Type Certificate

Applicant: **WP Holding GmbH**

Address: **Reichenbacher Str. 67**
08056 Zwickau
Germany

Type of power generating unit	Stationary energy storage with grid inverter for grid parallel operation	**PowerCore** (for details see *Supplement of certificate* on p.2)
Technical data:	Max. apparent power:	264 kVA[1]
	Nominal output AC voltage:	400 V
	Nominal frequency:	50 Hz
Technical data determined by measurements:	Max. active power P_{Emax} / Max. active power peak P_{600}	(for details see *Supplement of certificate* on p.2)
Firmware version:	310-01-06-xx-S (with xx=41 or higher)	

Validated type model:	Model file:	REFU_TG4_09.08.2022.7z
	Identification number (MD5):	582445af419417efa64b7a376de86b36

Grid connection regulation: **VDE-AR-N 4110:2018-11** – Technical requirements for the connection and operation of customer installations to the medium voltage network (TCR medium voltage) [1]

Pertinent standards / Guidelines: Technical guidelines:
FGW TR 3 Rev. 25 [2], FGW TR 4 Rev. 09 [3], FGW TR 8 Rev. 09 [4]

The power generating units, stated in the certificate, were tested and certified according to the technical guidelines referenced to the grid connection regulation. The electrical characteristics fulfil the requirements of the grid connection regulation with deviations:

- Quasi-steady-state operation
- Dynamic network stability (reactive current characteristic according to TCR medium voltage)
- Active power output and network security management
- Active power adjustment as a function of the grid frequency
- Protection technology and protection settings on generating unit level
- Power quality

The manufacturer has provided proof of certification of the quality management system of his production facility in accordance with ISO 9001

Restrictions, deviations or notes on usage: see *Supplement of Certificate* on p.3.
[1] For details see *Supplement of Certificate* on p.2.

The certificate includes the following information:

- technical data of the power generating unit, the auxiliary equipment used and the software version used
- schematic structure of the power generating units
- summarized information on the properties of the power generating unit.

The certificate is comprised of 80 pages (including Annex of 77 pages).

BV project number	:	**18TH0270**			
Certificate no.	:	**U23-0264_0**	**Certification scheme**	:	**NSOP-0032-DEU-ZE-V01**
Issued	:	**2023-03-28**	**Valid until**	:	**2027-06-01**

Certification body

Georg LORITZ

DAkkS Deutsche Akkreditierungsstelle D-ZE-12024-01-00

Certification body of Bureau Veritas Consumer Products Services Germany GmbH accredited according to DIN EN ISO/IEC 17065

A partial representation of the certificate requires the written approval of Bureau Veritas Consumer Products Services Germany GmbH

Supplement of Certificate (U23-0264_0)

Type of power generating unit:	Stationary energy storage with grid inverter for grid parallel operation	**PowerCore Ausbaustufe 1/3**	**PowerCore Ausbaustufe 2/3**	**PowerCore Ausbaustufe 3/3**
Technical data:	Nominal active output power:	88 kW	2 x 88 kW [1)]	3 x 88 kW [1)]
	Max. apparent power:	88 kVA	2 x 88 kVA [1)]	3 x 88 kVA [1)]
	Nominal output AC voltage:	400 V		
	Nominal frequency:	50 Hz		
Technical data determined by measurements:	Max. active power P_{Emax} / Max. active power peak P_{600} [2)]:	1,01 p.u. / 89,245 kW [2)]		
Firmware version:		310-01-06-xx-S (with xx=41 or higher)		

1) The Product "PowerCore is designed for three different variants and differs in storage capacity and number of used inverters.

2) The P_{Emax} is *the highest 10-min mean of the active power of a power generating unit* defined according to VDE-AR-N 4110:2018 [1]. The *P_{600}* is *the maximum active power peak of the overall system (averaging period 10 min)* defined according to FGW TR 3 Rev. 25 [2].

The stated values on the front page of this certificate were determined according to test 4.1.1, FGW TR 3 Rev. 25 [2].

The active power results of the REFUsol 88K 880P100 can be applied to the REFUstor 88K 420P088, REFUstor 100K 421P100 and REFUstor 50K 421P050/REFUstor 50K(scaled by $P_{n,\ not\ measured}$ / $P_{n,\ REFUsol\ (88K\ 880P100)}$).

The certificate is comprised of 80 pages (including Annex of 77 pages).

BV project number	:	**18TH0270**
Certificate no.	:	**U23-0264_0**
Issued	:	**2023-03-28**
Certification scheme	:	**NSOP-0032-DEU-ZE-V01**
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Supplement of Certificate (U23-0264_0)

Restrictions, deviations or notes on usage:

- Only one interface for specifying active power is implemented on the PGU. Separate specifying active power by grid operators and direct sellers is not possible. Prioritization of different setpoints must be carried out on the plant level e.g. in the superimposed PGS controller.
- The PGUs in the series do not provide test terminals for on-site testing. For necessary on-site testing, a separate test terminal must be installed additionally.
- The Q(U) characteristic settable in the inverter must be shifted by -3%P_n in order to get the actual Q(U) characteristic.
- The PGUs in the series provide the control functions of Q(P) control and Q with voltage limitation function but these were not tested according to TG3 Rev. 25. These functions must be implemented on the PGS controller level if required on the plant level.

The certificate is comprised of 80 pages (including Annex of 77 pages).

BV project number	:	**18TH0270**			
Certificate no.	:	**U23-0264_0**	**Certification scheme**	:	**NSOP-0032-DEU-ZE-V01**
Issued	:	**2023-03-28**	**Valid until**	:	**2027-06-01**

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Certification body of Bureau Veritas Consumer Products Services Germany GmbH accredited according to DIN EN ISO/IEC 17065

Description of the revisions of certificate U23-0264_0	
Rev. 0	First issue

Annexes included in certificate U23-0264_0

1. Annex 1 – Guidelines, test reports and documents

This certificate is based on following guidelines, test reports and documents:

Reference	Guidelines
[1]	Technische Regeln für den Anschluss von Kundenanlagen an das Mittelspannungsnetz und deren Betrieb (TAR Mittelspannung), VDE-AR-N 4110:2018-11 / *Technical requirements for the connection and operation of customer installations to the medium voltage network (TCR medium voltage), VDE-AR-N 4110:2018-11*
[2]	Technische Richtlinien für Erzeugungseinheiten und –anlagen TEIL 3 (TR3), Bestimmung der elektrischen Eigenschaften von Erzeugungseinheiten und -anlagen, Speicher sowie für deren Komponenten am Mittel-, Hoch- und Höchstspannungsnetz, Revision 25, Stand 01.09.2018 / *Technical Guidelines for Power Generating Units and Systems PART 3 (TG3), Determination of the Electrical Characteristics of Power Generating Units and Systems, Storage Systems as well for their Components in Medium-, High- and Extra-High Voltage Grids, Revision 25, Dated 01/09/2018*
[3]	Technische Richtlinien für Erzeugungseinheiten und –anlagen TEIL 4 (TR4), Anforderungen an Modellierung und Validierung von Simulationsmodellen der elektrischen Eigenschaften von Erzeugungseinheiten und -anlagen, Speicher sowie deren Komponenten, Revision 09, Stand 01.02.2019 / *Technical Guidelines for Power Generating Units and Systems PART 4 (TG4), Demands on Modelling and Validating Simulation Models of the Electrical Characteristics of Power Generating Units and Systems, Storage Systems as well as their Components, Revision 09, Dated 01/02/2019*
[4]	Technische Richtlinien für Erzeugungseinheiten, -anlagen und Speicher sowie für deren Komponenten TEIL 8 (TR8), Zertifizierung der elektrischen Eigenschaften von Erzeugungseinheiten und -anlagen, Speicher sowie für deren Komponenten am Stromnetz, Revision 09, Stand 01.02.2019 / *Technical Guidelines for for Power Generating Units, Systems and Storage Systems as well as for their Components PART 8 (TG8), Determination of the Electrical Characteristics of Power Generating Units and Systems, Storage Systems as well for their Components in Medium-, High- and Extra-High Voltage Grids, Revision 09, Dated 01/02/2019*
[5]	Kurzschlussströme in Drehstromnetzen Teil 0: Berechnung der Ströme, DIN EN 60909-0 (VDE 0102):2016-12 / *Short-circuit currents in three-phase a.c. systems Part 0: Calculation of currents (IEC 60909-0:2016)*

Reference	Test reports
[6]	18TH0270_TR3_2 TG3 test report according to FGW TG3 Rev.25, issued by Bureau Veritas Consumer Products Services Germany GmbH on 16. Jan. 2023
[7]	18TH0270_TR4_1 TG4 test report according to FGW TG4 Rev.09, issued by Bureau Veritas Consumer Products Services Germany GmbH on 16. Aug. 2022
[8]	18TH0270_TR8_0_WP Holding TG8 evaluation report according to FGW TG8 Rev.09, issued by Bureau Veritas Consumer Products Services Germany GmbH on 24. Mar.2023
[9]	18TH0270_TR3_0_excerpt-part_1_1 Extract from the TG3 test report, issued by Bureau Veritas Consumer Products Services Germany GmbH on 18. Aug. 2022
[10]	18TH0270_TR3_0_excerpt-part_2_2 Extract from the TG3 test report, issued by Bureau Veritas Consumer Products Services Germany GmbH on 16. Jan. 2023
[11]	18TH0270_TR3_0_excerpt-part_3_1 Extract from the TG3 test report, issued by Bureau Veritas Consumer Products Services Germany GmbH on 18. Aug. 2022

1. Annex 1 – Guidelines, test reports and documents

The compliance to the grid connection regulation of the power generating units is shown by the results in the test report (*18TH0270_TR3_2*) which includes all type tests stated in the certificate. The type tests were conducted by Bureau Veritas Consumer Products Services Germany GmbH.

The compliance to the grid connection regulation of the simulation model is verified by the validation report (*18TH0270_TR4_1*). The simulations were conducted by Bureau Veritas Consumer Products Services Germany GmbH.

The summary of the grid connection regulation compliant certification of the unit

- REFUstor 88K 420P088

is stated in the certification report (*18TH0270_TR8_0*_WP Holding).

Reference	Certification-relevant documents provided by manufacturer
[12]	Manufacturer's certificate on specific data of a Photovoltaic Converter, dated 15. Dec 2022: F.0_xxx_xxx_TR3_Manufacturer certificate_V06
[13]	Manufacturer's declaration on type testing, dated 23. May 2022: F.1_xxx_xxx_Declaration of manufacturer on type testing_V03
[14]	Parameter list, V8.0, dated 16. Jan 2023: F.2_REFUsol_REFUstor_TR3_Parameter list_V08
[15]	Manufacturer's declaration for compliance to technical requirements of the VDE-AR-N 4110:2018-11, dated 15. Dec 2022: F.4_42x_880_Declaration of manufacturer_V08
[16]	P_Q_Tabellen_880P_420P_421P_graph_2022-08-18_für BV_v08

2. Annex 2 – Technical characteristics of the power generating unit (Manufacturer's data)

2.1. Technical data of the power generating unit (Manufacturer's data)

Herstellerbescheinigung zu spezifischen Daten eines Photovoltaik-Wechselrichters vom Typ 420P088.020 (REFUstor 88K)

Manufacturer's certificate on specific data of a Photovoltaic Converter of the type 420P088.020 (REFUstor 88K)

