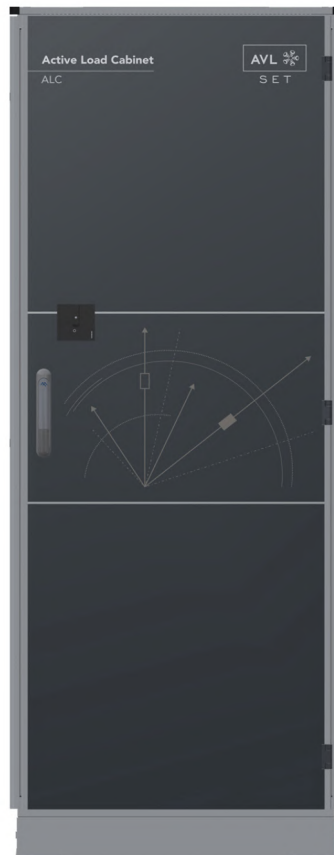




E 07 - 03/2026

PRODUCT GUIDE

Active Load Cabinet ALC

Hardware: ALC_v3.2, Software: 5R3.0



Mess- und Prüftechnik. Die Experten.

**Ihr Ansprechpartner /
Your Partner:**

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1 Warnings and safety instructions

This handbook contains important warning and safety notes that must be observed by the user.

The product has been designed exclusively for the specific purpose defined in the instructions for use. No warranty nor liability will be assumed for any applications outside of the described purpose nor for any disregarding of the required prerequisites and safety measures.

1.1 User note

This manual must be read carefully before use and kept for future reference.

Activities of any kind (operation/maintenance/repair etc.) may only be carried out by qualified electricians or instructed personnel. Ensure that all operating and service personnel have read the operating and safety instructions before commissioning. Instruction by qualified personnel is absolutely necessary, as work is carried out with life-threatening voltages. It is also pointed out that the installed system is a laboratory version which follows the IEC 61010-1 standard.

This manual is intended for specialized personnel who develop and test controls for electric motors. Specialized knowledge in the field of electrical drives and measurement technology is required.

The manual covers the project-specific scope of functions.

1.2 Intended use

The product may only be set up in accordance with the required performance and scope of delivery and operated in the configuration described in this manual. The product may only be used for testing suitable inverter control units.

The supplied software is part of the product and may only be modified with the consent of AVL SET GmbH. Any use beyond this is not in accordance with the intended purpose. AVL SET GmbH is not liable for damages resulting from misuse or improper handling.

The product is designed for use in industrial development departments and may only be operated in clean and dry rooms. Modifications or extensions are only permitted with the consent of AVL SET GmbH.

The product is designed for stationary installation. The electrical connections for the operating voltages, intermediate circuit voltages and phase voltages may only be connected by qualified electricians or persons trained in electrical engineering.

A safety briefing and training of the operators by AVL SET GmbH is mandatory before starting the test activity. Telephone support cannot be seen as a substitute for safety instruction and/or training.

The test stand may only be operated after verification of compliance with all requirements and safety precautions. The management and supervision of the product is the responsibility of the qualified electrician. At appropriate intervals, this person has to make sure that the instructions given are being observed and that work is being carried out in accordance with safety requirements. In this respect, the electrician is responsible for the assigned activities. AVL SET GmbH does not assume any warranty or liability if requirements and safety precautions have not been checked.

1.3 Electrical safety rules

Do not work on live parts. Therefore, a de-energized state must be established before starting setup, installation, commissioning, or maintenance work and must be ensured for the duration of the work. This is done by applying the five electrical safety rules. These safety rules must be carried out correctly and in the correct sequence to achieve the desired protective effect. The following safety rules must be observed:

1. Disconnect from mains
2. Secure against restarting
3. Ensure absence of voltage
4. Grounding and shorting

5. Cover and isolate nearby voltage-carrying parts

1.4 Danger to life due to high voltages and currents

DANGER



The product is operated with high voltages and currents. Operation is only permitted in fault-free operating condition. Special precautions must be taken during commissioning and maintenance work. The five electrical safety rules must be observed during maintenance work.

High voltages (here: high-voltage range AC up to 1000 V / DC up to 1000 V) can occur throughout the interior and on the supply lines and connections.

The present electrical hazards can lead to accidents and injuries or even death. Hazards are caused by:

1. Electrical body flow
2. Arc exposure
3. Secondary accidents

DANGER



1. Before working on the product measure the DC link voltage at the DC terminals.
2. Only when the DC link voltage has dropped below 60 V may work be performed on the product
3. The control circuit (for power supply units, sockets, etc.) remains under voltage even after it has been switched off or the emergency stop button has been pressed.
4. Do not touch any metallic parts until the absence of voltage has been confirmed by measurement.
5. Unused electrical cables must always be removed.

DANGER



The use of high currents and large inductances generates strong electromagnetic fields. There is a health hazard for wearers of pacemakers and other active or passive body aids.

1.5 Surface temperature

CAUTION



When opening control cabinets, it should be noted that increased surface temperature is to be expected inside.



- ▶ While operation and before starting maintenance work, it is essential to check the temperature. This applies in particular to connections of the cooling water system and the electrical power path.

1.6 Hot water in the cooling system

DANGER



Danger of scalding!

The coolant may be hot and under pressure.



1. Do not open any hoses or connections.
2. The product must cool down for at least 30 minutes after operation. Observe the product-specific technical description of the cooling system.
3. Do not remove the hoses until they have cooled down.

1.7 Additives in the coolant

The coolant is provided with an anti-corrosion agent.

- The product-specific safety instructions must be observed.
- The product-specific technical description must be observed.

1.8 Grounding

The product must be connected to the protective earth or to a potential equalization bar. Removing protective earth connections inside or outside the cabinets is not permitted.

1.9 Protective earth

The protective earth must be protected against mechanical damage.

1.10 Procedure in case of malfunctions

The product must be taken out of operation and secured against unauthorized restarting in the following cases:

- Cabinets, components or cables are visibly damaged.
- Grounding cables are disconnected or damaged.
- Components inside are loose.
- The product does not operate without malfunctions and error messages are output.
- Coolant leaks.

1.11 Occupational safety

During assembly and installation, the regulations of the employers' liability insurance association and the relevant company regulations must be observed.

- Use appropriate lifting and hoisting devices

Precautionary measures must be taken to prevent hazards and keep the operators healthy. The applicable occupational health and safety laws and company guidelines must be communicated and observed. Depending on the activity, appropriate protective clothing must be worn. This includes the following minimum equipment:

- Safety shoes during transport, assembly and installation
- Protective gloves during transport, assembly and installation

Forgotten tools can lead to serious short circuits during operation and destruction.

- Before commissioning, especially after maintenance work, make sure that no tools have been forgotten in the control cabinet.

WARNING



Increased noise level

Hearing protection must be worn if the noise level exceeds the company-specific and/or legally defined limits. Due to varying environmental conditions (e.g., sound insulation of the test cell, the test specimen, or the selected test procedures), it is not possible to make universally valid statements about the noise level in the operating area.



1.12 Transport

The product is shipped from the factory in sealed transport boxes. Transport may only be carried out using suitable transport vehicles. Unsuitable transport vehicles can lead to injuries and damage.

Suitable transport vehicles are all industrial trucks. The product may only be lifted from below.

1.13 Warranty seal

For safety reasons, certain components are provided with a seal that may only be broken by AVL SET personnel. Any unauthorized damage to the seal is considered an unauthorized modification, which will void the warranty provided by AVL SET.

1.14 Residual risks

DANGER



Danger due to moisture

The product must not be exposed to rain or permanent moisture. Should an object or liquid get inside, disconnect the product from the power supply and have it checked by a specialist before you continue to use it.

DANGER



Explosion hazard

The product must not be operated in potentially explosive environments.

2 Product description

The Active Load Cabinet (ALC) is an active load for functional HV tests of inverters (Unit Under Test, UUT). The focus here is on load tests for running individual predefined operating points with both reactive and active power. The ALC thus enables comprehensive validation of the hardware development process for inverters. In addition, the ALC can also be used to carry out an extended function tests on selected samples.

For the operation of the ALC, a water/water heat exchanger as well as a UUT conditioning are also required.

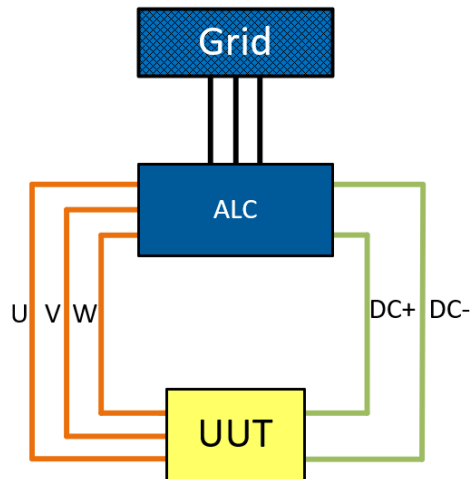


Fig. 1: Characterization of the Active Load Cabinet

2.1 Product design and interfaces

The product is designed as a cabinet and contains the following functional units.

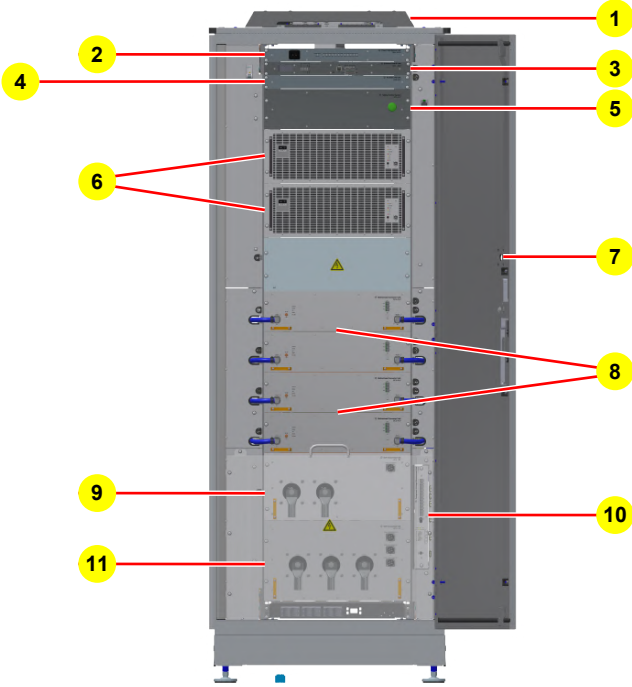


Fig. 2: Active Load Cabinet

Legend for figure:

- | | | | |
|----|---------------------------------|----|--|
| 1 | Signal interface | 2 | Power Distribution Unit (PDU) 24 V |
| 3 | Cabinet Control Unit (CCU) | 4 | Auxiliary I/O Unit (AXU) |
| 5 | Safety Control System (SCS) | 6 | High-voltage power supply |
| 7 | Main switch | 8 | Active Load Unit (ALU) |
| 9 | UUT Connection Unit DC (UCU-DC) | 10 | Comparator Voltage Measurement Unit (CVMU) |
| 11 | UUT Connection Unit AC (UCU-AC) | | |

2.1.1 Signal interface

The signal interface is located on the roof of the cabinet.

