PowerCache®
250kVA/273kWh Industrial Energy Storage System
Operator Manual

Prepared for:	Date: 19-03-2021
Owners/Operators using Modbus TCP / 3rd party controller - Commercial in Confidence -	Rev: B1 – Branch with simplified, reduced interfaces and reduced functionality for use with a 3rd-party Modbus TCP Microgrid controller only Authors: MJ, DS, AT

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Date	Revision	Description	Done by
10/02/2021	PT-OM-CF-21-0201	Modbus Operation	DS
19/03/2021	PT-OM-CF-21-0203	Fire Hazard Update Maintenance Update	DS, MJ

1 How to Read This Document

1.1 Who Should Read This Manual?

- Owners, Operators, their technical service providers, and engineers that operate the system or integrate its control into the site or distribution network operation
- Maintenance personnel

1.2 Scope

1.2.1 Exclusion

PowerCache is a functionally highly flexible device customised to a specific site or application. By reading this Operator Manual, a user, or its technical service personnel cannot commission the PowerCache. Commissioning is not in the scope of this document. PowerTec's service is required to commission a PowerCache.

This document is not order-specific. It relates to a PowerCache model, or a specific group of applications of the model. The treatment of a subject in this manual does not necessarily indicate that the related functions or components are part of your project scope of supply.

1.2.2 Inclusions

- Operation of the BESS via a 3-rd party Modbus TCP controller
- Electrical switching, isolation and bonding for safe maintenance work and limited operation via local control elements
- Maintenance

1.3 Drawings

The electrical as-built SLD and interface diagrams are found as appendices to this document (list of appendices above).

1.4 Figures

Figures are for reference only. A figure does not necessarily exactly reflect your version. The appearance of an object in a figure does not indicate that it is a part of the scope of supply.

1.5 Finding Your Way Around the Document

This document works with colours and background shading. We recommend reading it on a computer screen. If print-out is required, a colour printer with a resolution >= 600dpi must be used. Subjects are identified by headlines, easiest found by the Table of Content or a “find” function.

1.6 Abbreviations, Symbols and Acronyms

Abbreviation	Description
4G	Mobile telecommunications technology
AC	Alternating Current
BESS	Battery Energy Storage System
BSC / BMS / BMU	Batter Section Controller / Battery Management System / Battery Management Unit
BoL	Beginning of lifetime of a battery

BPU	Battery Protection Unit (module with battery string switching and protection circuitry
CB, Q	Circuit Breaker
CP/CV-charging	Constant power / constant voltage charging of a battery system
CT	Current Transformer
DC	Direct Current
EKIP	Breaker electronic trip unit (ABB product name)
FOLCB	Fused Overhead Line Connection Box
GUI	Graphic User Interface
IoT	Internet of things
IPC	Industrial, rugged, fan-less PC
JSA	Job Safety Analysis
LV	Low Voltage
MAC	Media Access Control Address – a unique identifier for network devices
MDS	Material Data Safety Sheet
MEN	Multiple Earthed Neutral
Modbus	Open standard serial communications protocol (published by Modicon)
Novec	Artificial gas for Li-Ion battery fire extinguishing
OEM	Original Equipment Manufacturer
O&M	Operation and Maintenance
P	Active power
PaDECS®	Parallel Distributed Energy Resources Control System
PaDEC B	Grid Battery Energy Storage System controller
PaDEC N	Microgrid or grid segment to main Network connection breaker controller
PCS	Power Conversion System
NXP	Inverter product from OEM Vacon, used in the system
PowerCache®	PowerTec's Stabilising Grid Battery Energy Storage product series
PPE	Personal Protective Equipment
Q	Reactive power
RTU	Remote Terminal Unit
RUI	Remote User Interface
S	Apparent power
SAT	Site acceptance test
SCADA	System Supervisory Control and Data Acquisition
SDS	Safety Data Sheet
SLD	Single Line Diagram
SoC	State of charge (in %) of a battery system
SoH	State of health (e.g. in % of remaining capacity) of a battery system or module
SWMS	Safe Work Method Statement
TCP/IP	Transmission Control Protocol / Internet Protocol
VPN	"Virtual Private Network": Secure encrypted access to the BESS via the internet

2 Introduction

PowerCache® is PowerTec's standardised Battery Energy Storage System product series. For the size of 250kVA/270kWh, a PowerCache is deployed as two cabinets: A Battery Cabinet with the battery modules, and an Inverter Cabinet with the inverter, grid connection transformer, main breaker, inter-tie protection relay as well as control and communication systems. The compact, outdoor, ground mounted, modular system is flexible in its application. Applications areas include industrial, commercial and community microgrids, as well as EV fast-charging stations.

PowerCache is a grid-stabilising and grid-forming inverter/battery energy storage system. It includes the "Parallel Distributed Energy Resources Control System" PaDECS® for application control and integration & aggregation with other electricity assets on site and with energy market operators. Using an inverter that can switch between a dynamically controlled voltage source mode and a grid-standards compliant current source mode, a comprehensive range of distribution grid support and energy market functionality is available that make the system unique in its application versatility.

Model-No: JH32P1C14x3-250k588T

Figure 1 – EV-Charging Buffer and Microgrid PowerCache BESS at a car dealership

3 Hazards

3.1 Scope and Exclusions

This section analyses hazards and described their mitigation. The following high-risk work areas are covered and not covered:

- **Covered:** Electrical installation on an isolated network, commissioning, operation, and battery specific hazards

- **NOT COVERED,** i.e. the subjects require further hazard analysis and safe work method documentation by a professional expert transport company or electrical installation company, before conducting these works:
  a) Working at height
  b) Transport, lifting and mechanical installation specific hazards
  c) Utility network specific work practices e.g. supply interruption and isolation practices

- this manual only provides references but does not provide safety instructions for activities and hazards marked as NOT COVERED. The worker must follow references and 3rd party safe work methods for these activities.

3.2 Safe Work Practices Normative and External References

The following documents are normatively referenced and are to be adhered to:

- The most stringent of the safe work practices described in this document and
  - Project-specific SWMS (Safe Work Method Statement) and the JSA (Job Safety Analysis) prepared for the specific site, according to the legislation.
  - Work Health and Safety Act 2011 (Federal)
  - Electricity Safety Act 1998 (Victoria)
  - OHS 2004 Act (WorkSafe Victoria), and respective other applicable state legislation (e.g. the “Work Health and Safety Regulation 2017” (SafeWork NSW), or the “Managing electrical risks in the workplace Code of Practice 2020” (Safe Work SA)
  - Where interaction or connection work with a DNSP is required: The safe work practices and hazard analysis document of that DNSP and the DNSP’s industry association in that state. If the work is done in Victoria:
    - Victorian Electricity Supply Industry (VESI): The Green Book 2019 (Draft), incl.
    - EnergySafe Victoria: The Code of Practice on Electrical Safety for Work on or Near HV Electrical Apparatus (the Blue Book)
  - The safe work practices, hazard analysis documents and SWMS of the installer and/or the site principal contractor on the specific site.
- Specific state legislative requirements about electrical installation safety. In Victoria:
  - Electricity Safety (Installations) Regulations 2009
  - Electricity Safety (Equipment) Regulations 2009
  - Electricity Safety (Management) Regulations 2009

The safe work practices, hazard analysis documents and SWMS of the installer and/or the site principal contractor to adhere to include specialist areas, not mentioned further in this document:

a) Working at height
b) Transport, lifting and mounting
c) Installation on power networks
d) Power network supply interruption and isolation

3.3 Arc Flash Category and PPE

When disconnected from the utility line, an arc flash potential remains from the battery.
The Battery string Voltage is 588V … 820V. During installation work, the battery should be discharged to ~25% SoC, such that the voltage is not much more than 600V.

The arc flash energy is calculated from the following technical features:

- Battery string nominal current: 126A
- Application maximum sustained system DC current: 444A / sustained string DC current: 148A
- Battery system fuse type: Bussmann, IGBT Type Size 230 -FU, fuse rating: 500A
- Battery string fuse type: Bussmann FWA, fuse rating: 200A
- Battery module fuse type: Bussmann FWA, fuse rating: 200A
- Battery string fault characteristic: L/R = 3ms
- Prospective system fault current: 18kA / prospective string fault current: 6k

With the given fuse characteristics:

⇨ Actual system fault level:
3 x 2.3kA = 7kA, fuse virtual pre-arcing time (time to fuse melting): <2ms

PPE according to arc flash PPE category 2 must be worn when working on, and after closing the DC strings, when energising the equipment, or when working on the batteries: Arc-Rated Clothing, Minimum Arc Rating of 8cal/cm2, arc-rated long-sleeve shirt and pants or arc-rated coverall, arc-rated flash suit hood or arc-rated face shield and arc-rated balaclava, arc-rated jacket, parka, rainwear, or hard hat liner.

Protective Equipment: Hard hat, Safety glasses or safety goggles, Hearing protection (ear canal inserts), Heavy duty gloves (1000V rated gloves), Leather footwear.

3.4 General Electrical Hazards

- Dangerous electrical voltages 415Vac, 820Vdc, 24Vdc
- Grounding and short circuiting does not apply to the batteries!
  Never attempt to ground any part of the DC system!
- Regardless of further notices or legal requirements, and in addition to the work methods and installation practices described in AS3000:2018 – Part 2, the following five safety rules in accordance with EN 50110-1:2004 must be applied:

1. Disconnect completely (all supplies and internal sources of dangerous voltages)
2. Protect against re-connection

3. Establish a voltage-level of Zero Volts (to ground of AC circuits)
4. Earth and short AC (does not apply to the DC system!)
5. Neighbouring parts which are energised and under voltage need to be covered or separated

3.5 Multiple Sources of Supply

A high level of awareness is required when working on the various elements of the system because there are multiple sources of dangerous supply voltages:

1. Grid supplies (415V 3 Phase) via external power cables into the AC compartment

2. Grid supplies (415V 3 Phase) via external voltage sense cables into the AC and Control compartments

3. Multiple 820V DC supplies
   a) from the battery cabinet to the inverter cabinet (DC and inverter compartments) via DC power cables – parallel supply from three battery DC strings,
   b) via DC auxiliary supply cables from the inverter-side of the DC disconnect switch in the DC compartment to the LCL-filter in the inverter compartment
   c) from the pre-charge rectifier to the inverter (if contactor K6 is closed)

4. Multiple 240V AC auxiliary power supplies throughout both cabinets
   a) the grid, 3-pahse connected via the inverter cabinet to both cabinets, and
   b) the AC UPS (AC 240V single phase), located in the control compartment of the battery cabinet and supplying to both cabinets

5. DC UPS (24V DC) in the inverter cabinet

Appropriate isolation and work practices are to be followed:

1. Shut down the system:
   Option a: If Modbus is available, execute a SYS STOP command and battery SHUTDOWN command, otherwise
   Option b: Press E-STOP in the battery cabinet to isolate both AC and DC. Warning: Inverter cabinet E-Stop only stops and isolates the inverter cabinet.

2. Open and lock the SYSTEM AC ISOLATOR in the external switchboard (Opening Q2 in the AC cabinet is not enough, as 415V sensor voltages ae still available)

3. Set the inverter selector switch (OFF-RUN-START) to the OFF position. If the inverter has been running, wait for 5 minutes for its DC capacitors to discharge.

4. Check that the string isolation breakers in the 3 battery racks are in tripped or OFF position and locked.

5. Turn off the AC UPS, located in the battery cabinet's control compartment

6. If working on the control system hardware, shutdown the 24V DC UPS by pulling the two exposed DC fuses on the Weidmueller DC UPS battery module

3.6 Battery-Specific Hazards

3.6.1 DC System Hazards

- During DC system installation, short-circuiting battery (+) and battery (–) poles or short-circuiting inverter (+) and inverter (-) poles or interconnecting battery and inverter with wrong polarity can cause serious equipment damage, when the system is stated up.
  ➔ Read the Installation Manual to avoid polarity mistakes!
- Dangerous electrical voltage 820Vdc exists in the battery cabinet, in the inverter cabinet's DC compartment and in the inverter compartment.
- Grounding and short circuiting does not apply to work on the batteries! The DC circuits are at floating potential and must be kept at floating potential. Never attempt to ground any part of the DC system!
- Parallel battery DC strings: Always ensure that the string isolation breakers in all 3 battery racks are in tripped position, and locked in that position, when working on the DC system.