Datum / Date: 2022-12-15 **Seite/Page 4/5**

1	**Allgemeines und Ausgangsgrößen**			**General and Output values**
1	Hersteller	REFU Storage Systems GmbH		manufacturer
2	Typenbezeichnung	420P088.020		type name
3	Einspeisung (einphasig/dreiphasig)	3 ~		no. of phases (single-phase/three-phase)
4	Nennscheinleistung	88	kVA	rated apparent power
5	Nennwirkleistung	88	kW	rated active power
6	AC-Nennspannung	400	V	rated AC-voltage
7	AC-Nennfrequenz	50/60	Hz	rated frequency
8	Beitrag zum Stoßkurzschlussstrom (i_p nach IEC 60909-0)	0.128	kA	contribution to initial short circuit current (i_p according to IEC 60909-0)
2	**DC Eingangsgrößen**			**DC Input**
1	Min. Spannung (P_N)	858	V	min. voltage (P_N)
2	Max. Spannung (P_N)	900	V	max. voltage (P_N)
3	Max. DC-Eingangsspannung	1000	V	max. DC input voltage
4	Max. DC-Eingangsstrom	153	A	max. DC input current
5	Max. Modulleistung	-	kW_p	max. peak power
3	**Wechselrichter-Leistungsteil**			**Converter-Power section**
1	Hersteller	REFU Storage Systems GmbH		manufacturer
2	Typenbezeichnung	420P088.020		type name
3	Nennscheinleistung	88	kVA	rated apparent power
4	Art (HF/NF-Trafo, trafolos)	trafolos		generic type (HF/LF-transformer, without)
5	Taktfrequenz	24	kHz	pulse rate of inverter
6	Art der Leistungsregelung (MPPT)	- (battery inv.)		generic type of power control (MPPT)
7	Software-Version	310-01-06-41-S		software version
4	**Sonstige elektrische Komponenten**			**Other electric components**
1	Art der Netzkopplung	-		generic type of interconnection
2	- Hersteller	-		- manufacturer
3	- Typenbezeichnung	-		- type
4	Netzschutz integriert (Ja/Nein)	JA		integrated grid protection (Yes/No)
5	Netzschutzhersteller	REFU Storage Systems GmbH		grid protection manufacturer
6	- Typenbezeichnung	-		- type
7	Typenbezeichnung der Abschalteinheit (angesteuert vom Netzschutz)	-		circuit breaker type controlled by the grid protection
8	Oberschwingungsfilter (ja/nein)	yes		harmonic filter (yes/no)
5	**Typenprüfung**			**Type test**
1	Prüfbehörde			testing authority
2	Aktenzeichen			reference
3	Seriennummer des Wechselrichters			serial number of converter

Anschrift des Herstellers
Address of manufacturer

REFU Storage Systems GmbH
Marktstr. 185
72793 Pfullingen

15.12.2022
i.A. [signature]

Stempel, Datum, Unterschrift
stamp, date, signature

Der Hersteller des PV-Wechselrichters bestätigt, dass der PV-Wechselrichter, dessen elektrischen Eigenschaften in den Prüfberichten abgebildet sind, hinsichtlich seiner technischen Daten mit den o.g. Positionen identisch ist.

The manufacturer of the PV-Converter confirms that the PV-Converter whose power quality is measured and depicted in the test reports, is identical with the above entries with regard to its technical data

F.0 BUREAU VERITAS CPS Germany – Manufacturer's declaration / V01 09/19

Figure 1 – Manufacturer's certificate on specific data from [12]

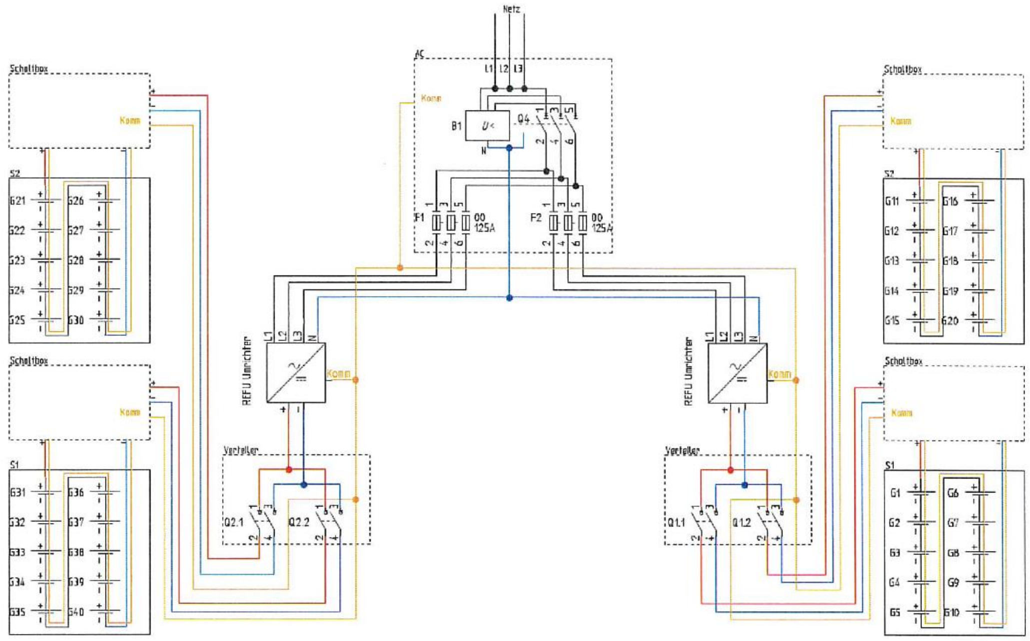
2. Annex 2 – Technical characteristics of the power generating unit (Manufacturer's data)

2.2. Description of the power generating unit

Since the electrical properties of the PGU dependent on the installed inverter, the properties of the REFUstor 420P88K are described below. The manufacturer of the PGU has confirmed in a manufacturer's declaration that the electrical properties of the inverter (shown in unit certificate U22_0380_3) are not affected by the additions on the DC side. The results of the REFUstor 420P88K can be transferred directly on the PGU (expansion stage 1/3). For the other expansion stages the results have to be summed up correspondingly

Description of the power circuit of the storage unit

Blockschaltbild – Ausbauvariante 2/3:



Batteriespeicher (S1, S2)	Der Energiespeicher verfügt über integrierte Li-Ionen-Batteriespeicher mit einem Gesamtenergieinhalt von ca. 93 kWh (10 Batteriemodule je Batterieschrank). Der Batteriespeicher besteht aus 2, 4 oder 6 separaten Batterieschränken (je nach Ausbaustufe) mit einer Energie von jeweils ca. 93,2 kWh. Innerhalb dieser Batterieschränke sind jeweils 10 Batteriemodule in Reihe geschaltet. Die Batteriemodule sind mechanisch in einem Rack zu je einem Strang befestigt und elektrisch miteinander verbunden. Darüber hinaus ist jedes Batteriemodul mithilfe von Datenleitungen an eine Steuerungselektronik angebunden.
Schaltbox	Die Schaltbox ist im Rack des Batteriespeichers integriert und enthält das Batteriemanagementsystem (BMS) sowie die wesentlichen Komponenten zum sicheren und kontrollierten Ein- bzw. Abschalten eines Batteriestranges.
Umrichter	Der Umrichter bildet die Schnittstelle zwischen dem dreiphasigen 400 V-Netzanschlusspunkt der Kundenanlage, den Batterieschränken und den internen sowie externen Verbrauchern. Die Bedienung/Steuerung des Umrichters erfolgt über das Display an der Vorderseite oder über Remote. Die LEDs am Display geben Auskunft über den aktuellen Status des Umrichters.

2. Annex 2 – Technical characteristics of the power generating unit (Manufacturer's data)

Description of the power circuit of the inverter (Figure 2 & Figure 3)

The inverter converts DC voltage into AC voltage.

The input and output are protected by SPDs to earth. The unit is providing EMC filtering at the input and output towards mains. The unit does not provide galvanic separation from input to output (transformerless). The output is switched off redundantly by the high power switching bridge and two relays in series. This assures that the opening of the output circuit will also operate in case of a single error.

The REFUstor 420P088K is a bidirectional battery inverter that is used to connect a battery.

Power electronic inverter for injection of direct current generated by means of storage system with power electronic converter for feeding power generated by battery modules into the public AC grid (discharging operation mode, PGU) or draw energy from the public AC grid to charge the battery (charging operation mode, Load).