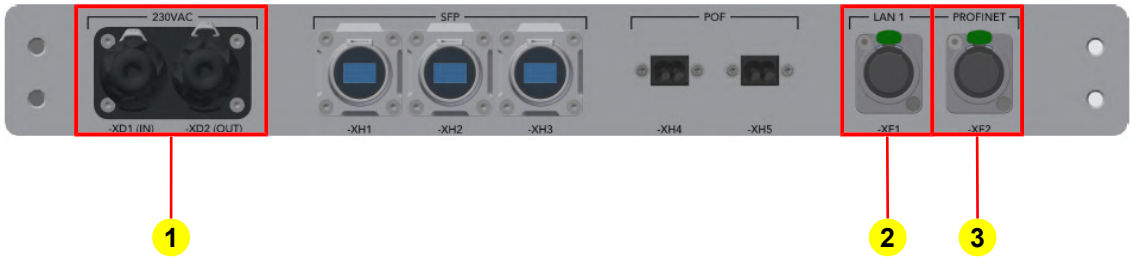


Fig. 3: Signal interface

Legend for figure:

- | | | | |
|---|------------------|---|-------------------|
| 1 | Auxiliary supply | 2 | Automation system |
|---|------------------|---|-------------------|

Legend for figure: (Continued)

3 Safety system

2.1.1.1 Auxiliary supply

A signal interface is installed on the roof of the ALC, which serves as a connection area for the auxiliary supply.



Fig. 4: Auxiliary supply

The auxiliary supply of the ALC is realized by a NAC3PX-TOP connector.

Interface	Description	Connector type
XD1	230 V _{AC} Auxiliary supply input	NAC3FXW
XD2	230 V _{AC} Auxiliary supply output	NAC3MXW

The required specification of the connection on the customer side for the auxiliary supply of the ALC is described below.

Description	Value
AC voltage in V _{AC1PE/N}	220 - 240
Frequency in Hz	50 ... 60
AC current in A	16
AC power in kW	3.7

2.1.1.2 Rotor Position Emulation

The Rotor Position Emulation (RPE) can be connected to the ALC. The connection is located at the signal interface on the roof of the ALC.



Fig. 5: Rotor Position Emulation

The connection to the Rotor Position Emulator is made via a LC-LC plug.

Interface	Description	Connection Type
XH1	Rotor Position Emulation	LC-LC

2.1.1.3 Automation system

The connection for the automation system is located in the signal interface on the roof of the ALC.



Fig. 6: Automation system

The ALC can receive setpoint specifications from the higher-level automation system. The available parameters and their limits can be found in the software interface description5R3.0

The automation system is connected using an RJ45 connector.

Interface	Description	Connector type	Communication protocol
XF1	Automation system	RJ45	Ethernet

2.1.1.4 Safety system

The connection for the safety system is also located in the signal interface on the roof of the ALC.



Fig. 7: Safety system

This is a field bus that can be integrated into a higher-level security system.

Interface	Description	Connection type	Communication protocol
XF2	Safety system	RJ45	Profinet

2.1.2 Power Distribution Unit 24-12

The Power Distribution Unit (PDU) generates the mandatory auxiliary supply voltages for the internal supply of the cabinet components. Via the main switch, the product can be disconnected from the 1-phase mains. The LED lights show the status of the supplies.



Fig. 8: PDU 24-12

Interface	Function
Switch Power ON	Activates and deactivates the PDU (generation of the auxiliary voltages) Lights if PDU is active
LED „Power Supply Active“	Lights if PDU is active Does not light in case of error
LED's „24 V Active“ Ch1 ... Ch12	Lights if channel is active Does not light in case of error (per channel)

Tab. 1: PDU 24-12 Interfaces

The main switch of the PDU is accessible when the front door is opened.

2.1.3 Cabinet Control Unit

The Cabinet Control Unit (CCU) contains the central FPGA platform. Furthermore, external components such as the emulation of the rotor position sensor are connected here.

The FPGA platform fulfills the following functions:

- Calculation of the setpoint for every BCU
- Evaluation of the internal measurement technology
- Control of the rotor position sensor emulation

In the ALC the CCU is used 1 time.

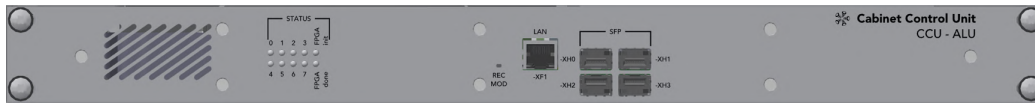


Fig. 9: Cabinet Control Unit

The interfaces of the CCU are described below.

Interfaces	Function
Status LED's 0 ... 7	Lights circumferential in green: CCU active Lights circumferential in red: BCU active
Status LED's FPGA	Init: Voltage applied to FPGA Done: FPGA ist programmiert
LAN-XF1	Ethernet connection (RJ45 socket, 1 Gbit): Plant control via TCP/IP-Protocol
SFP-XH0	Not used
SFP-XH1	Not used
SFP-XH2	Not used
SFP-XH3	Not used

Tab. 2: Interfaces CCU

2.1.4 Safety Control System

The SCS ensures safe operation. The integrated fieldbus can be coupled with a higher-level safety system (test bench protection).



Fig. 10: SCS

The SCS fulfills the following functions:

- Communication via Profinet between SCS and higher-level safety system
- Control and monitoring of the switch-on and switch-off procedure
- Safety functions including emergency shutdown
- Control of the safety-related AC contactors, safety-related reading of the safety-related voltage measurement and the insulation monitors

2.1.5 Auxiliary I/O Unit

The Auxiliary I/O Unit (AXU) provides digital and analog inputs and outputs for internal product communication.

The AXU communicates with the CCU via POF.

The AXU module is supplied with 24 V via the PDU.

The AXU fulfills the following functions:

- Control and monitoring of the installed high-voltage power supply unit
- Controlled discharge of DC link
- Control and monitoring of the DC contactors
- Reading out the flow sensor, temperature sensor and leakage sensor

2.1.6 High-voltage power supply

Both the UUT and the Active Load Units of the ALC are supplied with the unidirectional high-voltage power supply unit of the product. Thereby, a EA-PU-11000-80-4U with an output of 30 kW is installed.

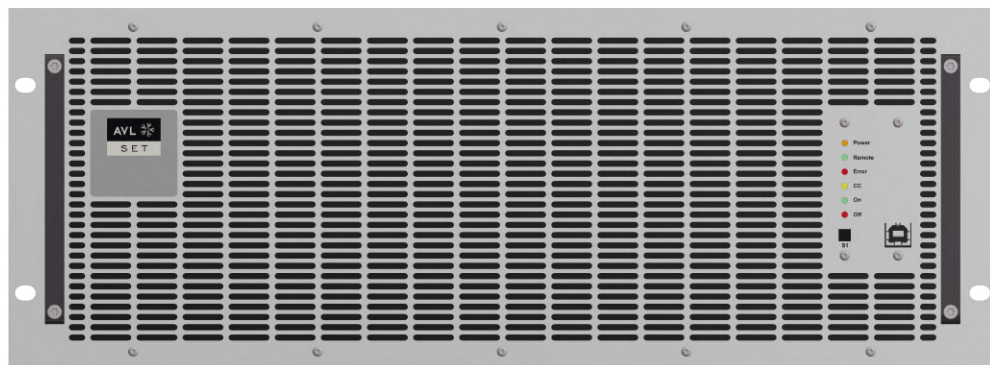


Fig. 11: High-voltage power supply

2.1.7 Active Load Unit

The Active Load Unit (ALU) consists of two components: Bidirectional Converter Unit (BCU) and Choke Unit.

The BCU is the key component of the ALU. The BCU is water-cooled, the flow is on the left (XL1), the return on the right (XL2). The communication is via the "SFP" interface to the CCU. The 24V supply is provided by the PDU.

The number of BCUs installed depends on the configuration of the ALC. In the configuration with 3 phases and 280 A_{RMS} the BCU is required twice. In the configuration with 3 phases and 560 A_{RMS} the BCU is required 4 times.

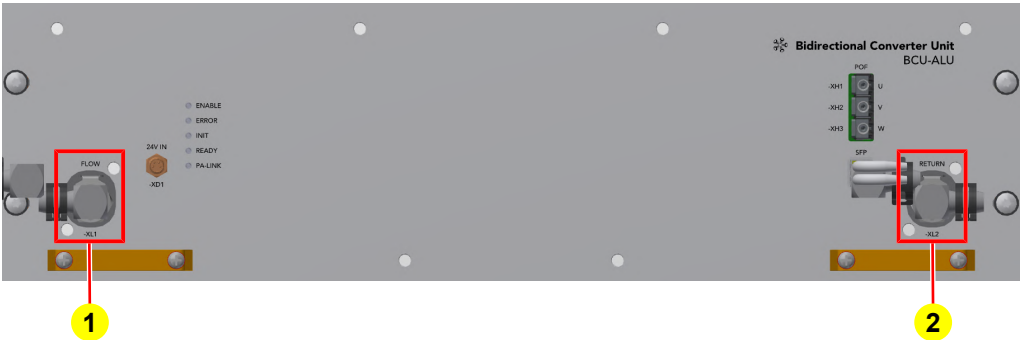


Fig. 12: Bidirectional Converter Unit

Legend for figure:

- 1 Flow
- 2 Return

The interfaces of the BCU are described below.

Interface	Function
POF-XH1	POF Port IN: Fibre optic cable for the connection from the C-VMU (phase U)
POF-XH2	POF Port IN: Fibre optic cable for the connection from the C-VMU (phase V)
POF-XH3	POF Port IN: Fibre optic cable for the connection from the C-VMU (phase W)
SFP-XH4	SFP Port IN: Fibre optic cable for the connection of the CCU

Tab. 3: Interfaces BCU

The current operating status is displayed for each BCU via the LED lights.

LED	Color	Functionality
Enable	Yellow LED off	BCU active BCU not active
Error	Red Blue Magenta Green	Sum error Software not configured Sum error and software not configured Software configured

Tab. 4: BCU LED lights

LED	Color	Functionality
Init	Red	FPGA configuration error
	Green	FPGA configuration error-free
Ready	Red	FPGA error
	Green	FPGA error-free
PA-Link	Red	Communication error
	Green	Communication error-free

Tab. 4: BCU LED lights (Continued)

The inductors required for the phases of the BCU are installed in the Choke Unit. The Choke Unit has a connection area for the DC input of the BCU and an output for the phases. An NTC temperature sensor is installed in the Choke Unit. This is connected to the AXU using an M8 sensor cable (4-pin).

Two BCUs can be connected to each choke unit.

2.1.8 UUT Connection Unit DC

The UUT Connection Unit DC (UCU-DC) is located on the front of the ALC. This acts as an interface to the UUT and provides a connection area for the DC supply of the UUT.