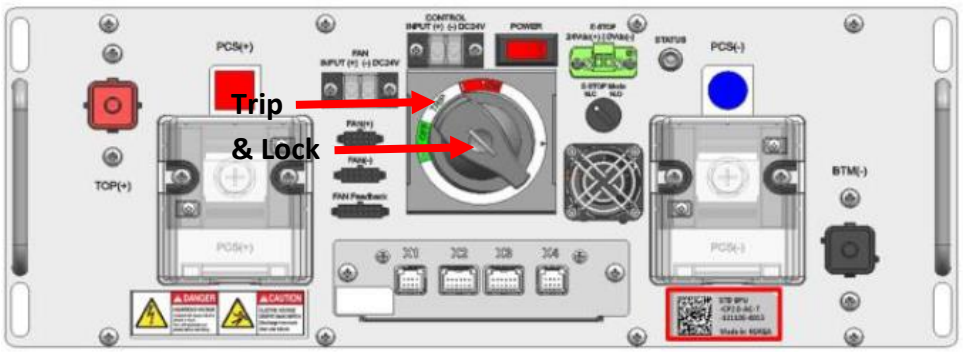


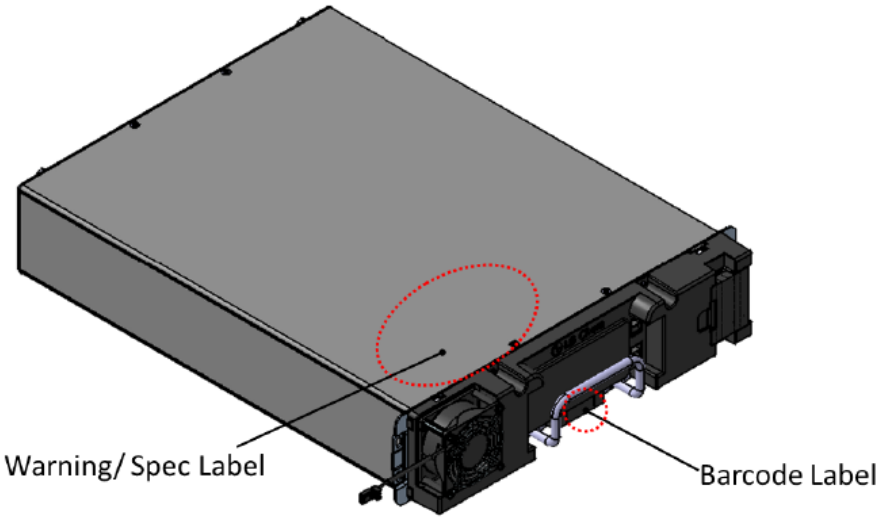
Figure 2 – Isolation of DC strings

3.6.2 Battery Handling

- The battery modules have a weight of 47kg each – work with two strong men or use a stacker to remove or re-install battery modules. The mullions in the cabinet's front a back middle need to be removed for better handling of the heavy batteries.
- Damage or mishandling can result in leakage of the electrolyte or flammable gas, with a consequent hazardous situation.
- Do not place battery modules on flammable construction materials, in areas where highly flammable materials are stored, in potentially explosive environments or in highly humid environments.
- Do not stack objects on the battery modules. Maximum stacking height of the OEM battery transport boxes is 3
- Do not touch or use the battery if liquid is spilled on the module.
- Any mishandling of the battery including dropping, deforming, impacting, cutting or penetrating is likely to damage the unit and might cause a leakage of electrolyte and fire.

For first aid measures in case of contact with inner chemicals of the battery cells due to module damage, see Document Folder - Material Safety Data Sheet (MSDS).

For more details, please consider the warnings on the battery module label:



Warning / Spec Label and Barcode label on the Battery module

Figure 3 – Battery module warning signs and their meaning

3.6.3 Battery Environment and Installation

Do not expose battery modules to temperatures more than 50°C or to condensing humidity. LGChem battery module management systems internally track temperature, even when disconnected.

3.6.4 Before Working on the Battery Racks

Before working on the battery racks:

1. Set the inverter selector switch (OFF-RUN-START) to the OFF position
2. Open the DC disconnect switch S4 in the DC compartment of the inverter cabinet
3. Ensure that the string isolation breakers in the 3 battery racks are in tripped or OFF position

3.7 Inverter-Specific Hazards

3.7.1Electrical Hazards

- The inverter includes a DC capacitor that is charged to up to 850Vdc, when operating. After stopping the inverter (SYS STOP) and executing a battery SHUTDOWN, the capacitor discharges slowly through its dissipation resistor. Danger of electrical shock!
  - ⇨ Wait for 5 minutes after shutdown before any work on the system to ensure a fully discharged DC capacitor (see marking on the inverter)
- 820Vdc auxiliary power supply is provided to the LCL filter
- The pre-charge circuit creates 530Vdc voltage, if contactor K6 is closed, even if the inverter circuit breaker Q5 is open. Main system circuit breaker Q2 must be opened to protect against unintended pre-charge
- 240V auxiliary power or voltage measurement supplies are present at the inverter, the inverter AUTO/MAN – OFF/RUN/START control circuitry, the LCL-filter, the inverter control, and the D7 voltage transformer
- 24Vdc supply is present at the inverter, the inverter AUTO/MAN – OFF/RUN/START control circuitry, the LCL-filter, and the inverter control

3.7.2 Noise

The inverter and adjacent LCL filter emit a ~5000Hz and ~10000Hz switching noise at hazardous levels. When operating the system with open cabinet doors, wear noise protection for any work that lasts longer than a few minutes!

3.7.3 Before Working on the Inverter

Before working on the inverter, in addition to the general safe work practices:

1. Set the inverter selector switch (OFF-RUN-START) to the OFF position.
2. Open DC disconnect switch S4
3. Trip and lock all 3 battery DC string breakers
4. Wait for 5 minutes for the inverter DC bus capacitor to discharge
5. Turn OFF the inverter compartment fan control on the control escutcheon (blue button)
6. Wait for the fan to spin out when opening the inverter compartment door. Do not touch the spinning fan!

Note: These measures are for isolated work on the inverter and in the inverter compartment only. Follow isolation instructions in section 3.5 of other equipment or compartments are involved!

3.8 Cabinet Hazards

3.8.1Electrical Hazards

- Exposed wires, busbar and terminals with dangerous voltages exist behind lift-off panels (inverter cabinet: DC compartment, AC compartment and Transformer compartment). Protection of exposed terminals by Perspex wall or similar is only foreseen in compartments with doors.
  ➔ Never energise or operate the system or any part of it when any lift-off panel is removed without special safety measures. Keep your distance, fence off the area and continuously supervise the area. Only operate if absolutely necessary and only for short periods.

3.8.2 Hot Surfaces

- The LCL filter and Transformer can reach surface temperatures of up to 130deg C!
- Risk of fire from hot components under or shortly after operation getting in touch with external flammable material and
- Risk of injury from touching hot surfaces
  ➔ Before opening any covers or doors please consider enough cooling time!

3.8.3 Moving Parts Hazards

- Risk of injuries due to moving parts:
  - Inverter compartment main fan (powerful fan with 3000qm/h) – Must be turned OFF before opening the inverter compartment door! A protection mechanism shuts down the fan, when the door is opened, but it takes up to a minute for the fan to come to a complete standstill. The fan also spins, when it is off and the inverter built-in fan is running, sucking air through it. Therefore, the inverter must also be OFF before opening the door.

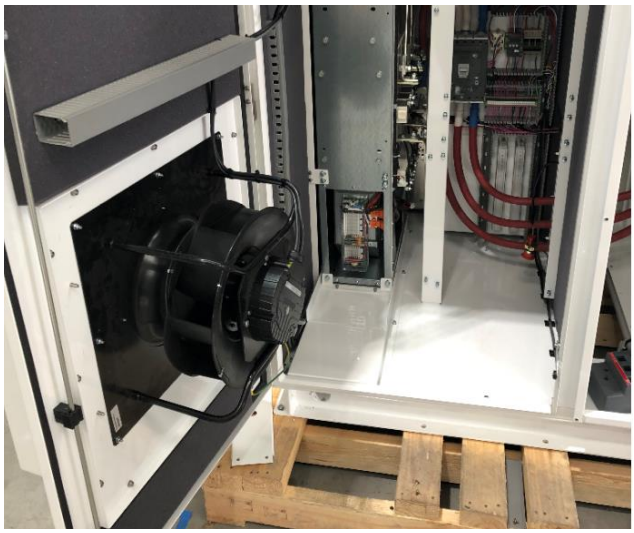


Figure 4 – Moving part hazard from the powerful inverter compartment fan

- Smaller battery and inverter module fans – do not touch!

3.8.4 Condensing Humidity and Rain

- Risk of electrical shock and equipment damage in case of condensing humidity or water on the equipment
  ➔ Do not open the cabinets during rain
  ➔ Do not work on the device in rain
  ➔ Close the cabinet doors, do not work with the equipment when moisture or water is visible on its components or walls. This typically occurs
  - on cold early mornings
  - on hot humid days, after opening the door of a cooled compartment and the internal surfaces are colder the external air

3.8.5 Fire

The following information is a practical information specific to the device intended to complement general fire-fighting regulations. Local fire-fighting regulations are to be adhered to with priority. Please ensure you are generally informed about how to handle a Lithium-Ion Polymer battery fire.

The LG Chem battery system has a hierarchy of redundant mechanical, electrical and signal-based protections that provide the highest level of protection against battery fire emergence and propagation available for Lithium-Ion batteries to date. When used according to this manual, a battery fire is extremely unlikely.

In the unlikely case of a real or suspected battery fire, where smoke is visible, or heat can be sensed, proceed as follows:

- Confirm that it is the battery cabinet that is on fire. The battery cabinet is the one with the three air conditioning systems in the doors (for example the left one in Figure 1).
  If it is the other cabinet (the inverter cabinet), then handle it as an electrical switchboard fire.
  In any case, the electrical system including the battery modules will have shut-down and isolated automatically on internal fire alarm.
- In case of doubt about the presence and status of a battery fire, check with the owner or the OEM (PowerTec emergency service number 0431 730 229). They can identify status details remotely.
- In case of a battery fire, the electrical systems will have shut down and isolated and the Novec synthetic suspension-based fire extinguishing system will have deployed. The system has the double effect of stopping a Lithium-Ion battery fire by cooling the cabinet down (stopping thermal run-away) and replacing the air with an inert gas. The system operates with a sensor tube wound through battery racks and detects a battery module fire early and locally.
  The 3M™ Novec™ 1230 Fire Protection Fluid is a colourless, transparent liquid with an almost un-noticeable smell, that is heavier than water, and non-conductive.
- **DO NOT** open cabinet doors for a minimum of 5 minutes after detecting the fire or the fire system deployment, or until no smoke or heat or other sign of fire can be detected outside the battery cabinet. **Warning:** A smouldering battery-fire may be fuelled by air entering the cabinet when opening a door.
- After opening doors, handle the battery fire as a Lithium-Ion battery fire (contains conductive Lithium-Ion polymer). Refer to general classifications and regulations.

3.8.6 Fire Suppression System Hazards

The following hazards exist, and precautionary statements are made with reference to the Globally Harmonized System of Classification and Labelling of Chemicals (GHS).

Hazards:

- **H280** Contains gas under pressure; may explode if heated – maximum storage temperature for the gas bottle is 50°C.
- **H314** Causes severe skin burns and eye damage.
- **H318** Causes serious eye damage.
- **H412** Harmful to aquatic life with long lasting effects.
- **AUH044** Risk of explosion if heated under confinement

Precautionary statement – Prevention:

- **P260** Do not breathe dust/fume/gas/mist/vapours/spray.
- **P280** Wear protective gloves/protective clothing/eye protection/face protection.
- **P273** Avoid release to the environment.

Precautionary statement - Response:

- **P301+P330+P331** IF SWALLOWED: Rinse mouth. Do NOT induce vomiting.
- **P303+P361+P353** IF ON SKIN (or hair): Remove/Take off immediately all contaminated clothing. Rinse skin with water/shower.
- **P305+P351+P338** IF IN EYES: Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do. Continue
- rinsing.
- **P310** Immediately call a POISON CENTER or doctor/physician.
- **P363** Wash contaminated clothing before reuse.
- **P304+P340** IF INHALED: Remove victim to fresh air and keep at rest in a position comfortable for breathing.

Precautionary statement – Storage:

- **P405** Store locked up.
- **P410+P403** Protect from sunlight. Store in a well-ventilated place.

Precautionary statement - Disposal:

- **P501** Dispose of contents/container in accordance with local regulations.

For details see attached Safety Data Sheet: “Wormald Novec 1230 Safety Data Sheet”.

4 System Overview

4.1 Application Overview

The PowerCache® Model **JH32P1C14x3-250k588T** is a Battery Energy Storage and grid-stabilisation/forming system, with rating 250kVA/273kWh, operating both

- Grid-parallel (on-grid) and
- Islanded (off-grid) to maintain power at the site during grid outages.

It is customised to operate with highly dynamic loads and other on-site generation.

Use-cases include:

- Lopping of site peak load and peak PV generation, avoiding site feeder over-load and reducing demand cost
- Network Support with voltage support and phase balancing
- Energy wholesale trading and energy market services (incl. FCAS)
- Site uninterrupted power supply (cannot be combined with FCAS)

Based on its two principal inverter functionalities

- Virtual Synchronous Machine (Dynamic Voltage source) and
- Current source

and its built-in complex range of dynamic controls and sequence controls, it offers comprehensive control features for

- Distribution network constraints resolution
- Distribution network voltage and phase stabilisation
- On-grid/off grid transitions and black-start
- Dispatch to provide energy market services and wholesale energy trading
- Community energy storage and balancing

The PowerCache is functionally composed of

- An inverter system, 3-phase, 4-quadrant, fully symmetrical power rating,
- Utility-application grade Li-Ion batteries with battery management unit,
- PaDECS® overlaid control system
- BESS main AC breaker and multi-function, inter-tie protection relay
- AC isolation, step-up and filter transformer
- Isolation, protection, safety, alarming and auxiliary systems
- Optional FCAS high resolution meter.

The electrical string design principle is of transformer-connected type, coupling at 375V and connecting to 415V 3-phase LV.