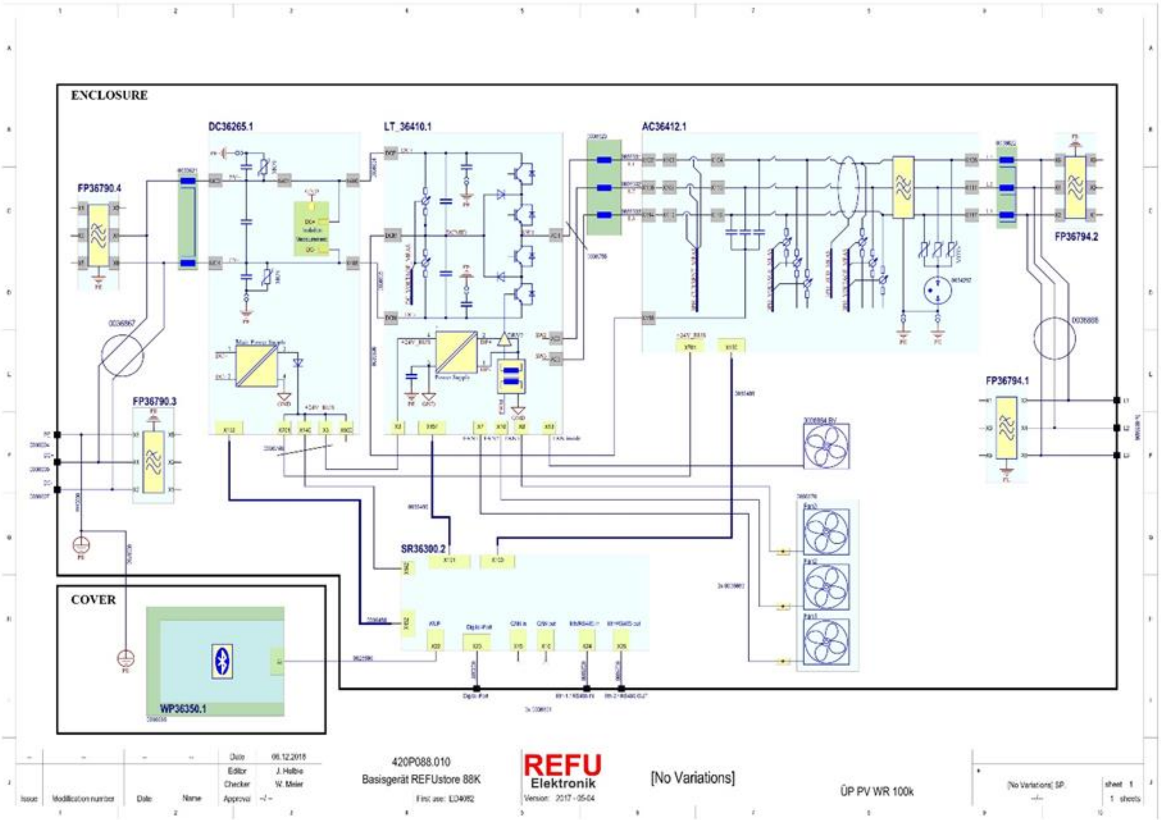


Figure 2 – Block diagram of the battery inverter

2. Annex 2 – Technical characteristics of the power generating unit (Manufacturer’s data)

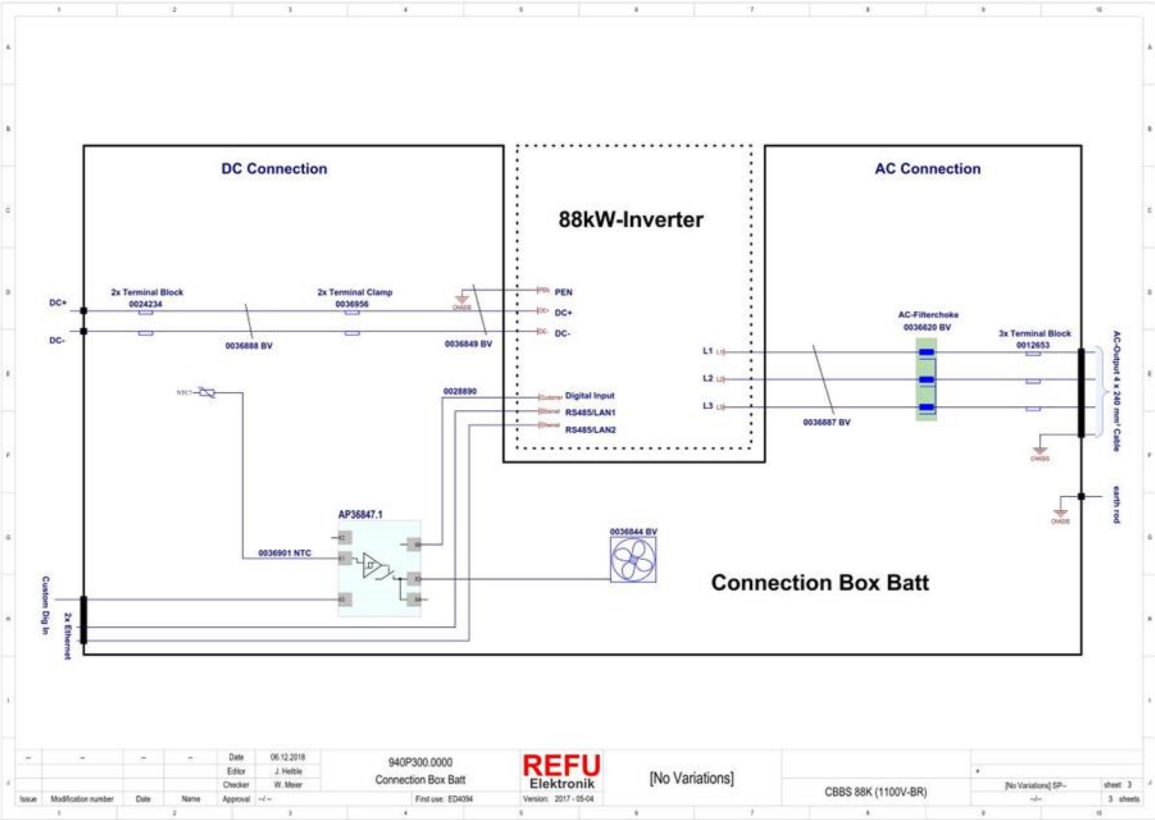


Figure 3 – Block diagram Connection boxes

2. Annex 2 – Technical characteristics of the power generating unit (Manufacturer’s data)

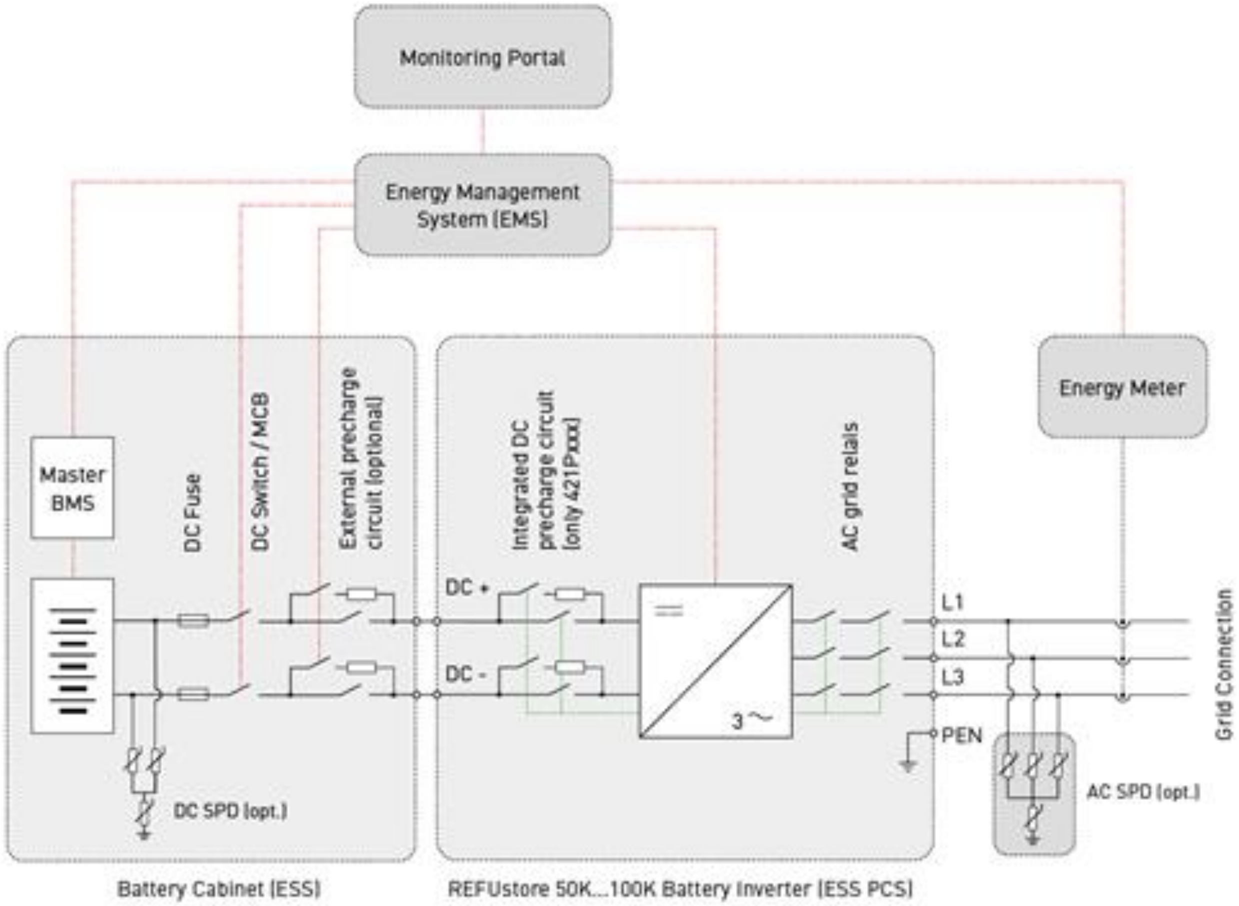
Description of the differences of the models within a series:

The "PowerCore" energy storage unit is used to store and release energy. The energy storage unit is connected via a three-phase 400 V grid connection point of the customer's plant. The "PowerCore" product is designed for three different design variants (expansion stages) and differs in the storage capacities: 186 kWh (expansion stage 1/3); 372 kWh (expansion stage 2/3); 558 kWh (expansion stage 3/3). Each expension stage consists of one, 2 or 3 inverters of type REFUstor 420P088K.

The additions around the grid inverter do not influence its behavior, since no influence is exerted on the grid-serving functions (voltage, frequency, power control) by the control of the energy storage device. In addition, an interface is provided for the utility in terms of remote action.

~~**Description of a typical installation (Figure 4)** *(Manufacturer’s data)*:~~

~~The REFUstor unit is usually connected to a battery system on the DC side. The AC side is connected to the available mains supply.~~



~~**Figure 4 – Scheme of an installation**~~

Description of the connection to the remote-control receiver *(Manufacturer’s data)***:**

The ripple control receiver is connected to an external data acquisition device via a digital input.

The corresponding conversion of the power setpoint can be specified via the logical linking of the registers.

2. Annex 2 – Technical characteristics of the power generating unit (Manufacturer's data)

2.3. Description of software version and interfaces

Following is the software and firmware version used for the TG3 testing [14]:

4. Main Components of the regulating system

Main components of the control system with firmware and software	
Main component(s) of the control system (Hardware on which the control software is operated)	SR36300.2
Firmware version (clear identification of the firmware)	310-01-06-42-S

☐ The parameters can be read out using the following software.

Name:	REFUvis
Version:	1.8.0.23

Figure 5 – Software and firmware version used for the TG3 testing from [14]

Note:

All models are using the same firmware. The parameterization is dependent on the several types, all within one firmware. The software to change the parameters is called REFUset.

if not specified otherwise, the following applies:

(Any updates have influence on the verified AC electrical behaviour of the PGU need to be informed and approved by Bureau Veritas Consumer Products Services Germany GmbH.)

2. Annex 2 – Technical characteristics of the power generating unit (Manufacturer's data)

Following are the interfaces provided on the PGU level for active and reactive power setting, and behaviour of the PGU in the event of a communication failure with the PGS controller [15]:

Die Arten der Sollwertvorgabe und Schnittstellen zur Regelung der Blindleistungsbereitstellung sind dokumentiert. Angabe der Q-Übergangsfunktion über eine Sprungantwort für die Schnittstellen/Sollwert-Kombinationen. / *The types of setpoint value specifications and interfaces for control of the reactive power provision are documented.* *The types of setpoint value specifications and interfaces for control of the reactive power provision are documented.*	The following interfaces (RS485, Ethernet) and corresponding software tools (REFUset for all interfaces,) or PGS controllers (REFUcontrol) are available for setting / controlling active and reactive power. There are no differences regarding the setpoint accuracy and settling / response times between the interfaces / software tools: Hereby, the pick up of a new setpoint of Q and cosφ is guaranteed within 10 s. The pick up of a new setpoint of P is guaranteed within 1 s.

Herstellererklärung zur Einhaltung der technischen Anforderungen der VDE-AR-N 4110:2018-11 / VDE-AR-N 4120:2018-11
Manufacturer's declaration for compliance to technical requirements of the VDE-AR-N 4110:2018-11 / VDE-AR-N 4120:2018-11
Datum / *Date*: 2022-08-17

Anforderung / *Requirement*	**Erklärung / *Declaration***
4. Wirkleistung / *Active power*	
Angabe zu Schnittstellen zur Wirkleistungsvorgabe (Netzbetreiber, Direktvermarkter) getrennt umgesetzt sowie konzeptionell überprüft, ob niedrigster Wirkleistungswert übernommen wird (auch bei sich zeitlich überschneidenden Vorgaben). / *Details of interfaces for specifying active power (grid operator, direct seller) implemented separately as well as the concept checked to make sure lowest active power value is accepted (even if specifications overlap in time).*	There are no separate interfaces for specifying active power by the grid operator and the direct seller For the use of this control, the PGU plant controller or the energy management controller, respectively, has to be used. Generally is the P-derating function with the lowest P-setpoint priorised.
Sind Schnittstellen zur Wirkleistungsvorgabe (Netzbetreiber, Direktvermarkter) getrennt umgesetzt? Ob niedrigster Wirkleistungswert übernommen wird (auch bei sich zeitlich überschneidenden Vorgaben)? / *If Interfaces for specifying active power (grid operator, direct seller) implemented separately? If lowest active power value is accepted (even if specifications overlap in time).*	There are no separate interfaces for specifying active power by the grid operator and the direct seller For the use of this control, the PGU plant controller or the energy management controller, respectively, has to be used. Generally the P-derating function with the lowest P-setpoint will be priorised.

Figure 6 – Interfaces provided on the PGU level for active and reactive power setting from [15]

Im Falle einer Kommunikationsstörung zum EZA Regler können EZE mit einem vorgegebenen Wert bzw. Verfahren betrieben werden. / *In the event the communication with the PGS controller is disturbed, PGU can be operated with a predefined value or process.*	The Power limitation setpoint P1162.0 can be changed to a preset value (P1216.0) in case of a communication error. The Q-setpoint values will be kept in case of a communication loss. When the heartbeat control is activated, the unit will switch off in case of a communication error. (P1770.0-1773.0)

Figure 7 – Behaviour of the PGU in the event of a communication failure with the PGS controller [15]

3. Annex 3 – Extract from the test report

3.1. Power quality

4.3 Power quality characteristics / Netzrückwirkungen

4.3.2 Switching operations / *Schalthandlungen*

Case of switching operation / *Art der Schalthandlung*	Start-up at $P_{available}$ < 10%P_n / *Einschalten bei* $P_{verfügbar}$ < 10%P_n			
Max. number of switching operations / *Max. Anzahl Schalthandlungen*, N_{10} (Manufacturer's data / *Herstellerangabe*)	20			
Max. number of switching operations / *Max. Anzahl Schalthandlungen*, N_{120} (Manufacturer's data / *Herstellerangabe*)	240			
Grid impedance angle / *Netzimpedanzwinkel*, ψ_k	30°	50°	70°	85°
Flicker step factor / *Flickerformfaktor*, $k_f(\psi_k)$	0,03	0,03	0,03	0,03
Voltage change factor / *Spannungsänderungsfaktor*, $k_u(\psi_k)$	0,34	0,33	0,30	0,28
Case of switching operation / *Art der Schalthandlung*	Start-up at $P_{available}$ = 100%P_n / *Einschalten bei* $P_{verfügbar}$ = 100%P_n			
Max. number of switching operations / *Max. Anzahl Schalthandlungen*, N_{10} (Manufacturer's data / *Herstellerangabe*)	20			
Max. number of switching operations / *Max. Anzahl Schalthandlungen*, N_{120} (Manufacturer's data / *Herstellerangabe*)	240			
Grid impedance angle / *Netzimpedanzwinkel*, ψ_k	30°	50°	70°	85°
Flicker step factor / *Flickerformfaktor*, $k_f(\psi_k)$	0,06	0,05	0,04	0,03
Voltage change factor / *Spannungsänderungsfaktor*, $k_u(\psi_k)$	1,19	1,02	0,75	0,51
Case of switching operation / *Art der Schalthandlung*	Service disconnection at rated power / *Serviceabschaltung bei Nennleistung*			
Max. number of switching operations / *Max. Anzahl Schalthandlungen*, N_{10} (Manufacturer's data / *Herstellerangabe*)	1			

