Innovation in energy storage

Version 3.1 – 05-05-2023

Lithium-Ion RS series battery module

- Manual -

MGRS12S4P176-300, MGRS14S3P132-300, MGRS16S3P132-300, MGRS24S2P088-300,
MGRS12S4P176-500, MGRS14S3P132-500, MGRS16S3P132-500, MGRS24S2P088-500,

MG Energy Systems B.V.

TABLE OF CONTENTS

1 GENERAL

Before continuing read the instructions in this chapter carefully and be sure the instructions are fully understood. If there are questions after reading the instructions please consult MG Energy Systems.

1.1 Document history

Table 1 - Document history

Rev.	Date	Changes	Revision author
2.0	28-01-2019	Initial document.	Mark Scholten
2.1	02-04-2019	Minor changes, corrections, and additions in sections 7.3, 7.5, 7.6, 9.2, 12.1	Ane Tjitze Rienstra / Mark Scholten
2.2	27-05-2019	Additions in chapter 13.1.	Wilco Portinga
2.3	12-07-2019	Minor changes, corrections.	Mark Scholten
2.4	25-11-2019	Revised the complete document.	Ane Tjitze Rienstra
2.5	05-12-2019	Minor changes, corrections.	Mark Scholten
2.6	07-05-2020	Section 7.6: - Added minimum volume of PPS tank related to PPS fluid volume. - Replaced 'pressure vessel' by 'pressure tank' for clarity in maritime related use of the battery. - Added 'at least one PPS per battery string' as mandatory Added section 7.2.1 with an explaination of the battery strategy and available capacity. Section 8.7 - Added line that it is mandatory to use at least one PPS per battery string. Removed section 9.1.3 about servicing the desicant. Chapter 10: - Updated and added ratings. - Updated nominal capacity and energy.	Ane Tjitze Rienstra
2.7	26-05-2020	Added statements for limiting factors in section 8.5 and 12.2.	Ane Tjitze Rienstra
2.8	10-06-2020	- Added and restructured the requirements for off-gas ventilation ducting.	Ane Tjitze Rienstra
2.9	01-06-2022	- Updated template. - Updated scope of delivery - Added links to product information at the MG Download Center.	Mark Scholten
3.0	31-03-2023	- Updated connection procedure - Added Commissioning points - Added Decommissioning procedure - Added and changed fluid cooling design requirements - Updated images - Updated fluid cooling schematic	Mark Scholten
3.1	17-4-2023	- Added and adjusted Decommissioning procedure - Fixed typo's	Mark Scholten

1.2 Terms, abbreviations, and definition

Table 2 - Terms, abbreviations, and definitions

Battery cell	*Battery cell;* the smallest building block in a battery, a chemical unit. or cell is the bare Lithium-Ion battery cell.
Battery module	*Battery module;* is an assembly of submodules, BMS, fluid cooling and outer enclosure.
Battery stack	*Battery stack;* is a set of multiple cells in cell cassettes constructed as one.
BMS	*Battery Management System;* The BMS is the electronics that monitors the battery cell parameters to keep it within the operation specifications.
CAN-bus	*Controller Area Network bus;* CAN-bus is a standard serial databus that provides data communication between two or more devices.
C-rate	*C-Rate;* the current (A) used to charge/discharge the battery system divided by the rated ampèr-hours (Ah).
DeviceNet	*DeviceNet*; is a network protocol used in the automation industry to interconnect control devices for data exchange, standardised in the IEC 62026-3.
EMS	*Energy Management System;* The EMS controls all power sources and consumers in a system.
Ethylene glycol	*Ethylene glycol;* is an organic compound with the formula $(CH_2OH)_2$ *(IUPAC name: ethane-1,2-diol)*. This name is often used for a mixture of Ethylene Glycol and water too. Only Ethylene glycol based coolant is allowed to be used with the RS series battery.
HVIL	*High Voltage Interlock Loop;* is a wire loop which is created for protection of pulling cables from the battery system while in operation. It shuts down the system when loop is not closed.
IC	*Integrated Circuit;* is a chip containing an electronics circuit;
MSDS	*Material Safety Data Sheet;* is a document that lists information relating to occupational safety and health for the use of various substances and products.
NMEA 2000	*National Marine Electronics Association's* NMEA 2000 is a plug-and-play communications standard used for connecting marine sensors and display units within ships and boats, standardised in the IEC 61162-1.
PCB	*Printed Circuit Board;* is a board containing an electronic circuit;
PCBA	*Printed Circuit Board Assembly;* is a board containing an electronic circuit including passive and active components;
PPS	*Propagation Prevention System*; a fluid based protection system to prevent cell-to-cell and module-to-module propagation in case of a thermal runaway of one cell.
Propylene glycol	*Propylene glycol;* is a synthetic organic compound with the chemical formula $C_3H_8O_2$ (IUPAC name: propane-1,2-diol). This name is often used for a mixture of Propylene Glycol and water too. Propylene glycol based coolant must NOT be used with the RS series battery.
SoC	*State-of-Charge;* is the remaining capacity in a battery cell or module in percent (%).
SoH	*State-of-Health;* is a figure of merit of the condition of a battery (or a cell, or a battery pack), compared to its ideal conditions.

1.3 This revision

This revision replaces all previous revisions of this document. MG Energy Systems B.V. has made every effort to ensure that this document is complete and accurate at the time of writing. In accordance with our policy of continuous product improvement, all data in this document is subject to change or correction without prior notice.

1.4 Scope

This product manual contains technical description, installation, safety and commissioning instructions and other relevant information for the MG RS battery series.

1.4.1 Document structure

This document is structured into three categories:

- System design: Guidelines and general recommendations for system integrators and designers.
- Installation, commissioning and maintenance: Procedures and instructions for installers and maintenance personnel.
- Operation: Instructions and procedures for general users.

1.5 Related documents

More related documents for the MG RS battery module can found on our Download Center.

2 SAFETY INSTRUCTIONS

2.1 Safety message level definition

Table 3 - Safety message levels overview

WARNING:
A hazardous situation which, if not avoided, could result in death or serious injury.

CAUTION:
A hazardous situation which, if not avoided, could result in minor or moderate injury.

LIMITATION:
A limitation to use which must be considered for safe use of the equipment.

ELECTRICAL HAZARD:
The possibility of electrical risks if instructions are not followed in a proper manner.

NOTICE:

- A potential situation which, if not avoided, could result in an undesirable result or state.
- A practice not related to personal injury.

2.2 User health and safety

General precautions

This product is designed and tested in accordance with international standards. The equipment should be used according the intended use only.

WARNING:
A battery is a permanent energy source which cannot be turned off.

ELECTRICAL HAZARD:

- Wear applicable personal protective equipment when working on a battery system.
- Use insulated tools when working on a battery system.
- Make sure the locale health and safety regulations for working on battery systems are followed.

2.2.1 Qualifications and training

The personnel responsible for the assembly, operation, inspection, and maintenance of the battery system must be appropriately qualified. The user company must do the following tasks:

- Define the responsibilities and competency of all personnel working on the battery system.
- Provide instruction and training.
- Ensure that the contents of the operating and safety instructions have been fully understood by the personnel.
- Check the local safety rules and guidelines they have higher preference over the manufacturers specification in case of regulatory conflicts.

Instruction and training can be carried out by MG Energy Systems B.V. by order of the user company.

2.2.2 Non-compliance risks

Failure to comply with all safety precautions can result in the following conditions:

- Death or serious injury due to electrical, mechanical, and chemical influences.
- Environmental damage due to the leakage of dangerous materials.
- Product damage.
- Property damage.
- Loss of all claims for damages.

2.2.3 Unacceptable modes of operation

The operational reliability of this product is only guaranteed when it is used as intended. The operating limits on the identification tag and in the data sheet may not be exceeded under any circumstances. If the identification tag is missing or worn, contact MG Energy Systems B.V. for specific instructions.

WARNING:
The battery modules may only be used in combination with a MG Master HV or MG Master LV.

3 TRANSPORT, STORAGE, UNPACKING AND HANDLING

3.1 Transport

The package and transport instructions provided by the manufacturer must be followed under all circumstances.

Notes on transport:

- Use original packaging materials.
- Lithium-Ion batteries are dangerous goods and must be transported according to the applicable rules.
- Transportation company and shipper must be qualified to transport and package dangerous goods.
- The SoC during transport must be ≤ 30%.

For details on transport of this battery module see the MSDS and general transport instructions.

CAUTION:
It is not allowed to transport, connect or operate a damaged battery.

NOTICE:
No liability can be accepted for damage during transport if the equipment is not transported in its original packaging or if the original packaging is opened before the destination is reached.

NOTICE:
The SoC of the battery as delivered from factory is ≤ 30%.

3.2 Storage

The storage instructions provided by the manufacturer must be followed in all circumstances.

Notes on storage:

- Battery module must be stored in its original packaging.
- Store in a dry, clean, and conditioned location.
- Local regulations for storage of dangerous goods may be applicable.
- Recommended storage temperature of the battery module is between +10°C to +25°C.
- It is recommended to limit the battery charge between 50% and 70% SoC. This will limit calendric aging.

The battery module's SoC is decreasing 1% per year when not connected to any equipment. Recharging is required when the voltage is in the range of the cut-off voltage.

NOTICE:
Check the voltage of the stored battery module every year.
When the battery module voltage is below the cut-off voltage, recharging is required. Contact MG Energy Systems for specific instructions and tools.

3.3 Unpacking

Follow these handling guidelines when handling the product to prevent damage during unpacking:

- Use care when handling the product.
- Leave protective caps and covers on the product until installation.

NOTICE:
Do NOT remove the exhaust overpressure protection!

3.3.1 Lifting the battery module

Use the handles on the side of the battery module for lifting:

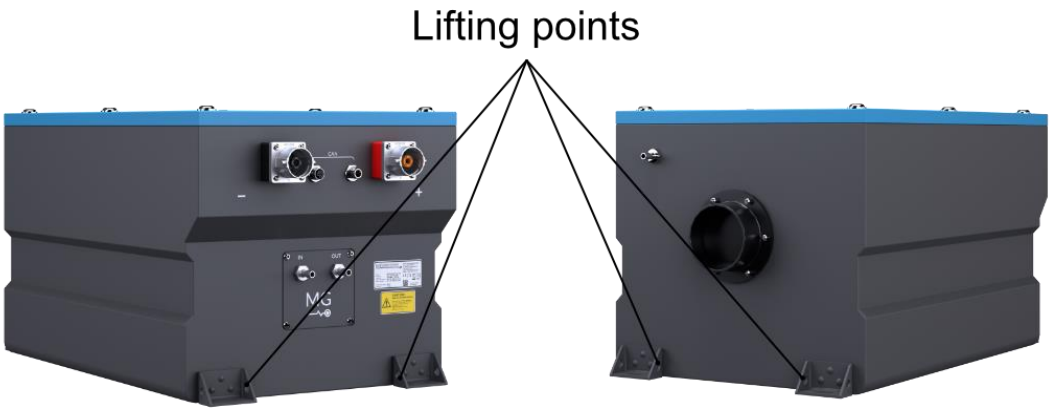


Figure 1 - RS battery module lifting points

CAUTION:
Always take the local applicable standards and regulations regarding the prevention of accidents into account when handling the product.

CAUTION:
Be aware of the total mass of the product and do not lift heavy objects unassisted.

3.3.2 Scope of delivery

The scope of delivery is as following:

- MG RS battery module of type as described in chapter 5.
- 1x Quick installation guide – RS Battery module.

NOTICE:
Not within the scope of delivery:

- Power cables and connectors (details can be found in chapter 6.3.2).
- Communication cables and connectors (details can be found in chapter 6.3.1).
- Exhaust parts.
- Fuses.
- RS Rack system.
- Master BMS, either MG Master HV or MG Master LV.

4 GENERAL DESCRIPTION

High safety and flexible system configurations were the design principles during the development of the RS series Lithium-Ion battery. A modular and compact design makes system integration more flexible, especially in refit applications. Adding redundant BMS and a unique cell-to-cell propagation protection takes safety to the next level. The fluid thermal management keeps the battery cells on temperature to extend cycle life and to improve the peak power performance. These features make this battery suitable for large energy storage applications as well as small peak power packs in hybrid solutions.

All relevant information of this product can be found on the MG Download Center.

4.1 Battery system components

MG Energy Systems Lithium-Ion battery system consists of the following components:

- One or more MG RS battery modules;
- One or more MG Master HV or MG Master LV battery management systems; Details of these battery management controllers can be found in their separate description documents;

4.2 Functional description

MG Energy Systems battery system philosophy is to have one master BMS, e.g. a MG Master HV, per string of battery modules which communicates with one or more slave BMSs integrated in the Lithium-Ion battery module(s). The slave BMSs are monitoring the battery cell parameters like cell voltage, cell temperature, and humidity inside the enclosure. Besides monitoring, the slave BMS also controls balancing of cells based on the input of the master BMS.

All these parameters are send to the MG Master HV via a dedicated CAN-bus which collects all the data and monitors these parameters with different thresholds. When a parameter exceeds the threshold this will first be communicated to the user via the, separated, auxiliary CAN-bus. If the exceeded threshold stays, the master BMS has the possibility to disconnect the batteries from the system by opening the main contactors.

Functional and safety features of the MG RS battery module are:

- Modular design in combination with flexible rack design makes integration in small spaces possible.
- Robust enclosure with high IP rating.
- Exhaust system with over-pressure mechanism, used to output toxic gasses to a safe area during a thermal runaway of a battery cell. This avoids containment of gases within the battery space and therefor lowers the systems complexity to limit the risks involved.
- Cell level fluid thermal management (cooling/heating) to increase performance, safety, and cycle life.
- Redundant Battery Management System in each MG RS battery module to guarantee maximum safety and stable operation.
- Unique cell-to-cell and module-to-module propagation protection during a failure.
- Each string of batteries has its own MG Master BMS for protection, control, and logging.
- Marine type approvals for DNV and Lloyds.

4.3 Battery module schematic overview

Figure 2 shows the internal schematic overview of the MG RS battery module.