4.2 Generalised SLD

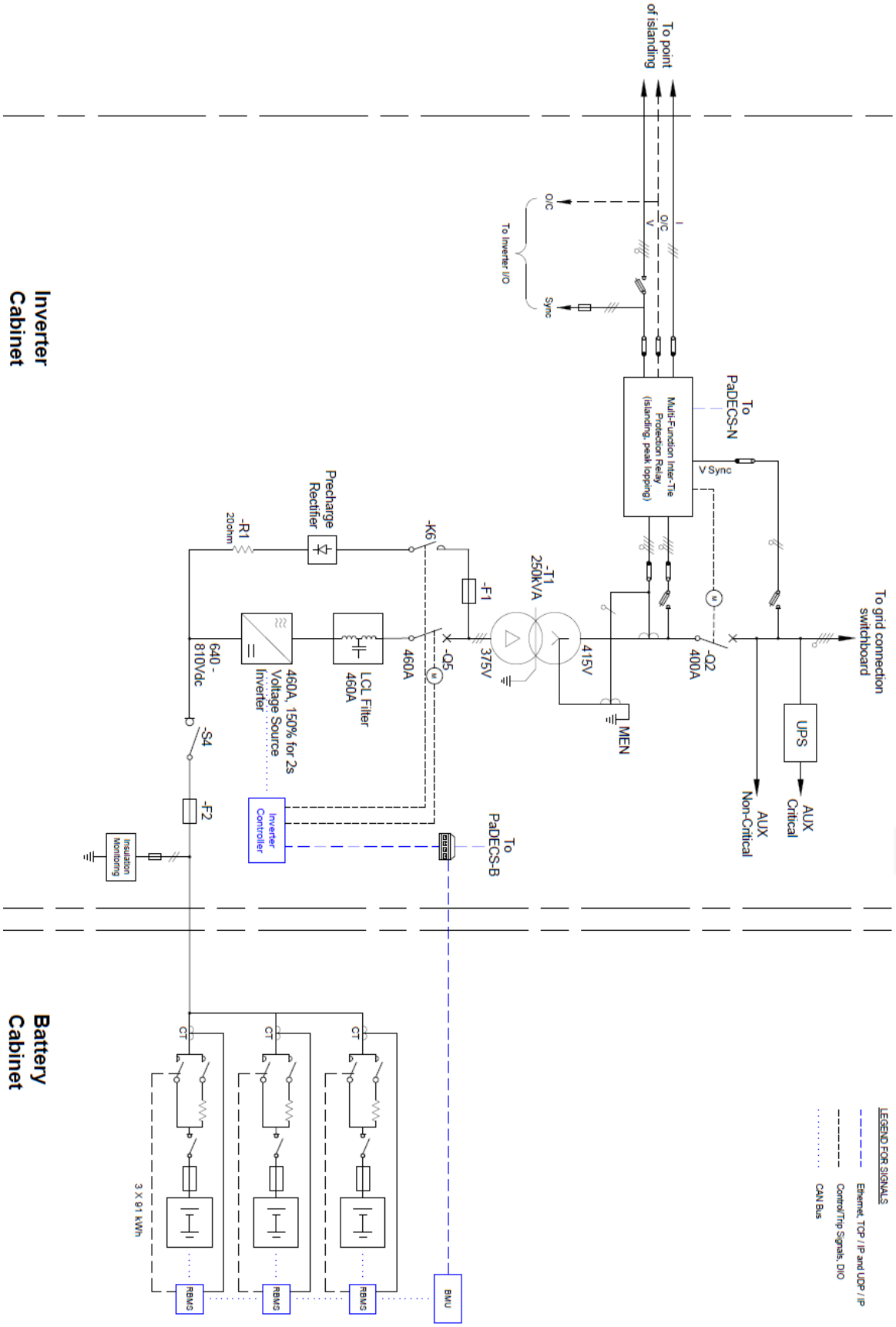
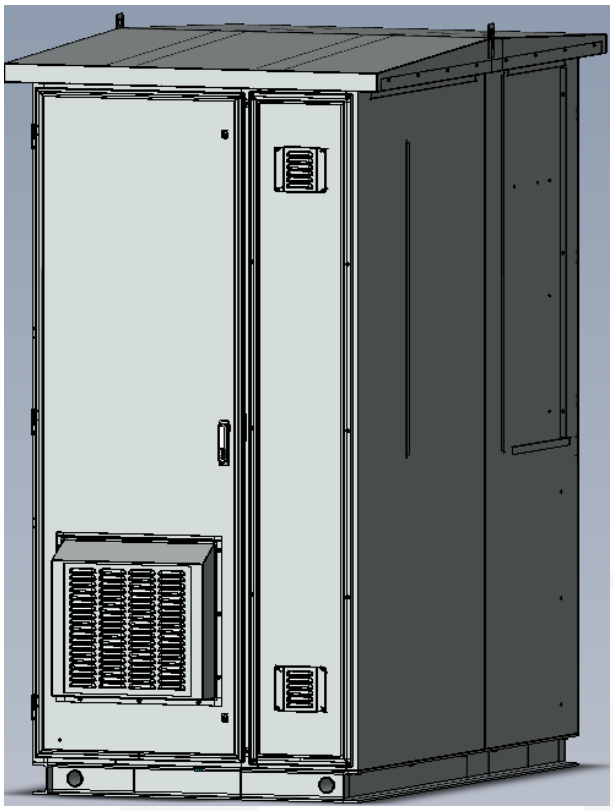
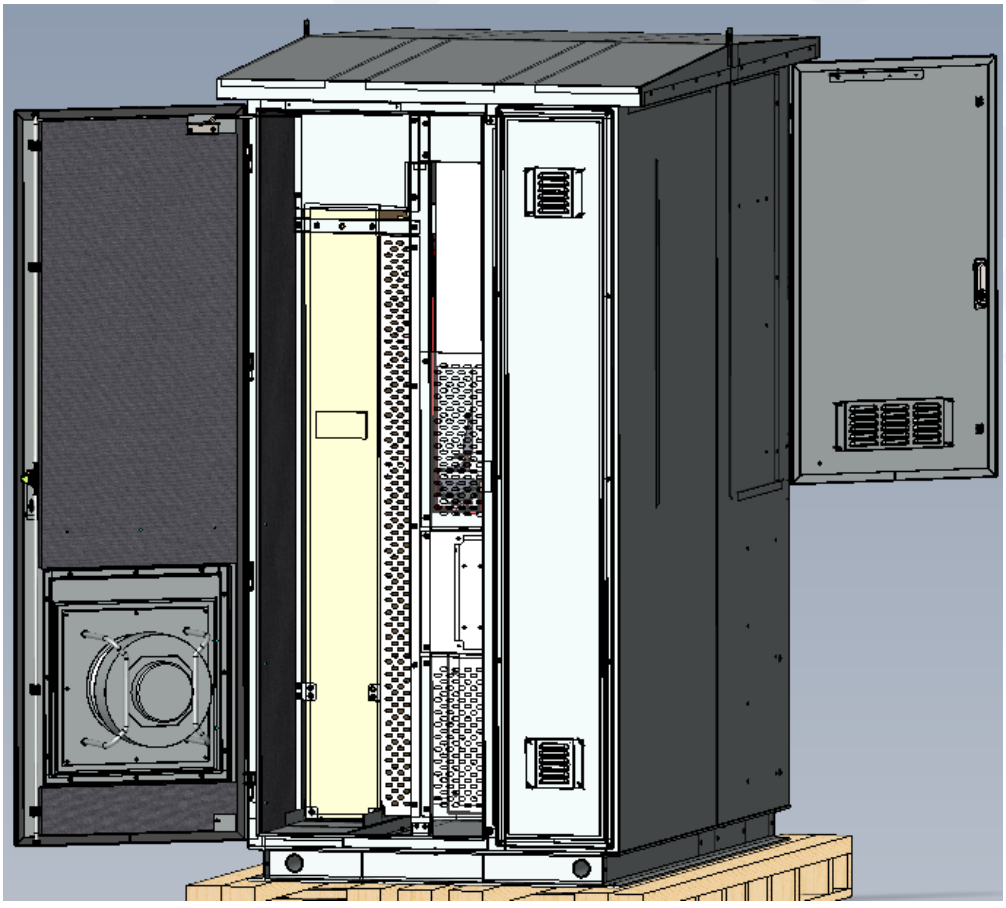


Figure 5 – Simplified BESS SLD – for the Grid Connection SLKD, see Installation Manual.

4.3 Cabinets





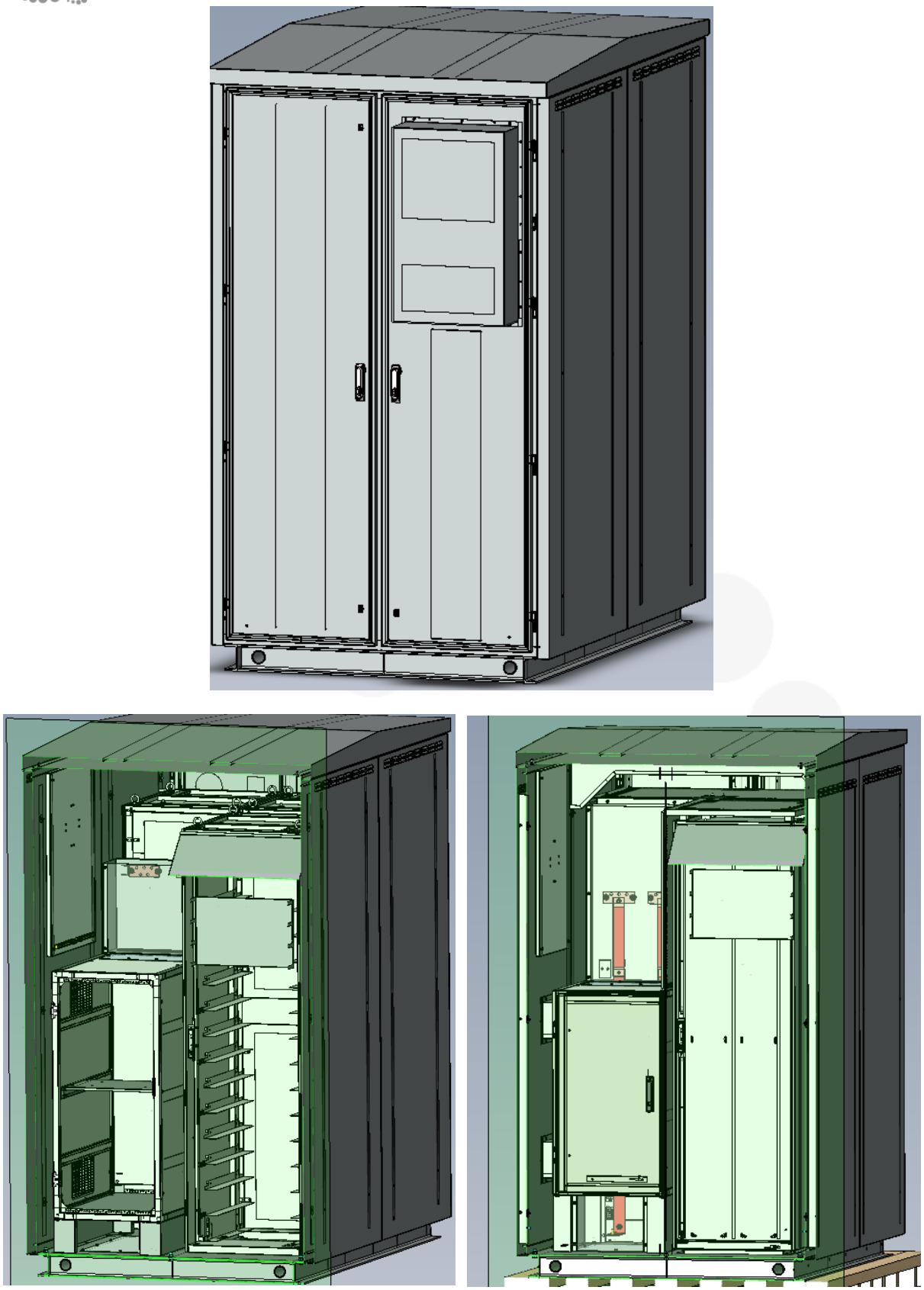


Figure 6 – Simplified cabinet drawing – serial no 1 and 2+

5 Switching, Isolation & Safe Electrical Work Instructions

5.1 AC Switching and Isolation Device Identification & Summary

Operational Identity	Device/Function	Comments
Q2	Motorised Circuit Breaker in the BESS- between the BESS and the Network	Physically a 630A LV 3 Pole motorised Circuit Breaker with a built-in 400A electronic trip unit– set to Automatic operation
"Inverter I/O breaker"	Circuit Breaker in the switchboard, isolating the battery from the site LV bus.	

Table 1: AC Switching and Isolation Device Identification & Summary

5.2 BESS Components Manual START/STOP and OPEN/CLOSE Control

5.2.1 Overview

Hierar-chy	\ Component Control Level \	Inverter	Battery	Protection Relay and Breaker
Highest	**System (Modbus TCP)**	SYS_START/SYS_STOP (system start/stop functions)		
	Sys-Components (Modbus TCP)	*Automatic/Operator,* SHUTDOWN/GET_READY		*Automatic/Operator,* OPEN/CLOSE
	Field Device (via elements on the escutcheon)	*AUTO/MAN,* OFF/RUN/START	-	*AUTO/MAN,* OPEN/CLOSE Q2 (BESS)
Lowest	**Field Device (via elements on the device)**	I/O (Keypad)	-	*AUTO/MAN* (on the Breaker), I/O (on the Breaker)

Table 2: Mode selection (in Italics) and component START/STOP or OPEN/CLOSE control hierarchy.

Manual operation is not a standard operation mode and should be avoided where possible. Use the Modbus interface, if you have access, or call the operator or OEM Service to operate via remote control access!

Normally, for maintenance work, the whole system is shut down.
For test purposes, an individual component with all dependent components downstream of that component, can be taken into Manual control mode and operated manually (Table 2).

The mode that operates a Powercache component, called an "Asset", independently from the other system components, e.g., the protection relay and breaker independently from the inverter/battery, is called Operator Mode. Automatic Mode, in contrast, puts the BESS under one coordinated control.

5.2.2 Restrictions of Manual Operation

- The control buttons on the breaker are not to be used to prevent unsynchronised closing! The breaker is therefore mechanically locked to AUTO operation. Manual closing of the breaker must be done via the protection relay and is always subject to a Sync-Check. CLOSE will only be successful, if the inverter is stopped, or the grid and inverter voltage are in sync.
- The inverter cannot be started manually via the START selection on the escutcheon of the control compartment, unless it is set up with a specific parameter set for manual operation. Call PowerTec Service if manual START is required.

5.1 Circuit Breaker Q2

- Q2 is the automated motorised circuit breaker that connects the BESS to the Network. When Q2 is closed, the BESS is Online. When Q2 is open, the BESS is Offline.
- Q2 has an in-built electronic protection unit (EKIP) that will operate and backup the protection provided by the Protection Relay.
- Normally Q2 is in AUTO mode and is thus controlled by the BESS control system. It opens/closes via the BESS automatic control when the BESS Starts and Stops under certain conditions only (see use cases and transitions). However, control and status readings are available via the Protection Relay fascia panel (and via the VPN remote access). These Open and Close commands may be used in different circumstances by engineering personnel, including to fully disconnect the BESS, from the grid, for maintenance and to de-energise the transformer.

