A Bosch Company

IndraDrive ML

Power Generating Units with HMU05

Project Planning Manual
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HMU05 universal inverters can be used as **grid inverters in power generating units for the public grid system** (low-voltage grid, medium-voltage grid) while complying with VDE-AR-N 4110:2018-11.

⚠ WARNING	**Observe Project Planning Manual "IndraDrive ML Drive Systems with HMU05" (de: R911344278; en: R911344279).**

This documentation is a supplement of the Project Planning Manual "IndraDrive ML Drive Systems with HMU05" and is only valid together with the Drive Systems with HMU05 manual.

2 Important directions for use

2.1 Intended use

2.1.1 Introduction

Rexroth products are developed and manufactured to the state-of-the-art. They are tested prior to delivery to ensure operational safety and reliability.

⚠ WARNING **Personal injury and property damage by incorrect use of the products!**

The products have been designed for use in an industrial environment and may only be used as intended. Failure to use them in the intended way may cause situations resulting in property damage and personal injury.

☞ Rexroth as the manufacturer shall not honor any warranty, liability or compensatory claims for damages resulting from unintended use of the products. The user alone shall bear the risks of unintended use of the products.

Before using Rexroth products, make sure that all the prerequisites for an intended use of the products are satisfied:

- Anyone that in any way, shape or form uses our products must have read and understood the relevant safety instructions and the intended use.
- Do not change the original state of the hardware products, i.e., do not make any structural modifications. Software products must not be decompiled and their source codes must not be modified.
- Damaged or defective products must not be installed or commissioned.
- It has to be ensured that the products are installed according to the provisions specified in the documentation.

2.1.2 Areas of use and application

Universal inverters of the "HMU05" series can be used as **grid inverters in power generating units for the public grid system** (medium-voltage grid, low-voltage grid) while complying with VDE-AR-N 4110:2018-11.

Controlling and monitoring the devices may require additional sensors and actuators.

☞ The devices may only be used with allowed accessories and attachments. Components that are not expressly mentioned may neither be attached nor connected. The same applies to cables and lines.

Operation is only allowed in the specified configurations and combinations of the components using the software and firmware as specified in the relevant functional description.

Devices have to be programmed before commissioning to ensure that the motor executes the functions specific to the application.

Devices may only be operated under the defined assembly and installation conditions, in the specified mounting position and under the specified ambient conditions (temperature, degree of protection, humidity, EMC, etc.).

2.2 Unintended use

"Unintended use" refers to using the devices outside of the operating conditions, technical data and specifications described in this documentation.

Devices must not be used, if …

- they are exposed to operating conditions that do not meet the specified ambient conditions. This includes, for example, operation under water, under extreme temperature fluctuations or extreme maximum temperatures.
- Furthermore, devices must not be used in applications that have not been expressly authorized by Rexroth. Please refer to the specifications in the general safety instructions!

☞ Components of the Rexroth IndraDrive ML system are **products of Category C3** (with restricted distribution) in accordance with IEC 61800-3. The Category C3 comprises EMC limit values for line-based and radiated noise emission.

Compliance with these Categories requires the appropriate measures of interference suppression (e.g., mains filters, shielding measures) to be used in the drive system.

These components are not provided for use in a public low-voltage grid supplying residential areas. If these components are used in such a mains, high-frequency interference is to be expected. This can require additional measures of interference suppression.

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3 Safety instructions for electric drives and controls

3.1 Definitions of terms

Application documentation Application documentation comprises the entire documentation used to inform the user of the product about the use and safety-relevant features for configuring, integrating, installing, mounting, commissioning, operating, maintaining, repairing and decommissioning the product. The following terms are also used for this kind of documentation: Operating Instructions, Commissioning Manual, Instruction Manual, Project Planning Manual, Application Description, etc.

Component A component is a combination of elements with a specified function, which are part of a piece of equipment, device or system. Components of the electric drive and control system are, for example, supply units, drive controllers, mains choke, mains filter, motors, cables, etc.

Control system A control system comprises several interconnected control components placed on the market as a single functional unit.

Device A device is a finished product with a defined function, intended for users and placed on the market as an individual piece of merchandise.

Electrical equipment Electrical equipment encompasses all devices used to generate, convert, transmit, distribute or apply electrical energy, such as electric motors, transformers, switching devices, cables, lines, power-consuming devices, circuit board assemblies, plug-in units, control cabinets, etc.

Electric drive system An electric drive system comprises all components from mains supply to motor shaft; this includes, for example, electric motor(s), motor encoder(s), supply units and drive controllers, as well as auxiliary and additional components, such as mains filter, mains choke and the corresponding lines and cables.

Installation An installation consists of several devices or systems interconnected for a defined purpose and on a defined site which, however, are not intended to be placed on the market as a single functional unit.

Machine A machine is the entirety of interconnected parts or units at least one of which is movable. Thus, a machine consists of the appropriate machine drive elements, as well as control and power circuits, which have been assembled for a specific application. A machine is, for example, intended for processing, treatment, movement or packaging of a material. The term "machine" also covers a combination of machines which are arranged and controlled in such a way that they function as a unified whole.

Manufacturer The manufacturer is an individual or legal entity bearing responsibility for the design and manufacture of a product which is placed on the market in the individual's or legal entity's name. The manufacturer can use finished products, finished parts or finished elements, or contract out work to subcontractors. However, the manufacturer must always have overall control and possess the required authority to take responsibility for the product.

Product Examples of a product: Device, component, part, system, software, firmware, among other things.

Project Planning Manual A Project Planning Manual is part of the application documentation used to support the sizing and planning of systems, machines or installations.

Qualified persons In terms of this application documentation, qualified persons are those persons who are familiar with the installation, mounting, commissioning and operation of the components of the electric drive and control system, as well as with the hazards this implies, and who possess the qualifications their work requires. To comply with these qualifications, it is necessary, among other things,

1) to be trained, instructed or authorized to switch electric circuits and devices safely on and off, to ground them and to mark them

2) to be trained or instructed to maintain and use adequate safety equipment

3) to attend a course of instruction in first aid

User A user is a person installing, commissioning or using a product which has been placed on the market.

3.2 General information

3.2.1 Using the Safety instructions and passing them on to others

Do not attempt to install and operate the components of the electric drive and control system without first reading all documentation provided with the product. Read and understand these safety instructions and all user documentation prior to working with these components. If you do not have the user documentation for the components, contact your responsible Rexroth sales partner. Ask for these documents to be sent immediately to the person or persons responsible for the safe operation of the components.

If the component is resold, rented and/or passed on to others in any other form, these safety instructions must be delivered with the component in the official language of the user's country.

Improper use of these components, failure to follow the safety instructions in this document or tampering with the product, including disabling of safety devices, could result in property damage, injury, electric shock or even death.

3.2.2 Requirements for safe use

Read the following instructions before initial commissioning of the components of the electric drive and control system in order to eliminate the risk of injury and/or property damage. You must follow these safety instructions.

- Rexroth is not liable for damages resulting from failure to observe the safety instructions.
- Read the operating, maintenance and safety instructions in your language before commissioning. If you find that you cannot completely understand the application documentation in the available language, please ask your supplier to clarify.
- Proper and correct transport, storage, mounting and installation, as well as care in operation and maintenance, are prerequisites for optimal and safe operation of the component.
- Only qualified persons may work with components of the electric drive and control system or within its proximity.
- Only use accessories and spare parts approved by Rexroth.
- Follow the safety regulations and requirements of the country in which the components of the electric drive and control system are operated.
- Only use the components of the electric drive and control system in the manner that is defined as appropriate. See chapter "Appropriate Use".
- The ambient and operating conditions given in the available application documentation must be observed.
- Applications for functional safety are only allowed if clearly and explicitly specified in the application documentation "Integrated Safety Technolo-

gy". If this is not the case, they are excluded. Functional safety is a safety concept in which measures of risk reduction for personal safety depend on electrical, electronic or programmable control systems.

- The information given in the application documentation with regard to the use of the delivered components contains only examples of applications and suggestions.

  The machine and installation manufacturers must

  – make sure that the delivered components are suited for their individual application and check the information given in this application documentation with regard to the use of the components,
  – make sure that their individual application complies with the applicable safety regulations and standards and carry out the required measures, modifications and complements.
- Commissioning of the delivered components is only allowed once it is sure that the machine or installation in which the components are installed complies with the national regulations, safety specifications and standards of the application.
- Operation is only allowed if the national EMC regulations for the application are met.
- The instructions for installation in accordance with EMC requirements can be found in the section on EMC in the respective application documentation.

  The machine or installation manufacturer is responsible for compliance with the limit values as prescribed in the national regulations.
- The technical data, connection and installation conditions of the components are specified in the respective application documentations and must be followed at all times.

National regulations which the user has to comply with

- European countries: In accordance with European EN standards
- United States of America (USA):
  – National Electrical Code (NEC)
  – National Electrical Manufacturers Association (NEMA), as well as local engineering regulations
  – Regulations of the National Fire Protection Association (NFPA)
- Canada: Canadian Standards Association (CSA)
- Other countries:
  – International Organization for Standardization (ISO)
  – International Electrotechnical Commission (IEC)

3.2.3 Hazards by improper use

- High electrical voltage and high working current! Danger to life or serious injury by electric shock!
- High electrical voltage by incorrect connection! Danger to life or injury by electric shock!
- Dangerous movements! Danger to life, serious injury or property damage by unintended motor movements!
- Health hazard for persons with heart pacemakers, metal implants and hearing aids in proximity to electric drive systems!

- Risk of burns by hot housing surfaces!
- Risk of injury by improper handling! Injury by crushing, shearing, cutting, hitting!
- Risk of injury by improper handling of batteries!
- Risk of injury by improper handling of pressurized lines!

3.3 Instructions with regard to specific dangers

3.3.1 Protection against contact with electrical parts and housings

☞ This section concerns components of the electric drive and control system with voltages of **more than 50 volts**.

Contact with parts conducting voltages above 50 volts can cause personal danger and electric shock. When operating components of the electric drive and control system, it is unavoidable that some parts of these components conduct dangerous voltage.

High electrical voltage! Danger to life, risk of injury by electric shock or serious injury!

- Only qualified persons are allowed to operate, maintain and/or repair the components of the electric drive and control system.
- Follow the general installation and safety regulations when working on power installations.
- Before switching on, the equipment grounding conductor must have been permanently connected to all electrical components in accordance with the connection diagram.
- Even for brief measurements or tests, operation is only allowed if the equipment grounding conductor has been permanently connected to the points of the components provided for this purpose.
- Before accessing electrical parts with voltage potentials higher than 50 V, you must disconnect electrical components from the mains or from the power supply unit. Secure the electrical component from reconnection.
- With electrical components, observe the following aspects:

  Always wait **30 minutes** after switching off power to allow live capacitors to discharge before accessing an electrical component. Measure the electrical voltage of live parts before beginning to work to make sure that the equipment is safe to touch. Measure the electrical voltage both conductor against conductor and conductor against ground (PE).

  Particularly if **DC bus ground capacitor pairs without discharging resistors (HAS04.1-003-NN1-NN)** are used, dangerous voltages against ground may be present for more than **24 hours** after the power supply was switched off. Only when voltage cannot be measured anymore between the positive and the negative DC bus connections is it allowed to discharge the DC bus ground capacitor pairs against ground. For this purpose, use the appropriate high-resistance device (e.g., DUSPOL® by "Benning Elektrotechnik und Elektronik GmbH & Co. KG"; observe the Operating Manual!).
- Install the covers and guards provided for this purpose before switching on.
- Never touch electrical connection points of the components while power is turned on.
- Do not remove or plug in connectors when the component has been powered.
- Under specific conditions, electric drive systems can be operated at mains protected by residual-current-operated circuit-breakers sensitive to universal current (RCDs/RCMs).

- Secure built-in devices from penetrating foreign objects and water, as well as from direct contact, by providing an external housing, for example a control cabinet.

High housing voltage and high leakage current! Danger to life, risk of injury by electric shock!

- Ground or connect the electrical drive and control system components with the equipment grounding conductor to the grounding points before power-on and commissioning.
- Connect the equipment grounding conductor of the components of the electric drive and control system permanently to the main power supply at all times. The leakage current is greater than 3.5 mA.
- Establish an equipment grounding connection with a minimum cross section according to the table below. With an outer conductor cross section smaller than 10 mm^2 (8 AWG), the alternative connection of two equipment grounding conductors is allowed, each having the same cross section as the outer conductors.

<table>
<tr><th rowspan="2">Outer conductor cross section</th><th colspan="2">Minimum cross section of equipment grounding conductor
Leakage current ≥ 3.5 mA</th></tr>
<tr><th>1 equipment grounding conductor</th><th>2 equipment grounding conductors</th></tr>
<tr><td>1.5 mm^2 (16 AWG)</td><td rowspan="5">10 mm^2 (8 AWG)</td><td>2 × 1.5 mm^2 (16 AWG)</td></tr>
<tr><td>2.5 mm^2 (14 AWG)</td><td>2 × 2.5 mm^2 (14 AWG)</td></tr>
<tr><td>4 mm^2 (12 AWG)</td><td>2 × 4 mm^2 (12 AWG)</td></tr>
<tr><td>6 mm^2 (10 AWG)</td><td>2 × 6 mm^2 (10 AWG)</td></tr>
<tr><td>10 mm^2 (8 AWG)</td><td>-</td></tr>
<tr><td>16 mm^2 (6 AWG)</td><td rowspan="3">16 mm^2 (6 AWG)</td><td>-</td></tr>
<tr><td>25 mm^2 (4 AWG)</td><td>-</td></tr>
<tr><td>35 mm^2 (2 AWG)</td><td>-</td></tr>
<tr><td>50 mm^2 (1/0 AWG)</td><td>25 mm^2 (4 AWG)</td><td>-</td></tr>
<tr><td>70 mm^2 (2/0 AWG)</td><td>35 mm^2 (2 AWG)</td><td>-</td></tr>
<tr><td>X mm^2</td><td>(X × 0.5) mm^2
(applies to X ≥ 50)</td><td>-</td></tr>
</table>

Tab. 3-1: Minimum cross section of equipment grounding connection

3.3.2 Protective extra-low voltage as protection against electric shock

Protective extra-low voltage is used to allow connecting devices with basic insulation to extra-low voltage circuits.

On components of an electric drive and control system provided by Rexroth, all connections and terminals with voltages up to 50 volts are PELV ("Protective Extra-Low Voltage") systems. It is allowed to connect devices equipped with basic insulation (such as programming devices, PCs, notebooks, display units) to these connections.

Danger to life, risk of injury by electric shock! High electrical voltage by incorrect connection!

If extra-low voltage circuits of devices containing voltages and circuits of more than 50 volts (e.g., the mains connection) are connected to Rexroth products, the connected extra-low voltage circuits must comply with the requirements for PELV ("Protective Extra-Low Voltage").

3.3.3 Protection against dangerous movements

Dangerous movements can be caused by faulty control of connected motors. Some common examples are:

- Improper or wrong wiring or cable connection
- Operator errors
- Wrong input of parameters before commissioning
- Malfunction of sensors and encoders
- Defective components
- Software or firmware errors

These errors can occur immediately after equipment is switched on or even after an unspecified time of trouble-free operation.

The monitoring functions in the components of the electric drive and control system will normally be sufficient to avoid malfunction in the connected drives. Regarding personal safety, especially the danger of injury and/or property damage, this alone cannot be relied upon to ensure complete safety. Until the integrated monitoring functions become effective, it must be assumed in any case that faulty drive movements will occur. The extent of faulty drive movements depends upon the type of control and the state of operation.

Dangerous movements! Danger to life, risk of injury, serious injury or property damage!

A **risk assessment** must be prepared for the installation or machine, with its specific conditions, in which the components of the electric drive and control system are installed.

As a result of the risk assessment, the user must provide for monitoring functions and higher-level measures on the installation side for personal safety. The safety regulations applicable to the installation or machine must be taken into consideration. Unintended machine movements or other malfunctions are possible if safety devices are disabled, bypassed or not activated.

To avoid accidents, injury and/or property damage:

- Keep free and clear of the machine’s range of motion and moving machine parts. Prevent personnel from accidentally entering the machine’s range of motion by using, for example:
  - Safety fences
  - Safety guards
  - Protective coverings
  - Light barriers
- Make sure the safety fences and protective coverings are strong enough to resist maximum possible kinetic energy.

- Mount emergency stopping switches in the immediate reach of the operator. Before commissioning, verify that the emergency stopping equipment works. Do not operate the machine if the emergency stopping switch is not working.
- Prevent unintended start-up. Isolate the drive power connection by means of OFF switches/OFF buttons or use a safe starting lockout.
- Make sure that the drives are brought to safe standstill before accessing or entering the danger zone.
- Additionally secure vertical axes against falling or dropping after switching off the motor power by, for example,
  - mechanically securing the vertical axes,
  - adding an external braking/arrester/clamping mechanism or
  - ensuring sufficient counterbalancing of the vertical axes.
- The standard equipment **motor holding brake** or an external holding brake controlled by the drive controller is **not sufficient to guarantee personal safety**!
- Disconnect electrical power to the components of the electric drive and control system using the master switch and secure them from reconnection ("lock out") for:
  - Maintenance and repair work
  - Cleaning of equipment
  - Long periods of discontinued equipment use
- Prevent the operation of high-frequency, remote control and radio equipment near components of the electric drive and control system and their supply leads. If the use of these devices cannot be avoided, check the machine or installation, at initial commissioning of the electric drive and control system, for possible malfunctions when operating such high-frequency, remote control and radio equipment in its possible positions of normal use. It might possibly be necessary to perform a special electromagnetic compatibility (EMC) test.

3.3.4 Protection against electromagnetic and magnetic fields during operation and mounting

Electromagnetic and magnetic fields!

Health hazard for persons with active implantable medical devices (AIMD) such as pacemakers or passive metallic implants.

- Hazards for the above-mentioned groups of persons by electromagnetic and magnetic fields in the immediate vicinity of drive controllers and the associated current-carrying conductors.
- Entering these areas can pose an increased risk to the above-mentioned groups of persons. They should seek advice from their physician.
- If overcome by possible effects on above-mentioned persons during operation of drive controllers and accessories, remove the exposed persons from the vicinity of conductors and devices.

3.3.5 Protection against contact with hot parts

Hot surfaces of components of the electric drive and control system. Risk of burns!

- Do not touch hot surfaces of, for example, braking resistors, heat sinks, supply units and drive controllers, motors, windings and laminated cores!
- According to the operating conditions, temperatures of the surfaces can be **higher than 60 °C** (140 °F) during or after operation.
- Before touching motors after having switched them off, let them cool down for a sufficient period of time. Cooling down can require **up to 140 minutes**! The time required for cooling down is approximately five times the thermal time constant specified in the technical data.
- Before touching chokes after having switched them off, let them cool down for a sufficient period of time. Cooling down can require **up to 140 minutes**!
- After switching off supply units and drive controllers, wait **15 minutes** to allow them to cool down before touching them.
- Wear safety gloves or do not work at hot surfaces.
- For certain applications, and in accordance with the respective safety regulations, the manufacturer of the machine or installation must take measures to avoid injuries caused by burns in the final application. These measures can be, for example: Warnings at the machine or installation, guards (shieldings or barriers) or safety instructions in the application documentation.

3.3.6 Protection during handling and mounting

Risk of injury by improper handling! Injury by crushing, shearing, cutting, hitting!

- Observe the relevant statutory regulations of accident prevention.
- Use suitable equipment for mounting and transport.
- Avoid jamming and crushing by appropriate measures.
- Always use suitable tools. Use special tools if specified.
- Use lifting equipment and tools in the correct manner.
- Use suitable protective equipment (hard hat, safety goggles, safety shoes, safety gloves, for example).
- Do not stand under hanging loads.
- Immediately clean up any spilled liquids from the floor due to the risk of falling!

3.3.7 Battery safety

Batteries consist of active chemicals in a solid housing. Therefore, improper handling can cause injury or property damage.

Risk of injury by improper handling!

- Do not attempt to reactivate low batteries by heating or other methods (risk of explosion and cauterization).
- Do not attempt to recharge the batteries as this may cause leakage or explosion.
- Do not throw batteries into open flames.
- Do not dismantle batteries.

- When replacing the battery/batteries, do not damage the electrical parts installed in the devices.
- Only use the battery types specified for the product.

☞ Environmental protection and disposal! The batteries contained in the product are considered dangerous goods during land, air, and sea transport (risk of explosion) in the sense of the legal regulations. Dispose of used batteries separately from other waste. Observe the national regulations of your country.

3.3.8 Protection against pressurized systems

According to the information given in the Project Planning Manuals, motors and components cooled with liquids and compressed air can be partially supplied with externally fed, pressurized media, such as compressed air, hydraulics oil, cooling liquids and cooling lubricants. Improper handling of the connected supply systems, supply lines or connections can cause injuries or property damage.

Risk of injury by improper handling of pressurized lines!

- Do not attempt to disconnect, open or cut pressurized lines (risk of explosion).
- Observe the respective manufacturer's operating instructions.
- Before dismounting lines, relieve pressure and empty medium.
- Use suitable protective equipment (safety goggles, safety shoes, safety gloves, for example).
- Immediately clean up any spilled liquids from the floor due to the risk of falling!

☞ Environmental protection and disposal! The agents (e.g., fluids) used to operate the product might not be environmentally friendly. Dispose of agents harmful to the environment separately from other waste. Observe the national regulations of your country.

3.4 Explanation of signal words and the Safety alert symbol

The Safety Instructions in the available application documentation contain specific signal words (DANGER, WARNING, CAUTION or NOTICE) and, where required, a safety alert symbol (in accordance with ANSI Z535.6-2011).

The signal word is meant to draw the reader's attention to the safety instruction and identifies the hazard severity.

The safety alert symbol (a triangle with an exclamation point), which precedes the signal words DANGER, WARNING and CAUTION, is used to alert the reader to personal injury hazards.

⚠ DANGER

In case of non-compliance with this safety instruction, death or serious injury **will** occur.

⚠ WARNING

In case of non-compliance with this safety instruction, death or serious injury could occur.

⚠ CAUTION

In case of non-compliance with this safety instruction, minor or moderate injury could occur.

NOTICE

In case of non-compliance with this safety instruction, property damage could occur.

4 Definition of signs

Reference: VDE-AR-N 4110:2018-11: Appendix B.8

Definition of signs for active power values and reactive power values (load reference arrow system):

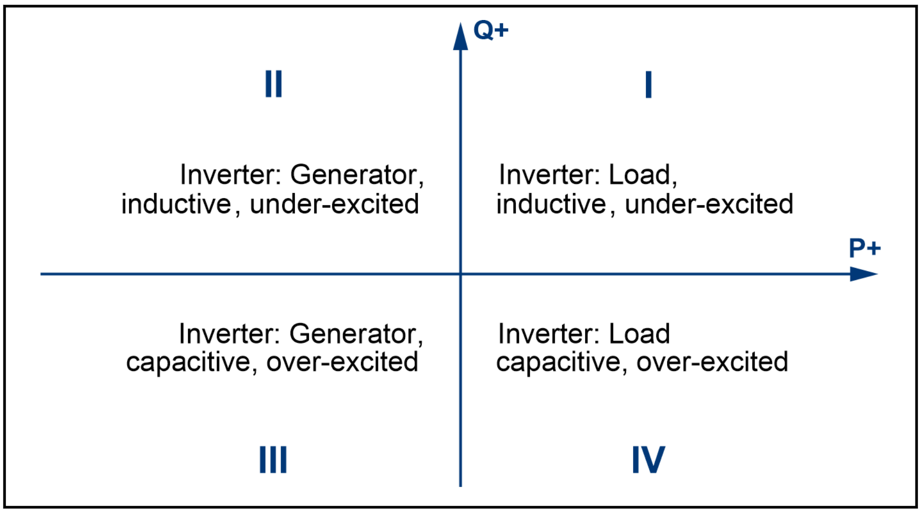


Fig. 4-1: Definition of signs for active power values (P) and reactive power values (Q)

This definition applies accordingly to active currents and reactive currents, i.e. P < 0, I < 0 or Q < 0, I < 0.

Only **clockwise grids** are supported. In the case of a counter-clockwise grid, the displayed frequency value is negative.

If possible, the counter-clockwise grid can be turned into a clockwise grid by changing two mains connection phases (e.g., L1 and L3).

5 Electrical data (nominal values and rated values)

5.1 Electrical data HMU05.1N-xxxxx-xxxx-N-A4-D7 (liquid-cooled / air-cooled, 500 V type)

HMU05.1N -xxxxx-xxxx- N-A4-D7-Pxx-NNNN	f_n Hz	U_r V_{rms}	$U_{d\text{-}nom}$ V_{dc}	S_{rE} 3) kVA	P_{rE} 1)/ 2) kW	I_r A_{rms} active current / total current	P-0-1370 3) kVA	I_{skPF} $I_{(1)skPF}$ $I_{(2)skPF}$ A_{rms}	$Z_{(2)PF}$ Ω	$I_{k''}$ A_{rms}	I_k A_{rms}	I_p A	U_{batt} 4) V
F0140-0350 W0140-0350	50	400	750	140	133	192 / 214	146.9	212	0.54	270	270	717	717-800
F0170-0430 W0170-0430				170	161	233 / 257	177.6	256	0.45	324	324	858	
F0220-0510 W0220-0510				214	209	302 / 320	222.3	321	0.36	390	390	1014	
F0270-0660 W0270-0660				266	256	370 / 401	277.1	400	0.29	486	486	1305	
F0340-0820 W0340-0820				337	323	466 / 504	349.9	505	0.23	608	608	1621	
F0430-1040				429	408	590 / 639	445	643	0.18	763	763	2026	
F0540-1300				539	513	741 / 795	555.8	802	0.14	968	968	2593	

f_n	Nominal frequency
I_k	Contribution to continuous short-circuit current; I_k= maximum short-circuit current
$I_{k''}$	Contribution to initial short-circuit current; $I_{k''}$ = maximum source current
i_p	Peak short-circuit current
I_r	Rated current; I_r = nominal current (@ U_r=400V_{rms} / U_d=750V_{dc}) (active current/total current)
$I_{(1)skPF}$, $I_{(2)skPF}$, I_{skPF}	RMS value of source current in the case of single-, double-, triple-pole faults (@ U_r=400V_{rms})
$Z_{(2)PF}$	Short-circuit negative-sequence impedance (@ U_r=400V_{rms})
P-0-1370	Apparent power limit of inverter; P-0-1370 (@ U_r=400V_{rms} / U_d=750V_{dc}) 3)
P_{rE}	Rated active power; P_{rE} = nominal active power (@ U_r=400V_{rms} / U_d=750V_{dc}) 1) / 2)
S_{rE}	Rated apparent power; S_{rE} = nominal apparent power (@ U_r=400V_{rms} / U_d=750V_{dc}) 3)
U_{batt}	Battery voltage that can be connected; U_{batt} = nominal battery voltage (@ U_r=400V_{rms} / F_FRT=1.25) 4)
$U_{d\text{-}nom}$	Nominal DC bus voltage
U_r	Rated voltage; U_r = nominal voltage
1)	Grid input voltage (U_{grid}) and active power (P_r), derating • Allowed grid voltage range 250V < U_{grid} < 423V • With U_{grid} < U_r (nominal voltage), take a derating of U_{grid} / U_r into account for the active power. • With U_{grid} > U_r (nominal voltage), the active power remains limited to the nominal value.
2)	DC bus voltage (U_d) and active power (P_r), derating • With U_d < $U_{d\text{-}nom}$ (nominal voltage), take a derating of U_d / $U_{d\text{-}nom}$ into account for the active power. • With U_d > $U_{d\text{-}nom}$ (nominal voltage), the active power remains limited to the nominal value.

3)	Values for voltages other than the nominal voltage are provided upon request.
4)	To connect lower battery voltages, adjust the grid input voltage according to the formula below: • $U_{grid} \leq (U_{batt} - 10) / (\sqrt{2} \times F\_FRT)$ • Furthermore, it is required to reduce the power according to 1), 2), 3).

