ENGINEERING TOMORROW

Design Guide

VACON® NXP DCGuard™

drives.danfoss.com

Contents

1 Introduction

1.1 Purpose of this Design Guide

This design guide is intended for qualified personnel, such as:

- Project and systems engineers.
- Design consultants.
- Application and product specialists.

The design guide provides technical information to understand the capabilities of VACON® NXP DCGuard™ for integration into DC supply systems. Its purpose is to provide design considerations and planning data for integration of the device into a system. It caters for the selection of the drive units and options for the application in a diversity of installations. Reviewing the detailed product information in the design stage enables developing a well-conceived system with optimal functionality and efficiency.

1.2 Additional Resources

Other resources are available to understand installation, programming, operation, and options.

- The VACON® NXP DCGuard™ operating guide provides information about the installation and operation of the VACON® NXP DCGuard™ application.
- The VACON® NXP DCGuard™ application guide provides greater detail on how to work with the application software and how to set the parameters of the AC drive modules.
- VACON® NXP Common DC Bus and VACON® NXP Liquid-cooled Common DC Bus user manuals provide detailed information for the installation, commissioning, and operation of the AC drive modules.
- The operating and installation guides for VACON® options give detailed information about specific drive options.

Supplementary publications and manuals are available from Danfoss. See www.danfoss.com for listings.

1.3 Manual Version

This manual is regularly reviewed and updated. All suggestions for improvement are welcome.

The original language of this manual is English.

Table 1: VACON® NXP DCGuard™ Design Guide Version

Version	Release date	Remarks
A	04.12.2018	First release

1.4 Type Approvals and Certifications

VACON® NXP DCGuard™ is type approved as a circuit breaker/DC-bus tie breaker. For a list of the approvals and certifications, see the VACON® NXP DCGuard™ product page at www.danfoss.com.

NOTICE

VACON® NXP DCGuard™ acts as a protection device in a DC power distribution system. Separate approvals as a DC-bus tie breaker can be required.

2 Safety

2.1 Safety Instructions

A safety guide is included in the product delivery. Read the safety instructions carefully before starting to work in any way with the system or its components.

The warnings and cautions in the safety guide give important information on how to prevent injury and damage to the equipment or the system. Read the warnings and cautions carefully and obey their instructions.

The product manuals with applicable safety, warning, and caution information can be downloaded from https://www.danfoss.com/en/service-and-support/.

3 Product Overview

3.1 DC Grids and Selectivity

Utilizing DC grids rather than AC grids enables power distribution with lower power losses. However, there are few or no international standards for building a DC grid, especially in marine applications. Short circuit handling is a challenge in DC grids and it is difficult to ensure the required system functionality by using fuses. Ensuring selectivity and limited short circuit energy requires more sophisticated protection devices.

Ensuring selectivity in a common-DC system is a challenge, and it becomes even more challenging when there are several inverters connected to the same DC bus. In a short circuit in the DC bus, the protection fuses burn, but often so do the fuses feeding other vital equipment in the same system. Even fuses which are not connected directly (nearest) to the short circuit can burn, for example, the fuses feeding inverters in another place in the same DC bus.

During the first 100–200 µs after a short circuit occurs, the capacitors inside each inverter will supply current to the fault. Since capacitors can feed out current extremely fast, selectivity is difficult to achieve by only using fuses. One way to improve the total selectivity in a common-DC-bus system is to split the system in two separate DC grids by using a fast-current cutter/DC-bus tie device.

Danfoss Drives has developed a new fast-current cutter/DC-bus tie device, the VACON® NXP DCGuard™. The semiconductor protection device is based on standard VACON® NXP inverter hardware and new software. During a short circuit, the VACON® NXP DCGuard™ disconnects the healthy side from the faulty side in microseconds, before the short circuit affects the healthy side. The fast isolation ensures that the healthy side can continue to operate as normal, also after the short circuit situation. The DCGuard cannot influence what happens inside the faulty DC grid during a short circuit situation.

3.2 Selectivity with Fuses

In some demanding applications (for example, marine applications) there is a requirement that a single fault must not shut down the complete system. Because of this requirement, it is required to build the system so that it can withstand a fault without having a total blackout.

Maintaining the required DC voltage on the healthy side of the DC grid during a fault is one of the main challenges when using fuses to disconnect the healthy part of the DC grid from the faulty part in a short circuit situation. When a short circuit happens, the voltage on the faulty side is close to 0 V. Because of the low resistance inside the fuses, also the voltage on the healthy side decreases. It takes time for the fuses to clear the fault, so there is a significant risk that also the voltage on the healthy side decreases below the undervoltage trip limit for the inverters in the healthy side. The result is a total blackout.

illustration 1 shows the DC voltage in grids 1 and 2, and the DC current through the fuses when there is a fault in DC grid 2.

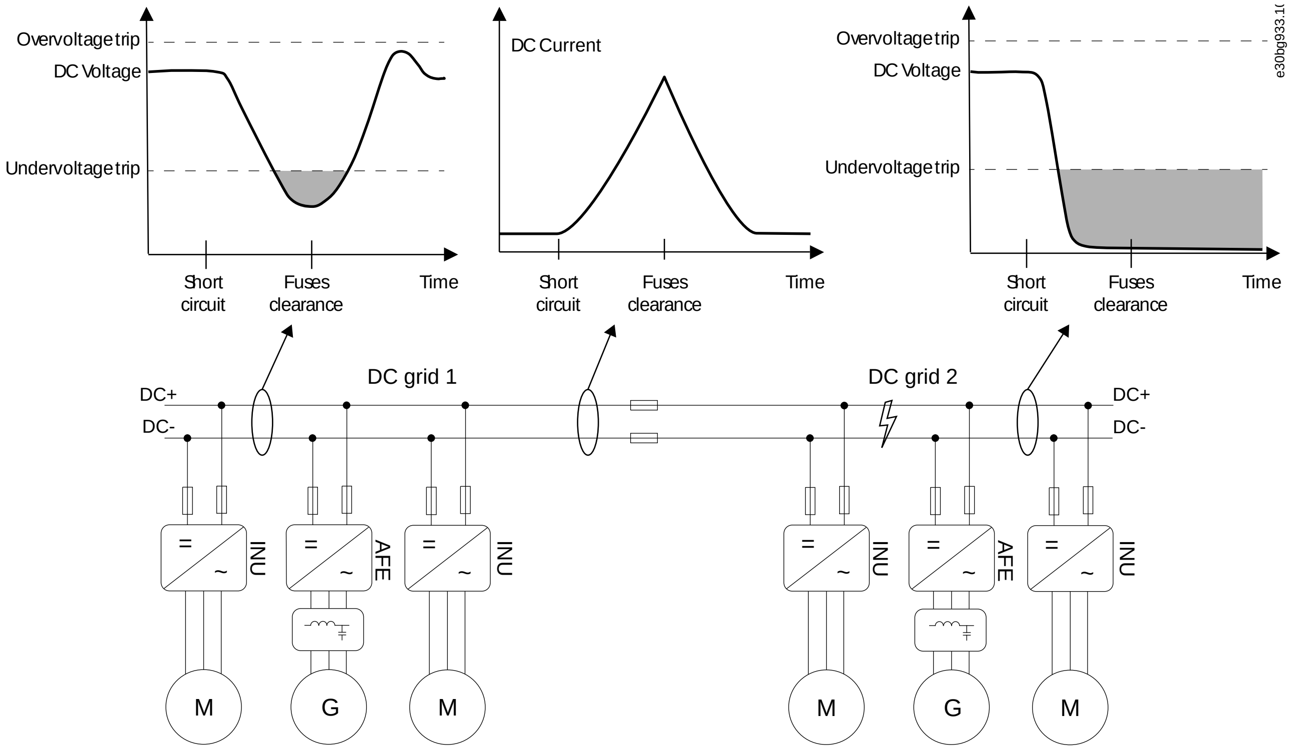


Illustration 1: Example of Selectivity with Fuses in a Fault Situation

3.3 Application Functionality

VACON® NXP DCGuard™ is a fast DC current cutter device that detects and cuts off an outgoing short-circuit current. The main function is to isolate the faulty DC grid from the healthy DC grid, before that fault affects the healthy DC grid.

Two inverter units in a DCGuard peer-to-peer topology are required to be able to cut off short-circuit current both ways.

VACON® NXP DCGuard™ consist of VACON® NXP inverter units and application software ADFIF102. To ensure the correct functionality and safety level, always use the following components together with the DCGuard in a peer-to-peer system:

- An upstream mechanical disconnector if safe disconnection is required.
- Type aR supply fuses in each DC supply line (see the VACON® NXP DCGuard™ design guide for instructions).
- A dU/dt filter (a standard VACON® dU/dt filter can be used).

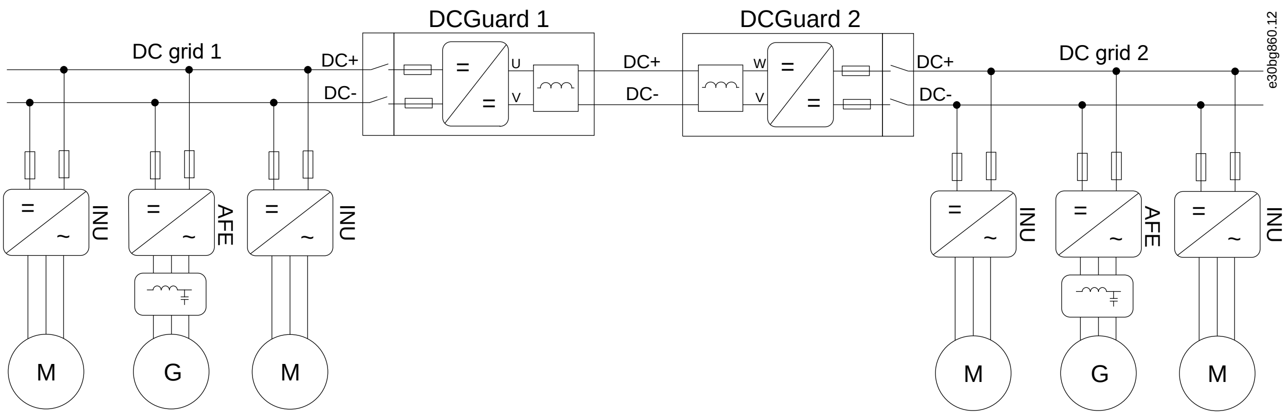


Illustration 2: **VACON® NXP DCGuard™ Peer-to-Peer Topology**

3.4 Protection Functions

The VACON® NXP DCGuard™ application has different short-circuit protection levels. The levels can be used to ensure correct system selectivity. The instant current cut-off is non-programmable, but the other functions can be programmed. The protection functions also have separate programmable responses.

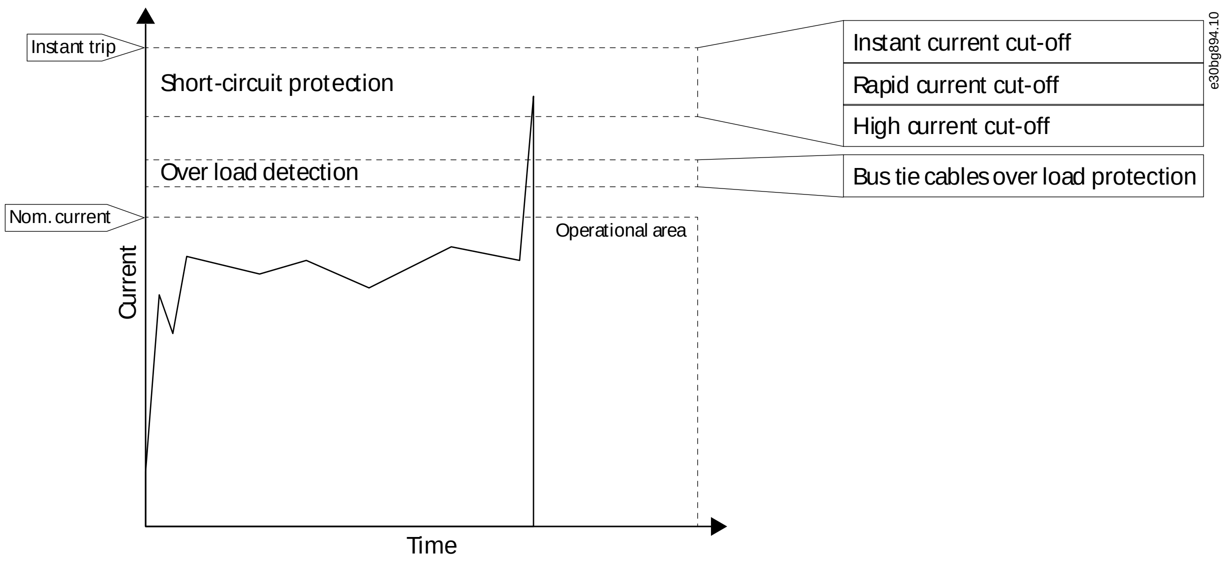


Illustration 3: **VACON® NXP DCGuard™ Safety Layers**

3.4.1 Instant Current Cut-Off

- Non-programmable short-circuit current cut-off.
- VACON® NXP DCGuard™ trips within µs to fault F1 in a low impedance short circuit.
- The functionality is handled by the VACON® NXP inverter hardware.

3.4.2 Rapid Current Cut-Off

- Programmable short-circuit current cut-off.
- VACON® NXP DCGuard™ trips within 10–100 μs to fault F63, F64, or F65 in a low to medium impedance short circuit.
- This functionality is handled by the system software and requires enough inductance in the output filter. If there is a short circuit in the bus-tie cables, a standard dU/dt filter does not have enough inductance to ensure an exact tripping level.
- For details about programming this function, see the VACON® NXP DCGuard™ Application Guide.