  Remark: Q2 is set to automatic operation (AUTO) as a standard. It should always remain in AUTO to prevent unsynchronised closing when the BESS is running. If manual operation is required, always operate Q2 via the protection relay, by setting the relay to MAN (never operate the breaker directly)!

5.2 Circuit Breaker Q2 Operating Instructions

5.2.1 Location of Breaker, Breaker Controls and Breaker Status Indications

Q2 is in the AC compartment of the Inverter Cabinet. The status of MCB can be viewed on site by observing the LEDs on the Protection Relay, located on the BESS control compartment panel or in special circumstances on Q2 itself.

Figure 7 – Protection Relay display and pushbuttons

The Protection and Control Relay is in the BESS inverter cabinet, control compartment.

Normal operation of the MCBs is via the BESS Control System (Relay control set to AUTO). For operation via the Relay fascia panel buttons the control must beset to MAN.

- Press the top “AUTO/MAN” button, until the “MAN” LED illuminates
- Use the second button “O/C Q2” to change the status of Q2. If Q2 is closed it will open immediately when button pressed
- Always return the Control back to AUTO (via the top button)

5.2.2 Device Operating Procedures

The circuit breakers Q2 and Q5 have electronic trip units and AC activated motor operators.

Figure 8 – Circuit Breaker (Q2) with motor-operator

Auto/Manual Selector

Control	Description
Auto	The control system within the BESS cabinet can operate it. The local push button (Red) can be used to open the CB, but it CANNOT be closed manually.
Manual	The control system in the BESS Cabinet CANNOT operate the Circuit Breaker. Locally the Circuit Breaker can be Opened or Closed using the ON (Red) and OFF (green) buttons and the leaver for spring operation.

The diagrams below depict the fact that if the CB trips, you must RESET it before it can be closed again. If it was in Manual this is by using the handle and Opening the CB first. If it was in Auto this is by sending a Remote Open Command, then sending a Remote Close Command.

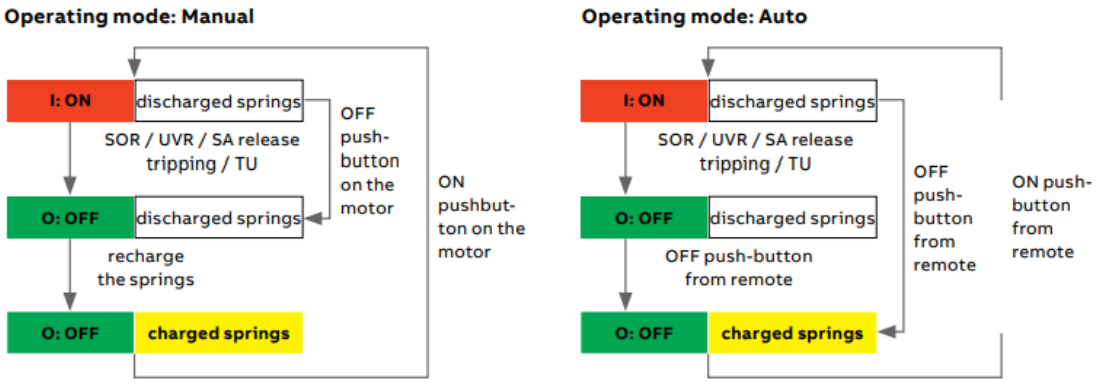


Figure 9 – Circuit Breaker Q2: Automatic and Manual Operation Sequences

Signalling of the Circuit Breaker status ON-OFF is indicative of the position of the main contacts.
ON = CLOSED (**Red**), OFF = OPEN (**Green**)

Operating principle:

Select he operating mode on the front of Q2 motor operator:

- **AUTO**: when the selector is in this position, the pushbuttons on the front of the motor are locked. Circuit-breaker closing is commanded remotely only by means of an electric impulse, whereas opening is allowed both remotely and from the front of the motor;

- MANUAL: the circuit-breaker can only be opened/closed from the front of the motor using the pushbuttons; **Manual operation of Q2 is NOT recommended.**

- **LOCKED**: when the selector is in this position, the circuit-breaker is open. The locking mechanism can be withdrawn and the motor can be locked in the open position

5.3 BESS External-Isolating Breaker Operating Instructions

The Inverter I/O breaker is in the site switchboard for isolating the battery from the site LV bus.

It must be OPEN & locked before commencing any work on the grid side or the BESS side! Open the breaker manually.

WARNING: When the BESS is isolated in the switchboard, there are still other sources of dangerous voltages in the BESS and the BESS may be set to keep operating.

5.4 BESS Shut-Down Instructions

5.4.1 Summary

1. Shut down the system:
   If Modbus TCP is used, or support by a Web-operator is available:
   Option a:
   - Execute a SYS STOP command
   - Execute a battery SHUTDOWN
   - Execute a network connection OPEN C

   otherwise
   Option b: Press E-STOP on the inverter control escutcheon. Do not press E-Stop in the battery cabinet unless you want to isolate the DC system internally.
2. Set the inverter selector switch (OFF-RUN-START) to the OFF position.
3. Only if working inside the BESS: Set the three battery string isolation breakers to OFF

5.4.2 Shut Down BESS Before Isolation

Shutdown the whole BESS System, such that the inverter is shut down and the DC link is not energised. After shutdown, the BESS System can only be re-started via pre-charging (automatic GET READY will be necessary).

If Modbus TCP is available and the inverter is running, then,

1) **Stop BESS by executing a SYS STOP Command** – stopping the inverter

2) **Shutdown BESS by execution a SHUTDOWN Command –** disconnecting DC

3) **Execute a network connection OPEN C** – opening Q2

else (Manual procedure):

1) Press the **E-STOP** (emergency stop) button on the inverter control panel. Do not press E-Stop in the battery cabinet unless you want to isolate the DC system internally.
2) **Open Q2** (from tripped position) via the protection relay in MAN mode.

Lock Q2.

Note: The only available direct manual way to shut down the BESS system is by pressing E-stop.

5.4.3 Prevent the Inverter from Restarting

Set the inverter selector switch (OFF-RUN-START) on the control compartment escutcheon to OFF.

5.4.4 Isolate DC Supply and Battery Strings

Before working inside the BESS, trip or open and lock the 3 battery string isolation breakers. They can be tripped by pressing the battery cabinet E-Stop button. You will have to remove the Perspex air baffles in front of the battery racks (by unscrewing them) and open the rack doors to manually open the breakers, lock them in the open position and, after finishing the work, to manually re-close the battery string breakers before resuming operation.
Attention: Do not bend the Perspex baffles too much as they easily break.

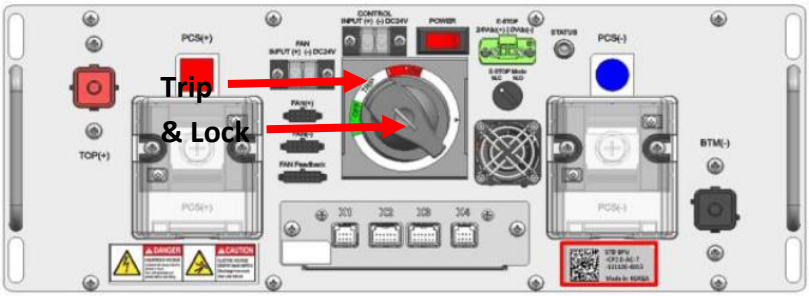


Figure 10 – Battery Protection Unit (BPU) with battery string isolation breaker

5.5 BESS Isolation Instructions

5.5.1 Summary

1. Check the Q2 is open (see BESS Shutdown instruction)
2. Open BESS connecting breaker Q3 (“Inverter I/O breaker”) in the switchboard
3. Disconnect the grid voltage sense and short the grid current transformer connections

5.5.2 Isolate BESS Mains from the Grid

Open BESS connecting breaker (Inverter I/O breaker) in the switchboard manually.

5.5.3 Isolate Grid Sensor Connections

Disconnect the grid voltage sense and short the grid current transformer connections to the protection relay. Use the test links in the AC compartment for this purpose. Refer to the protection wiring diagram to identify the relevant links.

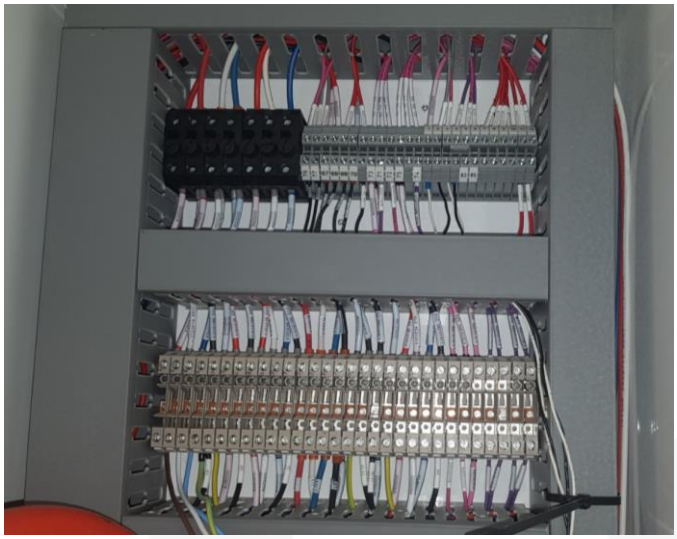


Figure 11 – Line CT and voltage sense secondary wires termination with protection test links

5.6 Safely Work on BESS Main Electrical System

The following plant items are considered as primary plant and require appropriate isolation, tagging, testing and, for AC systems, earthing:

- Incoming 3 Phase AC Cable,
- External Y-Side CTs
- Q2 Circuit Breaker,
- 415V/375V Star/Delta Transformer,
- Inverter Breaker Q5
- LCL Filter,
- Inverter,
- BPU Battery modules and Battery String Isolation Breakers
- all AC and DC power connections between these items.

Before working on the BESS electrical system:

1. Shutdown the BESS (section 5.4)
2. Isolate the BESS from the Grid (section 5.5)
3. Shutdown the AC UPS (in the battery control compartment), and isolate UPS supply via auxiliary breaker Q709.

The BESS is now isolated. Before commencing work ensure checks are undertaken to prove all incoming sources have been isolated and made safe.

6 Quickstart Guide (With Modbus TCP / 3rd-Party Controller)

6.1 Purpose

The Quickstart Guide explains ***What*** you need to do start and stop the BESS and to use its main operation modes via the Modbus TCP interface. For explanations about ***Why*** you need to follow these instructions, please see the subsequent sections.

6.2 Prepare for Automatic Operation

On the grid connection compartment escutcheon in the inverter cabinet half:

a) Set the protection relay to AUTO via the upper right button (AUTO MANUAL).
b) Under INVERTER CONTROL, set the OFF-RUN-START switch to RUN.
c) Under INVERTER CONTROL, set the AUTO-MAN switch to AUTO.
d) Make sure the E-STOP mushroom button is released (no E-Stop).

Figure 12 – Inverter escutcheon with operating elements, set for automatic operation.

On the battery protection units in each rack in the battery cabinet half, after an outage of auxiliary power or after a battery system E-Stop:

a) For each rack: Remove the Perspex air baffle, open the rack door and close the Battery Strings Isolator
b) Make sure the BSC is running and the E-STOP mushroom button is released (no E-Stop)
c) Only during commissioning (otherwise this happens automatically): On the BSC menu (Monitor), a "connect" command may be required.

Battery Strings Isolator

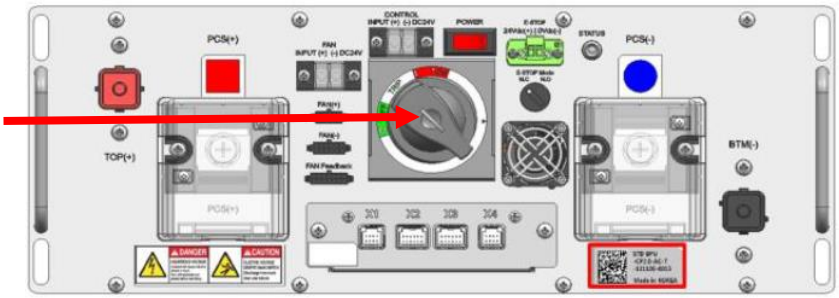


Figure 13 – Battery string protection unit facia with control elements

The BESS is now ready for automatic operation.

The operator starts the BESS via the Modbus TCP interface.
Authorised Service personnel that wish direct control access must either have the PowerTec VPN that allows operation via the Technical GUI or call PowerTec to operate the BESS.

6.3 Get BESS Ready for Automatic Operation (GET_READY)

Before starting the BESS, it must be Ready. Ready means, that both:

1) The inverter and the battery are equalised on the DC side and are connected via the contactors in the Battery Protection Units (BPUs)
2) The inverter is set to Ready mode via automatic control.

The BESS control automatically selects one of two possible methods to get Ready:

a) Pre-charge from grid AC (when grid connected)
b) Pre-charge from the battery via built-in pre-charge resistors (when islanded)

If Q2 or the switchboard connecting breaker is open, but site supply is present, GET READY fails.

Procedure to get the BESS into the Ready state:

1) Send a GET READY command via Modbus TCP
2) Wait for ca. 35sec
3) The system has successfully reached the Ready state, if the DC Contactor is Closed (StateDCContactor = Closed) and StateReady = yes
4) In the unlikely event that a Get Ready sequence fails, it can be repeated after executing ALARM RESET and SHUTDOWN

The BESS is now Ready for automatic operation and is Stopped.

6.4 Select System Control Modes (P, Q, f and V Control)

Before starting the BESS, you must select suitable modes of operation.