Tab. 5-1: Electrical data HMU05.1N-xxxxx-xxxx-N-A4-D7 (liquid-cooled / air-cooled, 500 V type)

Assignment mains filter, preconnected choke, mains capacitor and mains choke HMU05.1N-Wxxxx-xxxx-N-A4-D7 (air-cooled)

Components		Supply unit HMU05.1N-W…-N-A4-D7 (air-cooled)				
		0140-0350	0170-0430	0220-0510	0270-0660	0340-0820
Chopper choke HNL05.1R-…-N-A4-NNNW	0219-N0262	✓	✓			
	0135-N0327			✓		
	0117-N0409				✓	
	0130-N0514					✓
Preconnected choke HNL05.1R-	0045-N0327	(✓)	(✓)	✓		
	0054-N0409				✓	
	0043-N0514					✓
Mains capacitor HNC05.1N-…-NNNN	0050-A4	✓	✓			
	0075-A4			✓		
	0100-A4				✓	✓
Mains filter HNF05.1A-	500N-R0250-N-A5	✓				
	500N-R0320-N-A5		✓			
	500N-R0400-N-A5			✓		
	500N-R0600-N-A5				✓	✓

(✓) Optional

Tab. 5-2: Components for mains connection (HMU05.1N-W…-A4-D7)

Assignment mains filter, preconnected choke, mains capacitor and mains choke HMU05.1N-Wxxxx-xxxx-N-A4-D7 (liquid-cooled)

Components		Supply unit HMU05.1N-F…-N-A4-D7 (liquid-cooled)						
		0140-0350	0170-0430	0220-0510	0270-0660	0340-0820	0430-1040	0540-1300
Chopper choke HNL05.1R-…-N-A4-NNNF	0219-N0218	✓						
	0182-N0262		✓					
	0135-N0327			✓				
	0117-N0409				✓			
	0130-N0514					✓		
	0113-N0652						✓	
	0100-N0811							✓
Preconnected choke HNL05.1R-…-N-A4-NNNN	0045-N0327	(✓)	(✓)	✓				
	0054-N0409				✓			
	0043-N0514					✓		
	0050-N0652						✓	
	0040-N0811							✓
Mains capacitor HNC05.1N-…-NNNN	0050-A4	✓	✓					
	0075-A4			✓				
	0100-A4				✓	✓	✓ 1)	✓ 1)
	0150-A4						(✓) 1)	(✓) 1)
Mains filter HNF05.1A-	500N-R0250-N-A5	✓						
	500N-R0320-N-A5		✓					
	500N-R0400-N-A5			✓				
	500N-R0600-N-A5				✓	✓		
	500N-R1000-N-A5						✓	✓

(✓) Optional
1) If the supply unit is operated with a clock frequency of 3.8 kHz (for 7-fold parallel group)

Tab. 5-3: Components for mains connection (HMU05.1N-F…-A4-D7)

Notes:

1. In applications at the IT mains in which capacitive ground connection is not desired, the HNF05 mains filter is not required. Instead of the mains capacitor module HNC05…-NNNN use the specific design HNC05…-C001 (no ground capacitors).
2. If the inverter is connected to the grid via a its own isolating transformer, the preconnected choke is not required.

5.2 Electrical data HMU05.1N-xxxxx-xxxx-N-A5-11 (liquid-cooled, 690 V type)

HMU05.1N -xxxxx-xxxx- N-A5-11-Pxx-NNNN	f_n Hz	U_r V_{rms}	$U_{d\text{-}nom}$ V_{dc}	S_{rE} 3) kVA	P_{rE} 1)/2) kW	I_r A_{rms} active current / total current	P-0-1370 3) kVA	I_{skPF} $I_{(1)skPF}$ $I_{(2)skPF}$ A_{rms}	$Z_{(2)PF}$ Ω	$I_{k“}$ A_{rms}	I_k A_{rms}	I_p A	U_{batt} 4) V
F0140-0210	50	580	1100	114	111	111 / 124	121.1	121	1.39	157	157	415	1035-1120
F0170-0250				139	135	135 / 149	147	146	1.14	188	188	492	
F0220-0300				177	175	175 / 186	185.4	185	0.91	227	227	593	
F0270-0370				219	215	215 / 233	230.2	229	0.73	282	282	742	
F0400-0600				326	319	318 / 345	341.8	340	0.49	412	412	1223	
F0540-0750				439	431	429 / 462	459.3	457	0.37	562	562	1540	

f_n	Nominal frequency
I_k	Contribution to continuous short-circuit current: I_k = maximum short-circuit current
$I_{k“}$	Contribution to initial short-circuit current; $I_{k“}$ = maximum source current
i_p	Peak short-circuit current
I_r	Rated current; I_r = nominal current (@ U_r= 580V_{rms} / U_d=1100V_{dc}) (active current/total current)
$I_{(1)skPF}$, $I_{(2)skPF}$, I_{skPF}	RMS value of source current in the case of single-, double-, triple-pole faults (@ U_r=580V_{rms})
$Z_{(2)PF}$	Short-circuit negative-sequence impedance (@ U_r=580V_{rms})
P-0-1370	Apparent power limit of inverter; P-0-1370 (@ U_r=580V_{rms} / U_d=1100V_{dc}) 3)
P_{rE}	Rated active power; P_{rE} = nominal active power (@ U_r=580V_{rms} / U_d=1100V_{dc}) 1) / 2)
S_{rE}	Rated apparent power; S_{rE} = nominal apparent power (@ U_r=580V_{rms} / U_d=1100V_{dc}) 3)
U_{batt}	Battery voltage that can be connected; U_{batt} = nominal battery voltage (@ U_r=580V_{rms} / F_FRT=1.25) 4)
$U_{d\text{-}nom}$	Nominal DC bus voltage
U_r	Rated voltage; U_r = nominal voltage
1)	Grid input voltage (U_{grid}) and active power (P_r), derating • Allowed grid voltage range 250V < U_{grid} < 584V • With U_{grid} < U_r (nominal voltage), take a derating of U_{grid} / U_r into account for the active power. • With U_{grid} > U_r (nominal voltage), the active power remains limited to the nominal value.
2)	DC bus voltage (U_d) and active power (P_r), derating • With U_d < 924.6V (nominal DC bus voltage), take a derating of U_d / $U_{d\text{-}nom}$ into account for the active power **$P \le P_{rE} \times U_d$ / 924.6** • With U_d > $U_{d\text{-}nom}$ (nominal DC bus voltage), the active power remains limited to the nominal value.
3)	Values for voltages other than the nominal voltage are provided upon request.
4)	To connect lower battery voltages, adjust the grid input voltage according to the formula below: • $U_{grid} \le (U_{batt} - 10) / (\sqrt{2} \times F\_FRT)$ • Furthermore, it is required to reduce the power according to 1), 2), 3).

Tab. 5-4: Electrical data HMU05.1N-xxxxx-xxxx-N-A5-11 (liquid-cooled, 690 V type)

Assignment mains filter, preconnected choke, mains capacitor and mains choke for HMU05.1N-Xxxxx-xxxx-N-A5-11 (liquid-cooled)

Components		Supply unit HMU05.1N-F…-N-A5-11 (liquid-cooled)					
		0140-0210	0170-0250	0220-0300	0270-0370	0400-0600	0540-0750
Chopper choke HNL05.1R-	0649-N0127-N-A5	✓					
	0542-N0152-N-A5		✓				
	0434-N0190-N-A5			✓			
	0346-N0238-N-A5				✓		
	0234-N0352-N-A5					✓	
	0175-N0471-N-A5						✓
Preconnected choke HNL05.1R-	0125-N0152-N-A5	(✓)	✓				
	0100-N0190-N-A5			✓			
	0080-N0238-N-A5				✓		
	0054-N0352-N-A5					✓	
	0040-N0471-N-A5						✓
Mains capacitor HNC05.1N-…-NNNN	0040-A5	✓	✓				
	0050-A5			✓			
	0070-A5				✓		
	0100-A5					✓	
	0125-A5						✓
Mains filter HNF05.1A-	500N-R0150-N-A5	✓					
	500N-R0180-N-A5		✓				
	500N-R0250-N-A5			✓	✓		
	500N-R0400-N-A5					✓	
	500N-R0600-N-A5						✓

(✓) Optional

Tab. 5-5: Components for mains connection (HMU05.1N-…-A5-11)

Notes:

1. In applications at the IT mains in which capacitive ground connection is not desired, the HNF05 mains filter is not required. Instead of the mains capacitor module HNC05…-NNNN use the specific design HNC05…-C001 (no ground capacitors).
2. If the inverter is connected to the grid via a its own isolating transformer, the preconnected choke is not required.

6 Power generating unit (PGU)

6.1 Schematic overview of the PGU

Power generating systems (PGS) are to be connected to the public grid system (medium-voltage grid, low-voltage grid) while complying with **VDE-AR-N 4110:2018-11**. Power generating systems consist of one or multiple power generating units (PGU). The central component of a power generating unit is the grid inverter.

A device of the Bosch Rexroth device range **IndraDrive ML** is used as **grid inverter**. The grid inverter, called **HMV05**, consists of the HMU05 inverter module and the HNA05 mains connection module.

The following paragraphs describe **3 exemplary system options**:

- 2 options for grid inverter as **buffer grid inverter**
  - Buffer directly at grid inverter
  - Buffer directly at grid inverter with fuel cell system
- 1 option for grid inverter as **non-buffer grid inverter**

6.1.1 Buffer grid inverter

The energy buffer is directly (option 1) or via a DC/DC converter (option 2) connected to the DC bus of HMV05. The energy buffers used here are battery buffers and fuel cells in conjunction with a battery buffer.

Option 1a: Buffer directly at grid inverter

In the simplest case, only a battery buffer is connected directly to the DC bus of HMV05.

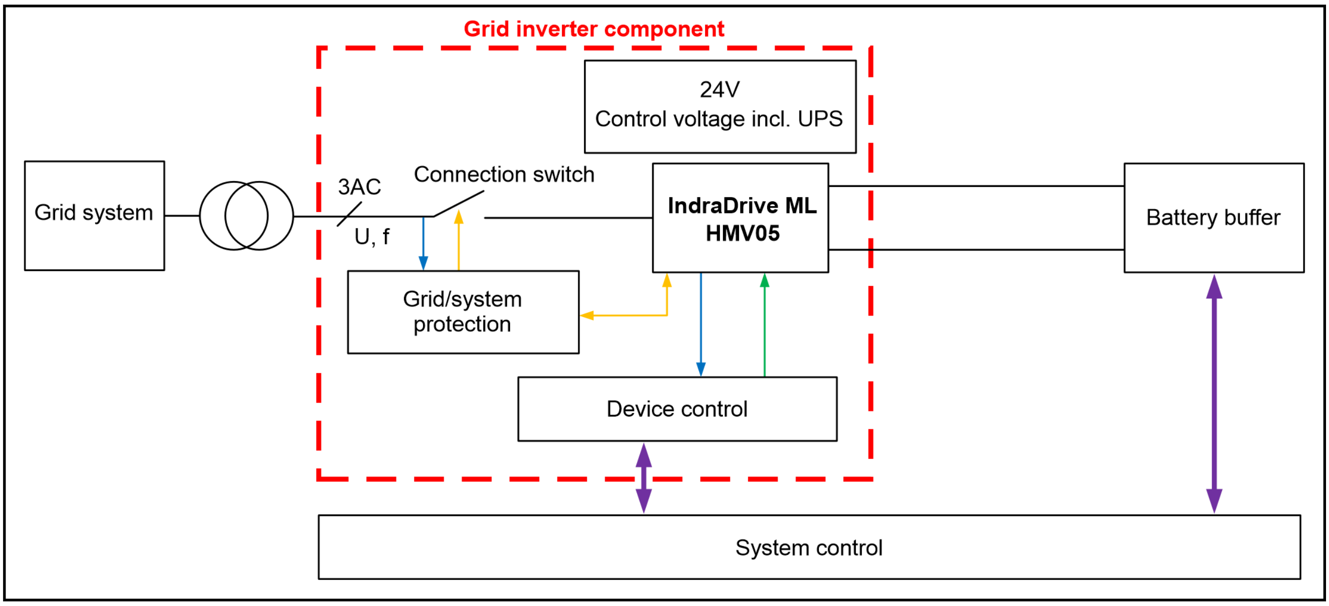


Fig. 6-1: PGU option buffer directly at grid inverter

Option 1b: Buffer directly at grid inverter with fuel cell system

In the case of a fuel cell system, a fuel cell, in addition to the battery buffer, is connected to the DC bus using a DC/DC converter. This fuel cell system is to be considered as a recharging unit.

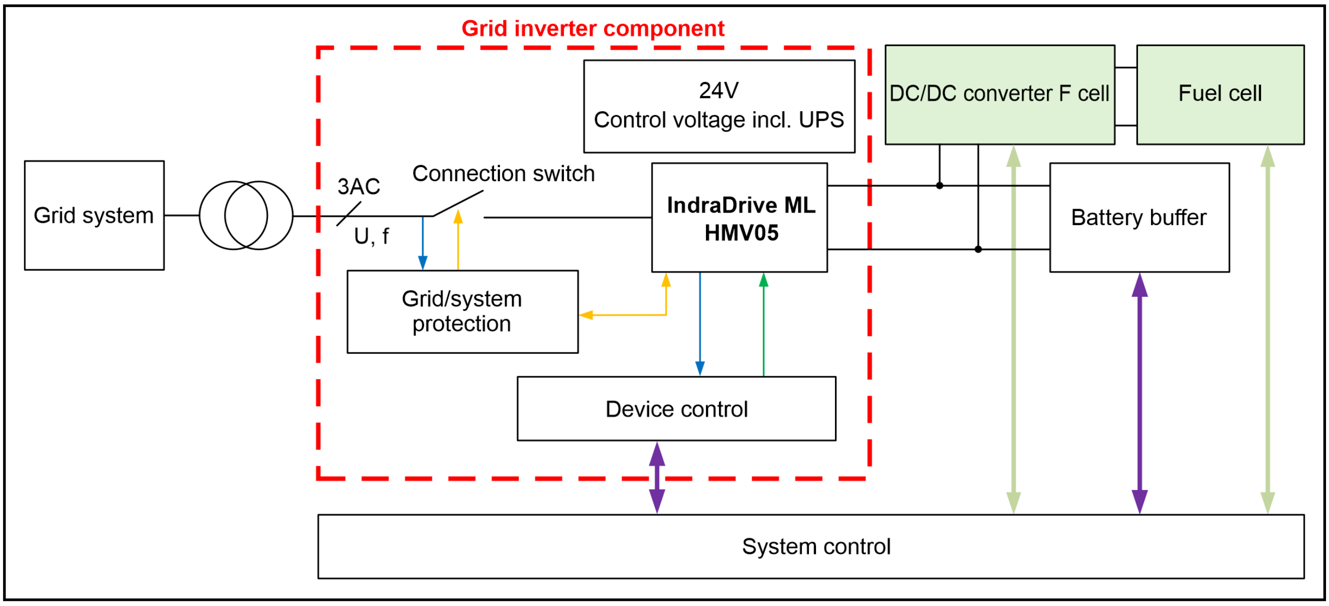


Fig. 6-2: PGU option buffer directly at grid inverter with fuel cell system

Device operation modes

If the energy buffer is directly connected to the DC bus of HMV05, the **mains current control** mode has to be set in **HMV05**.

In the case of a fuel cell system, the **DC/DC converter F cell** is operated in the **DC current control** mode.

Requirements on battery buffer

The voltage range of the battery has to be within the allowed **DC voltage limits** of HMV05. The battery needs to have appropriate **DC fuses** in DC+ and DC-. A **battery management system** (BMS) continuously monitors the battery and can switch off all poles of the battery under load via DC contactors, both during normal operation and in the case of error. The BMS monitors the battery at least with regard to overvoltage, overcurrent, overload, exhaustive discharge and overtemperature.

Requirements on fuel cells

The fuel cell always has to be connected to HMV05 **in conjunction with a battery buffer**. The battery buffer has to fulfill the same requirements as in a system in which only a battery is connected to the grid inverter.

The fuel cell itself is to be considered only as a **recharging unit**. The battery is required for rapid changes in active power for which conventional fuel cells are too slow.

Example FRT:

If HMV05 reaches the device limit **in the FRT case**, **HMV05 reduces the active power**. The reduction might happen so quickly that the fuel cell cannot reduce its power so fast. In this case, the battery absorbs the energy. As an alternative, the fuel cell can be actively disconnected from the DC bus.

After the **fault end**, the active power is increased to the pre-fault value as quickly as possible. In this case, too, the battery absorbs the rapid change in active power until the fuel cell for its part has increased its power.

Requirements on the DC/DC converter F cell

The **control dynamics** of the DC/DC converter F cell has to be in the range of HMV05.

Option 2a: Buffer with DC/DC converter at grid inverter

In the simplest case, only a battery buffer is connected to the DC bus of HMV05 using a DC/DC converter (DC/DC converter bat).

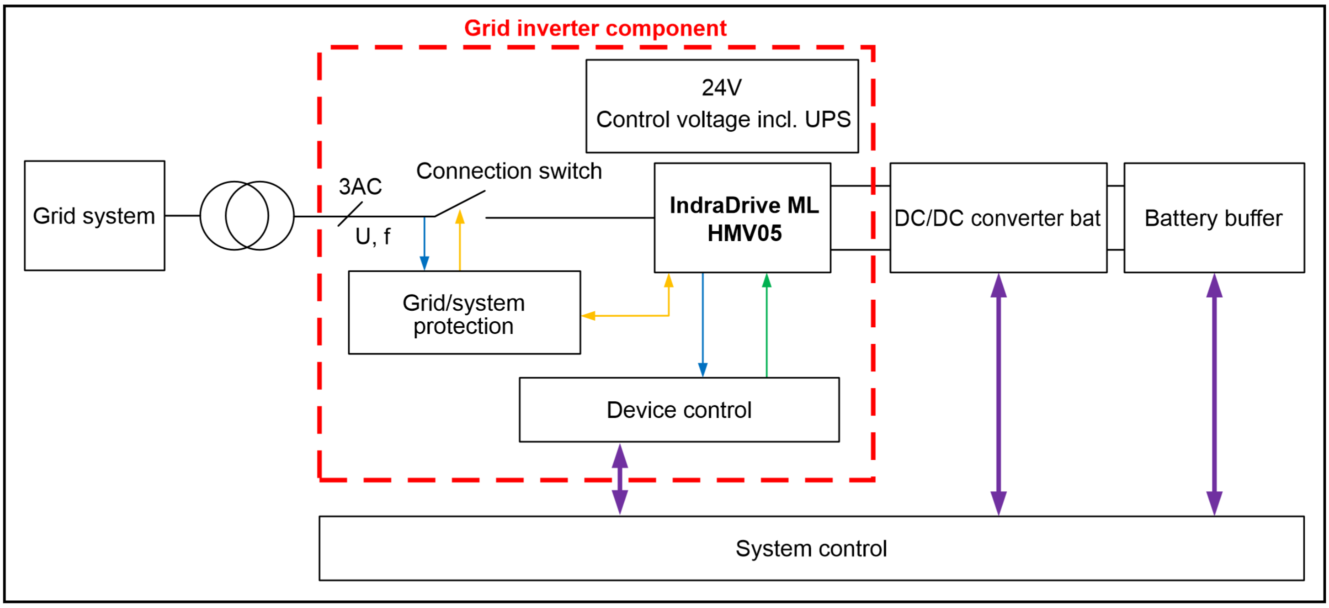


Fig. 6-3: PGU option buffer with DC/DC converter at grid inverter

Option 2b: Buffer with DC/DC converter at grid inverter with fuel cell system

In the case of a fuel cell system, a fuel cell is additionally connected to the DC bus using a second DC/DC converter (DC/DC converter F cell). This fuel cell system is to be considered as a recharging unit.

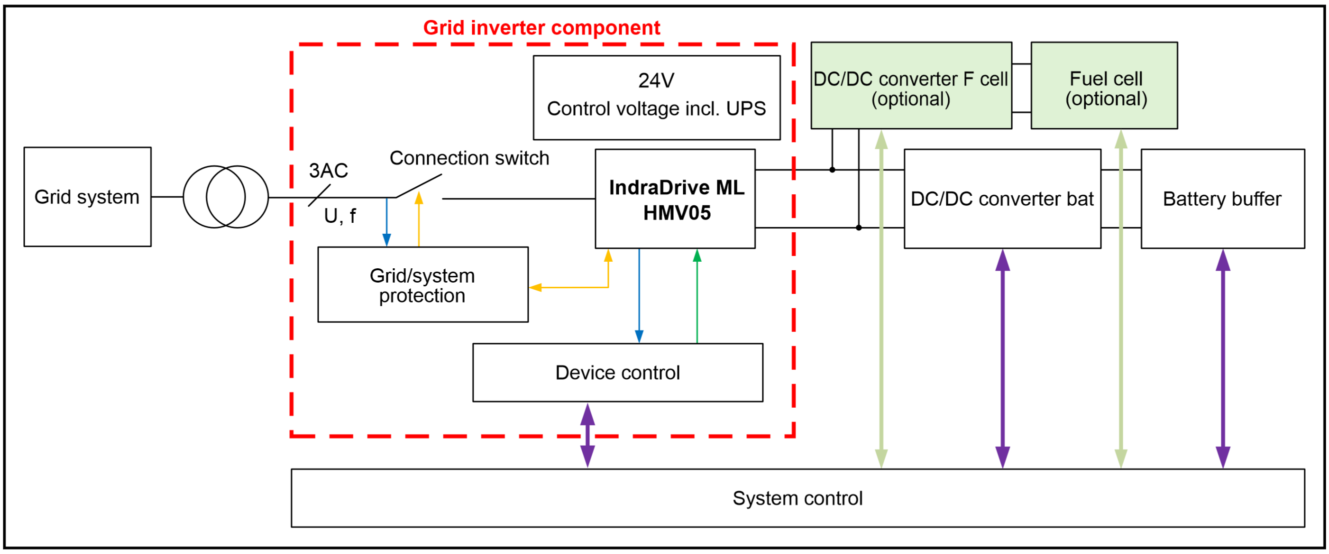


Fig. 6-4: PGU option buffer with DC/DC converter at grid inverter with fuel cell system

Device operation modes

If the battery buffer is connected to the DC bus of HMV05 via a DC/DC converter bat, there are **2 possibilities of control**:

1. The **mains current control** mode has been set in **HMV05**, the **DC/DC converter bat** works in **DC voltage control** and controls the DC bus voltage. The outcome is option 1.

2. The **DC bus voltage control** mode has been set in **HMV05**, the **DC/DC converter bat** works in **DC current control**. The system control has to cyclically transmit the current command value for the DC/DC converter bat from HMV05 to the DC/DC converter bat.

In the case of a fuel cell system, the additional **DC/DC converter F cell** is operated in the **DC current control** mode.

Requirements on battery buffer

The battery needs to have appropriate **DC fuses** in DC+ and DC-. A **battery management system** (BMS) continuously monitors the battery and can switch off all poles of the battery under load via DC contactors, both during normal operation and in the case of error. The BMS monitors the battery at least with regard to overvoltage, overcurrent, overload, exhaustive discharge and overtemperature.

Requirements on fuel cells

The fuel cell always has to be connected to the grid inverter **in conjunction with a battery buffer**. The battery buffer has to fulfill the same requirements as in a system in which only a battery is connected to the grid inverter.

The fuel cell itself is to be considered only as a **recharging unit**. The battery is required for rapid changes in active power for which conventional fuel cells are too slow.

Requirements on the DC/DC converter bat

The **control dynamics** of the DC/DC converter bat has to be in the range of the grid inverter. Option 2b additionally requires fast communication (cycle time ≤ 30 ms) between grid inverter and DC/DC converter bat for exchanging the command values.

Optional protective function in DC/DC converter bat: If the voltage in the DC bus increases and exceeds a certain threshold, the DC/DC converter bat can limit the active command value.

Requirements on the DC/DC converter F cell

The **control dynamics** of the DC/DC converter F cell has to be in the range of the grid inverter.

6.1.2 Non-buffer grid inverter

Option 3: Generator-based power generating unit, hydropower plant

Instead of an energy buffer, an **HMS05 motor inverter** is connected to the HMV05 grid inverter. A generator driven by a hydraulic turbine is connected to the motor inverter. Through the flow rate of the water, the system control controls the power to be supplied to the grid.

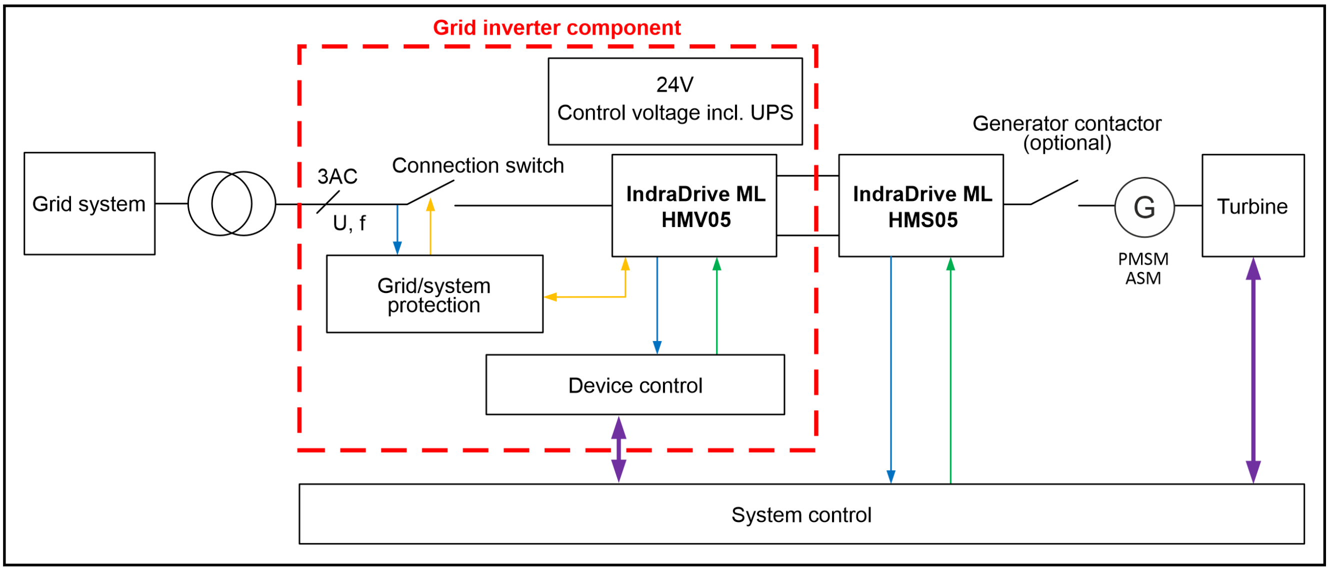


Fig. 6-5: PGU as generator-based power generating unit, hydropower plant

Device operation modes

The **DC bus voltage control** mode has been set in **HMV05**. The **torque control** mode has been set in **HMS05**.

Therefore, this option corresponds to option 2b (2nd device operation mode). The command current only has to be converted to a torque with a scaling factor.

Requirements on HMS05 motor inverter

The **dynamics** of the HMS05 motor inverter has to be in the range of the grid inverter.

Behavior in the FRT case:

If the active power has to be reduced in the FRT case, this is done by **reducing the torque for the motor inverter**. In extreme cases to 0 Nm. At the same time, the system control has to reduce the flow rate to reduce the power.

In the meantime, the **turbine** keeps driving the generator. If the speed of the generator becomes too high (in the field weakening range, PMSM machines generate high EMF voltage), the DC bus voltage is limited by braking resistors. Optionally or additionally, generator contactors can be installed; they open when a DC bus voltage threshold is exceeded.

After **fault end**, the active power has to be increased to the pre-fault value as quickly as possible. For this purpose, the system control has to increase the flow rate as quickly as possible. With the appropriate sizing of the braking resistor, possibly necessary flow rate reduction during the fault is not required. In this case, the power is immediately available again.

6.1.3 Summary

The subject matter of the **Component certificate according to FGW TR8** is the sector marked "Grid inverter component" in the above figures.

This sector is for measured value acquisition and power conversion and ensures grid and system protection, static voltage support, as well as dynamic grid support. The system control explicitly does not belong to this sector. The system control can control multiple power generating units and therefore is a PGS controller as per definition. This PGS controller might possibly require a component certificate.

All described options are identical on the AC side. They differ in the DC connection and therefore in the active power behavior. The described requirements ensure that the necessary power gradients and actuating capacity can be complied with.

