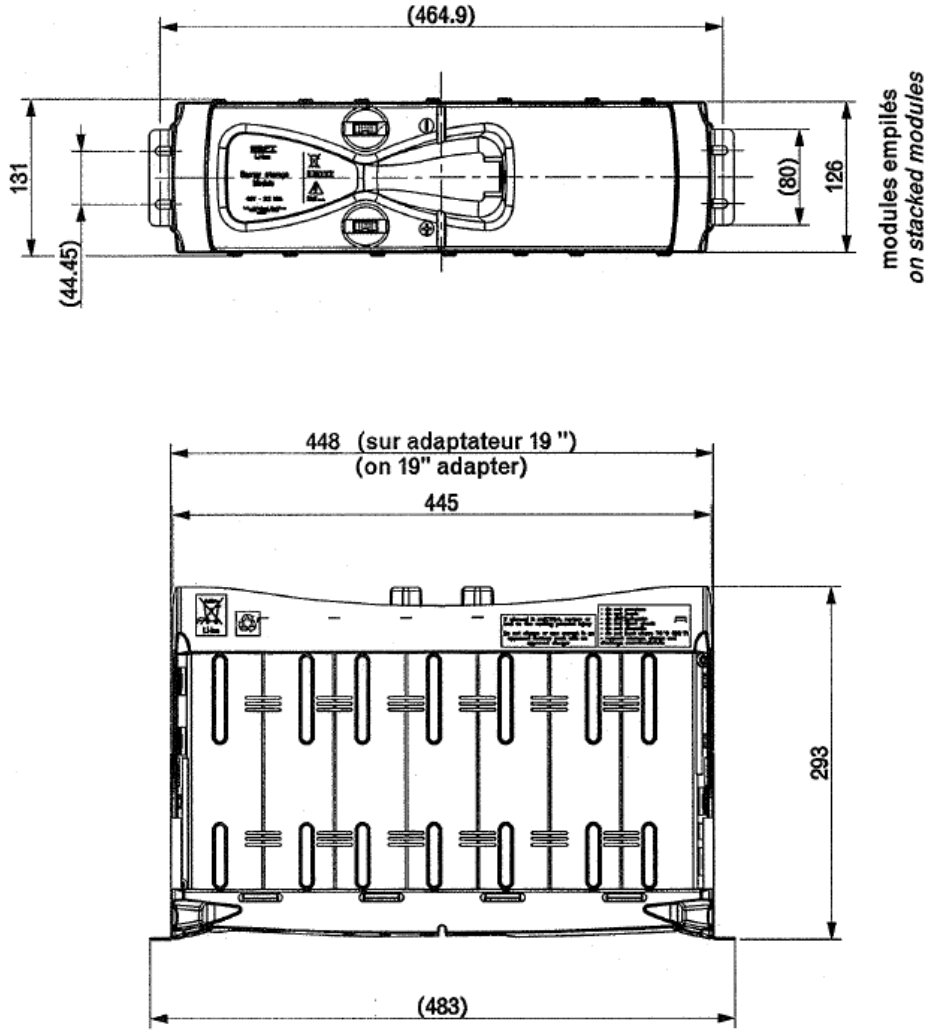
At the end of life, the battery pack has to be returned to a designed collecting centre for recycling. Please contact your Saft commercial support before shipment.

For transportation, apply following rules as a minimum:

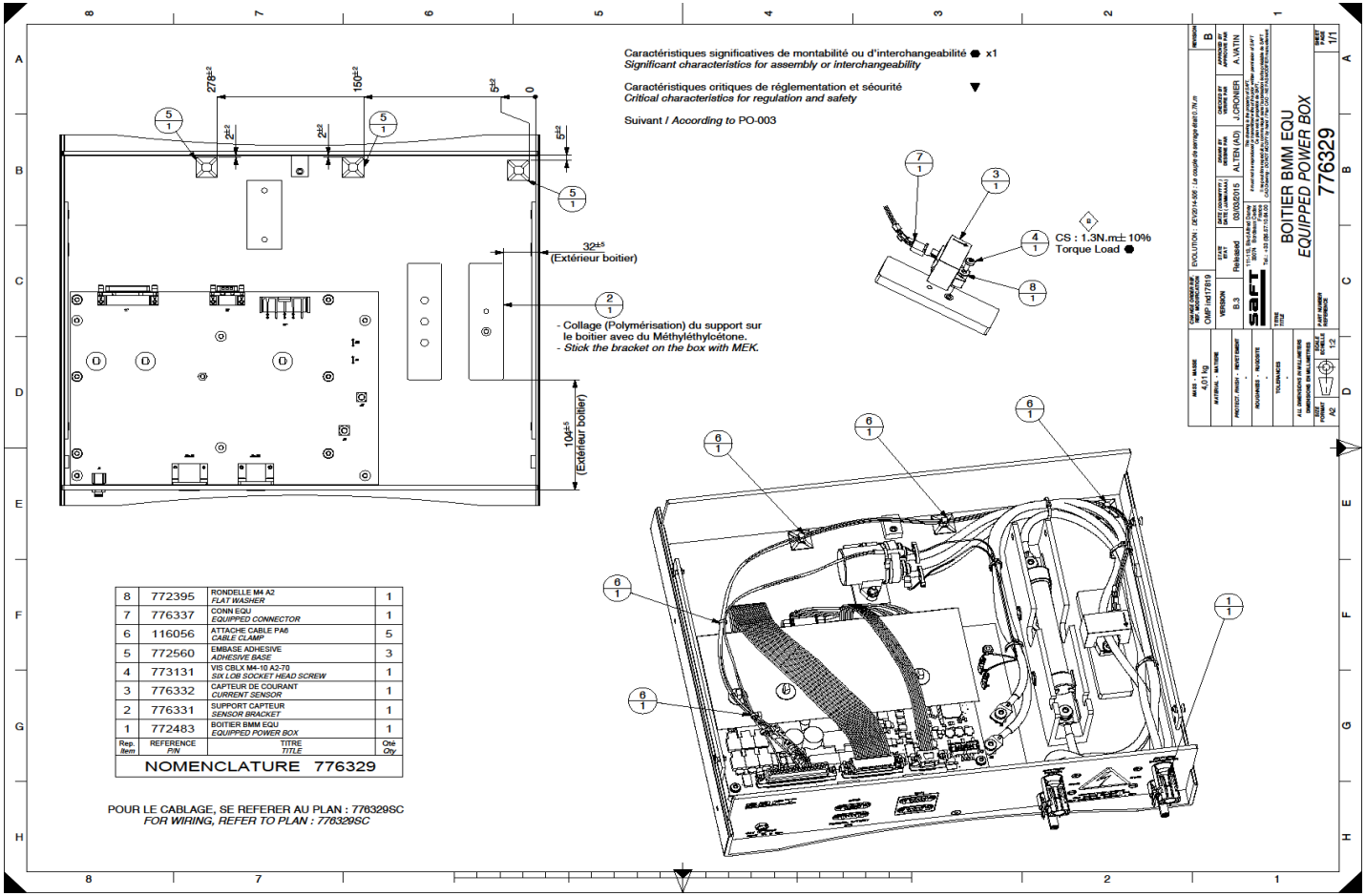
- discharge the unit(s)
- use a packaging conform to UN regulations
- pack the unit(s) in a way to avoid any risk of short-circuit between the terminals or the unit(s). It is recommended to individually pack each unit in a plastic bag
- do not store close to a heat point
- keep the packaging in a dry place
- use a strong packaging to handle the weight of the products
- design the packaging to avoid internal moves during transportation or handling
- correctly identify the packaging at the outside with the type and the quantity of unit(s).
- if possible, use the original packaging.

For updated disposal information, please connect to SAFT web site:
http://www.saftbatteries.com/group/sustainability/environnemental-responsibility