If the BESS is operating on the network, i.e., grid supply is available and the site mains breaker (here called Q1) is closed, you must select a:

1) P Control mode (Active power control mode)
2) Q Control mode (Reactive power control mode)

Standard modes that determine active power are:

a) Active Power Setpoint for the BESS inverter output (Select P Set Central)

Standard modes that determine reactive power are:

a) Reactive Power Setpoint for the BESS inverter output (Select Q Set Central)
b) Voltage Droop control (Select VQ Droop)

For peak lopping modes (S Lop, P Lop) and combined mode (Smart), availability is customised. Please see detail operating instructions. These advanced functions may not be used with a 3rd-party controller.

If the BESS is operating in an island, i.e., the site mains breaker is open or tripped, you must also select:

1) f Control mode (Frequency control mode)
2) V Control mode (Voltage control mode)

The standard mode that determines the frequency is:

a) Frequency drooping with active load (PF Droop)

The Standard mode that determines the voltage is:

a) Voltage drooping with reactive load (Select QV Droop)

6.5 Select Setpoints

If you select the P Control mode (Active power control mode) P Set Central on grid or operate islanded, then you must define a P setpoint.

If you select the Q Control mode (Reactive power control mode) Q Set Central on grid or operate islanded, then you must define a Q setpoint.

The BESS reference system is a generator reference system:

- Positive active power is injected/discharged into the grid.
- Negative active power is absorbed/charged from the grid.
- Positive reactive power raises the grid voltage.
- Negative reactive power lowers the grid voltage.

The limits for P & Q setpoints are:

- -250kW < P Set Central < 250kW
- -250kVAr < Q Set Central < 250kVAr

If the combined P and Q setpoints exceed the total apparent power (S) limit of 250kVA, then P has priority and Q is reduced such that S reaches 250kVA.

Setpoints can be changed anytime during operation. There is no restriction on step changing the P setpoint. The maximum step change permissible for a Q setpoint is 80kVAr.

If you operate on grid, and you select the Q Control mode (Reactive power control mode) VQ Droop,
- The droop slope is set via a system parameter VQDroop, e.g., 7% (100% Q at 7% voltage deviation)
- The positive and negative dead-band for voltage control can be set as a setpoint, e.g., +5%/-3%

If the combined P and Q setpoints exceed the total apparent power (S) limit of 250kVA, then P is reduced until S reaches 250 kVA, however Q is limited to 100kVAr, such that active power of 230kW is always available.

If you operate the BESS islanded, then you must also define a frequency setpoint FSetp and a voltage setpoint Vsetp. In PF Droop and QV Droop mode, the P and Q setpoints represent the offset of the BESS droop curves (i.e., P at f = Fsetp, Q at V = Vsetp). If operating islanded in parallel with other generators, the P and Q setpoints determine load-sharing via the droop and offset method.

The frequency and voltage droop slopes are system parameters PFDroop and QVDroop.

6.6 Start and Stop the System (SYS START, SYS STOP)

Before operation, please make sure you followed the instructions in section 0 and set the desired modes and setpoints!

The BESS control automatically selects one of two possible automatic system start sequences:

a) If grid supply is available and Q1 is Closed: Starting up on the network
b) If grid supply is not available or Q1 is Open: Starting up islanded

When starting up islanded, the BESS automatically adapts to the situation, whether Q1 is open or closed with no supply, and whether there is parallel generation on-line or not.

The BESS must never be started when dis-connected from the microgrid switchboard by any external control! It synchronises from the voltage at its terminals, if any.

Procedure to start up the BESS:

1) Confirm that the system is Ready by checking the system actual indication StateReady
2) Send the command SYS START
3) Wait for about 20sec (on-grid) or up to 1min (islanded). The system indication 'StateTransition' will be "starting_up_on_grid" or "starting_up_islanded" during the transition, and 'none' when finished.

The BESS is now Running automatically.

Procedure to stop the BESS:

1) Send the command SYS STOP
2) Wait for about 15sec. The System Indication State 'StateTransition' will be "shutting_down_on_grid" or "shutting_down_islanded", during the transition, and 'none' when finished.
3) Should the system not stop in an emergency the following back-up functions are available
   - Send an EMERGENCY STOP Command.
   - Send a SHUTDOWN command: Disconnects the battery and the inverter, will cause the inverter to trip.

6.7 Shut Down (SHUTDOWN)

1) Send a SHUTDOWN command
2) Wait for ca. 15sec

The BESS is now shut down, i.e. the DC contactor between the inverter and battery is open.

6.8 Island and Re-Integrate (ISLAND, GRID, and Auto-Islanding)

If the site main breaker (Q1) is part of a microgrid control, whether by PaDECS or a 3rd-party controller, the BESS can carry out:

a) A controlled, operator-triggered segregation of the Microgrid from the utility network,
b) Spontaneous islanding on loss of supply (if enabled via parameter settings),
c) Synchronisation and re-integration of the Microgrid into the utility network

a) Controlled Islanding		
BESS	**PaDECS-N or external controller**	**Physical change**
	⇦ ISLAND command	
Control P,Q to unload site feeder		
		Site power ~0
	Site breaker OPEN if unloaded ⇨	
		Site breaker (Q1) opens
Change to off-grid control dynamics	hardwire	
StateGridConnect = island ⇨		

b) Spontaneous Islanding on Loss of Supply		
BESS	**Internal or external relay**	**Physical change**
		Loss of supply
	Immediate Site breaker OPEN ⇨	Site breaker (Q1) opens
Change to off-grid control dynamics	hardwire	
StateGridConnect = island ⇨		

c) Re-Integration		
BESS	**PaDECS-N or external controller**	**Physical change**
	⇦ GRID command	
Control f, V to sync to site feeder		
		Network and Microgrid in sync
	Site breaker CLOSE if sync ⇨	
		Site breaker (Q1) closes
Change to on-grid control dynamics	hardwire	
StateGridConnect = grid ⇨		

Spontaneous Islanding on loss of supply is enabled via the following parameter settings:

1) The inverter always operates as voltage source (Battery.SourceModeOnGrid = vsi)
2) The dynamics setting can autonomously change for islanded operation (System.ConfigAutSegregate = y)

Remark: By nature, with these settings, active anti-islanding is not available. It is contradictory to spontaneous islanding.

7 Detail Operating Instructions

7.1 Naming and Definitions

Although the application as a single BESS does not make use of many of the PaDECS control features, the naming of components and control sequences is kept consistent with the generic case. For example, the inverter/battery unit is called an "Asset", and the grid connection is called another "Asset".

7.2 Inverter/Battery GET_READY, SHUTDOWN

The table below summarises the two basic commands to the Inverter/Battery unit. These commands only apply to the inverter/battery unit, i.e., not to the whole BESS.

Battery Asset-level Command	Resulting asset status	Battery contactor after command	Inverter status after command	Available per Modbus	Sys Start possible from this status?	Get Ready possible from this status?
GET_READY	Ready	Closed	Ready, Stopped	Y	Y	N
SHUTDOWN	not Ready	Open	not ready	Y	N	Y

Table 3: Inverter/Battery Asset Base Commands

GET READY works both, on grid and islanded.

GET READY and SHUTDOWN do not depend on, or change, the protection relay settings, the BESS main breaker and do not use high-level system protections.

GET_READY and SHUTDOWN are made available via Modbus

Resulting status of GET READY command is:

"Ready" means that the DC strings are connected to the inverter, i.e. the DC contactor is closed, the batteries are creating sufficient inverter input DC voltage for the inverter and the inverter is set to "ready" mode via its control

7.3 BESS System Remote Control

7.3.1Remote Control User Interface Selection

The BESS can be remote controlled and monitored by the operator via the following interface:

1. **Modbus TCP**

The available controls and actuals (measurement points) are specified in the Modbus Map.

7.3.2 Commands, Modes and Setpoints

The following table gives a functional summary.

Command, Mode or Setpoint	**Type**	**Function – Short Description**
SYS START	System Command	Starts the System automatically with suitable settings, both on the network, or islanded. Starting islanded works both, stand alone and diesel parallel. The selection is automatic.
SYS STOP	System Command	Stops the System automatically, both on grid and islanded. Note: Islanded SYS_STOP may cause loss of AC auxiliary supply (UPS still available for ca. 10min)
ISLAND	System Command	Unloads the site feeder, opens Q1 (if under PaDECS control), waits for Q1 to be open and adapts control dynamics to islanded operation
GRID	System Command	Auto-synchronises the Microgrid to the site feeder, closes Q1 (if under PaDECS control), waits for Q1 to be closed and adapts control dynamics back to grid operation
EMERGENCY STOP	System Command	Results in System E-Stop – Trips the main AC breaker Q2 and the inverter, disconnects the DC strings by opening DC contactors – no automatic recovery possible!
RESET ALARM	System Command	Reset of all latched system alarms that can be resolved
GET READY	Battery Command	Automatic sequence connecting the battery to the inverter: On-grid: pre-charge inverter (AC charge), start the inverter, equalise DC, close DC contactors Off-grid: close DC contactors (DC charge)
SHUTDOWN	Battery Command	Automatic sequence to stop the inverter and open the DC Contactor
CLOSE C	Breaker Command	Closes main AC breaker Q2 – this command is only required before a GET READY on grid. In all other cases Q2 is operated automatically!
OPEN C	Breaker Command	Opens main AC breaker Q2 – this command is only required after SHUTDOWN on grid. ON al other cases Q2 is operated automatically!
P SET CENTRAL	Mode	Set active power control mode to inverter active power setpoint when grid connected
S LOP	Mode	Set active power control mode to site apparent power peak lopping
<PSetpCentral>	Setpoint	Set PSetpCentral to <PSetpCentral/kW>
<SplThreshSite>	Setpoint	Set SplThreshSite to <SplThreshSite /kVA>
VQ DROOP	Mode	Set re-active power control mode to voltage support using Q to compensate drooping voltage, when grid connected
Q SET CENTRAL	Mode	Set re-active power control mode to inverter re-active power setpoint when grid connected

<QSetpCentral>	Setpoint	Set QSetpCentral to <QSetpCentral/kVAr>
<VQDroopDeadbandNeg>	Setpoint	Set VQDroopDeadbandNeg to <VQDroopDeadbandNeg /%> (on grid only)
<VQDroopDeadbandPos>	Setpoint	Set VQDroopDeadbandPos to <VQDroopDeadbandPos /%> (on grid only)
<VSetp>	Setpoint	Set VSetp to <Vsetp/V> (Voltage setpoint)
<FSetp>	Setpoint	Set FSetp to <Fsetp/Hz> (Frequency setpoint)

The following table gives a functional summary of the available System control modes:

System Mode	Range / Options	Description
ModePControl	psetcentral / slop	Active Power (P) Control Mode, when on-grid: Active Power Setpoint Mode / Apparent Power Peak Lopping
ModeQControl	vqdroop/ qsetcentral	Reactive Power Q control mode, when on-grid: Reactive Power Droop with Voltage / Reactive Power Setpoint Mode
ModeFControl	No options	Frequency control mode, when off-grid: Drooping with P
ModeQControl	No options	Voltage control mode, when off-grid: Drooping with Q

7.3.3 Discrete System States

The following table gives a functional summary of the System states:

System State	Range / Options	Description
StateBreakerCentral	unknown/open/ closed	Mechanical Status of the main circuit breaker (Q2)
StateGridConnect	unknown/grid/ island/no_supply	System grid connection state (logic from network supply status, Q2 status and inverter status)
StateOperation	offline/online	Online, if inverter is online, i.e. Q2 is closed
StatePrecharge	y/n	
StateRun	running/stopped/ tripped	Running for an inverter means modulating

7.4 BESS Control via Local Elements

Figure 14 – Inverter escutcheon control elements, set for automatic operation

The BESS cannot easily be operated manually via local control elements. A specific set of parameters is required for the inverter. If manual operation is required for commissioning or testing, please call PowerTec service.

Certain individual manual devices operations are possible with BESS with its standard parameters:

Operation	**Local control**	**Condition**
Stop the Inverter	Turn Inverter START/STOP switch to OFF	none
Shut down AC System (all AC primary components)	Press E-Stop	none
OPEN/CLOSE Q1 or Q2	Set Relay to MAN via CTRL button on Relay. Press Q1 or Q2 button	Inverter must be synchronised, if running - unsynchronised closing is suppressed

Protection Relay push buttons are:

- AUTO / MAN control (of Q1 and Q2)
- Open/Close Q1 or Q2

7.5 Emergency Stop Facility

7.5.1 Evoking Emergency Stop of the AC Systems

Use any of the following actions:

- Press E-Stop mushroom button on the control compartment escutcheon (inverter cabinet)
- Press E-Stop mushroom button in the inverter compartment (inverter cabinet)
- Send EMERGENCY STOP via Modbus

7.5.2 Evoking Emergency Stop of the whole BESS (AC and DC Systems)

- Press mushroom button beside or on the battery control compartment (battery cabinet)

Warning: After an E-Stop, please consider the inverter DC charge. Please wait for 5min for full discharge before undertaking maintenance works.

7.5.3 Notifications

Notifications are sent to the Modbus, as well as via a hard-wired signal to the mobile SMS emergency alarms manager, sending an SMS to all subscribed operators.

7.5.4 Recover from Emergency Stop

Once the cause for the alarm has been resolved, and the any emergency stop button has been unlatched, execute an Alarm Reset via Modbus and the system can Get Ready again.

7.6 System Commands (SYS START, SYS STOP, ISLAND, GRID)

7.6.1 Definition of Control Sequences and Transitions

"Sequences" run sequentially on one "Asset" (e.g. the inverter/battery system) after receiving an Asset Command. Commands evoking Sequences are: GET_READY & SHUTDOWN, described in section 7.2.

In contrast, "Transitions" normally run in parallel on multiple PaDECs, or on one PaDEC in coordination with a 3rd-party Microgrid Controller and change the effect of the BESS on the microgrid or state of the microgrid status. The different controllers operate asynchronously in parallel. Synchronisation between the controls happens at specific intermediate system states, e.g., the inverter control waits for the site breaker to be closed. System Commands evoking Transitions are: SYS START, SYS STOP, ISLAND and GRID.