3.4.3 High Current Cut-Off

- Programmable high circuit current cut-off.
- VACON® NXP DCGuard™ trips within 100 ms to fault F86, F87, or F88 if the current is too high for a too long time.
- This functionality is handled by the VACON® NXP DCGuard™ application software.
- For details about programming this function, see the VACON® NXP DCGuard™ Application Guide.

3.4.4 Overload Detection

- Programmable overload detection.
- VACON® NXP DCGuard™ trips within 100 ms to fault F83, F84, or F85 in an overload situation in the DC cables out from the DCGuard.
- This functionality is handled by the VACON® NXP DCGuard™ application software.
- For details about programming this function, see the VACON® NXP DCGuard™ Application Guide.

3.5 Controlled Voltage Ramp-Up

To prevent a high inrush current when a VACON® NXP DCGuard™ is connecting to the bus-tie cables, a controlled voltage ramp up of the bus-tie cable voltage is always performed before closing the DCGuard. The voltage is ramped up from the current level to full DC voltage. Typically, the voltage rise time from 0 V to full DC voltage is 200–400 ms. The voltage rise time and switching frequency are programmable.

3.5.1 Controlled Voltage Ramp-Up of a Loaded System

VACON® NXP DCGuard™ can perform a controlled voltage ramp-up of a loaded system, but the voltage rise time must be adjusted case by case. The maximum current must stay below the tripping limit for the VACON® NXP DCGuard™ units during the controlled voltage ramp-up.

3.5.2 Controlled Voltage Ramp-Up into a Short Circuit

If a controlled voltage ramp-up is performed to a system where a short circuit is present, the VACON® NXP DCGuard™ detects the short circuit and trips.

3.6 System Control Principle

VACON® NXP DCGuard™ is only one component in a complete system, which often includes different layers of controls with different responsibilities.

- The Energy Management System (EMS) optimizes the energy efficiency of the system. The optimization can include selecting and prioritizing the use of different energy sources. Normal time scales are from tens of seconds to hours.
- The Power Management System (PMS) includes controlling the power balance in a system which has multiple energy/power sources. Normal time scales are from grid cycle (20 ms/50 Hz) to seconds.
- The Power Conversion System (PCS) is the system relevant to the VACON® NXP DCGuard™. The PCS includes Power Conversion Control (PCC) and Power Conversion Hardware (PCH), which is the VACON® NXP hardware. The PCS controls the power conversion between the energy storage and the system. Normal time scales are from micro seconds to grid cycles.
- The Storage System (SS) includes the Battery Management System (BMS) and the battery. The BMS monitors the storage system and the storage cell level phenomena.

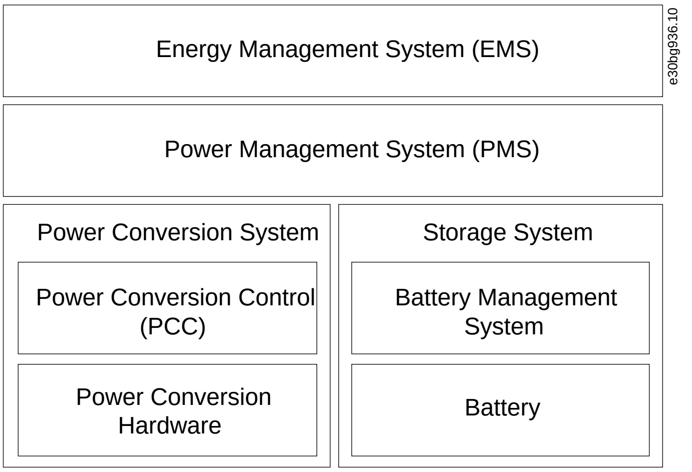


Illustration 4: Typical Layers in a Control System

3.7 Application Requirements

The VACON® NXP DCGuard™ application requires:

- NXP3 control board VB761 revision D or newer.
- System software version NXP00002V193 or newer.

3.8 System Integrator Responsibilities

The VACON® NXP DCGuard™ is developed to be used as a component in a common-DC system. System design and control must be done by the system integrator.

The VACON® NXP DCGuard™ peer-to-peer system is made of two independent DCGuard units, although they operate as a pair. It is the responsibility of the system integrator to implement the two DCGuard units in to the system, to ensure correct functionality, and to ensure correct safety level.

Especially consider the following when designing the system:

- A fault in one of the two DCGuard units must lead to the opening of the other DCGuard unit.
- To ensure safe disconnection of the VACON® NXP DCGuard™ and the bus-tie cables, a mechanical disconnector is required in front of each DCGuard.
- The mechanical disconnector in front of each DCGuard unit must only be closed when the voltage level on both sides of the mechanical disconnector is within the limits of the mechanical disconnectors closing capacity. Meaning that the inrush current is within the mechanical disconnectors closing capacity.
- The mechanical disconnector in front of each DCGuard unit must only be opened when the conducted current is less than the maximum breaking capability of the mechanical disconnector.
- Closing a DCGuard unit must only be possible when the other side of the system is ready to be powered up.
- VACON® NXP liquid-cooled inverters do not control or monitor the cooling liquid flow through their own cooling elements. The system integrator must therefore take responsibility of implementing sufficient control and monitoring of the cooling liquid circuit.
- If the active control place for the DCGuard unit is keypad, make sure that there is a possibility to stop the DCGuard also in case the keypad is removed from the drive. In case the parameter *Keypad/PC fault mode* (ID 1329) is set to 0/*No response* or 1/*Warning*, it must be ensured on system level that there is the possibility for local control. This can be done, for example, by forcing to I/O or fieldbus control by a digital input.

3.9 System Selectivity

VACON® NXP DCGuard™ has received several Type approval certificates, but often the approval societies require an approval of the whole system. To get such a system approval, a selectivity study of the faulty side is required.

MATLAB®/Simulink® can be used to simulate what happens inside the faulty side of the DC grid during a short circuit. Contact the nearest Danfoss Drives representative for more information.

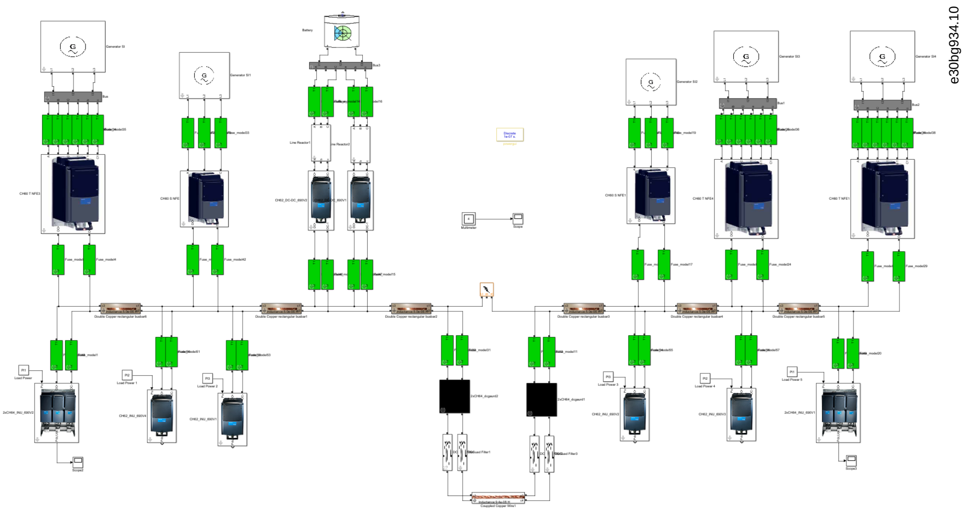


Illustration 5: Model of a Complete DC-Supply System

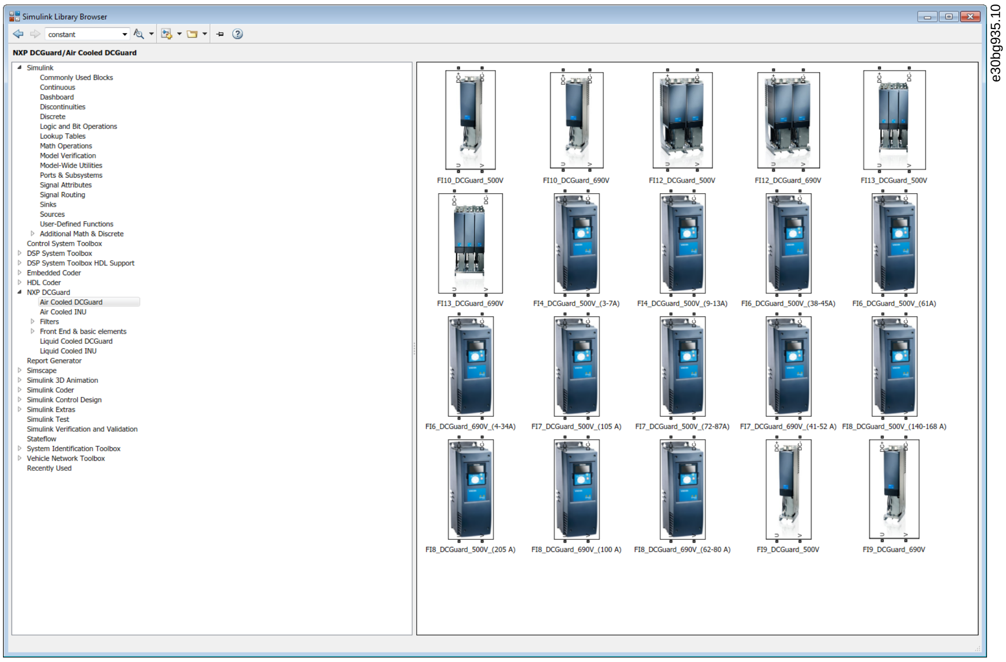


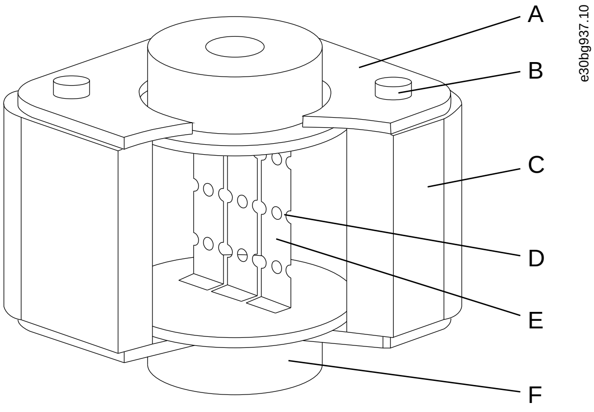
Illustration 6: VACON® NXP DCGuard™ Library in Simulink®

4 Component Overview

4.1 Fuses

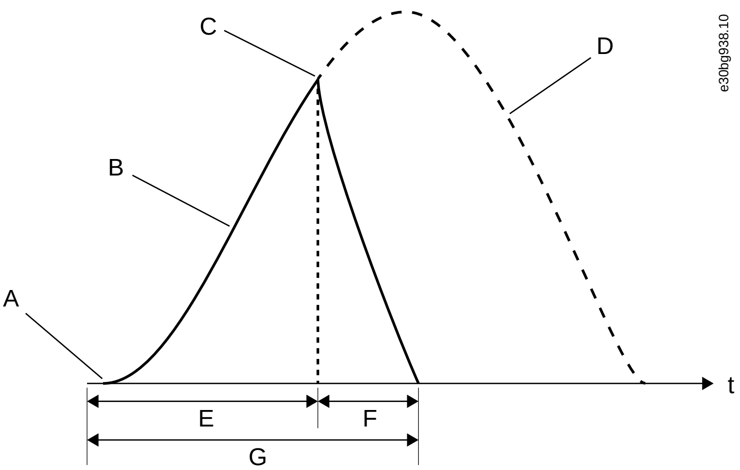
Always protect the VACON® NXP DCGuard™ with aR-type fuses in each DC-supply line.

If there is a short circuit inside the VACON® NXP DCGuard™ unit, the aR-type fuses in each DC-supply line disconnect the unit from the feeding DC grid. The fuses are back-up fuses for semiconductor protection and only give protection against the effects of short circuit current. The fuses do not give any overload protection.



A End plate	**B** Screw
C Ceramic body	**D** Reduced sections of element ("weak spots")
E Element	**F** End fitting

Illustration 7: Structure of a Type aR Fuse



A Start of fault	**B** Actual current
C Peak fault current reached at start of arcing	**D** Possible unrestricted fault current
E Pre-arcing time	**F** Arcing time

G Total clearing time	

Illustration 8: Fuse Functionality in a Fault Situation

See the VACON® NXP user manuals for instructions for the fuse selection. The fuses are not included in the VACON® NXP DCGuard™ delivery.

CAUTION

INCORRECT FUSE CONFIGURATION

In certain cases, the correct fuse configuration can differ from the default configuration given in the VACON® NXP user manual!

- To find the correct fuse configuration, do a system calculation.

4.2 Filters

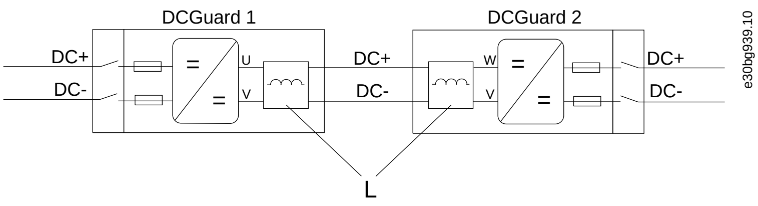
VACON® NXP DCGuard™ requires a dI/dt filter in each of the connected output phases (U, V, W).

