CUBE – Compact Universal Bi-directional Efficient DC/DC Converter

A Compact High Power Density BOOST or BUCK Converter

Installation, Operation and Maintenance Manual for use with the full line of CUBE DCDC Converters

Alencon Systems – Passionate About Power

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2 General Information

All efforts have been made to ensure the accuracy of material provided in this document at the time of release. Items are subject to continuous development and improvements. All specifications and descriptions are subject to change without notice.

2.1 Purpose

This manual provides information about installing, operating, maintaining, and troubleshooting the Alencon CUBE DCDC Converter.

Who Should Read this Manual?

This manual should be read by anyone who needs to:

- Understand the product
- Plan the installation
- Install the product
- Commission the product
- Operate the product
- Maintain the product, if necessary

2.2 Product Warranty

Alencon Systems warrants to you, the original purchaser, that each of its products will be free from defects in materials and workmanship for three years from the date of purchase. Extended warrantees of an additional five (5), ten (10) and twenty (20) years are also available for purchase.

This warranty does not apply to any products which have been repaired or altered by persons other than repair personnel authorized by Alencon System, or which have been subject to misuse, abuse, accident, or improper installation. This warranty does not cover the repair or replacement of any goods which fail as a result of damage in transit, misuse, neglect, accident, Act of God, abuse, improper handling, misapplication, modification, improper storage, excessive stress, faulty or improper installation, testing or repair, negligent maintenance, or failure to comply with the written instructions for installation, testing, use or maintenance (if any) provided by Alencon Systems. Alencon Systems assumes no liability under the terms of this warranty as a consequence of such events.

Because of Alencon Systems' high quality-control standards and rigorous testing, most of our customers never need to use our warranty service. If an Alencon Systems product is defective, it will be repaired or replaced at no charge during the warranty period. For out-of-warranty repairs, you will be billed according to the cost of replacement materials, service time and freight. Please consult Alencon Systems for more details. If you think you have a defective product, follow these steps:

- Collect all the information about the problem encountered. (For example, issues you are encountering in your PV array) Note anything abnormal when the problem occurs.
- Call Alencon Systems or your licensed Alencon Systems dealer and describe the problem. Please have your manual, product, and any helpful information readily available.
- If your product is diagnosed as defective, obtain an RMA (return merchandise authorization) number from Alencon Systems. This allows us to process your return more quickly.
- Carefully pack the defective product (preferably in the original packaging material it was shipped in), a fully completed Repair and Replacement Order Card and a photocopy proof of purchase date (such as your sales receipt) in a shippable container. A product returned without proof of the purchase date is not eligible for warranty service.

2.3 Warnings, Cautions and Notes

	***Warning!***	*Warnings indicate conditions, which if not observed, can cause personal injury!*
	***Caution!***	*Cautions are included to help you avoid damaging hardware or losing data.*
	***Note!***	*Notes provide optional additional information.*

2.4 Packing List

The CUBE is assembled and fully tested at the Alencon factory. Before installation, please ensure the following items have been shipped:

- Commensurate # of CUBE Units specified for your project

FIGURE 1: PICTURE OF A CUBE UNIT

2.5 Ordering Information

Model Number Description

	Max Rated Voltage	Max Rated Power	Application (directionality)	Voltage Modality*	Model Number
1	1500 V	430 KW	Solar (unidirectional)	Non-Interleaved	**CUBE-15-PV-N**
2	1000 V	470 KW	Solar (unidirectional)	Non-Interleaved	**CUBE-10-PV-N**
3	1500 V	430 KW	Energy Storage (bidirectional)	Non-Interleaved	**CUBE-15-ES-N**
4	1000 V	470 KW	Energy Storage (bidirectional)	Non-Interleaved	**CUBE-10-ES-N**
5	1500 V	430 KW	Solar (unidirectional)	Interleaved	**CUBE-15-PV-I**
6	1000 V	470 KW	Solar (unidirectional)	Interleaved	**CUBE-10-PV-I**
7	1500 V	430 KW	Energy Storage (bidirectional)	Interleaved	**CUBE-15-ES-I**
8	1000 V	470 KW	Energy Storage (bidirectional)	Interleaved	**CUBE-10-ES-I**

*Voltage modality refers to the ability for Primary and Secondary voltage ranges to overlap. Interleaved (overlapping) modality not available until 2023.

3 Important Safety Instructions

SAVE THESE INSTRUCTIONS– This manual contains important instructions for use with the CUBE that shall be followed during installation and maintenance of these devices.

FIGURE 2: THE GRAPHIC ABOVE INDICATES THAT THE CUBE IS A GROUNDING CONDUCTOR

WARNING! Always ground the CUBE chassis before energizing the unit.

WARNING! Battery can present a risk of electrical shock, burn from high short-circuit current, fire or explosion from vented gases. Observe proper precautions.

FIGURE 3: THE GRAPHIC ABOVE INDICATES THAT THE CUBE ACTS AS A DIRECT CURRENT SUPPLY

Installation of this equipment must be performed by an authorized electrician in accordance with the local and NEC ANSI/NFPA 70 and OSHA requirements.

1. Before installing and using the CUBE, read all instructions presented in this manual and the cautionary markings shown on the CUBE's enclosure.

2. For service and maintenance of the CUBE contact Alencon Systems LLC or a certified Alencon Systems service center. Opening the device or attempting to perform a non-authorized repair will void the warranty.

3. During operation, hazardous voltages and currents may be present. Only authorized and qualified personnel should perform servicing/installation.

4. Disconnect switches or contactors <u>must</u> be wired between the CUBE primary/secondary and connected sources (PV array or otherwise).

5. Do not disconnect output (direction dependent) contactors or switches while equipment is operating. Shutdown the DCDC converter by sending "Shutdown" command using the controller (see Section 11.2).

6. Always use input disconnect switch to shut down the CUBE before disconnecting the output. This is conversion direction dependent when using bidirectional CUBE-ES.

7. Always close output disconnect switches before closing input switches. This is conversion direction dependent when using bidirectional CUBE-ES.

8. The CUBE may require external fusing depending on the installation. Consult the NEC or other relevant electrical code.

9. Exposed PV strings to sunlight represent a shock hazard at the wires and exposed terminals. Disconnect CUBE primary and secondary switches or contactors performing any work on the CUBE. Test any terminal for voltage before touching them.

10. Prior to disconnecting any inputs/outputs use an ammeter clamp to check for the absence of current in the wires.

11. Only use accessories recommended or approved by the manufacturer.

12. Ensure that wiring is in good conditions and that all wiring is sized according to NEC 310-16 specifications. Ignoring to do so may result in a risk of fire.

13. PV modules produce electrical energy when exposed to light and thus can create an electrical shock hazard. Wiring of the PV modules should only be performed by qualified personnel.

14. Always have CUBE manual on hand, for reference.

4 Introduction

Alencon's Combined Universal Buck-Boost Electronics (CUBE) for large scale DCDC power conversion, is a unique and cost-effective solution for optimizing the performance of large-scale PV plants, Battery energy storage systems (BESS), Fuel Cells, Hydrogen Electrolyzers and Fast EV charging installations.

The CUBE series of DCDC converters is a highly compact DCDC conversion unit with 5X the power density of other non-isolated DCDC conversion units. The CUBE achieves its unrivaled power density by using a silicon-carbide based power train instead of bulky traditional silicon insulated-gate bipolar transistor (IGBTs). The CUBE operates at much higher frequency than the IGBT converters. This allows it to use a smaller water-cooled inductor.

The combined air/water cooling system facilitates high-power density allowing Alencon to offer the CUBE at a very cost-effective price point, letting plant owners and project developers more easily monetize the benefits the device offers and achieve higher project returns while future proofing a PV plant over its lifetime.

5 CUBE Features

5.1 CUBE Hardware Modalities

CUBE is a non-isolated Buck-Boost DCDC converter. The CUBE operates as a step-up or step-down DCDC converter subject to certain product features. The CUBE is offered in two modalities the N and I series, as described below:

5.1.1 Non-Interleaved Modality – N-Series

When purchased in the Non-Interleaved Modality (CUBE N series), the CUBE can boost the voltage in one direction and buck into the other direction. Buck OR Boost DCDC converter is applicable for cases when the voltage on one side of the converter is always less than voltage on the other side of the converter.

5.1.2 Interleaved Modality – I-Series

In this configuration CUBE can Boost and Buck the voltage in both directions of the converter. Buck OR Boost DCDC converter is applicable for cases when the voltage range on one side of the converter overlaps with voltage range on the other side of the converter, i.e. the voltages are interleaved. The CUBE I-series is slated for availability in the second half of 2023.

5.2 Available Control Modes

5.2.1 STANDBY

Standby is an idle control mode, used when no power conversion is desired.

5.2.2 MANUAL

Switching frequency is set directly through the controller. This control mode is used only for testing and troubleshooting by Alencon Systems personnel.

5.2.3 PV MPPT

Autonomous control mode, where the DCDC maximizes power harvested from the connected PV array by modifying the voltage level.

5.2.4 PRIMARY VOLTAGE CONTROL

CUBE maintains a specified voltage on the primary bus.

5.2.5 SECONDARY VOLTAGE CONTROL

CUBE maintains a specified voltage on the secondary bus.

5.2.6 PRIMARY CURRENT CONTROL

CUBE maintains a specified current as measured on the device primary side.

5.2.7 SECONDARY CURRENT CONTROL

CUBE maintains a specified current as measured on the device secondary side.

5.2.8 PRIMARY POWER CONTROL

CUBE maintains a specified power as measured on the device primary side.

5.2.9 SECONDARY POWER CONTROL

CUBE maintains a specified power as measured on the device secondary side.

5.3 CUBE Protection Modes:

Protective functions as triggered by measurements on the primary or secondary side of the DCDC converter. The trip conditions are configurable, project specific and pre-defined in the CUBE memory, they can be modified to some degree, if necessary, during deployment.

5.3.1 Primary/Secondary overvoltage (P-OVP, S-OVP)

The primary/secondary voltage is too high for normal operation. CUBE will TRIP and enter STANDBY mode.

5.3.2 Primary/Secondary undervoltage (P-UVP, S-UVP)

The primary/secondary voltage is too low for normal operation. CUBE will TRIP and enter STANDBY mode.

5.3.5 Primary/Secondary Overcurrent (P-OCP, S-OCP)

Operational current magnitude is limited to protect from hardware damage. If limit is exceeded, CUBE will TRIP and enter STANDBY mode.

5.4 Environmental Protection

The CUBE has software functions designed to protect it from extreme external conditions of high temperature and moisture. The trip conditions are configurable, project specific and pre-defined in the CUBE memory, though they can be modified as necessary during deployment.

5.4.7 Power Semiconductors Over temperature (S-OT)

Monitors the temperature of the Power Semiconductors. CUBE enters STANDBY mode if the limit is exceeded.

5.4.8 Control PCB Overtemperature (C-OT)

Monitors the temperature on the PCB. CUBE enters STANDBY mode if the limit is exceeded.

5.4.9 MCU Overtemperature (M-OT)

Monitors the temperature on the Microcomputer. CUBE enters STANDBY mode if the limit is exceeded, to prevent the DCDC converter from failure.

6 CUBE Applications

The CUBE can be configured to serve two different broad use cases: CUBE PV and CUBE ES.

6.1 CUBE-PV: Photovoltaic Installations

In PV installations the CUBE balances the PV voltage with the inverter DC bus voltage. It helps to harvest peak PV power by providing maximum power point tracking (MPPT). If PV voltage is always lower or always higher than DC bus the N-series CUBE can be used. Otherwise, I-series CUBE should be used.