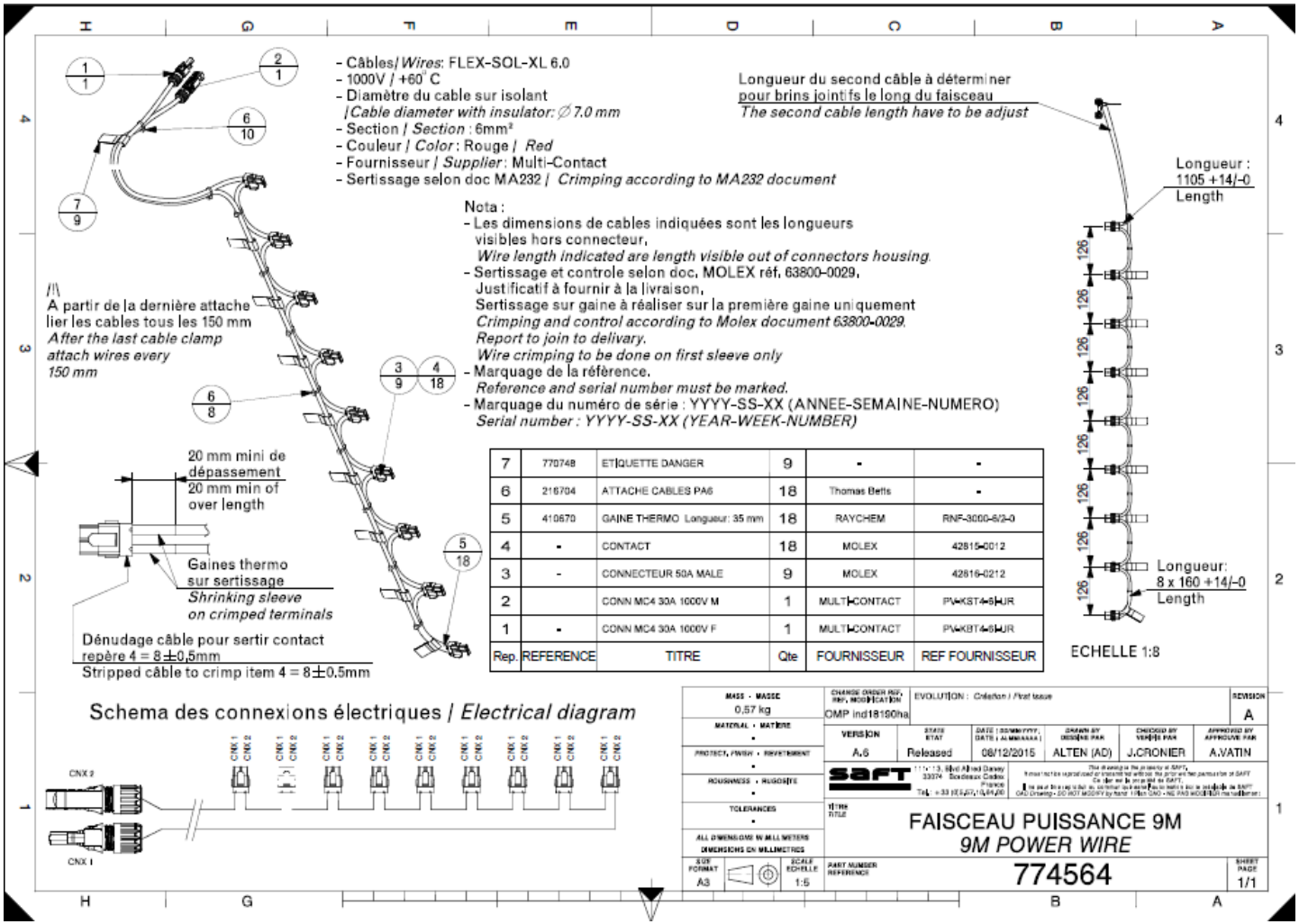
10. APPENDIX I: MODULE MECHANICAL DRAWING



11. APPENDIX II: BMM MECHANICAL DRAWING

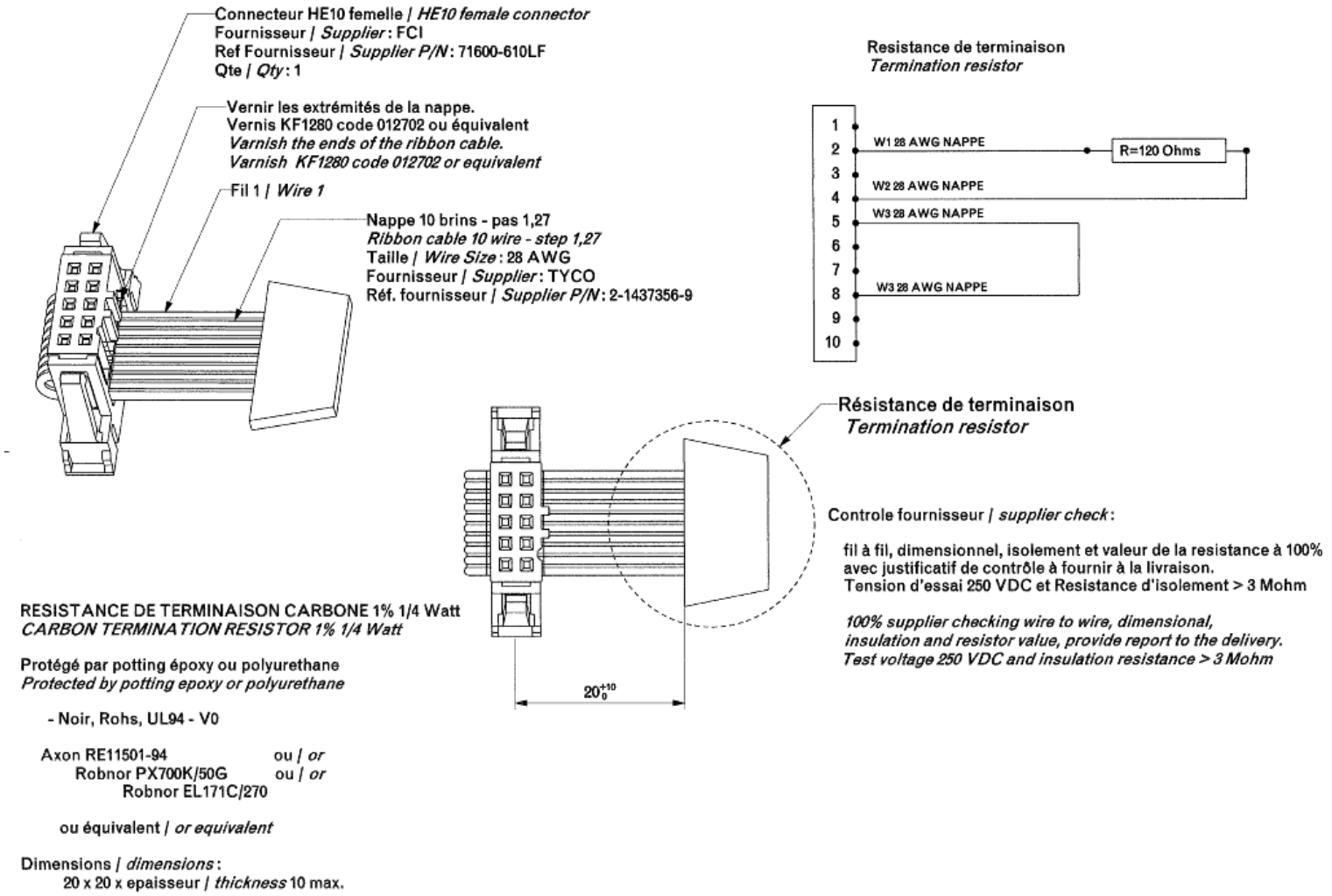


12. APPENDIX III: POWER CABLE CONNECTION DRAWING