The purpose for the inductance is to limit the current rise time, so that the programmable protection functionality of the VACON® NXP DCGuard™ can detect the short circuit and cut the current. If there is a short circuit in the terminals, the dI/dt filter has a higher dI/dt, but is protected by the overcurrent protection of the VACON® NXP inverter hardware.

The filters for VACON® NXP DCGuard™ must fulfill these specifications:

- Approximately 2% inductance. See 4.2.1 Calculating the Filter Impedance.
- Full continuous DC current.
- Short time 5 kHz switching frequency.

A standard VACON® dU/dt filter has about 1.5–2% inductance and it can be used as the required dI/dt filter for VACON® NXP DCGuard™. All VACON® dU/dt filters are designed for 0–70 Hz and can therefore conduct the same amount of DC current as the AC current rating. For more information, see the VACON® NX Filters User Manual.



L Inductor	

Illustration 9: VACON® NXP DCGuard™ with Serial-Connected Inductances in Each Output Phase

4.2.1 Calculating the Filter Impedance

If the required inductance (L) value is known, the impedance (Z) in percentage can be calculated from:

$$Z(\%) = 2\pi\sqrt{3} \cdot \frac{I\mathrm{RMS} \cdot f \cdot L}{V\mathrm{LL}}$$

V_{LL} is the line-to-line voltage, I_{RMS} is the RMS current and f is the frequency.

If the impedance percentage is known, the required inductance can be calculated from:

$$L = \frac{V\text{LL} \cdot Z(\%)}{2\pi\sqrt{3} \cdot I\text{RMS} \cdot f}$$

Example:

DUT-0420-6-0-P

- V_{LL} = 690 V
- L = 47 µH
- I_{RMS} = 420 A
- f = 50 Hz
- Z(%) = 0.0156 ≈ 2%

The inductor impedance at DC (f = 0 Hz) is basically 0% and is limited only by the inductor DC resistance. In DUT-0420-6-0-P the DC resistance is 0.000411 Ω per phase, which corresponds to a 0.17 V voltage drop at the full current of 420 A.

Example:

DUT-1200-6-0-P

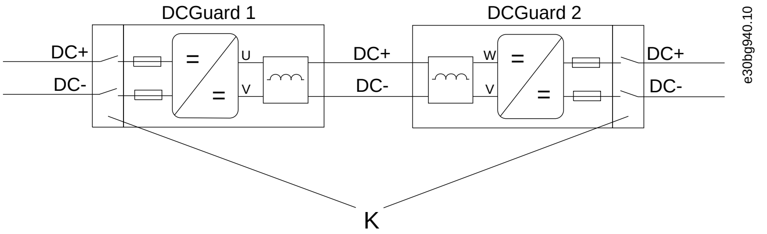
- V_{LL} = 690 V
- L = 16 µH
- I_{RMS} = 1200 A
- f = 50 Hz
- Z(%) = 0.0151 ≈ 2%

4.3 Mechanical Disconnectors

The main purpose of the mechanical disconnector is to ensure a safe disconnection of the VACON® NXP DCGuard™ from the feeding DC grid. The functionality of the VACON® NXP DCGuard™ is not dependent on a mechanical disconnector to provide overcurrent and short-circuit protection. To ensure safe disconnection of the DCGuard and bus-tie cables, a mechanical disconnector is required on the feeding DC grid side of each DCGuard.

The mechanical disconnector can be manual or electrically operated. Opening and closing of the mechanical disconnector must follow the guidelines given in this manual. Operation that is not according to these guidelines can cause damage on the equipment. VACON® NXP DCGuard™ does not have a functionality to prevent incorrect operation of the mechanical disconnector. The system integrator is therefore responsible for implementing precautions to ensure that the opening and closing of the mechanical disconnector is always according to the given guidelines.

The mechanical disconnectors are not included in the VACON® NXP DCGuard™ delivery.



K	Mechanical disconnector

Illustration 10: Mechanical Disconnectors Installation Locations

4.3.1 Closing the Mechanical Disconnectors

The mechanical disconnectors must only be closed when the voltage levels on both sides of the mechanical disconnectors are within the closing capacity limits of the disconnectors. The inrush current must be within the closing capacity of the mechanical disconnectors.

There are two alternative ways to close the mechanical disconnectors:

- The mechanical disconnectors can be closed when both the DC bus and the DCGuard are powered down, so that there is no DC voltage present in the DC bus or the DCGuard.
- The mechanical disconnectors can be closed when the input and output sides of the mechanical disconnectors are charged with the same DC-voltage level.

CAUTION

UNSAFE OPERATION OF THE MECHANICAL DISCONNECTORS

VACON® NXP DCGuard™ has no functionality to prevent unsafe operation of the mechanical disconnectors.

- The system integrator must ensure correct and safe closing and opening of the mechanical disconnectors.

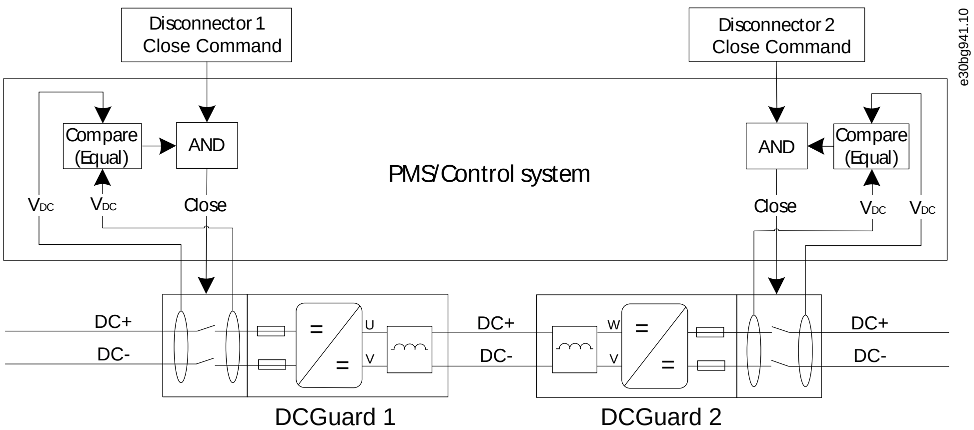


Illustration 11: Closing Logic of the Mechanical Disconnectors

4.3.2 Opening the Mechanical Disconnectors

The mechanical disconnectors must only be opened when the conducted current is less than the maximum breaking capability of the mechanical disconnectors.

There are two alternative ways to open the mechanical disconnectors:

- The mechanical disconnectors can be opened when both the DC bus and the DCGuard are powered down, so that there is no DC voltage present in the DC bus or the DCGuard.
- The mechanical disconnectors can only be opened when the conducted current is less than the maximum breaking capability of the mechanical disconnectors. VACON® NXP DCGuard™ has an output signal indicating that it is open and the conducted current is less than 5% of the nominal current. This signal can be used as an indication of the current level, but the PMS/system integrator control system must take the final opening decision.

⚠ CAUTION ⚠

UNSAFE OPERATION OF THE MECHANICAL DISCONNECTORS

VACON® NXP DCGuard™ has no functionality to prevent unsafe operation of the mechanical disconnectors.

- The system integrator must ensure correct and safe closing and opening of the mechanical disconnectors.

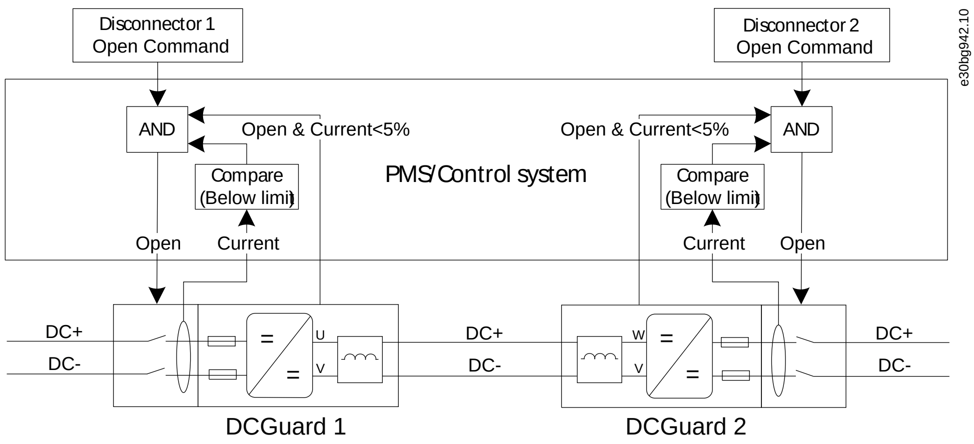


Illustration 12: Opening Logic of the Mechanical Disconnectors

5 Specifications

5.1 Technical Data

Table 2: Technical Data for VACON® NXP DCGuard™

Input voltage U_{IN}	Voltage class 5: 380–500 V (±10%) / DC-link voltage = 465–800 V DC (±0%) Voltage class 6: 525–690 V (±10%) / DC-link voltage = 640–1100 V DC (±0%)
Rated current	Rated AC current = Rated DC current Examples: • Rating for NXP1500 690 V used as a motor drive: 1500 A, 0–320 Hz • Rating for NXP1500 690 V used as VACON® NXP DCGuard™: 1500 A DC
Networks	IT Grid, with appropriate insulation monitoring to PE
Output voltage	Normal operation: $U_{IN} \approx U_{OUT}$ Charging from 0 V to $\approx U_{IN}$
Output frequency	Normal operation: DC voltage (directly connected to DC terminals) Charging: DC voltage (Pulse Width Modulation)
Output filter	dI/dt filter, recommended 2% inductance
Switching frequency	Normal operation: No switching / 0 kHz Charging: 1–10 kHz; Factory default 5 kHz
Control method	Individual IGBT control
AC short-circuit current	Maximum AC short circuit current to be < 100 kA
DC short-circuit current	Limited by the aR fuses in each DC supply line Use aR fuses according to the VACON® NXP inverter user manual. *(1)*
Overvoltage protection	500 V / Voltage class 5: 911 V DC 690 V / Voltage class 6: 1258 V DC
Undervoltage protection	500 V / Voltage class 5: 333 V DC 690 V / Voltage class 6: 460 V DC
IGBT hardware overcurrent protection current	$\leq I_H \times 3–5$ *(2)*
IGBT hardware overcurrent protection delay	Hardware circuit, instant without time delay

[1] *In certain cases, it can be required to do a system calculation to find a proper fuse configuration, which can differ from the default fuse configuration given in the manuals.*

[2] *Unit dependent. See* *5.5 Power Ratings*.

5.2 Nameplate

The VACON® NXP inverter units have a nameplate which contains the information listed in table 3.

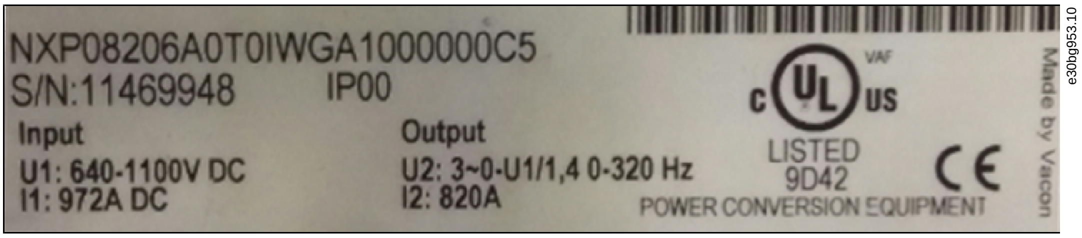


Illustration 13: The Nameplate of a VACON® NXP Inverter

Table 3: Information Listed in a VACON® NXP Inverter Nameplate

Marking	Definition	Additional information
NXP08206…	Type code	See the VACON® NXP inverter user manual for more information
S/N	Serial number	Unique serial number
IP00	IP protection	See the VACON® NXP inverter user manual for more information
U1	Input voltage	DC voltage
I1	Input current	DC-link current (I=P/U)
U2	Output voltage	0–320 Hz
I2	Output current	True RMS current

5.3 Voltage and Current Rating Guidelines

When using the VACON® NXP inverter as a VACON® NXP DCGuard™ unit, the nameplate value U1 is used as the voltage rating. In normal operation, VACON® NXP DCGuard™ has approximately the same output DC voltage as the input DC voltage. After start-up, in normal operation, there is no IGBT switching. The heat losses in a VACON® NXP DCGuard™ unit are therefore lower than in a normal motor inverter.

The rated DC current of the VACON® NXP DCGuard™ is the same as the AC current rating of the VACON® NXP inverter, that is, the I2 value on the nameplate. For example, an NXP1500 inverter is rated for a 1500 A DC current when used as VACON® NXP DCGuard™ and 1500 A AC current when used as a motor inverter.

Required load current is the primary sizing criteria for VACON® NXP DCGuard™. For example, if it is required to have 500 A going from one side of the DC bus to the other, a 500 A DCGuard is required.

illustration 14 explains the difference in voltage and current ratings when using a VACON® NXP inverter as a motor inverter and as a VACON® NXP DCGuard™ unit.

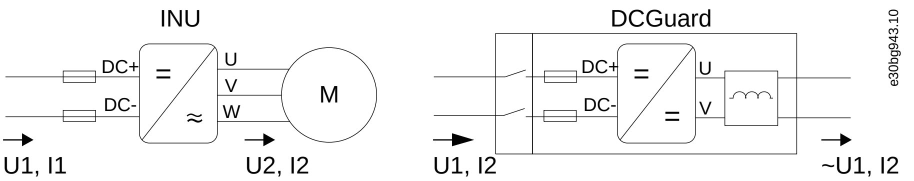


Illustration 14: Nameplate Voltage and Current Ratings for a VACON® NXP Inverter

5.4 Operation Temperature Range

Air-Cooled Units

The current ratings for VACON® NXP air-cooled inverters follow these conditions:

- Maximum output current: $I_2 = I_L$. See the VACON® NXP air-cooled user manual.
- Maximum ambient temperature: 40˚C.
- Maximum ambient temperature: 40–50˚C, when derating 1.5%/˚C.