The CUBE-PV – is a unique and cost-effective solution for optimizing the performance of large-scale PV plants keeping PV array at MPPT. The CUBE-PV is a monolithic DCDC optimizer that can accept the combined input of upwards of 75 PV strings depending on string voltage, current rating, and desired level of power output. The CUBE-PV can also be used to repower existing PV plants.

The flow of energy is unidirectional – from PV to DC bus. When at night the voltage on PV is low, CUBE-PV shuts down at dusk and isolates the PV from the DC bus. At sunrise the CUBE-PV automatically wakes-up and begins to supply harvested PV energy to the DC bus.

6.1.1 CUBE-PV Applications

- In new PV construction or in repowering to boost the PV voltage to a higher DC inverter voltage or buck the PV voltage if DC inverter bus is lower than the PV voltage.
- In new PV construction or in repowering when a centralized inverter defines the DC bus voltage, the CUBE provides distributed MPPT to maximize harvesting.
- In new construction when a centralized inverter shares the DC bus with a BESS and PV system
- The N-series CUBE is used when the DC bus voltage is always higher than PV voltage or when the DC bus voltage is always lower than PV voltage. If PV voltage is interleaved with DC bus voltage I-series CUBE should be used.

6.1.2 CUBE-PV in New PV Plants

For new PV plants, including the CUBE into initial system design can reduce balance of system (BoS) cost, by reducing cabling cost through higher voltage and lower current while at the same time improving PV yield with distributed MPPTs and improved inverter efficiency.

The CUBE will provide a voltage determined by optimal input to central inverter or battery connected to a common voltage DC bus.

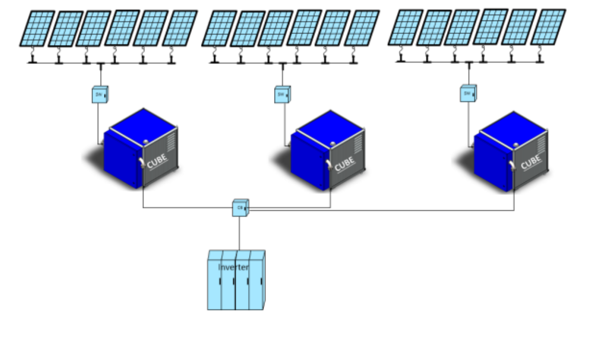
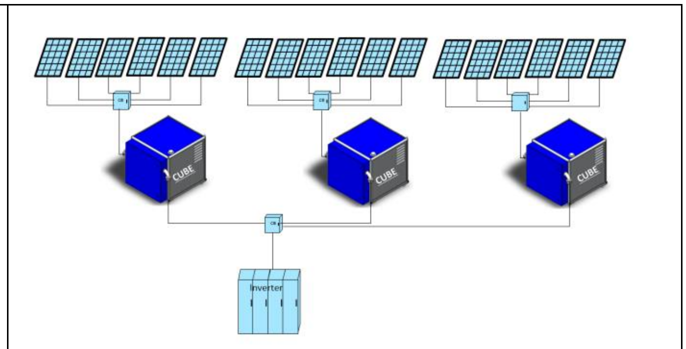
	
With one input switch	With input combiner box

FIGURE 4: DIAGRAM OF DEPLOYED CUBES IN A NEWLY CONSTRUCTED PV PLANT.

6.1.3 CUBE-PV in PV Centric DC Coupled Solar + Storage:

The CUBE is a unique solution for DC-coupling of PV and Storage. When deployed with battery energy storage systems, the DC bus, in some implementations, may be shared with the storage terminal as shown in **Error! Reference source not found.** 5. In this case the inverter operates in a constant voltage mode. The CUBE will match the PV voltage to the battery voltage and provide granular, distributed MPPT.

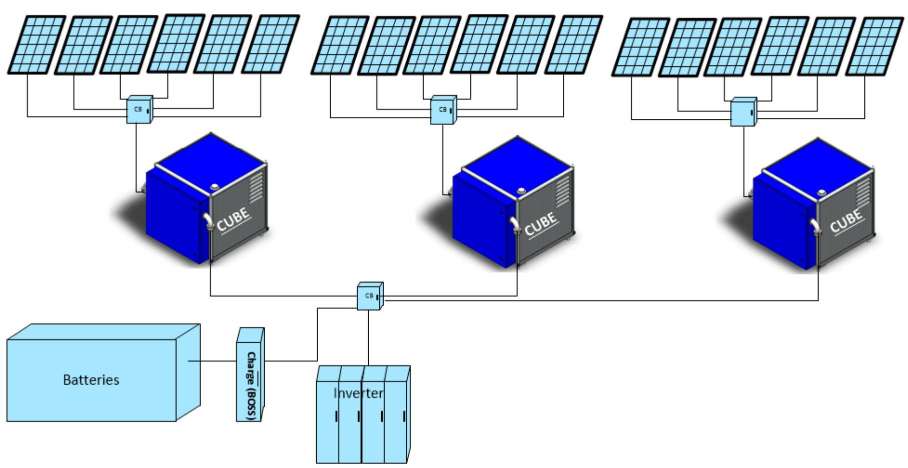


FIGURE 5: DIAGRAM OF A DC-COUPLED SOLAR + STORAGE SYSTEM USING THE CUBE

6.1.4 Grounding of PV panels

PV systems are negatively or positively grounded at the suggestion of the PV panel manufacturer. Alternatively, The PV systems may be ungrounded or "floating". The CUBE does not provide galvanic isolation between primary and secondary; hence it has no impact on the array's grounding scheme.

6.2 CUBE-ES: Battery Energy Storage Systems

In a BESS the CUBE is used to control charge and discharge of the batteries to a common DC bus. If BESS voltage is always lower or always higher than DC bus the N-series CUBE can be used. Otherwise, I-series CUBE should be used.

The CUBE-ES – is a unique and cost-effective solution for **BESS, Fuel Cells, Hydrogen Electrolyzers, or Fast EV charging**. The CUBE-ES is a bi-directional DCDC converter and can provide upwards of 500A controlled current in both directions depending on system voltages and configuration.

6.2.1 DC Coupled, Battery Centric Solar + Storage

The CUBE-ES can be used for "battery centric" DC coupling applications where the CUBE is installed between the battery and a DC bus.

In a DC Coupled Battery Centric Solar + Storage deployment, the PV may be connected to the DC bus directly or by means of other DCDC converters. The role of the CUBE-ES is to control the charge or discharge battery current according to the commands from the system controller.

6.2.2 Standalone Battery Systems

The CUBE offers a unique solution for coupling lower voltage batteries to higher voltage inverters. As battery energy storage technology evolves, many novel battery chemistries are coming on the market that operate at voltages that may not be ideal for high voltage power conversion systems (PCSs). Alternatively, there can be cases where higher voltage batteries must be paired with lower voltage PCS.

6.3 Fuel Cell Integration (FC)

For Fuel Cell applications the CUBE is typically used to raise fuel cell voltage to a higher battery or DC bus voltage. The CUBE controls the current rate from the fuel cell. Because the fuel cell voltage is generally lower than the DC bus voltage, the N-series CUBE may be used.

The CUBE offers a unique solution for coupling lower voltage fuel cells into higher voltage inverters. Fuel cells typically operate at lower voltages than most modern, grid connected inverters. The CUBE can be an ideal solution for integrating fuel cells into grid scale applications by stepping up their voltage.

6.4 Hydrogen Electrolyzing Installations (HEI)

In HEI the CUBE is used to supply the proper voltage to PEM electrolyzers. Modern and future electrolyzers require tens of megawatts of regulated DC power. CUBE-ES may serve as modules when paralleled together to control the needed level of DC power. The modular structure will provide a higher reliability for the whole system.

6.5 Fast Automobile Charging Technology (FACT)

In FACT the CUBE is used in conjunction with isolated DCDC converters to control charging of the internal BESS and supply voltage to the automobile charge dispensers.

CUBE ES will serve the EV market DC Fast Charging stations and offer impressive cost reduction. The power electronic equipment that will cut the cost of the hardware inside DC fast charging stations while reducing the installation and operation cost by leveling the demand from peaks defined by sporadic pattern of EVs driving in the charging stations.

7 Technical Specifications

7.1 Electrical Specifications

CUBE	1000 Volt Series	1500 Volt Series
Electrical Parameters		
Maximum Voltage	1000 V	1500 V
Maximum Power Point Trackers (MPPTs) per CUBE	1	
Operating Voltage – High Side[1 2]	50 – 1000 V	50 – 1400 V
Operating Voltage – Low Side[1]	50 – 1000 V	50 – 1400 V
MPPT Voltage Range	50 – 950 V	540 – 1350 V
Maximum Short Circuit Current (Isc)	700 A	400 A
Maximum Operating Current @ 25 C	525 A	350 A
Maximum Power per Input @ 25 C	470 KW	430 KW
Maximum Power per Input @ 50 C	330 KW	310 KW
Isolation	Non-Isolated, Buck-Boost Topology	
Operating Information		
Peak / CEC Weighted Efficiency	99.5% / 98.5%	
Storage Temperature	0 C to 85 C	
Cooling	Internal, closed loop water cooling	
Environmental Rating	NEMA 3R	
Humidity	0 – 95%	
Operating Ambient Temperature	0 C to 50 C	
Certifications	UL1741, IEC 62109-1, CSA C22.2	
Communications	Modbus TCP/IP via Alencon Communications Environment (ACE)	
Form Factor		
Packaging	Pad Mounted, Outdoor Rated	
Size (L x W x H)	.76 x .67 x .72 M	
Weight	250 KG	

Specifications are subject to change without notice

[1] CUBE internal auxiliaries turn on at 500 V DC. To operate the unit below 500 V, an external 24V/10A power supply is needed.

[2] To achieve rated currents, high side voltage must always be higher than the low side. When voltages overlap, current rating will be halved.

7.2 Mechanical Specifications

The precise dimensions of the CUBE device can be found in Figure 6 below.