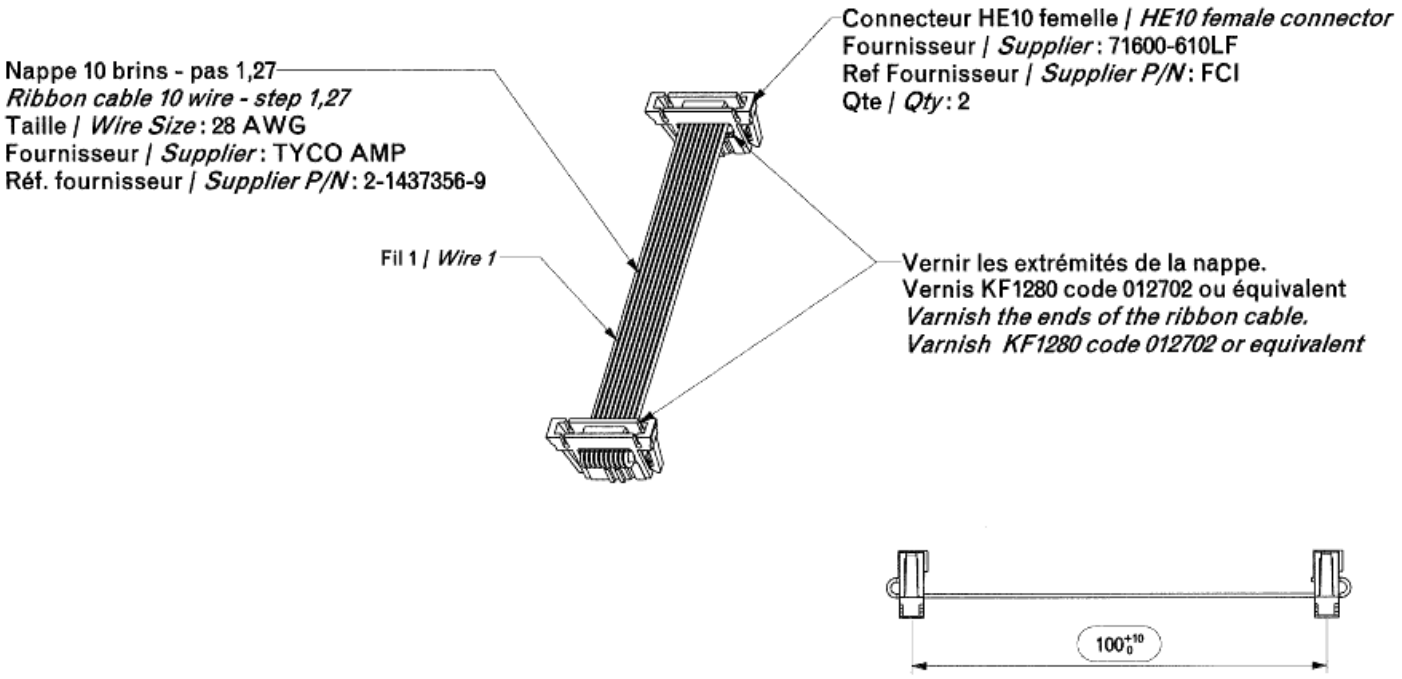


Rep.	REFERENCE	TITRE	Qte	FOURNISSEUR	REF FOURNISSEUR
7	770748	ETIQUETTE DANGER	9	-	-
6	216704	ATTACHE CABLES PA6	18	Thomas Betts	-
5	410670	GAINE THERMO Longueur: 35 mm	18	RAYCHEM	RNF-3000-6/2-0
4	-	CONTACT	18	MOLEX	42815-0012
3	-	CONNECTEUR 50A MALE	9	MOLEX	42816-0212
2		CONN MC4 30A 1000V M	1	MULTI-CONTACT	PV-KST4-6-UR
1	-	CONN MC4 30A 1000V F	1	MULTI-CONTACT	PV-KBT4-6-UR