3. Annex 3 – Extract from the test report

4.3 Power quality characteristics / Netzrückwirkungen				
Max. number of switching operations / *Max. Anzahl Schalthandlungen*, N_{120} (Manufacturer's data / *Herstellerangabe*)	12			
Grid impedance angle / *Netzimpedanzwinkel*, ψ_k	30°	50°	70°	85°
Flicker step factor / *Flickerformfaktor*, $k_f(\psi_k)$	0,90	0,72	0,47	0,25
Voltage change factor / *Spannungsänderungsfaktor*, $k_u(\psi_k)$	1,17	0,98	0,71	0,49

Note / *Anmerkung*:

The tests were conducted on the REFUsol 100K 880P100. /

Die Prüfungen wurden am REFUsol 100K 880P100 *durchgeführt.*

$S_{k,fic}/S_n$ in the fictitious grid was set to / *Das Kurzschlussverhältnis im fiktiven Netz wurde gesetzt zu*: 20

For the same SCR $S_{k,fic}/S_n$ in the fictitious grid, the flicker step and voltage change factors of the REFUsol 100K 880P100 can be applied to REFUstor 88K 420P088, REFUstor 100K 421P100 directly and for REFUstor 50K 421P050 / REFUstor 50K 420P050 scaled (by the factor $P_{max,\ notmeasure}$ / $P_{max,\ REFUsol\ 100K\ 880P100}$).

3. Annex 3 – Extract from the test report

4.3.3 Flicker												
REFUsol 100K 880P100 @ 50% with connection box @ 400V												
P in %	0	10	20	30	40	50	60	70	80	90	100	Max
Netzimpedanzwinkel/ Network impedance phase angle ψ_k	Flicker coefficient / *Flickerkoeffizient*, c(ψ_k)											
30	0,23	0,25	0,25	0,28	0,45	0,6	0,87	0,69	2,45	2,01	2,17	2,45
50	0,25	0,29	0,25	0,29	0,42	0,59	0,82	0,74	1,96	1,62	1,73	1,96
70	0,29	0,32	0,26	0,3	0,38	0,58	0,79	0,78	1,39	1,18	1,19	1,39
85	0,3	0,33	0,26	0,31	0,38	0,58	0,79	0,81	1,13	0,97	0,91	1,13
REFUsol 100K 880P100 @ 180V with connection Box												
P in %	0	10	20	30	40	50	60	70	80	90	100	Max
Netzimpedanzwinkel/ Network impedance phase angle ψ_k	Flicker coefficient / *Flickerkoeffizient*, c(ψ_k)											
30	0,33	0,32	0,57	0,86	1,15	1,11	1,52	1,60	1,60	1,35	1,24	1,60
50	0,38	0,39	0,83	1,26	1,71	1,65	2,29	2,38	2,43	2,02	1,74	2,43
70	0,43	0,45	1,00	1,52	2,09	2,02	2,82	2,93	3,05	2,49	2,09	3,05
85	0,46	0,47	1,06	1,61	2,23	2,17	3,02	3,16	3,31	2,67	2,20	3,31
REFUstore 88K 420P088 @ 400V with connection Box												
P in %	0	10	20	30	40	50	60	70	80	90	100	Max
Netzimpedanzwinkel/ Network impedance phase angle ψ_k	Flicker coefficient / *Flickerkoeffizient*, c(ψ_k)											
30	0,23	0,24	0,26	0,31	0,55	0,71	1,01	0,77	2,44	1,92	2,07	2,44
50	0,23	0,26	0,25	0,30	0,48	0,65	0,89	0,74	1,96	1,57	1,67	1,96
70	0,25	0,28	0,24	0,29	0,41	0,58	0,77	0,71	1,38	1,13	1,18	1,38
85	0,26	0,28	0,25	0,29	0,38	0,54	0,72	0,69	1,07	0,92	0,90	1,07
REFUstore 88K 420P088 @ 180V with connection Box												
P in %	0	10	20	30	40	50	60	70	80	90	100	Max
Netzimpedanzwinkel/ Network impedance phase angle ψ_k	Flicker coefficient / *Flickerkoeffizient*, c(ψ_k)											
30	0,38	0,43	0,46	0,69	1,11	1,30	1,12	1,53	1,58	1,99	2,43	2,43
50	0,50	0,57	0,63	1,04	1,61	1,96	1,57	2,21	2,18	2,65	3,50	3,50
70	0,60	0,68	0,75	1,28	1,93	2,42	1,87	2,68	2,60	3,14	4,23	4,23
85	0,63	0,72	0,79	1,37	2,07	2,61	1,97	2,85	2,75	3,29	4,48	4,48

Note / *Anmerkung*:

$S_{k,fic}/S_n$ in the fictitious grid was set to / *Das Kurzschlussverhältnis im fiktiven Netz wurde gesetzt zu*: 20

The flicker coefficient, c(ψk) results of the REFUsol 100K 880P100 can be applied to REFUstor 88K 420P088, REFUstor 100K 421P100 directly and for REFUstor 50K 421P050 / REFUstor 50K 420P050 scaled (by the factor $P_{max,\ notmeasure}$ / $P_{max,\ REFUsol\ 100K\ 880P100}$).

The flicker coefficient, c(ψk) for one inverter model operated at 400V AC can be transferred to the same inverter model operated at a different AC voltage by the factor $P_{max,\ V\ notmeasured}$ / $P_{max,400V}$

3. Annex 3 – Extract from the test report

4.3.4 Harmonics / *Oberschwingungen*												
REFUstor 88K 420P088 @ 400V with connection Box												
P/P_n [%]	5	10	20	30	40	50	60	70	80	90	100	max
Order / *Ordnung*	I_h [% I_{ref}][I_{ref} = 127,5A]											
2	0,11	0,14	0,17	0,17	0,19	0,18	0,18	0,19	0,19	0,20	0,21	0,21
3	0,11	0,13	0,20	0,21	0,21	0,20	0,16	0,14	0,15	0,25	0,15	0,25
4	0,07	0,02	0,03	0,03	0,04	0,04	0,04	0,03	0,03	0,03	0,04	0,07
5	0,04	0,26	0,87	0,84	0,65	0,37	0,30	0,37	0,45	0,48	0,53	0,87
6	0,07	0,05	0,05	0,05	0,05	0,05	0,06	0,05	0,06	0,06	0,05	0,07
7	0,38	0,20	0,49	0,57	0,46	0,28	0,25	0,31	0,32	0,34	0,42	0,57
8	0,03	0,03	0,03	0,03	0,03	0,02	0,03	0,03	0,02	0,03	0,03	0,03
9	0,04	0,08	0,08	0,04	0,05	0,06	0,04	0,05	0,06	0,07	0,06	0,08
10	0,04	0,04	0,03	0,03	0,03	0,03	0,03	0,03	0,03	0,03	0,03	0,04
11	0,43	0,35	0,17	0,31	0,28	0,16	0,07	0,11	0,12	0,15	0,16	0,43
12	0,03	0,05	0,04	0,03	0,03	0,04	0,03	0,03	0,03	0,03	0,03	0,05
13	0,39	0,45	0,11	0,24	0,20	0,09	0,06	0,07	0,06	0,08	0,10	0,45
14	0,03	0,02	0,01	0,01	0,01	0,01	0,01	0,01	0,02	0,01	0,02	0,03
15	0,02	0,05	0,08	0,04	0,02	0,02	0,04	0,03	0,04	0,04	0,03	0,08
16	0,03	0,03	0,04	0,03	0,04	0,04	0,04	0,04	0,03	0,03	0,03	0,04
17	0,34	0,43	0,21	0,22	0,18	0,08	0,02	0,04	0,03	0,04	0,05	0,43
18	0,04	0,06	0,05	0,06	0,06	0,06	0,06	0,06	0,05	0,05	0,05	0,06
19	0,40	0,38	0,27	0,20	0,18	0,09	0,02	0,02	0,03	0,03	0,05	0,40
20	0,03	0,03	0,04	0,03	0,03	0,03	0,03	0,03	0,03	0,03	0,03	0,04
21	0,06	0,04	0,04	0,05	0,02	0,03	0,03	0,03	0,03	0,04	0,03	0,06
22	0,02	0,02	0,02	0,02	0,02	0,02	0,02	0,02	0,02	0,02	0,02	0,02
23	0,40	0,36	0,44	0,27	0,20	0,13	0,06	0,07	0,06	0,08	0,10	0,44
24	0,02	0,03	0,03	0,03	0,03	0,03	0,03	0,03	0,02	0,02	0,03	0,03
25	0,47	0,37	0,43	0,26	0,20	0,12	0,07	0,06	0,09	0,09	0,11	0,47
26	0,03	0,02	0,02	0,02	0,02	0,02	0,02	0,02	0,02	0,02	0,02	0,03
27	0,05	0,08	0,08	0,06	0,03	0,02	0,02	0,03	0,03	0,04	0,03	0,08
28	0,02	0,03	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,03
29	0,32	0,49	0,45	0,28	0,20	0,14	0,08	0,08	0,10	0,11	0,13	0,49
30	0,02	0,03	0,02	0,02	0,01	0,01	0,02	0,02	0,02	0,02	0,03	0,03
31	0,44	0,46	0,42	0,28	0,21	0,14	0,09	0,10	0,11	0,12	0,14	0,46
32	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,02	0,02
33	0,05	0,06	0,09	0,05	0,05	0,03	0,02	0,03	0,03	0,04	0,04	0,09
34	0,02	0,02	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,02
35	0,28	0,32	0,35	0,24	0,17	0,13	0,09	0,09	0,10	0,11	0,14	0,35
36	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01
37	0,43	0,30	0,32	0,24	0,18	0,13	0,09	0,10	0,11	0,13	0,15	0,43
38	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01
39	0,07	0,06	0,06	0,04	0,04	0,03	0,02	0,02	0,02	0,03	0,02	0,07
40	0,01	0,02	0,02	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,02
41	0,28	0,29	0,24	0,18	0,14	0,12	0,09	0,08	0,09	0,11	0,13	0,29
42	0,02	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,02
43	0,28	0,19	0,21	0,18	0,15	0,12	0,09	0,10	0,11	0,12	0,15	0,28
44	0,02	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,02
45	0,05	0,03	0,03	0,03	0,03	0,03	0,02	0,02	0,02	0,03	0,03	0,05
46	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01
47	0,22	0,07	0,13	0,14	0,12	0,10	0,09	0,09	0,10	0,11	0,13	0,22
48	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01
49	0,10	0,07	0,09	0,12	0,12	0,10	0,08	0,09	0,09	0,10	0,12	0,12
50	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01
THC [% I_{ref}]	1,41	1,38	1,54	1,37	1,10	0,72	0,56	0,64	0,71	0,79	0,87	1,54