6.2 General functional principle

Main components of the power generating system

- System control
  - Centrally controls power generating unit(s)
  - Controls components such as heating unit, cooling system and dehumidifier
  - Monitors transformer and switchgear
  - Provides external interface to the user (power supply company)
  - Facilitates remote access to entire power generating system
  - Generates logbooks
  - Generates command values for power generating unit / implements desired operating strategy
  - Controls (re)start of the power generating system
- Device control and HMV05
  - Form a unit
  - Used for measured value acquisition and power conversion
  - Allows static voltage support, dynamic grid support
- Grid and system protection
  - Grid and system protection
  - Disconnection protection device for power generating unit
- Energy buffer
  - DC voltage source/sink
  - Has a buffer management system for monitoring, protecting and controlling the energy buffer

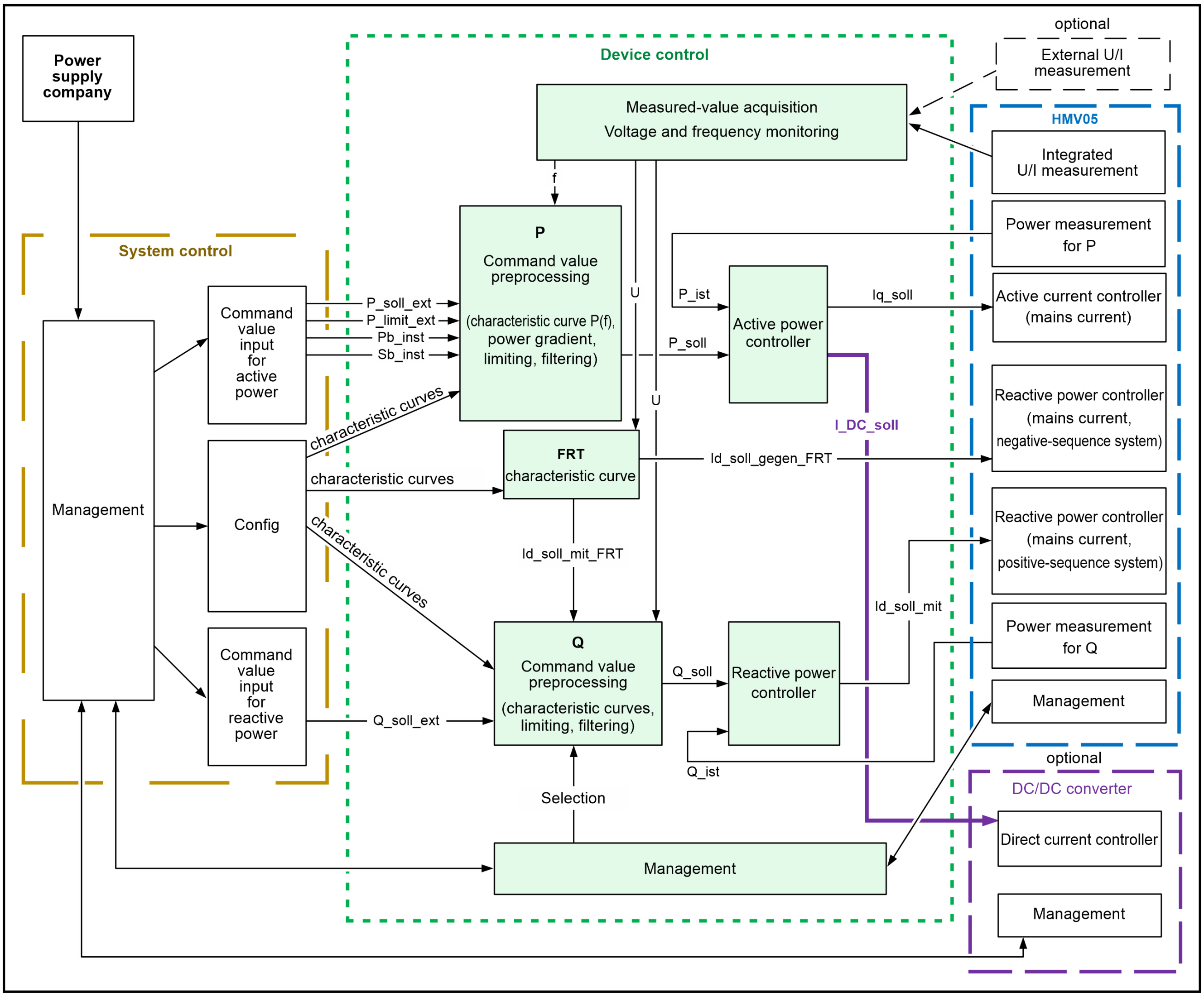


Fig. 6-6: Interaction of system control, device control and HMV05

Command value generation, command value preprocessing and command value setting

The power supply company communicates only with the system control. The energy management and the operating strategy of the energy buffer are implemented in the **system control**. Therefore, the system control communicates with the energy buffer. The system control generates and transmits **command values** for the active power and command values for the reactive power to the device control. The communication between system control and device control takes place via the so-called master communication.

In the **device control**, the entire **command value preprocessing** takes place (characteristic curves, limitations, prioritizations, …).

Iq_soll: Only exists if HMV05 is operated in the „mains current control“ mode (option 1 and option 2a). The preprocessed command value for the active power is transmitted to an active power controller that generates the command value for the active current Iq_soll. Iq_soll is cyclically transmitted to HMV05.

I_DC_soll: Only exists if HMV05 is operated in the „DC bus voltage control“ mode (option 2b and option 3). The preprocessed command value for the active power is transmitted to an active power controller that generates the command value for the active current I_DC_soll.

I_DC_soll has to be cyclically transmitted by the system control to the DC/DC converter (option 2b) or motor inverter (option 3).

Id_soll_mit: The preprocessed command value for the reactive power is transmitted to a reactive power controller that generates the command value for the reactive current in the positive-sequence system Id_soll_mit. Any additional reactive current contribution in the positive-sequence system resulting from the dynamic grid support is taken into account. Id_soll_mit is cyclically transmitted to HMV05.

Id_soll_gegen: The command value for the reactive current in the negative-sequence system Id_soll_gegen results from the dynamic grid support. Id_soll_gegen is cyclically transmitted to HMV05.

The actual command value setting takes place in HMV05. Here, the command currents are set by the current controller: active current controller (mains current), reactive current controller (mains current, positive-sequence system) and reactive current controller (mains current, negative-sequence system).

7 Operating ranges of the power generating unit

7.1 Limits in quasi-static operation

Reference: VDE-AR-N 4110:2018-11: Chapter 10.2.1.2

The table below shows the limits of voltage and frequency for the quasi-static operation of IndraDrive ML HMV05. The rated voltage U_r at the low-voltage terminals of the component is used as the reference voltage. Transient voltage dips and voltage rises (±5% U_r/min) can be run through according to the voltage-time characteristics for the dynamic grid support. The ranges can be limited by the required settings of the decoupling protection.

Description	Value
Max. voltage (short-time operation: at least 60 s)	130% U_r
Max. voltage (continuous operation)	119% U_r
Min. voltage (continuous operation)	85% U_r
Min. voltage (short-time operation: at least 60 s)	80% U_r
Max. voltage gradient in continuous operation without grid disconnection	> 5% U_r /min
Max. frequency (short-time operation: at least 30 min)	65.0 Hz
Max. frequency (continuous operation)	52.0 Hz
Min. frequency (continuous operation)	48.0 Hz
Min. frequency (short-time operation: at least 30 min)	45.0 Hz
Max. frequency gradient in continuous operation without grid disconnection	±4 Hz/s

Tab. 7-1: Voltage and frequency operating ranges in quasi-static operation

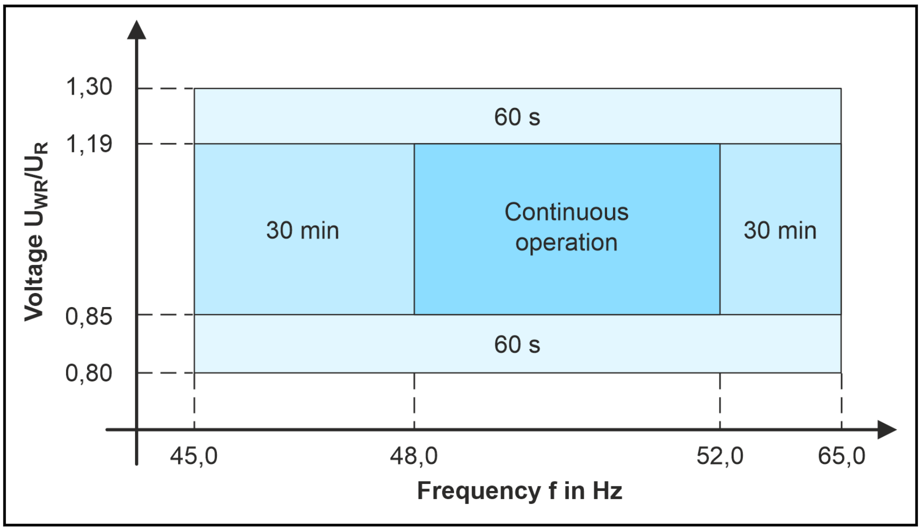


Fig. 7-1: Voltage and frequency operating ranges in quasi-static operation

7.2 Supplying reactive power, UQ diagram

The reactive power requirements according to VDE-AR-N 4110:2018-11: chapter 10.2.2.2 are fulfilled by the device when the active power is reduced (acceptable according to standard).

The tables for the UQ diagram specify operation at maximum possible active power. Furthermore, an example of operation at reduced active power (to approx. $0.8 \times P_{b\ inst}$) is specified.

7.2.1 UQ diagrams for series HMU05.1N-Fxxxx-xxxx-N-A4-D7 / HMU05.1N-Wxxxx-xxxx-N-A4-D7

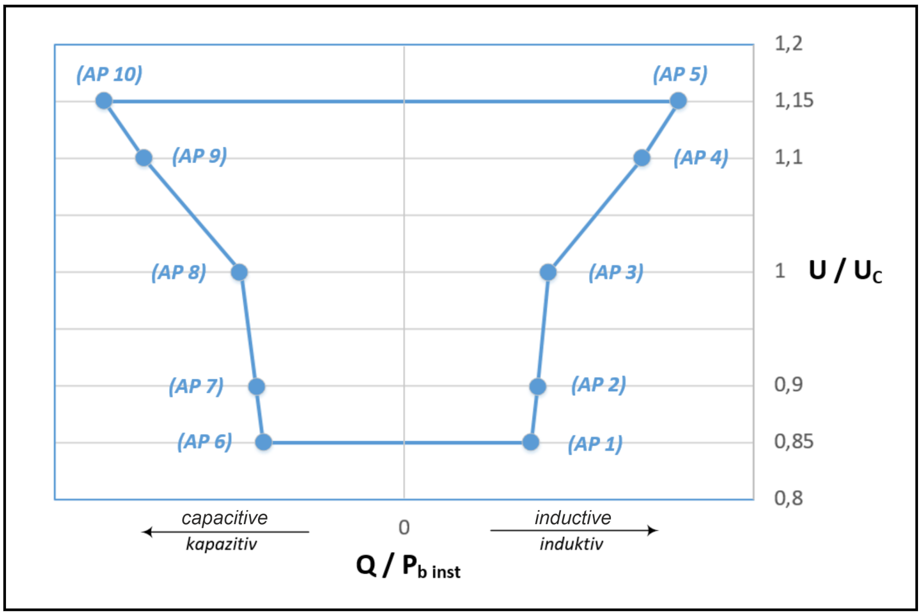


Fig. 7-2: UQ diagram. Working points AP1...10 see tables

HMU05.1N-F0140-0350-N-A4-D7 / HMU05.1N-W0140-0350-N-A4-D7										
Active power		Mains voltage		Inductive reactive power			Capacitive reactive power			
		U/U_C	U	Point	$Q/P_{b\ inst}$	Q	Point	$Q/P_{b\ inst}$	Q	
max. active power	113 kW	0.85	340 V	AP 1	0.31	41 kVAr	AP 6	-0.36	-48 kVAr	
	119 kW	0.9	360 V	AP 2	0.32	42 kVAr	AP 7	-0.38	-50 kVAr	
	133 kW = $P_{b\ inst}$	1	400 V	AP 3	0.34	45 kVAr	AP 8	-0.41	-55 kVAr	
		1.1	440 V	AP 4	0.52	70 kVAr	AP 9	-0.62	-82 kVAr	
		1.15	460 V	AP 5	0.60	80 kVAr	AP 10	-0.70	-93 kVAr	
red. active power	100 kW	0.85	340 V	AP 1	0.48	64 kVAr	AP 6	-0.54	-71 kVAr	
		0.9	360 V	AP 2	0.56	75 kVAr	AP 7	-0.62	-83 kVAr	
		1	400 V	AP 3	0.70	94 kVAr	AP 8	-0.78	-104 kVAr	
		1.1	440 V	AP 4	0.81	108 kVAr	AP 9	-0.90	-120 kVAr	
		1.15	460 V	AP 5	0.86	115 kVAr	AP 10	-0.96	-128 kVAr	

Tab. 7-2: Working points AP1...10

HMU05.1N-F0170-0430-N-A4-D7 / HMU05.1N-W0170-0430-N-A4-D7									
Active power		Mains voltage		Inductive reactive power			Capacitive reactive power		
		U/U_C	U	Point	$Q/P_{b\ inst}$	Q	Point	$Q/P_{b\ inst}$	Q
max. active power	137 kW	0.85	340 V	AP 1	0.30	49 kVAr	AP 6	-0.35	-56 kVAr
	145 kW	0.9	360 V	AP 2	0.31	51 kVAr	AP 7	-0.36	-59 kVAr
	161 kW = $P_{b\ inst}$	1	400 V	AP 3	0.34	54 kVAr	AP 8	-0.40	-65 kVAr
		1.1	440 V	AP 4	0.53	86 kVAr	AP 9	-0.61	-98 kVAr
		1.15	460 V	AP 5	0.61	99 kVAr	AP 10	-0.70	-112 kVAr
red. active power	120 kW	0.85	340 V	AP 1	0.50	80 kVAr	AP 6	-0.54	-87 kVAr
		0.9	360 V	AP 2	0.58	93 kVAr	AP 7	-0.63	-101 kVAr
		1	400 V	AP 3	0.72	116 kVAr	AP 8	-0.78	-126 kVAr
		1.1	440 V	AP 4	0.83	134 kVAr	AP 9	-0.91	-146 kVAr
		1.15	460 V	AP 5	0.88	143 kVAr	AP 10	-0.97	-156 kVAr

Tab. 7-3: Working points AP1...10

HMU05.1N-F0220-0510-N-A4-D7 / HMU05.1N-W0220-0510-N-A4-D7									
Active power		Mains voltage		Inductive reactive power			Capacitive reactive power		
		U/U_C	U	Point	$Q/P_{b\ inst}$	Q	Point	$Q/P_{b\ inst}$	Q
max. active power	177 kW	0.85	340 V	AP 1	0.21	44 kVAr	AP 6	-0.26	-54 kVAr
	188 kW	0.9	360 V	AP 2	0.22	45 kVAr	AP 7	-0.27	-56 kVAr
	209 kW = $P_{b\ inst}$	1	400 V	AP 3	0.23	47 kVAr	AP 8	-0.29	-61 kVAr
		1.1	440 V	AP 4	0.45	93 kVAr	AP 9	-0.52	-110 kVAr
		1.15	460 V	AP 5	0.53	110 kVAr	AP 10	-0.61	-129 kVAr
red. active power	150 kW	0.85	340 V	AP 1	0.48	99 kVAr	AP 6	-0.52	-109 kVAr
		0.9	360 V	AP 2	0.55	116 kVAr	AP 7	-0.61	-127 kVAr
		1	400 V	AP 3	0.69	144 kVAr	AP 8	-0.76	-158 kVAr
		1.1	440 V	AP 4	0.79	166 kVAr	AP 9	-0.87	-182 kVAr
		1.15	460 V	AP 5	0.84	176 kVAr	AP 10	-0.93	-194 kVAr

Tab. 7-4: Working points AP1...10

HMU05.1N-F0270-0660-N-A4-D7 / HMU05.1N-W0270-0660-N-A4-D7									
Active power		Mains voltage		Inductive reactive power			Capacitive reactive power		
		U/U_C	U	Point	$Q/P_{b\ inst}$	Q	Point	$Q/P_{b\ inst}$	Q
max. active power	218 kW	0.85	340 V	AP 1	0.25	65 kVAr	AP 6	-0.30	-78 kVAr
	231 kW	0.9	360 V	AP 2	0.26	67 kVAr	AP 7	-0.32	-81 kVAr
	256 kW = $P_{b\ inst}$	1	400 V	AP 3	0.28	71 kVAr	AP 8	-0.35	-89 kVAr
		1.1	440 V	AP 4	0.48	123 kVAr	AP 9	-0.56	-145 kVAr
		1.15	460 V	AP 5	0.56	144 kVAr	AP 10	-0.65	-167 kVAr
red. active power	200 kW	0.85	340 V	AP 1	0.41	104 kVAr	AP 6	-0.45	-117 kVAr
		0.9	360 V	AP 2	0.50	127 kVAr	AP 7	-0.55	-141 kVAr
		1	400 V	AP 3	0.65	166 kVAr	AP 8	-0.72	-184 kVAr
		1.1	440 V	AP 4	0.76	195 kVAr	AP 9	-0.84	-216 kVAr
		1.15	460 V	AP 5	0.81	209 kVAr	AP 10	-0.90	-232 kVAr

Tab. 7-5: Working points AP1...10

HMU05.1N- F0340-0820-N-A4-D7 / HMU05.1N- W0340-0820-N-A4-D7									
Active power		Mains voltage		Inductive reactive power			Capacitive reactive power		
		U/U_C	U	Point	$Q/P_{b\ inst}$	Q	Point	$Q/P_{b\ inst}$	Q
max. active power	274 kW	0.85	340 V	AP 1	0.27	87 kVAr	AP 6	-0.31	-99 kVAr
	290 kW	0.9	360 V	AP 2	0.28	90 kVAr	AP 7	-0.32	-105 kVAr
	323 kW = $P_{b\ inst}$	1	400 V	AP 3	0.30	97 kVAr	AP 8	-0.35	-114 kVAr
		1.1	440 V	AP 4	0.51	165 kVAr	AP 9	-0.58	-186 kVAr
		1.15	460 V	AP 5	0.59	192 kVAr	AP 10	-0.67	-215 kVAr
red. active power	250 kW	0.85	340 V	AP 1	0.43	138 kVAr	AP 6	-0.47	-151 kVAr
		0.9	360 V	AP 2	0.52	168 kVAr	AP 7	-0.56	-182 kVAr
		1	400 V	AP 3	0.67	217 kVAr	AP 8	-0.73	-235 kVAr
		1.1	440 V	AP 4	0.79	256 kVAr	AP 9	-0.86	-277 kVAr
		1.15	460 V	AP 5	0.85	274 kVAr	AP 10	-0.92	-297 kVAr

Tab. 7-6: Working points AP1...10

HMU05.1N-F0430-1040-N-A4-D7									
Active power		Mains voltage		Inductive reactive power			Capacitive reactive power		
		U/U_C	U	Point	$Q/P_{b\ inst}$	Q	Point	$Q/P_{b\ inst}$	Q
max. active power	347 kW	0.85	340 V	AP 1	0.29	119 kVAr	AP 6	-0.32	-132 kVAr
	367 kW	0.9	360 V	AP 2	0.31	125 kVAr	AP 7	-0.34	-139 kVAr
	408 kW = $P_{b\ inst}$	1	400 V	AP 3	0.33	135 kVAr	AP 8	-0.37	-153 kVAr
		1.1	440 V	AP 4	0.54	222 kVAr	AP 9	-0.60	-244 kVAr
		1.15	460 V	AP 5	0.63	257 kVAr	AP 10	-0.69	-281 kVAr
red. active power	300 kW	0.85	340 V	AP 1	0.51	207 kVAr	AP 6	-0.54	-219 kVAr
		0.9	360 V	AP 2	0.59	240 kVAr	AP 7	-0.62	-254 kVAr
		1	400 V	AP 3	0.73	299 kVAr	AP 8	-0.78	-317 kVAr
		1.1	440 V	AP 4	0.85	348 kVAr	AP 9	-0.90	-369 kVAr
		1.15	460 V	AP 5	0.91	372 kVAr	AP 10	-0.97	-395 kVAr

Tab. 7-7: Working points AP1...10

HMU05.1N-F0540-1300-N-A4-D7									
Active power		Mains voltage		Inductive reactive power			Capacitive reactive power		
		U/U_C	U	Point	$Q/P_{b\ inst}$	Q	Point	$Q/P_{b\ inst}$	Q
max. active power	436 kW	0.85	340 V	AP 1	0.28	144 kVAr	AP 6	-0.31	-157 kVAr
	462 kW	0.9	360 V	AP 2	0.29	151 kVAr	AP 7	-0.32	-165 kVAr
	513 kW = $P_{b\ inst}$	1	400 V	AP 3	0.32	164 kVAr	AP 8	-0.35	-182 kVAr
		1.1	440 V	AP 4	0.54	279 kVAr	AP 9	-0.59	-301 kVAr
		1.15	460 V	AP 5	0.63	325 kVAr	AP 10	-0.68	-348 kVAr
red. active power	400 kW	0.85	340 V	AP 1	0.43	222 kVAr	AP 6	-0.46	-235 kVAr
		0.9	360 V	AP 2	0.53	270 kVAr	AP 7	-0.55	-284 kVAr
		1	400 V	AP 3	0.69	352 kVAr	AP 8	-0.72	-370 kVAr
		1.1	440 V	AP 4	0.82	419 kVAr	AP 9	-0.86	-440 kVAr
		1.15	460 V	AP 5	0.88	451 kVAr	AP 10	-0.92	-474 kVAr

Tab. 7-8: Working points AP1...10

7.2.2 UQ diagrams for series HMU05.1N-Fxxxx-xxxx-N-A5-11

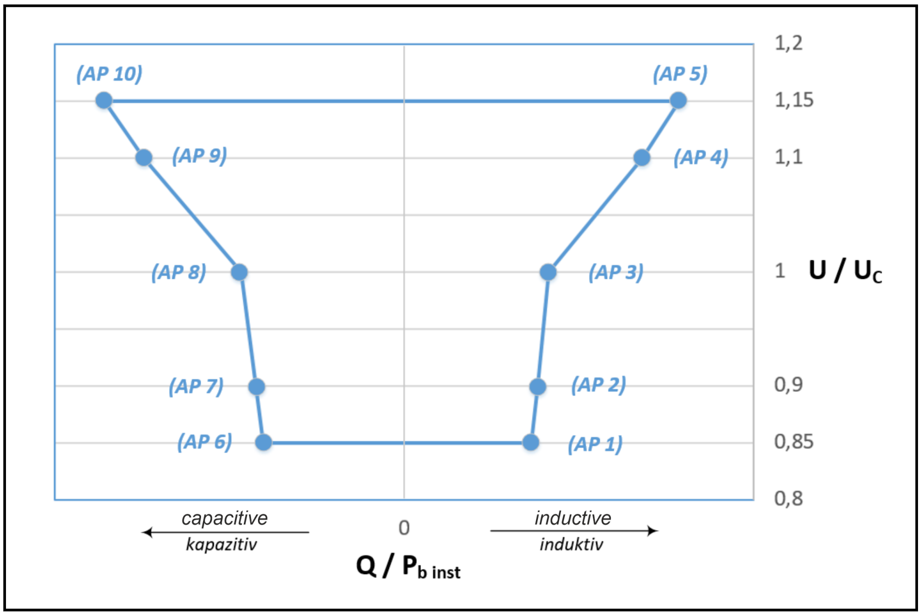


Fig. 7-3: UQ diagram. Working points AP1...10 see tables

HMU05.1N-F0140-0210-A5-11									
Active power		Mains voltage		Inductive reactive power			Capacitive reactive power		
		U/U_C	U	Point	$Q/P_{b\ inst}$	Q	Point	$Q/P_{b\ inst}$	Q
max. active power	95 kW	0.85	493 V	AP 1	0.22	24 kVAr	AP 6	-0.32	-36 kVAr
	100 kW	0.9	522 V	AP 2	0.22	24 kVAr	AP 7	-0.33	-37 kVAr
	111 kW $P_{b\ inst}$	1	580 V	AP 3	0.21	24 kVAr	AP 8	-0.36	-40 kVAr
		1.1	638 V	AP 4	0.37	42 kVAr	AP 9	-0.54	-61 kVAr
		1.15	667 V	AP 5	0.43	48 kVAr	AP 10	-0.62	-69 kVAr
red. active power	80 kW	0.85	493 V	AP 1	0.46	51 kVAr	AP 6	-0.56	-63 kVAr
		0.9	522 V	AP 2	0.52	59 kVAr	AP 7	-0.64	-72 kVAr
		1	580 V	AP 3	0.64	72 kVAr	AP 8	-0.78	-88 kVAr
		1.1	638 V	AP 4	0.71	80 kVAr	AP 9	-0.89	-99 kVAr
		1.15	667 V	AP 5	0.75	84 kVAr	AP 10	-0.93	-105 kVAr

Tab. 7-9: Working points AP1...10

HMU05.1N-F0170-0250-A5-11									
Active power		Mains voltage		Inductive reactive power			Capacitive reactive power		
		U/U_C	U	Point	$Q/P_{b\ inst}$	Q	Point	$Q/P_{b\ inst}$	Q
max. active power	115 kW	0.85	493 V	AP 1	0.23	31 kVAr	AP 6	-0.31	-43 kVAr
	122 kW	0.9	522 V	AP 2	0.23	32 kVAr	AP 7	-0.33	-45 kVAr
	135 kW = $P_{b\ inst}$	1	580 V	AP 3	0.24	32 kVAr	AP 8	-0.35	-48 kVAr
		1.1	638 V	AP 4	0.41	56 kVAr	AP 9	-0.55	-75 kVAr
		1.15	667 V	AP 5	0.48	65 kVAr	AP 10	-0.63	-86 kVAr
red. active power	100 kW	0.85	493 V	AP 1	0.44	60 kVAr	AP 6	-0.53	-72 kVAr
		0.9	522 V	AP 2	0.52	70 kVAr	AP 7	-0.61	-83 kVAr
		1	580 V	AP 3	0.65	88 kVAr	AP 8	-0.76	-104 kVAr
		1.1	638 V	AP 4	0.73	99 kVAr	AP 9	-0.87	-118 kVAr
		1.15	667 V	AP 5	0.77	105 kVAr	AP 10	-0.93	-126 kVAr

Tab. 7-10: Working points AP1...10

HMU05.1N-F0220-0300-A5-11									
Active power		Mains voltage		Inductive reactive power			Capacitive reactive power		
		U/U_C	U	Point	$Q/P_{b\ inst}$	Q	Point	$Q/P_{b\ inst}$	Q
max. active power	149 kW	0.85	493 V	AP 1	0.16	28 kVAr	AP 6	-0.24	-41 kVAr
	158 kW	0.9	522 V	AP 2	0.16	28 kVAr	AP 7	-0.24	-43 kVAr
	175 kW = $P_{b\ inst}$	1	580 V	AP 3	0.15	27 kVAr	AP 8	-0.26	-46 kVAr
		1.1	638 V	AP 4	0.35	62 kVAr	AP 9	-0.48	-85 kVAr
		1.15	667 V	AP 5	0.42	75 kVAr	AP 10	-0.57	-100 kVAr
red. active power	130 kW	0.85	493 V	AP 1	0.40	71 kVAr	AP 6	-0.48	-84 kVAr
		0.9	522 V	AP 2	0.48	84 kVAr	AP 7	-0.57	-100 kVAr
		1	580 V	AP 3	0.61	108 kVAr	AP 8	-0.72	-127 kVAr
		1.1	638 V	AP 4	0.70	123 kVAr	AP 9	-0.83	-146 kVAr
		1.15	667 V	AP 5	0.74	130 kVAr	AP 10	-0.88	-155 kVAr

Tab. 7-11: Working points AP1...10

HMU05.1N-F0270-0370-A5-11									
Active power		Mains voltage		Inductive reactive power			Capacitive reactive power		
		U/U_C	U	Point	$Q/P_{b\ inst}$	Q	Point	$Q/P_{b\ inst}$	Q
max. active power	183 kW	0.85	493 V	AP 1	0.19	41 kVAr	AP 6	-0.27	-59 kVAr
	194 kW	0.9	522 V	AP 2	0.19	41 kVAr	AP 7	-0.29	-62 kVAr
	215 kW = $P_{b\ inst}$	1	580 V	AP 3	0.19	41 kVAr	AP 8	-0.31	-66 kVAr
		1.1	638 V	AP 4	0.37	80 kVAr	AP 9	-0.51	-110 kVAr
		1.15	667 V	AP 5	0.44	95 kVAr	AP 10	-0.59	-128 kVAr
red. active power	150 kW	0.85	493 V	AP 1	0.48	103 kVAr	AP 6	-0.56	-121 kVAr
		0.9	522 V	AP 2	0.54	117 kVAr	AP 7	-0.64	-138 kVAr
		1	580 V	AP 3	0.66	143 kVAr	AP 8	-0.78	-168 kVAr
		1.1	638 V	AP 4	0.74	160 kVAr	AP 9	-0.88	-190 kVAr
		1.15	667 V	AP 5	0.78	168 kVAr	AP 10	-0.93	-201 kVAr

Tab. 7-12: Working points AP1...10

HMU05.1N-F0400-0600-A5-11									
Active power		Mains voltage		Inductive reactive power			Capacitive reactive power		
		U/U_C	U	Point	$Q/P_{b\ inst}$	Q	Point	$Q/P_{b\ inst}$	Q
max. active power	271 kW	0.85	493 V	AP 1	0.20	64 kVAr	AP 6	-0.28	-90 kVAr
	287 kW	0.9	522 V	AP 2	0.20	65 kVAr	AP 7	-0.29	-93 kVAr
	319 kW = $P_{b\ inst}$	1	580 V	AP 3	0.20	65 kVAr	AP 8	-0.31	-100 kVAr
		1.1	638 V	AP 4	0.39	125 kVAr	AP 9	-0.52	-167 kVAr
		1.15	667 V	AP 5	0.46	147 kVAr	AP 10	-0.60	-193 kVAr
red. active power	200 kW	0.85	493 V	AP 1	0.56	179 kVAr	AP 6	-0.64	-205 kVAr
		0.9	522 V	AP 2	0.62	199 kVAr	AP 7	-0.71	-227 kVAr
		1	580 V	AP 3	0.73	234 kVAr	AP 8	-0.84	-269 kVAr
		1.1	638 V	AP 4	0.81	258 kVAr	AP 9	-0.94	-300 kVAr
		1.15	667 V	AP 5	0.84	269 kVAr	AP 10	-0.99	-315 kVAr

Tab. 7-13: Working points AP1...10

HMU05.1N-F0540-0750-A5-11									
Active power		Mains voltage		Inductive reactive power			Capacitive reactive power		
		U/U_C	U	Point	$Q/P_{b\ inst}$	Q	Point	$Q/P_{b\ inst}$	Q
max. active power	366 kW	0.85	493 V	AP 1	0.19	83 kVAr	AP 6	-0.26	-114 kVAr
	388 kW	0.9	522 V	AP 2	0.20	84 kVAr	AP 7	-0.28	-119 kVAr
	431 kW = $P_{b\ inst}$	1	580 V	AP 3	0.20	85 kVAr	AP 8	-0.30	-128 kVAr
		1.1	638 V	AP 4	0.39	170 kVAr	AP 9	-0.51	-221 kVAr
		1.15	667 V	AP 5	0.47	201 kVAr	AP 10	-0.60	-258 kVAr
red. active power	300 kW	0.85	493 V	AP 1	0.48	209 kVAr	AP 6	-0.56	-240 kVAr
		0.9	522 V	AP 2	0.55	239 kVAr	AP 7	-0.63	-274 kVAr
		1	580 V	AP 3	0.68	293 kVAr	AP 8	-0.78	-336 kVAr
		1.1	638 V	AP 4	0.76	329 kVAr	AP 9	-0.88	-381 kVAr
		1.15	667 V	AP 5	0.80	347 kVAr	AP 10	-0.93	-403 kVAr

Tab. 7-14: Working points AP1...10

7.3 Supplying reactive power, PQ diagram

The PQ diagram shows how the reactive power is supplied in accordance with VDE-AR-N 4110:2018-11: chapter 10.2.2.3.