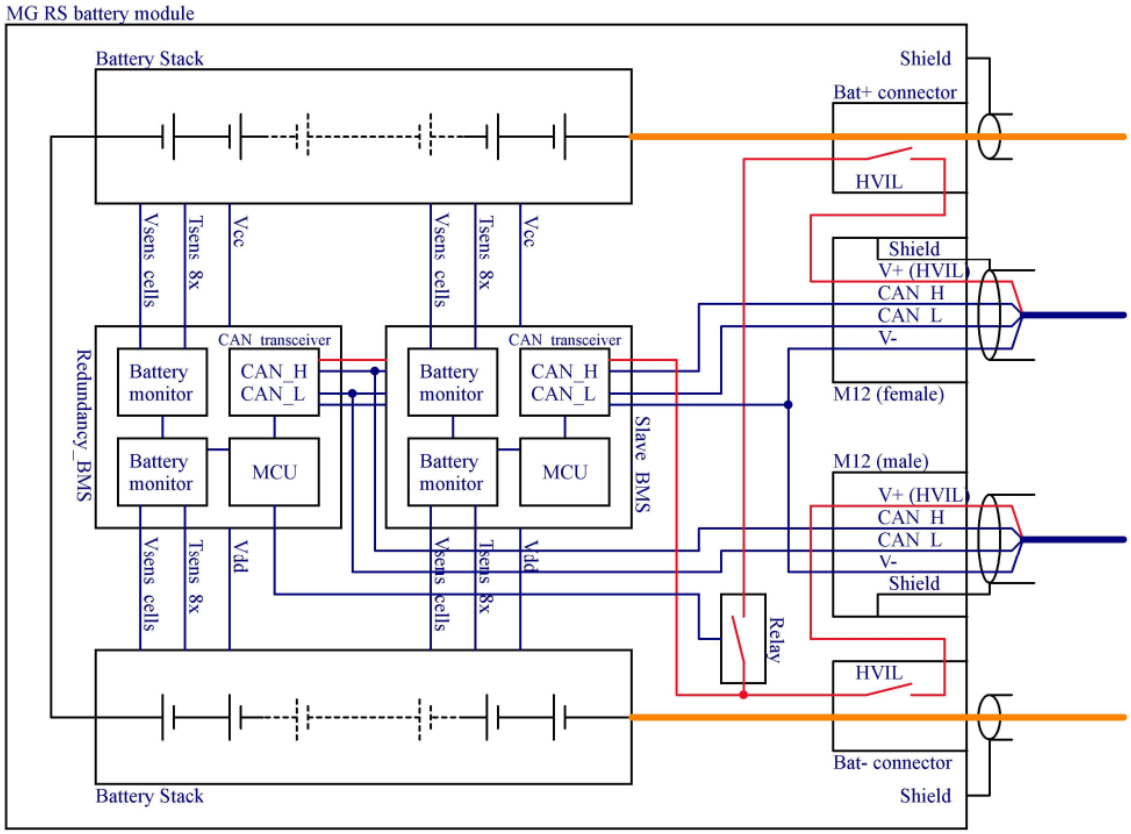


Figure 2 - Battery module schematic overview

4.4 Example systems

Different kind of battery systems can be created because of the modular design. Battery modules can be placed in series and parallel to create higher voltages and larger capacities.

Contact MG Energy Systems B.V. for more information about possible configurations.

4.4.1 Low voltage systems

Low voltages systems up to 96 VDC are setup with the MG Master LV. For more information about the MG Master LV, please refer to the data sheet and manual.

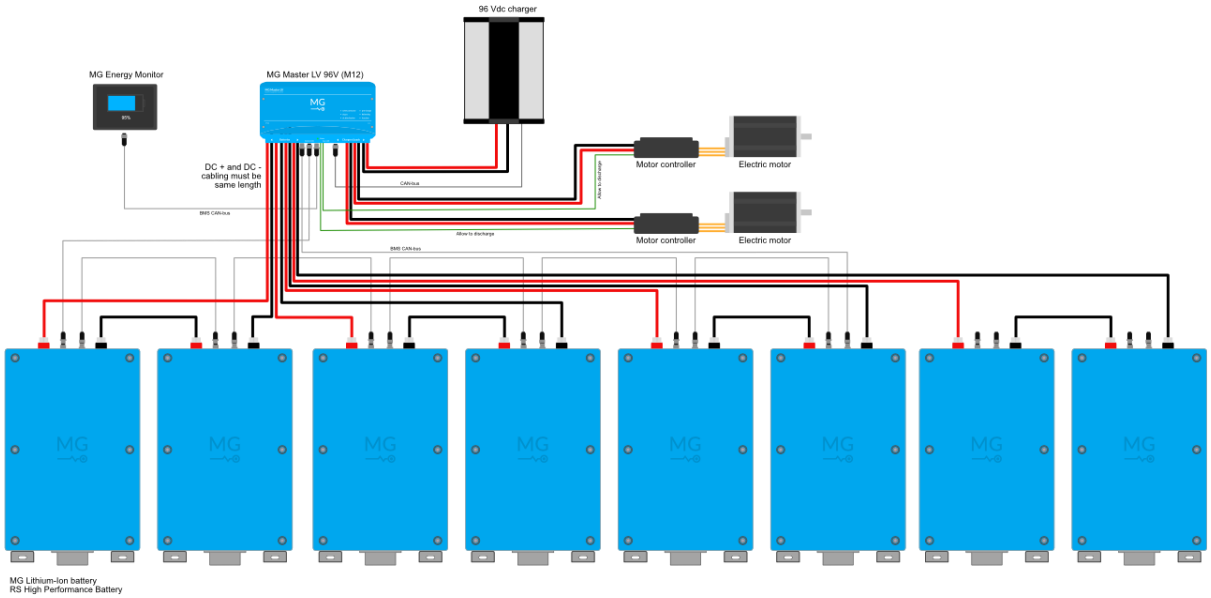


Figure 3 - 96 V RS battery system with MG Master LV example

Low voltage systems can also be setup with the MG Master HV. In this case the system can be used in marine class register approved systems.

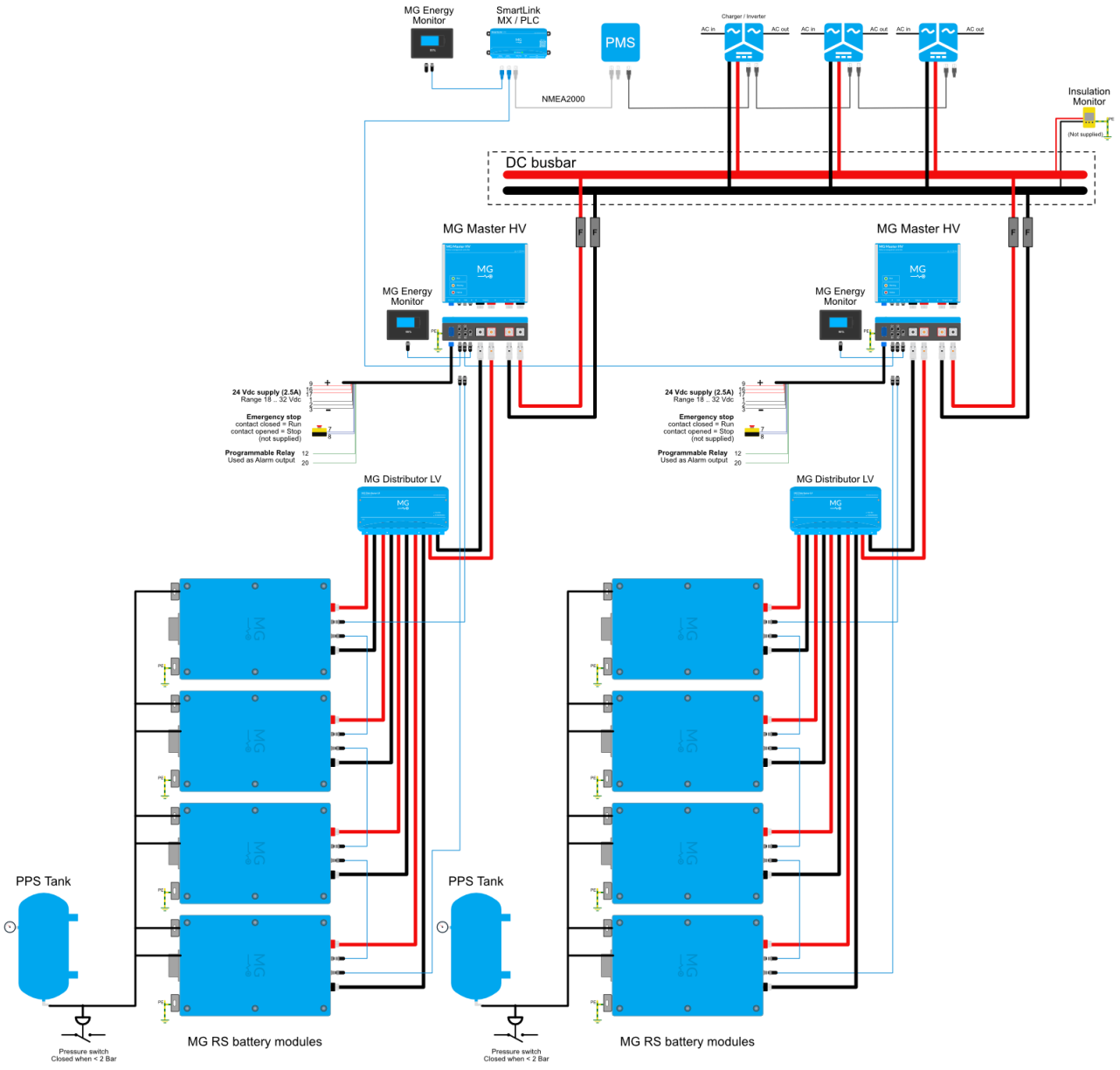


Figure 4 - Low voltage RS battery system in combination with a MG Master HV (DNV and Lloyds type approved)

NOTICE:
When using the MG Master HV at lower voltages, i.e. 48VDC up to 144VDC, the pre-charge circuit may not be sufficient. This is depending on the capacity of the connected equipment. Refer to the manual of the MG Master HV for detailed information.

4.4.2 High voltage systems

High voltage systems from 144 VDC up to 900 VDC are setup with the MG Master HV. For more information about the MG Master HV, please refer to the data sheet and manual.

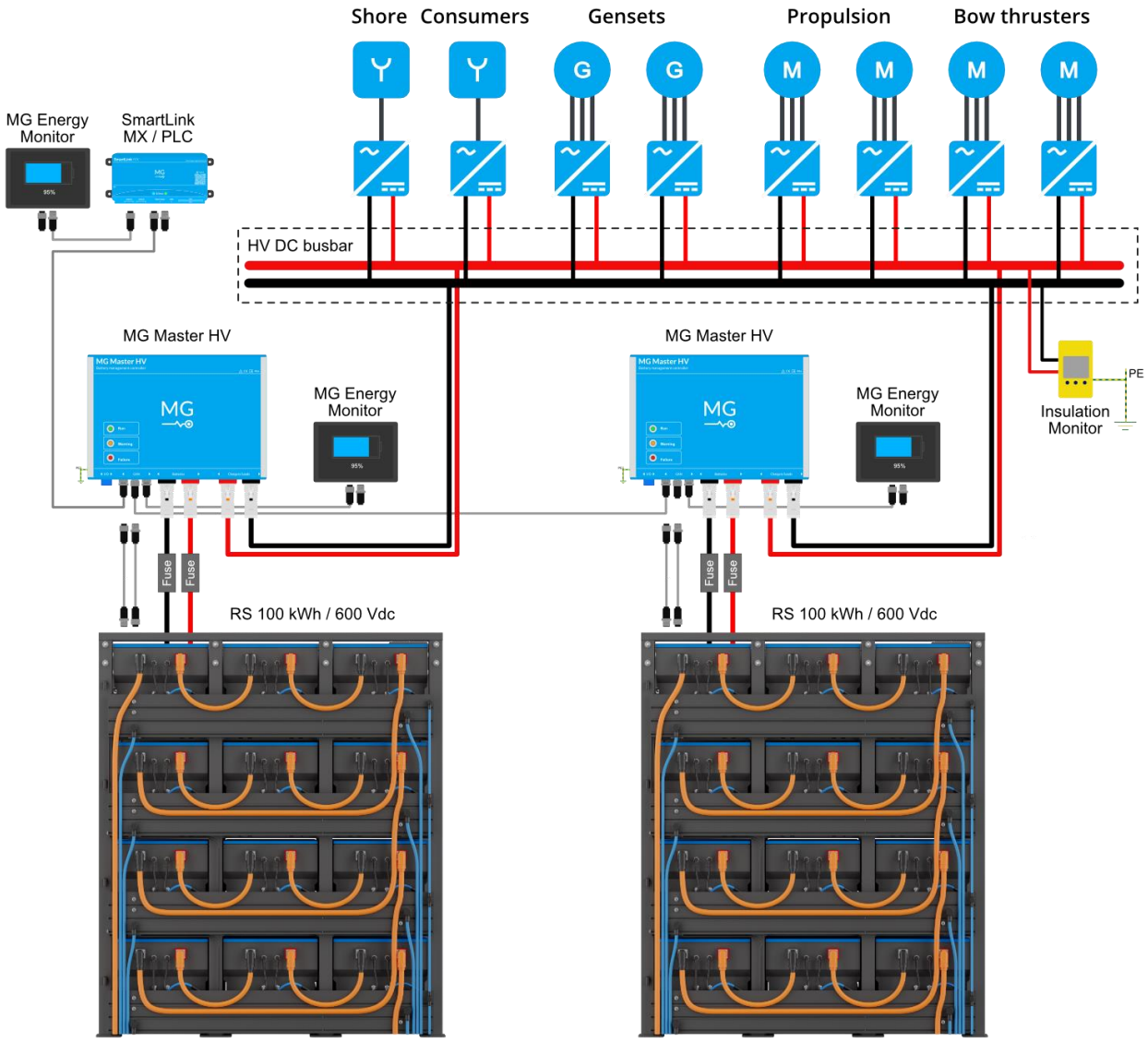


Figure 5 - High voltage system example with RS battery rack (DNV and Lloyds type approved)

5 MODELS

5.1 Models and configurations

The RS series lithium-ion battery features 4 configurations varying in voltage and capacity. This makes a system scalable to the needs of the application. All configurations have the same enclosure dimensions, safety features and components.

5.1.1 Battery designation

As per IEC 62620 it is required to state a standard designation per battery module configuration. For the RS series lithium-ion battery these are given in table 4.

Table 4 - Battery module designation as per IEC 62620

Article number	Designation
MGRS12S4P176-xxx (yy)	INP/13/155/250/[4P12S]M/-10NA/95
MGRS14S3P132-xxx (yy)	INP/13/155/250/[3P14S]M/-10NA/95
MGRS16S3P132-xxx (yy)	INP/13/155/250/[3P16S]M/-10NA/95
MGRS24S2P088-xxx (yy)	INP/13/155/250/[2P24S]M/-10NA/95

5.1.2 Power connector options

Each of the configurations is available with Amphenol PowerLok™ 300 Series, Amphenol PowerLok™ 500 Series or Amphenol PowerLok™ 500 Series generation 2 power connectors. The difference of the power connectors is the handling of the continuous current. See chapter 6.3.2 for details.

5.1.3 Ordering information

The power connector configuration can be ordered as following:

- <Article number> – 300 for the 300 series connectors.
- <Article number> – 500 for the 500 series connectors.
- <Article number> – 500 (G2) for the 500 series Generation 2 connectors.

Example: **MGRS12S4P176-300** or **MGRS12S4P176-500** or **MGRS12S4P176-500 (G2)**

For detailed ordering information see Appendix C.