The power cables are fastened via:

- M10 x 20
- Tightening torque: 35 Nm

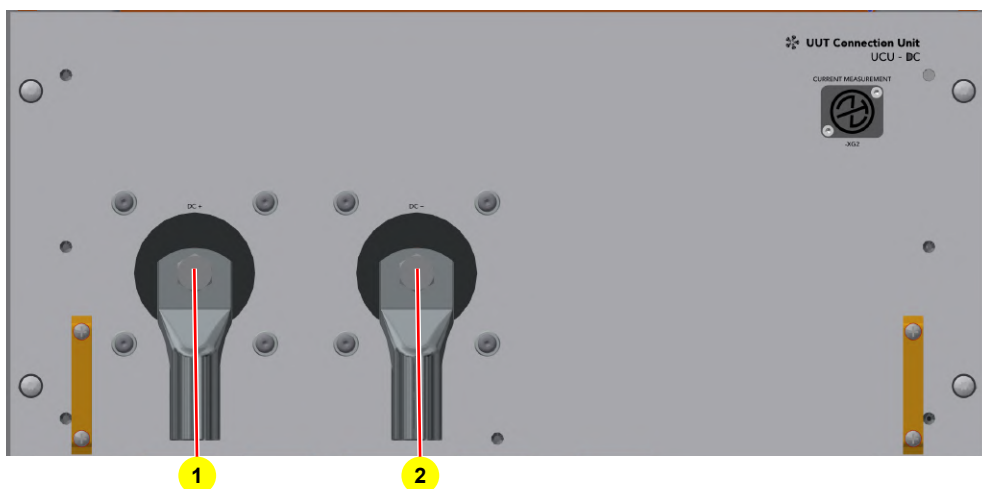


Fig. 13: UUT Connection Unit DC

Legend for figure:

1 Connection DC+

2 Connection DC-

The connection cables can be routed downwards out of the cabinet. To prevent touching the connections during operation, there is a touch guard (UCU-DC and UCU-AC). The door of the cabinet can be closed during operation.

2.1.9 Comparator Voltage Measurement Unit

The Comparator Voltage Measurement Unit enables high-speed signal acquisition and communication with both the CCU and the BCU. The phase connection is located on the back of the voltage measurement unit.

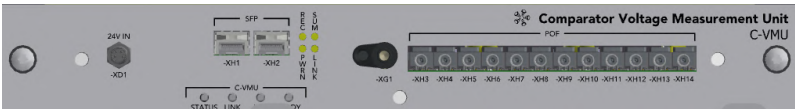


Fig. 14: Comparator Voltage Measurement Unit

The interfaces of the CVMU are described below.

Interface	Funktion
SFP-XH1	SFP Port IN: Fibre optic cable from the CCU
SFP-XH2	Not used
POF-XH3 ... POF-XH6	POF Port OUT: Fibre optic cable for connection to one BCU each (phase W)
POF-XH7 ... POF-XH10	POF Port OUT: Fibre optic cable for connection to one BCU each (phase V)
POF-XH11 ... POF-XH14	POF Port OUT: Fibre optic cable for connection to one BCU each (phase U)
XG1	4 mm laboratory socket OUT: DC potential at UCU DC-

Tab. 5: Interfaces CVMU

2.1.10 UUT Connection Unit AC

The UUT Connection Unit (UCU-AC) serves as an interface for the AC phases U, V and W of the UUT.

The power cables are fastened via:

- M10 x 20
- Tightening torque: 35 Nm

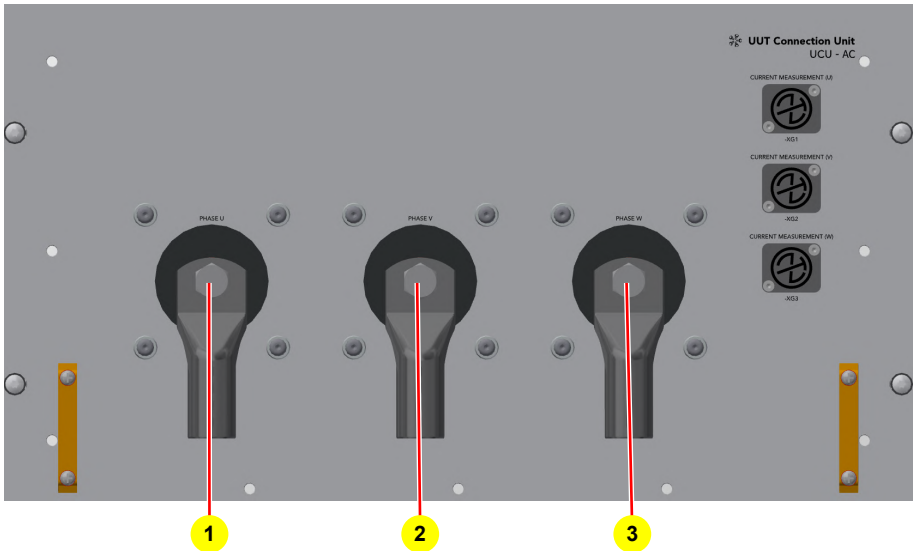


Fig. 15: UUT Connection Unit AC

Legend for figure:

- 1

AC-Connection phase U
- 2

AC-Connection phase V
- 3

AC-Connection phase W

2.1.11 High-voltage power supply

The high-voltage power supply of the ALC is located inside the cabinet. For this purpose, the three phases L1, L2 and L3 and PE are each attached with an M8 cable lug. The C-rail attached below serves as strain relief for the high-voltage cables.

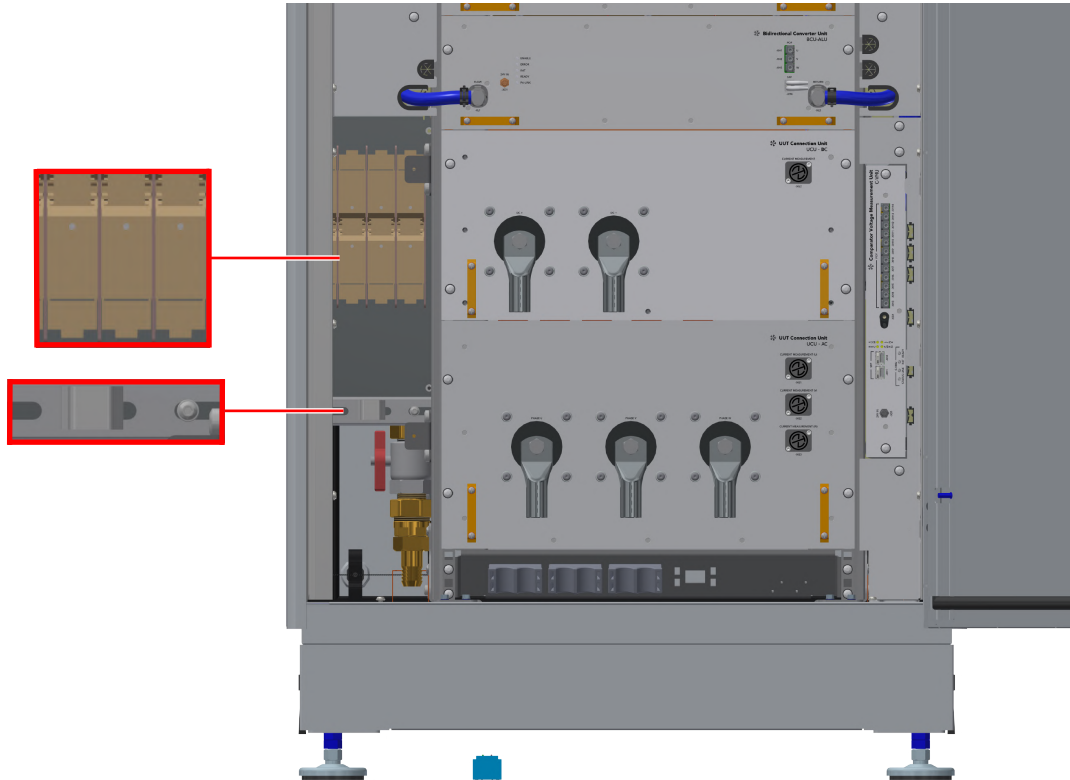


Fig. 16: High-voltage power supply

The required specification of the connection on the customer side for the high-voltage power supply is described below.

Description	Value
AC Voltage in V_{AC3PH}	380 ... 480 +/- 10%
Frequency in Hz	45 ... 65
AC Current in A	64
AC Power in kW	Depending on the number of high-voltage power supply units installed in the ALC 1 high-voltage power supply unit: 30 kW 2 high-voltage power supply unit 60 kW

2.1.12 Cooling water connection

The ALU of the ALC must be cooled. For this purpose, the ALC has connections for a cooling unit inside the cabinet.

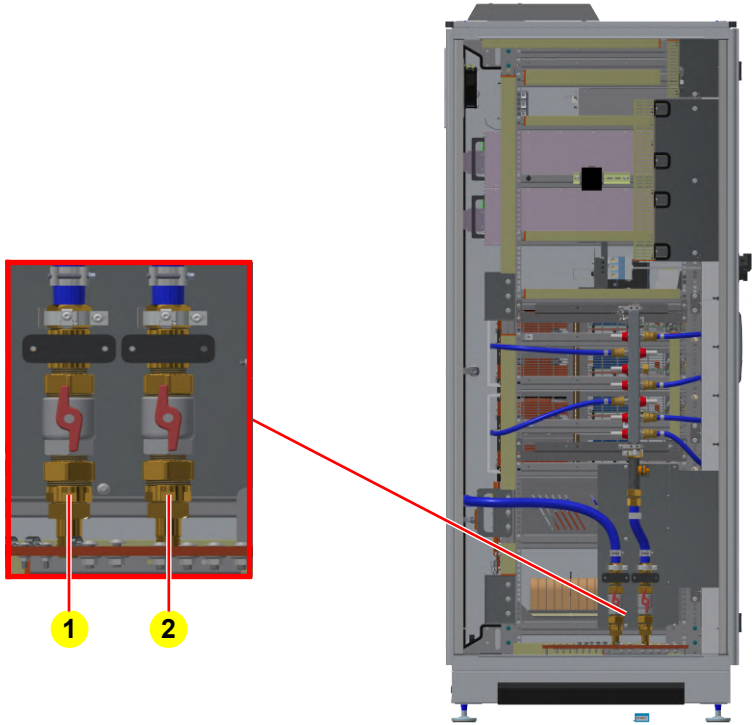


Fig. 17: Water connection

Legend for figure:

- 1 Return
- 2 Flow

No cooling unit is integrated in the ALC. For this reason, a cooling unit is required on the customer side. This cooling unit must meet the following requirements.