3. Annex 3 – Extract from the test report

Interharmonics at continuous operation / *Zwischenharmonische im Normalbetrieb*

REFUstor 88K 420P088 @ 400V with connection Box

P/P_n [%]	0 - 5	10	20	30	40	50	60	70	80	90	100	max
f [Hz]	I_h [% I_{ref}]											
75	0,03	0,04	0,05	0,06	0,09	0,10	0,13	0,12	0,14	0,14	0,15	0,15
125	0,03	0,03	0,03	0,03	0,03	0,03	0,04	0,04	0,04	0,04	0,04	0,04
175	0,03	0,03	0,03	0,02	0,02	0,02	0,03	0,03	0,03	0,03	0,03	0,03
225	0,04	0,03	0,03	0,02	0,02	0,02	0,03	0,02	0,03	0,03	0,03	0,04
275	0,02	0,03	0,02	0,02	0,02	0,02	0,02	0,02	0,02	0,02	0,02	0,03
325	0,03	0,02	0,02	0,02	0,02	0,02	0,02	0,02	0,02	0,02	0,03	0,03
375	0,02	0,03	0,03	0,02	0,02	0,02	0,02	0,02	0,03	0,03	0,02	0,03
425	0,04	0,03	0,03	0,02	0,02	0,02	0,02	0,02	0,02	0,02	0,02	0,04
475	0,02	0,03	0,03	0,02	0,02	0,02	0,03	0,03	0,03	0,03	0,02	0,03
525	0,04	0,04	0,03	0,02	0,02	0,02	0,02	0,02	0,02	0,02	0,02	0,04
575	0,02	0,02	0,02	0,02	0,02	0,02	0,02	0,02	0,02	0,02	0,02	0,02
625	0,03	0,03	0,02	0,02	0,02	0,02	0,02	0,02	0,02	0,02	0,02	0,03
675	0,02	0,03	0,02	0,02	0,02	0,03	0,02	0,02	0,02	0,03	0,02	0,03
725	0,04	0,03	0,02	0,02	0,02	0,02	0,02	0,02	0,02	0,02	0,02	0,04
775	0,02	0,03	0,03	0,02	0,02	0,02	0,02	0,03	0,03	0,02	0,02	0,03
825	0,04	0,03	0,02	0,02	0,02	0,02	0,02	0,02	0,02	0,02	0,02	0,04
875	0,02	0,02	0,02	0,02	0,02	0,02	0,02	0,02	0,02	0,02	0,02	0,02
925	0,02	0,02	0,02	0,02	0,02	0,02	0,02	0,02	0,02	0,03	0,02	0,03
975	0,03	0,03	0,02	0,03	0,03	0,03	0,02	0,02	0,02	0,02	0,02	0,03
1025	0,03	0,03	0,02	0,03	0,02	0,02	0,02	0,02	0,02	0,03	0,03	0,03
1075	0,03	0,03	0,03	0,03	0,03	0,03	0,02	0,02	0,03	0,03	0,03	0,03
1125	0,03	0,03	0,02	0,04	0,02	0,02	0,02	0,02	0,02	0,02	0,02	0,04
1175	0,02	0,02	0,02	0,03	0,02	0,02	0,02	0,02	0,02	0,02	0,02	0,03
1225	0,02	0,02	0,02	0,03	0,02	0,02	0,02	0,02	0,02	0,03	0,03	0,03
1275	0,03	0,02	0,02	0,04	0,02	0,03	0,02	0,02	0,02	0,02	0,02	0,04
1325	0,02	0,02	0,02	0,03	0,02	0,02	0,02	0,02	0,02	0,03	0,03	0,03
1375	0,03	0,02	0,03	0,03	0,02	0,03	0,02	0,02	0,02	0,03	0,03	0,03
1425	0,02	0,03	0,02	0,04	0,02	0,02	0,02	0,02	0,02	0,02	0,02	0,04
1475	0,02	0,02	0,02	0,03	0,02	0,02	0,02	0,02	0,02	0,02	0,02	0,03
1525	0,02	0,01	0,02	0,03	0,02	0,02	0,02	0,02	0,02	0,03	0,03	0,03
1575	0,03	0,02	0,02	0,04	0,02	0,02	0,02	0,02	0,02	0,02	0,02	0,04
1625	0,02	0,02	0,02	0,03	0,02	0,02	0,02	0,02	0,02	0,03	0,03	0,03
1675	0,03	0,01	0,02	0,03	0,02	0,02	0,02	0,02	0,02	0,02	0,03	0,03
1725	0,02	0,02	0,02	0,04	0,02	0,02	0,02	0,02	0,02	0,02	0,02	0,04
1775	0,02	0,02	0,02	0,02	0,02	0,02	0,02	0,02	0,02	0,02	0,02	0,02
1825	0,02	0,01	0,01	0,02	0,02	0,02	0,01	0,01	0,02	0,02	0,02	0,02
1875	0,04	0,02	0,01	0,03	0,02	0,02	0,01	0,01	0,01	0,02	0,02	0,04
1925	0,01	0,01	0,01	0,02	0,02	0,02	0,02	0,02	0,02	0,02	0,03	0,03
1975	0,02	0,01	0,01	0,02	0,02	0,02	0,02	0,02	0,02	0,02	0,02	0,02

3. Annex 3 – Extract from the test report

Higher Frequencies components / *Höhere Frequenzen im Normalbetrieb*												
REFUstor 88K 420P088 @ 400V with connection Box												
P/P_n [%]	0 - 5	10	20	30	40	50	60	70	80	90	100	max
f [kHz]	I_h [% I_{ref}][											
2,1	0,35	0,33	0,31	0,24	0,20	0,17	0,13	0,13	0,15	0,17	0,20	0,35
2,3	0,23	0,08	0,13	0,14	0,12	0,11	0,09	0,09	0,10	0,11	0,13	0,23
2,5	0,11	0,07	0,09	0,12	0,12	0,10	0,08	0,09	0,10	0,10	0,12	0,12
2,7	0,18	0,12	0,09	0,12	0,13	0,12	0,10	0,10	0,11	0,12	0,13	0,18
2,9	0,07	0,06	0,08	0,09	0,09	0,08	0,07	0,07	0,07	0,07	0,08	0,09
3,1	0,10	0,05	0,07	0,08	0,09	0,09	0,08	0,08	0,08	0,09	0,08	0,10
3,3	0,13	0,06	0,06	0,09	0,11	0,11	0,10	0,10	0,11	0,11	0,10	0,13
3,5	0,08	0,11	0,05	0,08	0,09	0,09	0,09	0,09	0,09	0,09	0,08	0,11
3,7	0,16	0,12	0,06	0,09	0,09	0,09	0,10	0,10	0,10	0,09	0,08	0,16
3,9	0,23	0,19	0,07	0,12	0,16	0,16	0,18	0,17	0,16	0,15	0,12	0,23
4,1	0,18	0,14	0,08	0,08	0,13	0,15	0,16	0,15	0,14	0,14	0,13	0,18
4,3	0,26	0,12	0,09	0,09	0,09	0,13	0,17	0,18	0,17	0,18	0,15	0,26
4,5	0,17	0,11	0,07	0,06	0,05	0,05	0,07	0,09	0,12	0,10	0,09	0,17
4,7	0,06	0,04	0,04	0,04	0,03	0,03	0,04	0,05	0,06	0,08	0,06	0,08
4,9	0,08	0,03	0,04	0,04	0,02	0,02	0,02	0,03	0,04	0,08	0,09	0,09
5,1	0,05	0,02	0,02	0,03	0,02	0,02	0,02	0,02	0,02	0,07	0,10	0,10
5,3	0,03	0,02	0,02	0,02	0,02	0,01	0,02	0,02	0,02	0,03	0,06	0,06
5,5	0,03	0,02	0,01	0,02	0,02	0,01	0,01	0,02	0,02	0,03	0,04	0,04
5,7	0,03	0,02	0,01	0,02	0,02	0,01	0,01	0,01	0,01	0,02	0,03	0,03
5,9	0,03	0,02	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,02	0,02	0,03
6,1	0,02	0,02	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,02	0,02
6,3	0,02	0,01	0,01	0,01	0,02	0,01	0,01	0,01	0,01	0,01	0,02	0,02
6,5	0,02	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,02
6,7	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01
6,9	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,02	0,02
7,1	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01
7,3	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01
7,5	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01
7,7	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01
7,9	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01
8,1	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01
8,3	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01
8,5	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01
8,7	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01
8,9	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01

Note / *Anmerkung*:

The stated harmonics are maximum values of all 3 phases. / *Die angegebenen Harmonischenwerte sind Maximalwerte über alle 3 Phasen.*

3. Annex 3 – Extract from the test report

4.3 Power quality characteristics / Netzrückwirkungen

Auszug aus dem Prüfbericht / Extract from the test report
Teil1: Netzverträglichkeit / Part 1: Power Quality

Auszug Nr./ Extract No:

"Technische Richtlinie Teil 3 Rev./ Version 25, FGW

4.3.5 Unbalances / *Unsymmetrie*

REFUsol 100K 880P100 with connection box @ 400V											
P [%P_n]	0	10	20	30	40	50	60	70	80	90	100	Max
u_i [%I_{1+}]	0,78	0,16	0,15	0,17	0,14	0,1	0,07	0,06	0,11	0,27	0,05	0,27
REFUsol 100K 880P100 with connection box @ 180V											
P [%P_n]	0	10	20	30	40	50	60	70	80	90	100	Max
u_i [%I_{1+}]	1,37	0,68	0,33	0,16	0,12	0,1	0,13	0,12	0,11	0,1	0,07	0,68
REFUstor 421P100 with connection box @ 400V											
P [%P_n]	0	10	20	30	40	50	60	70	80	90	100	Max
u_i [%I_{1+}]	0,26	0,14	0,09	0,07	0,05	0,17	0,16	0,16	0,16	0,16	0,02	0,17
REFUstor 420P088 with connection box @ 400V											
P [%P_n]	0	10	20	30	40	50	60	70	80	90	100	Max
u_i [%I_{1+}]	0,78	0,16	0,15	0,17	0,14	0,1	0,07	0,06	0,11	0,27	0,05	0,27
REFUstor 420P088 with connection box @ 180V											
P [%P_n]	0	10	20	30	40	50	60	70	80	90	100	Max
u_i [%I_{1+}]	1,03	0,54	0,24	0,12	0,09	0,07	0,06	0,05	0,05	0,04	0,07	0,54

Note / *Anmerkung*:
The unbalance current results of the REFUsol 100K 880P100 can be applied to REFUstor 88K 420P088, REFUstor 100K 421P100 directly and for REFUstor 50K 421P050 / REFUstor 50K 420P050 scaled (by the factor $P_{max,\ notmeasure}$ / $P_{max,\ REFUsol\ 100K\ 880P100}$).
The unbalance current results for one inverter model operated at 400V AC can be transferred to the same inverter model operated at a different AC voltage by the factor $P_{max,\ V\ notmeasured}$ / $P_{max,400V}$

Figure 8 – Results of power quality from [9]

3. Annex 3 – Extract from the test report

3.2. Active power

4.1 Active power output / Wirkleistungsabgabe

Auszug Nr. / Extract No: 18TH0270_TR3_1 "Technische Richtlinie Teil 3" Rev./Version 25, FGW			
Anlagentyp/Installation type: REFUsol 100K 880P100		Herstellerangaben/Manufacturer´s specifications:	
Anlagenhersteller/Manufacturer: REFU Elektronik GmbH		Anlagenart/Generic type of installation: Grid-tied photovoltaic and battery inverter with connection box	Nennleistung/Rated power Pn: 88 kW
Prüfbericht/ testreport: 18TH0270_TR3_1		Messzeitraum/ Period of measurement: 2022-03-13; 2022-05-23	
Nenndaten / Rated data:			
Nennscheinleistung S_n	88 kVA	Nennstrom I_n	128A
Nennfrequenz f_n/ rated frequency f_n	50 Hz	Nennspannung U_n / rated Voltage U_n	400 V

4.1.1 Power peaks / *Wirkleistungsspitzen*

Power peaks / *Wirkleistungsspitzen* [W]		Normalized Power peaks / *Normierte Wirkleistungsspitzen* [p.u. base / *Basis* P_n]		*Anzahl der verwendeten 10-Minuten-Datensätze*
$P_{0,2}$	89282,5	$p_{60}=P_{60}/P_n$	1,015	2
P_{60}	89263,5	$p_{60}=P_{60}/P_n$	1,014	
P_{600}	89244,8	$p_{60}=P_{60}/P_n$	1,014	

Note / *Anmerkung*:

The tests were conducted on the REFUsol 100K 880P100. /

Die Prüfungen wurden am REFUsol 100K 880P100 *durchgeführt.*

The tests were conducted under normal operation (Q=0).

At cosφ = 1 the active power equals the apparent power.