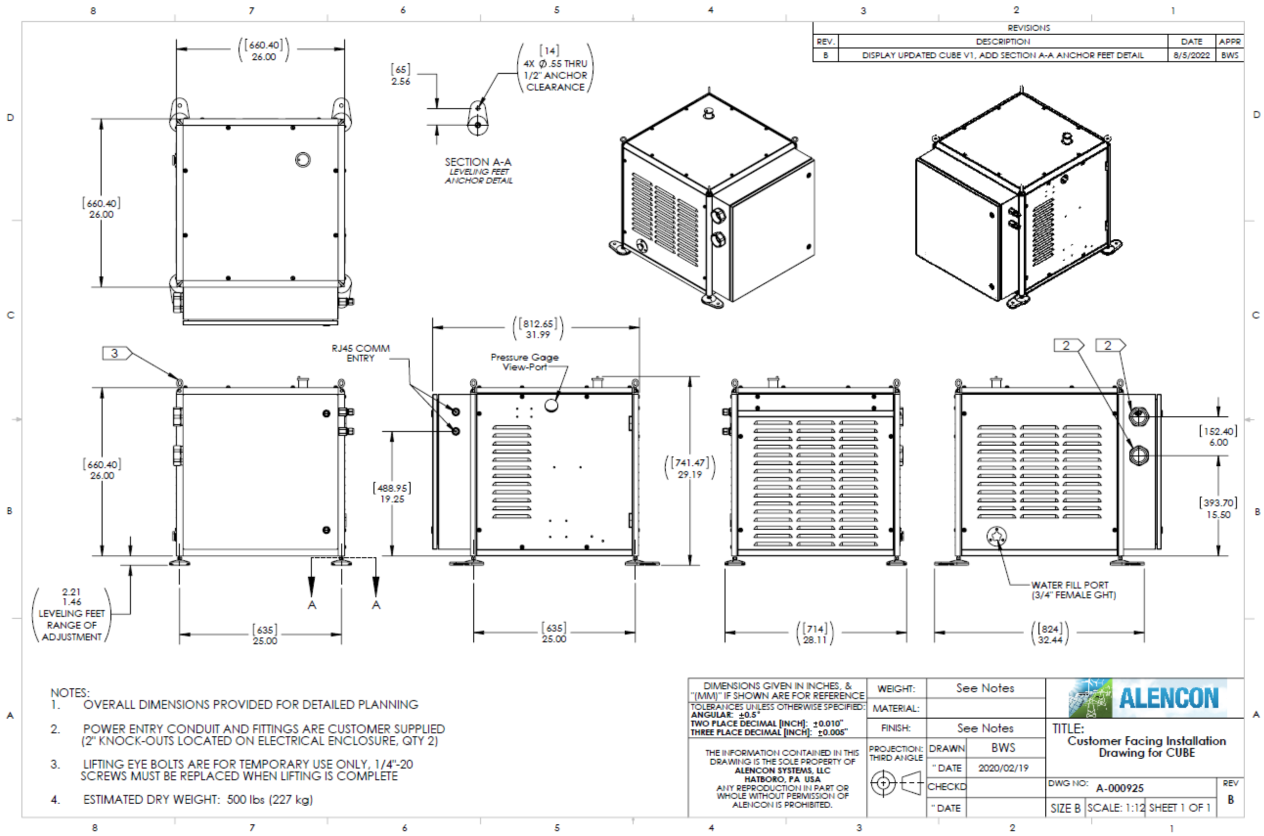


FIGURE 6: MECHANICAL DIMENSIONS OF CUBE

8 CUBE Hardware

This section provides information on how the CUBE is constructed and its principles of operation.

The CUBE with can be configured to operate as:

1. Step-up DCDC converter (Boost)
2. Step-down DCDC converter (Buck)

The CUBE construction is comprised of two main sections; the **electrical compartment**, and the **inductor enclosure** which houses the water-cooling system as well.

FIGURE 7: CUBE – TWO SECTIONS

8.1 Electrical Compartment

The majority of HV and LV electronics are within the NEMA 3R rated compartment at the front of the CUBE device.

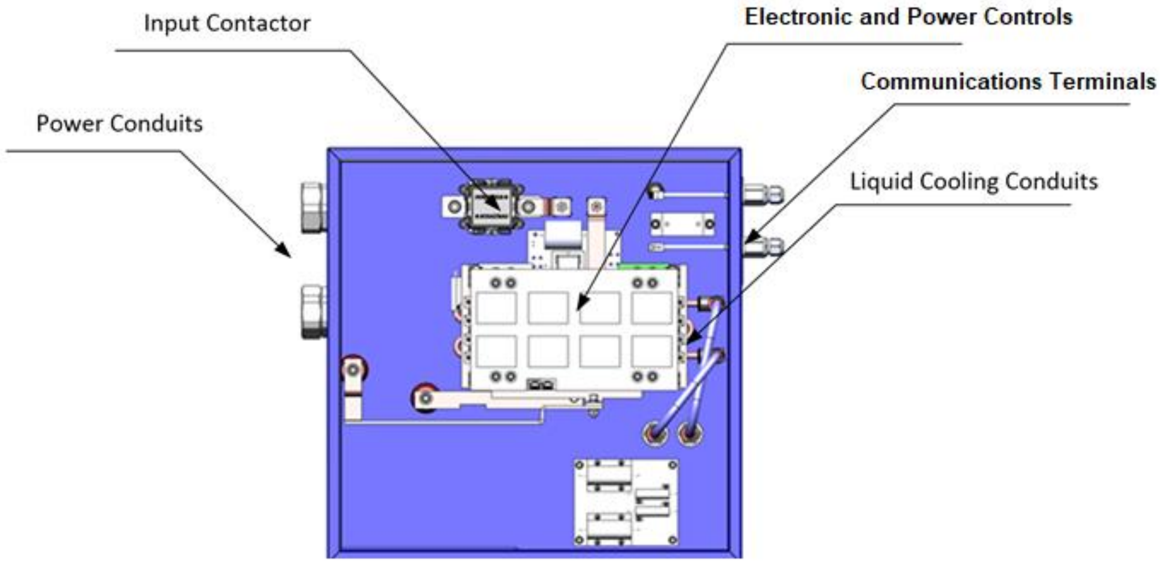


FIGURE 8: ELECTRICAL COMPARTMENT

8.2 Inductor Enclosure

The CUBE's inductor and water-cooling system are stored in the larger back part of the device. This part of the enclosure is not watertight as the equipment within is all weather resistant.

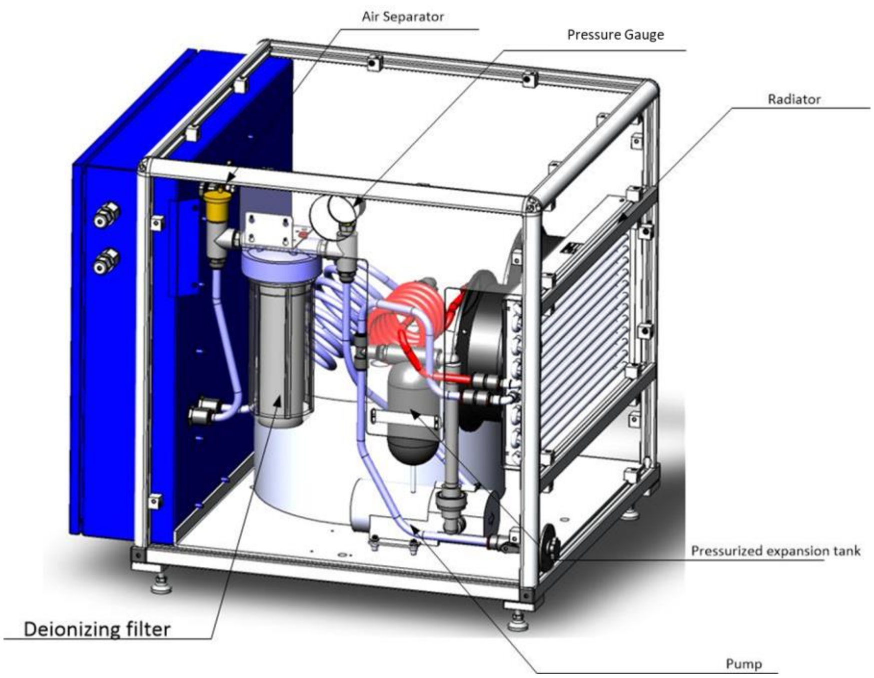


FIGURE 9: MAIN ENCLOSURE, LIQUID COOLING SYSTEM

8.2.1 Water-cooling System

The CUBE is equipped with a pressurized, liquid cooling system. During normal operation, the pump will circulate the coolant (deionized water) through the system. A filter keeps the deionized water at low conductivity and a pressurized expansion tank keeps the incoming pressure above the pump's cavitation point. The pressure gauge should show 20 – 30 PSI when the pump is working and 4 – 8 PSI when it is not.

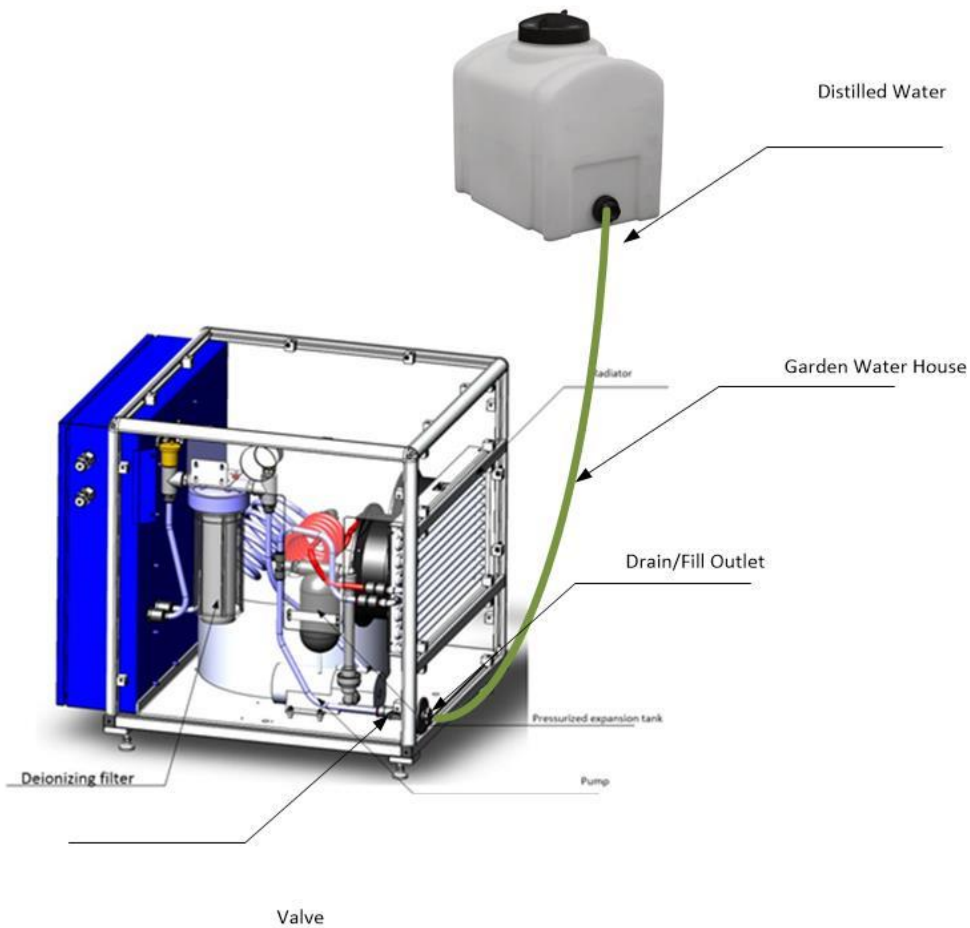


FIGURE 10: REFILLING LIQUID COOLING SYSTEM

9 Isolators and Disconnects

Alencon requires using disconnects (or contactors) to enable an electrical cut-off of the CUBE from its primary and secondary power sources/loads. Prior to disconnecting the CUBE primary and secondary terminals, the device should be shutdown (see Section 11.2).

Always disconnect CUBE from both power sources before performing maintenance.

Disconnects must be rated to the max input voltage and UL approved.

Do not disconnect the CUBE output (direction dependent) while under load.

Always use an appropriately rated disconnect to isolate CUBE from input power source (direction dependent) before disconnecting the output.

You may select from one of two options:

1. Built-in disconnects on integrated power equipment (battery, inverter, etc.)
2. Combiner Box and Third party disconnects

9.1 Built-in Disconnects

Most inverters and battery energy storage systems have mechanical disconnect switches and or electrical relays that will isolate the devices in question from the CUBE. If these are present on the source devices for the CUBE primary or secondary, an additional disconnect is not required.

9.2 Combiner Box and Third Party Disconnects

When the CUBE is connected to a PV array or other equipment without built-in disconnects, the combiner box disconnect or other third party disconnect switches can be used.

10 CUBE Installation

Only skilled professionals with experience installing electrical systems should perform installation of the CUBE.