Connections	1 x Flow, 1 x Return Hose nozzle with union nut 1" flat sealing Each with shut-off valve
Nominal operating pressure in bar	3
Maximum operating pressure in bar	4
Nominal flow rate in l/min	24
Coolant	Mixture of 25% Innovatek Protect IP and 75% distilled water
Flow temperature customer house water via heat exchanger in °C	18 ... 25

2.1.13 Fan fuse

A fan is installed in the ALC. This fan has its own fuse, which is located on the front of the cabinet. The exact position of the fuse can be seen in the following figure.

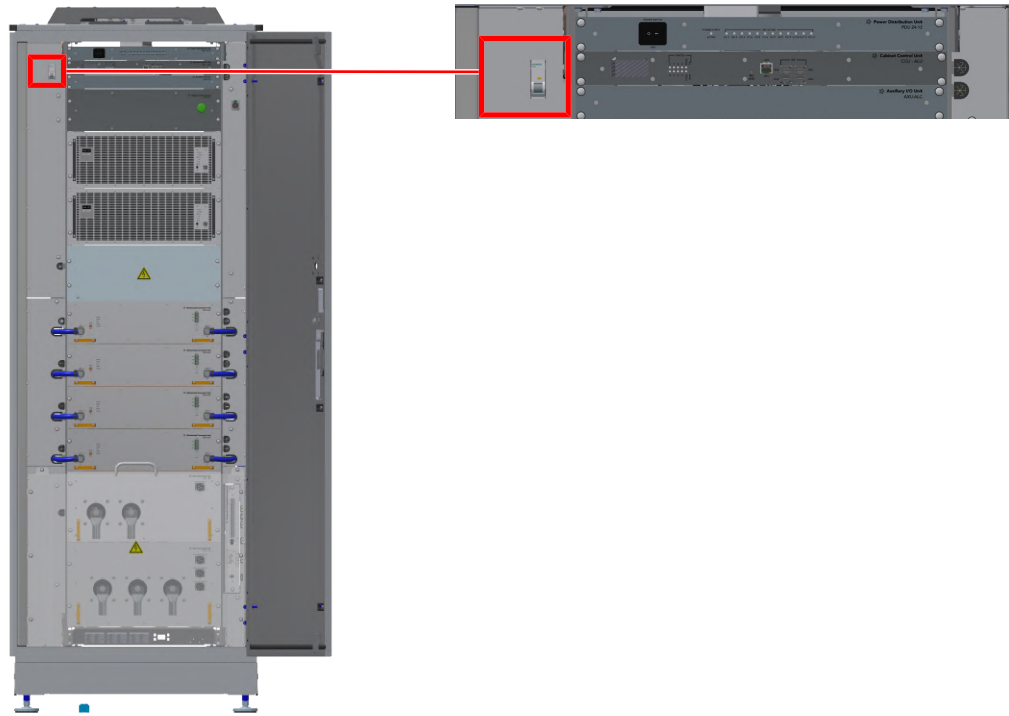


Fig. 18: Fan fuse

For replacement or maintenance, the fan must be deactivated via the fuse.

3 Operating mode

The ALC provides various operating modes, which are described below.

3.1 Selection of operating mode

The desired operating mode can only be selected in the states Off and Standby. The current state of the ALC can be displayed via the parameter "*ESC state index*". The states are described in the following table. All possible states of the ALC are described in the separate software interface description 5R3.0 .

Value	Description
30	Off: The ALC is switched off and error-free. The safety release has not been issued and the UUT can be set up.
40	Standby: The safety release is issued and the HV supply can be activated.

The parameter „*operation mode*“ can be used to select the desired operating mode. The assignment of the parameter „*operation mode*“ is described in the following table.

Value	Operating mode
0	R-L-Mode
1	Bidirectional Calibrationmode
2	Unidirectional Calibrationmode
3	Active Discharge Testmode
4	Three-phase current source mode
5	Four-quadrant mode

3.2 R-L-Mode

In R-L-Mode, the ALC represents an R-L load, which consists of a resistor (R) and an inductance (L) connected in series. With the help of the components installed in the ALC and a mathematical model, the current that would flow at a real R-L load is emulated. Due to the emulated resistance, it is possible to load the UUT with both active and reactive power on the DC and AC side. This makes it possible to test the power electronics of the UUT under more realistic conditions. It should be noted that the power flow is limited exclusively to motor operation.

This mode can be used, for example, for a functional test of the UUT. It should be noted that additional equipment, such as an automation system, UUT mounting, cooling system, etc. may be required to perform the functional test.

To be able to use this mode, contactors K3 and K4 of the ALC must be closed. The contactors are switched automatically by selecting the operating mode.

The topology of the R-L-Mode is shown in the following diagram.

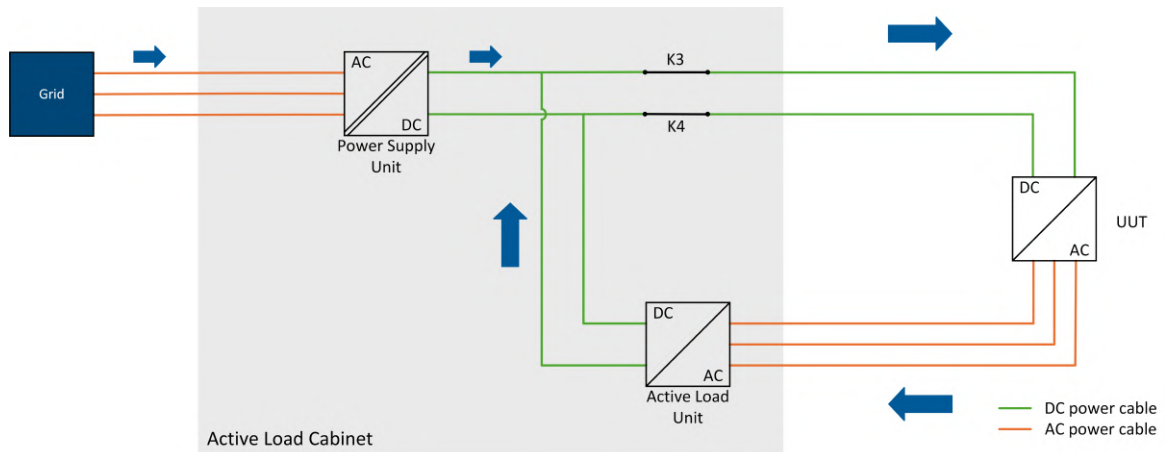


Fig. 19: Topology R-L-Mode

This mode is activated if the parameter „*operation mode*“ is set to the value 0 in the Off or Standby states.

The phase resistance R is parameterized via the parameter „*phase resistance R*“.

Parameter	Characterization	Unit	Min	Max
phase resistance R	Parameterization of the phase resistance R	mOhm	0	100,000

The phase inductance L is parameterized via the parameter „*phase inductance L*“.

Parameter	Characterization	Unit	Min	Max
phase inductance L	Parameterization of the phase inductance L	μH	50	1,000

3.3 One-phase current source mode

In calibration mode, the ALC functions as an adjustable current source. Within this mode, the ALC can generate a current space indicator with adjustable amplitude, frequency or phase position.

This mode can be used to calibrate the UUT internal AC current sensors. However, it should be noted that the measurement deviations of the sensors must be determined using external measuring equipment.

Within the one-phase current source mode, the ALC provides two different options: Unidirectional power source mode and the bidirectional power source mode. These two approaches differ in terms of the current flow.

3.3.1 Bidirectional Calibrationmode

In Bidirectional Calibrationmode, the ALC provides a DC current via any AC phase of the UUT (U, V or W). The injected current flows back to the ALC via another AC phase, closing the circuit.

To be able to use the Bidirectional Calibrationmode, the UUT must be in Active Short Circuit (AKS) Modus (high oder low).

The contactors K3 and K4 of the ALC must be open. The contactors are automatically switched accordingly by selecting the operating mode.

The available phase combinations are described in the following table.

Phase with current setpoint	Phase with negative current setpoint
U	V
V	W
W	U

An example current flow and the corresponding switch position of the ALC can be seen in the following illustration.

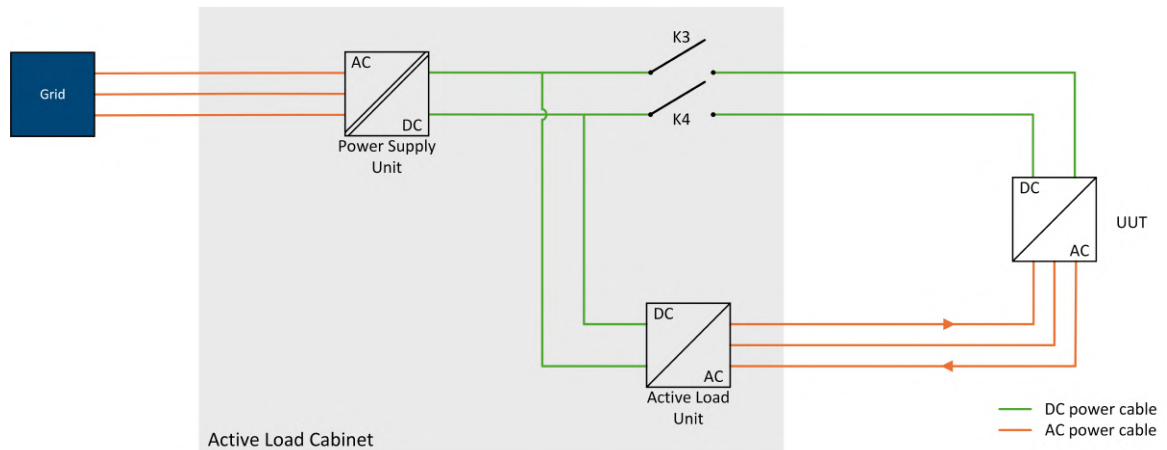


Fig. 20: Topology Bidirectional Calibrationmode

This mode is activated if the parameter „*operation mode*“ is set to the value 1 in the Off or Standby states.

The phase via which the desired current is to be injected and fed back is selected via the parameter „*select calibration phase*“.

The following table describes the assignment of the parameter „*select calibration phase*“.

Value	Phase with current setpoint	Phase with negative current setpoint
0	U	V
1	V	W
2	W	U

The current setpoint for the selected phase combination is parameterized via the parameter „*manual current amplitude*“.

Parameter	Characterization	Unit	Min	Max
manual current amplitude	Current setpoint for the selected phase combination	A	560	560

3.3.2 Unidirectional Calibrationmode

Within the Unidirectional Calibrationmode, the ALC provides a DC current and applies it to any AC phase of the UUT (U, V or W). The other two phases are regulated to 0 A. The AC phase via which the current is to be injected can be selected individually. The current is fed back to the ALC via the DC phase of the UUT, thus closing the circuit.

For a positive calibration current, the inverter must be in the ASC of the high-side and for a negative calibration current, the inverter must be in the ASC of the low-side.

The supply voltage is automatically set to 50 V in this operating mode.

To be able to use this mode, contactors K3 and K4 of the ALC must be closed. By selecting the operating mode, the contactors are switched automatically.

An example current flow and the appropriate position of the ALC contactors can be seen in the following illustration.