Liquid-Cooled Units

The current ratings for VACON® NXP liquid-cooled inverters follow these conditions:

- Maximum output current: $I_2 = I_{TH}$. See the VACON® NXP liquid-cooled user manual.
- Maximum cooling liquid temperature: 45˚C.
- Maximum ambient temperature: 50˚C.
- Maximum ambient temperature: 50–55˚C, when derating 2.5%/˚C.

5.5 Power Ratings

5.5.1 Air-Cooled 500 V Units

Table 4: VACON® NXP DCGuard™ Power Ratings with Air-Cooled 500 V VACON® NXP Inverter Units

Type code	Unit type	Enclosure size	DCGuard current I_2 [A]	DC power @800 V P_{DC} [kW]	Over current and short circuit protection, Instant trip ≤ [A]
NXP00035A2T0SSS	NXP0003	FR4	3	2	10
NXP00045A2T0SSS	NXP0004	FR4	4	3	15
NXP00055A2T0SSS	NXP0005	FR4	5	4	19
NXP00075A2T0SSS	NXP0007	FR4	7	6	25
NXP00095A2T0SSS	NXP0009	FR4	9	7	33
NXP00125A2T0SSS	NXP0012	FR4	12	10	40
NXP00165A2T0SSS	NXP0016	FR5	16	13	53
NXP00225A2T0SSS	NXP0022	FR5	22	18	70
NXP00315A2T0SSS	NXP0031	FR5	31	25	101
NXP00385A2T0SSS	NXP0038	FR6	38	30	136
NXP00455A2T0SSS	NXP0045	FR6	45	36	167
NXP00615A2T0SSS	NXP0061	FR6	61	49	202
NXP00725A2T0SSS	NXP0072	FR7	72	58	268
NXP00875A2T0SSS	NXP0087	FR7	87	70	317
NXP01055A2T0SSS	NXP0105	FR7	105	84	383
NXP01405A2T0SSS	NXP0140	FR8	140	112	462

Type code	Unit type	Enclosure size	DCGuard current I_2 [A]	DC power @800 V P_{DC} [kW]	Over current and short circuit protection, Instant trip ≤ [A]
NXI01685A0T0ISF	NXI0168	FI9	168	134	616
NXI02055A0T0ISF	NXI0205	FI9	205	164	748
NXI02615A0T0ISF	NXI0261	FI9	261	209	902
NXI03005A0T0ISF	NXI0300	FI9	300	240	1078
NXI03855A0T0ISF	NXI0385	FI10	385	308	1320
NXI04605A0T0ISF	NXI0460	FI10	460	368	1694
NXI05205A0T0ISF	NXI0520	FI10	520	416	2024
NXI05905A0T0ISF	NXI0590	FI12(2×FI10)	590	472	2288
NXI06505A0T0ISF	NXI0650	FI12(2×FI10)	650	520	2596
NXI07305A0T0ISF	NXI0730	FI12(2×FI10)	730	584	2860
NXI08205A0T0ISF	NXI0820	FI12(2×FI10)	820	656	3212
NXI09205A0T0ISF	NXI0920	FI12(2×FI10)	920	736	3608
NXI10305A0T0ISF	NXI1030	FI12(2×FI10)	1030	824	4048
NXI11505A0T0ISF	NXI1150	FI13	1150	920	4532
NXI13005A0T0ISF	NXI1300	FI13	1300	1040	5060
NXI14505A0T0ISF	NXI1450	FI13	1450	1160	5720
NXI17705A0T0ISF	NXI1770	FI14	1770	1416	7040
NXI21505A0T0ISF	NXI2150	FI14	2150	1720	8536
NXI27005A0T0ISF	NXI2700	FI14	2700	2160	10 120

5.5.2 Air-Cooled 690 V Units

Table 5: VACON® NXP DCGuard™ Power Ratings with Air-Cooled 690 V VACON® NXP Inverter Units

Type code	Unit type	Enclosure size	DCGuard current I_2 [A]	DC power @1100 V P_{DC} [kW]	Over current and short circuit protection, Instant trip ≤ [A]
NXP00046A2T0SSS	NXP0004	FR6	4.5	4	14
NXP00056A2T0SSS	NXP0005	FR6	5.5	4	20
NXP00076A2T0SSS	NXP0007	FR6	8	6	24
NXP00106A2T0SSS	NXP0010	FR6	10	8	33
NXP00136A2T0SSS	NXP0013	FR6	13.5	11	44
NXP00186A2T0SSS	NXP0018	FR6	18	14	59
NXP00226A2T0SSS	NXP0022	FR6	22	18	79
NXP00276A2T0SSS	NXP0027	FR6	27	22	97

Type code	Unit type	Enclosure size	DCGuard current I_2 [A]	DC power @1100 V P_{DC} [kW]	Over current and short circuit protection, Instant trip ≤ [A]
NXP00346A2T0SSS	NXP0034	FR6	34	27	119
NXP00416A2T0SSS	NXP0041	FR7	41	33	150
NXP00526A2T0SSS	NXP0052	FR7	52	42	180
NXP00526A2T0SSS	NXP0062	FR8	62	50	229
NXP00526A2T0SSS	NXP0080	FR8	80	64	273
NXP00526A2T0SSS	NXP0100	FR8	100	80	352
NXI01256A2T0ISF	NXI0125	FI9	125	100	440
NXI01446A2T0ISF	NXI0144	FI9	144	115	550
NXI01706A2T0ISF	NXI0170	FI9	170	136	634
NXI02056A2T0ISF	NXI0208	FI9	208	166	748
NXI02616A2T0ISF	NXI0261	FI10	261	209	915
NXI03256A2T0ISF	NXI0325	FI10	325	260	1148
NXI03856A2T0ISF	NXI0385	FI10	385	308	1430
NXI04166A2T0ISF	NXI0416	FI10	416	333	1430
NXI04606A2T0ISF	NXI0460	FI12(2×FI10)	460	368	1694
NXI05026A2T0ISF	NXI0502	FI12(2×FI10)	502	402	2024
NXI05906A2T0ISF	NXI0590	FI12(2×FI10)	590	472	2209
NXI06506A2T0ISF	NXI0650	FI12(2×FI10)	650	520	2596
NXI07506A2T0ISF	NXI0750	FI12(2×FI10)	750	600	2860
NXI08206A2T0ISF	NXI0820	FI12(2×FI10)	820	656	2860
NXI09206A2T0ISF	NXI0920	FI13	920	736	3608
NXI10306A2T0ISF	NXI1030	FI13	1030	824	4048
NXI11806A2T0ISF	NXI1180	FI13	1180	944	4532
NXI15006A2T0ISF	NXI1500	FI14(2×FI13)	1500	1200	5720
NXI19006A2T0ISF	NXI1900	FI14(2×FI13)	1900	1520	6600
NXI22506A2T0ISF	NXI2250	FI14(2×FI13)	2250	1800	8360

5.5.3 Liquid-Cooled 500 V Units

Table 6: VACON® NXP DCGuard™ Power Ratings with Liquid-Cooled 500 V VACON® NXP Inverter Units

Type code	Unit type	Enclosure size	DCGuard current I_2 [A]	DC power @800 V P_{DC} [kW]	Over current and short circuit protection, Instant trip ≤ [A]
NXP00165A0T0IWF	NXP0016	CH3	16	13	61

Type code	Unit type	Enclosure size	DCGuard current I_2 [A]	DC power @800 V P_{DC} [kW]	Over current and short circuit protection, Instant trip ≤ [A]
NXP00225A0T0IWF	NXP0022	CH3	22	18	83
NXP00315A0T0IWF	NXP0031	CH3	31	25	116
NXP00385A0T0IWF	NXP0038	CH3	38	30	138
NXP00455A0T0IWF	NXP0045	CH3	45	36	165
NXP00615A0T0IWF	NXP0061	CH3	61	49	226
NXP00725A0T0IWF	NXP0072	CH4	72	58	264
NXP00875A0T0IWF	NXP0087	CH4	87	70	319
NXP01055A0T0IWF	NXP0105	CH4	105	84	385
NXP01405A0T0IWF	NXP0140	CH4	140	112	512
NXP01685A0T0IWF	NXP0168	CH5	168	134	616
NXP02055A0T0IWF	NXP0205	CH5	205	164	754
NXP02615A0T0IWF	NXP0261	CH5	261	209	957
NXP03005A0T0IWF	NXP0300	CH61	300	240	616
NXP03855A0T0IWF	NXP0385	CH61	385	308	792
NXP04605A0T0IWF	NXP0460	CH62	460	368	946
NXP05205A0T0IWF	NXP0520	CH62	520	416	1069
NXP05905A0T0IWF	NXP0590	CH62	590	472	1210
NXP06505A0T0IWF	NXP0650	CH62	650	520	1334
NXP07305A0T0IWF	NXP0730	CH62	730	584	1500
NXP08205A0T0IWF	NXP0820	CH63	820	656	1685
NXP09205A0T0IWF	NXP0920	CH63	920	736	1888
NXP10305A0T0IWF	NXP1030	CH63	1030	824	2116
NXP11505A0T0IWF	NXP1150	CH63	1150	920	2359
NXP13705A0T0IWF	NXP1370	CH64	1370	1096	2812
NXP16405A0T0IWF	NXP1640	CH64	1640	1312	3366
NXP20605A0T0IWF	NXP2060	CH64	2060	1648	4229
NXP23005A0T0IWF	NXP2300	CH64	2300	1840	4722
NXP24705A0T0IWF	NXP2470	2×CH64	2470	1976	5073
NXP29505A0T0IWF	NXP2950	2×CH64	2950	2360	6058
NXP37105A0T0IWF	NXP3710	2×CH64	3710	2968	7617
NXP41405A0T0IWF	NXP4140	2×CH64	4140	3312	8501

5.5.4 Liquid-Cooled 690 V Units

Table 7: VACON® NXP DCGuard™ Power Ratings with Liquid-Cooled 690 V VACON® NXP Inverter Units

Type code	Unit type	Enclosure size	DCGuard current I_2 [A]	DC power @1100 V P_{DC} [kW]	Over current and short circuit protection, Instant trip ≤ [A]
NXP01706A0T0IWF	NXP0170	CH61	170	187	524
NXP02086A0T0IWF	NXP0208	CH61	208	229	641
NXP02616A0T0IWF	NXP0261	CH61	261	287	804
NXP03256A0T0IWF	NXP0325	CH62	325	358	1001
NXP03856A0T0IWF	NXP0385	CH62	385	424	1186
NXP04166A0T0IWF	NXP0416	CH62	416	458	1281
NXP04606A0T0IWF	NXP0460	CH62	460	506	1417
NXP05026A0T0IWF	NXP0502	CH62	502	552	1546
NXP05906A0T0IWF	NXP0590	CH63	590	649	1817
NXP06506A0T0IWF	NXP0650	CH63	650	715	2002
NXP07506A0T0IWF	NXP0750	CH63	750	825	2310
NXP08156A0T0IWF	NXP0815	CH63	815	897	2510
NXP08206A0T0IWF	NXP0820	CH64	820	902	2526
NXP09206A0T0IWF	NXP0920	CH64	920	1012	2834
NXP10306A0T0IWF	NXP1030	CH64	1030	1133	3172
NXP11806A0T0IWF	NXP1180	CH64	1180	1298	3634
NXP13006A0T0IWF	NXP1300	CH64	1300	1430	4004
NXP15006A0T0IWF	NXP1500	CH64	1500	1650	4620
NXP17006A0T0IWF	NXP1700	CH64	1700	1870	5236
NXP18506A0T0IWF	NXP1850	2×CH64	1850	2035	5698
NXP21206A0T0IWF	NXP2120	2×CH64	2120	2332	6530
NXP23406A0T0IWF	NXP2340	2×CH64	2340	2574	7207
NXP27006A0T0IWF	NXP2700	2×CH64	2700	2970	8316
NXP31006A0T0IWF	NXP3100	2×CH64	3100	3410	9548

5.6 Total Capacitance, Inductance, and Resistance

The total capacitance, inductance, and resistance for all VACON® NXP inverters are available from the nearest Danfoss Drives representative.

The requested data is given case by case and must only be used to make a selectivity study for a system including the VACON® NXP DCGuard™.

6 Electrical Installation Guidelines

6.1 DCGuard Topologies

VACON® NXP DCGuard™ can be used to give short circuit protection in different DC-grid topologies:

- Directional topology
- Peer-to-peer topology
- Ring topology

6.1.1 Directional Topology

VACON® NXP DCGuard™ can be used to give one directional protection. The directional topology only gives short circuit protection for a short circuit current going from the main DC grid to one of the DC subgrids.