The active power results of the REFUsol 100K 880P100 can be applied to REFUstor 88K 420P088, REFUstor 100K 421P100 directly and for REFUstor 50K 421P050 / REFUstor 50K 420P050 scaled (by the factor $P_{max, notmeasure}$ / $P_{max, REFUsol\ 100K\ 880P100}$).

The active power results for one inverter model operated at 400V AC can be transferred to the same inverter model operated at a different AC voltage by the factor $P_{max, V\ notmeasured}$ / $P_{max,400V}$.

4.1 Active Power Output / *Wirkleistungsabgabe*

4.1.2 Operating power limited by grid operator / *Leistungsbegrenzter Betrieb durch den Netzbetreiber*

The unit is able to run at reduced power. / *Die EZEs können mit reduzierter Leistung betrieben werden.*	☒ Yes / *Ja*	☐ No / *Nein*
Disconnection from the grid at external active power set-points at / *Trennung vom Netz bei Wirkleistungssollwertvorgabe von*:	At 0% setpoint the PGU stays connected without power feeding. *Bei 0% Sollwertvorgabe bleibt die EZE am Netz ohne Einspeisung.*	
REFUsol 100K 880P100		
Max. deviation of power setting / *Maximale Sollwertabweichung der Wirkleistung*	Exceeding / *Überschreitung*: -1,1 kW	Undercut / *Unterschreitung*: -1,2 kW
Settling time of the power output after a change in set-point with minimal gradient: / *Einschwingzeit der Leistung für einen Sollwertsprung mit minimalem Gradienten:*	$P_{70\%} \rightarrow P_{50\%}$	Time / *Zeit*: 52,30 s Gradient: -0,319%P_n/s
	$P_{50\%} \rightarrow P_{70\%}$	Time / *Zeit*: 44,34 s Gradient: 0,320%P_n/s
Settling time of the power output after a change in set-point with maximum gradient / *Einschwingzeit der Leistung für einen Sollwertsprung mit maximalem Gradienten*:	$P_{90\%} \rightarrow P_{10\%}$	Time / *Zeit*: 120,18 s Gradient: -0,638%P_n/s
	$P_{10\%} \rightarrow P_{90\%}$	Time / *Zeit*: 118,43 s Gradient: 0,637%P_n/s

Note / *Anmerkung*:

The setpoint accuracy and settling time results of the REFUsol 100K 880P100 can be applied to REFUstor 88K 420P088, REFUstor 100K 421P100 directly and for REFUstor 50K 421P050 / REFUstor 50K 420P050 scaled (by the factor $P_{max, notmeasure}$ / $P_{max, REFUsol 100K 880P100}$).

The setpoint accuracy and settling time results for one inverter model operated at 400V AC can be transferred to the same inverter model operated at a different AC voltage by the factor $P_{max, V notmeasured}$ / $P_{max,400V}$.

4.1 Active Power Output / *Wirkleistungsabgabe*

4.1.3 Active power feed-in as a function of grid frequency / *Wirkleistungseinspeisung in Abhängigkeit der Netzfrequenz*

REFUsol 100K 880P100		
Overfrequency / *Überfrequenz*	Mean power gradient at overfrequency / *Mittlerer Gradient der Wirkleistung zum Zeitpunkt der Frequenzüberhöhung*	Mean gradient / *Mittlerer Gradient* -40,07 %P_{mom}/Hz
	Max. Settling time / *Max. Einschwingzeit*	0,6 s
	Power gradient after recovery of overfrequency / *Gradient der Wirkleistung nach Rückkehr aus Überfrequenz*	Mean gradient / *Mittlerer Gradient:* -2,53% P_n/min Max. gradient / *Max. Gradient:* -2,53 %P_n/min
Underfrequency / *Unterfrequenz*	Mean power gradient at underfrequency / *Mittlerer Gradient der Wirkleistung zum Zeitpunkt der Frequenzunterschreitung*	Mean gradient / *Mittlerer Gradient* -40,60 %P_{mom}/Hz
	Max. Settling time / *Max. Einschwingzeit*	0,6 s
	Power gradient after recovery of underfrequency / *Gradient der Wirkleistung nach Rückkehr aus Unterfrequenz*	Mean gradient / *Mittlerer Gradient:* - 9,08%P_n/min Max. gradient / *Max. Gradient:* - 9,1%P_n/min

4.1 Active Power Output / *Wirkleistungsabgabe*

REFUstor 420P088		
Overfrequency / *Überfrequenz*	Mean power gradient at overfrequency / *Mittlerer Gradient der Wirkleistung zum Zeitpunkt der Frequenzüberhöhung*	Mean gradient / *Mittlerer Gradient* -101,68 %P_{mom}/Hz
	Max. Settling time / *Max. Einschwingzeit*	0,4 s
	Power gradient after recovery of overfrequency / *Gradient der Wirkleistung nach Rückkehr aus Überfrequenz **	Mean gradient / *Mittlerer Gradient:* -% P_n/min Max. gradient / *Max. Gradient:* -%P_n/min
Underfrequency / *Unterfrequenz*	Mean power gradient at underfrequency / *Mittlerer Gradient der Wirkleistung zum Zeitpunkt der Frequenzunterschreitung*	Mean gradient / *Mittlerer Gradient* -101,42 %P_{mom}/Hz
	Max. Settling time / *Max. Einschwingzeit*	0,6 s
	Power gradient after recovery of underfrequency / *Gradient der Wirkleistung nach Rückkehr aus Unterfrequenz*	Mean gradient / *Mittlerer Gradient:* - 8,63%P_n/min Max. gradient / *Max. Gradient:* - 8,66%P_n/min

3. Annex 3 – Extract from the test report

4.1 Active Power Output / *Wirkleistungsabgabe*

REFUstor 420P050		
Overfrequency / *Überfrequenz*	Mean power gradient at overfrequency / *Mittlerer Gradient der Wirkleistung zum Zeitpunkt der Frequenzüberhöhung*	Mean gradient / *Mittlerer Gradient* -100,68 $\%P_{mom}$/Hz
	Max. Settling time / *Max. Einschwingzeit*	0,6 s
	Power gradient after recovery of overfrequency / *Gradient der Wirkleistung nach Rückkehr aus Überfrequenz **	Mean gradient / *Mittlerer Gradient:* 9,44% P_n/min Max. gradient / *Max. Gradient:* 9,45 $\%P_n$/min
Underfrequency / *Unterfrequenz*	Mean power gradient at underfrequency / *Mittlerer Gradient der Wirkleistung zum Zeitpunkt der Frequenzunterschreitung*	Mean gradient / *Mittlerer Gradient* -101,71 $\%P_{mom}$/Hz
	Max. Settling time / *Max. Einschwingzeit*	0,6 s
	Power gradient after recovery of underfrequency / *Gradient der Wirkleistung nach Rückkehr aus Unterfrequenz*	Mean gradient / *Mittlerer Gradient:* - 9,52%P_n/min Max. gradient / *Max. Gradient:* - 9,65%P_n/min

Figure 9 – Results of active power control from [10]

The PGUs are able to be operated at reduced power [6].

At 0% setpoint the PGUs stay connected without power feeding.

3. Annex 3 – Extract from the test report

4.1 ACTIVE POWER OUTPUT

4.1.2 Operating power limited by grid operator

1. Determine the setpoint accuracy

REFUsol 100K 880P100

Active power step	Setpoint value		Actual value		Deviation	
[%P_n]	[kW]	[%P_n]	[kW]	[%P_n]	[kW]	[%P_n]
100	-88,0	100,0	-88,3	-100,3	-0,3	-0,3
90	-79,2	90,0	-80,5	-91,5	-1,3	-1,5
80	-70,4	80,0	-71,6	-81,4	-1,2	-1,4
70	-61,6	70,0	-62,7	-71,3	-1,1	-1,3
60	-52,8	60,0	-53,9	-61,3	-1,1	-1,1
50	-44,0	50,0	-45,0	-51,1	-1	-1,0
40	-35,2	40,0	-36,1	-41,0	-0,9	-0,9
30	-26,4	30,0	-27,1	-30,8	-0,7	-0,8
20	-17,6	20,0	-18,2	-20,7	-0,6	-0,7
10	-8,8	10,0	-9,3	-10,6	-0,5	-0,6
0	0,0	0,0	-0,1	-0,1	-0,1	-0,0

	Power setpoint [%P_n]	Deviation [kW]	Deviation [%P_n]
Maximum active power above the defined setpoint (1-minute mean)	70	-1,1	1,3
Maximum active power below the defined setpoint (1-minute mean)	80	-1,2	-1,4
Grid disconnection at xx% of P_n	*		

DC characteristics for test 4.1.2	
PV-curve simulated according to	EN 50530
Voltage of defined MPP [V]	690
Internal impedance [Ω]	0

Note:
* At 0% setpoint the PGU stays connected without power feeding.

The setpoint accuracy and settling time results of the REFUsol 100K 880P100 can be applied to REFUstor 88K 420P088, REFUstor 100K 421P100 directly and for REFUstor 50K 421P050 / REFUstor 50K 420P050 scaled (by the factor $P_{max,\ notmeasure}$ / $P_{max,\ REFUsol\ 100K\ 880P100}$).

The setpoint accuracy and settling time results for one inverter model operated at 400V AC can be transferred to the same inverter model operated at a different AC voltage by the factor $P_{max,\ V\ notmeasured}$ / $P_{max,400V}$.

Figure 10 – Results of active power control from [6]

3. Annex 3 – Extract from the test report

The active power gradient is implemented on the PGU level.

The max. active power output of the PGU is dependent on ambient temperature Active power derating starts not before Tu=40-45°C [15]:

3. Annex 3 – Extract from the test report

3.3. Reactive power

Extract from the test report - Part 2: grid control capability

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4.2 Reactive power provision / *Blindleistungsbereitstellung*

4.2.1 Reactive power response in the normal operation (Q = 0 kvar) / *Blindleistungsverhalten im Normalbetrieb (Q = 0 kvar)*

4.2.2 Measuring the maximum reactive power range (PQ diagram) / Vermessung des maximalen Blindleistungsstellberich (PQ-Diagramm)

REFUsol 100K 880P100

	P/P_n [%]	Q_{ind}	Q_0 [kvar]	Q_{cap}	P/P_n [%]	Q_{ind}	Q_0 [kvar]	Q_{cap}
Control of reactive power in normal operation mode and maximum reactive power range / *Blindleistungsverhalten im Normalbetrieb und maximaler Blindleistungsstellbereich*	0	13500	-2013	-13952	60	69203	-609	-70850
	10	27107	1652	-28008	70	61819	-9996	-62829
	20	54717	1114	-55909	80	52685	-1351	-52835
	30	82504	-767	-83906	90	42233	-1689	-38753
	40	79922	309	-80639	100	-527	-2013	-521
	50	75691	-143	-76188	---	---	---	---

Note / *Anmerkung*:

The reactive power results of the REFUsol 100K 880P100 can be applied to REFUstor 88K 420P088, REFUstor 100K 421P100 directly and for REFUstor 50K 421P050 / REFUstor 50K 420P050 scaled (by the factor $Q/P_{n,\ notmeasure}$ / $Q/P_{n,\ REFUsol\ 100K\ 880P100}$).

The reactive power results for one inverter model operated at 400V AC can be transferred to the same inverter model operated at a different AC voltage by the factor $Q/P_{n,\ V\ notmeasured}$ / $Q/P_{n,400V}$.