Inductive reactive power Q > 0:

In addition to the inductive reactive power Q, the following maximum active power P_{mom} can be permanently supplied or withdrawn at the mains connection:

$$P_{mom}(Q) = \min\left(P_{b\ inst};\sqrt{S_{HMU,max}^{2} - (Q + |Q_{HNC}|)^{2}}\right)$$

Fig. 7-4: Active power

The installed active power $P_{b\ inst}$, the maximum apparent power $S_{HMU,max}$ at the power section input, as well as the reactive power Q_{HNC} of the mains capacitor module, depend on the size (see tables below).

Capacitive reactive power Q < 0:

In addition to the capacitive reactive power Q, the following maximum active power can be permanently supplied or withdrawn at the mains connection:

$$P_{mom}(Q) = \min\left(P_{b\ inst};\sqrt{S_{HMU,max}^{2} - Q^{2}}\right)$$

Fig. 7-5: Active power

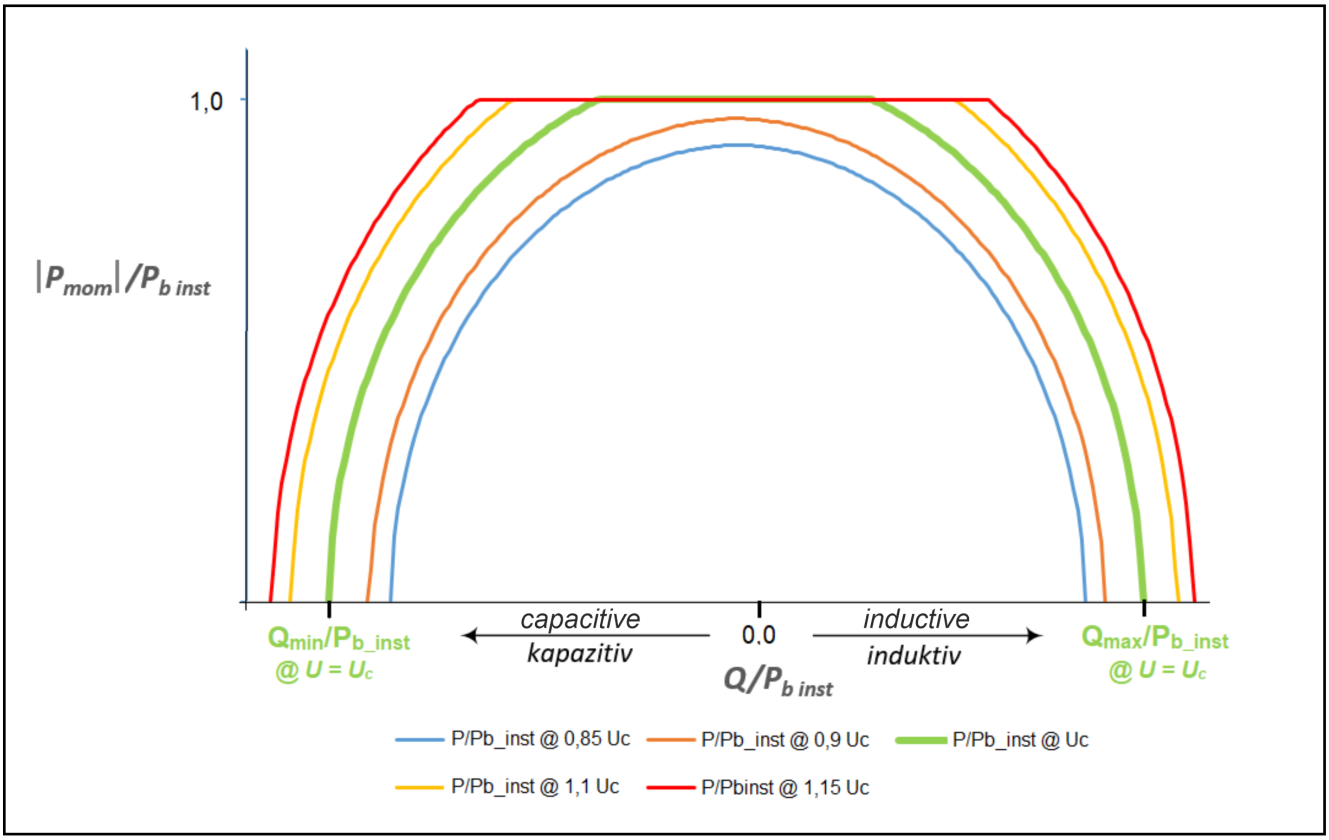


Fig. 7-6: PQ diagram

Note: In capacitive direction, the system control has to ensure that Q_{min} is complied with.

7.3.1 Parameters for PQ diagrams, series HMU05.1N-Fxxxx-xxxx-N-A4-D7 / HMU05.1N-Wxxxx-xxxx-N-A4-D7

HMU05.1N-F0140-0350-N-A4-D7 / HMU05.1N-W0140-0350-N-A4-D7								
U/U_C	U	$S_{HMU,max}$	$\|Q_{HNC}\|$	$P_{b\ inst}$	Q_{min} @P_{mom}=0	$Q_{min}/P_{b\ inst}$ @P_{mom}=0	Q_{max} @P_{mom}=0	$Q_{max}/P_{b\ inst}$ @P_{mom}=0
0.85	340 V	122 kVA	7.3 kVAr	133 kW	-122 kVAr	-0.92	116 kVAr	0.87
0.9	360 V	129 kVA	8.1 kVAr		-129 kVAr	-0.98	122 kVAr	0.92
1	400 V	144 kVA	10.0 kVAr		-144 kVAr	-1.08	134 kVAr	1.01
1.1	440 V	156 kVA	12.2 kVAr		-156 kVAr	-1.17	144 kVAr	1.08
1.15	460 V	162 kVA	13.3 kVAr		-162 kVAr	-1.22	149 kVAr	1.12

Tab. 7-15: Parameters for PQ diagrams

HMU05.1N-F0170-0430-N-A4-D7 / HMU05.1N-W0170-0430-N-A4-D7								
U/U_C	U	$S_{HMU,max}$	$\|Q_{HNC}\|$	$P_{b\ inst}$	Q_{min} @P_{mom}=0	$Q_{min}/P_{b\ inst}$ @P_{mom}=0	Q_{max} @P_{mom}=0	$Q_{max}/P_{b\ inst}$ @P_{mom}=0
0.85	340 V	148 kVA	7.3 kVAr	161 kW	-148 kVAr	-0.92	141 kVAr	0.87
0.9	360 V	156 kVA	8.1 kVAr		-156 kVAr	-0.97	149 kVAr	0.92
1	400 V	174 kVA	10.0 kVAr		-174 kVAr	-1.08	164 kVAr	1.01
1.1	440 V	189 kVA	12.2 kVAr		-189 kVAr	-1.17	177 kVAr	1.10
1.15	460 V	196 kVA	13.3 kVAr		-196 kVAr	-1.22	184 kVAr	1.14

Tab. 7-16: Parameters for PQ diagrams

HMU05.1N-F0220-0510-N-A4-D7 / HMU05.1N-W0220-0510-N-A4-D7								
U/U_C	U	$S_{HMU,max}$	$\|Q_{HNC}\|$	$P_{b\ inst}$	Q_{min} @P_{mom}=0	$Q_{min}/P_{b\ inst}$ @P_{mom}=0	Q_{max} @P_{mom}=0	$Q_{max}/P_{b\ inst}$ @P_{mom}=0
0.85	340 V	185 kVA	10.0 kVAr	209 kW	-185 kVAr	-0.89	176 kVAr	0.84
0.9	360 V	196 kVA	11.2 kVAr		-196 kVAr	-0.94	185 kVAr	0.89
1	400 V	217 kVA	13.8 kVAr		-217 kVAr	-1.04	204 kVAr	0.98
1.1	440 V	236 kVA	16.7 kVAr		-236 kVAr	-1.13	220 kVAr	1.05
1.15	460 V	245 kVA	18.2 kVAr		-245 kVAr	-1.17	227 kVAr	1.09

Tab. 7-17: Parameters for PQ diagrams

HMU05.1N-F0270-0660-N-A4-D7								
U/U_C	U	$S_{HMU,max}$	$\lvert Q_{HNC}\rvert$	$P_{b\ inst}$	Q_{min} @P_{mom}=0	$Q_{min}/P_{b\ inst}$ @P_{mom}=0	Q_{max} @P_{mom}=0	$Q_{max}/P_{b\ inst}$ @P_{mom}=0
0.85	340 V	231 kVA	12.7 kVAr	256 kW	-231 kVAr	-0.90	219 kVAr	0.85
0.9	360 V	244 kVA	14.3 kVAr		-244 kVAr	-0.95	231 kVAr	0.90
1	400 V	271 kVA	17.6 kVAr		-271 kVAr	-1.06	254 kVAr	0.99
1.1	440 V	294 kVA	21.3 kVAr		-294 kVAr	-1.15	273 kVAr	1.07
1.15	460 V	306 kVA	23.3 kVAr		-306 kVAr	-1.19	283 kVAr	1.10

Tab. 7-18: Parameters for PQ diagrams

HMU05.1N-F0340-0820-N-A4-D7 / HMU05.1N-W0340-0820-N-A4-D7								
U/U_C	U	$S_{HMU,max}$	$\lvert Q_{HNC}\rvert$	$P_{b\ inst}$	Q_{min} @P_{mom}=0	$Q_{min}/P_{b\ inst}$ @P_{mom}=0	Q_{max} @P_{mom}=0	$Q_{max}/P_{b\ inst}$ @P_{mom}=0
0.85	340 V	292 kVA	12.7 kVAr	323 kW	-292 kVAr	-0.90	279 kVAr	0.86
0.9	360 V	309 kVA	14.3 kVAr		-309 kVAr	-0.96	295 kVAr	0.91
1	400 V	342 kVA	17.6 kVAr		-342 kVAr	-1.06	325 kVAr	1.01
1.1	440 V	373 kVA	21.3 kVAr		-373 kVAr	-1.15	352 kVAr	1.09
1.15	460 V	388 kVA	23.3 kVAr		-388 kVAr	-1.20	365 kVAr	1.13

Tab. 7-19: Parameters for PQ diagrams

HMU05.1N-F0430-1040-N-A4-D7								
U/U_C	U	$S_{HMU,max}$	$\lvert Q_{HNC}\rvert$	$P_{b\ inst}$	Q_{min} @P_{mom}=0	$Q_{min}/P_{b\ inst}$ @P_{mom}=0	Q_{max} @P_{mom}=0	$Q_{max}/P_{b\ inst}$ @P_{mom}=0
0.85	340 V	371 kVA	12.7 kVAr	408 kW	-371 kVAr	-0.91	359 kVAr	0.88
0.9	360 V	393 kVA	14.3 kVAr		-393 kVAr	-0.96	379 kVAr	0.93
1	400 V	436 kVA	17.6 kVAr		-436 kVAr	-1.07	419 kVAr	1.02
1.1	440 V	475 kVA	21.3 kVAr		-475 kVAr	-1.16	455 kVAr	1.11
1.15	460 V	495 kVA	23.3 kVAr		-495 kVAr	-1.21	473 kVAr	1.16

Tab. 7-20: Parameters for PQ diagrams

HMU05.1N-F0540-1300-N-A4-D7								
U/U_C	U	$S_{HMU,max}$	$\lvert Q_{HNC}\rvert$	$P_{b\ inst}$	Q_{min} @P_{mom}=0	$Q_{min}/P_{b\ inst}$ @P_{mom}=0	Q_{max} @P_{mom}=0	$Q_{max}/P_{b\ inst}$ @P_{mom}=0
0.85	340 V	463 kVA	12.7 kVAr	513 kW	-463 kVAr	-0.90	451 kVAr	0.88
0.9	360 V	490 kVA	14.3 kVAr		-490 kVAr	-0.96	476 kVAr	0.93
1	400 V	544 kVA	17.6 kVAr		-544 kVAr	-1.06	527 kVAr	1.03
1.1	440 V	594 kVA	21.3 kVAr		-594 kVAr	-1.16	574 kVAr	1.12
1.15	460 V	620 kVA	23.3 kVAr		-620 kVAr	-1.21	597 kVAr	1.16

Tab. 7-21: Parameters for PQ diagrams

7.3.2 Parameters for PQ diagrams, series HMU05.1N-Fxxxx-xxxx-N-A5-11

HMU05.1N-F0140-0210-N-A5-11								
U/U_C	U	$S_{HMU,max}$	$\lvert Q_{HNC}\rvert$	$P_{b\ inst}$	Q_{min} @P_{mom}=0	$Q_{min}/P_{b\ inst}$ @P_{mom}=0	Q_{max} @P_{mom}=0	$Q_{max}/P_{b\ inst}$ @P_{mom}=0
0.85	493 V	101 kVA	11.4 kVAr	111 kW	-101 kVAr	-0.91	90 kVAr	0.81
0.9	522 V	107 kVA	12.8 kVAr		-107 kVAr	-0.96	95 kVAr	0.84
1	580 V	118 kVA	15.8 kVAr		-118 kVAr	-1.06	103 kVAr	0.92
1.1	638 V	127 kVA	19.2 kVAr		-127 kVAr	-1.14	108 kVAr	0.97
1.15	667 V	131 kVA	20.9 kVAr		-131 kVAr	-1.18	111 kVAr	0.99

Tab. 7-22: Parameters for PQ diagrams

HMU05.1N-F0170-0250-N-A5-11								
U/U_C	U	$S_{HMU,max}$	$\lvert Q_{HNC}\rvert$	$P_{b\ inst}$	Q_{min} @P_{mom}=0	$Q_{min}/P_{b\ inst}$ @P_{mom}=0	Q_{max} @P_{mom}=0	$Q_{max}/P_{b\ inst}$ @P_{mom}=0
0.85	493 V	123 kVA	11.4 kVAr	135 kW	-123 kVAr	-0.91	112 kVAr	0.82
0.9	522 V	130 kVA	12.8 kVAr		-130 kVAr	-0.96	117 kVAr	0.86
1	580 V	144 kVA	15.8 kVAr		-144 kVAr	-1.06	128 kVAr	0.94
1.1	638 V	155 kVA	19.2 kVAr		-155 kVAr	-1.14	136 kVAr	1.00
1.15	667 V	160 kVA	20.9 kVAr		-160 kVAr	-1.18	140 kVAr	1.03

Tab. 7-23: Parameters for PQ diagrams

HMU05.1N-F0220-0300-N-A5-11								
U/U_C	U	$S_{HMU,max}$	$\lvert Q_{HNC}\rvert$	$P_{b\ inst}$	Q_{min} @P_{mom}=0	$Q_{min}/P_{b\ inst}$ @P_{mom}=0	Q_{max} @P_{mom}=0	$Q_{max}/P_{b\ inst}$ @P_{mom}=0
0.85	493 V	155 kVA	13.8 kVAr	175 kW	-155 kVAr	-0.88	141 kVAr	0.80
0.9	522 V	163 kVA	15.4 kVAr		-163 kVAr	-0.93	149 kVAr	0.84
1	580 V	181 kVA	19.0 kVAr		-181 kVAr	-1.03	163 kVAr	0.93
1.1	638 V	195 kVA	23.0 kVAr		-195 kVAr	-1.11	172 kVAr	0.98
1.15	667 V	202 kVA	25.2 kVAr		-202 kVAr	-1.15	177 kVAr	1.01

Tab. 7-24: Parameters for PQ diagrams

HMU05.1N-F0270-0370-N-A5-11								
U/U_C	U	$S_{HMU,max}$	$\lvert Q_{HNC}\rvert$	$P_{b\ inst}$	Q_{min} @P_{mom}=0	$Q_{min}/P_{b\ inst}$ @P_{mom}=0	Q_{max} @P_{mom}=0	$Q_{max}/P_{b\ inst}$ @P_{mom}=0
0.85	493 V	192 kVA	18.3 kVAr	215 kW	-192 kVAr	-0.89	174 kVAr	0.81
0.9	522 V	203 kVA	20.5 kVAr		-203 kVAr	-0.94	183 kVAr	0.85
1	580 V	225 kVA	25.3 kVAr		-225 kVAr	-1.05	200 kVAr	0.93
1.1	638 V	242 kVA	30.7 kVAr		-242 kVAr	-1.12	212 kVAr	0.98
1.15	667 V	250 kVA	33.5 kVAr		-250 kVAr	-1.16	217 kVAr	1.01

Tab. 7-25: Parameters for PQ diagrams

HMU05.1N-F0400-0600-N-A5-11								
U/U_C	U	$S_{HMU,max}$	$\lvert Q_{HNC}\rvert$	$P_{b\ inst}$	Q_{min} @P_{mom}=0	$Q_{min}/P_{b\ inst}$ @P_{mom}=0	Q_{max} @P_{mom}=0	$Q_{max}/P_{b\ inst}$ @P_{mom}=0
0.85	493 V	286 kVA	25.2 kVAr	319 kW	-286 kVAr	-0.89	261 kVAr	0.82
0.9	522 V	302 kVA	28.2 kVAr		-302 kVAr	-0.95	274 kVAr	0.86
1	580 V	335 kVA	34.9 kVAr		-335 kVAr	-1.05	300 kVAr	0.94
1.1	638 V	360 kVA	42.2 kVAr		-360 kVAr	-1.13	318 kVAr	1.00
1.15	667 V	373 kVA	46.1 kVAr		-373 kVAr	-1.17	327 kVAr	1.02

Tab. 7-26: Parameters for PQ diagrams

HMU05.1N-F0540-0750-N-A5-11								
U/U_C	U	$S_{HMU,max}$	$\lvert Q_{HNC}\rvert$	$P_{b\ inst}$	Q_{min} @P_{mom}=0	$Q_{min}/P_{b\ inst}$ @P_{mom}=0	Q_{max} @P_{mom}=0	$Q_{max}/P_{b\ inst}$ @P_{mom}=0
0.85	493 V	384 kVA	30.9 kVAr	431 kW	-384 kVAr	-0.89	353 kVAr	0.82
0.9	522 V	406 kVA	34.7 kVAr		-406 kVAr	-0.94	371 kVAr	0.86
1	580 V	450 kVA	42.8 kVAr		-450 kVAr	-1.04	407 kVAr	0.94
1.1	638 V	485 kVA	51.8 kVAr		-485 kVAr	-1.12	433 kVAr	1.00
1.15	667 V	502 kVA	56.6 kVAr		-502 kVAr	-1.17	446 kVAr	1.03

Tab. 7-27: Parameters for PQ diagrams

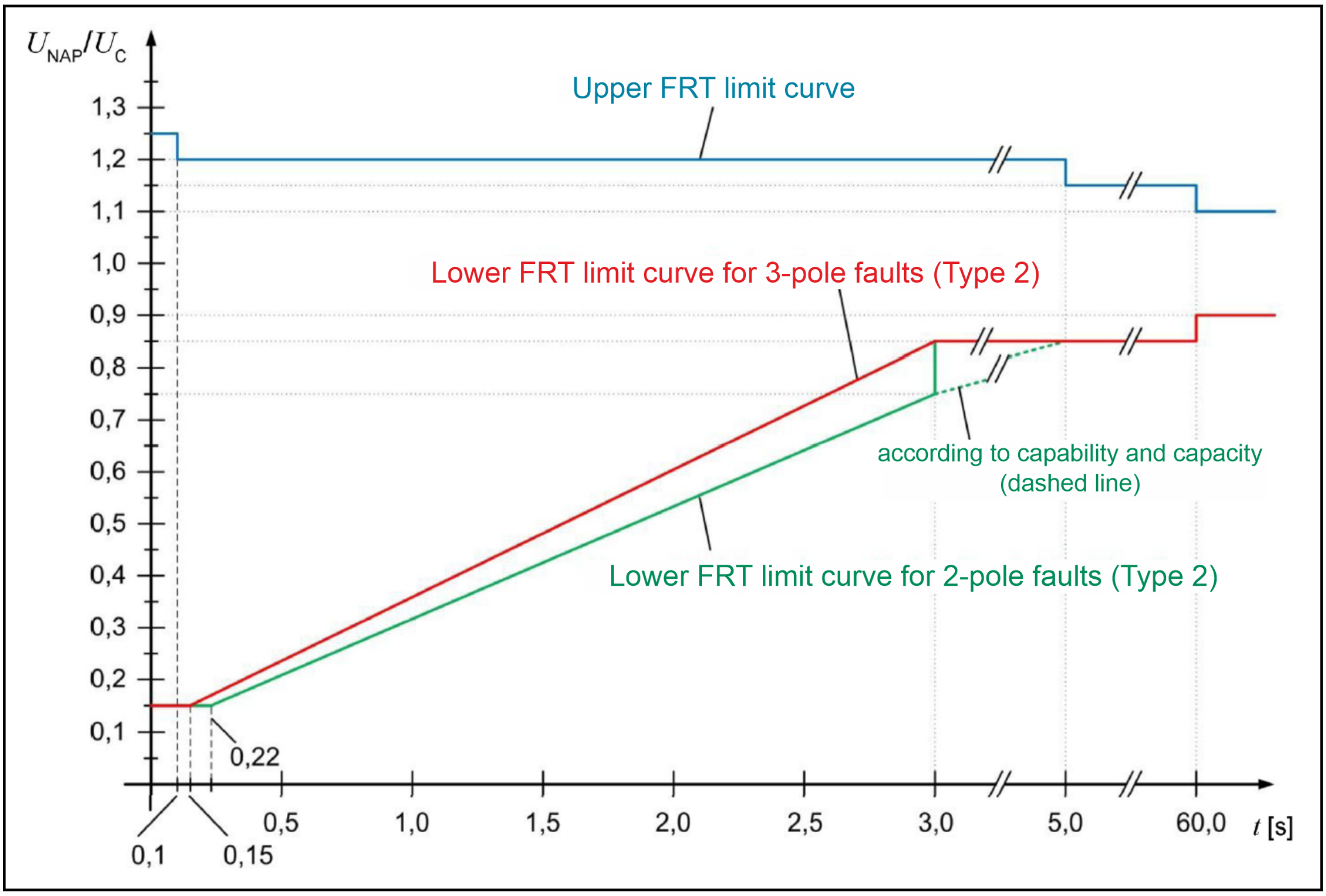
7.4 FRT limit curve (U/t diagram)

FRT (Fault Ride Through) means riding through faulty states.

7.4.1 FRT limit curve according to VDE

Reference: VDE-AR-N 4110:2018-11: Chapter 10.2.3.3

As long as all phase-to-phase voltages at the grid connection point are within the pictured limit curves, there is no instability of the power generating system and no disconnection from the grid in the entire operating range of the power generating system.