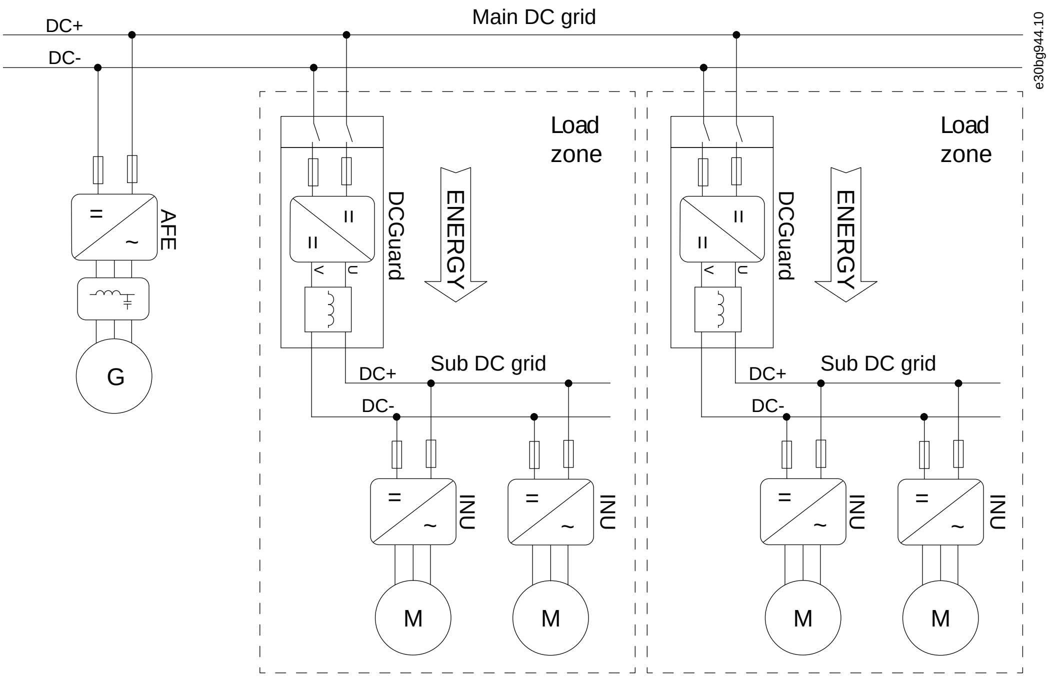


Illustration 15: VACON® NXP DCGuard™ Directional Topology

6.1.2 Peer-to-peer Topology

To give two-directional short-circuit protection, two VACON® NXP DCGuard™ units can be connected in a peer-to-peer topology. The connection between the two DCGuard units can be done by using two or three bus-tie cables.

The 2-cable connection is the default connection method, but also the 3-cable connection can be used if necessary.

2-Cable Connection

Connect the 2-cable connection according to the following guidelines:

- Connect the DC- bus-tie cable to the V-phase terminal in both units.
- Connect the DC+ bus-tie cable to the U-phase terminal in one unit and to the W-phase terminal in the other unit.

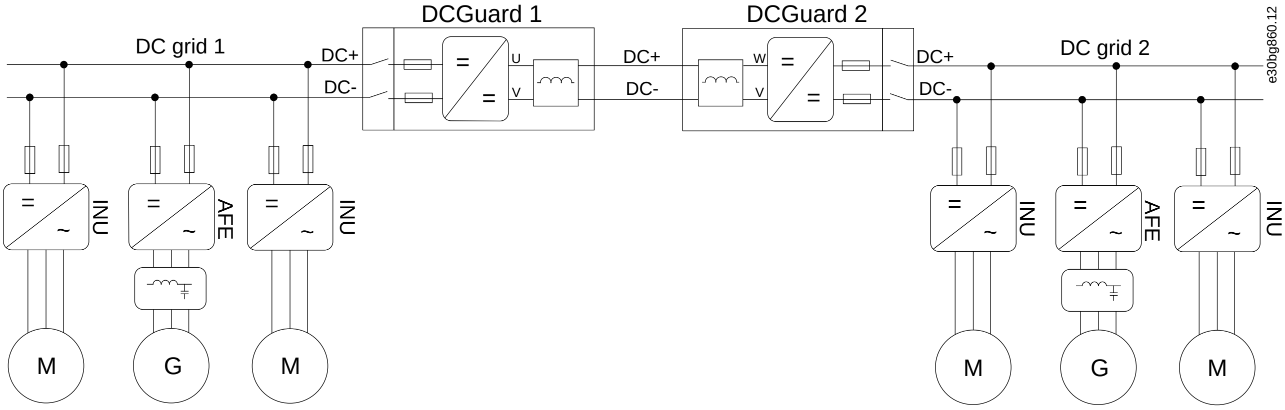


Illustration 16: VACON® NXP DCGuard™ Peer-to-peer Topology 2-Cable Connection

3-Cable Connection

Connect the 3-cable connection according to the following guidelines:

- Connect the DC- bus-tie cable to the V-phase terminal in both units.
- Connect the first DC+ bus-tie cable to the U-phase terminal in one unit and to the W-phase terminal in the other unit.
- Connect the second DC+ bus-tie cable to the W-phase terminal in one unit and to the U-phase terminal in the other unit.

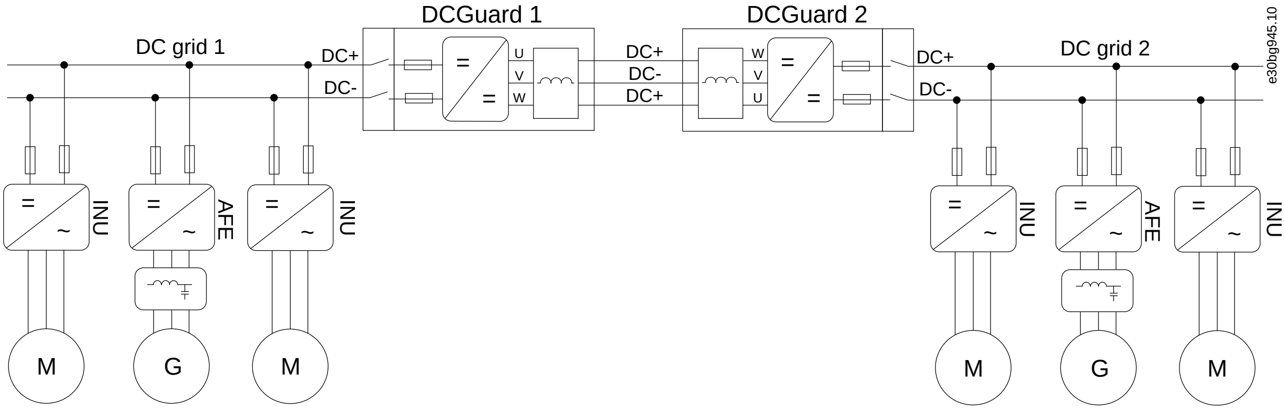


Illustration 17: VACON® NXP DCGuard™ Peer-to-peer Topology 3-Cable Connection

6.1.3 Ring Topology

Ring shaped topologies are used in some applications to connect two or more DC grids. VACON® NXP DCGuard™ can be used to form a ring topology by using several peer-to-peer connections.

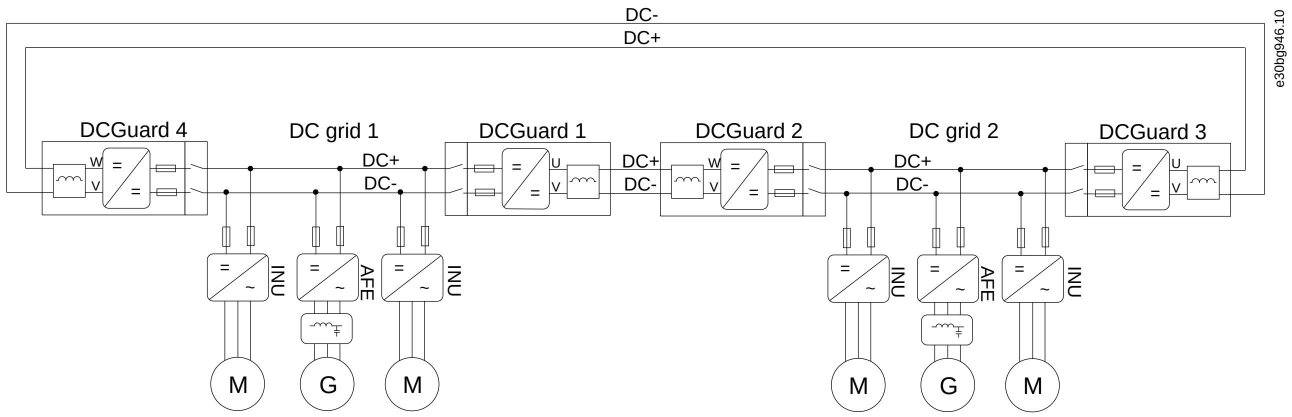


Illustration 18: VACON® NXP DCGuard™ Ring Topology

6.2 Parallel Installation

Two or more VACON® NXP DCGuard™ units can be installed in parallel to achieve a higher power rating. To have good current sharing between the DCGuard units, it is important that only identical systems are installed in parallel. The parallel systems must have identical:

- DCGuard units
- Filters
- Cable types
- Cable installation
- Fuses

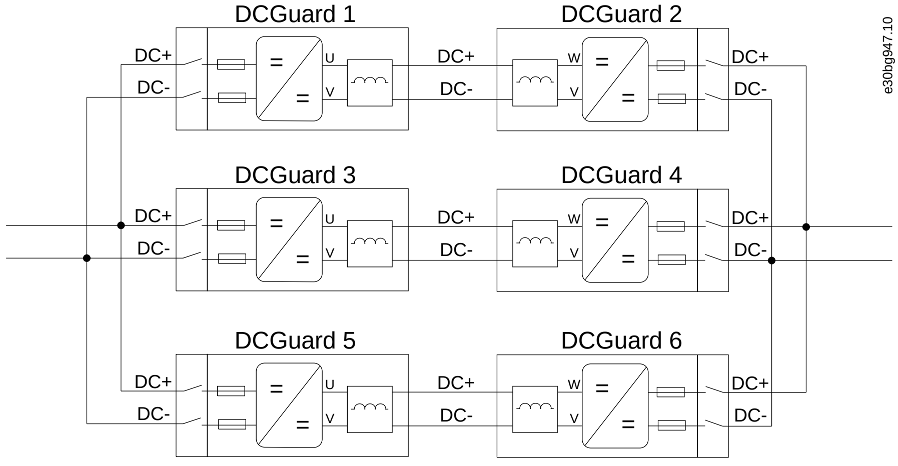


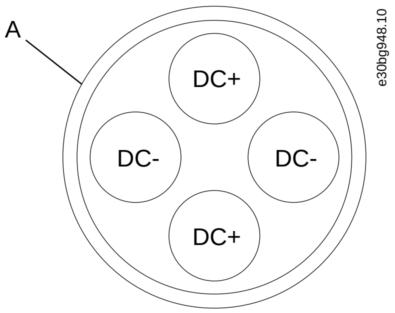
Illustration 19: Circuit Diagram of a Parallel Installation of Danfoss Units

6.3 Bus-Tie Cables

To connect two or more DCGuard units together, bus-tie cables are required.

Recommended specifications for the bus-tie cables:

- Shielded type cable.
  - The cable shield must be connected to ground at both ends.
- Symmetrical 4-wire cable.
  - Two wires for DC+ and two wires for DC-.
- The cable must withstand minimum 2×DC-link voltage.
  - In the worst case, the common-mode voltage is 2×DC-link voltage potential to ground.



A	Cable shield

Illustration 20: Recommended Bus-Tie Cable Type

6.4 HF Capacitors

It is recommended to connect the DC+ and DC- (clamp) of the DC grids to ground with HF capacitors. Select the size of the HF capacitors according to the system parasitic capacitance to ground.

- 10× system parasitic capacitance ≈ 100 V common-mode voltage to ground.
- 100× system parasitic capacitance ≈ 10 V common-mode voltage to ground.

In other words, system parasitic capacitance is where the common-mode voltage causes current to PE.

The following components have leakage current to ground driven by the common-mode voltage:

- Cables between INU and motor, and the motor itself.
- Cables between grid converter and isolation transformer, and the sine-wave filter itself.

6.5 Cabling

The cabling of the VACON® NXP DCGuard™ inverter units is different depending on the unit type and nominal current of the units. See:

- 6.5.1 Wiring Diagrams for Air-Cooled Inverter Units
- 6.5.2 Wiring Diagrams for Liquid-Cooled Inverter Units

Definitions for the wiring diagrams:

Item	Definition
-F	Fuse, type aR. See the VACON® NXP DCGuard™ design guide for instructions on fuse selection.
-K	Mechanical disconnector
-L	Output di/dt filter

6.5.1 Wiring Diagrams for Air-Cooled Inverter Units

Wiring diagrams for air-cooled inverter units, 500 V (465–800 V DC):

- NXP0003–NXP0520, enclosure sizes FR4 to FI10, see illustration 21.
- NXP0590–NXP0730, enclosure size FI12, see illustration 22.
- NXP0820–NXP1030, enclosure size FI12, see illustration 23.
- NXP1150–NXP1450, enclosure size FI13, see illustration 24.
- NXP1770–NXP2150, enclosure size FI14, see illustration 25.

Wiring diagrams for air-cooled inverter units, 690 V (640–1100 V DC):

- NXP0004–NXP0416, enclosure sizes FR4 to FI10, see illustration 21.
- NXP0460–NXP0590, enclosure size FI12, see illustration 22.
- NXP0650–NXP0820, enclosure size FI12, see illustration 23.
- NXP0920–NXP1180, enclosure size FI13, see illustration 24.
- NXP1500–NXP2250, enclosure size FI14, see illustration 25.