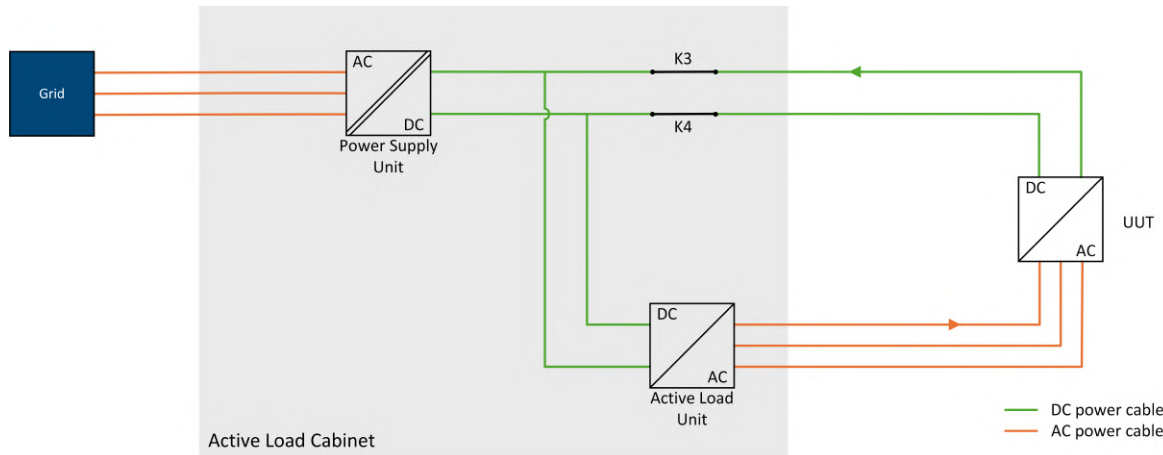


Fig. 21: Topology Unidirectional Calibrationmode

This mode is activated if the parameter „operation mode“ is set to the value 2 in the Off or Standby states.

The phase via which the desired current is to be injected and fed back is selected via the parameter „select calibration phase“.

The assignment of the parameter „select calibration phase“ is described in the following table.

Value	Phase with current setpoint	Phase with 0A current set-point
0	U	V, W
1	V	U, W
2	W	U, V

The current setpoint for the selected phases is parameterized via the parameter „manual current amplitude“.

Parameter	Characterization	Unit	Min	Max
manual current amplitude	Current setpoint for the selected phase	A	560	560

3.4 Active Discharge Testmode

This mode can be used to check the discharge capability of the UUT DC link.

The topology of the Active Discharge Testmode is shown in the following diagram.

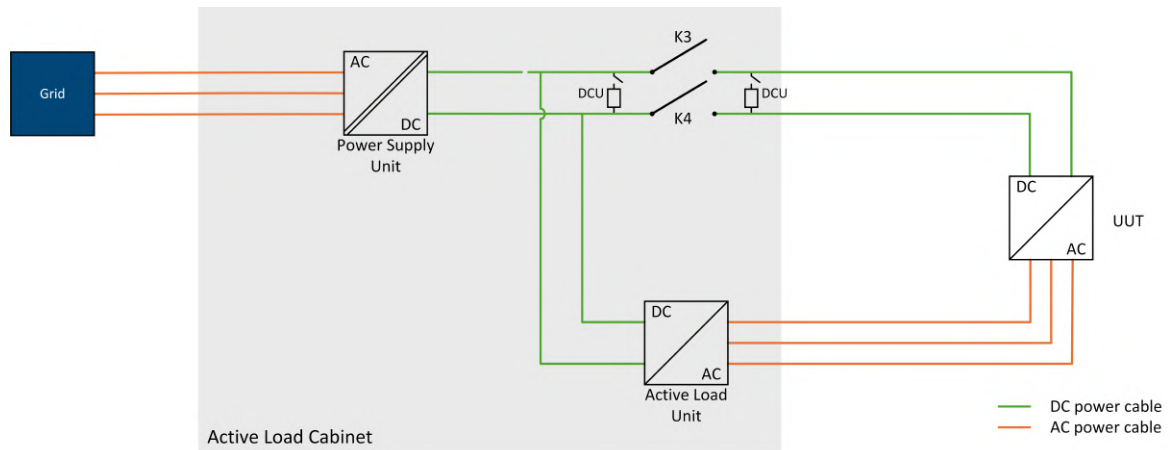


Fig. 22: Topology Active Discharge Testmode

Within this operating mode, contactors K3 and K4 can be switched via a parameter depending on the status of the ALC. Contactors K3 and K4 are combined under the parameter „*user manual contactor switching*“. To prevent the contactors from switching under load, they can only be switched in predefined states of the ALC. The possible switching states of the contactors, depending on the state of the ALC, are described in the following table.

	Off / Standby	Ready
K3 and K4	Can be opened and closed freely	Can only be opened

This mode is activated if the parameter „*operation mode*“ is set to the value 3 in the Off or Standby states.

The parameterization of this mode can be seen in the following table.

Parameter	Characterization	Unit	Min	Max
user manual contactor switching	Opening and closing contactors K3 and K4	-	0 (Close contactors)	1 (Open contactors)

3.5 Four-quadrant mode

In four-quadrant mode, a engine speed is set by the ALC. This can be positive or negative, so that forward and reverse operation is possible. Positive and negative torques can also be applied by the UUT regardless of the speed, so that all four quadrants in the torque/speed plane can be used. The ALC enables the testing of test points in all four quadrants. This leads to increased test coverage and more realistic tests.

To use this mode it is necessary that the contactor K3 and K4 are closed. The contactors are automatically closed by selecting the operating mode.

An example of the current flow and the appropriate position of the ALC contactors can be seen in the following illustration.

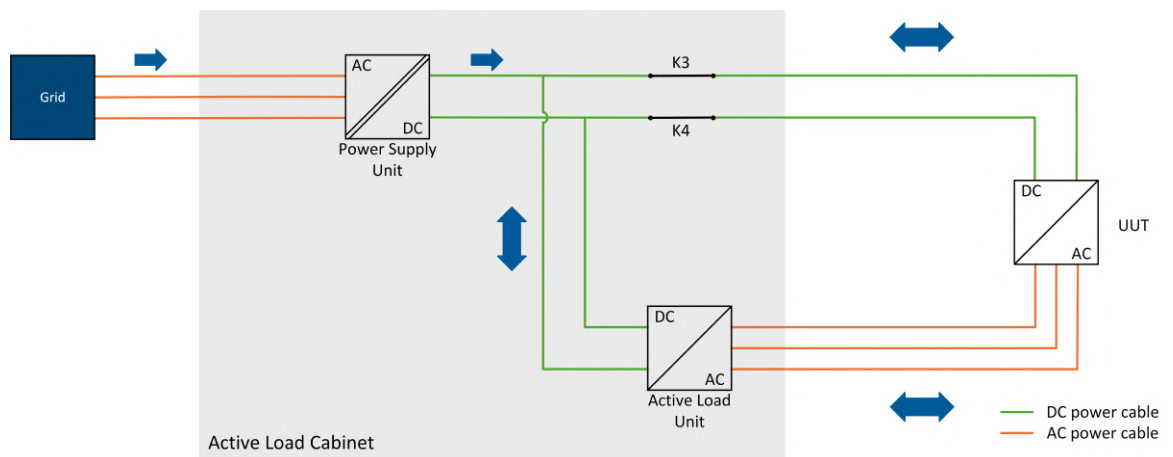


Fig. 23: Four-quadrant mode

To activate the mode, the “operation mode” parameter must be set to the value 5 in the OFF or Standby states.

The configuration of the Four-Quadrant Mode is done using the parameters listed in the following table.

Parameters	Characterization	Unit	Min.	Max.
Pole pairs	Number of pole pairs		1	256
Self-inductance L _{d_d}	Self-inductance of the d-axis	μH	50	1,000
Self-inductance L _{q_q}	Self-inductance of the q-axis	μH	50	1,000
Permanent magnet flux linkage psi _{PM}	Permanent magnet flux linkage	Vs	0	1
Stator phase resistance R _s	Stator phase resistance	mOhm	0	100,000

3.6 Three-phase Current Source

In three-phase current source mode, the ALC works as an adjustable current source. Within this mode, the ALC can imprint a symmetrical three-phase system with adjustable amplitude, frequency and phase position between current and voltage (corresponding to the power factor / cos phi) into the UUT. There are two different use cases here:

Standard Mode:

The ALC generates the phase angle itself. The angle information is transmitted to the UUT via rotor position emulation. For its part, the UUT must generate a phase-correct rotary voltage system based on the angle information provided.

Phase Reconstruction Feature:

The UUT generates the rotary voltage system itself. Based on the pulse width modulation of the UUT, the ALC reconstructs the phase position and imprints the desired current in the correct phase. This function enables initial prototypes of the hardware components to be tested, as only the basic software of the UUT is required and no detailed software is needed.

The block diagram below provides an example of how current flows in this mode.

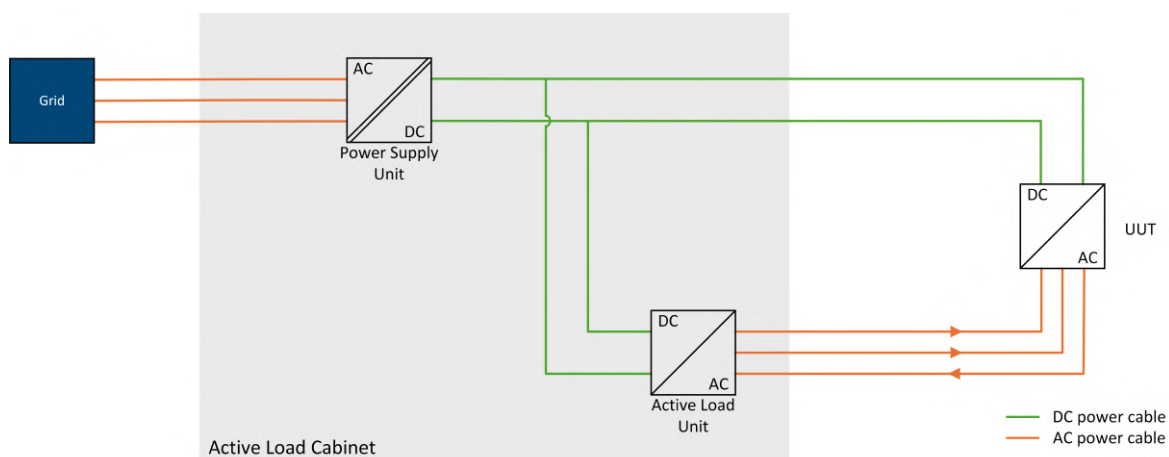


Fig. 24: Topology of the Three-phase Current Source

4 Technical data

4.1 General Nominal Data

Supply voltage, dimensions and weight	
Supply voltage ALC in V _{AC3PE}	380 ... 480 +/- 10%
Max. Power losses ALC + UUT in kW	30
Auxiliary supply voltage in V _{AC1PE/N}	220 ... 240
Frequency in Hz	45...65
Leakage current	>10
Footprint (W x D) in mm	798 x 969
Height, total in mm	2,217
Height plinth in mm	140
Weight in kg	up to 600
Protection class	IP54 (exception: IP00 from bottom)
Color (RAL)	7035
Noise level in dB(A)	Up to 85 @ 1m
Door hinge	Right
Door opening angle in °	180
Operating height max. above sea level in m	2,000
Installation site	Facility with limited access Installation on concrete or other non-flammable surfaces
Ambient temperature storage in °C	+5 ... +40
Ambient temperature transport in °C	-25 ... +60
Ambient temperature operation in °C	+5 ... +40
Relative humidity, max. in % ¹	20 ... 85, non-condensing