5.2 Identification label

The identification label of the MG RS battery module is located at the front of the enclosure.

Example identification label:

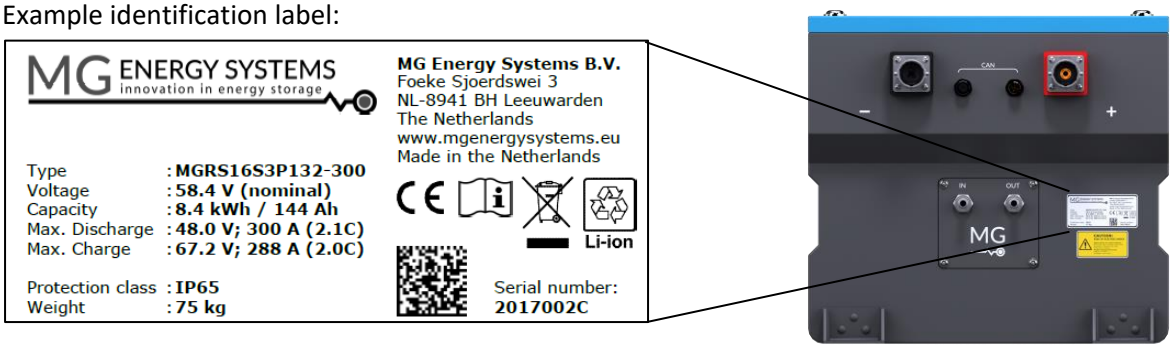


Figure 6 - Example identifications label

The identifications label shown in figure 6 contains written information about the product. The explanation of the symbols used on the identification label is stated in table 5.

Table 5 - Identification lable logo explaination

CE	Declaration of conformity with health, safety, and environmental protection standards for products sold within the European Economic Area as per directive 2014/35/EU.
	Symbol indication the manual must be red before installation and use of the device.
	Device is treated according the Waste Electrical and Electronic Equipment (WEEE) Directive 2012/19/EU.
	GS1 data matrix type barcode containing detailed product information.

5.2.1 Other labels

Figure 7 shows the additional labels on the battery module.

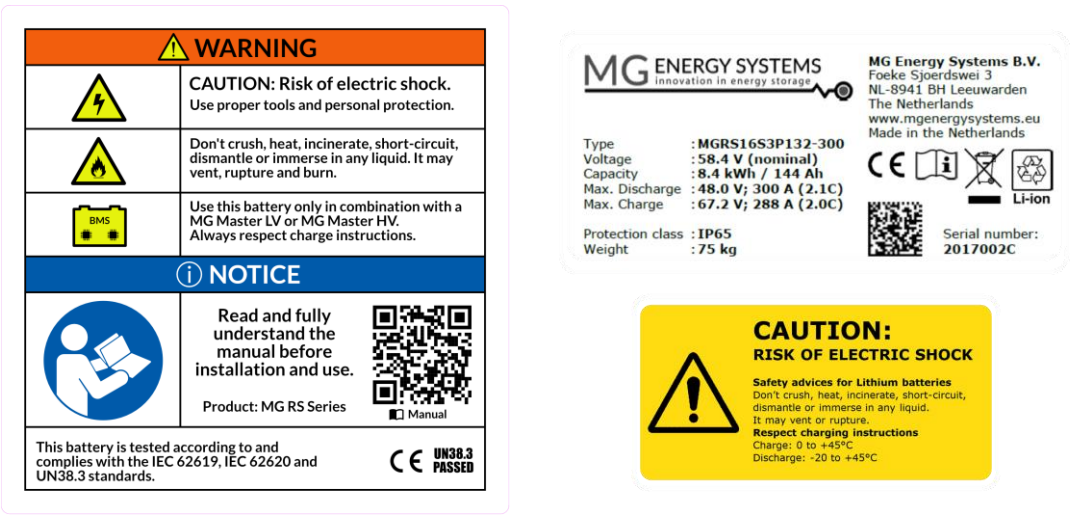


Figure 7 - Additional warning and informational labels

5.3 Approvals and standards

The RS battery conforms to an extensive list of standards and tests.

- DNV Type Approval
- Lloyds Type Approval
- Declaration of Conformity
- Material safety datasheet
- UN38.3 certificate

A complete list of all performed tests can be found at the following link:
RS List of Standards and Tests

6 OVERVIEW

This chapter shows an overview of the RS battery module.

6.1 Front overview

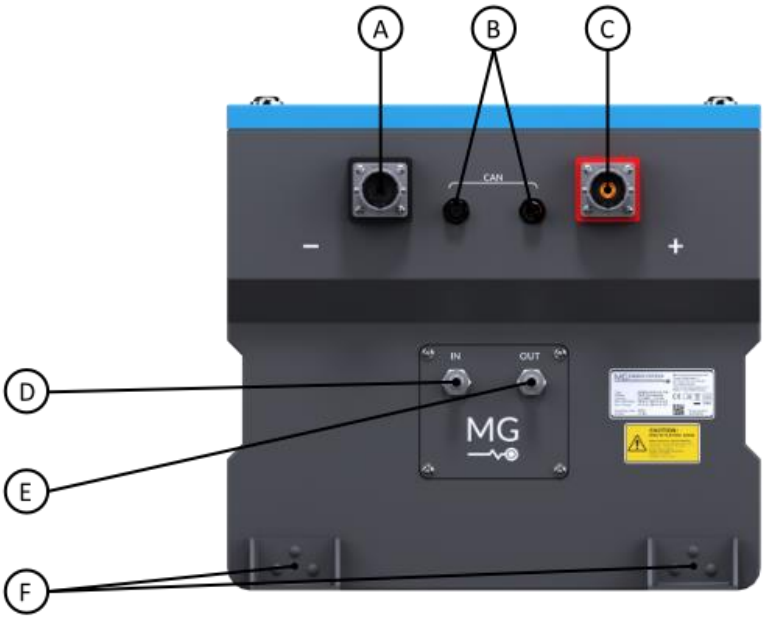


Figure 8 - Front overview

Table 6 - Module connection overview legend

Part	Description
A	Negative power connection
B	CAN-Bus communication M12
C	Positive power connection
D	Fluid cooling inlet
E	Fluid cooling outlet
F	Mounting brackets, lifting points and equipotential bonding connection

6.2 Rear overview

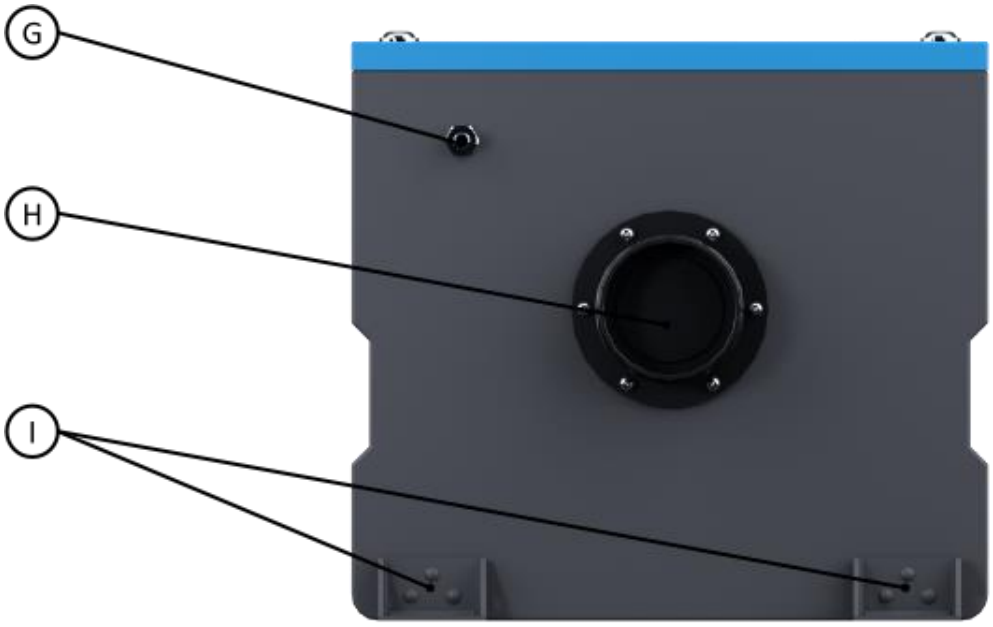


Figure 9 - Rear overview

Table 7 - Battery module rear view legend

Part	Description
G	PPS connection inlet
H	Gas exhaust
I	Mounting brackets and lifting points

6.3 Connection details

6.3.1 CAN-bus connector details

A MG Master BMS communicates with the connected battery modules via CAN-bus. This is a dedicated CAN-bus where only MG battery modules of the same type or other MG devices may be connected.

The CAN-Bus connection is used for several functions:

- Data communication between battery module(s) and master BMS;
- The battery module uses the CAN-Bus V+ voltage to enable the power of the internal BMS;
- The CAN-Bus V+ voltage is also used as HVIL voltage source;

6.3.1.1 Connector details

The connectors used for connecting the battery, auxiliary, and diagnostics CAN-bus are all of the same type, namely a circular M12 connector with 5 positions and A-coded keying.

Table 8 - Circular M12 connector with 5 positions A-coded details

Pin	Description	Connector view
1	Shield	
2	V+	
3	GND	
4	CAN-H	
5	CAN-L	

Cables to be used for the battery system are typically referred to as NMEA 2000 or DeviceNet compatible cables. The minimum requirements for cables are:

- Twisted pair connected to pins 4 and 5 for communication with a minimum wire cross sectional area of 0.2 mm^2 (24 AWG).
- Pair of conductors connected to pin 2 and 3 for power and HVIL with a minimum wire cross sectional area of 0.34 mm^2 (22 AWG).
- Cable with braided shielding connected to pin 1.

NOTICE:
Do NOT use sensor/actor cables. They often don't have any twisted pairs and are therefore not suitable for this application.

6.3.2 Power connections

For the RS battery module's power connections, Amphenol PowerLok™ 300 Series, Amphenol PowerLok™ 500 Series or Amphenol PowerLok™ 500 Series generation 2 power connectors are used. These power connectors can handle a voltage of 1000 VDC and have an integrated HVIL for safety.

The continuous current of the system is depending on the connected Amphenol PowerLok™ series, cable cross section and ambient temperature.

6.3.2.1 Connector details

Table 9, Table 10 and Table 11 show an overview of the standard connector types in relation with the models and the maximum currents. Contact MG Energy Systems B.V. for cable options and possibilities.

Amphenol PowerLok™ 500 Series	**Amphenol PowerLok™ 500 Series Generation 2**	**Amphenol PowerLok™ 300 Series**
		

Table 9 - Amphenol PowerLok™ 500 series

Brand	Amphenol PowerLok™	
Series	500 series	
	Positive terminal (orange)	***Negative terminal (black)***
Receptacle types (mounted on MG RS module)	PL00X-501-10-M10	PL00Y-501-10-M10
Plug must be of HVIL type.	**Over-moulded cable assembly:** PL20X-501-120: 350A PL20X-501-135: 400A PL20X-501-150: 500A PL10X-501-120: 350A PL10X-501-135: 400A PL10X-501-150: 500A	**Over-moulded cable assembly:** PL20Y-501-120: 350A PL20Y-501-135: 400A PL20Y-501-150: 500A PL20Y-501-120: 350A PL20Y-501-135: 400A PL20Y-501-150: 500A

Table 10 - Amphenol PowerLok™ 500 series Generation 2

Brand	Amphenol PowerLok™	
Series	500 series **Generation 2**	
	Positive terminal (orange)	***Negative terminal (black)***
Receptacle types (mounted on MG RS module)	PL00X-501-10-M10-2	PL00Y-501-10-M10-2
Plug must be of HVIL type.	**Plug connector:** PL28X-501-70-2-5: 250A PL28X-501-95-2-5: 300A PL28X-501-120-2-5: 400A PL18X-501-70-2-5: 250A PL18X-501-95-2-5: 300A PL18X-501-120-2-5: 400A	**Plug connector:** PL28Y-501-70-2-5: 250A PL28Y-501-95-2-5: 300A PL28Y-501-120-2-5: 400A PL18Y-501-70-2-5: 250A PL18Y-501-95-2-5: 300A PL18Y-501-120-2-5: 400A

Table 11 - Amphenol PowerLok™ 300 Series

Brand	Amphenol PowerLok™	
Series	300 series	
	Positive terminal (orange)	***Negative terminal (black)***
Receptacle types (mounted on MG RS module)	PL00X-301-10-M10	PL00Y-301-10-M10
Plug must be of HVIL type.	**Over-moulded cable assembly:** PL20X-301-35: 150A PL20X-301-50: 200A PL20X-301-70: 250A PL20X-301-95: 300A PL10X-301-35: 150A PL10X-301-50: 200A PL10X-301-70: 250A PL10X-301-95: 300A **Plug connector:** PL28X-301-35: 150A PL28X-301-50: 200A PL28X-301-70: 250A PL18X-301-35: 150A PL18X-301-50: 200A PL18X-301-70: 250A	**Over-moulded cable assembly:** PL20Y-301-35: 150A PL20Y-301-50: 200A PL20Y-301-70: 250A PL20Y-301-95: 300A PL10Y-301-35: 150A PL10Y-301-50: 200A PL10Y-301-70: 250A PL10Y-301-95: 300A **Plug connector:** PL28Y-301-35: 150A PL28Y-301-50: 200A PL28Y-301-70: 250A PL18Y-301-35: 150A PL18Y-301-50: 200A PL18Y-301-70: 250A

6.3.3 Fluid thermal management connections

Two types of fluid thermal connections are possible. See appendix C for the correct ordering information.

Connection type: Hose pillar Article: GT1410 MSV ED Material: Nickel-plated brass **Hose connection:** This liquid cooling connection accepts a hose with an inner-diameter (ID) of 10 mm.	
Connection type: Push-in Article: IQSL 1410 G MSV Material: Nickel-plated brass **Hose connection:** This liquid cooling connection accepts a calibrated hose with an outer-diameter (OD) of 10mm. For example 10 mm Parker / Legris hose.	

NOTICE:
Do NOT use transparent hoses.

6.3.4 Exhaust connection

The function of the exhaust connection with pressure relief is to release gasses in case of a thermal runaway event. The flammable and toxic gasses can be evicted from the module and released in a safe area (outside).

The diameter of the exhaust is dimensioned to connect piping with an inner diameter of 80 mm.