U_{NAP}	RMS value of current voltage at grid connection point
Upper FRT limit curve	Overvoltage limit curve
Lower FRT limit curve for 3-pole faults	3-phase voltage dips
Lower FRT limit curve for 2-pole faults	2-phase voltage dips

Fig. 7-7: Fault Ride Through limit curve for voltage curve at grid connection point for a type 2 power generating system; standard requirement for FRT limit curve. Source: VDE-AR-N 4110:2018-11

7.4.2 FRT limit curve according to device capacity

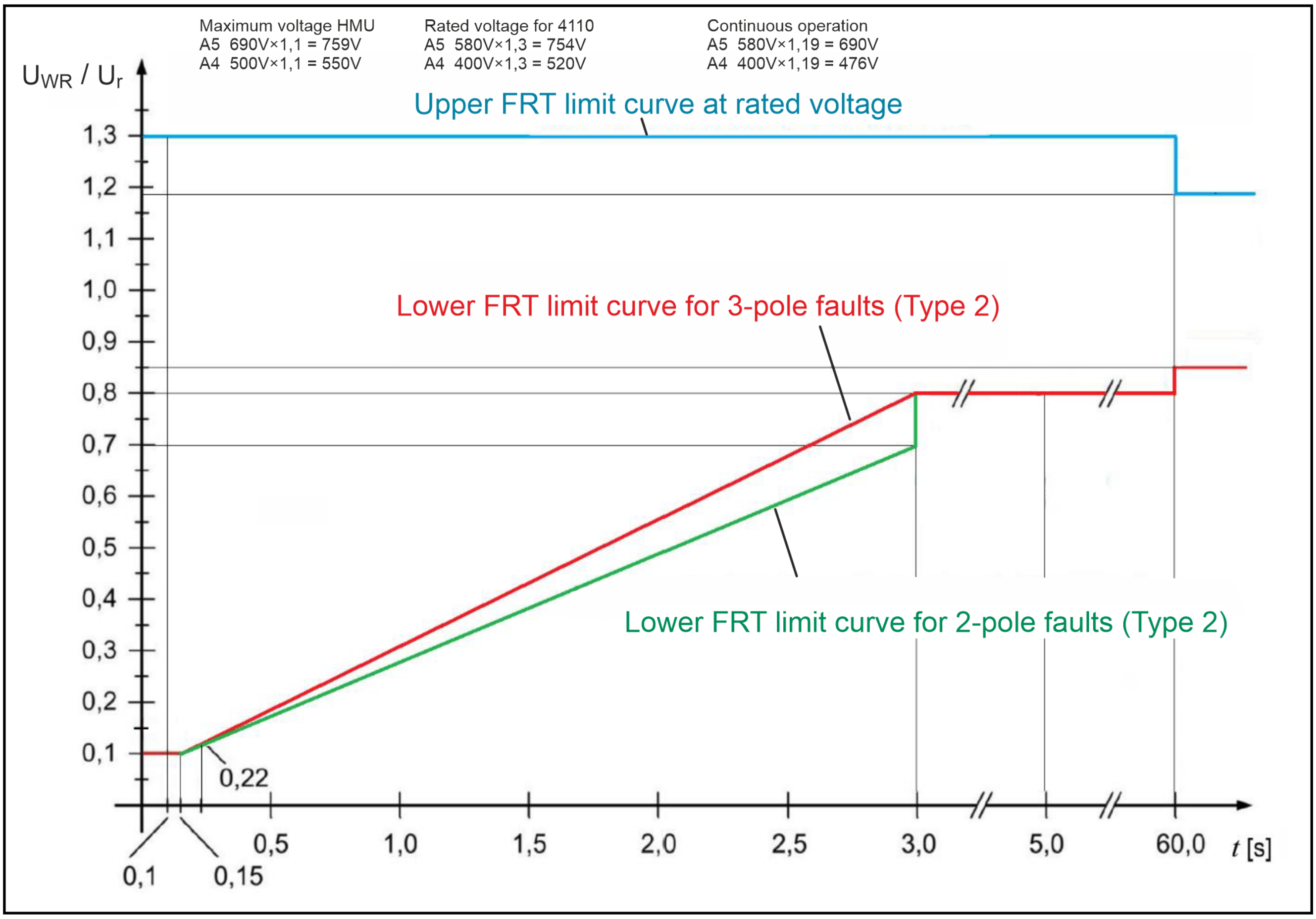


Fig. 7-8: Fault Ride Through limit curve put into effect

These limit curves can be allowed on the device side for HMU.

The settings of grid and system protection remain unaffected thereof and remain with the settings according to VDE-4110.

As regards the setting of U_C, an appropriate reserve in relation to the allowed device mains voltage has to be provided in order not to exceed an overvoltage up to $1.3 \times U_r$ at the grid inverter:

- For devices of the **400 V series** (HMU05.1N-…-A4), a mains voltage up to 550V is allowed. Therefore, $U_{WR} \leq 423V$. In this documentation, we assume $U_r = 400V$.
- For devices of the **580 V series** (HMU05.1N-…-A5), a mains voltage up to 759V is allowed. Therefore, $U_{WR} \leq 584V$. In this documentation, we assume $U_r = 580V$.

8 Grid-independent auxiliary energy supply UPS

The correct function of the power generating system requires a 24 V auxiliary power supply (24 V control voltage). To ensure the correct function of the power generating system, even in the case of grid faults such as voltage dips (see FRT), the 24 V control voltage has to be buffered independent of the grid. The 24 V control voltage has to be buffered for at least 5 seconds.

It is possible to use conventional solutions.

Example of 24 V control voltage buffering with **battery**:

Type	Manufacturer
QUINT-PS/3AC/24DC/20 (AC/DC power supply unit) QUINT-UPS/24DC/24DC/20 (UPS module) UPS-BAT/VRLA/24DC/12AH (battery)	Phönix Contact

Example of 24 V control voltage buffering from the **DC bus**:

Type	Manufacturer
QT20.241 (AC/DC power supply unit) QTD20.241 (DC/DC power supply unit) YR40.241 (redundancy module)	PULS

In the case of a fault with failure of the 24 V control voltage, the grid inverter does not work anymore. The output stage of the grid inverter is locked and the circuit breaker opens.

9 Protective functions with setting ranges

9.1 Disconnection protection

9.1.1 Grid and system protection relay and connection switch

As a disconnection protection device for the PGU, a **certified, external grid and system protection relay** is required.

In the case of limit value violations, the grid and system protection relay disconnects the connection between the public grid system and the power generating system by actuating connection switches. If measured voltage and frequency values are outside of threshold values required by standards, the relays / connection switches of the grid and system protection relay are switching.

The following monitoring and protective functions have been implemented in the grid and system protection relay:

- Voltage decrease protection U<
- Voltage decrease protection U<<
- Voltage increase protection U>>
- Voltage increase protection U>
- Frequency increase protection f>
- Frequency increase protection f>>
- Frequency decrease protection f<
- Frequency decrease protection f<<
- Island grid detection df/dt (Rate of Change of Frequency, ROCOF)
- Island grid detection, vector jump detection
- Unbalance detection

Thereby, the requirements of static and dynamic mains monitoring are fulfilled.

Reference: VDE-AR-N 4110:2018-11: Chapter 10.3.3.2

Voltage protection devices for disconnection protection have to be implemented in 3-phase form.

For measurement on the low-voltage side (like it is the case here), the voltage between outer conductor and neutral point has to be evaluated in the case of Dy machine transformers. In the case of Yd machine transformers, the voltage between the outer conductors has to be evaluated.

In the case of power generating units that have an IT mains configuration on the low-voltage side, the outer conductor voltages have to be evaluated.

Requirements for grid and system protection relay:

- Only use grid and system protection relay with a component certificate according to VDE-AR-N 4110

Requirements for connection switch:

- Use circuit breakers
- 3-pole galvanic isolation
- Sized for the maximum short-circuit current occurring at the point of installation
- Release delay < 70 ms

9.1.2 Overview of PGU with grid and system protection relay UFR1001E

Recommendation: grid and system protection relay UFR1001E by Ziehl.

It is possible to use grid and system protection relays and connection switches of other manufacturers.

The power generating unit is alternatively operated in the IT mains or in the TN mains.

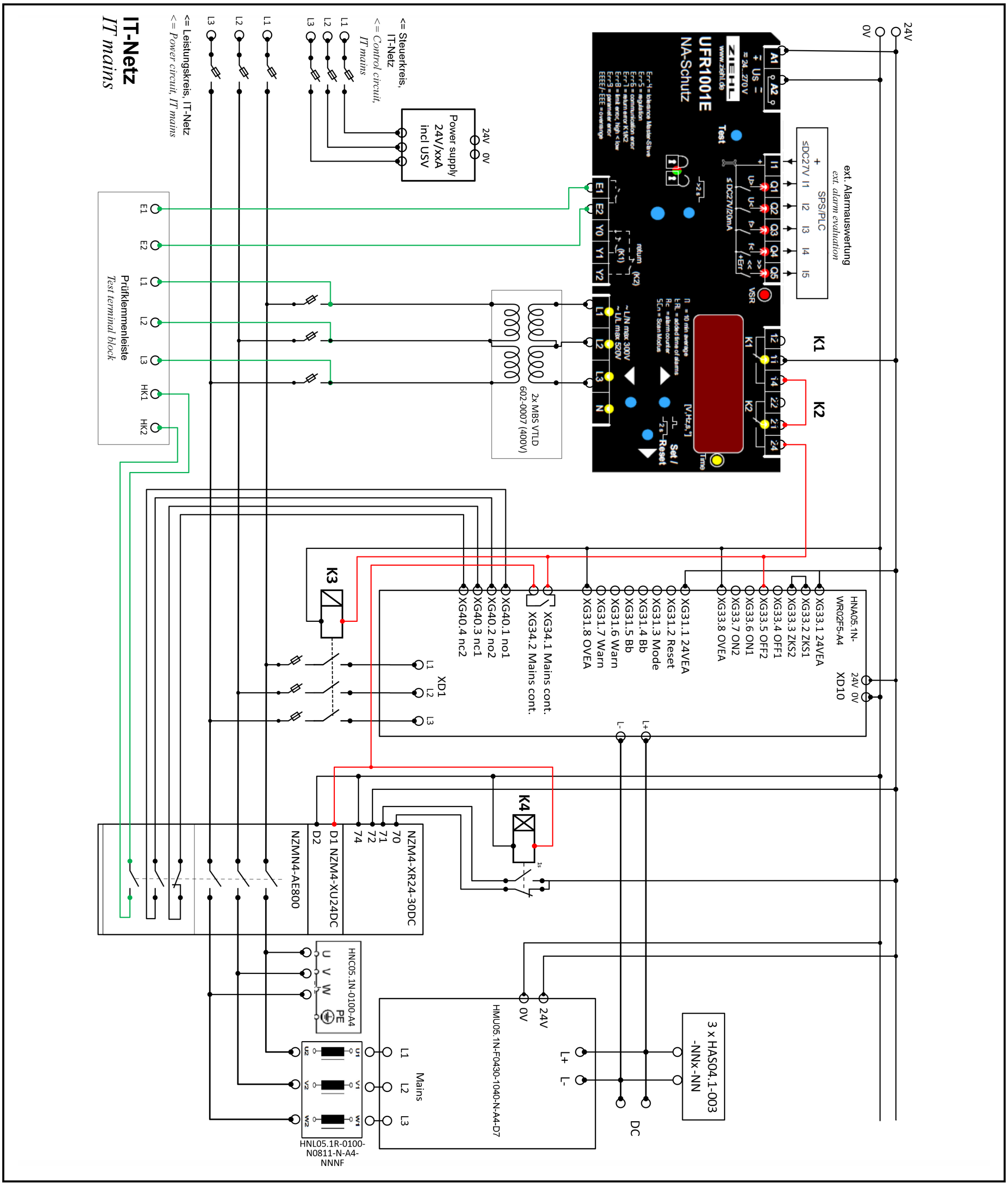


Fig. 9-1: Power generating unit in IT mains

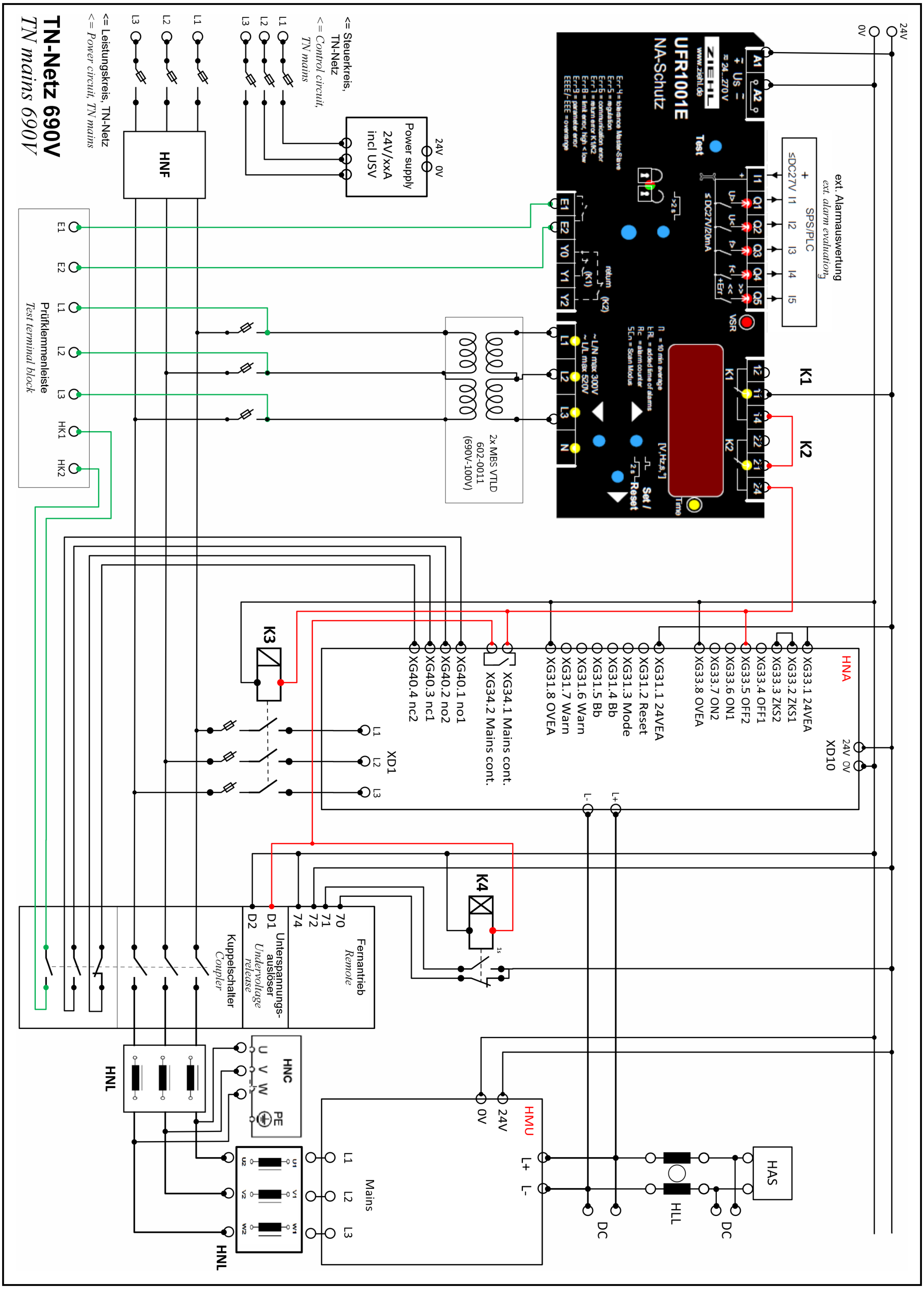


Fig. 9-2: Power generating unit in TN mains 690 V

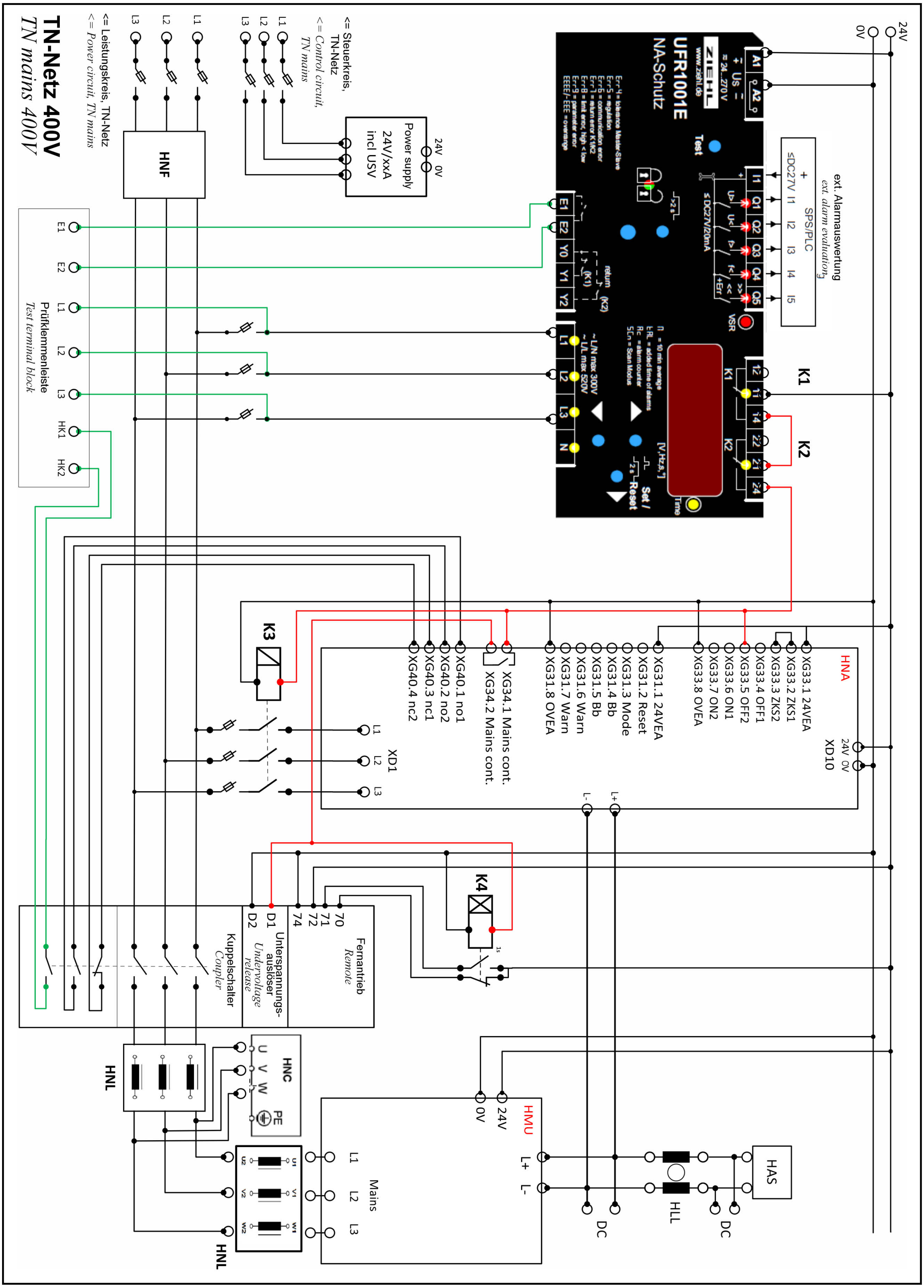


Fig. 9-3: Power generating unit in TN mains 400 V

9.1.3 Functional principle

Initial situation:

24V control voltage has been applied and is buffered by a UPS.

Switching on the power generating unit:

1. Ziehl UFR1001E contacts K1 and K2 close simultaneously if the switch-on conditions have been fulfilled. The HNA mains connection module is informed about this via XG33.5.
2. Contactor K3 closes and supplies HNA with the grid.
3. HNA and the internal HMU control recognizes this and, upon request by the system control, starts precharging the DC bus.
4. As soon as the precharging procedure has been completed, HNA closes XG34.

   Thus, 24V are present at the undervoltage release and at the coupling relay K4.
5. The coupling relay K4 picks up and requests the remote control switch to switch on.
6. The connection switch is closed and signals this via the auxiliary switches and XG40 to HNA and the HMU control.
7. HMU goes to control, according to the command values of the system control.

Switching off the power generating unit:

1. Upon request by the system control, control is switched off in HMU and XG34 opens.
2. The undervoltage switch triggers and the connection switch opens.
3. The remote-controlled mechanism also switches off.

Switching off by grid and system protection relay UFR1001E in the case of error:

1. Ziehl UFR1001E opens K1 and/or K2.
2. Thus, HNA gets an OFF command and initiates the immediate power off (control off and XG34 opens).
3. In parallel, K3 and K4 and the undervoltage release are, without delay, no longer supplied with current.
4. The undervoltage switch triggers and the connection switch opens.
5. The remote-controlled mechanism also switches off.

9.2 Island grid detection / method for detecting unintended island grid generation

Reference: VDE-AR-N 4105:2018-11: Chapter 6.5.3

For power generating systems, VDE-AR-N 4105:2018-11 demands a method for island grid detection. **Island grid detection** can be activated via „P-0-1319: Dynamic grid support, configuration". The combination of island grid detection and dynamic grid support is not provided.

Via an adjusted voltage phasor, the active method for detecting unintended island grid generation ensures the displacement of grid frequency / grid voltage in the case of active island grid, i.e. unintended disconnection from the grid. As a result, the monitoring thresholds of the grid and system protection are exceeded/fallen below, and grid disconnection occurs. In mains operation, the adjusted voltage phasor does not have any effect.

Note: This function is only available if the Application ID in „P-0-1411: Device control version register“ has the value 0b0010.

9.3 Self-protection

The grid inverter monitors currents and voltages. If currents or voltages exceed critical threshold values, an error reaction occurs, the output stage is switched off and the connection switch is actuated.

The following error cases cause **disconnection from power supply**:

- Overcurrent in power section of grid inverter
- Overvoltage in DC bus
- Overvoltage of AC mains connection voltage
- Thermal overload of grid inverter

10 System control

The system control is not part of the grid inverter's scope of supply and has to be provided by the customer.

Main task of the system control:

- Centrally controls power generating unit(s)
- Controls components such as heating unit, cooling system and dehumidifier
- Monitors transformer and switchgear
- Provides external interface to the user (power supply company)
- Facilitates remote access to entire power generating system
- Generates logbooks
- Generates command values for power generating unit / implements desired operating strategy
- Controls (re)start of the power generating system
- Communicates with battery management system

11 Communication interface: Master communication

Implementation strategy

The communication between system control and the grid inverter takes place via the so-called **master communication**. The firmware of the grid inverter supports a number of **communication protocols**, such as Sercos or PROFINET. If a communication protocol is selected that is supported by the grid inverter firmware, all parameters of the device control and of the grid inverter firmware can be directly used.

If a communication protocol is required (e.g., Modbus TCP/IP) that is **not supported** by the grid inverter firmware, this protocol has to be implemented in the **device control**. For this purpose, a software library is generated from the software functionality of the device control described here. This software library then is included in a second device control project. Besides this library this project only contains the implementation of the desired communication protocol. In this way, the software functionalities for mains supply are separated from the communication with regard to architecture.

Communication protocol: Modbus TCP/IP

Modbus TCP/IP is a communication protocol that is not supported by the grid inverter firmware. Therefore, Modbus TCP/IP is implemented in the **device control**.

For this purpose, a **Modbus server** has been implemented in the power generating unit, since the power generating unit has to respond to Modbus requirements of external Modbus clients (system control).

The Modbus server has been implemented as an asynchronous Modbus server:

When the server receives a request, it puts it in the queue and starts processing. If a new request is received in the meantime, it is also put in the queue and processing is started in a separate thread. Whenever a request was processed, the result is returned (asynchronously).

12 Device control

The device control has been integrated in the HMV05 grid inverter. The specific functions according to VDE-AR-N 4110 were implemented in the device control:

- Active power control
- Reactive power control
- Dynamic reactive-current supply

The figure below shows the interaction of system control, device control and HMV05.

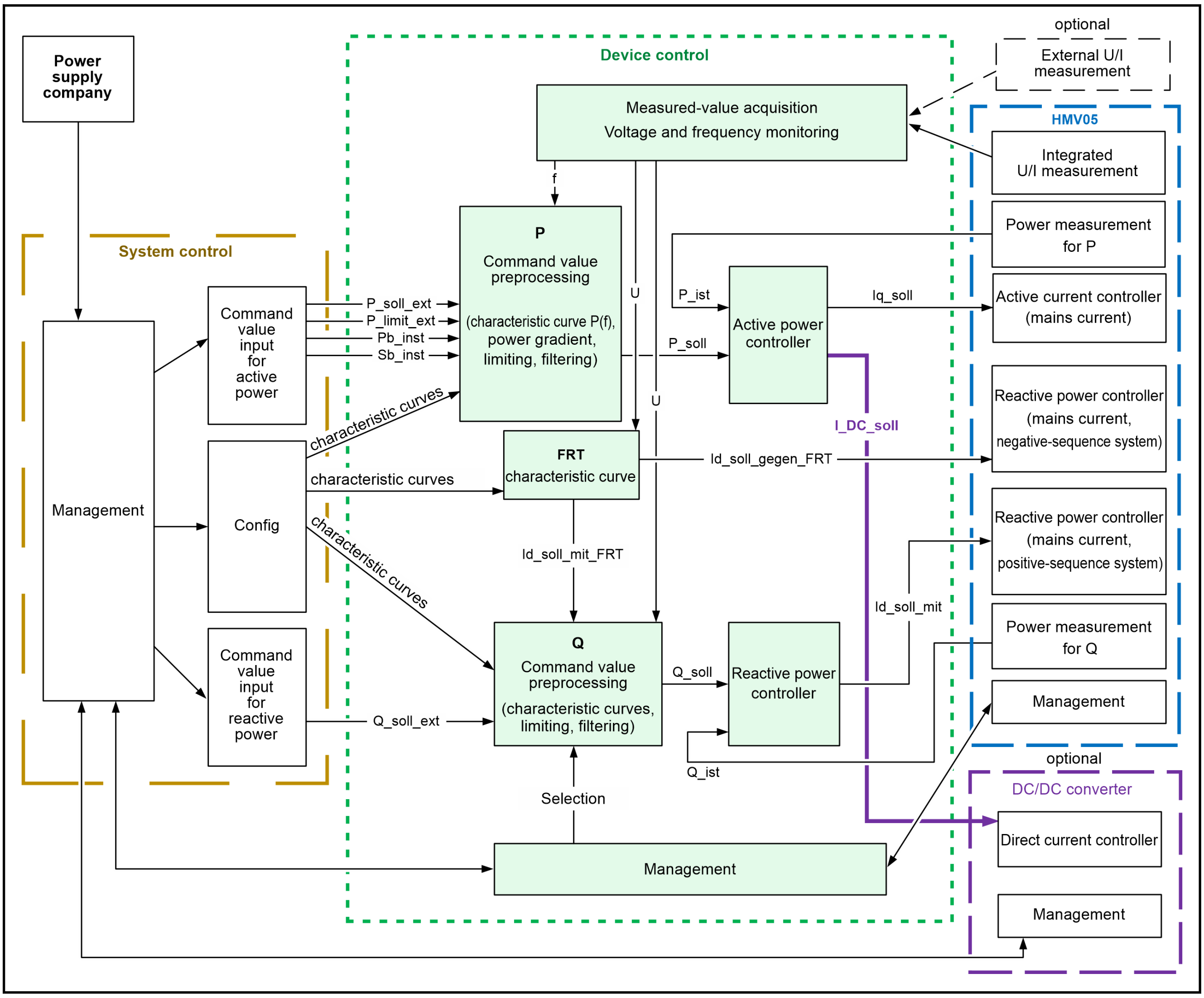


Fig. 12-1: Interaction of system control, device control and HMV05

The program of the device control is available in the form of a parameter file. We distinguish the following variants:

1. FWS-MLDEAX-**GSN-01V01**-D0-PS21-NNNNNNNN-NN.par

   GSN: Grid, standard master communication, VDE-AR-N 4110 functionality

Standard master communication comprises all communication protocols that the grid inverter firmware covers. This includes:

- Sercos
- EtherCAT
- EtherNet/IP
- PROFINET
- POWERLINK
- PROFIBUS-DP
- CANopen

2. FWS-MLDEAX-**GMN-01V01**-D0-PS21-NNNNNNNN-NN.par

   GMN: Grid, Modbus TCP/IP master communication, VDE-AR-N 4110 functionality

   Modbus TCP/IP is not supported by the grid inverter firmware and is therefore implemented in the device control.

3. FWS-MLDEAX-**GSI-01V00**-D0-PS21-NNNNNNNN-NN.par

   GSI: Grid, standard master communication, VDE-AR-N 4110 functionality with island grid detection

The positions highlighted in the type code (FWS-MLDEAX-***-*****-D0-PS21-NNNNNNNN-NN) are the version and the release of the device control software.

Via "P-0-1411: Device control version register", the version and release can be read at any time.