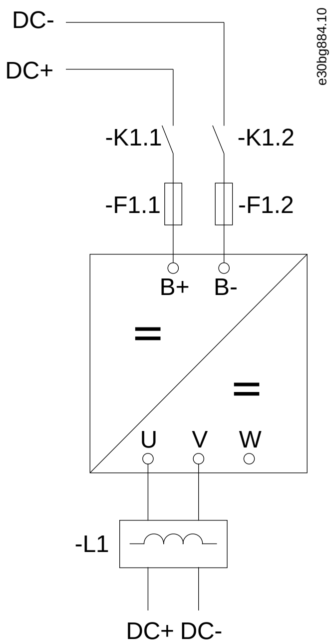


Illustration 21: Basic Wiring Diagram for Enclosure Sizes FR4–FI10

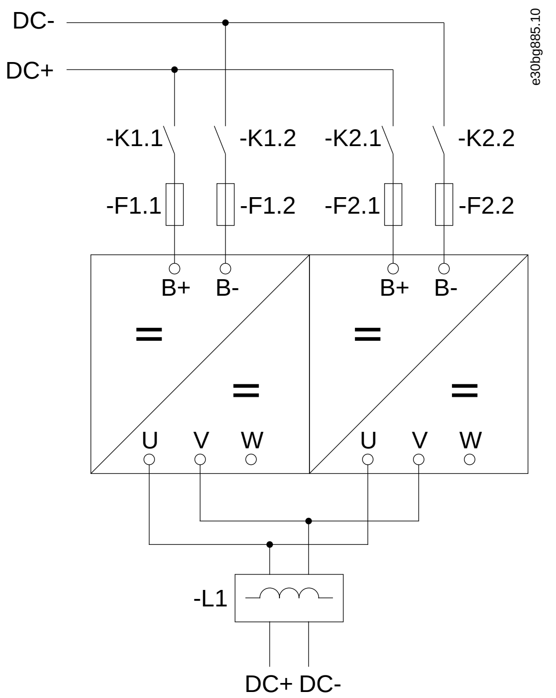


Illustration 22: Basic Wiring Diagram for Enclosure Size FI12 with 1 Output Filter (only valid for 500 V NXP0590–NXP0730 and 690 V NXP0460–NXP0590)

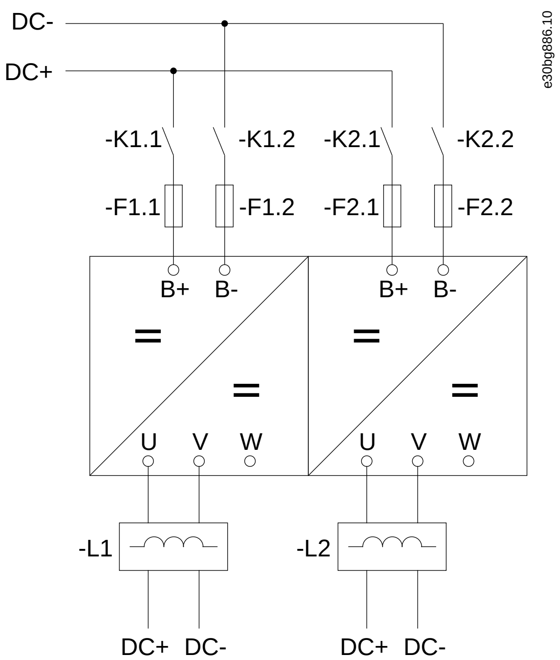


Illustration 23: Basic Wiring Diagram for Enclosure Size FI12 with 2 Output Filters

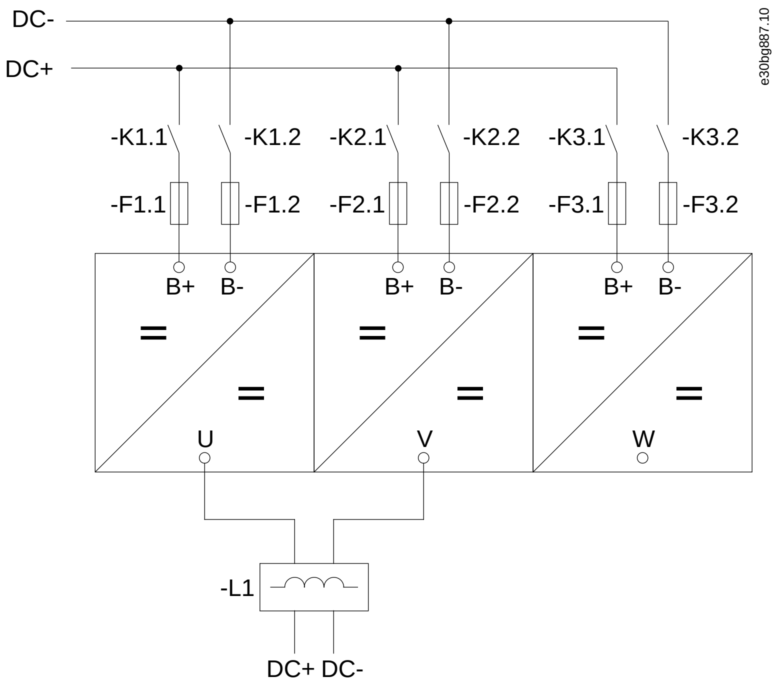


Illustration 24: Basic Wiring Diagram for Enclosure Size FI13

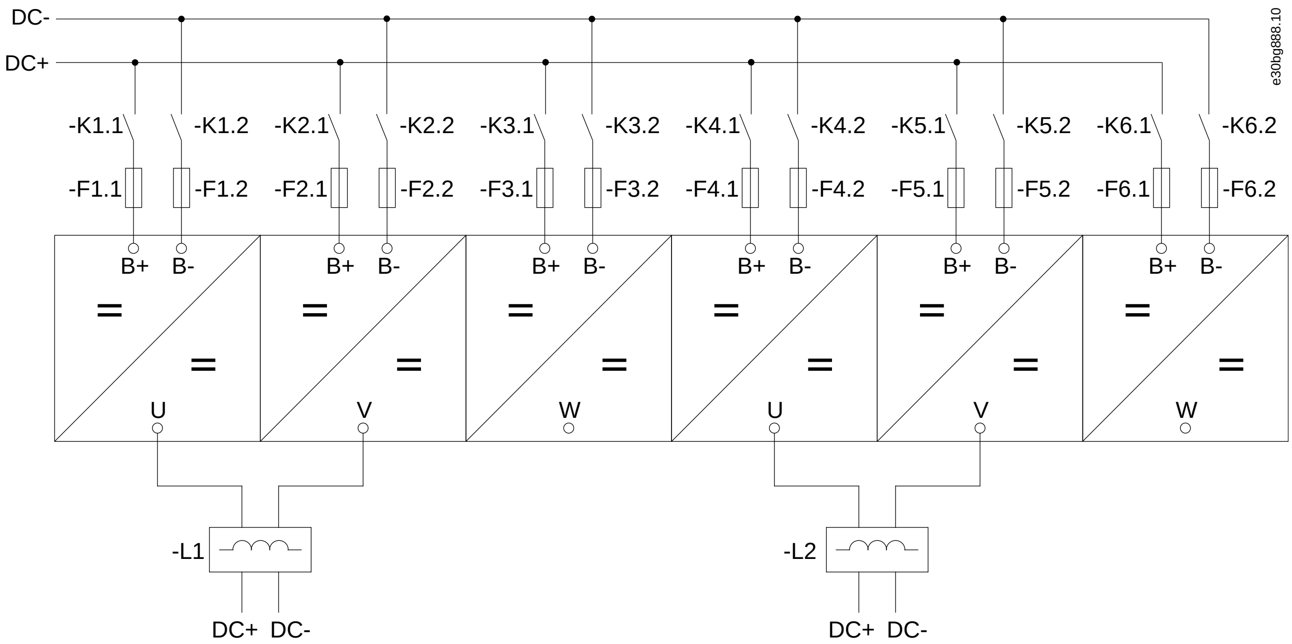


Illustration 25: Basic Wiring Diagram for Enclosure Size FI14

6.5.2 Wiring Diagrams for Liquid-Cooled Inverter Units

Wiring diagrams for liquid-cooled inverter units, 500 V (465–800 V DC):

- NXP0016–NXP0730, enclosure sizes CH3 to CH62, see illustration 26.
- NXP0820–NXP1150, enclosure size CH63, see illustration 27.
- NXP1370, enclosure size CH64, see illustration 28.
- NXP1640–NXP2300, enclosure size CH64, see illustration 29.
- NXP2470–NXP4140, enclosure size 2 x CH64, see illustration 30.

Wiring diagrams for liquid-cooled inverter units, 690 V (640–1100 V DC):

- NXP0170–NXP0502, enclosure sizes CH61 to CH62, see illustration 26.
- NXP0590–NXP0750, enclosure size CH63, see illustration 27.
- NXP0820–NXP1500, enclosure size CH64, see illustration 28.
- NXP1700, enclosure size CH64, see illustration 29.
- NXP1850–NXP3100, enclosure size 2 x CH64, see illustration 30.