Figure 10 - Exhaust on the rear of the RS battery module

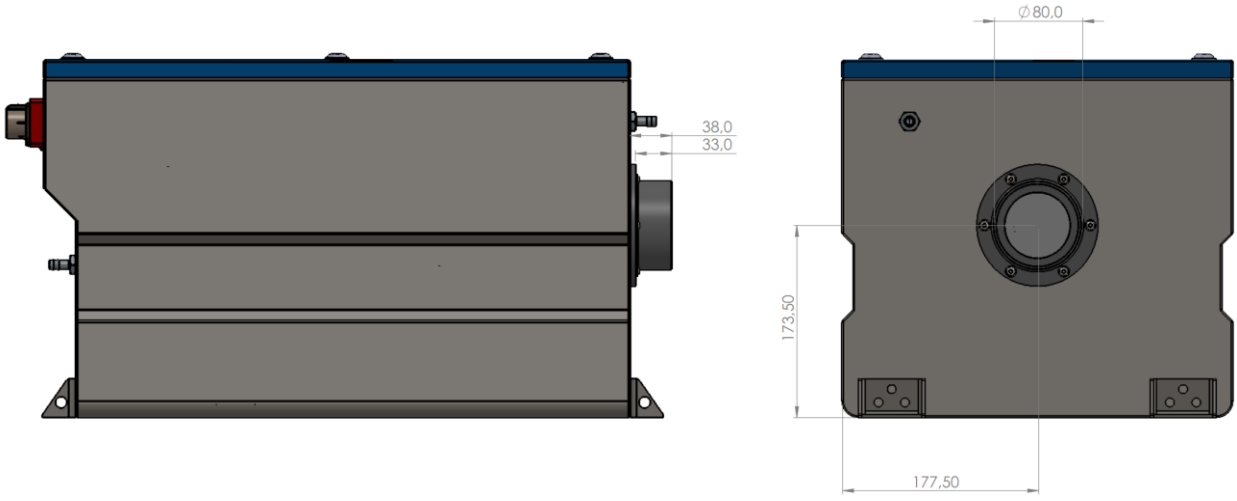


Figure 11 - Dimensions of the exhaust in mm

6.3.5 PPS connection

The PPS connection is used to fill the battery with a PPS fluid to prevent thermal runaway propagation in case of a single cell thermal runaway event. There are two types of connections possible. See appendix C for the correct ordering information.

Connection type: Hose pillar Article: GT1410 MSV ED Material: Nickel-plated brass **Hose connection:** This liquid cooling connection accepts a hose with an inner-diameter (ID) of 10 mm.	
Connection type: bare rigged pipe Material: Stainless steel rigged pipe **Connection:** Connection with compression coupling with rigged piping or a reinforced flexible hose of maximum 25 cm.	

See the MG RS PPS Tank manual for detailed information about the pressurized tank.

WARNING:
MG Energy Systems B.V. cannot be held responsible for any damage or costs caused by a thermal runaway event if the PPS connection is not connected to a pressurized container with at least 12 litres of PPS fluid.

NOTICE:
It is recommended to monitor the pressure on the PPS tank with a sensor that is connected to an alarm system.

7 BATTERY MODULE PROPERTIES

This chapter describes detailed information about the properties and behaviour of the RS battery modules.

7.1 Open-circuit voltage versus State-Of-Charge

The graphs below give information about the open-circuit voltage versus the State-Of-Charge for each configuration type of the RS battery module. These are valid when the battery module is in "Performance" mode. See chapter 7.2.1 for more information about battery strategy modes.

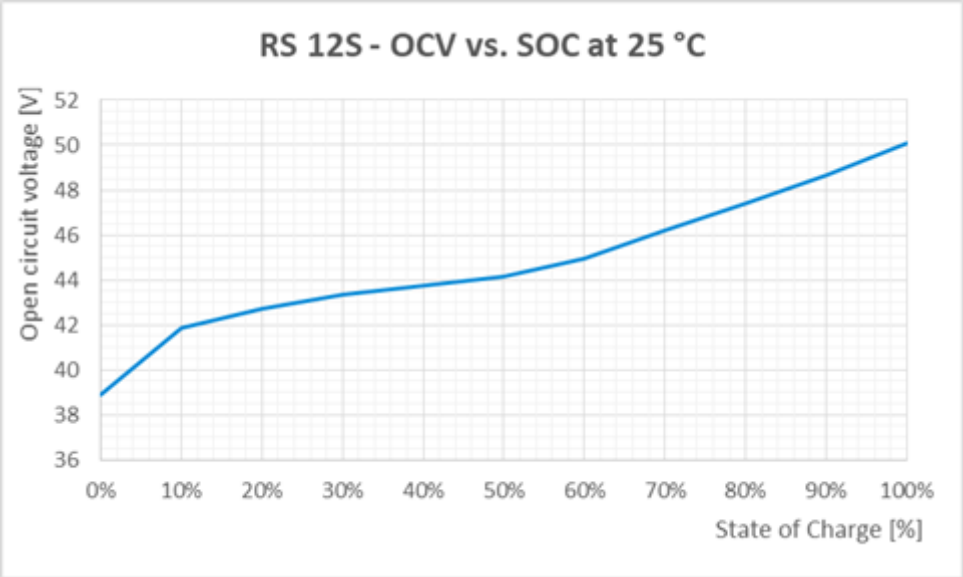


Figure 12 - 12S OCV vs. SOC

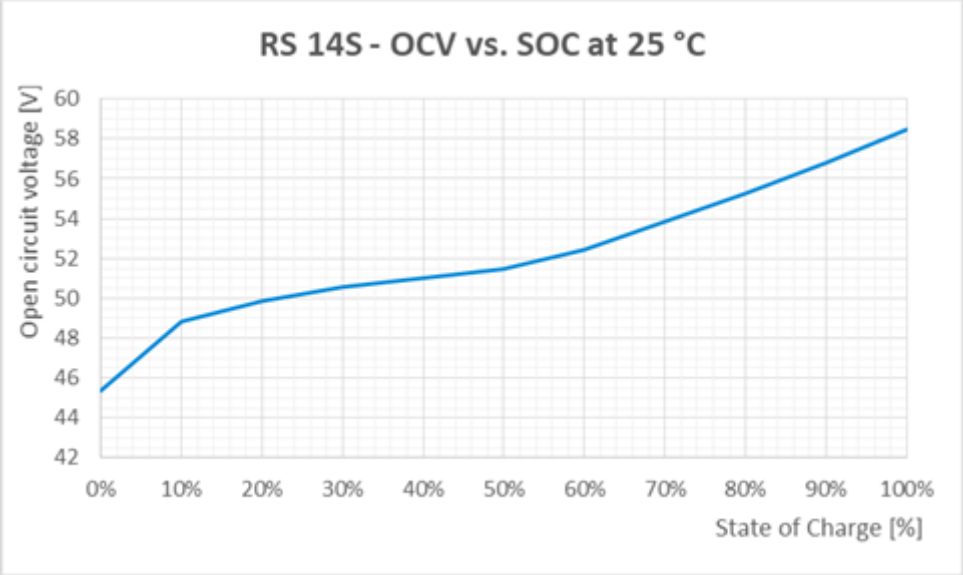


Figure 13 - 14S OCV vs. SOC

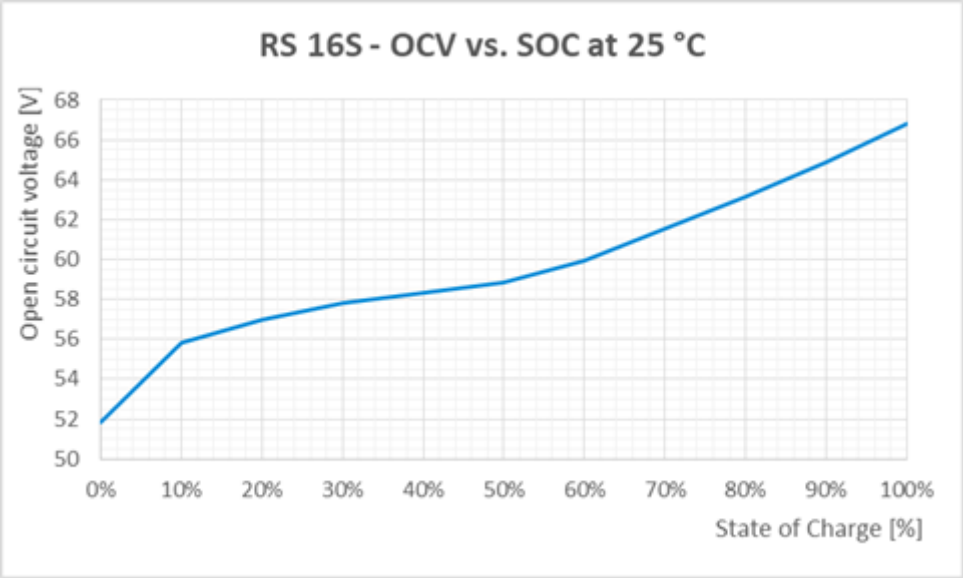


Figure 14 - 16S OCV vs. SOC

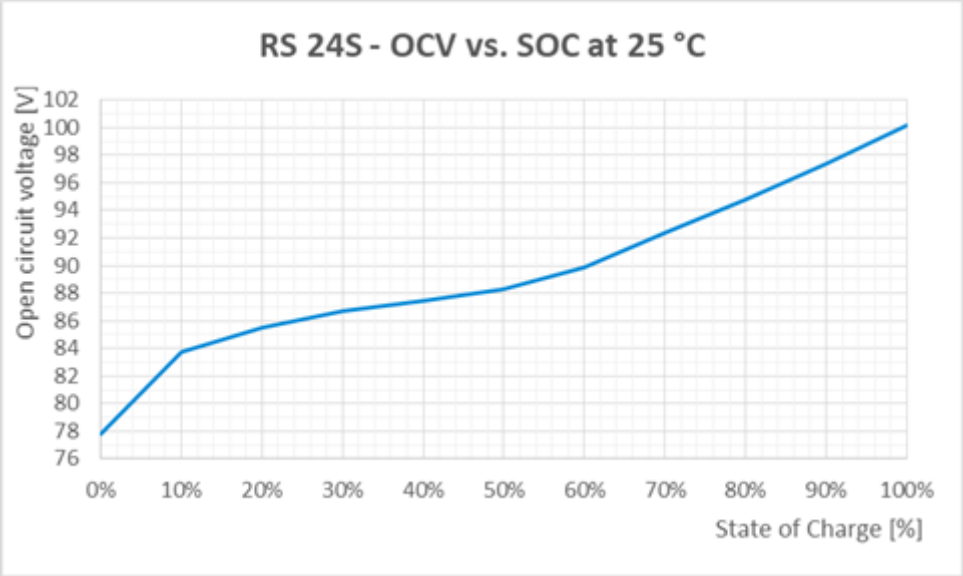


Figure 15 - 24S OCV vs. SOC

7.2 Battery capacity

7.2.1 Battery strategy

The battery system can operate according two different battery strategies, namely *default* and *performance*. The available capacity of the battery module is depending on the battery strategy. The available capacity is expressed as a fraction of the rated capacity of the battery module.

Table 12 - Available capacity per battery strategy

Battery strategy	Available capacity [% of rated capacity]
Default	85 %
Performance	100 %

The rated capacity of each battery module configuration can be found in the technical specification. A detailed description of the boundaries related to the battery strategy can be found in chapter 13. Selection of the battery strategy is done in the master BMS, please refer to the manual of the specific master BMS for details.

7.3 Internal resistance

The internal resistance of RS modules depends on different factors. Each module type has a different resistance due to the internal electrical configuration.

The main factor(s) influencing the resistance is temperature, and SOC (state of charge) and SOH (state of health). More extensive values can be found **APPENDIX: A.**

Table 13 - Average module internal resistance RS modules (new condition)

Model	Total pack resistance [mΩ] @ 20 °C	Heat rejection at 0.5C [W]	Heat rejection at 1C [W]	Heat rejection at 2C [W]
MGRS24S2P088 (96Ah)	20.5	48	191	763
MGRS16S3P132 (144Ah)	9.2			
MGRS12S4P176 (192Ah)	5.3			
MGRS14S3P132 (144Ah)	8.1	42	168	672

7.3.1 Internal resistance change towards EOL

All Lithium-Ion cell will age and lose some performance during use. This aging will affect different factors but mainly the internal resistance and capacity. Temperature and DOD (depth-of-discharge) are leading factors in the aging process. In general, the higher the temperature of the module during use, the faster the aging. Same is true for DOD, cell aging is worse if full cycles (100% DOD) occur on a regular base.

As a guideline for the change of internal resistance of the module, it can be expected to be double during its life (EOL is defined here at 70% SOH). This practically means that the heat generated by each module could double over its lifetime.

Table 14 - Expected module internal resistance RS modules (EOL condition)

Model	Total pack resistance [mΩ] @ 20 °C	Heat rejection at 0.5C [W]	Heat rejection at 1C [W]	Heat rejection at 2C [W]
MGRS24S2P088 (96Ah)	41	95	382	1526
MGRS16S3P132 (144Ah)	18.4			
MGRS12S4P176 (192Ah)	10.6			
MGRS14S3P132 (144Ah)	16.2	84	336	1344

7.4 Short-circuit currents

Detailed information about the short-circuit currents can be found in **APPENDIX: A.**

7.4.1 Short-circuit protection

Each battery module has a short-circuit protection bus-bar. This protection is designed such that it breaks in case of a module short-circuit. The breaking current is approximately 15C.

7.5 Fluid cooling volume

The RS battery module fluid cooling has a volume of approximately 1.7 litres.

7.6 Balancing

The slave BMS uses a passive balancing method to equalize the cell voltages. The balancing resistors have an equivalent resistance of 30 Ω to balance per cell. The balancing current is between 100 mA and 140 mA. The actual cell balancing algorithm is controlled by the master BMS, since balancing is performed over the complete battery pack.

8 INTEGRATION REQUIREMENTS AND INSTRUCTIONS

This chapter describes the integration requirements and instruction. Read this chapter carefully.

8.1 Risk assessment

Integration of a battery system requires in any case an assessment of the risks. Depending on the application, specific rules might apply.

A basic risk assessment is available in the RS - Basic risk assessment.
A description of the risks and control measures can be found in the RS - Safety description.

NOTICE:
Before integration design check the applicable rules for the application where the battery system will be integrated in.

8.2 Project process

The review of integration consists of the following steps:

1. Design of electrical installation by electrical system integrator.
2. Review of schematic of the actual electrical installation by MG.
3. Installation of the battery system by electrical system integrator.
4. Review of the installation by MG. Send pictures of the installation and connections.
5. Commissioning of the battery system (MG, electrical system integrator). Remote commissioning is possible. A skilled technician must be on site to configure and test the system.
6. System ready for use.

8.3 Location

The location of the battery system needs special attention, since some regulatory categorize Lithium-Ion battery systems as hazardous. Check for the local rules for the requirements of the battery system location in the used application.

General recommendations and requirements for the battery space with respect to the battery module are as following:

- Make sure the battery space is in accordance with the applicable rules.
- Keep the battery string connection cables as short as possible.
- Make sure that the DC cabling of each parallel battery or string have the same cable lengths.
- Ensure that the equipment is used under the correct operating conditions.