13 Active power control

13.1 Implementation in device control

Implementing active power control in device control:

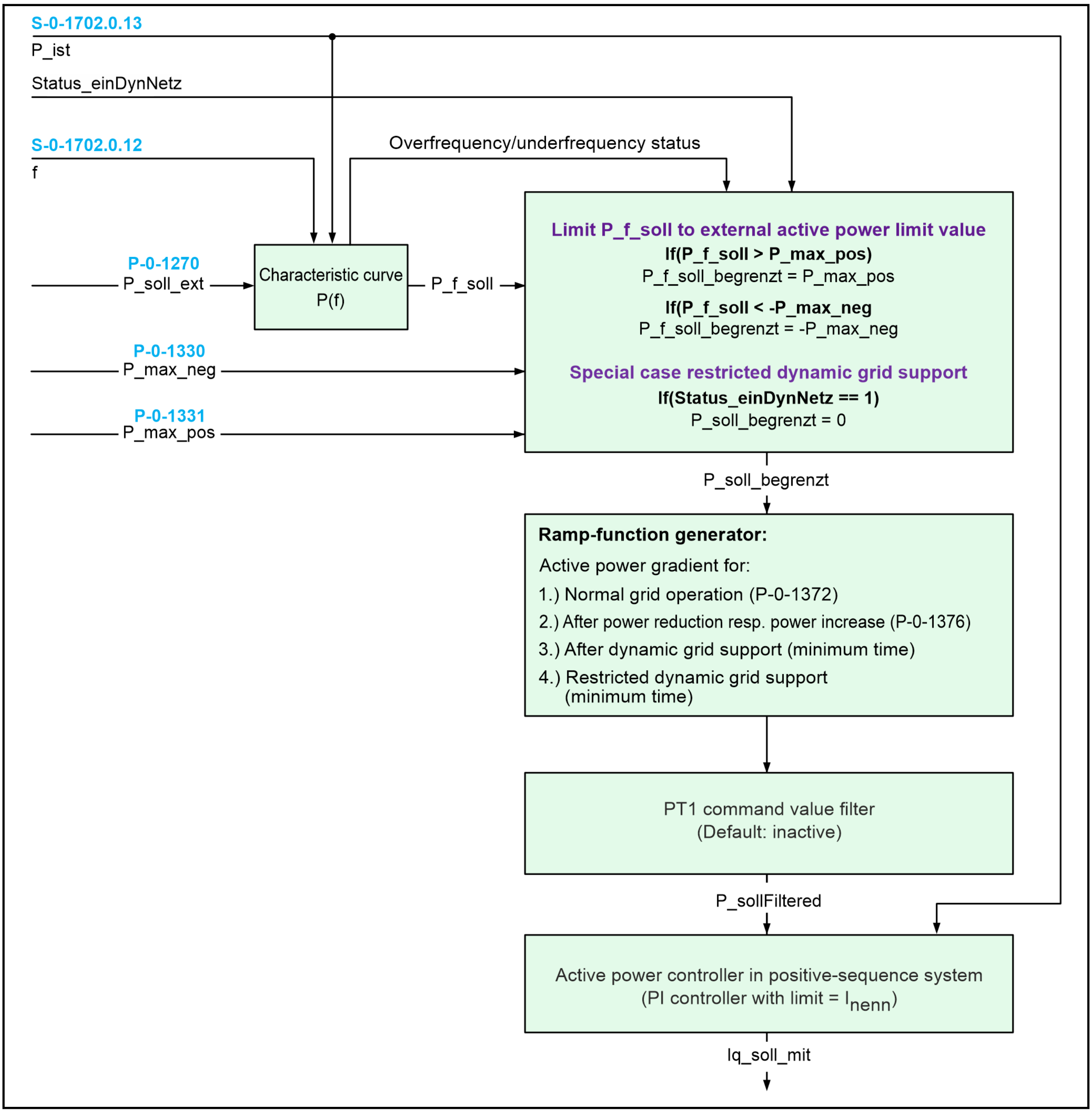


Fig. 13-1: Active power control

The apparent power limit of HMV05 has to be parameterized in P-0-1370. For the required value please see the electrical data.

The installed active power of the power generating system $P_{b\ inst}$ has to be entered in parameter P-0-1371. $P_{b\ inst}$ of the power generating system can be at most the device’s nominal active power of HMV05.

The specification of the active power output by the system control / power supply company (active power command value) takes place via the parameter P-0-1270.

This command value is preprocessed (limitations, ramp-function generator, PT1 filter) and transferred to the input of the active power controller as „P-0-1275, Active power for power supply company, effective cmd value“.

The actual value of the active power can be read via the parameter S-0-1702.0.13.

13.2 Power-frequency behavior

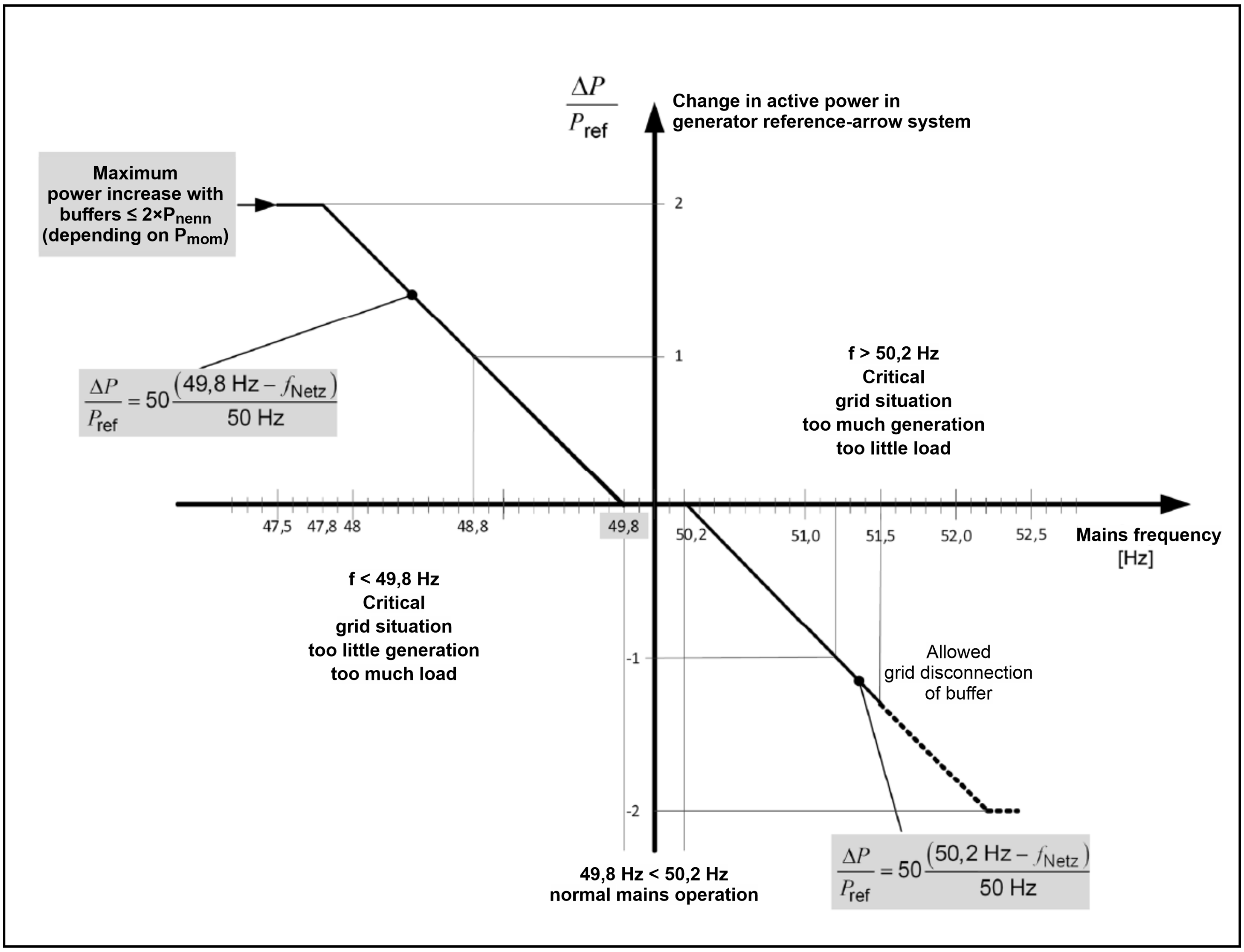
If the mains frequency is outside of the tolerance band of ±200 mHz around the nominal mains frequency of 50.0 Hz, there is a critical system state in the grid system, and all power generating systems, buffers and controllable consumers have to contribute to the mains frequency support.

Characteristic curves

The power generating system is able to adjust the active power working point in the case of underfrequency and in the case of overfrequency. For this purpose, the following characteristic curves have been implemented.

If bit 3 = 0 in P-0-1327, the grid inverter works as a buffer inverter. In this case, the following characteristic curve applies:

Adjusting the active power of steplessly controllable consumers and buffers of type 2 in the case of overfrequency and underfrequency with a droop of 2% and frequency limit values of 49.8 Hz and 50.2 Hz for the beginning of active power adjustment:

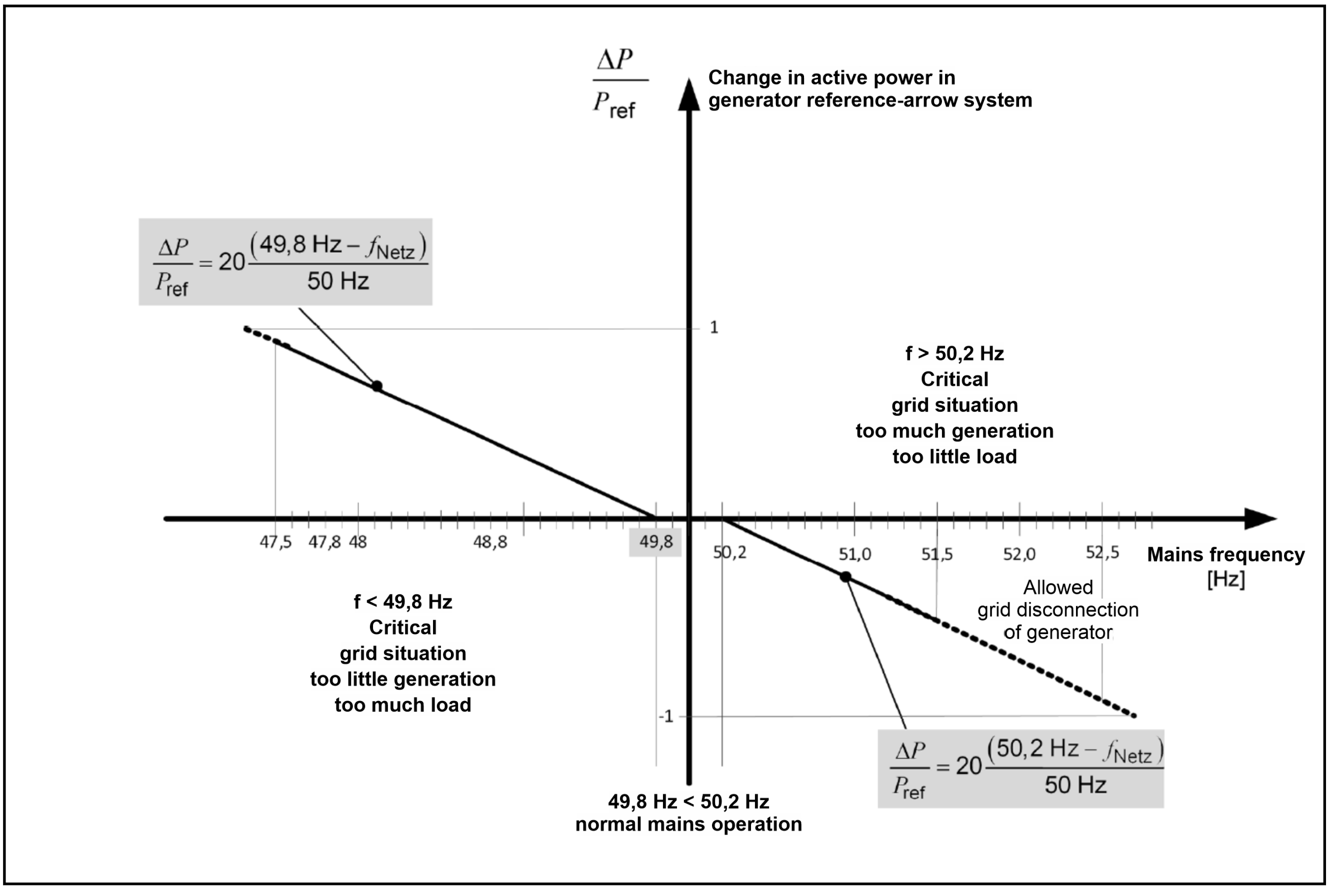


P_{ref}	Corresponds to $P_{b\ inst}$ or corresponds to P_{mom} for power generating systems of type 2 (excluding buffers) at point of time when 50.2 Hz are exceeded
ΔP	Change in power
f	Mains frequency

Fig. 13-2: Adjusting the active power depending on the mains frequency for buffer inverters (source: VDE-AR-N 4110:2018-11)

If bit 3 = 1 in P-0-1327, the grid inverter works as a non-buffer inverter. In this case, the characteristic curve according to the figure below applies.

Adjusting the active power of power generating systems of type 1 and type 2, as well as controllable consumers and buffers of type 1, in the case of overfrequency and underfrequency with a droop of 5% and frequency limit values of 49.8 Hz and 50.2 Hz for the beginning of active power adjustment:



P_{ref}	Corresponds to $P_{b\ inst}$ or corresponds to P_{mom} for power generating systems of type 2 (excluding buffers) at point of time when 50.2 Hz are exceeded
ΔP	Change in power
f	Mains frequency

Fig. 13-3: Adjusting the active power depending on the mains frequency for non-buffer inverters (source: VDE-AR-N 4110:2018-11)

Behavior in the case of overfrequency:

The frequency value for the beginning of power reduction in the case of overfrequency $f_{power\ reduction\_start}$ is set in P-0-1372. The default value for $f_{power\ reduction\_start}$ is 50.2 Hz.

The currently generated active power P_{ref} at the point of time when $f_{power\ reduction\_start}$ is exceeded is frozen and used as reference value.

Other than this, the setting $P_{ref} = P_{b\ inst}$ applies to buffer inverters. P_{ref} is reduced (if frequency rises) or increased (if frequency is reduced) with a gradient of $K_{power\ reduction\_gradient}$ of P_{ref} per Hz. However, it can only be increased if power was reduced beforehand.

$K_{power\ reduction\_gradient}$ is set in parameter P-0-1373. 100% of P_{ref} per Hz was selected as the default value for $K_{power\ reduction\_gradient}$. For buffer inverters, the value has to remain at 100% of P_{ref} per Hz.

If $f_{mains} > f_{power\ reduction\_start}$ then

- $P_{max,freq} = P_{ref} - (K_{power\ reduction\_gradient} \times P_{ref}) \times (f_{mains} - f_{power\ reduction\_start})$

else

- $P_{max,freq} = P_{cmd,input}$

with

- $P_{cmd,input}$ is the active power command value input by the power supply company / system control
- $P_{max,freq}$ is determined via the frequency-dependent characteristic curve

In the case of mains frequencies f > 67 Hz, the grid inverter switches off power.

Behavior in the case of underfrequency:

The frequency value for the beginning of power increase in the case of underfrequency $f_{power\ increase\_start}$ is set in P-0-1374. The default value for $f_{power\ increase\_start}$ is 49.8 Hz.

The currently generated active power P_{ref} at the point of time when $f_{power\ increase\_start}$ is exceeded is frozen and used as reference value.

Other than this, the setting $P_{ref} = P_{b\ inst}$ applies to buffer inverters. P_{ref} is reduced (if frequency rises) or increased (if frequency is reduced) with a gradient of $K_{power\ increase\_gradient}$ of P_{ref} per Hz. However, it can only be increased if power was reduced beforehand.

$K_{power\ increase\_gradient}$ is set in parameter P-0-1375. 100% of P_{ref} per Hz was selected as the default value for $K_{power\ increase\_gradient}$. For buffer inverters, the value has to remain at 100% of P_{ref} per Hz.

If $f_{mains} < f_{power\ increase\_start}$ then

- $P_{max,freq} = P_{ref} + (K_{power\ increase\_gradient} \times P_{ref}) \times (f_{power\ increase\_start} - f_{mains})$

else

- $P_{max,freq} = P_{cmd,input}$

with

- $P_{cmd,input}$ is the active power command value input by the power supply company / system control
- $P_{max,freq}$ is determined via the frequency-dependent characteristic curve

In the case of mains frequencies f < 43 Hz, the grid inverter switches off power.

End of the critical grid state and return to normal operation

Even if, after the frequency deviation, the mains frequency is back within the tolerance band of 50.0 Hz ±200 mHz, we still have to assume a critical grid state. The transition from the „critical grid state“ to the „normal grid operation“ is temporarily limited by a maximum change in the active command power, based on P_{mom}.

The power gradient for limiting this change in the active command power is specified in parameter P-0-1376. The default is 10% $P_{b\ inst/min}$. Only if the mains frequency is for 10 minutes continuously within the tolerance band of 50.0 Hz ±200 mHz, the normal grid operation is considered as having been reestablished, and this requirement no longer applies.

13.3 Active power gradient

Reference: VDE-AR-N 4110:2018-11: Chapter 10.2.4.1

The following power gradients are complied with for increasing and reducing the active power output in the case of power generating systems (technical minimum power ↔ 100% $P_{b\ inst}$) and buffers (0 ↔ 100% $P_{b\ inst}$):

- no faster than with 0.66% $P_{b\ inst}$ per second
- no slower than with 0.33% $P_{b\ inst}$ per second

Other than that, power generating systems may react more slowly to command value input by third parties; in the case of increase in performance, however, not slower than 4% $P_{b\ inst}$ per minute.

The power gradient for increasing and reducing the active power output for normal grid operation and switch-on is specified in parameter P-0-1329. The default value is 0.66% $P_{b\ inst}$ per second.

Note: There is the use case „Participation in primary control power market“ (not described in VDE-AR-N 4110). Here, the power gradients do not count, but the fastest possible command value input. In this case, the value 0 has to be set in P-0-1329. Thereby, the ramp function is deactivated.

The active power command value is optionally filtered. The time constant of the PT1 filter can be parameterized in P-0-1325. The default value is 0, i.e. the filter does not take effect.

13.4 Grid security management

Reference: VDE-AR-N 4110:2018-11: Chapter 10.2.4.2

Power generating systems have to be able to reduce their active power to a power value specified by the power supply company at the grid connection point, without disconnection from the grid. This value corresponds to a percentage value related to the installed active feed-in power $P_{b\ inst}$. The power reduction has to be possible in every operating state and from every working point.

Use the parameter P-0-1330 to limit the active power flowing from the power generating system to the power grid.

Use the parameter P-0-1331 to limit the active power flowing from the power grid to the power generating system. If the power generating system cannot absorb any energy, P-0-1331 has to be set to 0.

14 Reactive power control

14.1 Implementation in device control

The reactive power control was implemented in the device control. For an overview of implementation, see figure below.

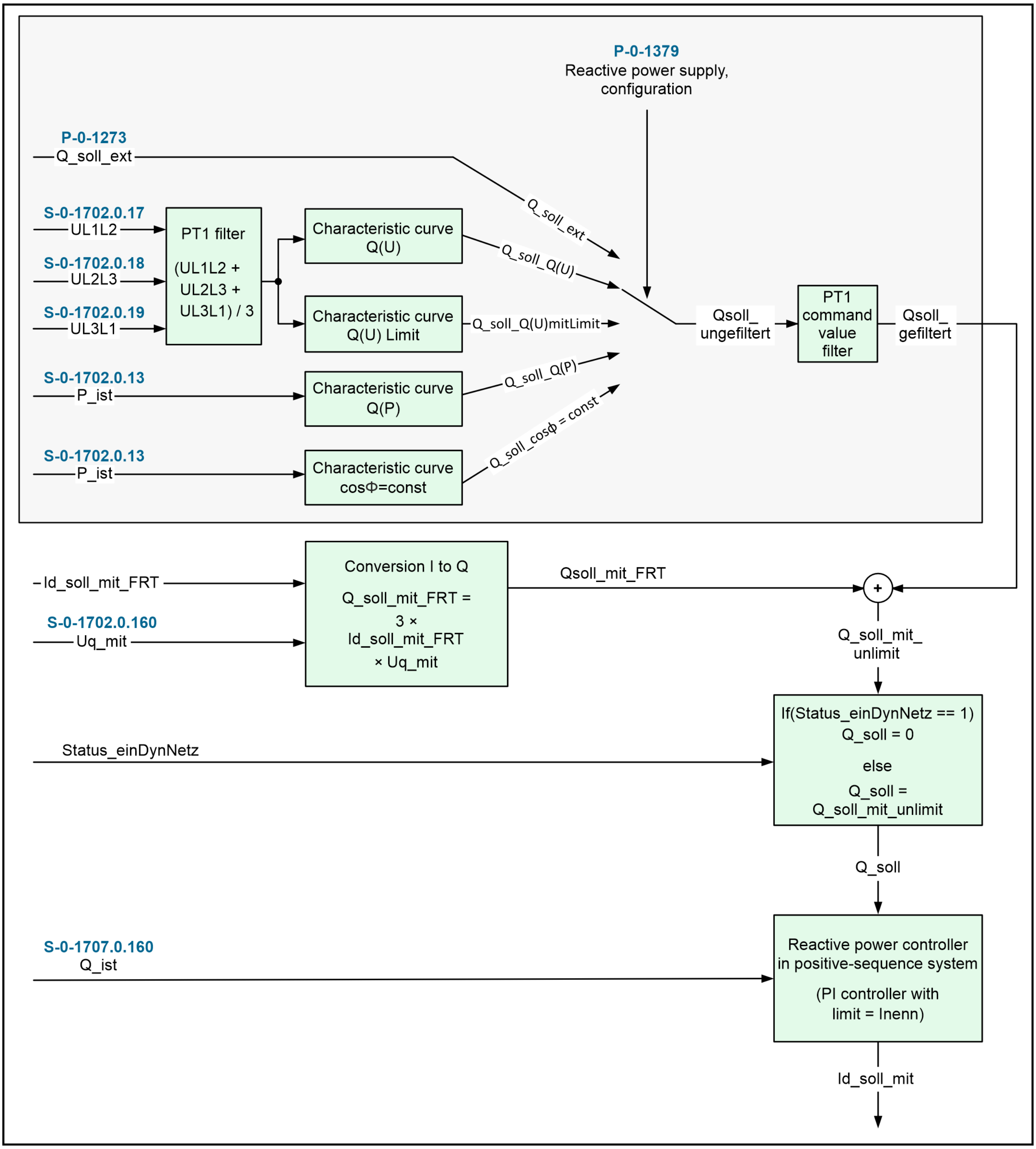


Fig. 14-1: Overview of reactive power control

14.2 General conditions

Reference: VDE-AR-N 4110:2018-11: Chapter 10.2.2.1

Static voltage support means providing reactive power by a power generating system for voltage support in the distribution grid. The static voltage support is supposed to keep slow (quasi-static) voltage changes in the distribution grid within a tolerable limit.

The **specified supply voltage U_c** has to be stored once in P-0-1377, converted to the voltage at the grid inverter, when the power generating system is commissioned. Voltage drops on transformer, cables, etc., as well as the transformation ratio of the transformer, have to be taken into account.

The specification of the **reactive power output** by the system control / power supply company (reactive power command value) takes place via the parameter P-0-1273.

This command value is preprocessed (limitations, PT1 filter, additive command value) and transferred to the input of the reactive power controller as „P-0-1274, Reactive power for power supply company, effective cmd value".

The actual value of the **reactive power** can be read via the parameter S-0-1707.0.160.

14.3 Methods for supplying reactive power

Reference: VDE-AR-N 4110:2018-11: Chapter 10.2.2.4

The PGU supports the following methods for supplying reactive power at the grid connection point:

a) Reactive power - voltage curve Q(U)

b) Reactive power characteristic as function of active power Q(P)

c) Reactive power with voltage limitation function

d) Displacement factor cosΦ

The supply of reactive power relates to the positive-sequence system components of the fundamental waves of current and voltage. The supply of reactive power only applies to the operation of the power generating system as a generator.

The control behavior of the reactive power (methods **a)**, **b)** and **c)**) at the grid connection point is carried out in a qualitative way according to a PT1 behavior for all command value jumps.

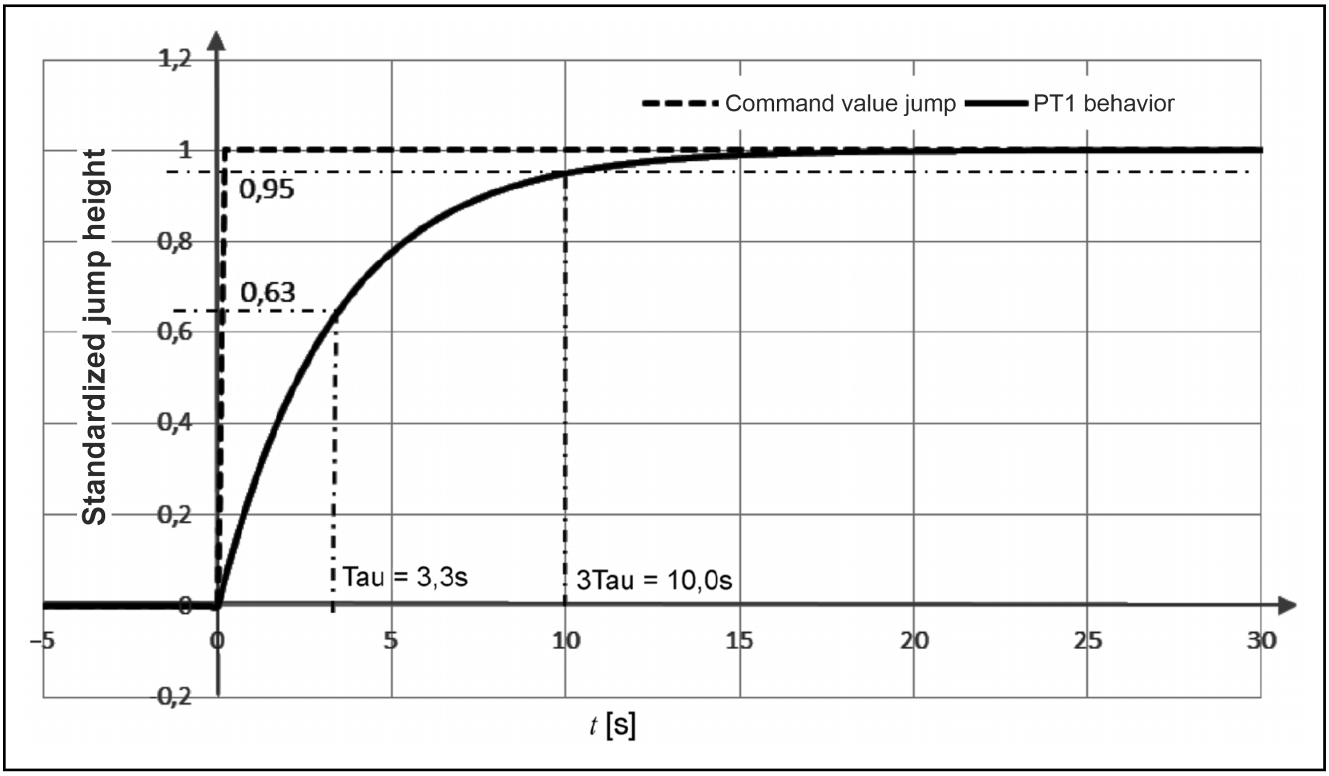


Fig. 14-2: Example of control behavior for a command value jump with the height 1 (standardized) and a timing (3 τ) of 10 s (source: VDE-AR-N 4110:2018-11)

For this purpose, a **PT1 filter** for the reactive power command value has been implemented in the PGU. The filter time constant of the PT1 filter can be adjusted in P-0-1378.

Note: There is the use case „Participation in primary control power market“ (not described in VDE-AR-N 4110). Here, the fastest possible command value input counts. In this case, the value 0 has to be set in P-0-1378. Thereby, the PT1 filter is deactivated.

The desired method has to be configured in P-0-1379. It is possible to change the method in running operation via the master communication. When switching between the control methods, the new command value is not attained faster than the required PT1 behavior and not slower than in 4 minutes.

A settling time of up to one minute applies to method **d)**, a transition behavior according to PT1 being qualitatively required.

Ad a) Reactive power - voltage curve Q(U)

It is the objective of this method that the power generating system, depending on the current operating voltage of the medium-voltage grid, exchanges reactive power with the grid at the grid connection point (Q = f(U)).

The power supply company specifies the characteristic curve. The specified voltage U_{Q0}/U_c can be specified via master communication, all other variables (pitch, dead band) have been preset.