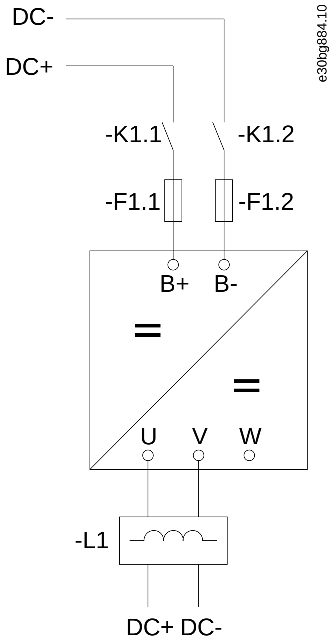


Illustration 26: Basic Wiring Diagram for Enclosure Sizes CH3–CH62

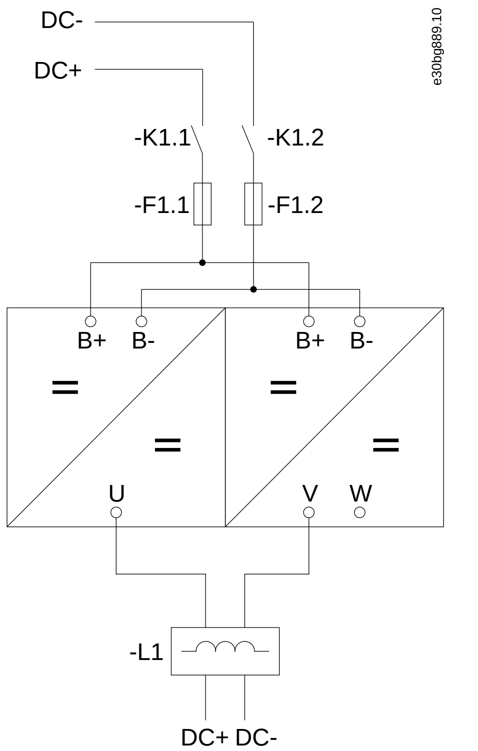


Illustration 27: Basic Wiring Diagram for Enclosure Size CH63

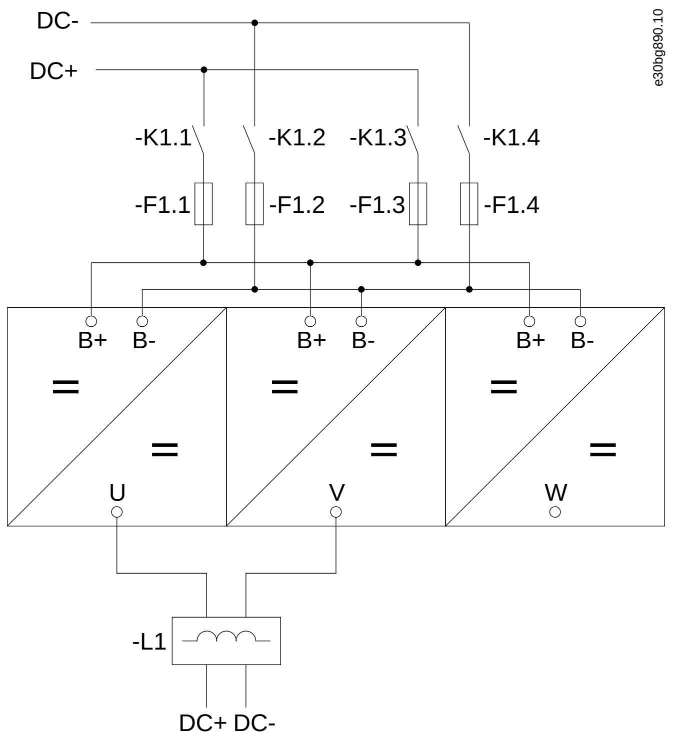


Illustration 28: Basic Wiring Diagram for Enclosure Size CH64 with 4 Input Fuses

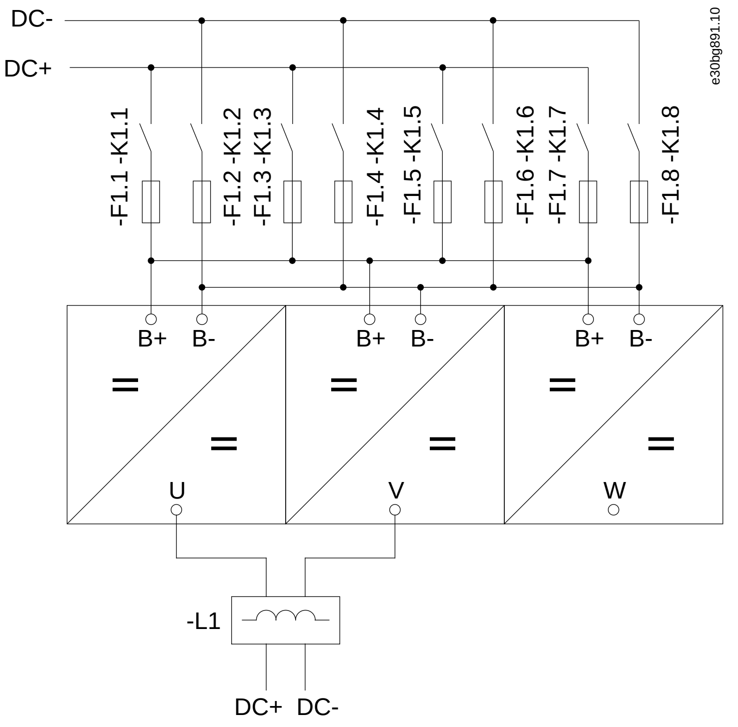


Illustration 29: Basic Wiring Diagram for Enclosure Size CH64 with 8 Input Fuses

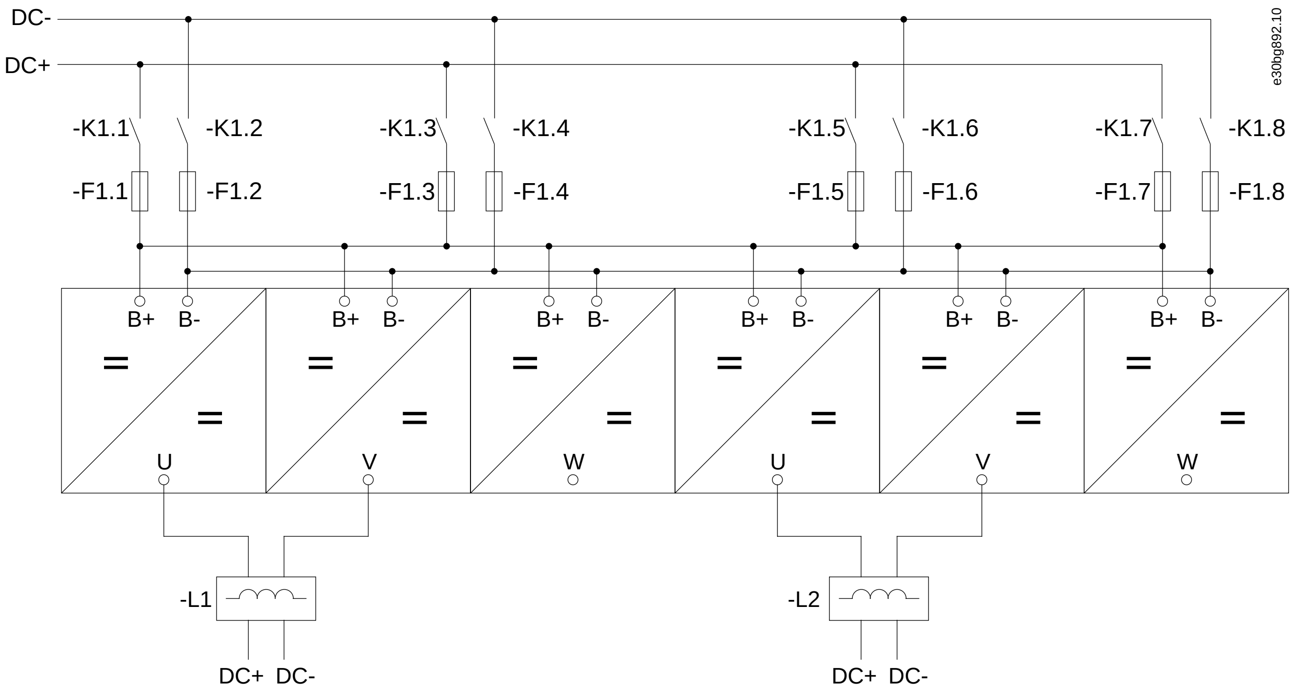


Illustration 30: Basic Wiring Diagram for Enclosure Size 2 x CH64

6.6 Terminal Definitions

The terminals used in the VACON® NXP DCGuard™ application are:

- DC-bus connections: Terminals B+ and B-
- Peer-to-peer connections: Terminals U, V, and W

The locations of the terminals in the different inverter unit enclosure sizes are shown in the illustrations in:

- 6.6.1 Terminal Locations in Air-Cooled Inverter Units
- 6.6.2 Terminal Locations in Liquid-Cooled Inverter Units

6.6.1 Terminal Locations in Air-Cooled Inverter Units

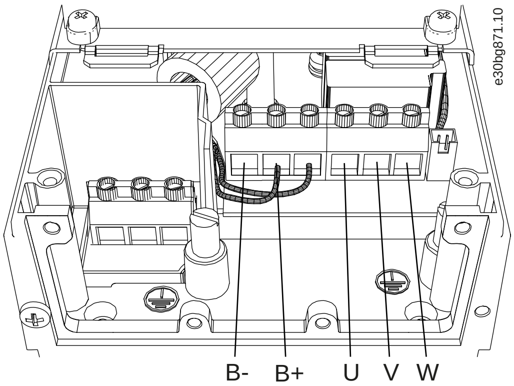


Illustration 31: Terminal Locations in Enclosure Sizes FR4 and FR5

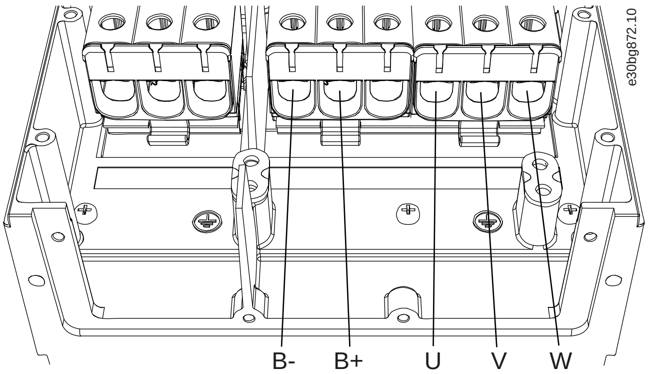


Illustration 32: Terminal Locations in Enclosure Size FR6

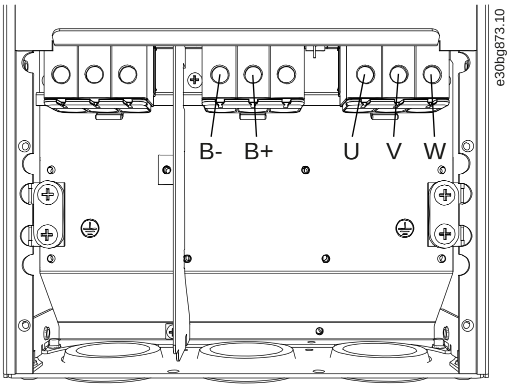
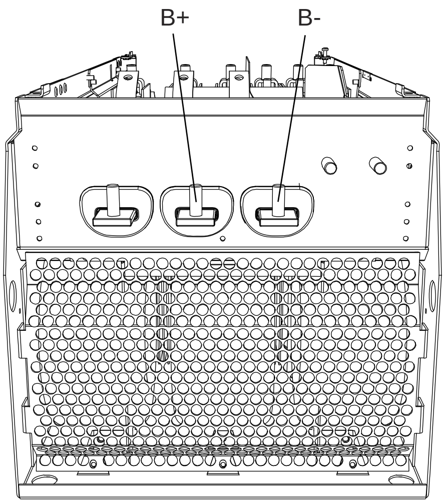