8.3.1 Environment

The battery modules must be placed in a space that is moisture free, non-condensing and protected against fluid (water, oil etc.) ingress.

WARNING:
Moisture or water can damage the battery and its electronics. This might lead to dangerous situations.

8.4 Thermal management

8.4.1 Design rules

Below a list of design rules for the liquid cooling system.

- Connect the liquid cooling of each battery module in parallel.
- Pressure less return. This means an open buffer tank that equalizes with the ambient pressure and a sufficient return line diameter size to limit the pressure drop.
- Install a pressure indicator at the inlet and outlet of the system.
- Inlet temperature may not be lower than 20 °C and Non-condensing.
- When using chilled liquid with a heat exchanger, make sure an active temperature control is installed to bypass the heat exchanger.
- Install a flow sensor or indicator.
- Install a low level switch in the buffer tank.
- Recommended is to install a particle filter of 500 µm at the inlet.

Find an example schematic of the liquid cooling system in Appendix B.

8.4.2 Requirements table

Cooling system	Fluid cooling system with pressure-less return (battery module's outlet side).
Coolant type	Ethylene glycol based with a ratio of 90% Ethylene glycol and 10% demineralised water. https://www.huchem.nl/ethyleen-glycol-100.html
Coolant inlet temperature	Range of 20 °C to 30 °C. Higher temperatures are possible at request. This could reduce cycle life and performance.
Maximum inlet pressure	0.7 bar (versus ambient)
Maximum outlet pressure	0.3 bar (versus ambient)
Operational flow	1 l/min with a pressure drop of 0.3 to 0.5 bar.

CAUTION:
The following aspects must be taken into account:

- Make sure the coolant solution is ethylene glycol based. The use of propylene glycol based coolants can lead to permanent damage of the battery module's interior.
- Make sure that the cooling inlet and outlet are not reversed. Reverse flow can lead to excessive pressure on the battery module's interior resulting in permanent damage.
- No vacuum filling or filling with the use of external pumps are allowed.
- Make sure height difference of all components not exceed 2m.
- Always use hoses, tubes and other components for compatibility with the required regulations and class register.
- Take into account the relative positioning of the pump, buffer tank and batteries for an optimal functioning liquid cooling system.

NOTICE:
When system requirements are not clear or cannot be fulfilled, please contact MG Energy Systems to discuss other possibilities and solutions.

8.4.3 Parts selection

In the paragraphs below some parts selection suggestions.

NOTICE:
For class register type approved system use equipment that is approved according to their specific rules.

8.4.3.1 Pump

There are two main parameters to select the right pump. The pressure and the flow.

The flow is depending on the number of battery modules that are connected and the charge/discharge rate of the batteries.

- < 1C charge/discharge = 1 l per min / module
- > 1C charge discharge = 2 l per min / module (only permitted when strictly necessary)

For example using 8x RS battery modules with a C-rate of < 1C, the required flow is 8 l per minute.

The pressure that is required for the pump is around 1 Bar. In almost all cases this will result in 0.7 Bar as a maximum with the higher viscosity of the cooling fluid.

The table below shows a number of pumps that can be used:

Pump brand	**Link**
SPX Flow – Johnson Pump Marine	https://www.spxflow.com/johnson-pump-marine/products/cm-magnetically-driven-with-brushless-motor/ https://www.spxflow.com/johnson-pump-marine/products/cm-magnetically-driven-with-brush-motor/
Grundfos	Alpha 2 Or Similar.

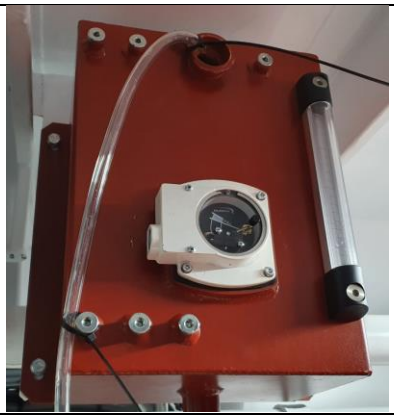
CAUTION:
Select a pump that has a ***stainless steel*** pump house.

8.4.3.2 Buffer tank

The buffer tank can be a small tank depending on the system size. For a few battery module a small plastic tank could be used. For larger systems a smaller fuel tank could be used or similar solution.

Important is that the buffer tanks are open to the ambient and placed in the return line of the cooling system. This will result in a minimum pressure on the battery module cooling outlet.

Minimum required buffer tank size: 5 litres

Small fuel tank with low level switch	Plastic buffer tank
	

8.5 Propagation protection system (PPS)

The battery module is equipped with a thermal Propagation protection Systems (PPS). At the rear of each battery module a connection point is available to prevent cell-to-cell and module-to-module thermal runaway propagation. When a thermal runaway event occurs, the PPS fluid will be automatically released into the battery module. The propagation protection fluid is normally contained in a pressurised tank, a PPS tank.

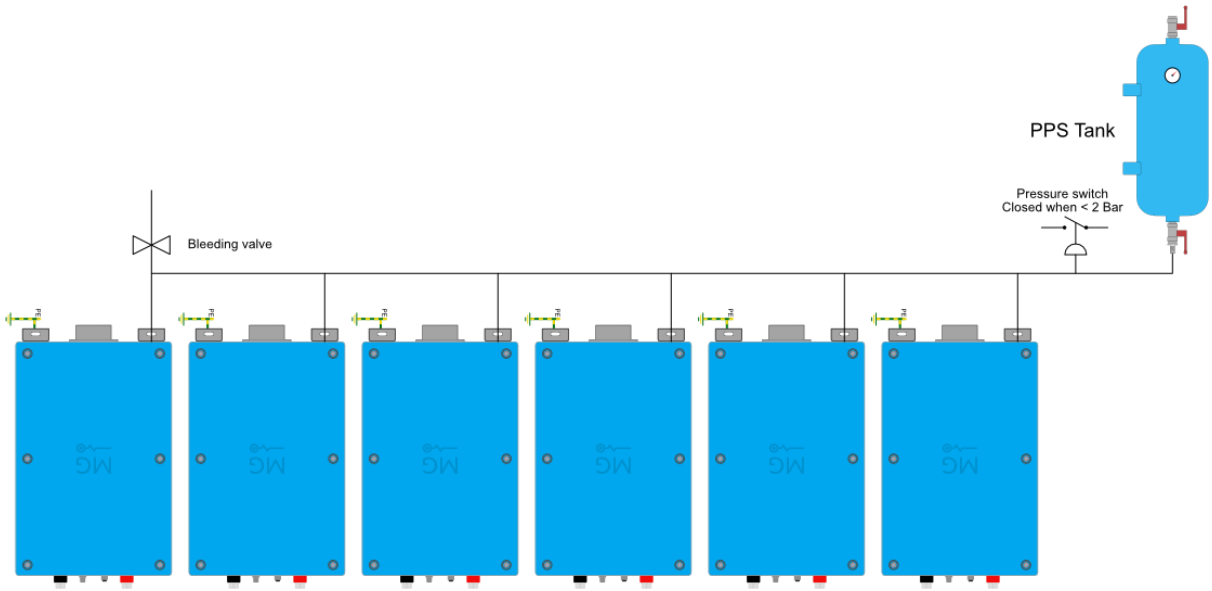


Figure 16 - Propagation prevention system connection schematic

NOTICE:
Multiple battery modules can be connected in parallel to one PPS tank. It is recommended to install at least one PPS tank per six batteries. It is mandatory to use at least one PPS tank per battery string.

WARNING:
Make sure the Propagation Protection System is used as described under all circumstances.

LIMITATION:
A single PPS pressure container can, for integration reasons, serve more than one battery module by parallel connection. In such a situation it must be considered than when the PPS system is triggered in one battery module, the remaining parallel connected battery modules are unprotected from that point on.

CAUTION:
When the PPS is activated, fluid will flow into the battery module. When there is flowing more than 12 litres into the battery module it will reach the exhaust output and fluid will flow into the exhaust ducting.

8.5.1 PPS tank

There is a standard PPS tank part available. The ordering information of this tank can be found in Appendix C.

More detailed information about the PPS tank, such as installation instructions and commissioning can be found in the MG RS PPS Tank Manual.

8.6 Exhaust

The exhaust system has the function to channel the released gasses during a thermal runaway event to a safe area. To be able to do this, an exhaust output with pressure relief is designed at the rear of the battery module. A ducting system can be connected to extract the toxic and flammable gasses from the module and prevent it from releasing the gasses in the battery area (closed area).

The battery module is provided with an exhaust connection as described in chapter 6.3.4.

To provide a connection to a ducting system two optional parts are available.

Sleeve part: MGRS00100002	**Flange part: MGRS00100001**
	
	

8.6.1 Example ducting arrangement

Figure 17 shows an example of a ducting arrangement of the battery modules.

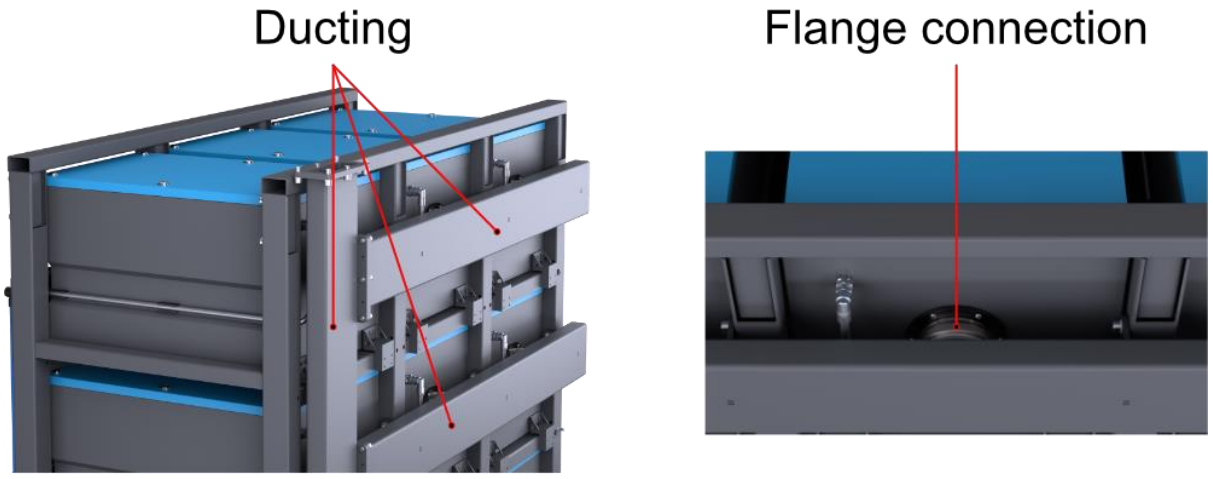


Figure 17 - Example ducting and flange connection

Recommended options for the exhaust ducting design are:

- Add a drain to the lowest points in the ducting system. This will help to remove any liquids for example the liquid of the PPS after a thermal runaway event;

- Add a nozzle to apply air pressure to the ducting system. This will help to clean the exhaust system from remaining gasses after a thermal runaway event and makes it safe to remove the broken battery module.

8.7 Inclination

The maximum inclination angle is ±7.5 °. Main reason for this is the functioning of the PPS.

8.8 Battery rack

It is recommended to mount the battery modules in a rack secured with all four mounting brackets. Different parameters need to be taken into account when designing the battery rack:

- Weight of the battery modules;
- Shock and impact requirements;
- Battery module spacing;
- Fluid cooling and exhaust pipes.

There are two options for a battery rack:

- The customer/shipyard/OEM manufacturer designs and produce their own battery rack;
- MG provides their standard RS battery Rack. Including exhaust and liquid cooling manifolds. For more information about the standard rack contact MG Energy Systems B.V.;

8.8.1 MG RS battery rack

The standard MG RS battery rack provides all the necessary requirements to install, connect and mount the battery modules. Different physical layouts can be configured to fulfil the requirements of the application. Figure 18 shows an example rack configuration.

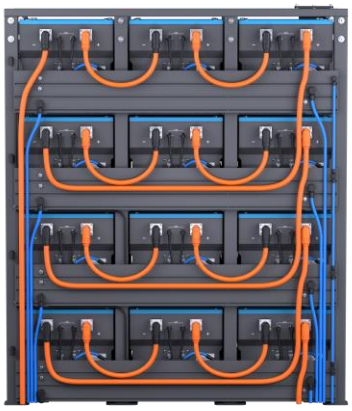


Figure 18 - RS Rack example

Refer to the MG RS battery rack description document for detailed information about the standard RS Rack.

NOTICE:
Always order battery modules with the push-in and PPS tube options when RS battery modules are used in a standard MG RS battery rack.

8.8.2 Battery rack requirements

8.8.2.1 Battery module spacing requirements

Figure 19 shows the minimum spacing of the battery modules.

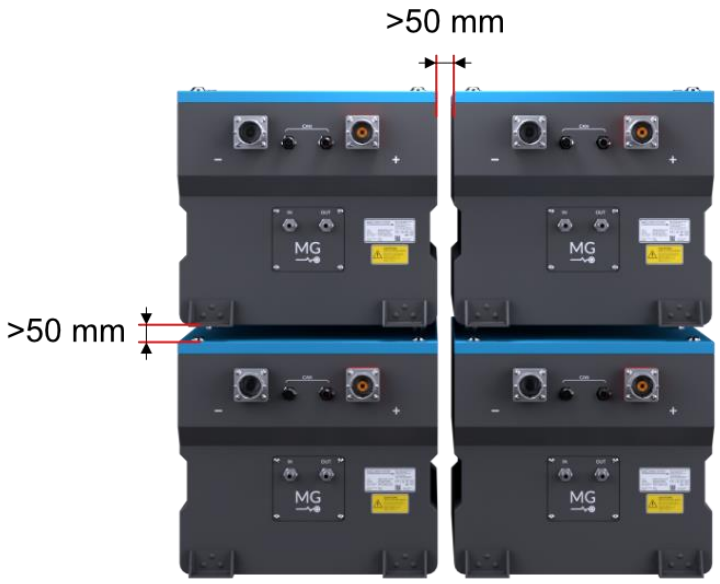


Figure 19 - Space requirements between battery modules

8.8.2.2 PPS tube option

It is recommended to use the PPS tube option when a standard RS Rack is used as shown in Figure 20.

Figure 20 - PPS tube options mounted on the RS battery module

8.8.2.3 Battery rack cable layout

Figure 21 shows an example cable layout for a 2 by 2 module configuration.