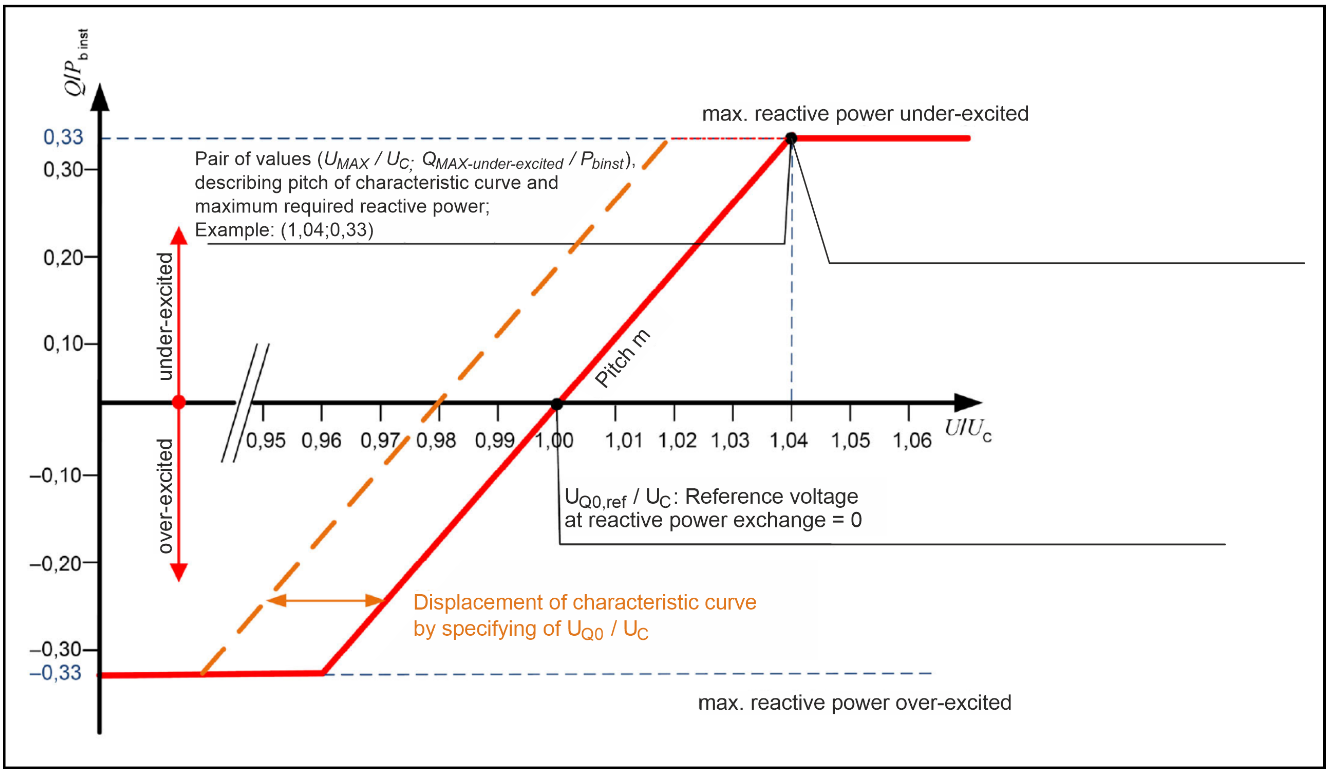


Fig. 14-3: Example of a Q(U) characteristic (source: VDE-AR-N 4110:2018-11)

The power supply company specifies the characteristic curve. The specified voltage U_{Q0}/U_c causes the characteristic curve to be displaced. The specified voltage U_{Q0}/U_c can be changed in P-0-1380 via master communication in running operation.

All other variables (pitch of characteristic curve, voltage dead band) have been preset, i.e. they are parameterized once during commissioning.

Voltage dead band

Can be set in P-0-1384 from ±0%U_c to ±5%U_c in steps of 0.5% at most. If the power supply company does not specify a value, ±0%U_c is considered the standard value.

As soon as the voltage exceeds the limit of the dead band, a new command value is calculated and used. This command value can result from either the value of the characteristic itself or the intersection of the measured mains voltage and the exceeded dead band limit.

Defining the characteristic curve

The pitch of the characteristic curve m results from the specified reference voltage $U_{Q0,ref}/U_c$, at $Q/P_{b\ inst} = 0$ and the pair of values (U_{MAX}/U_c; $Q_{MAX\text{-}under\text{-}excited}/P_{b\ inst}$):

Pitch m = $(Q_{MAX\text{-}under\text{-}excited}/P_{b\ inst}) / (U_{MAX}/U_C – U_{Q0,ref}/U_C)$

The pair of values (U_{MAX}/U_c; $Q_{MAX\text{-}under\text{-}excited}/P_{b\ inst}$) and $U_{Q0,ref}/U_c$ are specified by the power supply company in the planning stage. It has to be possible to set the pitch in a value range 5 ≤ m ≤ 16.5. Unless specified otherwise by the power supply company, (1.04; 0.33) and $U_{Q0,ref}/U_c$ = 1.00 is considered as the standard pair of values.

U_{MAX}/U_c is parameterized in parameter P-0-1381, $Q_{MAX\text{-}under\text{-}excited}/P_{b\ inst}$ in P-0-1382 and $U_{Q0,ref}/U_c$ in P-0-1383.

The behavior in the case of master communication failure is set via "P-0-1379: Reactive power supply, configuration".

Ad b) Reactive power characteristic as function of active power Q(P)

It is the objective of this method that the power generating system, depending on the current active power output (P_{mom}), feeds reactive power to the grid ($Q = f(P_{mom})$).

During commissioning, the characteristic curve is defined once from a maximum of 10 interpolation points. It does not need to be changed in running operation. Between these interpolation points, the characteristic curve is interpolated in linear form. The power supply company specifies the interpolation points as a pair of values as follows:

- Reactive power in relation to the installed active power in operation ($Q_{EA,\ soll}/P_{b\ inst}$ [%]) in a range according to the figure below
- Active power in relation to the installed active power in operation ($P_{mom}/P_{b\ inst}$ [%]) in a range from 10% to 100%

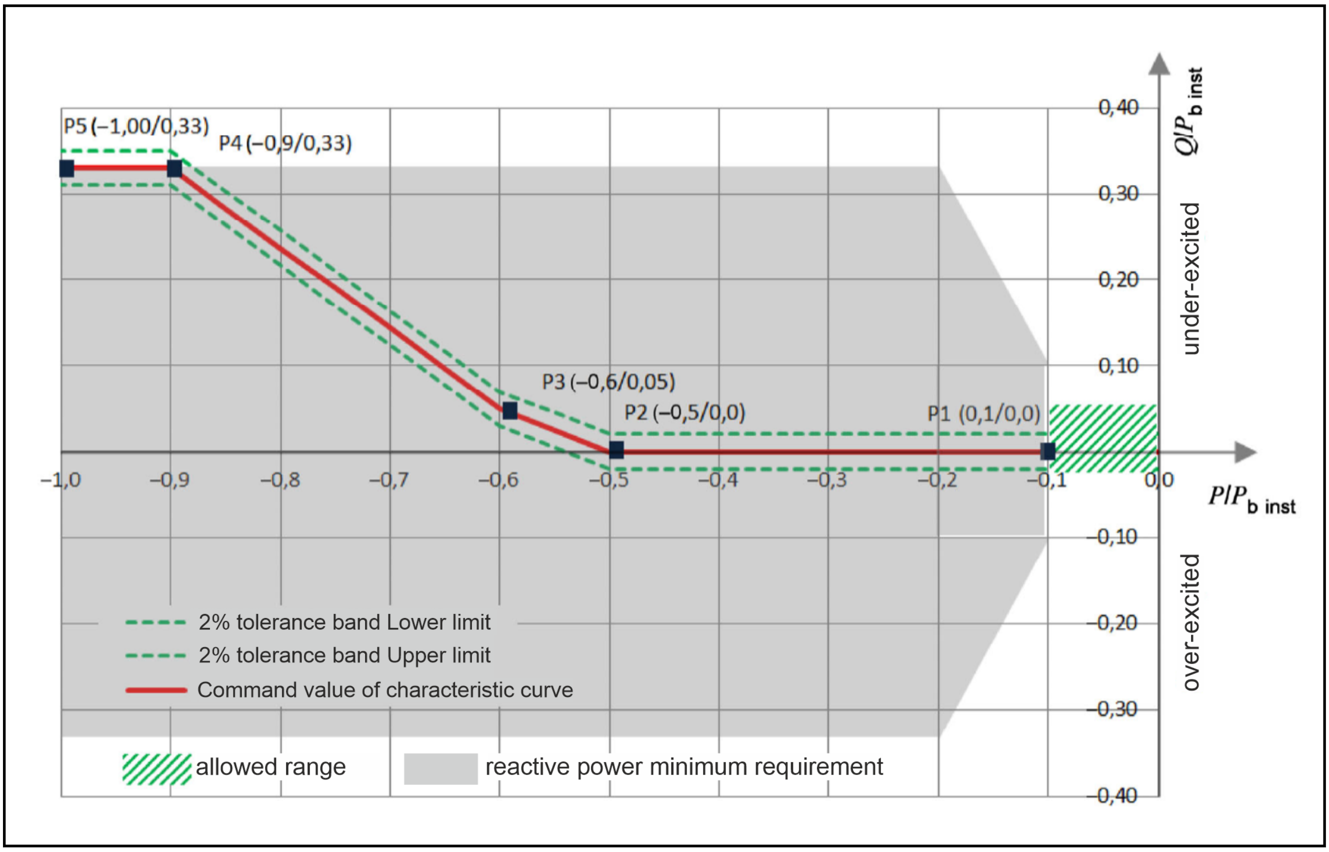


Fig. 14-4: Example of a Q(P) characteristic (source: VDE-AR-N 4110:2018-11)

P-0-1311[0..10] defines the P-axis for the Q(P) characteristic. The Q-axis is specified by P-0-1311[15..25].

P-0-1311[0..10], Q(P) characteristic: Active power

At least two list values have to be input. The number of list values has to comply with that in "P-0-1311[15..25], Q(P) characteristic: Reactive power". Only negative active power values – power flow from grid inverter to grid - can be specified. The active power values have to be input in relation to the installed active power in operation $P_{b\ inst}$. The list is completed with the value 0.

P-0-1311[15..25], Q(P) characteristic: Reactive power

At least two list values have to be input. The number of list values has to comply with that in "P-0-1311[0..10], Q(P) characteristic: Active power". Positive Q values cause inductive behavior. Negative Q values cause capacitive behavior. The reactive power values have to be input in relation to the installed active power in operation $P_{b\ inst}$. The list is completed with the value 0.

Generally, the following applies: Linear interpolation occurs between the values of the characteristic curves. For values outside of the working points defined in the first or last row, a reactive power command value is used in accordance with the limit working point, i.e. the last value also takes effect beyond the range.

The behavior in the case of master communication failure is set via "P-0-1379: Reactive power supply, configuration". If master communication fails, switching to a method according to a), c) or d) can be set. According to standard, continuing to travel with the value last valid is not intended for this method.

Ad c) Reactive power with voltage limitation function

It is the objective that the power generating system, according to the figure below and as far as possible independent of the active power supply, feeds reactive powers specified by the power supply company to the grid (Q_{EA} = const).

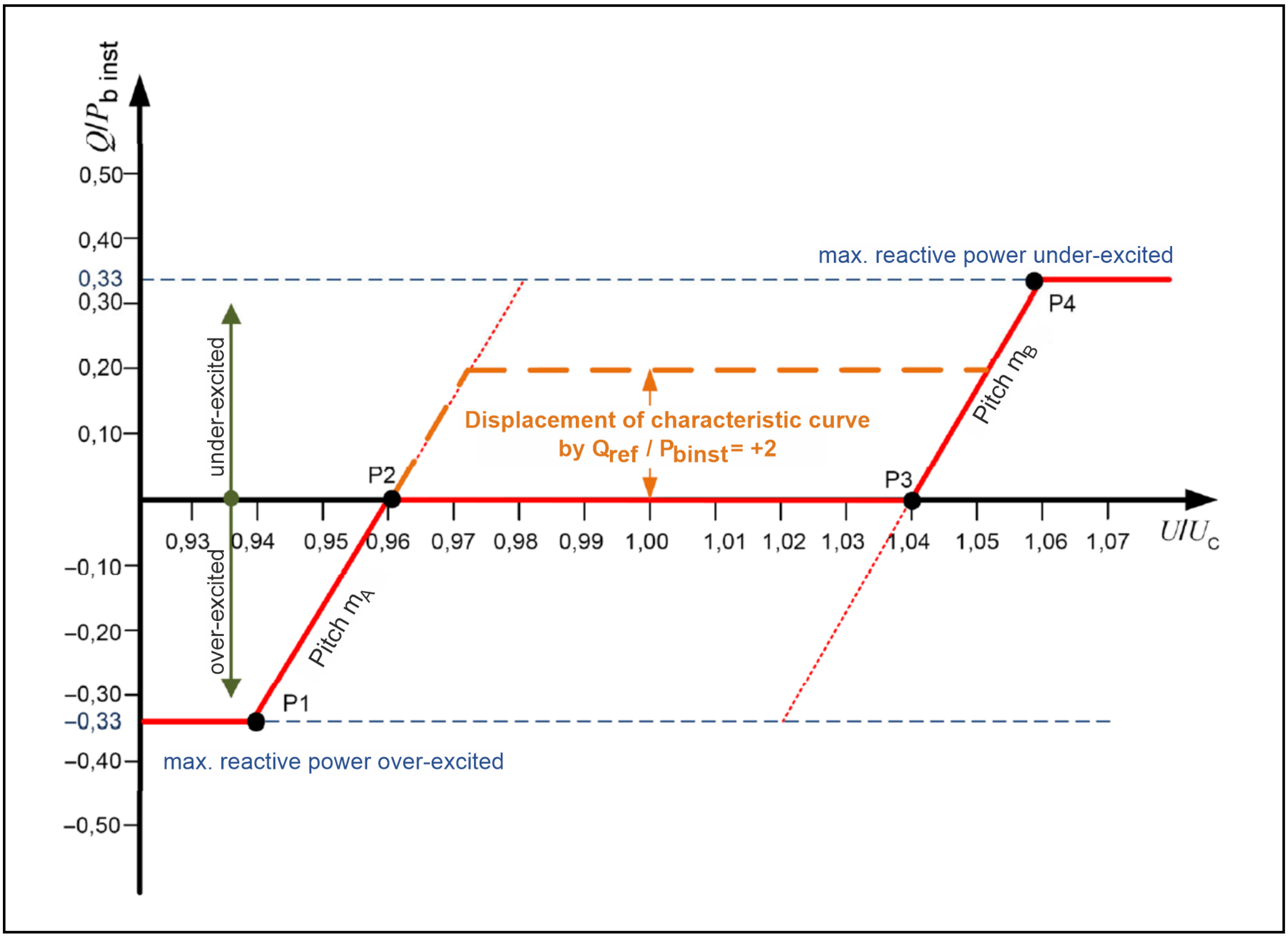


Fig. 14-5: Example of a Q input requirement (source: VDE-AR-N 4110:2018-11)

The method is represented in the form of a characteristic curve. The **characteristic curve** is defined by inputting the following 4 pairs of values (see parameter P-0-1311[30..35]):

- P1 (U_{P1}/U_c; $Q_{P1}/P_{b\ inst}$), P2 (U_{P2}/U_c; $Q_{ref}/P_{b\ inst}$)
  - pitch of segment of characteristic curve
    mA = ($Q_{P1}/P_{b\ inst}$ – $Q_{ref}/P_{b\ inst}$) / (U_{P1}/U_c – U_{P2}/U_c)
- P3 (U_{P3}/U_c; $Q_{ref}/P_{b\ inst}$), P4 (U_{P4}/U_c; $Q_{P4}/P_{b\ inst}$)
  - pitch of segment of characteristic curve
    mB = ($Q_{ref}/P_{b\ inst}$ – $Q_{P4}/P_{b\ inst}$) / (U_{P3}/U_c – U_{P4}/U_c)

For reasons of stability, pitches greater than m = 24 are not allowed.

Unless specified otherwise by the power supply company, the following pairs of values apply:

- P1 (0.94; –0.33) P2 (0.96; 0)
- P3 (1.04; 0) P4 (1.06; +0.33)

Via the master communication, the reactive power value $Q_{ref}/P_{b\ inst}$ can be preset in P-0-1325 in steps of 1% $P_{b\ inst}$, and thereby the range of the characteristic curve can be vertically displaced between P2 and P3, taking the pitches m_A and m_B into account.

The behavior in the case of master communication failure is set via "P-0-1379: Reactive power supply, configuration".

Ad d) Displacement factor cosΦ

It is the objective of displacement factor control that the power generating system feeds power with a constant relation of active power and apparent power to the grid ($\cos\Phi_{EA}$ = const).

The power supply company specifies a displacement factor command value via P-0-1385. The value is specified with a minimum step size of $\Delta\cos\Phi = 0.005$.

Thus, this is what applies to the reactive power to be supplied:

$Q = [P \times \sqrt{(1- (\cos\Phi_{EA} \times \cos\Phi_{EA}))}] / \cos\Phi_{EA}$

The behavior in the case of master communication failure is set via "P-0-1379: Reactive power supply, configuration".

15 Dynamic reactive-current supply

15.1 General information

Reference: VDE-AR-N 4110:2018-11: Chapter 10.2.3.1

It is the objective of the dynamic grid support to prevent generation capacity from being switched off accidentally and thus the grid stability from being at risk in the case of temporary voltage dips or increases.

To assess the FRT limit curves in the case of voltage decrease, use the lowest of the three phase-to-phase voltages at the grid connection point; in the case of voltage increase, use the highest of the three phase-to-phase voltages at the grid connection point.

Criterion for fault start (whatever comes first):

- Occurrence of an abrupt voltage change (measured fundamental wave instantaneous value of a voltage deviates by an absolute value of at least 5% of the nominal voltage peak value from the instantaneous value of the continued pre-fault voltage)

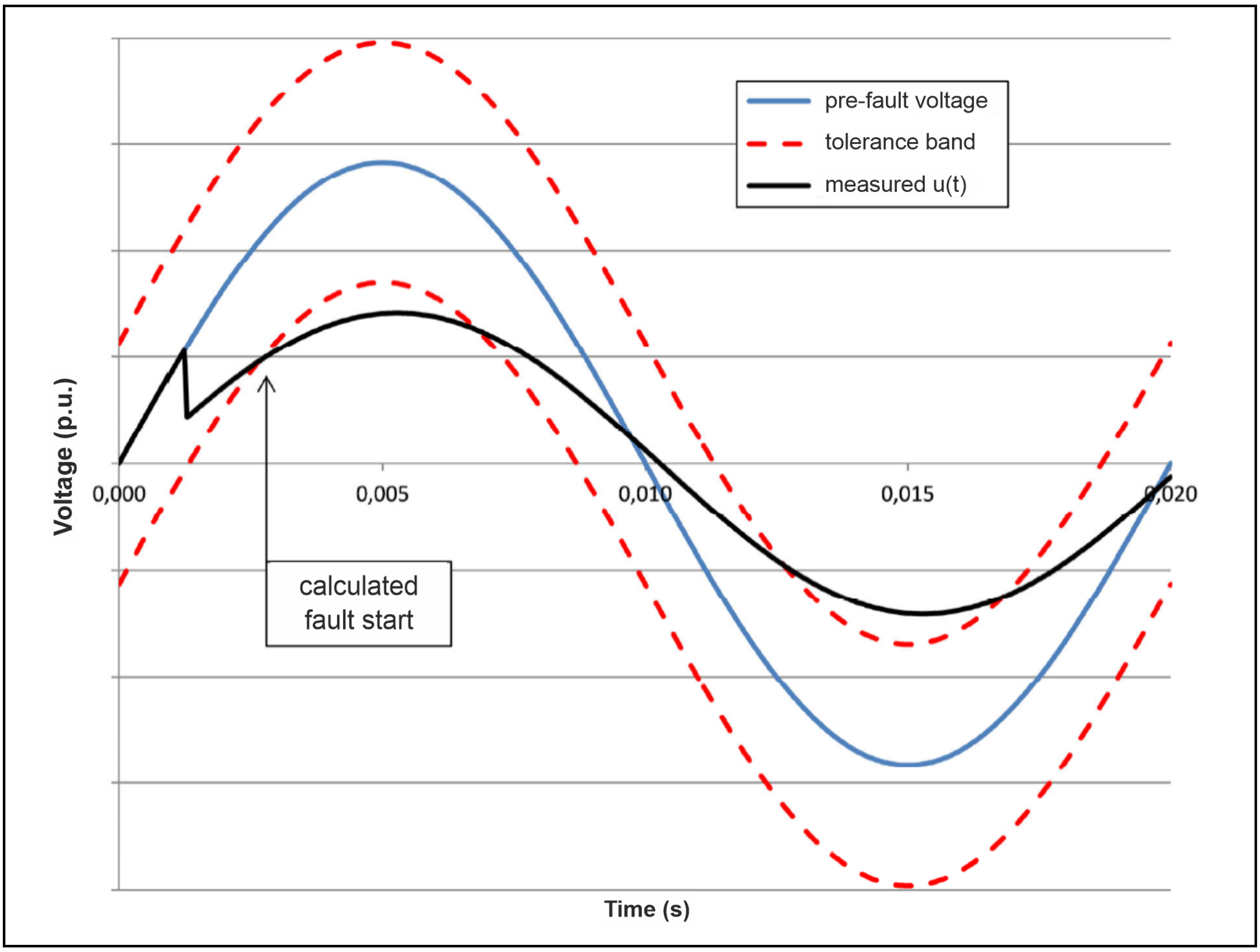


Fig. 15-1: Example of an abrupt voltage change (source: VDE-AR-N 4110:2018-11)

- Voltages > 1.1 U_c or < 0.9 U_c

Criterion for fault end (whatever comes first):

- Re-entry of all phase-to-phase voltages in the range of U_c ±10%U_c;
- 5 seconds after error start.

During a grid error, the power generating systems have to be able to support the grid voltage by supplying an appropriate reactive current. In the case of asymmetric errors, the power generating system has to supply reactive current not only in the positive-sequence system, but also in the negative-sequence system.

The HMV05 grid inverter complies with these specifications and in the case of error generates the required reactive current both in the positive-sequence system and in the negative-sequence system.

As long as the power limit of the power generating system is not exceeded, the active power supply is not reduced.

When the power limit has been reached, the active power is reduced in favor of the reactive power. If the active power is reduced to 0, the reactive power can at most have the value of P-0-1370.

In the case of limitation, the currents in the co-system and in the counter system are reduced in approximately equal parts.

If the criterion for fault start has been fulfilled, bit 0 of parameter S-0-1703.0.155 is set to 1. At the fault end, bit 0 of S-0-1703.0.155 is reset to 0.

The lower voltage limit in relation to P-0-1377 is specified in parameter P-0-1316. The default value is 0.90.

The upper voltage limit in relation to P-0-1377 is specified in parameter P-0-1317. The default value is 1.10.

Riding through multiple faults:

The grid inverter has been designed for riding through multiple successive grid faults. If the device limit of the grid inverter is reached, the active power is reduced in favor of the reactive power. As a result thereof, the active power of the energy source (e.g., battery buffer, PV system) has to be reduced.

15.2 Voltage support in the case of grid faults by reactive-current supply with comprehensive dynamic grid support

Reference: VDE-AR-N 4110:2018-11: Chapter 10.2.3.3.2

With the fault start, the power generating units have to support the voltage by adjusting (increasing or reducing) the reactive current I_B (by an additional reactive current ΔI_B).

The additional reactive current Δi_B of the power generating unit has to be proportional to the voltage deviation Δu ($\Delta i_B = k \times \Delta u$), k being the gain factor. It is defined by the straight line ($2 \leq k \leq 6$) in the figure below. The additional reactive current in the positive-sequence system Δi_{B1} is proportional to the change in positive-sequence system voltage Δu_1, the additional reactive current in the negative-sequence system Δi_{B2} is proportional to the change in negative-sequence system voltage Δu_2.

The gain factor k (= characteristic curve pitch) can be set – in relation to the terminals of the power generating units – between 2 and 6 in steps of 0.5. The default value for k is 2. k is used for the positive-sequence system and for the negative-sequence system. The k-value is input via the parameter P-0-1318.

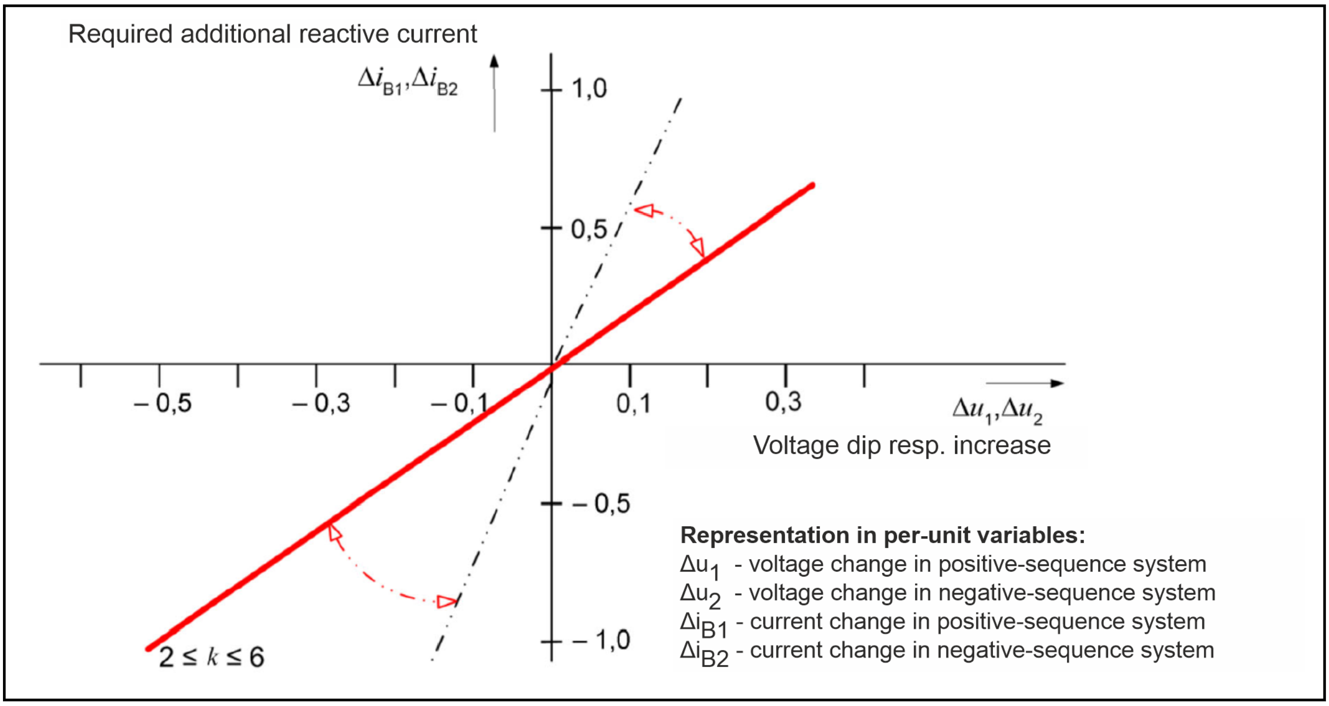


Fig. 15-2: Principle of voltage support in the case of grid faults (source: VDE-AR-N 4110:2018-11)

Reference point for the voltage change first is the grid connection point. The voltage change is the deviation of the absolute grid voltage value from the 1-minute average value U_{1min} of the grid voltage before fault start related to U_c:

$\Delta u_{1.2} = \Delta U_{1.2} / U_c$.

Reference current for the additional reactive current is the rated current I_r:

$\Delta i_{B1,2} = \Delta I_{B1,2} / I_r$

The characteristic curve provides the **additional** reactive current Δi_B as a function depending on the voltage deviation Δu. If a reactive current had already been supplied before fault start, this current has to be used for calculation together with the additional reactive current $I_{Bnew} = I_{Bold} + \Delta i_B \times I_r$. In this case, I_r is the rated current $I_r = P_{b\ inst} / (\sqrt{3} \times U_c)$. There are 2 characteristic curves: one for the positive-sequence system and one for the negative-sequence system (identified with indices 1 and 2).