Illustration 33: Terminal Locations in Enclosure Size FR7



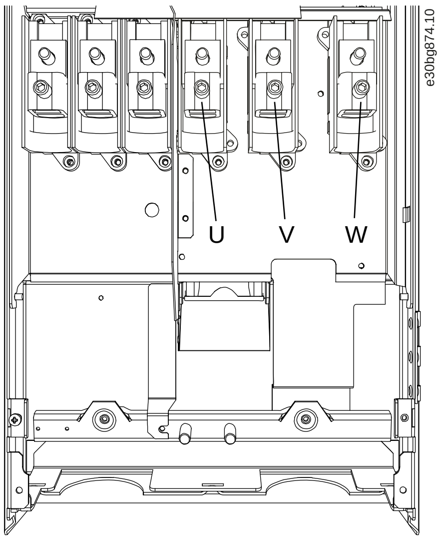


Illustration 34: Terminal Locations in Enclosure Size FR8

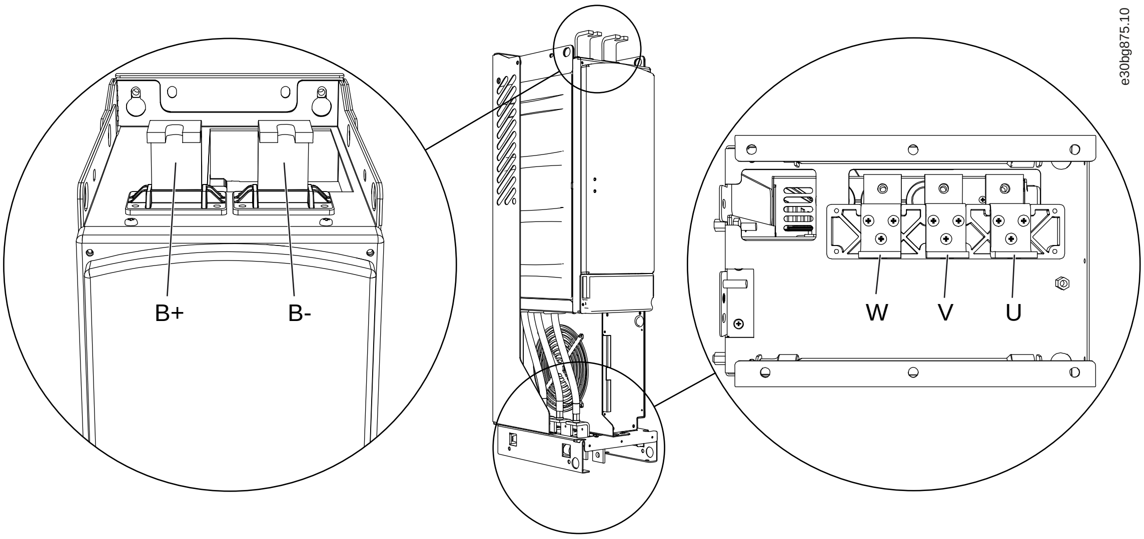


Illustration 35: Terminal Locations in Enclosure Sizes FI9, FI10, and FI12

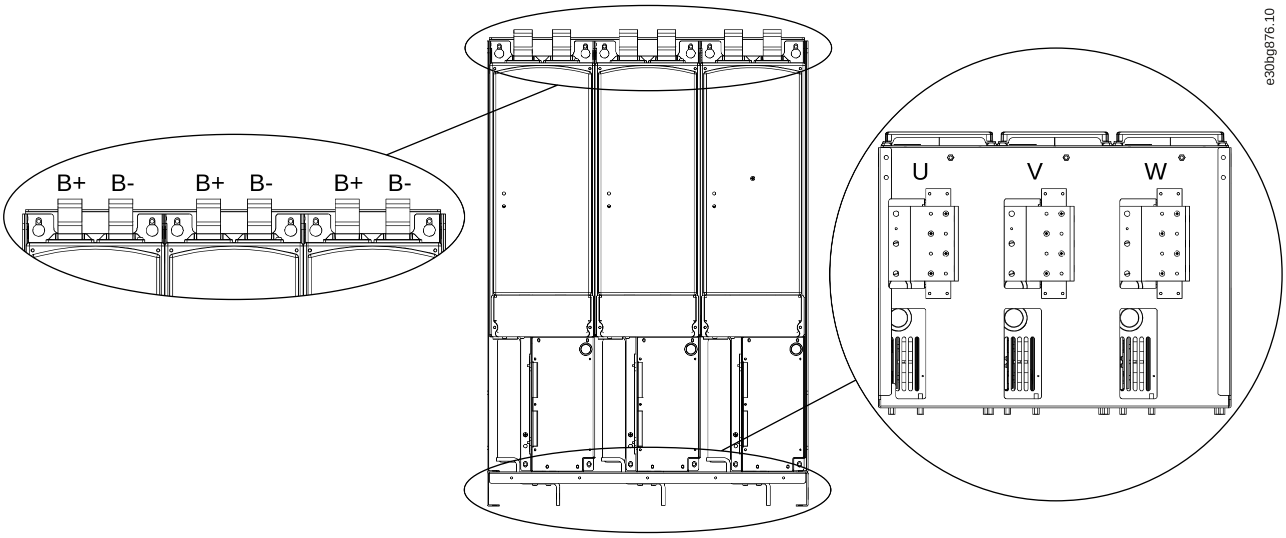


Illustration 36: Terminal Locations in Enclosure Sizes FI13 and FI14

6.6.2 Terminal Locations in Liquid-Cooled Inverter Units

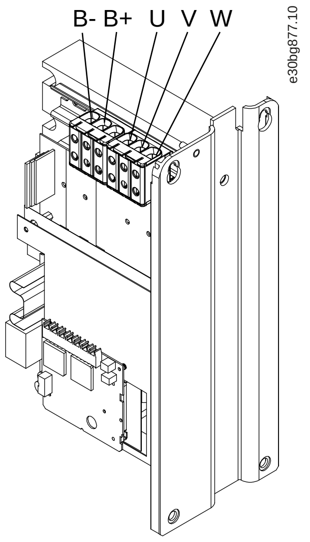


Illustration 37: Terminal Locations in Enclosure Size CH3

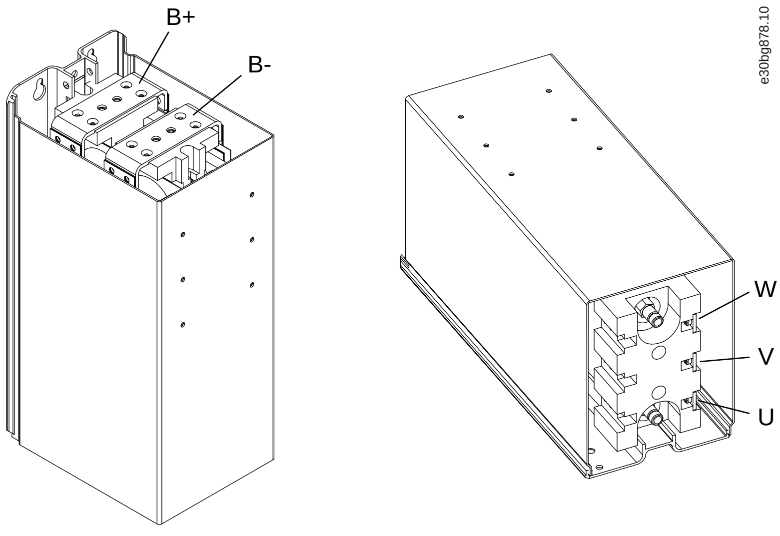


Illustration 38: Terminal Locations in Enclosure Size CH4

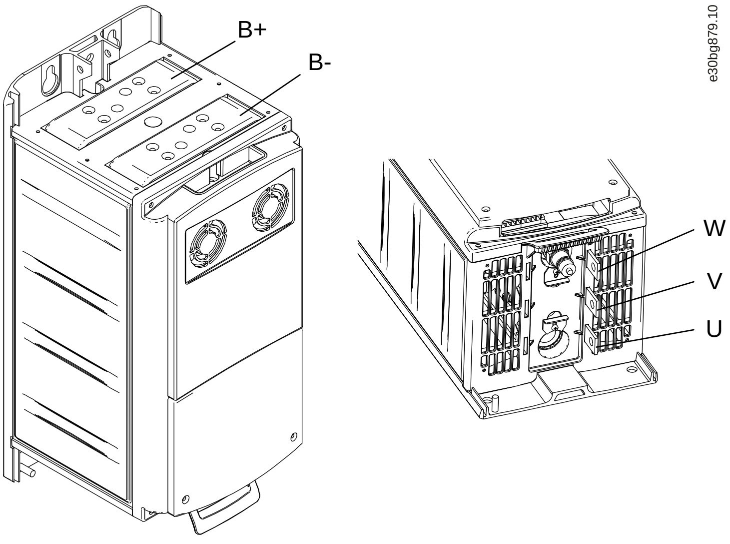


Illustration 39: Terminal Locations in Enclosure Size CH5

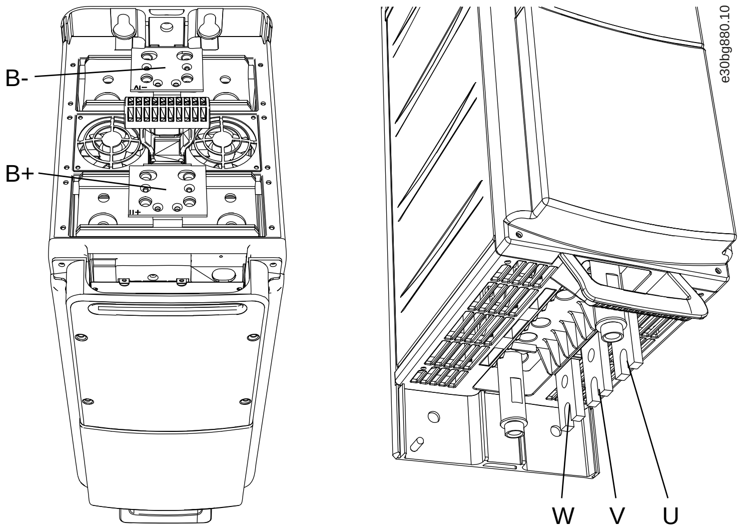


Illustration 40: Terminal Locations in Enclosure Size CH61

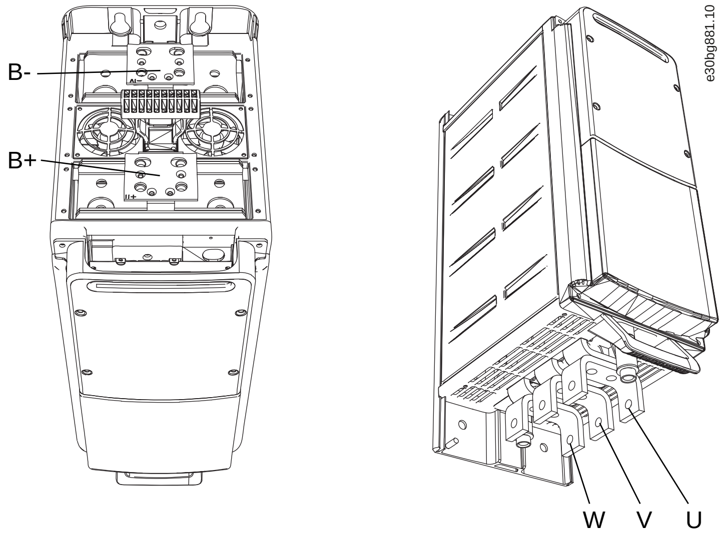


Illustration 41: Terminal Locations in Enclosure Size CH62

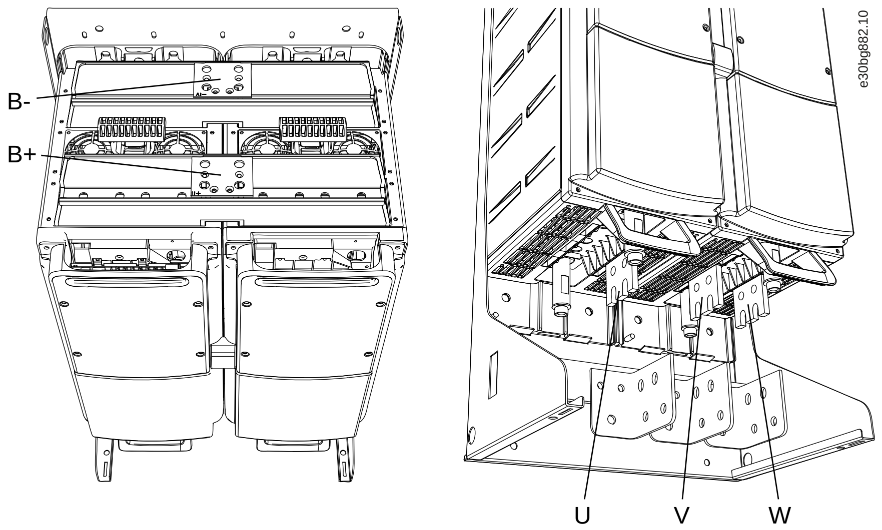


Illustration 42: Terminal Locations in Enclosure Size CH63

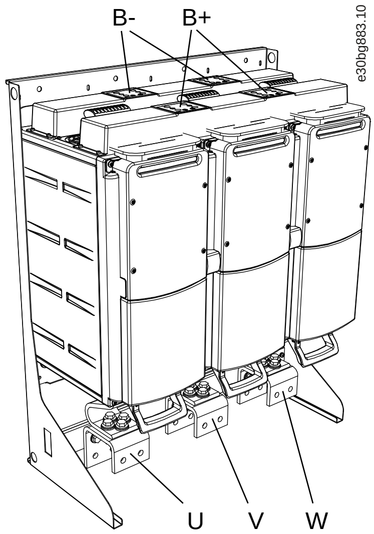


Illustration 43: Terminal Locations in Enclosure Size CH64

6.7 Control I/O Configuration

The figure shows the default I/O configuration for the VACON® NXP DCGuard™ application and a basic description of the terminals and signals of the I/O board.

For more information on control terminals, see the VACON® NXP DCGuard™ application guide.

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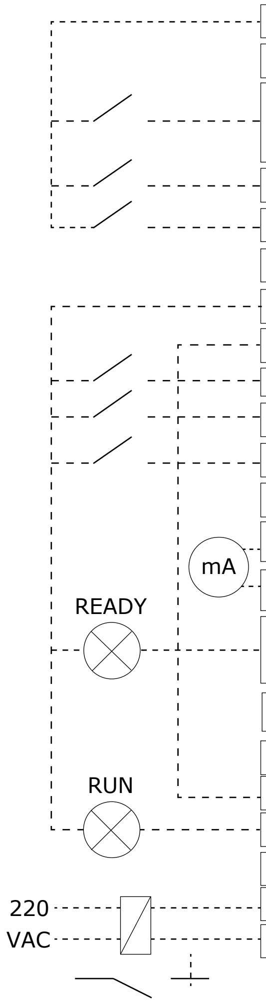

Standard I/O board			
Terminal		**Signal**	**Description**
1	+10Vref	Reference voltage output	Voltage for potentiometer, etc.
2	AI1+	Analog input 1 Range 0-10 V, R_i = 200 Ω Range 0-20 mA R_i = 250 Ω	Analog input 1 Input range selected by jumpers Default range: Voltage 0-10 V
3	AI1-	I/O Ground	Ground for reference and controls
4	AI2+	Analog input 2 Range 0-10 V, R_i = 200 Ω Range 0-20 mA R_i = 250 Ω	Analog input 2 Input range selected by jumpers Default range: Current 0-20 mA
5	AI2-		
6	+24V	Control voltage output	Voltage for switches, etc. max 0.1 A
7	GND	I/O ground	Ground for reference and controls
8	DIN1	Start Request (Close Request) Programmable G2.2	Contact closed = Start Request (Contact closed = Close Request)
9	DIN2	Programmable G2.2	No function defined at default
10	DIN3	Programmable G2.2	No function defined at default
11	CMA	Common for DIN1-DIN3	Connect to GND or +24 V
12	+24V	Control voltage output	Voltage for switches (see #6)
13	GND	I/O ground	Ground for reference and controls
14	DIN4	Programmable G2.2	No function defined at default
15	DIN5	Programmable G2.2	No function defined at default
16	DIN6	Programmable G2.2	No function defined at default
17	CMB	Common for DIN4-DIN6	Connect to GND or +24 V
18	AO1+	Analog output 1 Programmable G2.3	Output range selected by jumpers Range 0-20 mA, R_L max. 500 Ω Range 0-10 V, R_L > 1 kΩ
19	AO1-		
20	DO1	Digital output Programmable G2.3	Programmable Open collector, I ≤ 50 mA, U ≤ 48 V DC
OPTA2			
21	RO1	Relay output 1 Programmable G2.3	Switching capacity 24 V DC / 8 A 250 V AC / 8 A 125 V DC / 0.4 A
22	RO1		
23	RO1		
24	RO2	Relay output 2 Programmable G2.3	Switching capacity 24 V DC / 8 A 250 V AC / 8 A 125 V DC / 0.4 A
25	RO2		
26	RO2		

Illustration 44: The Default I/O Configuration for the VACON® NXP DCGuard™ Application

7 How to Select the VACON® NXP DCGuard™

7.1 VACON® Select Web Tool

The VACON® Select Web Tool is a useful and easy-to-use tool for selecting the correct VACON® NXP DCGuard™ for applications. See illustration 45.

The tool gives the following information:

- Recommended VACON® NXP unit
- Recommended filter (dU/dt)
- Recommended aR fuses (from VACON® NXP manuals)
- Efficiency calculation
- Drawings

The web tool is accessible to Danfoss Drives personnel and is available at http://select.corp.intra.vacon.com/sizing/login.jspx. Contact the nearest Danfoss Drives representative for more information.

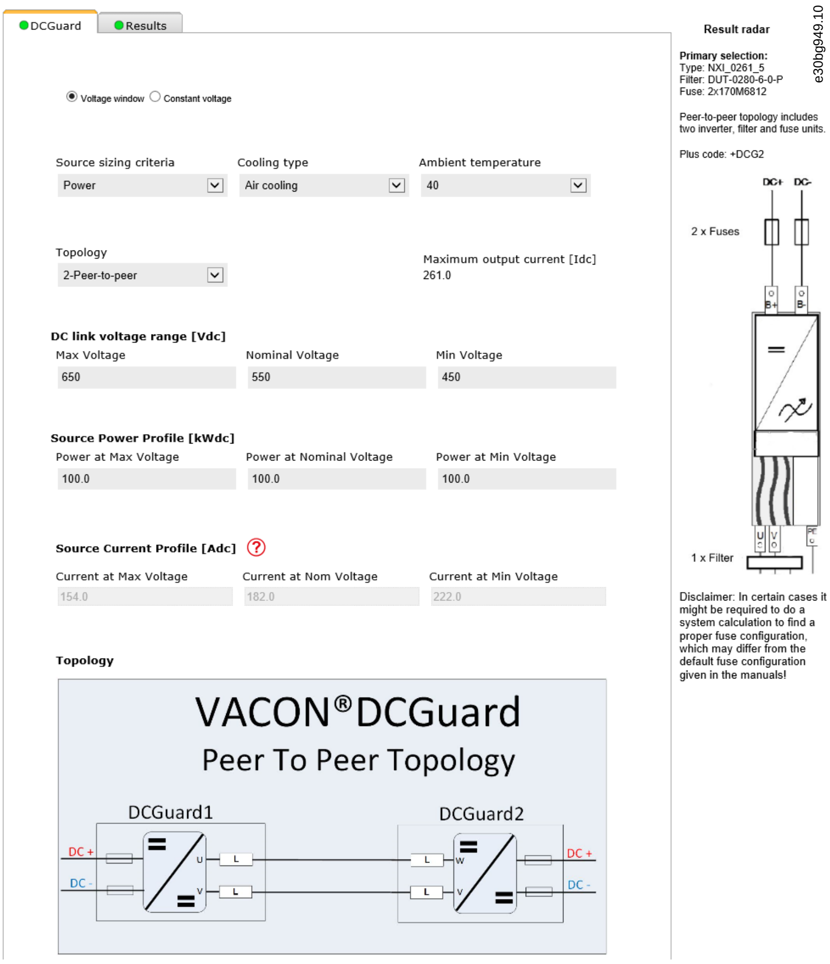

Illustration 45: Screenshot from the VACON® Select Web Tool

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Vacon Ltd
Member of the Danfoss Group
Runsorintie 7
65380 Vaasa
Finland
drives.danfoss.com