Installation instructions should be followed exactly; improper installation of the CUBE could void the warranty of the CUBE and any or all its component parts. Thoroughly read any project specific setup or commissioning instructions from Alencon Systems before beginning the installation.

If any instructions are unclear, or any additional information is required during the process, please contact Alencon Systems LLC for assistance (see Appendix C).

10.1 Install criteria

The following information should be considered when selecting the locations for installation.

Disconnect CUBE primary and secondary from power sources while performing the installation to reduce the risk of shock during the process. Test any wire or terminal for presence of high voltage before touching them.

The primary or secondary voltage at the CUBE converter must never exceed its rated voltage, (i.e., 1000V for the CUBE 1000). Exposure to voltage higher than that may cause damage to the CUBE and will void the warranty.

The minimum voltage, maximum voltage and maximum current ratings can be found on the CUBE serial number label (see Figure 12). The CUBE will not deliver any power if the primary voltage is below the minimum specified primary voltage.

10.2 Install procedure

The CUBE has been designed to be quickly deployed in the field. Much of the system configuration is done at Alencon's factory prior to shipping to decrease the amount of time needed for install and commissioning the system in the field.

A summary of the steps to install and prepare CUBE for commissioning is provided below:

1) Locate the system layout schematic provided by your system integrator. This diagram should show the location where the CUBE needs to go, including its LIN (Local Identification Number)
2) CUBE placement and mechanical install
3) Mount primary/secondary disconnects and put into OPEN (off) position
4) Ground the CUBE chassis
5) Electrical connections
6) Communications connections

10.3 System Layout Schematic and/or Installation Drawing

System installers and/or integrators should supply installation drawings showing the location of where the CUBE is to be installed. As well, the single line diagram should show electrical interconnections. A simplified version of such a SLD is provided below.

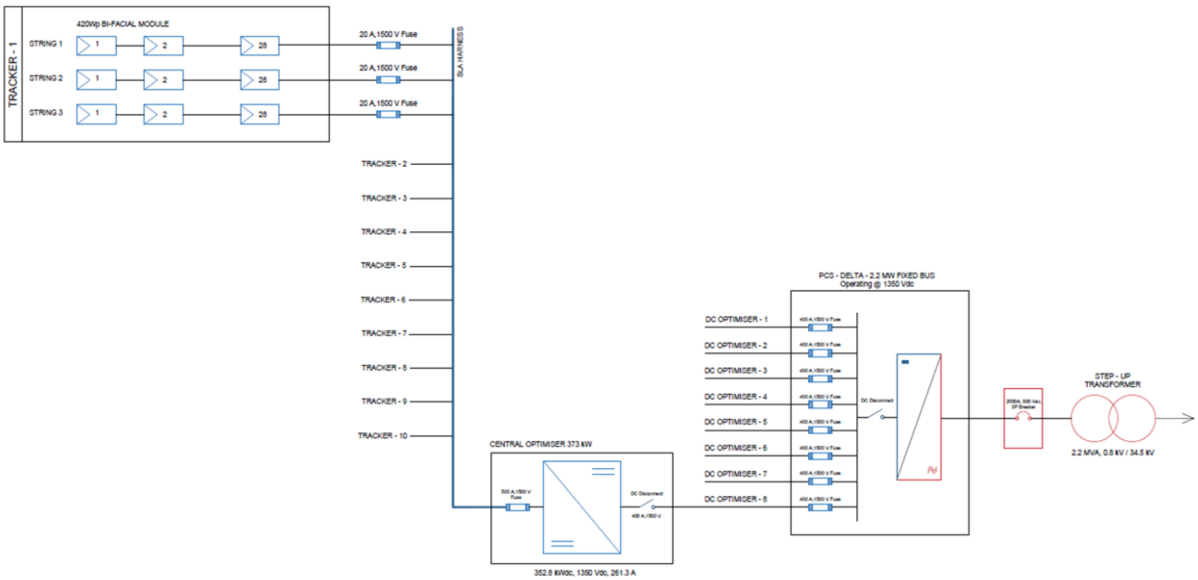


FIGURE 11: SAMPLE OF A SINGLE LINE DIAGRAM (SLD) INCLUDING CUBE

The installation drawing indicates the location of each CUBE and shows its Local Identification Numbers (LIN). Prior to shipment, each CUBE is identified with a unique serial number. Should a CUBE need to be replaced in the field, the replacement CUBE will have same LIN as the previous, but a different serial number. A permanent label showing the serial number of each CUBE is affixed to the inside of the front compartment door as shown below in Figure 12.

FIGURE 12: CUBE SN LABEL

10.4 Mechanical Install

10.4.1 Selecting Location

The following considerations should be made when selecting the CUBE location.

Indoor/Outdoor: The CUBE is NEMA 3R rated and can be safely deployed indoors or outdoors without additional weather protection.

Mounting Pad: Consult your EPC firm for a specification of the mounting pad construction, this will likely depend on hurricane regulations, by location.

Temperature: The CUBE can be stored in any location, where ambient temperature ranges from -40 to +85 °C.

The CUBE should be operated only when ambient temperature is within -5 to +50 °C.

Clearance: For safety in operation and maintenance, make sure that the CUBE has enough clearance around the unit, recommendations are in the table below.

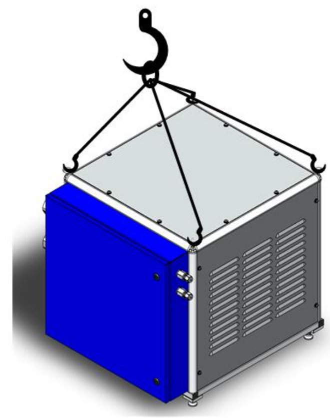
Direction	**Recommended Minimum Clearance**
Above	15 inches
Below	6 inches
Front (Electrical panel)	36 inches – OSHA, NFPA, and NEC requirement.
Back (Air filter access)	24 inches
Right Side (Plumbing access)	36 inches
Left Side	12 inches

10.4.1 CUBE Placement

To place the CUBE in its designated location:

1. The CUBE can be transported into location by forklift truck or by crane, see Figure 13.
2. Convenient removable I-hooks are provided, that can be used on the 4 corners of the CUBE top surface to lift and place the CUBE in desired location.
3. The CUBE comes with four adjustable legs. The legs can be permanently fixed with optional mounting brackets, see Figure 144.

Moving by Forklift Truck



Moving by Crane

FIGURE 13: MOVING THE CUBE

Legs

Mounting Bracket

FIGURE 14 : CUBE ADJUSTABLE LEGS AND MOUNTING BRACKETS

10.5 CUBE Grounding Requirements

PV Grounding

CUBE supports positive, negative, and floating grounding schemes. The chassis of the CUBE must be connected to main earth ground. Not properly grounding the CUBE enclosure can be dangerous for operators and maintenance personnel.

The size of the grounding conductor is usually based on the size of the largest conductor in the DC system.

Shock hazard

All power terminals are considered to have a high voltage potential to ground. To reduce the risk of shock during installation, treat all terminals as high voltage and test for voltage before touching exposed wiring. The work should be performed by qualified service personnel.

Ground lug is located at the bottom of the electrical compartment of the CUBE. Main earth connection can be made directly to the lug, which is already bonded to the enclosure door.

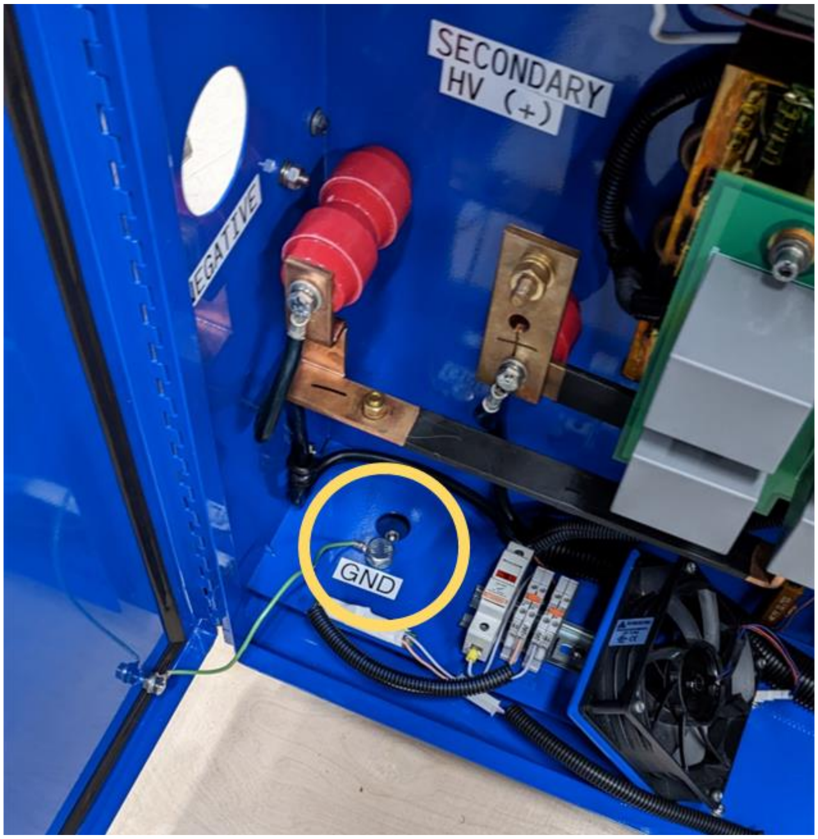


FIGURE 15: CUBE GROUND LUG LOCATION EXAMPLE (IN ORANGE)

10.6 Connecting the CUBE Primary and Secondary to Source/Load Cables

Ensure the sources are off (disconnects are in OPEN positions), before making connections to the CUBE primary or secondary.

Fire Hazard: Wiring should not be undersized. The size of the wires must be selected based on the maximum short circuit current in the node. Ensure wiring is in accordance with the NEC or applicable code.

The electrical compartment has 3 landing points for power cables up to 500 KCMIL in size and 2 conduit knockouts for the cables to feed through (see Figures 16 and 17 below).