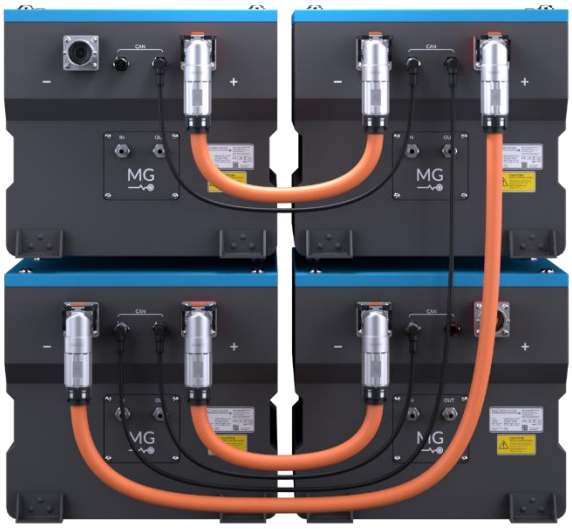


Figure 21 - Battery pack recommended cable layout for 2 by 2 modules

9 INSTALLATION

Read the installation instructions in this chapter before commencing installation activities.

WARNING:
Before continuing make sure the following instructions are met:

- Ensure that the connection cables are provided with fuses and circuit breakers.
- Never replace a protective device by a component of a different type. Refer to the ordering information sections of this manual or contact manufacturer for a correct replacement.
- Before switching the device on, check whether the available DC bus voltage range conforms to the configuration of the product as described in the manual.
- Ensure that the equipment is used under the correct operating conditions.
- Ensure that there is always sufficient free space around the product.
- Install the product in an environment that can sustain some heat. Ensure therefore that there are no chemicals, plastic parts, curtains or other textiles, etc. in the immediate vicinity of the equipment.

9.1 Installation procedures

Below the basic installation procedures at battery module level.

1. Mount the battery module: mounting procedure;
2. Equipotential bonding of the battery modules: equipotential bonding procedure;
3. Connect the battery module electrically: electrical connection procedure;
4. PPS connection procedure;
5. Exhaust connection procedure;

NOTICE:
During installation a check form needs to be used to log the installation procedure. This log will be checked during commissioning.

9.2 Mounting procedure

This procedure describes how to mount the battery module with respect to the integration requirements stated in chapter 8.

1. Lift the battery module to its location using the mounting points specified in Figure 22.
2. Use M8 bolts with body washers and spring washers or a lock nut for mounting.
3. Tighten the M8 bolts at the four mounting points with **20 Nm**.

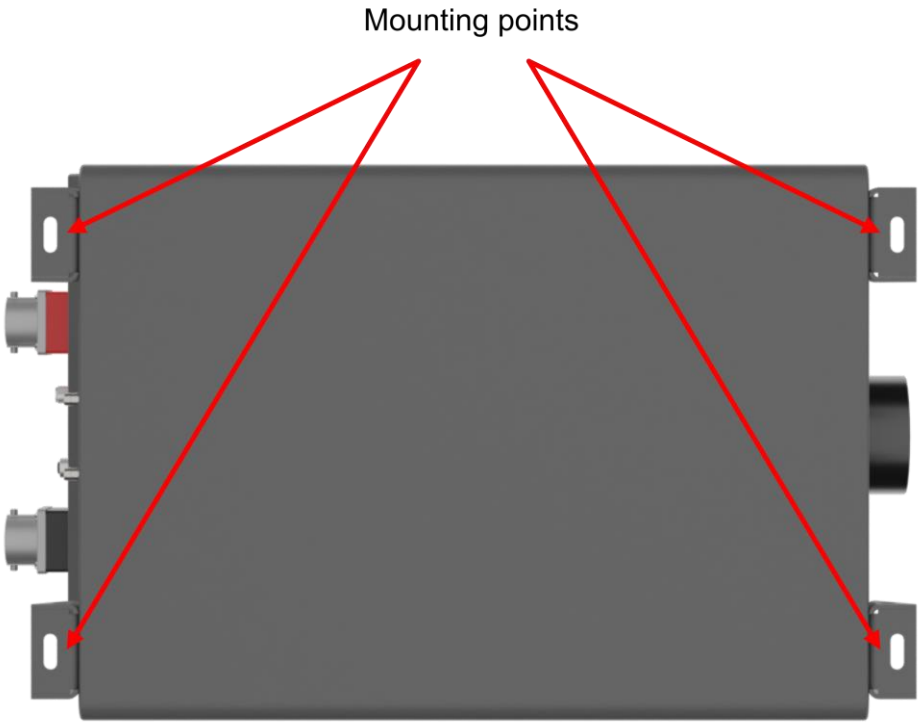


Figure 22 – Mounting points (bottom view)

Figure 23 - Front view mounting

9.3 Electrical connection procedure

The battery module can be used in combination with other battery modules of the same type and always in combination with a MG Master BMS.

ELECTRICAL HAZARD:
The battery modules can be placed in series up to 900 VDC. Make sure to wear proper insulation gloves and safety goggles. Take the local safety regulation and procedures into account before starting the connection procedure.

ELECTRICAL HAZARD:
Before connecting the DC power cables, make sure the other ends are protected or connected.

9.3.1 Equipotential bonding procedure

The equipotential bonding connection location of the battery module is the same as the mounting bracket. One of the four mounting points can be used to connect a bonding wire or a contact washer as shown in Figure 24. Equipotential bonding connection scheme and the required wire cross-section depend on local standards and regulation. The typical used wire cross-section is 16 mm^2 with a minimum of 10 mm^2.

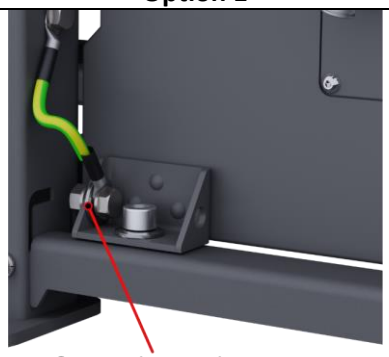
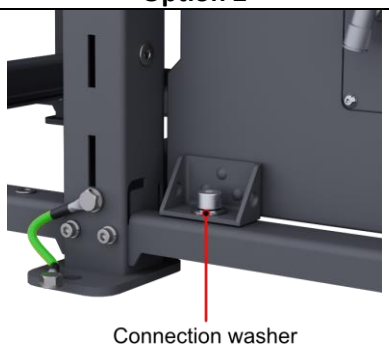
Option 1	Option 2
	

Figure 24 - Equipotential bonding options

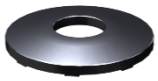


Figure 25 - Contact washer

NOTICE:
Local standards and regulation might be applied for sizing and connection type of the equipotential bonding.

NOTICE:
Make sure a contact washer is used to make a good connection through the powder coating.

9.3.2 CAN-Bus connection procedure

This section describes the connection of the RS battery communication cables.

9.3.2.1 Basic connection layout

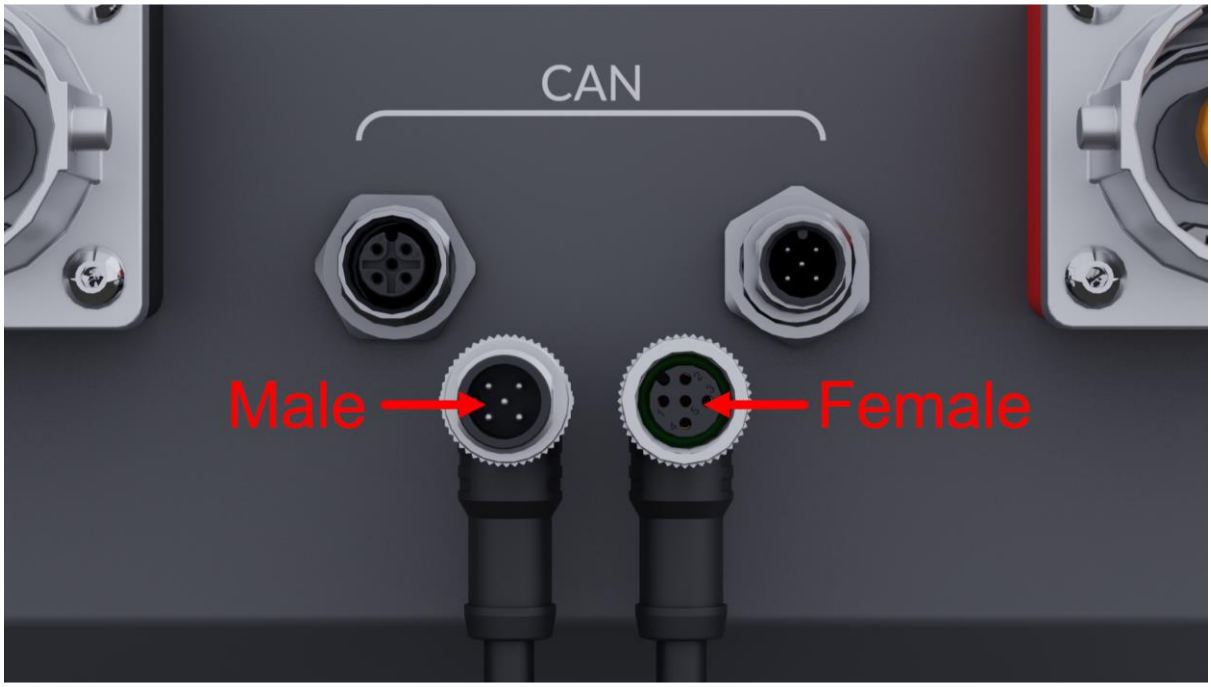
The layout of the CAN-Bus connection is as following:

1. Start with a CAN-bus cable at the MG Master BMS, the Battery CAN-Bus, and go to the first battery.
2. Connect from the first to the second battery. Repeat this until the last battery module.
3. Connect the last battery back at the MG Master BMS's Battery CAN-Bus.

9.3.2.2 Connecting procedure

The following procedure describes the connecting of a M12 connector to the RS battery module.

1. Check for the keying of the CAN-Bus connectors.

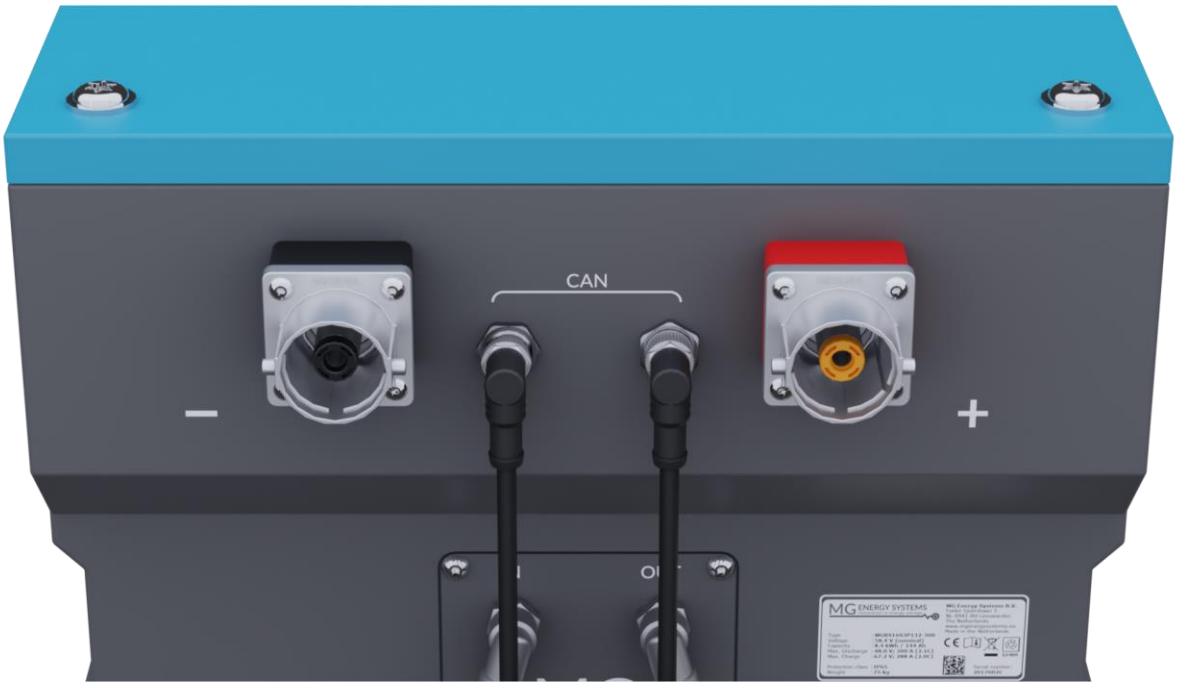


NOTICE:
To avoid EMC issues it is recommended not to route CAN-bus cables alongside power cables.

2. Bring the connections face of the cable connector up the device connector in such a way that the position of the key matches to that of the opposing connector.

3. Connector in place.

4. RS battery module with fully connected CAN-Bus M12 connectors.



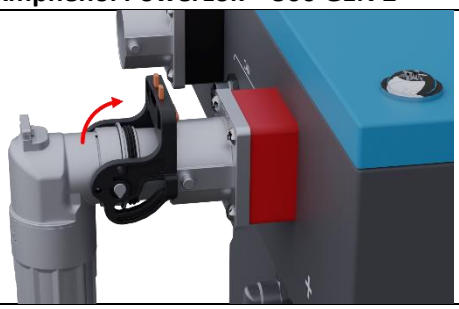
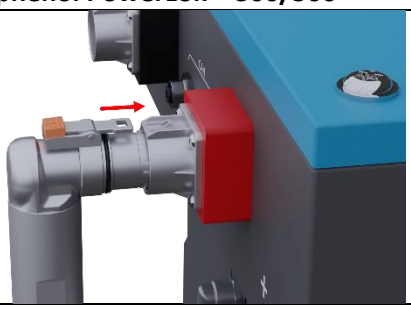
9.3.3 Power connection procedure

The power connections make use of the Amphenol PowerLok™ connectors. See section 6.3.2 for detailed information about types and cable sizes available.

ELECTRICAL HAZARD:
The battery modules can be placed in series up to 900 VDC. Make sure to wear proper insulation gloves and other applicable safety gear.

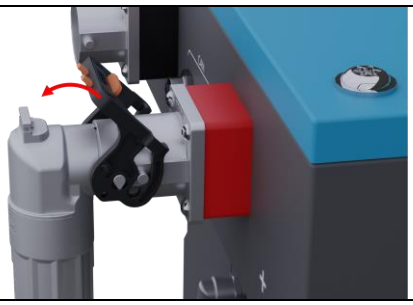
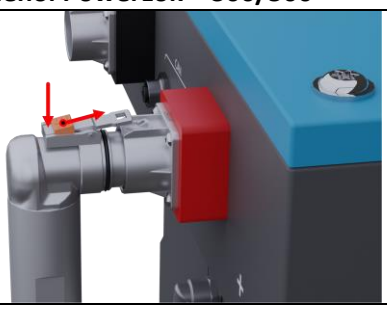
Follow this procedure to connect the Amphenol PowerLok™ connectors to the battery module:

1. Plug in the Amphenol PowerLok™.

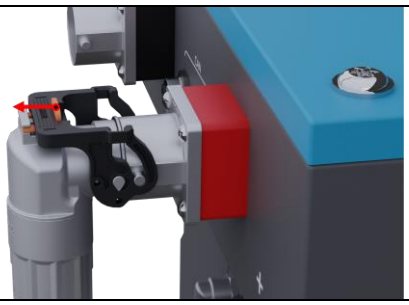
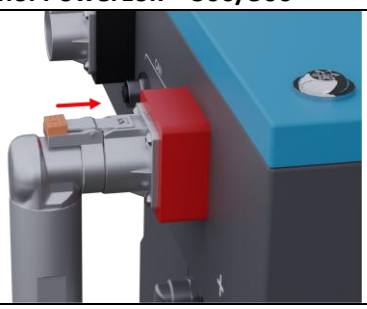
Amphenol PowerLok™ 500 GEN 2	Amphenol PowerLok™ 300/500
	
Make sure the black handle is facing forward.	Push the connector.