The BESS needs to be put into Ready state (GET READY command) before being able to start. When ready, the system can either be Running or Stopped, and can operate on the network or in an island.

7.6.2 Inter-Controller Coordination During Transitions

For intentional islanding (ISLAND) and re-integration (GRID), coordination between the inverter/battery controller and the grid connection controller is required.

See section 6.8 for a command sequence table.

7.6.3 Autonomous Transitions

Autonomous Functions are such system functions that initiate Transitions autonomously, i.e. without any operator or controller interaction.

Using a 3rd party controller, the only Autonomous Function enabled in Auto-Segregate. This is done via parameter setting (System.ConfigAutSegregate = y). Autonomous detection of an islanded state via a hardwired connection (see Installation Manual) is necessary to execute the required control dynamic change instantaneously.

7.6.4 Status After a Failed Transition

Transitions can fail due to a communication error, a hardware error, or a network condition not meeting the transition requirements. A failure results in a direct reset of the system to a consistent and safe state, or to a reset after a transition time-out. The reset works as follows:

- For all transitions:
  - Initialise the inverter and the protection relay.
  - If the connection status is detected as grid-connected:
    - Sets grid control parameters and grid protection.
  - If the connection status is detected as islanded:
    - Sets island control parameters and island protection.
- Additionally, if the transition that failed was a SYS STOP:
  - Attempt to stop the inverter.
  - Attempt to trip BESS breaker Q2.
  - If all the above fails, execute an E-Stop.

7.7 Charging the Battery

To charge the battery on the grid with a defined power set-point, use the system control mode P Set Central via the Modbus interface. Charge (-) or discharge (+) with the selected active power setpoint PSetpCentral. The power setpoint is immediately assumed as a step response, whenever the system is running. Scheduling is not provided with this function.

The steady state function supervises the SoC: Setting arbitrary active power setpoints up to +/- PNom is only permissible if

SoCMinNorm < SoC < SoCMaxNorm (typically 4% … 93%).

7.8 System Ratings

The following system ratings are physical features of the BESS and cannot be changed.

Quantity	type	Unit	Value	Description
SNom	feature	kVA	250.0 (83.3 per phase)	Nominal inverter Apparent Power, 4-quadrant symmetrical
SPeak	feature	kVA	275.0 (91.7 per phase)	Maximum Apparent Power when off-grid. Can be delivered for 1min in 10min.
PStatLoss	feature	kW	~3	Total system static losses - SoC remains constant if P set-point is set to this level
ECapBoL	feature	kWh	273	Full nominal DC energy capacity of the battery at the Beginning of Life

7.9 System Data

7.9.1 Categories

The system data pool consists of data from the following categories:

Category	Meaning	Normal frequency of use	Availability to set / read	
			Control Interfaces	File
System commands	Commands that change the effect on the Microgrid	Multiple per day, as needed	yes	
Asset commands	Commands that affect the internal status only	Rarely	Customised sub-set	
Modes	Operating modes that change the BESS behaviour	Multiple per day, as needed	Customised sub-set	
Setpoints	Target values for essential variables	Up to 1/sec	Customised sub-set	
Actuals	Measured variables and state variables	Up to 3/sec	Customised sub-set	
Alarms		Up to 3/sec	yes	
Parameters	Settings of characteristics	only for application changes		x
Features	Physical features that only change with hardware	only for physical changes		x

7.9.2 Key Parameters

The following are changeable system parameters. Parameter changes can be made by a commission engineer per upload of the parameter-file using the Commissioning GUI.

Setting	Type	Unit	Default	Limits	Description
FNom	System Parameter	Hz	50	47-53	Nominal Frequency
VNom	System Parameter	V	415	376 - 455	Nominal voltage
PfDroop	System Parameter	Hz	0.5	0.3 - 5	Frequency droop with P, when off-grid, e.g. 0.5Hz / 100% PNom
QVDroop	System Parameter		10.0	1.0 – 30.0	Voltage droop with Q, when off-grid, e.g. 10.0% of VNom / 100% of QNom
VQDroop	System Parameter		4.0	0.1 – 50.0	On grid voltage support by Q, e.g. 100% QNom at 4.0% VNom voltage variation
SLim	System Parameter	kVA	260	0.0 - 275	Apparent power limit for setpoints
KUnloading	System Parameter	%/s	20	1.0 - 50.0	Dynamics of power unloading of the network connection when intentionally islanding
KVoltageControl	System Parameter	%/s	12	0.0 – 100.0	Change per second to target of on-grid voltage support control
ConfigAutSegregate	System Parameter		y	y/n	Allow spontaneous islanding on loss of grid supply
SourceModeOnGrid	Battery Parameter		vsi	csi/vsi	Operate as voltage source or current source when on-grid.
SoCTarget	System Parameter	%	80	3.0 – 94.0	Target State of Charge (SMART Mode only)
SoCMaxAbs	Battery Parameter	%	99	85.0-99.0	Maximum SoC - under all conditions the inverter stops when reached
SoCMaxNorm	Battery Parameter	%	92	50.0-95.0	Maximum SoC in power control mode with arbitrary setpoint
SoCMinAbs	Battery Parameter	%	1	1.0-10.0	Minimum SoC at all conditions - inverter stops when reached
SoCMinNorm	Battery Parameter	%	4	1.0-20.0	Minimum SoC in power or current control mode with arbitrary setpoint

8 Interfaces, Communication and Auxiliary Systems

8.1 BESS Auxiliary Power

8.1.1 Overview

Auxiliary feed is taken from the BESS incoming mains in front of the main MCCB "Q2" to a D-Type MCB and is distributed accordingly. See AUX SLD Drawing.

The BESS Auxiliary power supply to the BESS is split into 2 categories.

- Critical (UPS backed)
- Non-Critical

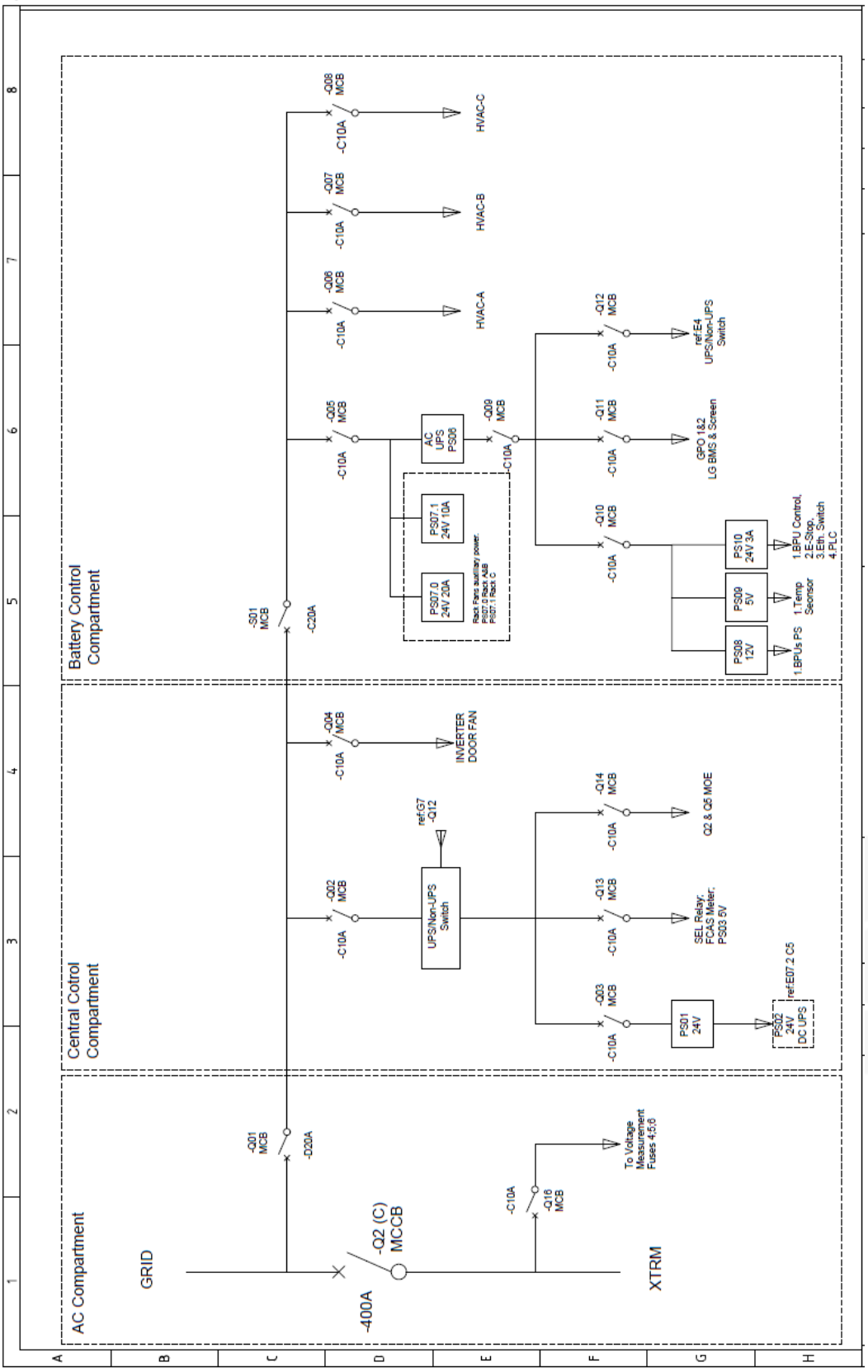
8.1.2 Critical -UPS Backed Auxiliary Power Supply

The main reason for the UPS backed loads are:

- to be able to operate Islanded in the event of a blackout (if applicable)
- to have visibility of the site and communication to all field device in event of a blackout/loss of mains supply.

The BESS contains a DC and an AC UPS.

The DC ups is directly supply from the AC UPS. In the case of loss of mains supply the AC UPS will continue to power the DC UPS (PS02) and other critical loads. Consequently, is the AC UPS runs empty the DC up will continue to power its load for about 20 minutes before it runs empty.


Battery Control Compartment
Central Cotrol Compartment
AC Compartment
GRID
-Q1 MCB
-D20A
-Q2 (C) MCCB
-400A
-S01 MCB
-C20A
-Q08 MCB
-C10A
HVAC-C
-Q07 MCB
HVAC-B
-Q06 MCB
HVAC-A
-Q05 MCB
AC UPS PS06
-Q09 MCB
PS07.1 24V 10A
PS07.0 24V 20A
Rack Fans auxiliary power: PS07.0 Rack A&B PS07.1 Rack C
-Q12 MCB
ref:E4 UPS/Non-UPS Switch
-Q11 MCB
GPO 1&2 LG BMS & Screen
-Q10 MCB
PS10 24V 3A
PS09 5V
PS08 12V
1.BPU Control, 2.E-Stop, 3.Eth. Switch 4.PLC
1.Temp Seonsor
1.BPUs PS
-Q04 MCB
INVERTER DOOR FAN
ref:G7 -Q12
-Q02 MCB
UPS/Non-UPS Switch
-Q14 MCB
Q2 & Q5 MOE
-Q13 MCB
SEL Relay, FCAS Meter, PS03 5V
-Q03 MCB
PS01 24V
PS02 24V DC UPS
ref:E07.2 C5
-Q16 MCB
To Voltage Measurement Fuses 4-5-6
XTRM

8.2 Environment Control Systems

8.2.1 Auxiliary Fans and Thermostats

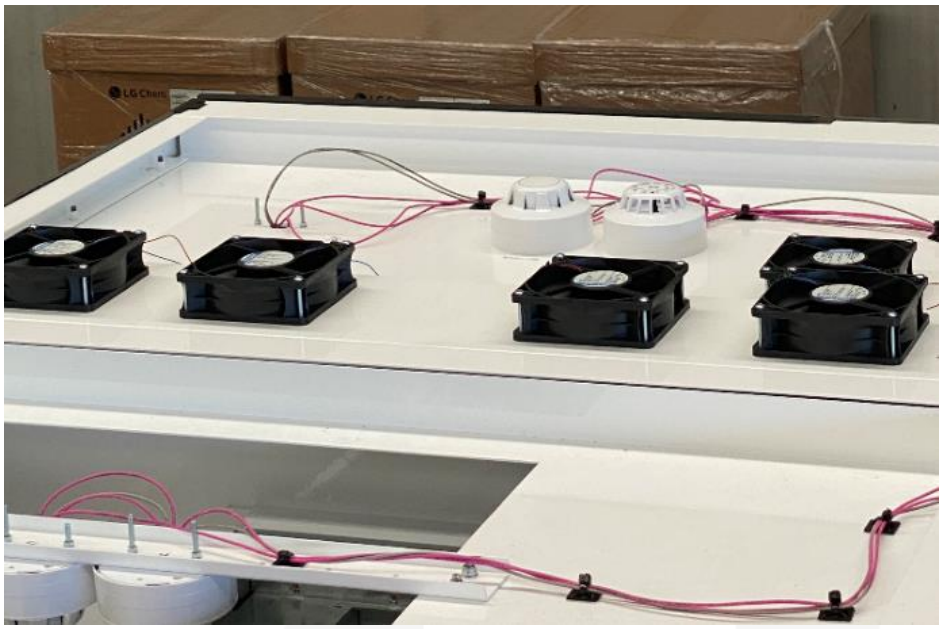


Figure 15 – Auxiliary fans in the inverter compartment roof

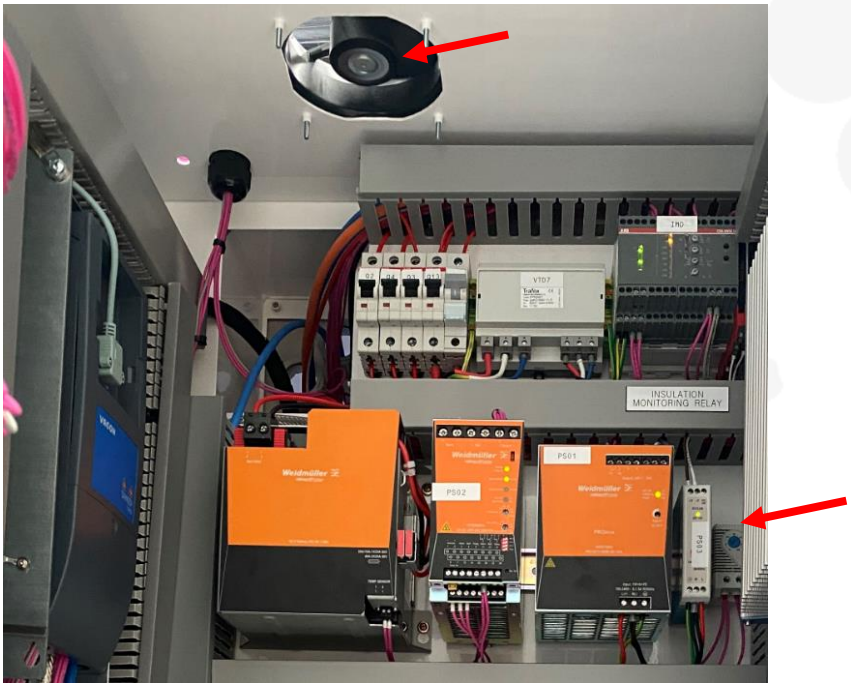


Figure 16 – Control compartment fan and thermostat (lower right)