1. Customer should supply watertight 2-inch conduit for the provided knockouts
2. Connect primary cables to the terminals PRIMARY (+) and COMMON (-)
3. Connect secondary cables to the terminals SECONDARY (+) and COMMON (-)

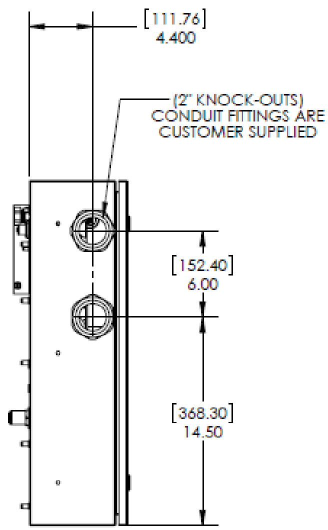


FIGURE 16: CUSTOMER SHOULD SUPPLY WATERTIGHT CONDUIT IN THE PROVIDED 2 INCH KNOCKOUTS

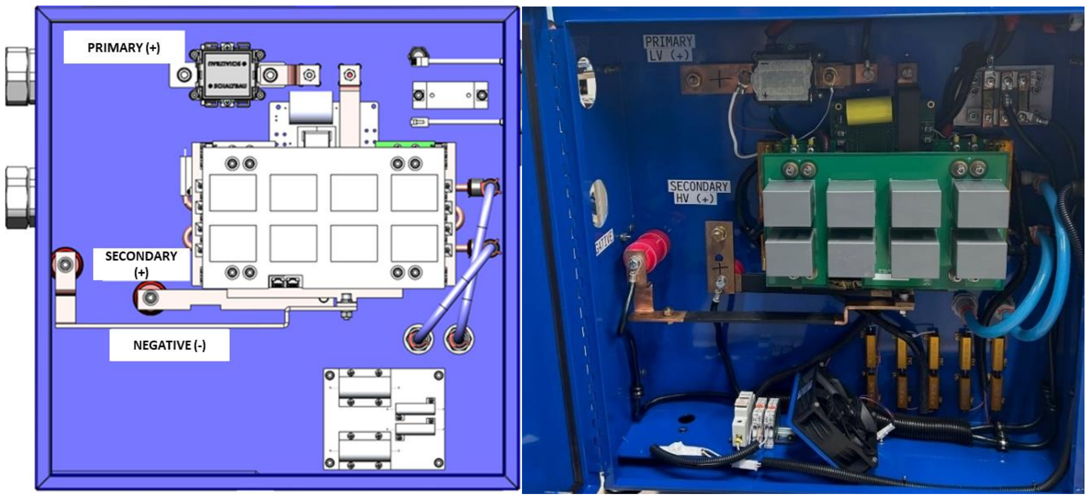


FIGURE 17: HIGH VOLTAGE TERMINATIONS

10.7 Pre-charge Circuits with Alencon CUBE

The CUBE primary has a contactor with a pre-charge resistor that is in parallel with the contactor. Therefore the primary side of the CUBE does not require an external pre charge circuit. If there is an additional disconnect present external to the CUBE, this disconnect must not be closed if the CUBE is not in SHUTDOWN state and the voltage difference between the CUBE input and the DC Bus is higher than 100 VDC.

CUBE secondary has no built in pre-charge circuit on the output. Therefore, if there is a disconnect between the CUBE secondary and the DC Bus the disconnect must not close without pre-charging the CUBE secondary.

Figure 18 below summarizes the requirements of a pre-charge circuit for the CUBE.

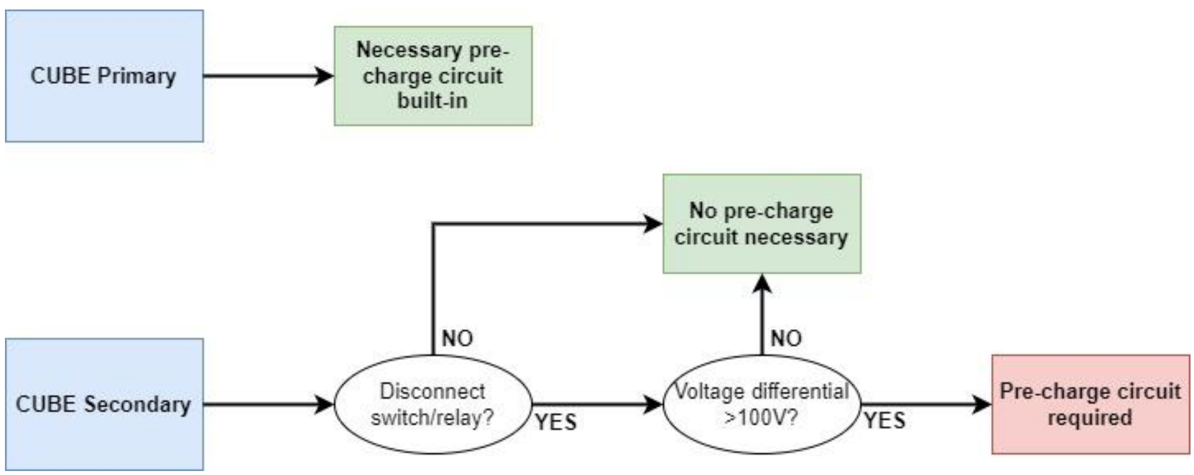


FIGURE 18: PRE-CHARGE CIRCUIT REQUIREMENTS WITH ALENCON CUBE

Note, requirement for an external pre-charge circuit with Alencon products needs to be assessed case-by-case and must be reviewed by Alencon engineers for final approval.

For more information see the Alencon Tech Note on Pre-charge Circuits

10.8 Connecting Comms Cables between CUBE and a PODD

CUBE units require a connection to the Alencon PODD device to establish communications and be controlled. Alencon specifies the use of:

- CAT5e or better STP cable
- Male RJ45 connectors, type B crimping
- 22 AWG conductors preferred (24 AWG are acceptable)

Note: CAT cabling should be rated for outdoor use if the cable run is not indoors or enclosed within conduit.

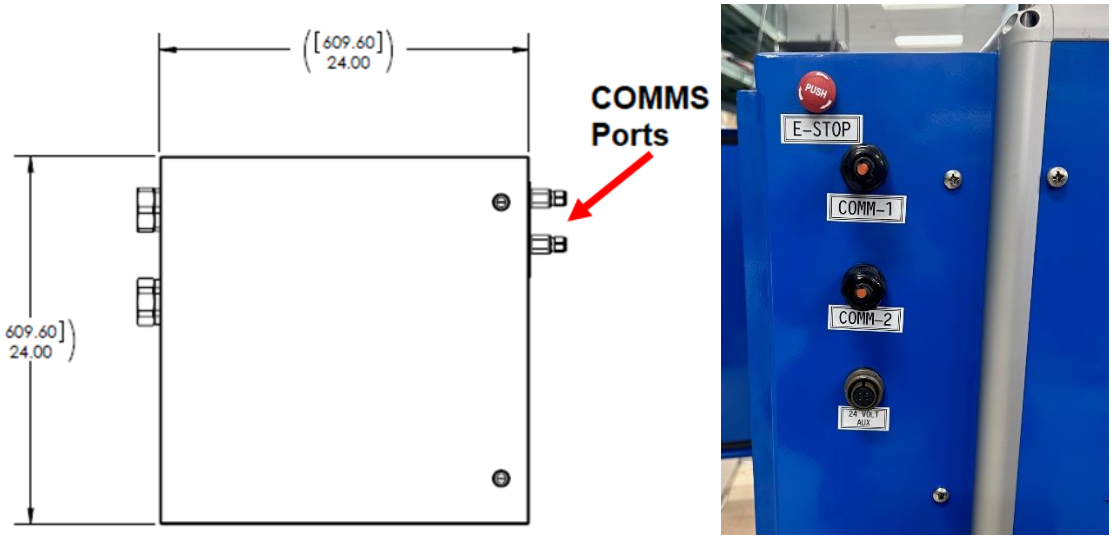


FIGURE 19: COMMS PORTS ON THE CUBE TO CONNECT TO THE PODD OR EXTERNAL SCADA

Comms cables can be connected as a daisy chain between multiple CUBE units and the PODD. A cable tester can be used to ensure the connection is sound for all 8 pins through the entire line.

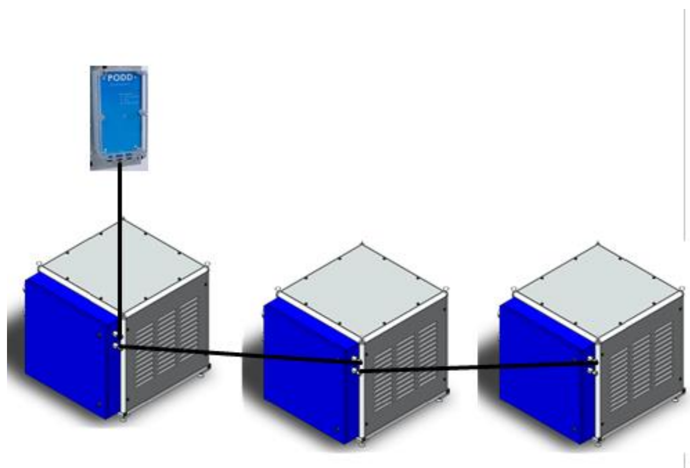


FIGURE 20: MULTIPLE CUBES CAN BE DAISY CHAINED TO A SINGLE PODD

11 Turning ON and OFF the CUBE

In some cases, such as for maintenance or troubleshooting, the CUBE needs to be turned off and isolated from primary and secondary sources. Use the full procedures below for safely turning ON and OFF the CUBE.

11.1 Steps to turn ON the CUBE:

Primary and secondary disconnect switches should be in the OPEN position at the beginning of this process.

1. Connect the CUBE secondary terminals and close the secondary disconnect.
2. Power on the CUBE device, using internal or external power source.
   a. Close the primary disconnect if relying on internal power source
   b. Keep the primary disconnect open if using external power source
3. Use the PODD or your integrated system controller to confirm that the CUBE is in SHUTDOWN state. If not, send a **Shutdown** command and see that it is enacted through the controller (see Section 12).
4. If not done previously, close the primary disconnect to the CUBE.
5. Use the PODD or other controller to check telemetry data for expected voltage measurements on both Primary and Secondary.
6. CUBE is on and ready for active control (see Section 12).

11.2 Steps to turn OFF the CUBE:

In the event of any maintenance or CUBE replacement, ensure that all CUBEs connected to the same source (primary or secondary) are turned OFF using this process.

1. Use the PODD or other controller to send a **Shutdown** command and cease power conversion on all CUBE channels (see Section 12).
2. If unable to use a controller to put the CUBE in SHUTDOWN state, the "input" switch (disconnect, contactors, etc.) should be opened such that the CUBE is isolated from power 'upstream' meaning:
   a. If operating in Primary to Secondary direction, open the Primary disconnect
   b. If operating in Secondary to Primary direction, open the Secondary disconnect
3. Only after the "input" disconnects are OPEN should the user open the "output" disconnect, so the CUBE is isolated from both primary and secondary.
4. Measure the primary and secondary DC currents using a clamp and verify no current flows to or from the CUBE. If current is still present, contact Alencon technical support directly.
5. Cables can now be disconnected from CUBE primary and secondary ports.

11.3 Commissioning your CUBE Device

The first time installing and turning ON the CUBE device, may be a different process than turning OFF and ON as desired for maintenance, troubleshooting or other reasons after the system is fully deployed.

Commissioning the CUBE includes:

1. Mechanical install of the CUBE (Section 10.4) and accessory devices.
2. Installing any additional safety hardware as required (Section 9)
3. Electrically connecting to Primary and Secondary (Section 10.6)
4. Connecting comms cables between CUBE unit(s) and the PODD (Section 10.7)
5. Turning ON the CUBE (Section 11)
6. Establishing communications with a PODD device (see PODD user manual)
7. Implementing final configuration changes (with assistance from Alencon technical support)
8. Controlling and operating the system (Section 12)

Alencon offers live commissioning support for all system deployments using the CUBE device. Please discuss this with your Alencon Systems representative if interested.

12 CUBE Operation

This section explains the operation of a CUBE, distinguishing between typical and atypical operation is key when troubleshooting your system.

When running the CUBE as a boost converter, power flows from primary to secondary. When running the CUBE as a buck converter, power flows from secondary to primary. Simplified circuit diagram of the converter is given in Figure 21.