13. APPENDIX IV: TERMINATION CONNECTION DRAWING (771611)



14. APPENDIX V: INTER MODULES CONNECTION DRAWING (771596)

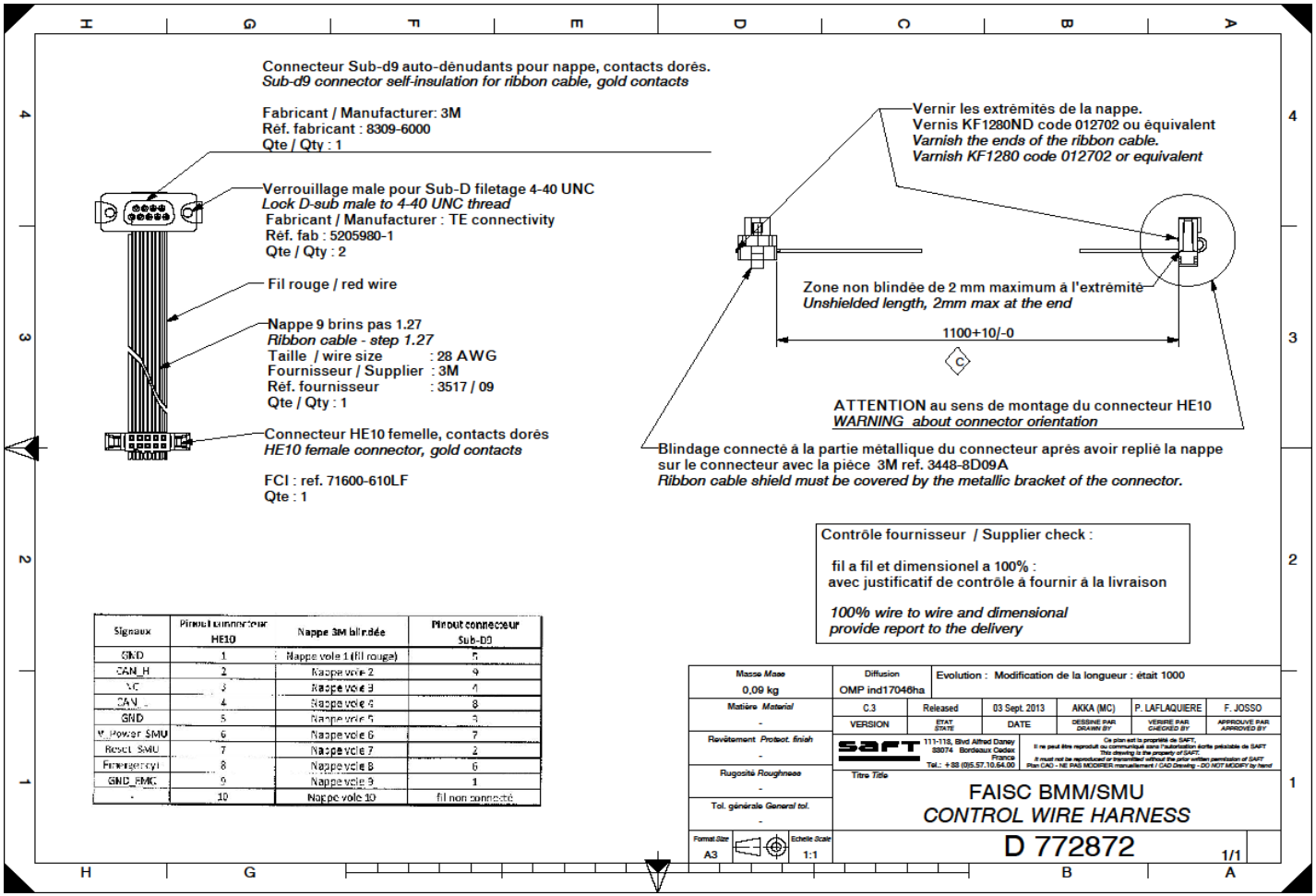


Controle fournisseur / *Supplier check* :

fil à fil et dimensionnel à 100%
avec justificatif de contrôle à fournir à la livraison.

100% supplier checking wire to wire and dimensional,
provide report to the delivery.

15. APPENDIX VI: MODULE TO BMM CONNECTION DRAWING (772872)



Signaux	Pinout connecteur HE10	Nappe 3M blindée	Pinout connecteur Sub-D9
GND	1	Nappe voie 1 (fil rouge)	5
CAN_H	2	Nappe voie 2	9
NC	3	Nappe voie 3	4
CAN_L	4	Nappe voie 4	8
GND	5	Nappe voie 5	3
V_Power SMU	6	Nappe voie 6	7
Reset SMU	7	Nappe voie 7	2
Emergency	8	Nappe voie 8	6
GND_BMC	9	Nappe voie 9	1
-	10	Nappe voie 10	fil non connecté

16. APPENDIX VII: FAULT CODES AND ALARM LIST OF THE BATTERY SYSTEM

Warnings are indicated in white color and Alarms are indicated in red color.

Fault n°	Description	Activation Condition	Reset level	SAFT action	Comments
1	Emergency alarm	Emergency redundant hardware channel is active during 3000ms	HW (ON/OFF)	Contactor opening and circuit-breaker opening	
2	Short circuit detected	Short circuit or overload detected (battery current > 55A during 40s	HW (ON/OFF) / Reset Client	Contactor opening and circuit-breaker opening	
3	A module is going over temperature	Module temperature > 50°C during 2s	HW (ON/OFF) / Reset Client / Auto-reset		
4	A module is over temperature	Module temperature > 60°C during 2s	HW (ON/OFF) / Reset Client / Auto-reset	Contactor opening	
5	A module is going under temperature	Module temperature < -20°C during 2s	HW (ON/OFF) / Reset Client / Auto-reset		
6	A module is under temperature	Module temperature < -25°C during 2s	HW (ON/OFF) / Reset Client / Auto-reset	Contactor opening	
7	A cell is going over charge	Cell voltage > 3.85V during 2s	HW (ON/OFF) / Reset Client / Auto-reset		
8	A cell is over charge	Cell voltage > 3.86V during 2s	HW (ON/OFF) / Reset Client / Auto-reset	Contactor opening	
9	A cell is going under voltage	Cell voltage < 2.7V during 2s	HW (ON/OFF) / Reset Client / Auto-reset		
10	A cell is under voltage	Cell voltage < 2.5V during 2s	HW (ON/OFF) / Reset Client	Contactor opening	
11	Cell voltage out of range	Cell voltage out of [1.5V ; 4.5V]	HW (ON/OFF) / Reset Client / Auto-reset	Contactor opening	
12	More T°C_module out of range than authorized	Loss of more than 5 module temperatures during 2s	HW (ON/OFF) / Reset Client / Auto-reset	Contactor opening	