$\Delta u_1 = (|U_{act\_1}| - U_{1min\_1}) / U_c$ for positive-sequence system (and negative-sequence system), U_{1min}: moving 1-minute average value of the rms value of a voltage

After fault start, the step response of the reactive current $\Delta i_{B1,2}$ at the power generating unit has to comply with the following reaction time of reactive-current supply:

a) response time: $T_{response\_90\%} \leq 30$ ms

b) settling time: $T_{settling\_\Delta x} \leq 60$ ms

15.3 Restricted dynamic grid support

Reference: VDE-AR-N 4110:2018-11: Chapter 10.2.3.3.3

Upon request of the power supply company, type 2 power generating systems have to be able to ride through voltage dips to values ≤ $0.7 \times U_c$ in such a way that, during the grid fault, the current supplied to the grid is no more than 20% of the rated current I_r at the latest 60 ms after the value has fallen below $0.7 \times U_c$, and after 100 ms it is no more than 10% I_r.

Note: For voltages > $0.7 \times U_c$, the requirements of comprehensive dynamic grid support apply.

When the power generating system is put into operation, the power supply company specifies whether the restricted dynamic grid support is required. This function is activated via the parameter P-0-1319.

The threshold of $0.7 \times U_c$ is permanently stored in the device control and cannot be parameterized.

HMV05 grid inverter controls as follows:

- in < 60 ms with regard to 20% of the rated current I_r
- in < 100 ms with regard to 10% of the rated current I_r

For voltages > $0.7 \times U_c$, the grid inverter works according to the requirements of comprehensive dynamic grid support. This means that when the device limit has been reached, the active power is reduced in favor of the reactive power.

For voltages < $0.7 \times U_c$, the device control immediately sets the command value for the active current to 0.

15.4 Active current recovery

Reference: VDE-AR-N 4110:2018-11: Chapter 10.2.3.3.4

If the grid voltage again is within the voltage range of U_c ±10%U_c after fault end and the active current of the power generating system was reduced during the grid fault, the active current has to be increased as quickly as possible immediately after fault end, until the pre-fault value of the active current or of the active power has been reached. The response time may not be more than 1 s.

The HMV05 grid inverter increases the active current / the active power to the pre-fault value after the end of the grid fault with a response time of ≤ 1 s.

15.5 Behavior after fault end until stationary operation has been reached for type 2 systems

Reference: VDE-AR-N 4110:2018-11: Chapter 10.2.3.4

If the grid voltage is still outside of the voltage range of U_c ±10%U_c after fault end and the protection mechanisms of the power generating units threaten to trigger, the power generating units have to adjust their reactive power behavior in such a way that triggering of the protection mechanisms is avoided. In favor of the this reactive power behavior, it is allowed to adjust the active power supply – as far as technically required. Within this space of time, the requirements on static voltage support do not apply.

16 Operating the customer installation

Reference: VDE-AR-N 4110:2018-11: Chapter 8.1

During the operation of the customer installation, situations in the grid may occur in which the requirements of VDE-AR-N 4110 cannot be fulfilled simultaneously and free of contradictions. In these situations, the following prioritization (in descending order) applies to the tasks and operating principles of self-protection, grid protection and the company's regulatory functions:

1. Avoiding or limiting possible damages to installations and equipment
2. Complying with the requirements on dynamic grid support
3. Requirements on the grid safety management by the power supply company (active power limit value)
4. Complying with the requirements on the behavior in the case of overfrequencies and underfrequencies
5. Complying with the requirements on the reactive power control strategy for static voltage support
6. Frequency control (controlling power range) (is not considered)

This prioritization has been permanently implemented in the grid inverter and cannot be changed by parameterization.

If the device limit of the grid inverter is reached, the active power is reduced in favor of the reactive power, with one exception. The only exception is the compliance with the requirements on the behavior in the case of overfrequencies and underfrequencies. In this case, the reactive power is reduced in favor of the active power when the device limit is reached.

17 Commissioning

17.1 Initial preparation

1. Install the firmware FWA-INDRV_-PSB-21V14-D5_FD.ibf.
2. Execute Load basic parameters.
3. Activate functional packages MSE and ML.
4. Parameters of HMV05 that have to be changed compared to the default setting (Load basic parameters):
   - S-0-1703.0.150, Mains synchronization proportional gain = 0.015
   - S-0-1703.0.151, Mains synchronization integral action time = 400ms
   - S-0-1703.0.152, Mains synchronization derivative action time = 0.000ms
   - S-0-1703.0.170, Mains undervoltage threshold = 50V
   - S-0-1703.0.171, Mains failure threshold = 20V
   - S-0-1703.0.172, Phase failure, threshold 3 = 100.0%
   - S-0-1709.0.150, Mains current controller, control word, bit 13 = 1
   - S-0-1703.0.153, Synchronization offset = 6.4°
   - S-0-1708.0.170, Negative-sequence current controller proportional gain = 1.3
   - S-0-1708.0.171, Negative-sequence current controller integral action time = 5ms

     If Modbus TCP/IP is desired as master communication: P-0-4089.0.1, Master communication: Protocol = 10
5. Set primary operation mode to „current control“.
6. Load MLD project as parameter file FWS-MLDEAX-xxx-xxxxx-D0-MP21.par.
7. Force HMV05 to reboot by switching off the 24V control voltage.
8. After the reboot check whether MLD is in the RUN state.
9. Switch HMV05 from PM to OM.
10. Set the following parameters:
    - P-0-1322, Reactive power controller, proportional gain = 1.2 (1/kV)
    - P-0-1323, Reactive power controller, integral action time = 5ms
    - If island grid detection is available and used, the following additional parameters have to be set:

      P-0-1311[40], Anti-islanding: Gain factor 1 = 400000

      P-0-1311[40], Anti-islanding: Gain factor 2 = -20000
11. Adjust parameters in accordance with the system that is to be commissioned (particularly P1370, P1371, P1327, P1330, P1331, P1379, P1377 and P1319).

17.2 Controlling the PGU

The parameter P-0-1409 is used to control the PGU, the parameter P-0-1410 is used to monitor the PGU.

Typical run-up that is to be implemented in the system control:

1. Actuate main switch or activate grid and system protection
2. Wait until main switch is closed or grid and system protection is active
3. Check whether grid inverter is in OM (P-0-1410, bit 6); if not, switch to OM (P-0-1409, bit 6)
4. Switch grid inverter to OPERATION_MODE (P-0-1409, bit 0…3)
5. Wait until grid inverter is in OPERATION_MODE (P-0-1410, bit 0…3)

The behavior of the power generating unit in the case of **communication failure** can be set in P-0-1379. In the standard setting, the power generating unit keeps working with the command values last received.

To check whether the communication between system control and grid inverter is still active, use the **heartbeat register** of P-0-1408. Alternately writing 0 and 1 to P-0-1408 triggers an **internal watchdog counter**. If the bit of P-0-1408 is not toggled for more than 1 minute, this is considered as a communication failure. The monitoring function can be activated / deactivated in P-0-1327. According to the standard, it is required to monitor the communication between power supply company and PGU. Since the power supply company communicates with the system control and not directly with the grid inverter, the monitoring function required by the standard has to be implemented in the system control.

The firmware version of the device control has been stored in P-0-1411.

Note: During the **initial commissioning** of the inverter, the inverter determines the DC bus capacitance. However, this only works if the DC bus had been uncharged before. In the case of power generating units for which the DC bus had already been precharged in another way during initial commissioning (e.g., precharged using a connected battery), the error **F8813** occurs during progression of the inverter. To avoid this error, the appropriate DC bus capacitance has to be stored once in the parameter S-0-1732.0.1.

18 Parameter list

18.1 Parameters in device control

Communication interface:

Name	P-0-1409: Power generating system, control word --, 2Byte, decimal, unsigned, no decimal places, MDT		
Structure	Bit	Description / function	Comment
TargetMode	0..3	0000: Switch system to MAINS_OFF_NO_DIS-CHARGE (bb) 0001: Switch system to MAINS_OFF_DISCHARGE (ZKS/bb) 0010: Switch system to DC_POWER_OFF_NO_DIS-CHARGE (Bb) 0011: Switch system to DC_POWER_OFF_DIS-CHARGE (ZKS/Bb) 0100: Switch system to DC_BUS_CHARGED (Lb) 0101: Switch system to OPERATION_MODE (LB) Rest: Reserved	
OperationModeSelection	4..5	00: OPERATIONMODE1 (primary operation mode) 01: OPERATIONMODE2 (1st secondary operation mode) 10: OPERATIONMODE2 (2nd secondary operation mode) 11: OPERATIONMODE2 (3rd secondary operation mode)	
TargetPhase	6	0 → 1: Switching from OM to PM 1 → 0: Switching from PM to OM	
Reserved	7		Optionally ActivateMain-sContactor
AckError	8	0 → 1: Fault acknowledged 0: Fault not acknowledged	
ReportComError	9	Signaling communication error between system con-trol and power supply company: 0: No communication error is present 1: A communication error is present	Optionally, the system con-trol can signal a communica-tion error between system control and power supply company to the device con-trol. This allows the optional functionality regarding the communication failure be-tween system control and de-vice control to be used (heartbeat).

Tab. 18-1: Parameters

Name	P-0-1410: Power generating system, status word --, 2Byte, decimal, unsigned, no decimal places, AT		
Structure	**Bit**	**Description / function**	**Comment**
ActualMode	0..3	0000: System in MAINS_OFF (bb) 0001: System in DC_POWER_OFF (Bb) 0010: System in DC_BUS_CHARGING (Charg) 0011: System in DC_DISCHARGING (ZKS) 0100: System in DC_BUS_CHARGED (Lb) 0101: System in OPERATION_MODE (LB) 0110: System in ERROR (Fxxx) 0111: System in UNKNOWN_STATE () Rest: Reserved	
ActualOperationMode	4..5	00: OPERATIONMODE1 (primary operation mode) 01: OPERATIONMODE2 (1st secondary operation mode) 10: OPERATIONMODE2 (2nd secondary operation mode) 11: OPERATIONMODE2 (3rd secondary operation mode)	
ActualPhase	6	0: OM 1: PM	
Reserved	7		Optionally StatusMainsCon-tactor
Error	8	0: No error is present 1: An error is present	
Warning	9	0: No warning is present 1: A warning is present	
Status_FRT	10	Status of dynamic grid support: 0: Dynamic grid support not active 1: Voltage dip/increase detected, dynamic grid sup-port active	

Tab. 18-2: Parameters

Name	P-0-1411: Device control version register Param-SP, 2Byte, decimal, unsigned, no decimal places		
Structure	**Bit**	**Description / function**	**Comment**
Release	0..3	Release number	
Version	7..4	Version number	
Test	11..5	Test number, if unequal to zero, it is a test version	
ID	15..12	Application ID: 0b0001: Grid functions for energy storage applications according to VDE-AR-N 4110 0b0010: Grid functions for energy storage applications with optional anti-islanding function	

Tab. 18-3: Parameters

Name	P-0-1412: Power generating system, limitation status --, 2Byte, decimal, unsigned, no decimal places, AT		
Structure	**Bit**	**Description / function**	**Comment**
P_f_power_reduction	0	TRUE if frequency-dependent active power reduction (P(f)) active	
P_f_power_increase	1	TRUE if frequency-dependent active power increase (P(f)) active	
P_f_critical_state	2	TRUE if after-effect critical state frequency-dependent active power adjustment P command value change only possible in restricted form for 10min (P-0-1376)	
DynGridSupport_criti-cal_state	3	TRUE if after-effect critical state dyn. grid support or restricted dyn. grid support P command value change as quickly as possible until a new command value has been reached.	
P_limit	5	TRUE if active power is limited (see P-0-1330 and P-0-1331).	Always takes effect
P_reduction_DynGridSup-port	6	TRUE if active power is reduced in favor of dyn. grid support.	Prio 1
Q_reduction_P_f	7	TRUE if reactive power is reduced in favor of active power (P(f)).	Prio 2
P_reduction	8	TRUE if active power is reduced in favor of reactive power.	Prio 3

Tab. 18-4: Parameters

Name	P-0-1327: Power generating system, configuration Param-SP, 4Byte, decimal, unsigned, no decimal places, PM/OM		
Structure	Bit	Description / function	Comment
OperationMode	0	0: Operation mode of HMV05 is mains current control Active current command value is cyclically transmitted from the device control to HMV05 1: Operation mode of HMV05 is DC bus voltage control Active current command value is written to parameter P-0-1272 The system control has to cyclically transmit this value to the DC/DC converter. The sign convention according to chapter 0 applies	
Reserved	1		
CommunicationHeartbeat	2	1: Heartbeat monitoring inactive 0: Heartbeat monitoring active	Monitoring for one-time bit toggling of P-0-1408 per minute
InverterType	3	0: Buffer inverter 1: Non-buffer inverter	The bit has an effect on the characteristic curve for the active power adjustment depending on the mains frequency
LoadDefault	15	0: Set standard-relevant registers of the control to default 1: Standard-relevant registers of the control were initialized	The bit is automatically set by the control as soon as registers were initialized once

- P-0-1408: Heartbeat
  - --, 2Byte, decimal, unsigned, no decimal places, PM/OM
  - Value range: 0 or 1
  - Default value: 0
- P-0-1272: I_DC_soll
  - --, 4Byte, decimal, signed, 3 decimal places, MDT

Active power behavior

- P-0-1370: Apparent power limit of inverter [kVA]
  - Param-SP, 4Byte, decimal, unsigned, 1 decimal place, PM
  - Value range: 0.0...6553.5kVA
  - Default value: 540.0kVA
- P-0-1371: Nominal active power of power generating system $P_{b\ inst}$ [kW]
  - Param-SP, 4Byte, decimal, unsigned, 1 decimal place, PM
  - Value range: 0.0…6553.5kW
  - Default value: 540.0kW
- P-0-1270: Active power for power supply company, command value [kW]
  - --, 4Byte, decimal, signed, 2 decimal places, MDT

  - Value range: -20000.00…+20000.00kW
  - Default value: --
- P-0-1275: Active power for power supply company, effective cmd value [kW]
  - --, 4Byte, decimal, signed, 2 decimal places, AT
- P-0-1330: Active power limit value, from grid inverter to grid [kW]
  - Param-SP, 4Byte, decimal, unsigned, 1 decimal place, PM/OM
  - Value range: 0.0…6553.5kW
  - Default value: 540.0kW
- P-0-1331: Active power limit value, from grid to grid inverter [kW]
  - Param-SP, 4Byte, decimal, unsigned, 1 decimal place, PM/OM
  - Value range: 0.0…6553.5kW
  - Default value: 540.0kW
- P-0-1329: Active power gradient for normal grid operation [% $P_{b\ inst}$ / s]
  - Param-SP, 4Byte, decimal, unsigned, 2 decimal places, PM
  - Value range: 0.00...100.00% / s
  - Default value: 0.66% / s
  - The value 0 deactivates the gradient generation.
- P-0-1325: PT1 active power command value filter time constant [s]
  - Param-SP, 4Byte, decimal, unsigned, 2 decimal places, PM
  - Value range: 0.00…655.35s
  - Default value: 0.00s
  - The value 0 deactivates the PT1 filter

Active power output depending on the mains frequency:

- P-0-1372: Power reduction starting frequency [Hz]
  - Param-SP, 4Byte, decimal, unsigned, 2 decimal places, PM
  - Value range: 0.00…655.35Hz
  - Default value: 50.20Hz
- P-0-1373: Power reduction gradient [% / Hz]
  - Param-SP, 4Byte, decimal, unsigned, 2 decimal places, PM
  - Value range: 0.00…655.35% / Hz
  - Default value: 100.00% / Hz
- P-0-1374: Power increase starting frequency [Hz]
  - Param-SP, 4Byte, decimal, unsigned, 2 decimal places, PM
  - Value range: 0.00…655.35Hz
  - Default value: 49.80Hz
- P-0-1375: Power increase pitch [% / Hz]
  - Param-SP, 4Byte, decimal, unsigned, 2 decimal places, PM
  - Value range: 0.00…655.35% / Hz
  - Default value: 100.00% / Hz
- P-0-1376: Active power gradient after power reduction or increase [% $P_{b\ inst}$ / min]
  - Param-SP, 4Byte, decimal, unsigned, 2 decimal places, PM

- Value range: 0.00…655.35% / min
- Default value: 10.00% / min

Reactive power general

- P-0-1377: Nominal voltage grid, secondary side [V]
  - Param-SP, 4Byte, decimal, unsigned, 1 decimal place, PM
  - Value range: 0.0…6553.5V
  - Default value: 400.0V
- P-0-1273: Reactive power for power supply company, command value [kvar]
  - --, 4Byte, decimal, signed, 2 decimal places, MDT
  - Value range: -20000.00…+20000.00kvar
  - Default value: --
- P-0-1274: Reactive power for power supply company, effective command value [kvar]
  - --, 4Byte, decimal, signed, 2 decimal places, AT
- P-0-1378: Time constant 1 τ reactive power command value filter [s]
  - Param-SP, 4Byte, decimal, unsigned, 2 decimal places, PM
  - Value range: 0.00…655.35s
  - Default value: 3.30s
  - The value 0 deactivates the PT1 filter.
  - The resulting settling time (3 τ) is P-0-1378 * 3
- P-0-1379: Reactive power supply, configuration
  - Param-SP, 4Byte, decimal, unsigned, no decimal places, PM/OM
  - Default value: 0x00000003

Name	P-0-1379: Reactive power supply, configuration		
Structure	Bit	Description / function	Comment
Q_ctrl	2..0	Selecting a method for supplying reactive power 000: Q(U) characteristic 001: Q(P) characteristic 010: Reactive power with voltage limitation function 011: Displacement factor cos φ 100: Command value input by power supply company	
Reserved	3		
Q_QU_Comloss	4	Behavior in the case of communication failure for method „Q(U) characteristic“: 0: Keep working with the last valid value for the specified voltage U_{Q0}/U_c (P-0-1380) 1: Operation with cos φ = 1	
Q_QULimit_ComLoss	5	Behavior in the case of communication failure for method „Reactive power with voltage limitation function“: 0: Keep working with the last valid value for $Q_{ref}/P_{b\ inst}$ (P-0-1326) 1: Use reference reactive power of P-0-1311[36]	
Q_cosPhi_ComLoss	6	Behavior in the case of communication failure for method „Displacement factor cos φ“: 0: Keep working with the last valid value for cos φ (P-0-1385) 1: Use reference displacement factor of P-0-1324	
Reserved	7		
Q_ctrl_ComLoss	11..8	Alternative switching to a different method: Selecting a method for supplying reactive power in the case of communication failure: 000: Switching not desired 001: Q(U) characteristic 010: Q(P) characteristic 011: Reactive power with voltage limitation function 100: Displacement factor cos φ	

Tab. 18-5:

Q(U) characteristic

- P-0-1380: Q(U) characteristic: U_{Q0}/U_c []
  - Param-SP, 4Byte, decimal, signed, 2 decimal places, PM/OM
  - Value range: -1.00…1.00
  - Default value: 0.00
- P-0-1381: Q(U) characteristic: U_{MAX}/U_c []
  - Param-SP, 4Byte, decimal, unsigned, 2 decimal places, PM
  - Value range: 0.00…655.35

- Default value: 1.04
- P-0-1382: Q(U) characteristic: QMAX-underexcited/$P_{b\ inst}$ []
  - Param-SP, 4Byte, decimal, unsigned, 2 decimal places, PM
  - Value range: 0.00…655.35
  - Default value: 0.33
- P-0-1383: Q(U) characteristic: $U_{Q0,ref}/U_c$ []
  - Param-SP, 4Byte, decimal, unsigned, 2 decimal places, PM
  - Value range: 0.00…655.35
  - Default value: 1.00
- P-0-1384: Q(U) characteristic: Voltage dead band [%]
  - Param-SP, 4Byte, decimal, signed, 1 decimal place, PM
  - Value range: 0.0…3276.7%
  - Default value: 0.0%

Q(P) characteristic

- P-0-1311[0..10]: Q(P) characteristic: Active power [P/$P_{b\ inst}$, 11 values, no units]
  - Param-SP, 4Byte, decimal, signed, 2 decimal places, PM
  - Value range: -1.00…0.00 (or in list parameter: -100…0)
  - Default value: --
- P-0-1311[15..25]: Q(P) characteristic: Reactive power [$Q_{EA,\ soll}/P_{b\ inst}$, 11 values, no units]
  - Param-SP, 4Byte, decimal, signed, 2 decimal places, PM
  - Value range: -1.00…1.00 (or in list parameter: -100…100)
  - Default value: --

Reactive power with voltage limitation function

- P-0-1311[30]: Reactive power with voltage limitation function: U_{P1}/U_c []
  - Param-SP, 4Byte, decimal, unsigned, 2 decimal places, PM
  - Value range: 0.00…2.00 (or in list parameter: 0…200)
  - Default value: 0.94 (or in list parameter: 94)
- P-0-1311[31]: Reactive power with voltage limitation function: U_{P2}/U_c []
  - Param-SP, 4Byte, decimal, unsigned, 2 decimal places, PM
  - Value range: 0.00…2.00 (or in list parameter: 0…200)
  - Default value: 0.96 (or in list parameter: 96)
- P-0-1311[32]: Reactive power with voltage limitation function: U_{P3}/U_c []
  - Param-SP, 4Byte, decimal, unsigned, 2 decimal places, PM
  - Value range: 0.00…2.00 (or in list parameter: 0…200)
  - Default value: 1.04 (or in list parameter: 104)
- P-0-1311[33]: Reactive power with voltage limitation function: U_{P4}/U_c []
  - Param-SP, 4Byte, decimal, unsigned, 2 decimal places, PM
  - Value range: 0.00…2.00 (or in list parameter: 0…200)
  - Default value: 1.06 (or in list parameter: 106)
- P-0-1311[34]: Reactive power with voltage limitation function: QP1/$P_{b\ inst}$ []

- Param-SP, 4Byte, decimal, signed, 2 decimal places, PM
- Value range: -1.00…1.00 (or in list parameter: -100…100)
- Default value: -0.33 (or in list parameter: -33)

- P-0-1311[35]: Reactive power with voltage limitation function: $Q_{P4}/P_{b\ inst}$ []
  - Param-SP, 4Byte, decimal, signed, 2 decimal places, PM
  - Value range: -1.00…1.00 (or in list parameter: -100…100)
  - Default value: 0.33 (or in list parameter: 33)
- P-0-1311[36]: Reactive power with voltage limitation function: Reference reactive power $Q_{ref}/P_{b\ inst}$ in the case of communication failure []
  - Param-SP, 4Byte, decimal, signed, 2 decimal places, PM
  - Value range: -1.00…1.00 (or in list parameter: -100…100)
  - Default value: 0.00
- P-0-1326: Reactive power with voltage limitation function: $Q_{ref}/P_{b\ inst}$ []
  - Param-SP, 4Byte, decimal, signed, 2 decimal places, PM/OM
  - Value range: -0.01…0.01
  - Default value: 0.00

Displacement factor cos φ

- P-0-1385: Displacement factor cos φ: Command value []
  - Param-SP, 4Byte, decimal, signed, 3 decimal places, PM/OM
  - Value range: -1.000…1.000
  - Default value: 1.000
- P-0-1324: Displacement factor cos φ: Reference displacement factor []
  - Param-SP, 4Byte, decimal, signed, 3 decimal places, PM
  - Value range: -1.000…1.000
  - Default value: 1.000

Dynamic grid support

- P-0-1316: Dynamic grid support: Lower voltage limit / U_c []
  - Param-SP, 4Byte, decimal, unsigned, 2 decimal places, PM
  - Value range: 0.00…655.35
  - Default value: 0.90
- P-0-1317: Dynamic grid support: Upper voltage limit / U_c []
  - Param-SP, 4Byte, decimal, unsigned, 2 decimal places, PM
  - Value range: 0.00…655.35
  - Default value: 1.10
- P-0-1318: Dynamic grid support: Gain factor []
  - Param-SP, 4Byte, decimal, unsigned, 1 decimal place, PM
  - Value range: 0.0…6553.5
  - Default value: 2.0
- P-0-1319: Dynamic grid support, configuration
  - Param-SP, 4Byte, decimal, unsigned, no decimal places, PM

Name	P-0-1319: Dynamic grid support, configuration		
Structure	Bit	Description / function	Comment
DynamicGridSupport	0	0: Comprehensive dynamic grid support 1: Restricted dynamic grid support	The dynamic grid support function is only active, if bit 1 has been set to 0.
AntiIslanding	1	0: Method for detecting unintended island grid generation not active 1: Method for detecting unintended island grid generation active	If this bit is set to 1, the dynamic grid support function of bit 0 is automatically deactivated.

Tab. 18-6: Parameters

- P-0-1328: Active power gradient after dyn. grid support [% $P_{b\ inst}$ / s]
  - Param-SP, 4Byte, decimal, unsigned, 2 decimal places, PM
  - Value range: 0.00…600.00% / s
  - Default value: 120.00% / s

Note: This gradient is also used for adjusting the active power depending on the mains frequency (overfrequency, underfrequency).

Controller settings

- P-0-1320: Active power controller, proportional gain [1/kV]
  - Param-SP, 4Byte, decimal, unsigned, 3 decimal places, PM/OM
  - Value range: 0.000…65.535 1/kV
  - Default value: 0.500 1/kV
- P-0-1321: Active power controller, integral action time [ms]
  - Param-SP, 4Byte, decimal, unsigned, 2 decimal places, PM/OM
  - Value range: 0.00…655.35ms
  - Default value: 10.00ms
- P-0-1322: Reactive power controller, proportional gain [1/kV]
  - Param-SP, 4Byte, decimal, unsigned, 3 decimal places, PM/OM
  - Value range: 0.000…65.535 1/kV
  - Default value: 0.900
- P-0-1323: Reactive power controller, integral action time [ms]
  - Param-SP, 4Byte, decimal, unsigned, 2 decimal places, PM/OM
  - Value range: 0.00…655.35ms
  - Default value: 10.00ms

Digital inputs/outputs

- – P-0-1276: Digital inputs
  - --, 4Byte, decimal, unsigned, no decimal places, AT
  - User-defined I/O mapping in IndraWorks
- P-0-1277: Digital outputs
  - --, 4Byte, decimal, unsigned, no decimal places, MDT
  - User-defined I/O mapping in IndraWorks

Island grid detection / method for detecting unintended island grid generation

- P-0-1311[40]: Anti-islanding: Gain factor 1

- Param-SP, 4Byte, decimal, signed, 1 decimal place, PM/OM
- Value range: -2000000.0…2000000.0 (or in list parameter: -20000000…20000000)
- Default value: 0.0

- P-0-1311[41]: Anti-islanding: Gain factor 2
  - Param-SP, 4Byte, decimal, signed, 1 decimal place, PM/OM
  - Value range: -2000000.0…2000000.0 (or in list parameter: -20000000…20000000)
  - Default value: 0.0

18.2 Parameters in HMV05

The HMV05 grid inverter runs with a dedicated firmware (≥ FWA-INDRV*-PSB-21V14-D5-1-MSE-ML). Firmware functions, parameters and diagnostics are desceibed in separate documentations.

Parameters of HMV05 required by the device control for data exchange (for information purposes only; no actions needed on the user side):

Device control → HMV05:

S-0-1720.0.1, Power supply control word

S-0-1703.0.155, Mains synchronization, control word

S-0-1706.0.11, Active-current generating component, command value

S-0-1706.0.12, Reactive-current generating component, command value

S-0-1706.0.191, Reactive-curr. generating comp. in neg.-sequ. syst., cmd val

Device control ← HMV05:

S-0-1720.0.2, Power supply status word

S-0-1707.0.160, Reactive power, actual value

S-0-1702.0.13, Mains power

S-0-1702.0.17, Phase-to-phase mains voltage L1-L2 RMS value

S-0-1702.0.18, Phase-to-phase mains voltage L2-L3 RMS value

S-0-1702.0.19, Phase-to-phase mains voltage L3-L1 RMS value

S-0-1702.0.12, Mains frequency

S-0-1702.0.160, Act. mains voltage value, q-component, positive-sequ. system

S-0-1702.0.161, Act. mains voltage value, d-component, positive-sequ. system

S-0-1702.0.162, Act. mains voltage value, q-component, negative-sequ. system

S-0-1702.0.163, Act. mains voltage value, d component, negative-sequ. system

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Notes

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