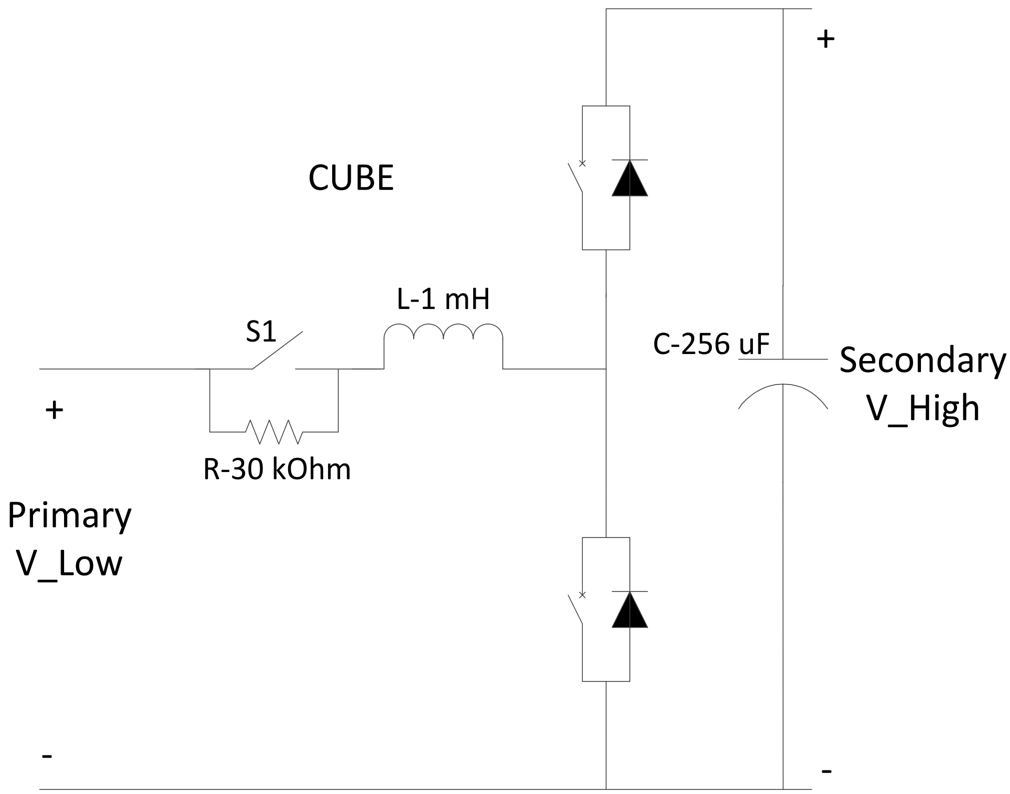


FIGURE 21: HIGH LEVEL CIRCUIT DIAGRAM OF CUBE

12.1 CUBE State Machine

Each CUBE operates as a state machine, where most state transitions are autonomous with the option of intervention using control commands sent through the PODD.

Main states may have lower-level state machines incorporated within. Arrows indicate the conditions of transfer from state to state. Commands can be issued from the Alencon PODD UI or the system controller via Modbus at any time.

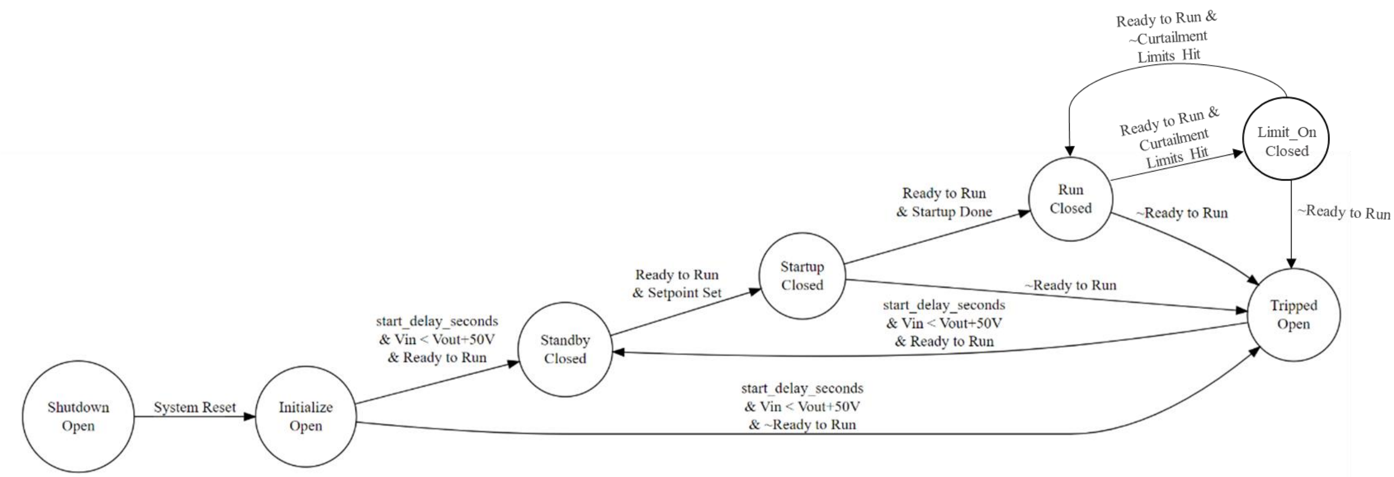


FIGURE 22: HIGH LEVEL STATE MACHINE DIAGRAM OF CUBE

Converter State	Contactor State	Power Conversion	Expected Commands
Shutdown	Open	No	System Reset
Initialize	Open	No	Shutdown
Standby	Closed	No	Current / Voltage Setpoint
Startup	Closed	Yes	Shutdown
Run	Closed	Yes	Setpoint / Shutdown
Limit_On	Closed	Yes	Setpoint / Shutdown
Tripped	Open	No	Setpoint / Shutdown

Find explanations of the statuses, commands, and conditions below. To avoid confusion in the following sections, statuses will be CAPITALIZED, commands will be **bolded**, and conditions will be *italicized*.

12.1.1 States

SHUTDOWN – Contactor is open

From any state the CUBE can be transferred into SHUTDOWN state upon receiving a **Shutdown** command. In the SHUTDOWN state no power conversion occurs. The CUBE stays in the SHUTDOWN state until a **System Reset** command is sent.

INIT – Contactor is open

Converter is initialized after receiving a system reset command, while in INIT it will wait until the converter transitions to Standby. The converter should automatically transition to STANDBY state when:

- Time delay is elapsed (configurable, default is 60 seconds)
- Vin < Vout + 50 V

STANDBY – Contactor is closed

Converter is ready to receive current or voltage setpoint command, upon receiving a setpoint, the converter will go to STARTUP mode. The DCDC converter is not producing power, it is ready to produce power but not all *startup limits* are satisfied, or *control mode* has not been set.

STARTUP – Contactor is closed

Current or voltage setpoint is already received. In the STARTUP state, the DCDC prepares the load for the RUN state. When *run limits* are satisfied, the DCDC automatically transitions to the RUN state unless a fault occurs mid-transition.

RUN – Contactor is closed

Power conversion is in progress, maintaining a consistent setpoint as requested from the controller. New current or voltage setpoint can be changed without leaving RUN mode. If the control mode or direction is changed, CUBE will go to STANDBY state. Alternatively, in MPPT mode, CUBE operates constantly adjusting to maintain maximum power.

LIMIT_ON – Contactor is closed

If *curtailment* is enabled and the DCDC is operating within the predefined *curtailment limits*, the CUBE will go to LIMIT_ON status. CUBE continues to operate at reduced power throughput, according to the application specific droop curve that has been written. If operating conditions return to standard *run limits*, the CUBE will return to RUN status.

For more information see the Alencon Whitepaper on DCDC curtailment.

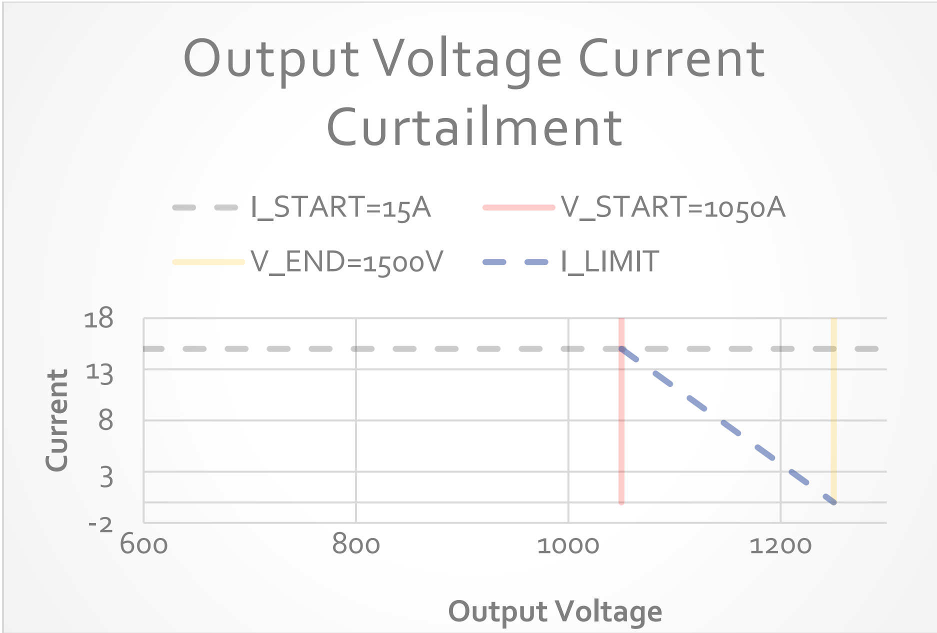


FIGURE 23: EXAMPLE OF CUBE CURTAILMENT

TRIPPED – Contactor is open

If, while in RUN or LIMIT_ON status, voltage, current or temperature exceed the pre-configured limits on the CUBE (i.e., hit a *trip condition*) it will enter TRIPPED state and move automatically to STANDBY state. When the TRIPPED state is entered, the DCDC stops all power conversion, and the contactor is open.

12.1.2 Commands

The following list contains the most common and useful commands that can be given to the CUBE from the PODD UI or external controller via Modbus. For full details on available Modbus commands and registers, please request Modbus Maps from Alencon Systems.

- **Clear Error** – remove error code flags from the UI, by resetting error code register. This has no effect on the state machine/operational flow of the CUBE.
- **Shutdown** – set the DCDC converter to the SHUTDOWN state and cease all power production.
- **System Reset** – initialize the DCDC converter to accept operating commands, which can be actively or automatically delivered.
- **Set Control** – Issue operating commands for how the CUBE should convert power. Including control mode, direction of conversion, setpoint, and setpoint timeout.
  - Options for **control mode** include:
    - STANDBY – idle state with no power conversion
    - Constant power – requires actively choosing the primary or secondary power setpoint
    - Constant current – requires actively choosing the primary or secondary current setpoint
    - Constant voltage – requires actively choosing the primary or secondary voltage setpoint
    - PV MPPT – autonomous operation, doesn't require setpoint
  - **Direction** of conversion options include:
    - Primary to Secondary (currents will display as positive values)
    - Secondary to Primary (currents will display as negative values)
    - NOTE: Bidirectionality is not available on all CUBE models
  - **Setpoint** can be given as any positive value from zero to the pre-defined maximum. If requested setpoint exceeds the maximum, CUBE will not accept that command.
  - **Setpoint timeout** controls a heartbeat function wherein the CUBE will go to STANDBY mode if a new setpoint is not received every X seconds, where X is the value given to this parameter. A setpoint timeout of 0 will disable the function.

12.1.3 Conditions

Bootup in shutdown

If evaluated as true, CUBE goes automatically to SHUTDOWN state when turned on. By default, the CUBE will be configured to evaluate as true, but this can be changed if necessary.

Control mode set

Available Control modes include:

- Primary/Secondary current
- Primary/Secondary power
- Primary/Secondary Voltage
- MPPT
- STANDBY

For *control mode set* to evaluate as true; the control mode, the direction, the setpoint, and the setpoint timeout must be written (except when control mode = MPPT or STANDBY).