14	CON+ voltage out of range	24Vdc Power Supply is greater than 27V or smaller than 17V for 1s	HW (ON/OFF) / Reset Client / Auto-reset		
15	High BMU supply	BMU supply voltage >32V during 0,5s	HW (ON/OFF) / Reset Client / Auto-reset		
16	BMU supply 12V too low	BMU supply voltage <8V during 0,5s	HW (ON/OFF) / Reset Client / Auto-reset		
17	Main contactor status not expected (opened)	Result of contactor auto-test. Expected : closed.	HW (ON/OFF) / Reset Client / Auto-reset		
18	Main contactor status not expected (closed)	Result of contactor auto-test. Expected : opened.	HW (ON/OFF) / Auto-reset	Contactor opening	
19	Over current in charge	Measured battery current > MAX(1.6 x IMR ; 55A) during 30s	HW (ON/OFF) / Reset Client	Contactor opening	
20	Over current in discharge	Measured battery current > MAX(1.1 x IMD ; 55A) during 30s	HW (ON/OFF) / Reset Client	Contactor opening	
21	SOC invalid	SOC calculation not updated after 2s	HW (ON/OFF) / Reset Client / Auto-reset		
22	SOH invalid	SOH calculation not updated after 72h	HW (ON/OFF) / Reset Client / Auto-reset		
23	BMU supply 24V too low	BMU supply voltage <17V during 0,5s	Auto-reset		
24	Fuse Blown	Fuse blown detected	HW (ON/OFF) / Reset Client / Auto-reset	Contactor opening	
25	Charge current discrepancy – 1st level	Measured battery current > MAX(1.1 x IMR ; 5) during 30s	HW (ON/OFF) / Reset Client / Auto-reset		
26	Charge current discrepancy – 2nd level	Measured battery current > (1.2 x IMR ; 10) during 30s	HW (ON/OFF) / Reset Client / Auto-reset		
28	SOC not adjusted during the required time	The SOC adjustment has not been requested since 1 month	HW (ON/OFF) / Reset Client / Auto-reset		
29	SMU communication problem	At least one SMU allocation has failed more than 3 times	HW (ON/OFF) / Reset Client / Auto-reset		

30	SMU re-connection failed	Number of re-connection attemps exceeds 3 for one SMU	HW (ON/OFF)	Contactor opening	
33	Battery current sensor out of range (lost)	Current measured > 60A or < -60A during 10s OR Main contactors open AND |Battery current| > 2A	HW (ON/OFF) / Reset Client / Auto-reset		
34	Autotest failure	At least one unit test has failed	HW (ON/OFF)	Contactor opening	
36	IBIT undone for 6 months	IBIT not requested by the client from 6 months and 24h	HW (ON/OFF)	Contactor opening	
37	Inconsistent temperatures	Delta temperature over all the module > 10°C during 2s	HW (ON/OFF) / Reset Client / Auto-reset		
38	Low SMUs supply voltage	Default on V_POWER_SMU	HW (ON/OFF) / Reset Client / Auto-reset	Contactor opening	
39	Unbalanced cells	Delta cell voltage over all the module > 100mV during 2s IF SOC > 20% and Vcell_min > 3.5V	HW (ON/OFF) / Reset Client / Auto-reset		
41	Communication to client lost	CAN message not received correctly by the BMM during a timeout depending on the CAN baud rate.	HW (ON/OFF) / Reset Client / Auto-reset		
42	Invalid cell number encountered	Number of cells not coherent with expected configuration (140 cell)	HW (ON/OFF)	Contactor opening	
43	Invalid SMU software version encountered	One or more SMU don't have the same software version	HW (ON/OFF)	Contactor opening	
44	IMD / IMR values are invalid	Error in the function calculating the IMD and IMR	HW (ON/OFF) / Reset Client / Auto-reset		

Remarks:

- HW reset is done by switching OFF/ON the 24V power supply
- Customer reset is done by sending a message by CAN open
- Self-reset is done when the fault condition disappear (with a hysteresis and delay).