NOTICE:
Orange is the positive terminal of the battery and black is the negative terminal of the battery. This cannot be switched because connectors are keyed.

2. Push in and lock the connector.

Amphenol PowerLok™ 500 GEN 2	Amphenol PowerLok™ 300/500
	
Pull the black handle down to lock the connector.	Push the orange/black lip forwards and down before pushing the connector in.

3. Lock and check if the connector is locked.

Amphenol PowerLok™ 500 GEN 2	Amphenol PowerLok™ 300/500
	
Push the orange pin in the black handle to lock it and check if it is locked.	Check if the connector is locked.

9.4 Fluid cooling connection procedure

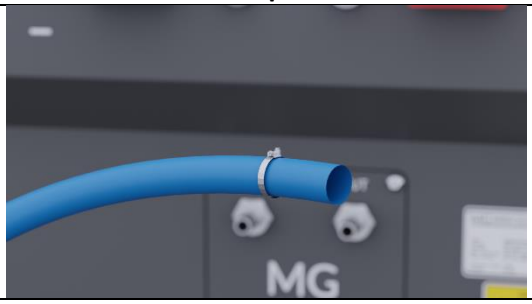
The fluid thermal management of the battery system is a two-line system, consisting of a cold supply line and hot return line. Each battery module is connected in parallel to the supply and return line, an example is shown in Appendix B.

For more information about the thermal management setup, e.g. pumps, heat exchanger, etc., please refer to chapter 8.4.

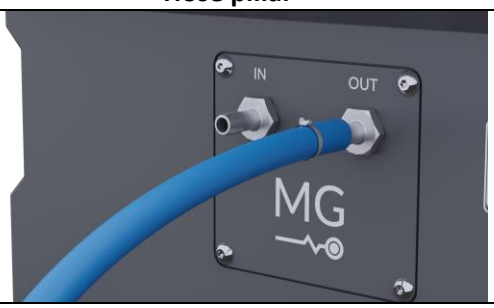
Fluid cooling hose connection is explained in the following steps.

1. Take the correct hose to connect to the fluid cooling connection.

WARNING:
Use the appropriate hose type for the different type of fluid connections. See chapter 6.3.3.

Push-in connector	Hose pillar
	
	Place a hose clamp on the hose.

2. Connect the hose to the fluid cooling connection.

Push-in connector	Hose pillar
	
Push the hose into the push in connection.	Push the hose over the pillar.

3. Check the locking of the hose connection.

Push-in connector	Hose pillar
	
Push the hose al the way into the connection and check if the hose is locked.	Push the hose al the way into the connection and lock the hose with the hos clamp.

4. Repeat the steps for all fluid cooling connections.

WARNING:
Do NOT connect the fluid cooling system before the cooling system is tested without the connection of the battery modules.

9.5 PPS connection

The PPS connection can be connected in two ways. Using the hose pillar option or the compression coupling which is used for the PPS tube option.

- Hose pillar connection: Follow the hose pillar connection in chapter 9.4.
- PPS tube connection: See chapter 6.3.5 for connection specifications.

WARNING:
Always test on leakages with an air pressurized PPS system first before filling the PPS tank with fluid. See the RS PPS Tank manual for details about this procedure.

9.6 Exhaust connection

The RS battery module will be connected to a flange or sleeve part which is mounted on a bigger exhaust ducting system. To have a leak free connection Molykote 55 O-ring grease needs to be added to the O-ring of the flange or sleeve part before sliding in the battery module.

Figure 26 - Adding grease to the O-ring in the flange or sleeve part

10 COMMISSIONING

The commissioning of an RS battery system must always be performed by an employee of MG Energy Systems B.V. or a technician trained by MG Energy Systems B.V.

10.1.1 Commissioning checklist

The commissioning consist at least of the following parts:

- Check the mechanical installation of the battery modules;
- Check exhaust installation;
- Check the equipotential bonding connections;
- Check fluid cooling installation;
- Filling and testing of fluid cooling installation;
- Check the PPS installation: Installation of the PPS tank and connections;
- Filling and testing of the PPS tank;
- Check electrical connections;
- Check insulation resistance;
- Configure the Master BMS;
- Start-up the system;
- Check charge and discharge limitation functionality;

Some of the points from the list can be covered in the early stages of the project to limit the onsite presence of the commissioning and detect design flaws early. See chapter 8.2 for details on the project process.

WARNING:
Do NOT fill the liquid cooling system with connected battery modules before the actual commissioning. Contact MG Energy Systems B.V. for instructions.

11 DECOMMISSIONING PROCEDURES

This chapter describes procedures to decommission the battery system or module for several situations.

11.1 Procedure: removing a malfunctioning battery module

This chapter describes the procedure to follow if a malfunction in a battery module has occurred.

WARNING:

- Use the correct personal safety gear.
- The released gasses during a thermal runaway are explosive and toxic.
- Always consult the local safety protocols before performing any procedures.

NOTICE:
The procedures in this chapter are indicative and can differ depending on the situation, (local) regulations and standards. Therefore MG Energy Systems B.V. cannot accept responsibility for damage, injury, or expenses resulting thereof.

11.1.1 Detecting malfunctioning

A malfunctioning battery module can lead to a number of different situations that takes the complete battery system out of operation. The list below shows the most plausible alarms that can occur on the MG Master BMS.

- High temperature alarm;
- Damaged temperature sensors alarm (at least 2);
- Damaged BMS: no communication, no temperatures, voltages etc;

Other signs of a malfunctioning battery module:

- Low insulation resistance;
- Leakage detection alarm;
- Low cooling fluid level switch alarm;
- Smoke/gas in the gas exhaust and coming out at the end of the ducting;
- PPS Tank released the containing fluid. Pressure drops towards 0 Bar;
- Enclosure of battery module has a higher temperature comparing to the other battery modules;
- A battery module emits an unusual smell.
- A battery module such a high temperature that it cannot be touched.
- A battery module changes colour and/or shape.

These alarms and signs, but not limited to, are an indication for a malfunctioning battery module.

NOTICE:
In case of the suspicion of a malfunctioning battery module or any anomalies pointing towards this. It is mandatory to stop the battery system from operating and contact MG Energy Systems B.V. for specific instructions.

11.1.2 Monitoring the battery module

Depending on the situation and damage, several actions may be taken.

11.1.2.1 Example situation 1

One of the battery modules in a system is malfunctioning and it still communicating with the MG Master BMS. In that case the temperature of the particular battery module can be monitored by the MG Diagnostic Tool or any other monitoring system which is digitally connected to the MG Master BMS.

11.1.2.2 Example situation 2

One of the battery modules in a system is malfunctioning and is not communicating anymore with the MG Master BMS. In that case it is advised to monitor the temperature of the battery module in another way, for example a thermal imaging camera or external temperature sensor.

11.1.3 Remove and secure the battery module

The following procedure is only applicable when the battery module has cooled down, and thermally stable to ensure a safe removal of the battery module.

1. Take the system out of operation. Contactors of the MG Master BMS open.
2. Disconnect the main power connectors from the MG Master BMS.
3. Find and inspect the particular battery module.
4. Before removing the battery module, verify whether the temperature has cooled down within safety levels. This can be checked with either a thermal imaging camera or using the MG Diagnostic Tool if possible.

WARNING:
Wear protective clothing and gloves to avoid injuries through heat.

5. Disconnect the power and communication connectors from the particular battery module.

ELECTRICAL HAZARD:
When there is a low insulation resistance in the battery system or battery module, make sure using proper insulation gloves before touching any parts of the battery system.

6. Clean the exhaust ducting system from any gas by blowing clean air through.
7. Remove the battery module.
8. Place the exhaust overpressure protection back into the module to contain the PPS media from spilling.

WARNING:
Keep the module horizontal during removal to maintain sufficient cooling of the PPS media around the internal battery cells.

9. Place the battery module in a water filled container at a safe location, for example outside. The temperature of the battery module will be kept low and the module is secured from a new event.

NOTICE:
In some cases it is not possible to remove and secure the battery module immediately. In those situations it is mandatory to constantly monitor the temperature of the battery module to be prepared for any emergency situation.

11.2 Procedure: removing a battery module from a functioning system

In some cases batteries need to be removed from a correct functioning system to be stored for a longer period of time and reinstalled later. This chapter describes the procedures for removing the batteries and prepare them for storage. Before starting the removal procedure make sure the battery bank is charged between 50% and 70% SoC.

11.2.1 Removing battery modules

The following procedure is only applicable when the battery module has cooled down, and thermally stable to ensure a safe removal of the battery modules.

1. Take the system out of operation. Contactors of the MG Master BMS open.
2. Disconnect the main power connectors from the MG Master BMS.

ELECTRICAL HAZARD:
Use proper insulation gloves before removing any parts of the battery system.

3. Disconnect all power cables from the batteries.
4. Disconnect all communication cables from all batteries.
5. Remove each battery module one by one.
6. Prepare the modules for a long storage period.

11.2.2 Prepare the battery module for a longer storage period

Additional preparations are required when the battery modules are stored for a longer period of time and are removed from a correct operating system.

- Flush every battery module, to extract the liquid cooling fluid, with low pressure air.
- Make sure the battery modules are charged between 50% and 70% SoC.
- Make sure the storage requirements from chapter 3.2 are met.

12 SERVICE

12.1 Maintenance

For maintenance it will be sufficient to inspect the following points once a year:

- Check power connectors for correct mating and locking.
- Check if all communication connections are mated.
- Check for traces of water, oil, moisture, any other fluids or dust.
- Check for signs of corrosion.
- Clean the device.
- Check status with the MG Diagnostic Tool when anomalies are detected.

ELECTRICAL HAZARD:
Do not poor or spray water directly onto the device. When cleaning the device be aware that the connected battery string is a permanent energy source. Even when the device is turned off, the battery power connections might carry dangerous voltage levels.

12.1.1 Cleaning

Cleaning of the device is best done using a dry or slightly damp cloth. Limit the use of cleaning agents. If a cleaning agent is to be used, use of an electrically non-conductive cleaning agent is advised.

It is important to keep the battery spaces clean and tidy in order to minimise the need for cleaning. Prevent the use of moisture, vaporizing agents, oil, grease, etc. in the vicinity of the device.

12.1.2 PPS system pressure

It is recommended to check the PPS pressure and liquid level on a regular bases. The pressure must be in range of 2 - 3 bar gauge pressure and the level of fluid must be 12 litres. Frequency of this check depends on the applicable rules, but must be done at least annually or the system can be applied with a pressure switch connected to an alarm system.

12.2 End-of-life

The battery module is considered end-of-life if the SoH is decreased to 70 %. After this period it is strongly advised to replace the battery module to ensure maximum safety.

If the application does not feature an EMS or the EMS does not support live monitoring of the SoH, it is good practice to check the SoH manually on a regular basis. Manually checking of the SoH can be done using the MG Diagnostic Tool software. The frequency on which the SoH check is carried out depends on the applicable rules, but must be done at least annually.

12.3 Disposal

Batteries marked with the recycling symbol must be processed locally via a recognized recycling agency. By agreement, they may be returned to the manufacturer. Batteries must not be mixed with domestic or industrial waste. Before disposal it is recommended to discharge the battery module to 0 VDC.

13 BOUNDARY LIMITS

The boundary limits that are used by the master for the battery modules are listed in this chapter. A level will be triggered when a boundary condition is true for a defined period of time.

Battery thresholds are compatible with the following master BMS firmware versions or higher:

- Master HV 1.13 or higher
- Master LV 1.23 or higher

13.1 Slave BMS

Boundary limits for the slave BMS are defined to keep the battery within the manufacturer specifications.

The tables with the boundary limits consist of:

- Name, description of the situation;
- Action, action on respond of the boundary, set/clear or failsafe;
- Boundary condition, contains a value that is needed for an action in combination with the time. This depends on the master strategy setting, default or performance;
- Time that the boundary condition has to be present before it will be triggered. Times indicated with "+" start counting if the previous boundary condition above is set.

13.1.1 Cell voltage

Table 15 Cell voltage boundary limits slave BMS

		Boundary condition		
Name	**Level**	**Default**	**Performance**	**Time**
Almost charged	Set	>= 3950 mV	>= 4150 mV	10 sec.
	Clear	< 3900 mV	< 4100 mV	10 sec.
Charged	Set	>= 4050 mV	>= 4200 mV	+10 sec.
	Clear	< 3950 mV	< 4150 mV	10 sec.
Over voltage warning	Set	>= 4150 mV	>= 4225 mV	+20 sec.
	Clear	< 4050 mV	< 4200 mV	20 sec.
Over voltage critical	Failsafe	>= 4200 mV	>= 4250 mV	+5 sec.
Almost discharged	Set	<= 3225 mV		10 sec.
	Clear	> 3275 mV		10 sec.
Discharged	Set	<= 3000 mV		+10 sec.
	Clear	> 3225 mV		10 sec.
Under voltage warning	Set	<= 2800 mV		+20 sec.
	Clear	> 3000 mV		20 sec.
Under voltage critical	Failsafe	<= 2700 mV		+5 sec.

13.1.2 Cell temperature charging

Table 16 Cell temperature charging boundary limits slave BMS

		Boundary condition		
Name	**Level**	**Default**	**Performance**	**Time**
Over temperature alert	Set	>= 38 °C		5 sec.
	Clear	< 37 °C		5 sec.
Over temperature	Set	>= 40 °C		+20 sec.
	Clear	< 38 °C		20 sec.
Over temperature critical	Failsafe	>= 45 °C and charge current > 5% battery capacity		+60 sec.
Under temperature alert	Set	<= 1 °C		5 sec.
	Clear	> 2 °C		5 sec.
Under temperature	Set	<= 0 °C		+20 sec.
	Clear	> 1 °C		20 sec.
Under temperature critical	Failsafe	<= -5 °C and charge current > 5% battery capacity		+60 sec.