Tab. 6: Supply voltage, dimensions and weight

¹ Dewpoint table

Humidity/ Room temperature	20 %	25 %	30 %	35 %	40 %	45 %	50 %	55 %	60 %	65 %	70 %	75 %	80 %	85 %
22 °C														
23 °C														
24 °C														
25 °C														
26 °C														
27 °C														
28 °C														
29 °C														
30 °C														
32 °C														
34 °C														
36 °C														
38 °C														
40 °C														

*green: ideal operation conditions *grey: no operation recommended

Cooling system	
Connections	1x flow, 1x return Each with union nut 1" flat sealing with hose nozzle Each with shut-off valve
Operation pressure nominal in bar	3
Operation pressure max. in bar	4
Flow rate nominal in l/min	24
Coolant	Mixture of 25% Innovatek Protect IP and 75% distilled water
Flow temperature in °C	18 ... 25
Specification Water (for coolant):	
Carbonate hardness in °dH	< 4
Total hardness in °dH	< 15
pH value	7.5 ... 8.5

Tab. 7: Data cooling system

Phase emulation and power	
Number of emulated phases	3
Phase current (AC) nominal in A_{RMS}	560
Phase current (AC) ¹ , max. in A_{RMS}	800 for 34 s
Phase current (DC) nominal in A_{DC}	560 (el. field frequency < 10 Hz)
Phase current (DC) max. in A_{DC}	800 for 34 s (el. field frequency < 10 Hz)
Time ratio overload operation to nominal operation	1:20
Power (AC) nominal in kW	Depending on the operating point
Power (AC) max. in kW	Depending on the operating point
Electrical frequency max. in kHz	Depending on the operating point and UUT
Current (DC) UUT, nominal in A_{DC}	600
Current (DC) UUT, maximal in A_{DC}	800 for 34 s
Installed basic inductance in μH (per BCU-ALU)	125
Switching frequency UUT in kHz	Up to 20
Supported modulation methods UUT	Support for continuous modulation methods <ul style="list-style-type: none"> • PWM with sine-triangle modulation • PWM with super-sine modulation • PWM with injection of the third harmonic
Protective functions	<ul style="list-style-type: none"> • Adjustable current limitation and overcurrent shutdown • Overload protection (temperature monitoring) • Leakage sensor

Tab. 8: Data phase emulation and power

¹ Derating of the phase current as a function of the electrical frequency

UUT limits	
Recommended min. supply voltage of the inverter in V_{DC}	300
Maximum supply voltage of the inverter in V_{DC}	1.000

Tab. 9: Data UUT limits

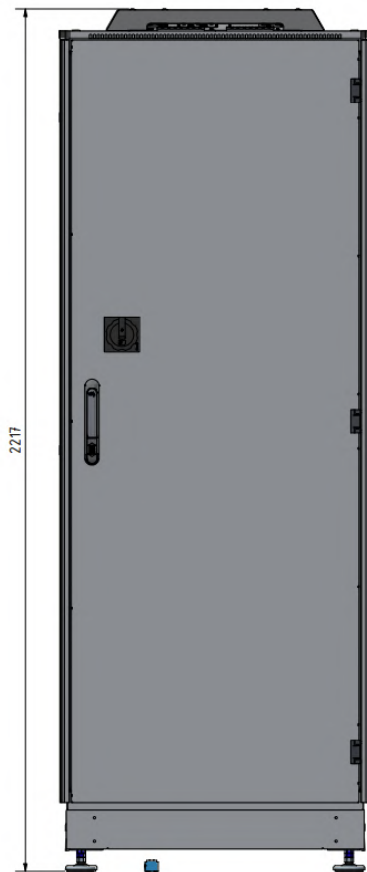
NOTICE



Overload limit

No overload is permitted from a voltage of $V_{DC} > 900V$.

4.2 Dimensions



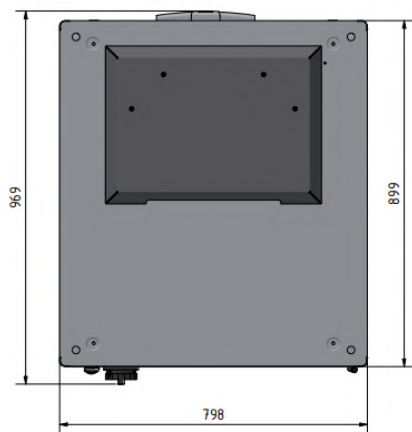
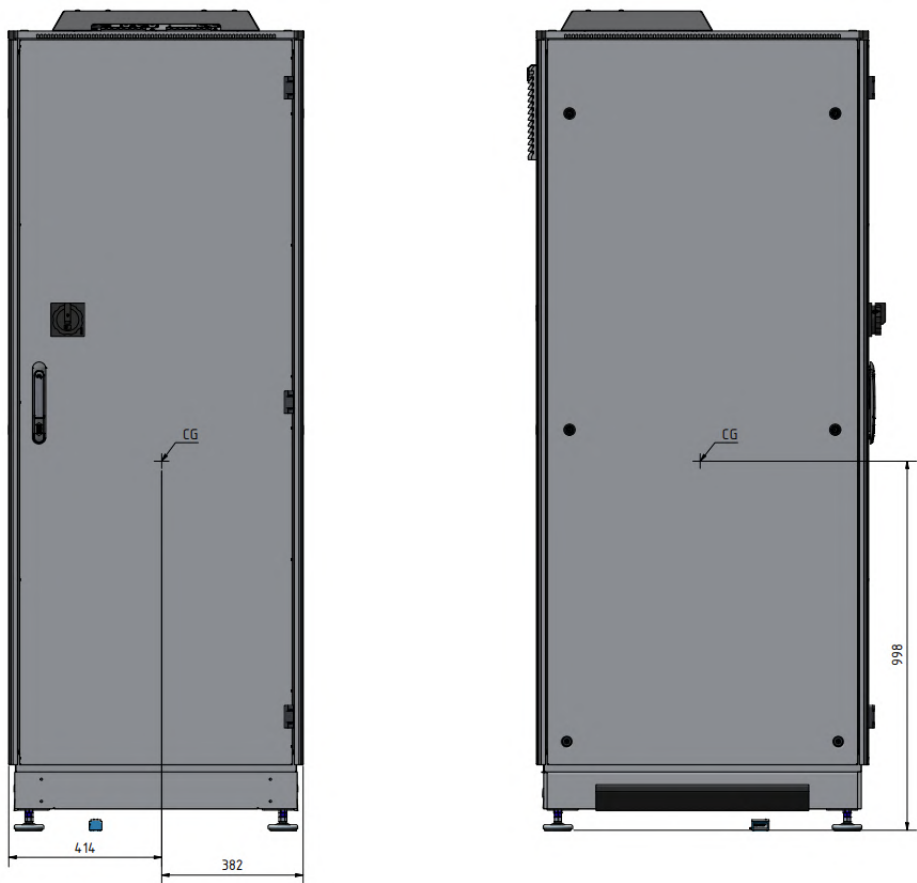


Fig. 25: Dimensions

The dimensions of the ALC are 2,217 mm x 798 mm x 969 mm (height x width x depth).

4.3 Center of gravity



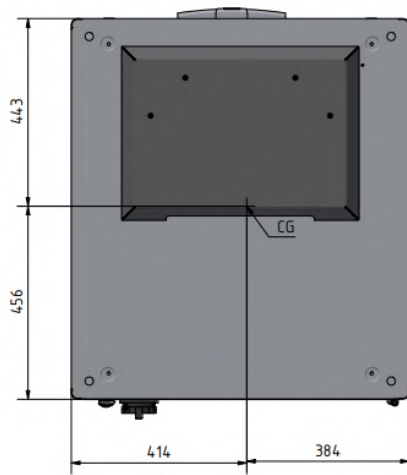


Fig. 26: Center of gravity

The center of gravity is at 998 x 414 mm x 456 mm (height x width x depth).

5 Installation

The following steps must be carried out in sequence to install the ALC:

1. Earthing the copper rail
2. Contacting the high-voltage and auxiliary supply
3. Venting the cooling circuit
4. Connection of the coolant
5. Connection of the safety system
6. Connection of the automation system

DANGER



It is essential to note that the first step is to connect the installed copper rail to the earthing point of the higher-level power supply. Only this step activates the safety functions of the ALC.

5.1 Earthing the copper rail

Before any further work can be carried out on the product, the copper rail of the ALC must be connected to the earthing point of the higher-level power supply.

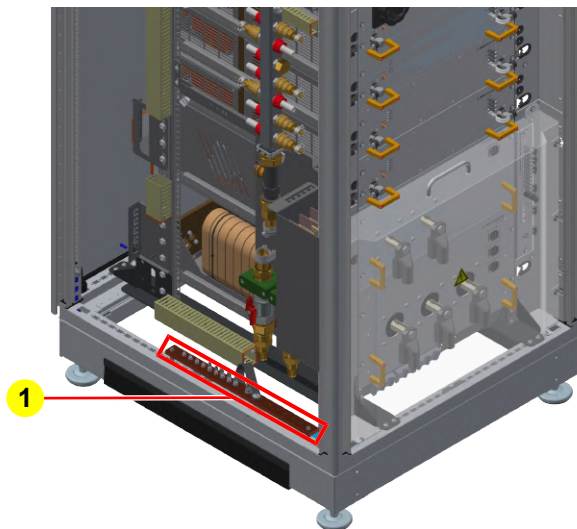


Fig. 27: Grounding rail

Legend for figure:

- 1 Copper rail

The following actions must be taken to achieve this:

- Connecting the ground strap
- Connecting the earthing cable: min 16 mm² copper cable

The earth strap and the earthing cable are each attached via:

- Cylinder head screw M8 x 25 + washer D8.4
- Opposite hexagon nut M8 + washer D8.4
- Tightening torque: 25 Nm

DANGER

The protective earth must be protected against mechanical damage.

5.2 Contacting the high-voltage and auxiliary supply

Connection terminals for the product's high-voltage supply are installed in the ALC. These are located inside the cabinet in the bottom left-hand area. Further information on the high-voltage supply of the ALC can be found in the section *High-voltage power supply* on page 18.