3. Annex 3 – Extract from the test report

4.2 Reactive power provision / *Blindleistungsbereitstellung*

4.2.3 Measuring separate operating points in the voltage-dependent PQ diagram / *Vermessung einzelner Arbeitspunkte des spannungsabhängigen PQ-Diagramms*

REFUsol 100K 880P100

Working points of the voltage dependent P-Q-diagram / *Arbeitspunkte des spannungsabhängigen P-Q-Diagramms*

WP / *AP*	U/U_n [%]	P/P_n [%]	Q [var]
1 ind.	0,900	-0,92	-344
2 ind.	0,899	-0,91	6369
3 ind.	0,899	-0,81	36541
4 ind.	0,898	-0,7	50618
5 ind.	0,898	-0,6	58855
6 ind.	0,897	-0,49	66245
7 ind.	0,897	-0,39	70925
8 ind.	0,897	-0,29	74422
9 ind.	0,897	-0,22	55230
10 ind.	0,898	-0,12	27896
11 ind.	0,898	-0,07	13953
1 cap. / *kap.*	0,899	-0,92	-352
2 cap. / *kap.*	0,899	-0,9	-6870
3 cap. / *kap.*	0,900	-0,8	-36760
4 cap. / *kap.*	0,900	-0,7	-49929
5 cap. / *kap.*	0,900	-0,6	-59059
6 cap. / *kap.*	0,900	-0,5	-65988
7 cap. / *kap.*	0,900	-0,4	-71135
8 cap. / *kap.*	0,900	-0,3	-74513
9 cap. / *kap.*	0,900	-0,2	-55498
10 cap. / *kap.*	0,899	-0,11	-27882
11 cap. / *kap.*	0,899	-0,05	-13686

WP / *AP*	U/U_n [%]	P/P_n [%]	Q [var]
1 ind.	1,098	-0,05	-13673
2 ind.	1,099	-0,11	-27530
3 ind.	1,099	-0,2	-55821
4 ind.	1,100	-0,31	-83831
5 ind.	1,100	-0,41	-80486
6 ind.	1,100	-0,51	-76250
7 ind.	1,100	-0,6	-70593
8 ind.	1,100	-0,7	-62741
9 ind.	1,100	-0,8	-52907
10 ind.	1,100	-0,9	-38611
11 ind.	1,099	-1	-620
1 cap. / *kap.*	1,098	-0,07	14195
2 cap. / *kap.*	1,097	-0,13	28161
3 cap. / *kap.*	1,097	-0,23	56213
4 cap. / *kap.*	1,097	-0,33	82972
5 cap. / *kap.*	1,097	-0,4	80720
6 cap. / *kap.*	1,097	-0,5	76328
7 cap. / *kap.*	1,097	-0,6	70746
8 cap. / *kap.*	1,097	-0,71	62835
9 cap. / *kap.*	1,098	-0,8	53106
10 cap. / *kap.*	1,098	-0,91	38448
11 cap. / *kap.*		-1	-622

3. Annex 3 – Extract from the test report

4.2 Reactive power provision / *Blindleistungsbereitstellung*

Note / *Anmerkung*:

The voltage dependent reactive power results of the REFUsol 100K 880P100 can be applied to REFUstor 88K 420P088, REFUstor 100K 421P100 directly and for REFUstor 50K 421P050 / REFUstor 50K 420P050 scaled (by the factor $Q/P_{n,\ notmeasure}$ / $Q/P_{n,\ REFUsol\ 100K\ 880P100}$).

The voltage dependent reactive power results for one inverter model operated at 400V AC can be transferred to the same inverter model operated at a different AC voltage by the factor $Q/P_{n,\ V\ notmeasured}$ / $Q/P_{n,400V}$.

3. Annex 3 – Extract from the test report

Extract from the test report - Part 2: grid control capability

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4.2 Reactive power provision / *Blindleistungsbereitstellung*

4.2.4 Reactive power following setpont / *Blindleistung nach Sollwertvorgabe*

REFUsol 100K 880P100

Control of reactive power through set-point signal / *Blindleistungsregelung durch Sollwertvorgabe*	☐ Power factor / *Verschiebungsfaktor*	☒ Reactive power / *Blindleistung*
	P_{bin} at / *bei*	50% P_n
Longest settling time / *Längste Einschwingzeit*	Parameter	Settling time / *Einschwingzeit*
	Fast settling time / *Schnelle Einschwingzeit* (3τ = 6 s)	8,643 s (- Q_{max} → + Q_{max})
	t < 60 s (3τ = 60 s)	101,634 s (- Q_{max} → + Q_{max})

Note / *Anmerkung*:

For country code setting VDE-AR-N 4110:2018-11, the Q - control functions show PT1 behaviour. The settling time was determined using a tolerance band of ±5% P_n. /

Für Ländereinstellung VDE-AR-N 4110:2018-11 zeigen die Q - Regelungsfunktionen PT1 Verhalten. Die Einschwingzeit wurde mit einem Toleranzband von ±5% P_n bestimmt.

REFUstor 100K 421P100

Control of reactive power through set-point signal / *Blindleistungsregelung durch Sollwertvorgabe*	☒ Power factor / *Verschiebungsfaktor*	☐ Reactive power / *Blindleistung*
	P_{bin} at /*bei*	50% P_n
Longest settling time / *Längste Einschwingzeit*	Parameter	Settling time / *Einschwingzeit*
	Fast settling time / *Schnelle Einschwingzeit* (3τ = 6 s)	8,39 s (- Q_{max} → + Q_{max})
	t < 60 s (3τ = 60 s)	67,96s (- Q_{max} → + Q_{max})

Note / *Anmerkung*:

For country code setting VDE-AR-N 4110:2018-11, the Q - control functions show PT1 behaviour. The settling time was determined using a tolerance band of ±5% P_n. /

Für Ländereinstellung VDE-AR-N 4110:2018-11 zeigen die Q - Regelungsfunktionen PT1 Verhalten. Die Einschwingzeit wurde mit einem Toleranzband von ±5% P_n bestimmt.

3. Annex 3 – Extract from the test report

4.2 Reactive power provision / *Blindleistungsbereitstellung*

REFUsol 100K 880P100		
Control of reactive power through set-point signal / *Blindleistungsregelung durch Sollwertvorgabe*	☐ Power factor / *Verschiebungsfaktor*	☒ Reactive power / *Blindleistung*
	P_{bin} at / *bei*	50%P_n
Set-point accuracy of reative power / *Einstellgenauigkeit der Blindleistung*	Set-point / *Sollwert*	Measured value / *Istwert*
	0,0 var	-445,4 var
	-38104,0 var	-38512,1 var
	38104,0 var	38356,9 var

Note / *Anmerkung*:

The reactive power results of the REFUsol 100K 880P100 can be applied to REFUstor 88K 420P088, REFUstor 100K 421P100 directly and for REFUstor 50K 421P050 / REFUstor 50K 420P050 scaled (by the factor $Q/P_{n, notmeasure}$ / $Q/P_{n, REFUsol\ 100K\ 880P100}$).

The rise time and settling time results of the REFUsol 100K 880P100 can be applied to REFUstor 88K 420P088, REFUstor 100K 421P100 directly and for REFUstor 50K 421P050 / REFUstor 50K 420P050 scaled (by the factor $Q/P_{n, notmeasured}$ / $Q/P_{n, REFUsol\ 100K\ 880P100}$).

The rise time and settling time results for one inverter model operated at 400V AC can be transferred to the same inverter model operated at a different AC voltage by the factor $Q/P_{n, V\ notmeasured}$ / $Q/P_{n,400V}$

3. Annex 3 – Extract from the test report

4.2 Reactive power provision / *Blindleistungsbereitstellung*

4.2.5 Q(U) control / *Q(U) Regelung*

4.2.6 Q(P) control / *Q(P) Regelung*

4.2.7 Reactive power Q with voltage limitation function / *Blindleistung Q mit Spannungsbegrenzungsfunktion*

Remark / *Anmerkung:*	The Q(U) control function was tested, please see test report. / *Die Q(U)- Regelung wurden geprüft, diese sind im Prüfbericht hinterlegt.* The reactive power Q with voltage limitation function and Q(P) controll function were not tested. / *Die Blindleistung Q mit Spannungsbegrenzungsfunktion und die Q(P) Regelung wurden nicht geprüft.*

Figure 11 – Results of reactive power control from [10]

3. Annex 3 – Extract from the test report

Description of methods for the reactive power supply [6]:

The type of the reactive power control on the lowest system level is based on Q.

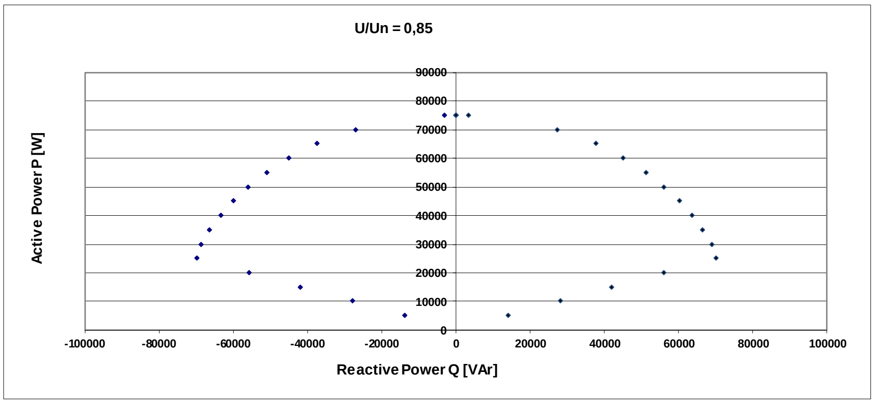
The units provide the following reactive power settings:

- Settable cosφ value (Range: +/- 72,5° for φ)
- Settable Q value (Range: +/- 95 kvar)
- Configurable Q(P)-curve (No: of supporting points 10)
- Configurable Q(U)-curve (No. of supporting points: 2 / 4 or 20 (depends on used function according to reactive power voltage characteristic curve Q(U) and reactive power with voltage limiting function.
- For battery inverters the similar Q-characteristic is provided in operation status CHARGE. Reactive power Q is limited by a minimum cos φ = 0,3 and by the max. apparent power 1,73*128 A *U_N and by the max. rms current 128 A

The resulting voltage dependent PQ operating points as follows [6]:

85% Un

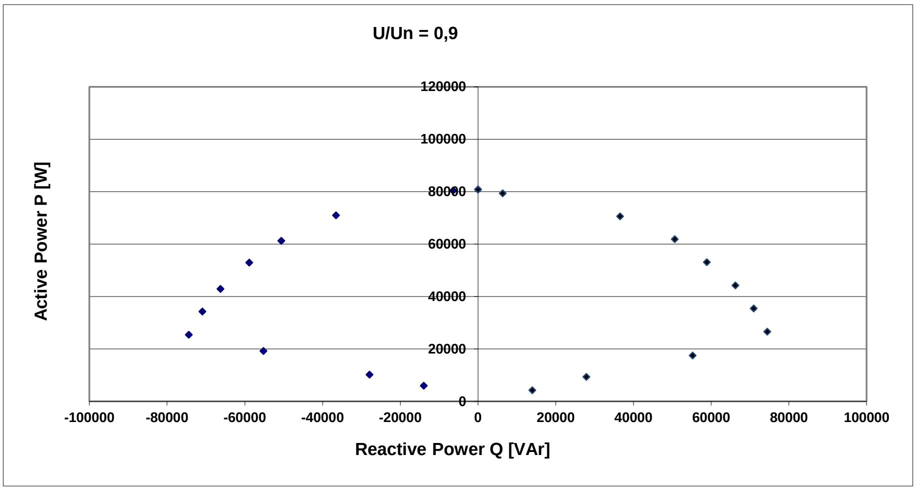
U/UN	0.85			
maxS	75072			
		ind.		cap.
P[%]	Pist[W]	MaxQ[VAr]	Pist[W]	Qist[VAr]
100	75072	0	75072	0
90	75072	0	75072	0
85	75072	0	75072	0
80	75072	0	75072	0
75	75000	-3287	75000	3287
70	70000	-27126	70000	27126
65	65000	-37561	65000	37561
60	60000	-45120	60000	45120
55	55000	-51096	55000	51096
50	50000	-55998	50000	55998
45	45000	-60090	45000	60090
40	40000	-63528	40000	63528
35	35000	-66414	35000	66414
30	30000	-68817	30000	68817
25	25000	-69938	25000	69938
20	20000	-55950	20000	55950
15	15000	-41963	15000	41963
10	10000	-27975	10000	27975
5	5000	-13988	5000	13988