13.1.3 Cell temperature discharging

Table 17 Cell temperature discharging boundary limits slave BMS

		Boundary condition		
Name	**Level**	**Default**	**Performance**	**Time**
Over temperature alert	Set	>= 48 °C		5 sec.
	Clear	< 47 °C		5 sec.
Over temperature	Set	>= 50 °C		+20 sec.
	Clear	< 48 °C		20 sec.
Over temperature critical	Failsafe	>= 55 °C		+60 sec.
Under temperature alert	Set	<= -29 °C		5 sec.
	Clear	> -28 °C		5 sec.
Under temperature	Set	<= -30 °C		+20 sec.
	Clear	> -29 °C		20 sec.
Under temperature critical	Failsafe	<= -35 °C and discharge current > 10% battery capacity		+60 sec.

13.1.4 Power terminal temperature

Table 18 Power terminal temperature boundary limits slave BMS

		Boundary condition		
Name	**Level**	**Default**	**Performance**	**Time**
Over temperature alert	Set	>= 60 °C		5 sec.
	Clear	< 59 °C		5 sec.
Over temperature	Set	>= 70 °C		+20 sec.
	Clear	< 60 °C		20 sec.
Over temperature critical	Failsafe	>= 80 °C		+60 sec.

13.1.5 Current

Table 19 Current boundary limits slave BMS

		Boundary condition		
Name	**Level**	**Default**	**Performance**	**Time**
Charging over current warning	Set	> 1.5C	> 2C	10 sec.
	Clear	<= 1.5C	<= 2C	10 sec.
Charging over current critical	Failsafe	> 2.4C		+20 sec.
Discharging over current warning	Set	> 2.0C	> 3C	10 sec.
	Clear	<= 2.0C	<= 3C	10 sec.

13.1.6 Balancing

Table 20 Balancing boundary limits slave BMS

		Boundary condition		
Name	**Level**	**Default**	**Performance**	**Time**
Offset cell voltage		> 5 mV		5 min.
Balancing cell voltage		>= 3855 mV	>= 3905 mV	5 min.
Battery pack current		current within ±5% battery capacity		5 min.

13.1.7 Deviation voltages and temperatures

Table 21 Deviation voltage and temperature boundary limits slave BMS

		Boundary condition		
Name	**Level**	**Default**	**Performance**	**Time**
Deviation cell voltage	Set	▪ Difference highest and lowest cell voltage >= 200 mV; ▪ lowest cell voltage >= 3225; ▪ current within ±5% battery capacity		4-6 min.
	Clear	▪ Difference highest and lowest cell voltage < 160 mV; ▪ lowest cell voltage >= 3225; ▪ current within ±5% battery capacity		4-6 min.
Deviation cell temperature	Set	Difference highest and lowest cell temperature >= 10 °C		4-6 min.
	Clear	Difference highest and lowest cell temperature < 8 °C		4-6 min.

13.1.8 Leakage detection

Table 22 - Leakage detection warning boundary limits slave BMS

		Boundary condition		
Name	**Level**	**Default**	**Performance**	**Time**
Leakage detection warning	Set	When detected.		60 sec.
	Clear	When not detected.		60 sec.

13.2 Redundancy BMS

The redundancy BMS has thresholds that are beyond the regular slave BMS thresholds stated in section 13.1. When a critical redundancy BMS level is triggered, the master is informed that the hard-wired interlock will be interrupted after 15 seconds. The Master BMS will go to fail-safe once the hard-wired interlock loop is interrupted.

13.2.1 Cell voltage

Table 23 Cell voltage boundary limits redundancy unit BMS

		Boundary condition		
Name	**Level**	**Default**	**Performance**	**Time**
Hardware failure warning	Set	= invalid		1 sec.
	Clear	= valid		1 sec.
Sensor failure critical	Interrupt HVIL	= invalid		75 sec.
Over voltage warning	Set	>= 4400 mV		1 sec.
	Clear	< 4400 mV		1 sec.
Over voltage critical	Interrupt HVIL	>= 4400 mV		40 sec.
Under voltage warning	Set	<= 2200 mV		1 sec.
	Clear	> 2200 mV		1 sec.
Under voltage critical	Interrupt HVIL	<= 2200 mV		40 sec.

13.2.2 Cell temperature

Table 24 Cell temperature boundary limits redundancy unit BMS

		Boundary condition		
Name	**Level**	**Default**	**Performance**	**Time**
Sensor failure warning	Set	= invalid		1 sec.
	Clear	= valid		1 sec.
Sensor failure critical	Interrupt HVIL	2 are more temperature sensor invalid		75 sec.
Over temperature warning	Set	>= 65 °C		1 sec.
	Clear	< 65 °C		1 sec.
Over temperature critical	Interrupt HVIL	>= 65 °C		75 sec.
Under temperature warning	Set	<= -38 °C		1 sec.
	Clear	> -38 °C		1 sec.
Under temperature critical	Interrupt HVIL	<= -38 °C		75 sec.

13.2.3 Power terminal temperature

Table 25 Power terminal temperature redundancy unit BMS

		Boundary condition		
Name	**Level**	**Default**	**Performance**	**Time**
Sensor failure warning	Set	= invalid		1 sec.
	Clear	= valid		1 sec.
Over temperature warning	Interrupt HVIL	>= 95 °C		1 sec.
Over temperature critical	Interrupt HVIL	>= 95 °C		75 sec.

14 TECHNICAL SPECIFICATIONS

The technical specifications of this product can be downloaded from the MG Download Center.

https://downloads.mgenergysystems.eu/rs/documents/technical-specification-en

15 DIMENSIONS

The dimensions of this product can be downloaded from the MG Download Center.

https://downloads.mgenergysystems.eu/rs/drawings/dimensions

16 ORDERING INFORMATION

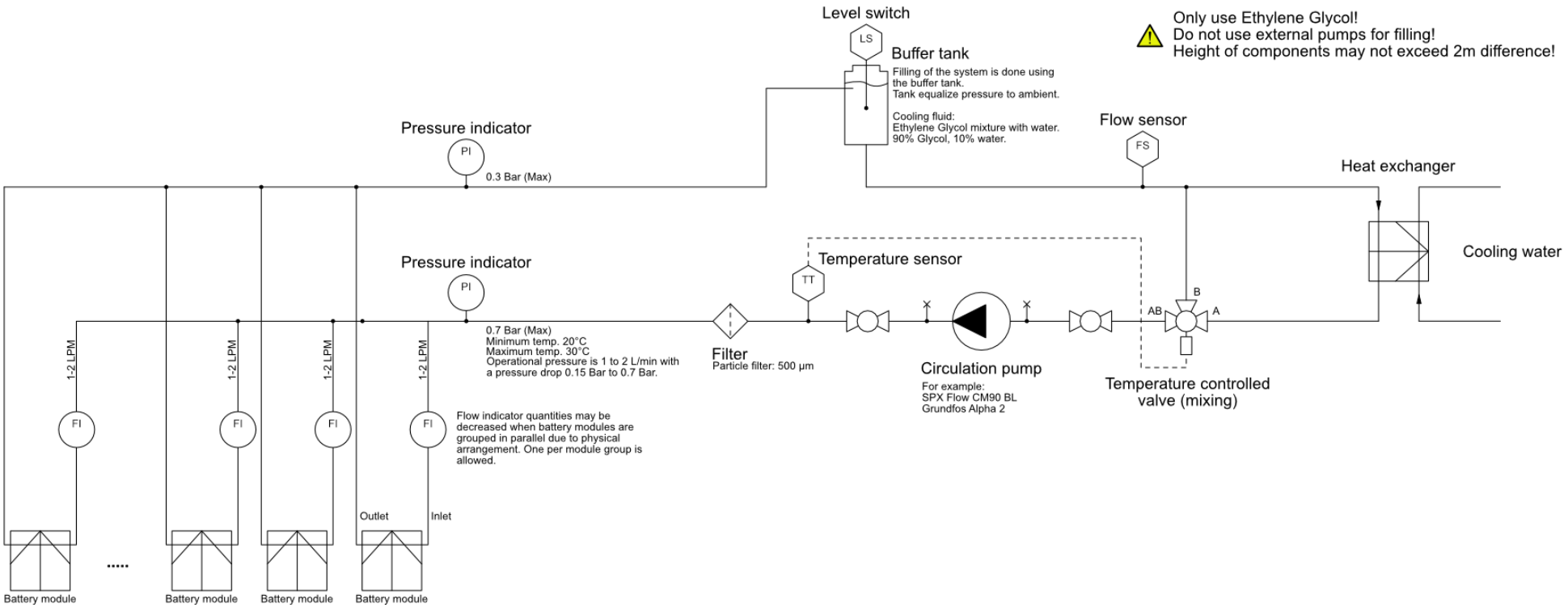
Appendix C shows detailed information about all possible ordering options.

APPENDIX: A

Detailed specification of the RS battery module, internal resistance, short circuit current and heat generation

SOC and temperature	Configuration	Module internal resistance [mΩ]	Peak short circuit current [kA] (cell voltage @ 4,2V)	Heat generation at 0.5C [W]	Heat generation at 1C [W]	Heat generation at 2C [W]
40-100 % SOC, 25 °C	MGRS24S2P088	14.4	7.0	33	133	531
	MGRS16S3P132	6.4	10.5			
	MGRS12S4P176	3.6	14.0			
	MGRS14S3P132	5.6	10.5	29	116	464
40-100 % SOC, 40 °C	MGRS24S2P088	10.2	9.9	24	94	376
	MGRS16S3P132	4.5	14.8			
	MGRS12S4P176	2.6	19.8			
	MGRS14S3P132	4.0	14.8	21	82	329
40-100 % SOC, 10 °C	MGRS24S2P088	25.2	4.0	58	232	929
	MGRS16S3P132	11.2	6.0			
	MGRS12S4P176	6.3	8.0			
	MGRS14S3P132	9.8	6.0	51	203	813
20% SOC, 25 °C	MGRS24S2P088	16.8	6.0	39	155	619
	MGRS16S3P132	7.5	9.0			
	MGRS12S4P176	4.2	12.0			
	MGRS14S3P132	6.5	9.0	34	135	542

APPENDIX: B


Level switch
LS
Buffer tank
Filling of the system is done using the buffer tank.
Tank equalize pressure to ambient.
Cooling fluid:
Ethylene Glycol mixture with water.
90% Glycol, 10% water.
Only use Ethylene Glycol!
Do not use external pumps for filling!
Height of components may not exceed 2m difference!
Flow sensor
FS
Heat exchanger
Cooling water
Pressure indicator
PI
0.3 Bar (Max)
Pressure indicator
PI
Temperature sensor
TT
0.7 Bar (Max)
Minimum temp. 20°C
Maximum temp. 30°C
Operational pressure is 1 to 2 L/min with a pressure drop 0.15 Bar to 0.7 Bar.
Filter
Particle filter: 500 µm
Circulation pump
For example:
SPX Flow CM90 BL
Grundfos Alpha 2
B
AB
A
Temperature controlled valve (mixing)
1-2 LPM
FI
Flow indicator quantities may be decreased when battery modules are grouped in parallel due to physical arrangement. One per module group is allowed.
Outlet
Inlet
Battery module
Battery module
Battery module
Battery module

APPENDIX: C

Ordering information table.

Name	Article number	PPS and cooling connections
MG RS Battery - 12S - 43.8V/192Ah/8400Wh - 300 Series	MGRS12S4P176-300	Hose pilar connections
MG RS Battery - 12S - 43.8V/192Ah/8400Wh - 300 Series	MGRS12S4P176-300	Push-in and PPS tube
MG RS Battery - 12S - 43.8V/192Ah/8400Wh - 500 Series	MGRS12S4P176-500	Hose pilar connections
MG RS Battery - 12S - 43.8V/192Ah/8400Wh - 500 Series - G2 connectors	MGRS12S4P176-500 (G2)	Hose pilar connections
MG RS Battery - 12S - 43.8V/192Ah/8400Wh - 500 Series - G2 connectors	MGRS12S4P176-500 (G2)	Push-in and PPS tube
MG RS Battery - 14S - 51.1V/144Ah/7400Wh - 300 Series	MGRS14S3P132-300	Hose pilar connections
MG RS Battery - 14S - 51.1V/144Ah/7400Wh - 300 Series	MGRS14S3P132-300	Push-in and PPS tube
MG RS Battery - 14S - 51.1V/144Ah/7400Wh - 500 Series	MGRS14S3P132-500	Hose pilar connections
MG RS Battery - 14S - 51.1V/144Ah/7400Wh - 500 Series - G2 connectors	MGRS14S3P132-500 (G2)	Hose pilar connections
MG RS Battery - 14S - 51.1V/144Ah/7400Wh - 500 Series - G2 connectors	MGRS14S3P132-500 (G2)	Push-in and PPS tube
MG RS Battery - 16S - 58.4V/144Ah/8400Wh - 300 Series	MGRS16S3P132-300	Hose pilar connections
MG RS Battery - 16S - 58.4V/144Ah/8400Wh - 300 Series	MGRS16S3P132-300	Push-in and PPS tube
MG RS Battery - 16S - 58.4V/144Ah/8400Wh - 500 Series	MGRS16S3P132-500	Hose pilar connections
MG RS Battery - 16S - 58.4V/144Ah/8400Wh - 500 Series - G2 connectors	MGRS16S3P132-500 (G2)	Hose pilar connections
MG RS Battery - 16S - 58.4V/144Ah/8400Wh - 500 Series - G2 connectors	MGRS16S3P132-500 (G2)	Push-in and PPS tube
MG RS Battery - 24S - 87.6V/96Ah/8400Wh - 300 Series	MGRS24S2P088-300	Hose pilar connections
MG RS Battery - 24S - 87.6V/96Ah/8400Wh - 300 Series	MGRS24S2P088-300	Push-in and PPS tube
MG RS Battery - 24S - 87.6V/96Ah/8400Wh - 500 Series	MGRS24S2P088-500	Hose pilar connections
MG RS Battery - 24S - 87.6V/96Ah/8400Wh - 500 Series - G2 connectors	MGRS24S2P088-500 (G2)	Hose pilar connections
MG RS Battery - 24S - 87.6V/96Ah/8400Wh - 500 Series - G2 connectors	MGRS24S2P088-500 (G2)	Push-in and PPS tube
RS Series exhaust - Ducting flange type	MGRS00100001	
RS Series exhaust - Ducting sleeve type	MGRS00100002	

17 CONTACT DETAILS

For specific questions please feel free to contact us.

17.1 Sales

For sales related questions, please contact a local dealer.

For specific sales questions, please contact our sales team:

MG Sales team
sales@mgenergysystems.eu

17.2 Technical support

For technical support, please follow the steps below:

1. Consult the Manual.
   Manual can be found on the MG Download Center.
2. Watch the Installation Videos.
   Videos can be found on MG's You Tube channel.
3. Check Your Software Version.
   Check and update the products software version to latest using the MG Connect App (Apple or Android) or MG Diagnostic Tool.
4. Contact MG Service Point.
5. Contact MG technical support.
   Send an email with your technical questions to support@mgenergysystems.eu.