A 230V auxiliary power supply is required to operate the ALC. The connection for this is located in the signal interface on the roof of the product.

5.3 Connection of the coolant

The product is cooled via a separate water/water heat exchanger, which is not included in the scope of delivery of the ALC. The connection for the water/water heat exchanger is located inside the cabinet in the bottom left-hand area. Further information on this can be found in the section *Cooling water connection* on page 18.

A coolant flow rate of 24l/min is required. Flow monitoring can be performed via a dedicated heat exchanger or the TCP client. To perform a check in TCP client, the "ESC" category must be selected under "Parameter Categories". The interface will then display several entries. The parameter "0x0904000c", labeled "flow rate 1", provides the flow rate of the ALC.

The flow rate can be manually adjusted at the water distributor located on the left side of the ALC. The adjustment options are shown in the illustration below.

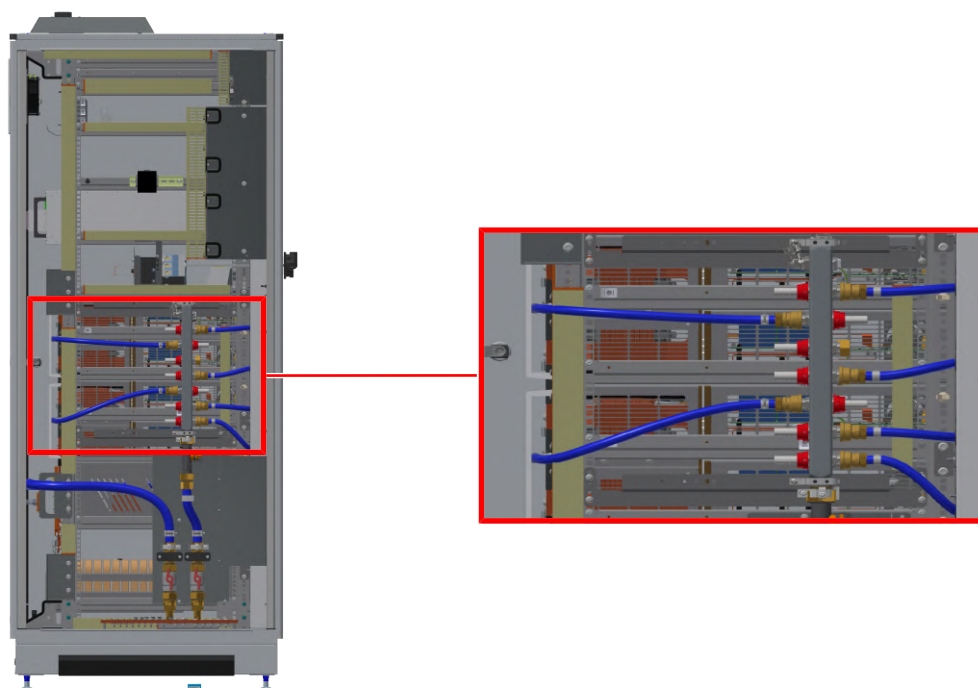


Fig. 28: Water distributor on the left side

The red protective caps must be removed from the adjustment points. The flow rate can be changed by turning the regulating element located underneath.

The flow rate of 24l/min must be evenly distributed across the six connected adjustment points. The build-in sight glasses can be used as an aid during manual adjustment.

To enable the flow rate described above, all control valves of the ALC must be open.

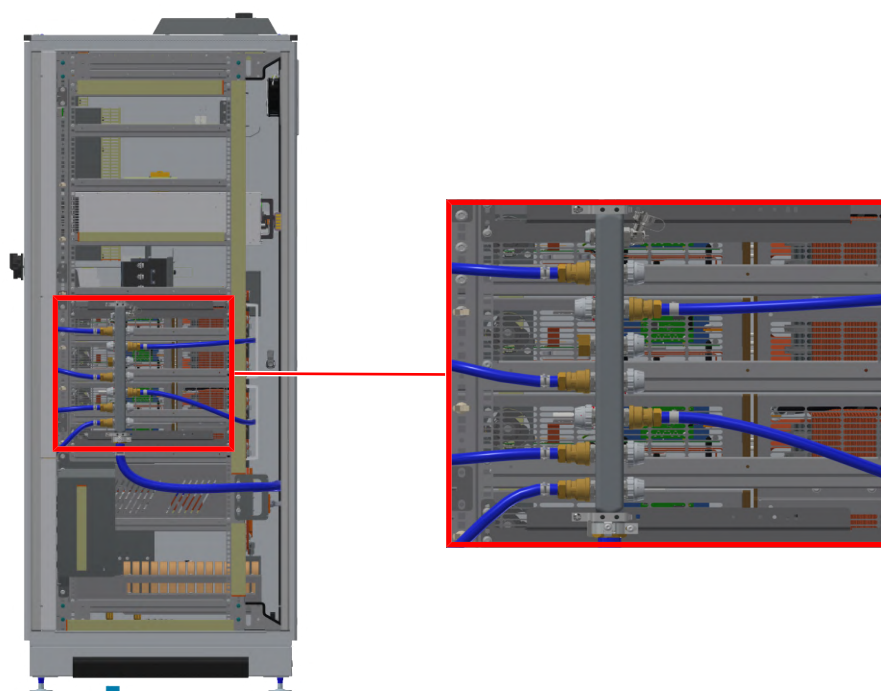


Fig. 29: Water distributor on the right side

These valves are located on the right inner side of the ALC and can be adjusted manually by turning.

5.4 Connection of the safety system

The connection between the ALC and the higher-level security system is made via an RJ45 connector. The connection for this is located in the signal interface on the roof of the ALC. A more detailed description of this interface can be found in the section *Safety system* on page 12.

5.4.1 Safety interface module

A SIEMENS SIMATIC ET200SP IM155-PN ST interface module is installed in the Active Load Cabinet. To control the interface module, a suitable Siemens CPU must be provided and programmed by the customer.

The safety interface module includes the following modules.

Module	Designation
-KF20	6ES7155-6AU01-0BN0
-KF20.1	6ES7193-6AR00-0AA0
-KF21	6ES7193-6BP00-0DA0
-KF21.1	6ES7136-6DB00-0CA0
-KF22	6ES7193-6BP00-0BA0
-KF22.1	6ES7136-6BA00-0CA0
-KF23	6ES7193-6BP00-0BA0
-KF23.1	6ES7131-6BH01-0BA0
-KF24	6ES7193-6BP00-0BA0

Tab. 10: Safety interface module

Module	Designation
-KF24.1	6ES7132-6FD51-0BA0

Tab. 10: Safety interface module (Continued)

The layout of the module is shown in the figure below.

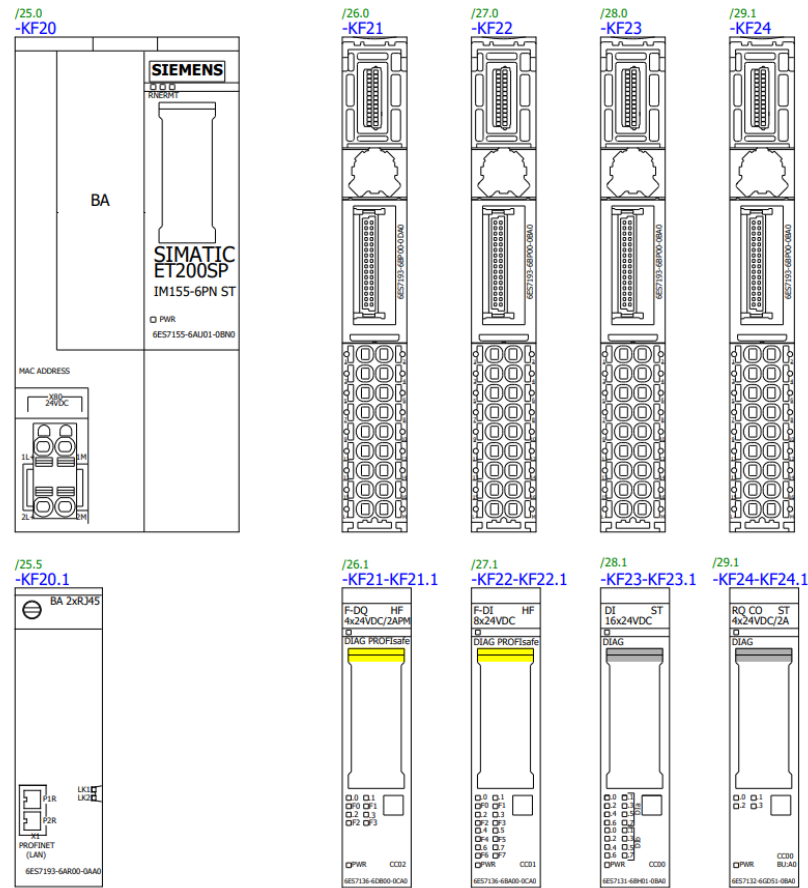


Fig. 30: Safety interface module

5.4.2 Topology overview of the safety interface

The topology of the Active Load Cabinet and all signals provided are shown in the following figure.

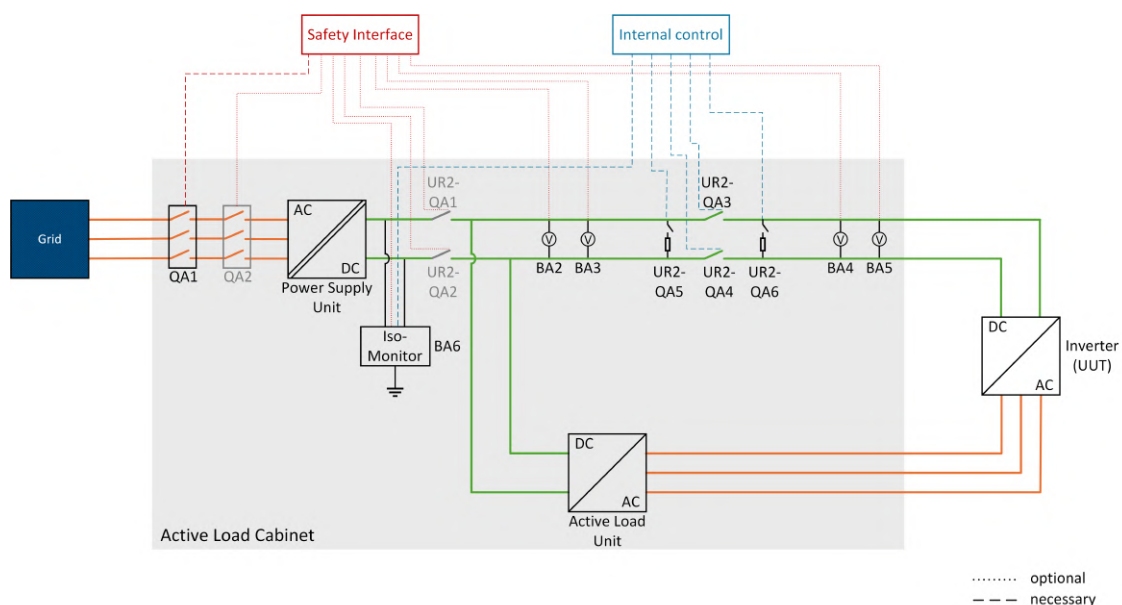


Fig. 31: Topology overview

5.4.3 Interface description of the safety interface

The following signals are provided at the interface.