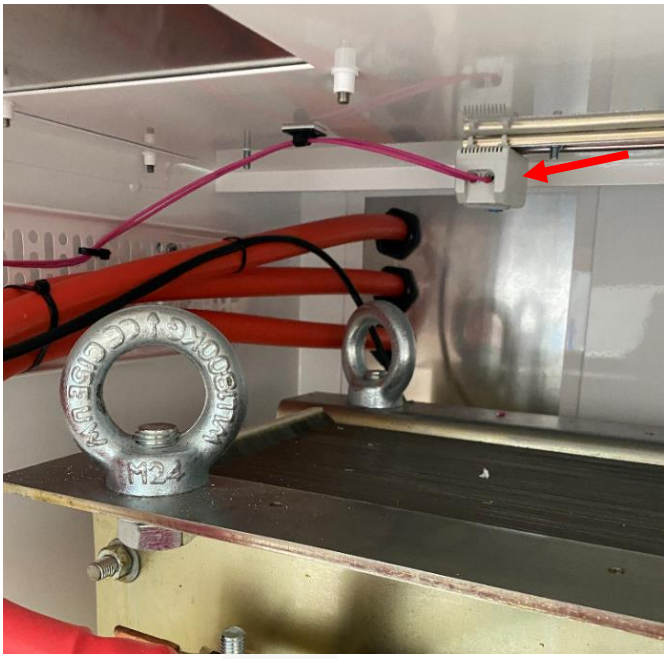


Figure 17 – Chimney fan thermostat in the transformer compartment – lift off the panel!

A further fan and thermostat set is in the battery control compartment ("black box").

8.2.2 Automatic Temperature and Humidity Control in the Cabinets

The inverter cabinet fan and the three battery-cabinet HVAC door units are normally automatically controlled by the Integrated Environmental Control PLC.

Sensors are:

a) An inverter cabinet air temperature sensor,
b) A battery cabinet air temperature sensor for the front battery rack and
c) A battery cabinet air temperature and humidity sensor for the two back battery racks.

Independently controlled actuators are:

1. The inverter cabinet fan with continuous speed control
2. The battery cabinet front HVAC door system with split cycle cooling system and heating
3. The battery cabinet two back HVAC door systems with split cycle cooling system and heating

The integrated control runs on the environment PLC. All actuators and sensors communicate via a single Modbus RS485 daisy chain across the two cabinets.

The following are the standard PLC parameters for the environmental control. They can only be changed by the OEM – PowerTec.

- HVAC cooling setpoint and hysteresis: 23°C +3°C/-2°C (26 – 21)
- HVAC normal heating setpoint and hysteresis: 11 +2°C/-2°C (9 – 13)
- HVAC humidity control heating setpoints: 85% +/-2% -> 16°C +/-1°C
- HVAC internal underlying local cooling setpoint in each device: 21°C +2°C /-1°C (23 – 20)
- HVAC internal underlying local heating setpoint in each device: 13°C +/-1°C (12 – 14)

- Fan: Turn on at 35°C, linear ramp speed up to max speed at 40°C, keep speed constant back to 35°C, linear ramp speed down starting at 35°C, down to 32°C

Automatic / Supressed control operation.

- The ON/OFF buttons on the control escutcheon will indicate if the Inverter Fan or the HVAC system is in automatic control. If the button is illuminated, the automatic control is ON. If the button is not illuminated, the automatic control is supressed and OFF.
- The control will automatically fall back to automatic if left OFF for 4 hours.

Figure 18 – Environmental Control ON/OFF toggle buttons

8.2.3 Battery Cabinet Air Conditioner Local Device Control Settings

Local setting of underlying or back-up setpoints of the HVAC system is done via the device display panels. Control parameters can be set with pushbuttons.

Figure 19 – HVAC Display Panel + Control Buttons

The display panel will indicate its device internal temperature under normal conditions. The lamps below the display temperature are described in the table below.

lamps	Description
	Flashing when self diagnose or temperature setting mode
	Lamp on when cooling
	Lamp on when heating
	Lamp on when external fan is running
	Flashing when alarm

To set the cooling and heating parameters, press and hold the ‘M’ button for 5 seconds.

With the arrow buttons, navigate through the 4 simple parameters. To select a parameter, press the ‘set’ button then with the arrows adjust accordingly. Press the ‘set’ button to confirm the parameter change. Press the ‘M’ button to exit once parameters changes are complete.

Code	Parameter name	Range
F01	Compressor start temperature	20～50℃
F02	Compressor stop hysteresis temperature	2～8℃
F03	Heater start temperature	-5～14℃
F04	Heater stop hysteresis temperature	1～5℃

8.2.4 Operating the HVAC System Without PLC control

For testing, preliminary operation during commissioning and as a back-up, in case the co-ordinated automatic control has problems, the battery cabinet air conditioners can be operated locally, using their internal sensors. To operate the air conditioners locally, the control wiring must be pulled out on all 3 devices. The control wiring terminal is plugged in between the display panel and the AC terminals. When operating the HVAC systems stand-alone, the settings must be different to the setting when operating as underlaid control to automatic coordinated PLC control:

- HVAC internal local cooling setpoint in each device: 23°C +/-3°C
- HVAC internal local heating setpoint in each device: 10°C +/-2°C

8.3 Measurement Interfaces

8.3.1Protection Relay X Supplies (Q2)

To be completed

8.3.2 Protection Relay Y Supplies (Q1)

To be completed

8.4 Protection Relay Test points

To be completed

8.5 Modbus TCP Interface For SCADA or 3rd-Party Microgrid Control

8.5.1 Physical Access

The PowerCache Modbus TCP interface is accessible via the right Ethernet port on the main control IPC located in the Inverter cabinet control compartment.

The factory settings of the external interface are the following:

- IP address: 192.168.1.214
- Subnet: 255.255.255.0

This interface IP address setting can be remotely changed by the OEM-PowerTec, if desired.

8.5.2 Modbus Map for SCADA Controller

The Modbus Map for a suitable SCADA system or 3rd party controller is provided in Appendix PT-MM-CO-20-000

8.5.3 Emergency Alarms Supervision

A set of six hardwired emergency alarms is available, if discrete I/O SCADA supervision is desired.

1. Protection relay ok
2. AC UPS on battery
3. AC UPS ok
4. Smoke and heat alarm
5. Insulation monitoring
6. Fire system activated or pressure low

9 Maintenance

9.1 Safety

Maintenance personnel must familiarise themselves with the hazards (section 3) and adhere to the safe work instructions (section 5) of this manual.

Shutdown and Isolate the BESS before maintenance work (see section 5.4)!

240V AC UPS and 24V DC-UPS backed auxiliary power is still available after isolation.

Turn off the AC UPS.

Figure 20 – AC UPS de-activation (in the battery control compartment)

The DC UPS battery has a limited number of cycles until it dies. Do not use the UPS when not required. The UPS function is interrupted by pulling the DC fuses on the UPS battery. Reinsert after work is finished.

Figure 21 – DC UPS de-activation (in the system control compartment)

9.2 Maintenance Intervals

1) Regular on-site maintenance of the BESS is to be carried out bi-annually by design.
2) Major maintenance works are required once, after 6 years.
3) Quarter-yearly system health checks by PowerTec via remote access are recommended.

9.3 Maintenance Service Provider and Access

Hardware maintenance requires physical access and is carried out by the Owner's maintenance service provider.

Quarter-yearly system health checks via remote access are recommended to be carried out by the OEM (PowerTec). This option requires a separate Service Agreement.

If selected, PowerTec needs unrestricted remote access to the PowerCache control network during maintenance work. A VPN service provides secure, remote, unrestricted access to the BESS control network. It is used by PowerTec for commissioning and maintenance access. The VPN complies with the highest communication security standards (ISO certified). The VPN gateway to the network is a Cybertec-DMM 450 Industrial 4G Modem Router. There is no IP communication connection between the PowerCache control network and any network SCADA network. A SCADA controller in the BESS, if any, is for independent monitoring of hard-wired signals only.

While connected to the BESS control network, PowerTec commits to the Owner's procedures and does not operate the BESS other than in the way agreed for the specific task or in an emergency.

9.4 List of Equipment that Requires Maintenance

Hardware components that require planned or preventative maintenance during the BESS 12-year design-lifetime are:

Object	Activity	Period	Remark
Main pleat filter in the inverter cabinet door	Inspect / replace	0.5y / 1-2y	
Main inverter cabinet impeller	Test	1y	remote test by OEM, Runtime: 6y
Filters and mesh behind louvers on doors or panels	Inspect / replace	1y / 1-2y	
Cabinet fans	Test	1y	Runtime: 6y
Inverter and LCL-filter Impellers	Replace	6y	
Door HVAC systems	Service / cooling efficiency test	1y / 3y	Efficiency test by HVAC technician
Fire system	Inspect & fill-test / replace	1y / 6y	
AC and DC UPS / UPS battery	Test	1y	remote test by OEM, Calendar life: 9-12y
Cabinet general	Cleaning / de-dusting	1y	

Health checks, any agreed software or parameter updates and any agreed functional adaptation of the BESS are carried out by accessing the components listed in section 9.4. A Health check may also reveal necessary reactive maintenance actions and allows to prepare spare parts.

9.5 Spare Parts

A spare parts list can be provided upon request.

Where a direct purchase is available, and a component does not require configuration beyond documented settings, the maintenance contractor can directly purchase it from the specified OEM or distributor.

Where the selection or the parameterisation of a component contains protected PowerTec solution IP, PowerTec is the channel to purchase the spare part. PowerTec can offer all spare parts on request.

9.6 Details of Scheduled On-Site Activities

9.6.1 Exchange of dirty or clogged air filters

Check period: 1y
Replacement period: 1-2y
Organisation: Owner's maintenance contractor

The inverter cabinet has:

- 4 air filters 110mm x 140mm on the AC and DC lift-off panels or doors (model-dependent)
- 1 air filter 140mm x 310mm on the control compartment door
- 1 air filter 140mm x 910mm on the transformer compartment lift-off panel
- 1 large pleat filter 3000qm/h Pure-V G4 Panel Filter 495x495x96mm in the door of the inverter compartment

For the first exchange: Prepare the filter and sizes. The material for the filter medium, as specified in the spare parts list, can be purchased from the OEM and cut into pieces. Alternatively, order a pre-cut filter set from PowerTec. Filters can be washed and reused for the next maintenance.

Filter exchange – quick & easy option:

Pull the used filters out from the bracket with your hands. Keep used filters – they can be washed and reused. The new filters can be carefully pushed in and arranged for the right fit by hand under the bracket.

Filter exchange – thorough, more labour-intensive option:

Remove the bracket by removing its M6 wing-bolts. This is necessary, if the used filters cannot be removed easily from under the bracket, or if the vermin mesh under the filters is clogged and requires cleaning.

Remove the vermin mesh and clean it with a brush. Re-install the vermin mesh and the bracket with the new filter inserted.

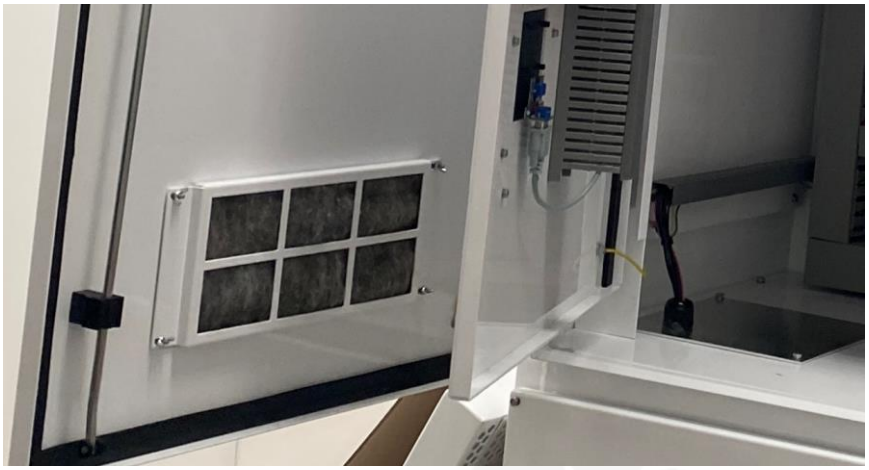


Figure 22 – Air filter and bracket

9.6.2 Test of cabinet fans

Check period: 1y
Replacement period: A need to replace is not expected during lifetime
Organisation: Owner's maintenance contractor

To test the cabinet fans, adjust the thermostat setting until the associated fan changes its status and re-adjust it to its original setting.