Voltages, currents, temps within STARTUP range (Startup limits)

Tests operating conditions are in the permissible startup range as defined in the config file:

- On board temperature
- Transistor temperature
- Primary and Secondary Voltages

Voltages, currents, temps within RUN range (Run limits)

Tests operating conditions are in the permissible run range as defined in the config file:

- On board temperature
- Transistor temperature
- Primary and Secondary Voltages
- Primary and Secondary Currents

Trip condition

Tests operating conditions don't exceed the operating boundaries as defined in the config file:

- On board temperature
- Transistor temperature
- Primary and Secondary Voltages
- Primary and Secondary Currents

Curtailment (Curtailment enabled & curtailment limits)

Tests operating conditions have entered the curtailment zone as defined in the config file. Corresponding curtailment options must be enabled within the config file as well, there are many curtailment options available.

12.2 Running CUBE as a Boost or a Buck Converter

The CUBE will operate as a boost converter when running it from primary to secondary. The input source is connected across Primary LV (+) and Negative (-) buses. The output is connected across Secondary HV (+) and Negative (-) buses. See Figure 24.

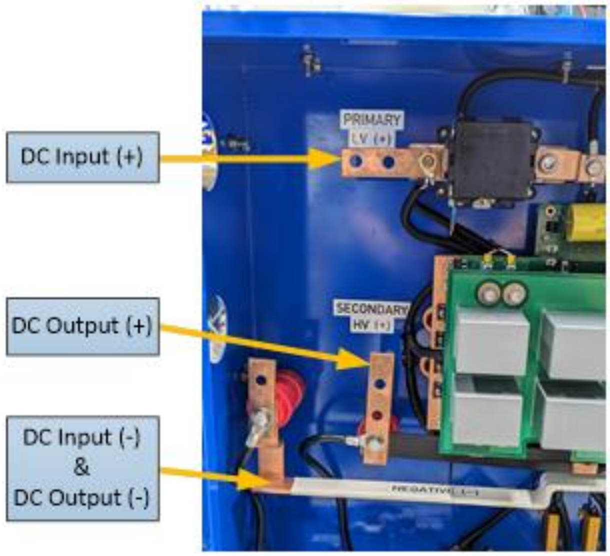


FIGURE 24: CONNECTING CUBE AS A BOOST CONVERTER

The CUBE will operate as a buck converter when running it from secondary to primary. The input source is connected across Secondary HV (+) and Negative (-) buses. The output is connected across Primary LV (+) and Negative (-) buses. See Figure 25.

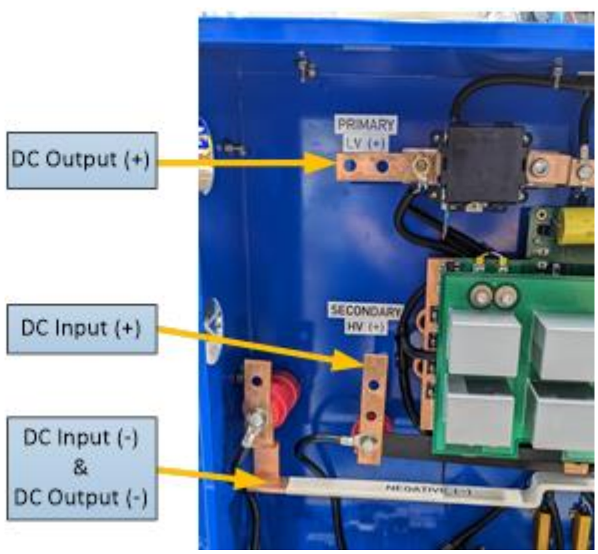


FIGURE 25: CONNECTING CUBE AS A BOOST CONVERTER

12.3 Running two CUBEs in series

Two CUBEs can be connected in series as shown in Figure 26. CUBE Boost will step up the voltage and the CUBE Buck will step it down. The voltage at the midpoint of the two CUBEs will be at an average of 1300 V. Please follow the steps below when operating the system:

- CUBE Boost will run as a voltage controller, it will control the voltage at the midpoint of two CUBEs. The control mode should be secondary voltage.
- CUBE Boost will run from Primary (V_Low) to Secondary (V_High). Direction must be set "Primary to Secondary".
- CUBE Buck will run as a current controller, it will control the power flow from the DC Bus-1 into DC Bus-2. The control mode can be current or power.
- CUBE Buck will run from Secondary (V_High) to Primary (V_Low). Direction must be set "Secondary to Primary".
- CUBE Boost can pre-charge its capacitor to the same voltage as the DC Bus-1 through its charge resistor.
- CUBE Buck can pre-charge its capacitor to the same voltage as the DC Bus-2 through its charge resistor.

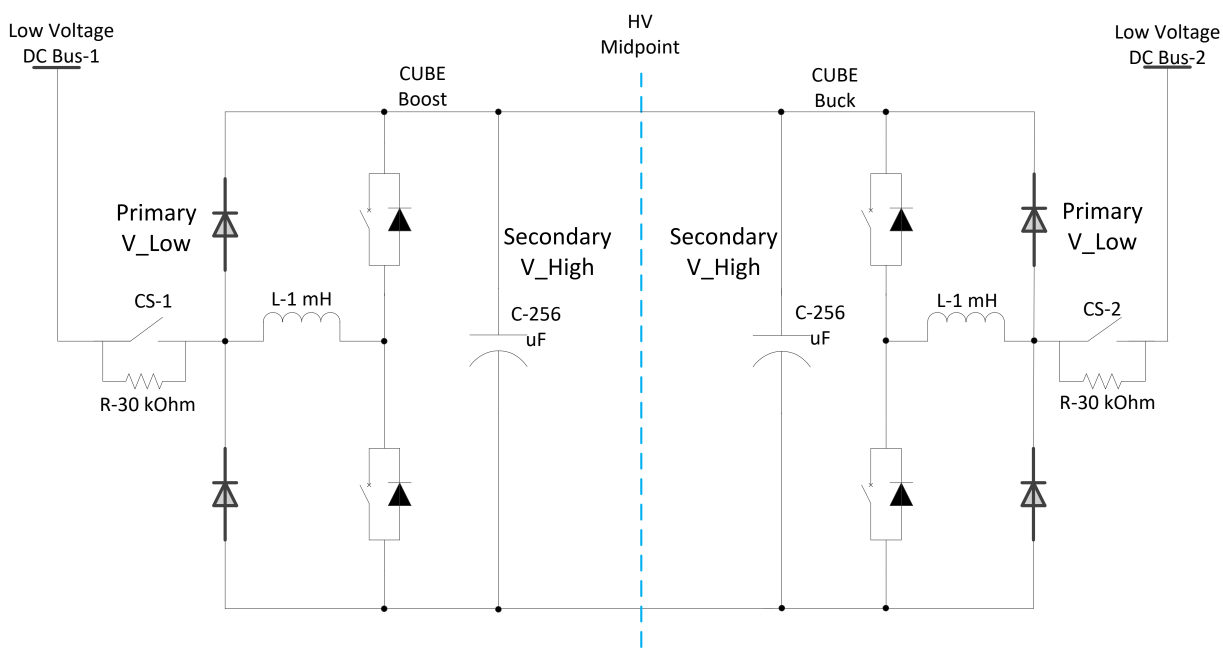


FIGURE 26: CONNECTING TWO CUBES IN SERIES, BACK-TO-BACK OPERATION

For more information on how to start and operate Two CUBEs in series, contact Alencon Technical Support.

12.4 Modbus Definitions and Map

A set Modbus register map and definitions document for the CUBE can be provided separately from this manual. Request these files from your Alencon representative.

13 CUBE Communication

The CUBE is an autonomous power conversion device when deployed in the PV array. It performs MPPT on the primary and its secondary voltage is dictated by the voltage set on the DC bus. However, by connecting the Alencon PODD, the user can perform data collection, configuration and firmware updates, and coordinated operation of multiple CUBE devices.

When deployed with an ESS, the CUBE will require active control through the PODD to function. The PODD as well allows the CUBE to communicate with an external SCADA system and or controller through the network.

13.1 PODD – Point of Data Distribution

The PODD communicates with CUBEs via MODBUS RTU. External SCADA systems communicate with the PODD via MODBUS TCP/IP. A single PODD can collect the operation data from up to 16 CUBEs. The PODD is also used for field software upgrades.

FIGURE 27: PODD

Multiple CUBEs can be daisy chained together via the communication terminals.

13.2 Alencon Communication Environment (ACE) - System Overview

Alencon's Communications Environment, the ACE, is an Internet of Things (IoT) hardware and software solution for controlling and monitoring your alternative energy assets utilizing Alencon's PODD device. The PODD can be used with other Alencon products including the CUBE, SPOT, GARD, and BOSS. The PODD acts as a gateway to integrate Alencon's power electronics with your plant level control systems or as a standalone controller and troubleshooting device.

13.3 CUBE User Interface (via PODD)

As soon as the CUBE has been turned on, the PODD UI can be used to access control functions and telemetry data. To ensure proper operation and communication of the CUBE with the PODD, two files are required:

- *metadata File*
- *config File*

Both these files would be pre-loaded onto the PODD or be provided by Alencon via secure file transfer. Open the PODD UI through a networked computer, to upload these files, read live telemetry data from the connected CUBE, and control the operation of the CUBE.

For more information refer to the PODD User Manual

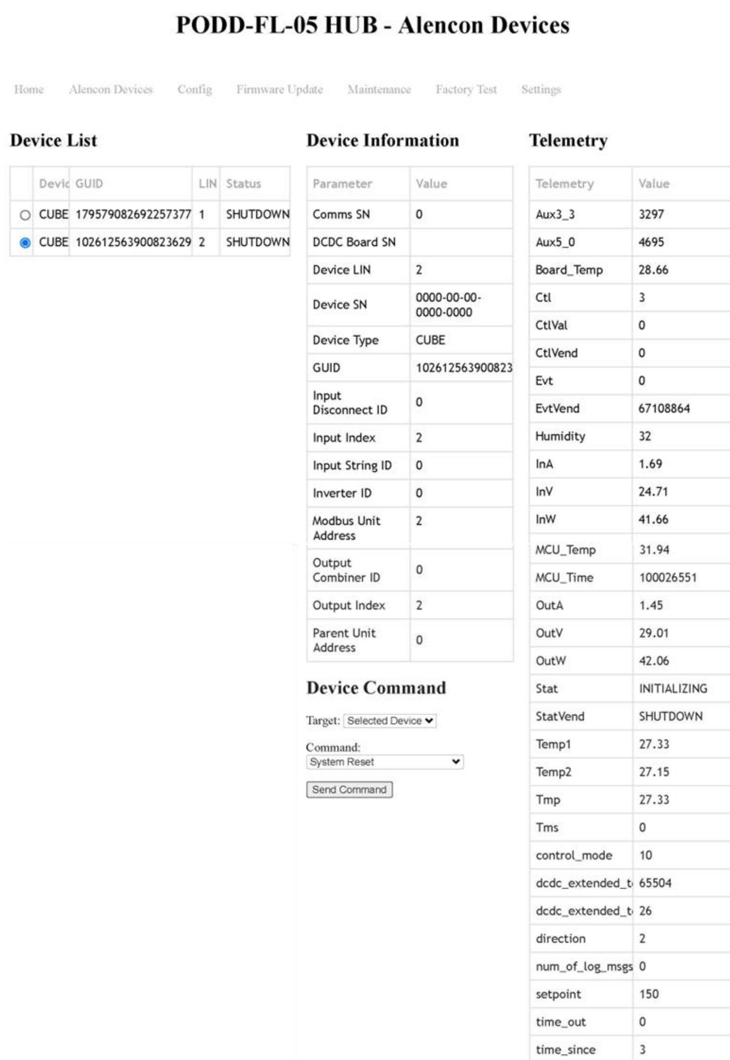


FIGURE 28: CUBE DEVICE TELEMETRY ON THE PODD UI

14 Maintenance and Servicing

14.1 General Maintenance

The CUBE is designed to require minimal maintenance. The firmware controls are designed to protect from overcurrent, overvoltage, undervoltage and overheating. Operational data is recorded and available to the customer via the PODD (see Section 13 – CUBE Communication).