Name	Module	Module address	Function
AC Contactor 1 (QA1)	KF21.1	Q0.0	AC contactor 1 switch
	KF23.1	I1.0	Feedback 1 AC contactor 1 (normally open)
	KF23.1	I1.1	Feedback 2 AC contactor 1 (normally closed)
AC Contactor 2 (QA2)	KF21.1	Q0.1	AC contactor 2 switch
	KF23.1	I1.2	Feedback 1 AC contactor 2 (normally open)
	KF23.1	I1.4	Feedback 2 AC contactor 2 (normally closed)
DC Contactor (UR2-QA1)	KF21.1	Q0.2	DC contactor 1 switch (optional)
	KF23.1	I1.5	Feedback DC contactor 1 (normally open)
DC Contactor (UR2-QA2)	KF21.1	Q0.3	DC contactor 2 switch (optional)
	KF23.1	I1.6	Feedback DC contactor 2 (normally open)
ISO-Monitor	KF22.1	I0.0	Feedback insulation monitor (closed = no error)
	KF22.1	I0.4	Feedback insulation monitor (opened = no error)
SVMU ALC (BA2)	KF22.1	I0.1	Feedback Voltage monitoring ALC channel1 relay contact (closed = voltage below 60V)

Tab. 11: Interface description of the safety interface

Name	Module	Module address	Function
SVMU ALC (BA3)	KF22.1	E0.5	Feedback Voltage monitoring ALC channel 2 relay contact (closed = voltage below 60V)
SVMU UUT (BA4)	KF22.1	I0.2	Feedback Voltage monitoring UUT channel 1 relay contact (closed = voltage below 60V)
SVMU UUT (BA5)	KF22.1	I0.6	Feedback Voltage monitoring UUT channel 2 relay contact (closed = voltage below 60V)
Signal SVMU ALC	KF24.1	QX.0	Feedback Voltage monitoring ALC DC link (optional)
Signal SVMU UUT	KF24.1	QX.1	Feedback Voltage monitoring UUT DC link (optional)

Tab. 11: Interface description of the safety interface (Continued)

5.5 Connection of the automation system

The connection between the ALC and the higher-level automation system is made via an RJ45 connector. The connection for this is located in the signal interface on the roof of the ALC. Further information on this signal interface can be found in the section *Automation system* on page 11.

5.6 IP addresses

To ensure stable network communication, IP addresses are assigned to individual components. The table below provides an overview of the addresses allocated for various configurations and components.

Component	IP address	Comment
Netmask	255.255.0.0	16 bit
First ALC in the system	172.20.1.xy	(10 – 99)
CCU	172.20.1.10	
EA PSU	172.20.1.12	
Insulation monitor	172.20.1.16	
Second ALC in the system (optional)	172.20.2.xy	(10 – 99)
CCU	172.20.2.10	
EA PSU	172.20.2.12	
Insulation monitor	172.20.2.16	
Third ALC in the system (optional)	172.20.3.xyz	(10 – 99)

Tab. 12: Assigned IP addresses (ALC)

Component	IP address	Comment
First test system	172.20.1.xyz	(100 – 199)
PUMA	172.20.1.100	
Conditioning unit	172.20.1.110	
Low voltage supply	172.20.1.120	
Power analyzer	172.20.1.130	
Climate chamber	172.20.1.140	
Second test system	172.20.2.xyz	(100 – 199)

Tab. 13: Assigned IP addresses (externe Komponenten)

5.7 Room layout

There are two possible ways to integrate the ALC into a room.

1. Fixed integration
2. Non-fixed integration

Location fixed integration:

In the case of a fixed installation, a maintenance area must be kept clear on all sides of the ALC. This area must be 50 cm wide on each side. The room layout for a fixed installation is shown in the following illustration.

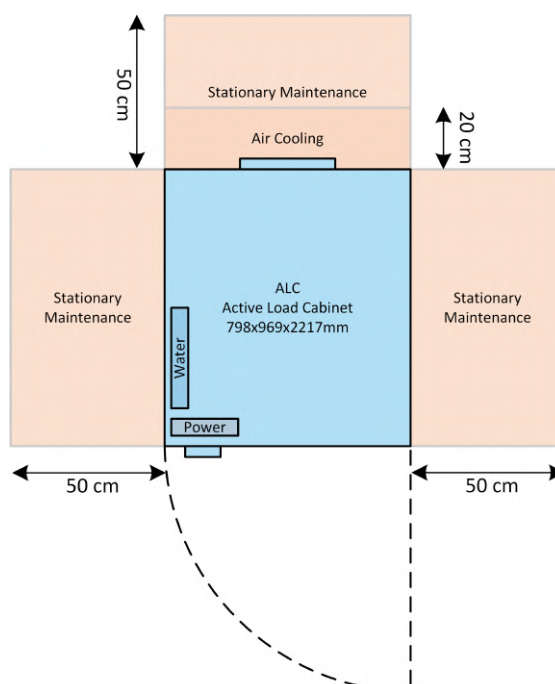


Fig. 32: Fixed installation of the ALC in a room

- A stationary maintenance area is provided on the left side. This area is required to connect the ALC to the water supply and to be able to read the internal flow rate.
- The stationary maintenance area on the right side provides access to the water distributor, where the internal flow rate can be adjusted.
- A clearance must be maintained at the rear side of the ALC to ensure proper air circulation for cooling. Additionally, a dedicated area is provided for stationary maintenance of the fan.

Non-fixed installation:

With a non-fixed installation, the ALC can still be moved after installation or during maintenance. Therefore, only a 20 cm deep area is required to ensure proper air circulation of the air cooler. This is illustrated in the following figure.

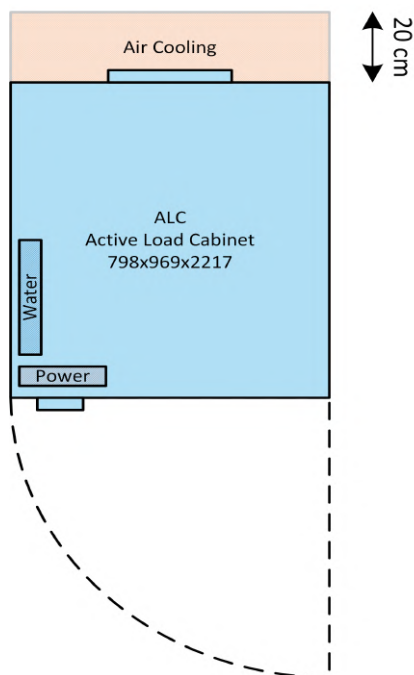


Fig. 33: Non-fixed installation of the ALC in a room

NOTICE



Non-fixed installation

The same maintenance areas as for the stationary integration apply. These can be established by moving the ALC for installation and maintenance purposes. During operation, only the indicated area for air cooling is required.

6 Commissioning

The following steps must be carried out in sequence to commission the ALC:

1. Turning the main switch
2. Controlling the AC contactors
3. Connecting with the ALC
4. Parametrization of the ALC

6.1 Turning the main switch

The ALC is switched to the "Standby" state by turning the mechanical switch on the cabinet and the switch on the PDU.

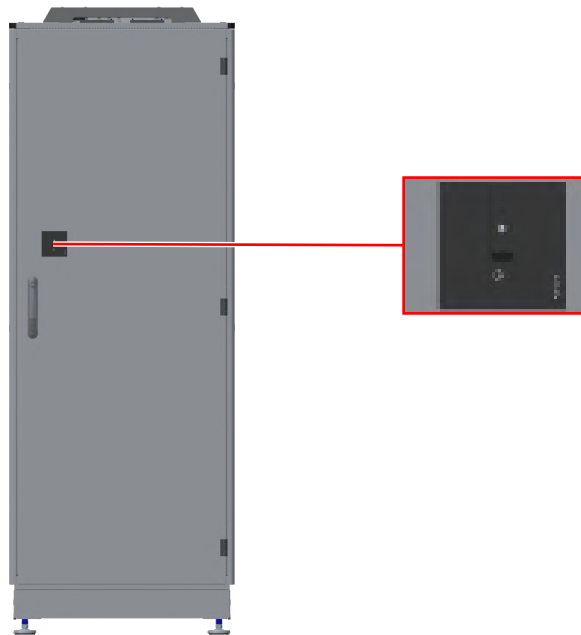


Fig. 34: Main switch of the ALC

6.2 Controlling the AC contactors

The hardware installed in the ALC is transferred to the signal interface on the roof of the ALC via a fieldbus. This involves an insulation monitor, a safety-related voltage detection system and one AC connector. The customer is responsible for controlling the entire safety system via the Profinet interface provided.

6.3 Connecting with the ALC

The TCP interface must be used to connect the ALC to an external automation system. The TCP protocol can be found in the interface description 5R3.0 of the ALC.

For a simplified integration, a Windows Dynamik Link Library (DLL) as well as a LabVIEW Driver Interface are available. The LabVIEW Driver Interface and the TCP-based transmission protocol are documented in the interface description 5R3.0 of the ALC.

6.4 Parametrization of the ALC

The ALC is also parameterized by executing a function via the DLL. The parameters available for this, their meaning and the state machine of the ALC can be found in the software interface description 5R3.0.

7 Maintenance schedule

Maintenance work	Maintenance interval
Replacing the filter mat for the fan	1 year
Replacing the cabinet fan	8 years
Replacing the cooling hose 9.5mm	10 years
Replacing the cooling hose 25.4mm	10 years

Tab. 14: Maintenance schedule ALC

Appendix

Applicable documents

Document	Document type	Content
7178EOC0000	EU Declaration of Conformity	EU Declaration of Conformity
7178MAN0005	Manual	Interface description 5R3.0
7178MAN000X	User guide	Transport and Assembly

Tab. 15: Applicable documents

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Glossary

AC

Alternating Current

AKS

active short circuit (German: aktiver Kurzschluss)

ALC

active load cabinet - The Active Load Cabinet is a standalone product to provide active and apparent power as an active load to the UUT.

ALU

active load unit

AXU

auxiliary I/O unit

CCU

cabinet control unit

CVMU

comparator voltage measurement unit

DC

Direct Current

DLL

dynamik link library - DLL generally means a dynamic program library.

PDU

power distribution unit - The PDU generates the necessary auxiliary voltages for the internal supply of the cabinet.

Qualified Persons

For the purposes of this documentation, persons are qualified if their technical training, knowledge and experience enables them to judge their tasks and to recognize potential hazards.

SCS

safety control system

UCU-AC

UUT connection unit AC

UCU-DC

UUT connection unit DC



Mess- und Prüftechnik. Die Experten.

**Ihr Ansprechpartner /
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