Follow section 8.2.1 to identify all cabinet fans and their respective thermostat locations. Detect the fan operation status acoustically or visually.
The fans are under the roof. The roof must be removed if a defect occurs that requires a fan exchange (see the installation manual). We do not expect that a cabinet fan requires exchange during the BESS lifetime, however, as experience with the BESS evolves, preventative cabinet fan exchanges during the 6-year major maintenance works may be an option.

9.6.3 Inverter and LCL-filter maintenance works including impeller replacement

Check period: none - (alarm in control system if defect)
Replacement period: 6y for the impellers
Organisation: Owner's maintenance contractor

Danfoss OEM instructions to be provided by PowerTec for the installation of the impellers into the components.

Use the ramp included in the supply (stored in the DC compartment) to remove the heavy LCL filter. The ramp fits the step of the cabinet plinths when placed on the cabinet and concrete floor in front of the LCL filter. A fan control cable along the inverter compartment floor can be oved out of the way to the front of the cabinet. Pull out the heavy LCL filter after removing its fixing bracket by using its handle and wheels.

If the system is often used at highest rating during its lifetime, it is possible that the LCL-filter capacitors must be exchanged before the end of system life. The requirement to do so will be indicated by an alarm or during an OEM remote health check, and the work must be carried out by a PowerTec or invert-OEM trained contractor.

Figure 23 – LCL Filter and ramp for LCL filter removal -stowed away in the DC compartment

9.6.4 UPS test

Check period:	1y
Replacement period:	Strongly depends on UPS usage
Organisation:	Owner's maintenance contractor

The DC UPS is set to stop after 20min of discharge or at 19.2Vdc (~25% SoC of UPS's battery) and has a specified lifetime of ~200 cycles at such depth of discharge. A need to replace the battery is not expected during lifetime, however several replacements of the built-in lead acid battery have been necessary with past PowerCaches.

The AC UPS, located in the battery control compartment, is an integrated system. A need to replace the battery is not expected during lifetime,

In case of a failure of any of the two UPSs, an alarm is issued through the control system.

Test:

- Disconnect the BESS auxiliary supply from mains by opening the auxiliary supply 3-phase breakers – left side of Q2, see **Figure 24**.

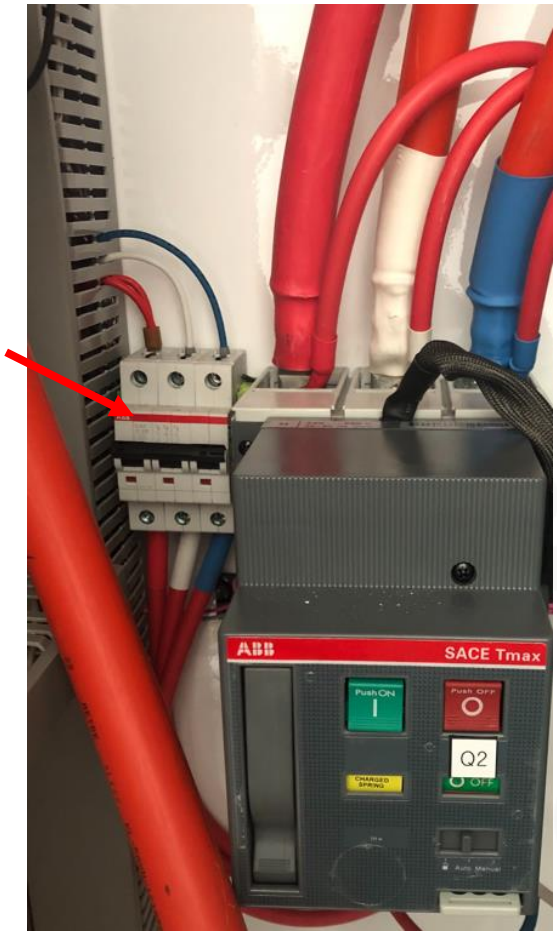


Figure 24 – System Auxiliary Supply Breaker

- Check that the AC UPS provides power by confirming that the 240V auxiliary supply is still on (Protection relay, BMS).
- Turn off the AC UPS by pressing in I/O button.
- Check that the DC UPS provides power by confirming that the 24V auxiliary supply is still on (PaDECS Control system, Modem).
- Reconnect grid auxiliary supply shortly after and turn the AC UPS back on. Avoid full discharge test of the DC UPS to prevent battery wear!
- Ensure that the discharge limit is set correctly to 20min (see DC UPS instructions manual attached)

9.7 Fire Suppression System Maintenance

Before performing any maintenance on the Novec 1230 fire suppression system, please ensure bottle ball valve is **isolated (OFF)**. The provided maintenance log must be filled in each time an annual maintenance procedure is performed.

Step 1

The first step of this procedure is a simple visual inspection of all equipment.

- Check bottle and discharge equipment for physical damage, deterioration or corrosion. If any deterioration or corrosion is evident, replace the damaged parts.
- Check all support brackets. Tighten loose fittings; replace all damaged or corroded parts.
- Inspect the tubing and ensure there is no abrasion, cuts, kinks, accumulation of dirt.
- Ensure the tubing is free of obstructions that would prevent detection of a fire.
- Check the pressure gauge to ensure that pressure is 240 PSIG at 70°F

Step 2

The second step of this procedure involves depressurising the sensor tube, verifying the weight of the agent bottle followed by a re-pressurization of the sensor tube.

- De-pressurize the tubing by removing the pressure gauge from the end of line device, there will be a loss of pressure at this time.
- Disconnect the tubing at the ball valve.
- Remove the bottle from the bracket.
- Weigh the cylinder with a certified scale. If there is a weight loss of more than 5% of the weight stamped on the cylinder label or if there is a 10% loss of pressure; remove and recharge or replace the cylinder assembly.
- Reinstall the bottle and pressurize the tubing in accordance with Section 7 ‘Fire System Installation’ of the ‘Pole-top Mounted PowerCache® BESS Installation and Commissioning Guide’

A six-year maintenance procedure will require a full replacement of all fire suppression equipment. This includes:

- Bottle
- Tubing
- End of line gauge
- Pressure switch

For details, see the Installation Manual, attached.

9.8 HVAC Maintenance

Before performing any maintenance on the Battery cabinet HVAC units, please ensure that auxiliary power to each device is switched off. To switch off the auxiliary power, use circuit breakers Q06, Q07 and Q08 that are in the Battery control cabinet.

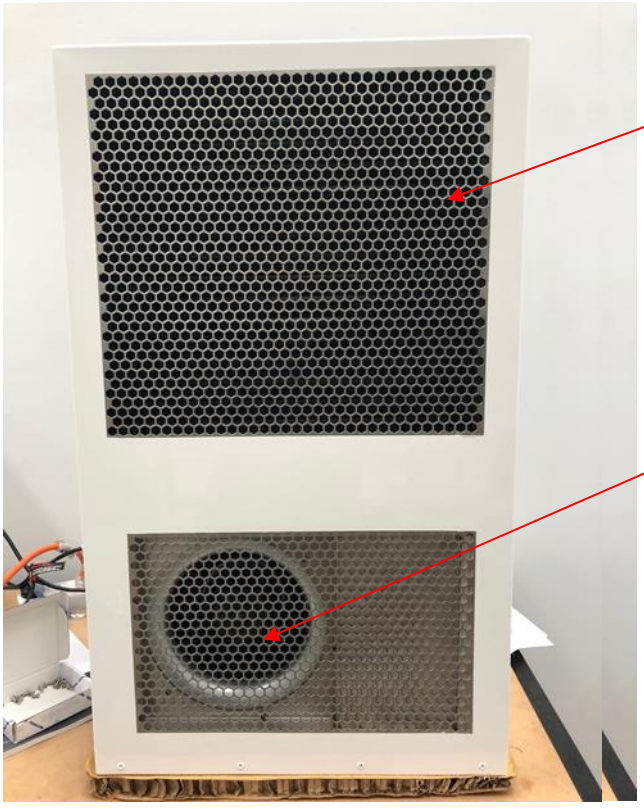
The HVAC maintenance schedule is split into two categories. These are:

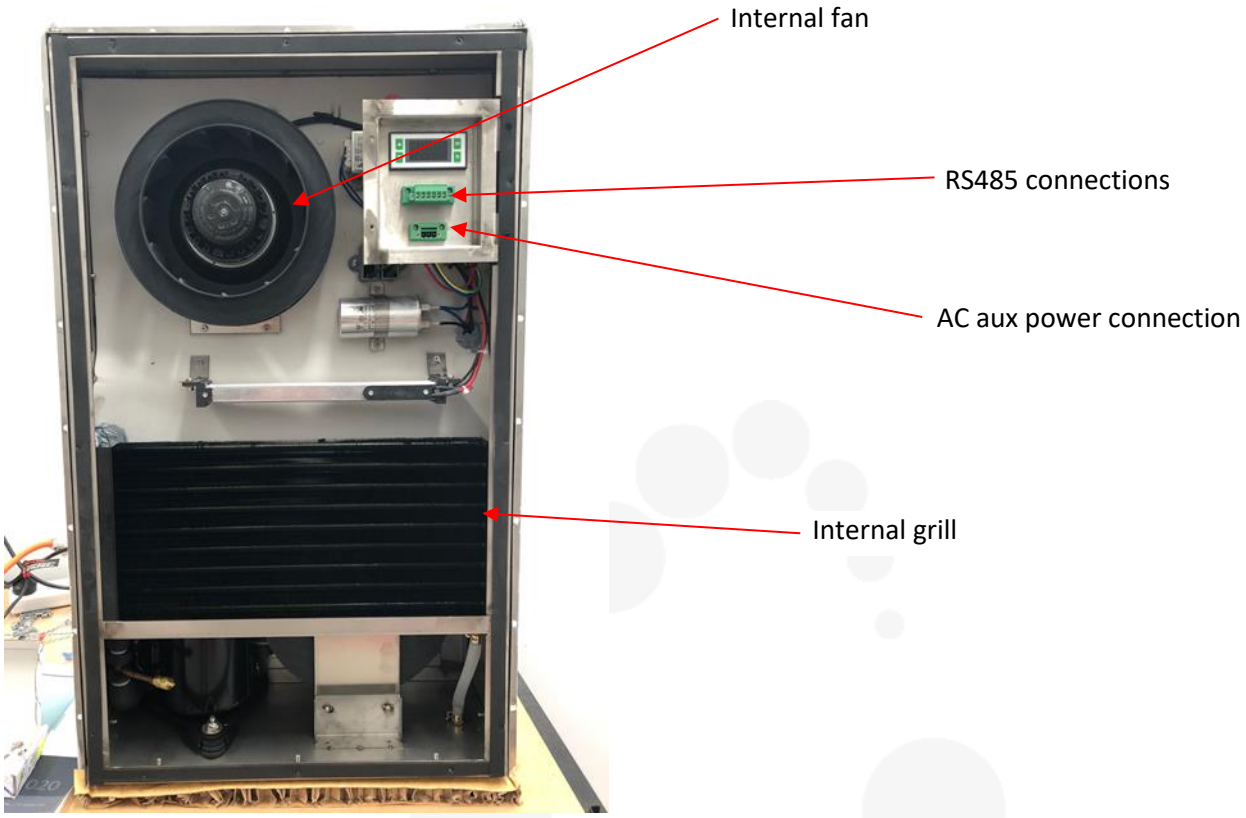
- Annual visual check, including light maintenance clean.
- 3-year cooling efficiency check.

9.8.1 HVAC Annual Maintenance

An annual maintenance service check is to be carried out by the operator's maintenance service provider. This includes:

- Use air gun to clean external fan through outer mesh
- Use brush or air gun to clear any vermin that may be stuck between external grill and outer mesh
- Remove internal cover and use air gun or brush to clean internal fan and grill
- Check RS485 and auxiliary power plug connections. Tighten terminal connections if necessary.
- Check outer silicon sealant between HVAC unit and cabinet door. If any damage has occurred, apply new silicon. The sealant ensures there is no water ingress.





9.8.2 3-year cooling efficiency check.

A 3-year cooling efficiency check can only be performed by a HVAC expert contractor. Re-gassing may be required. Refrigerant is R134-A.

9.9 Remote System Health Check and Support

9.9.1Scheduled Remote Maintenance

Check period: 3 months
Organisation: OEM (PowerTec) – optional Service Agreement required

- Quarter-yearly system health checks and component, functional and safety tests according to a checklist and a test plan, executed via remote access (4h program + report)
- Remote support of the Owner's maintenance contractor carrying out bi-annual mechanical/electrical on-site maintenance: phone consultation, and system operation or system testing via remote login.

The checklist and test plan for the Remote System Health Checks include:

a) Check for system anomalies, warnings, alarms or operation outside recommended parameters via alarm-manager and data-historian,
b) Check the protection relay event log for trips, alarms and functional issues,
c) Check the SoH of the battery, check for any module or string imbalance errors, over- or under-temperatures, cell faults or other battery alarms via the Battery Management Unit

d) Perform rack-balancing or cell balancing if required: operate individual racks, or leave the battery idle for one day to automatically balance,
e) Check inverter for OEM data logger event files and interpret files if any,
f) Check Data Historian health and file sizes,
g) Exercise the main breaker OPEN/CLOSE, E-stop, alarm manager with test alarms, alarm reset, battery SHUTDOWN/GET_READY. Exercise a transition to island, if function is enabled,
h) If agreed with the owner/principal, upload and test parameter, software or firmware updates.

9.9.2 Call Service

- Operational support and fault-analysis call-service
- Emergency support
- Daily summary operation check (via the PaDEDS Cloud server and VPN) and active reporting of operation outside recommended parameters or suspected faults.

Operational and emergency call-service includes:

- Quick Alarm or Fitness Check, on request from an operator,
- Consultation for interpretation of any alarm or other observation, and for determining the course of action (e.g., determining the need for site attendance),
- Change of functional parameters based on a change of local requirements.

Availability as per Service Agreement, if any.