If the CUBE is not operating as expected, attempt the following basic troubleshooting methods to regain proper operation:

- Check primary and secondary power sources for proper function.
- Check any fuses for continuity. If any fuses are blown, CUBE should be turned off (Section 11.2), fuse replaced and then CUBE can be turned back on (Section 11.1)
- Use the controller to send a **Shutdown** command, followed by a **System Reset** command, give the CUBE a few minutes to restart power conversion.
- Use the primary disconnect switch to turn off and on the CUBE. If the CUBE has an external 24V connection, that can be used to power cycle and reboot the device.

If CUBE still does not operate as expected, please contact Alencon Systems technical support for assistance with troubleshooting (see Appendix C).

14.2 Replacement of the air filter

The intake air filter is located directly behind the louvered back panel. The panel should be removed every two months and filter checked for dust penetration. If necessary, replace with suitable 19.875" x 22.5" x ½" thick Reusable metal Merv 4 panel filter.

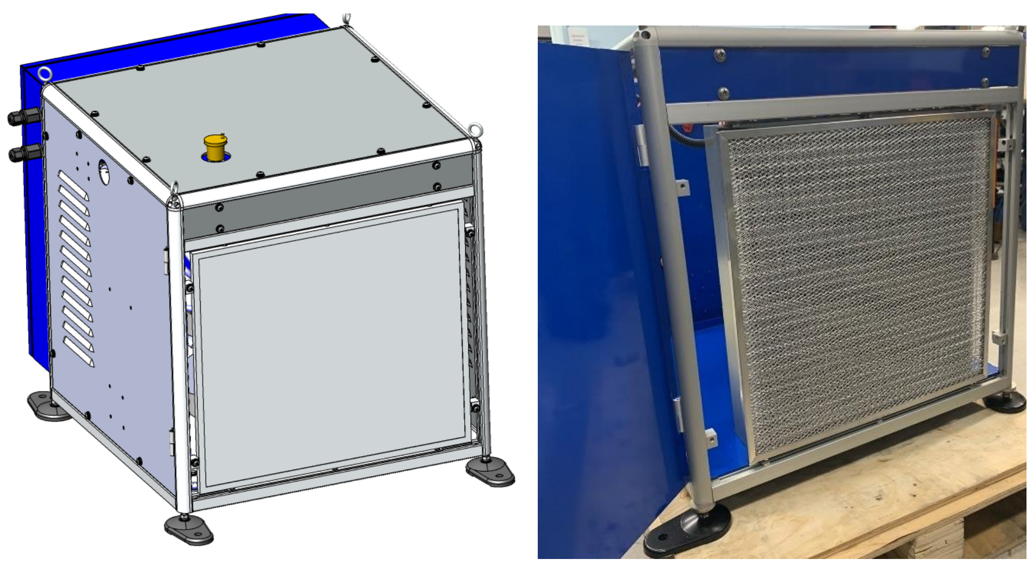


FIGURE 29: CUBE FILTER REPLACEMENT

14.3 Replacement of Deionized water filter

The deionized water filter is mounted on the swing away CUBE side panel. It is recommended to replace this filter after six months of operation. An Intelifil (IF-SM-DI010) 9.75" x 2.75" Mixed Bed DI Lowers TDS Filter or equivalent should be used.

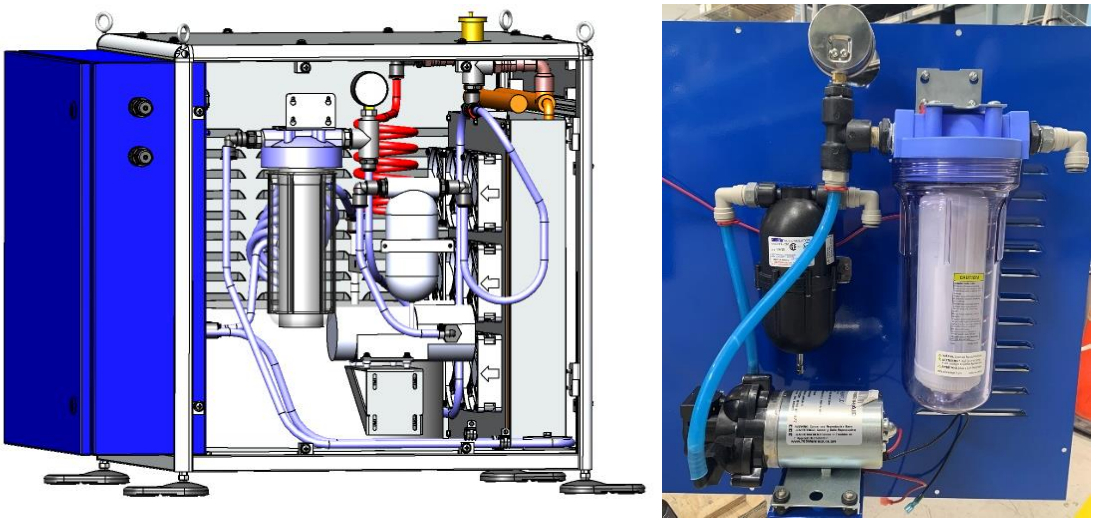


FIGURE 30: DEIONIZED WATER FILTER

14.4 Refilling the Coolant

⚠ Make sure the CUBE is disconnected from high voltage on both primary and secondary before refilling the coolant.

You can refill the coolant by connecting a hose with a tank full of deionized water. To do so, open the drain valve at the bottom of the CUBE and start the pump motor by connecting to an external 24-volt power supply.

Air in the system will build-up in the top of the water filter, the red button can be used to open the bleeder valve and release that air build-up. Allow the filter to fill to the top without overflowing before releasing the bleeder valve. After a couple minutes with the pump on air will build-up again at the filter.

The process of release and build-up should be repeated a few times to ensure the air is evacuated completely. A flashlight can be used to look for any remaining air bubbles in the opaque blue tubing.

14.5 Further Service and Repair

If the CUBE requires further servicing, disconnect it following the turn off procedure (Section 11.2) and contact Alencon Systems technical support, to assist with troubleshooting. The damaged CUBE may need to be returned to Alencon Systems or an authorized Alencon service agent.

Appendix A - Safety Precautions

A.1 Degree of Danger Symbols

	Warning!	*Warnings indicate conditions, which if not observed, can cause personal injury!*
	Caution!	*Cautions are included to help you avoid damaging hardware or losing data.*
	Note!	*Notes provide optional additional information.*

A.2 Electrical hazards

A.2.1 Electric shock from live voltage

High voltages are present at the equipment and its components. Some maintenance work must be done when voltage is present. Failure to adhere to the safety messages may lead to severe or lethal injuries due to electric shock. To avoid electric shock from live voltage:

- Wear class 2 personal protective equipment.
- Always perform work in compliance with the regulations specified in 29 CFR, Chapter XVII, Part 1910 (OSHA), NEC, and NFPA 70E.
- Do not touch any live components of the equipment or the medium-voltage grid.
- Follow all instructions precisely.
- Observe safety messages.
- Before performing any work on the equipment, always disconnect the equipment if voltage is not
- absolutely necessary.
- After disconnecting the equipment, wait at least 10 minutes for the equipment's capacitors to discharge completely.
- Before performing work on the equipment, ensure that no voltage is present (with a Voltmeter or other measuring instrument).

A.2.2 Danger due to Battery Voltage

CUBE may be connected to high voltage batteries on both primary and secondary sides of the equipment. Before beginning to work on the CUBE, disconnect the power sources on both primary and secondary sides.

A.2.3 Electric shock caused by ground fault

If a ground fault occurs, plant sections that are supposedly grounded may in fact be live. Failure to adhere to the safety messages may lead to severe or lethal injuries due to electric shock. To avoid electric shock from ground faults:

- Ensure that no voltage is present before touching any components.
- Wear class 2 personal protective equipment.

A.2.4 Electric shock due to damaged equipment

Operating damaged equipment can lead to hazardous situations that may result in serious or lethal injuries caused by electric shock. To avoid electric shock from damaged equipment:

- Only operate the equipment if it is in safe and technically faultless working order.
- Only operate the equipment if there is no visible damage.
- Regularly check the equipment for visible damage.
- Make sure that all external safety equipment is always freely accessible.
- Make sure that all safety equipment is in good working order.

A.3 Environmental hazards

A.3.1 Danger to life due to blocked escape routes

In hazardous situations, blocked escape routes can lead to serious injury or death. To avoid harm from blocked escape routes:

- An escape route of at least 3 ft. (915 mm) wide must always be available.
- Do not place any objects in the escape route area.
- Remove all tripping hazards from the escape routes.

A.3.2 Damage to the equipment caused by dust or moisture penetration

⚠ Dust intrusion or moisture penetration can damage and impair the functionality of the equipment. To avoid damage from dust or moisture penetration:

- Do not open the equipment when it is raining or when humidity exceeds 95%.
- Perform maintenance on the CUBE only when the environment is dry and free of dust
- Always close the electrical compartment door before energizing the CUBE.

A.3.3 Danger to life due to electric shock when the equipment is unlocked

Unlocked equipment can be opened by unauthorized persons. This means that unauthorized persons have access to components on which lethal voltages are present. To avoid danger from unlocked equipment:

- Ensure that unauthorized persons have no access to the equipment.
- Always lock the equipment
- Keep the electrical bus channel covered

Appendix B – Glossary

Word(s)/Acronyms	Definition
ACE	Alencon Communication Environment – a communication system containing hardware and software elements provided by Alencon to control power conversion equipment.
ALS	ALENCON Systems, LLC
BOSS	Bidirectional Optimizer for Storage Systems
BOSS-BOX	Container with (1) to (4) BOSS units and Junction Box
CUBE	Compact Universal Bi-directional Efficient DCDC Converter
DC	Direct Current
ESD	Electrostatic Discharge
ESS	Energy Storage System
FEED	Fused Electrical Disconnect
GARD	Ground and Arc fault Rapid Disconnect
GFDI	Ground-Fault Detection
GND	System Ground Potential
HV / LV	High Voltage / Low Voltage
IP	Internet Protocol
LD	Leak Detector
PODD	Point of Data Distribution
RTU	Remote Terminal Unit. Microprocessor controlled electronic protocol to exchange data with other devices
SCADA	Supervisory Control and Data Acquisition system. Performed by transmitting telemetry data to a master system and by using messages from the master supervisory system to control connected objects

SPOT	String Power Optimizer and Transmitter
SPOT-BOX	Container with (1) to (4) SPOT units and Junction Box
UI	User Interface

Appendix C – Technical Support and Assistance

Visit the Alencon Systems web site at www.alenconsystems.com where you can find the latest information about the product. Contact your distributor, sales representative, or Alencon Systems' technical support if you need additional assistance. Please have the following information ready before you call:

- Product name, serial number, and LIN (all can be located on the product label)
- Description of your peripheral attachments including fusing and cables

For technical support please email: support@alenconsystems.com or call **+1 (215) 816-3366**