3. Annex 3 – Extract from the test report

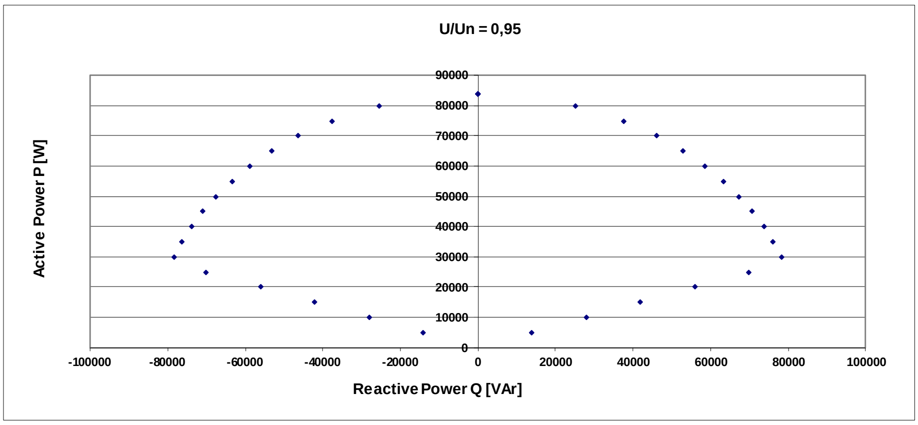
90% Un

U/UN	0.9			
maxS				
		ind.		cap.
P[%]	Pist[W]	Qist[VAr]	Pist[W]	Qist[VAr]
100	80831	0	80767	0
90	80396	-6369	79365	6369
80	71008	-36541	70617	36541
70	61236	-50618	61877	50618
60	52981	-58855	53086	58855
50	42945	-66245	44256	66245
40	34310	-70925	35433	70925
30	25426	-74422	26621	74422
20	19193	-55230	17484	55230
10	10186	-27896	9322	27896
5	6005	-13953	4286	13953



95% Un

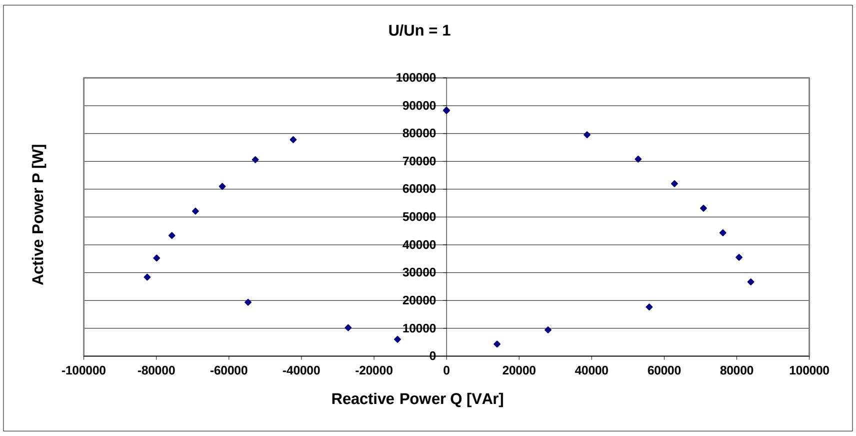
U/UN	0.95			
maxS	83904			
		ind.		cap.
P[%]	Pist[W]	Qist[VAr]	Pist[W]	Qist[VAr]
100	83904	0	83904	0
90	83904	0	83904	0
85	83904	0	83904	0
80	80000	-25296	80000	25296
75	75000	-37615	75000	37615
70	70000	-46259	70000	46259
65	65000	-53055	65000	53055
60	60000	-58651	60000	58651
55	55000	-63363	55000	63363
50	50000	-67379	50000	67379
45	45000	-70816	45000	70816
40	40000	-73756	40000	73756
35	35000	-76255	35000	76255
30	30000	-78357	30000	78357
25	25000	-69938	25000	69938
20	20000	-55950	20000	55950
15	15000	-41963	15000	41963
10	10000	-27975	10000	27975
5	5000	-13988	5000	13988



3. Annex 3 – Extract from the test report

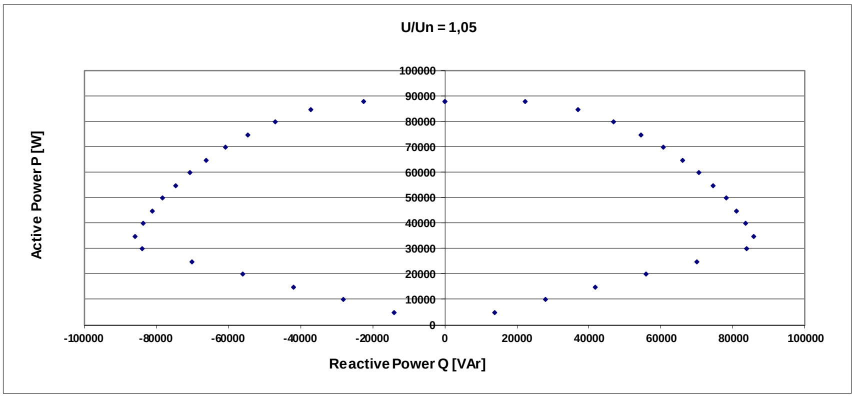
100% Un

U/UN	1			
maxS				
		ind.		cap.
P[%]	Pist[W]	Qist[VAr]	Pist[W]	Qist[VAr]
100	88320	0	88213	0
90	77777	-42233	79519	38753
80	70596	-52685	70756	52835
70	60944	-61819	61930	62829
60	52106	-69203	53101	70850
50	43315	-75691	44267	76188
40	35185	-79922	35461	80639
30	28368	-82504	26644	83906
20	19370	-54717	17639	55909
10	10205	-27107	9390	28008
5	6032	-13500	4299	13952



105% Un

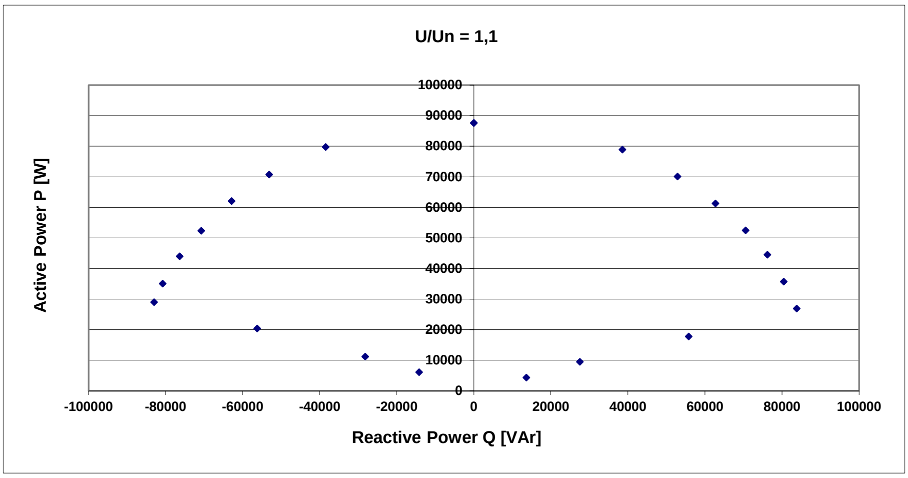
U/UN	1.05			
maxS	88320			
		ind.		cap.
P[%]	Pist[W]	Qist[VAr]	Pist[W]	Qist[VAr]
100	88320	0	88320	0
90	88320	-22360	88320	22360
85	85000	-37081	85000	37081
80	80000	-46904	80000	46904
75	75000	-54543	75000	54543
70	70000	-60827	70000	60827
65	65000	-66144	65000	66144
60	60000	-70710	60000	70710
55	55000	-74666	55000	74666
50	50000	-78102	50000	78102
45	45000	-81086	45000	81086
40	40000	-83666	40000	83666
35	35000	-85878	35000	85878
30	30000	-83926	30000	83926
25	25000	-69938	25000	69938
20	20000	-55950	20000	55950
15	15000	-41963	15000	41963
10	10000	-27975	10000	27975
5	5000	-13988	5000	13988



3. Annex 3 – Extract from the test report

110% Un

U/UN	1.1			
maxS				
		ind.		cap.
P[%]	Pist[W]	Qist[VAr]	Pist[W]	Qist[VAr]
100	87619	0	87598	0
90	79727	-38448	78916	38611
80	70776	-53106	70116	52907
70	62069	-62835	61316	62741
60	52371	-70746	52497	70593
50	44012	-76328	44553	76250
40	35058	-80720	35720	80486
30	28972	-82972	26905	83831
20	20381	-56213	17802	55821
10	11180	-28161	9475	27530
5	6073	-14195	4359	13673



115% Un

U/UN	1.15			
maxS	88320			
		ind.		cap.
P[%]	Pist[W]	Qist[VAr]	Pist[W]	Qist[VAr]
100	88320	0	88320	0
90	88320	-43589	88320	43589
85	85000	-52678	85000	52678
80	80000	-60000	80000	60000
75	75000	-66144	75000	66144
70	70000	-71414	70000	71414
65	65000	-75993	65000	75993
60	60000	-80000	60000	80000
55	55000	-83516	55000	83516
50	50000	-86603	50000	86603
45	45000	-89303	45000	89303
40	40000	-91652	40000	91652
35	35000	-93675	35000	93675
30	30000	-95394	30000	95394
25	25000	-69938	25000	69938
20	20000	-55950	20000	55950
15	15000	-41963	15000	41963
10	10000	-27975	10000	27975
5	5000	-13988	5000	13988

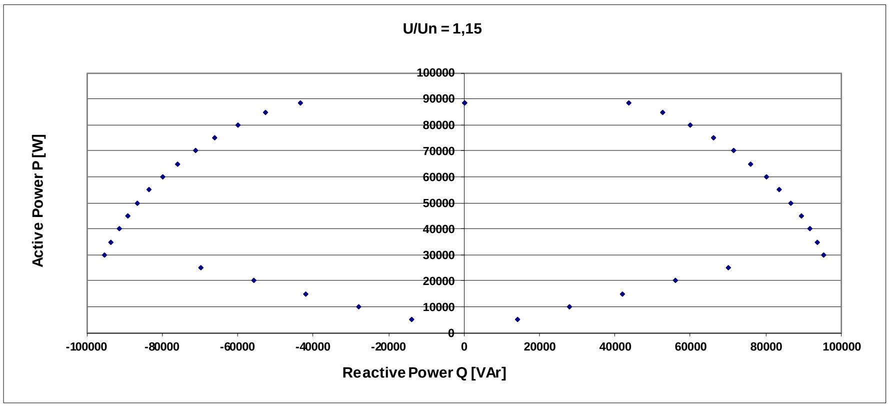


Figure 12 – Voltage dependent PQ operating points from [16]

3. Annex 3 – Extract from the test report

3.4. Protection system (on PGU level)

The following tests were carried out on the PGU integrated protection relay and the generating unit switch, the possible parameter setting of the PGU integrated protection relay is documented in [14], see *Annex 5 – Certification-relevant parameters*:

4.4 PGU DISCONNECTION FROM THE GRID / *PGU DISCONNECTION FROM THE GRID*

☒ The test of the whole trip circuit led to a successful shut down. /
Die Prüfung der Gesamtwirkungskette führte zu einer erfolgreichen Abschaltung.

REFUsol 100K 880P100

	Setting / *Einstellwert* [V] / [p.u. Un] / [Hz] Value / *Schwelle*	[ms] Time / *Zeit*	Release value / *Auslösewert* [p.u. Un] / [Hz] min.	max.	Disconnection time / *Abschaltzeit* [ms] min.	max.	Resetting ratio / *Rückfallverhältnis*	
Overvoltage protection / *Spannungssteigerungsschutz*: U>	400	180000	399,9	403,1	180000	180000	☒	≥ 0,98
	520	1	517,0	517,3	32,7	75,1	☐	< 0,98
Overvoltage protection / *Spannungssteigerungsschutz*: U≫	400	180000	399,9	403,1	180000	180000	----	
	520	1	517,1	517,4	29,9	95,1	----	
Undervoltage protection / *Spannungsrückgangsschutz*: U<	0,05	1	0,047	0,048	34,7	39,7	☒	≤ 1,02
	1	2400	0,995	0,997	2321	2328	☐	> 1,02
Undervoltage protection / *Spannungsrückgangsschutz*: U≪	0,05	1	0,048	0,048	33,9	76,1	----	
	1	800	0,994	0,994	723	758	----	
Overfrequency protection / *Frequenzsteigerungsschutz*: f>	50,00	5000	50,01		4966		----	
	55,00	1	54,95		72,8		----	
Overfrequency protection / *Frequenzsteigerungsschutz*: f≫	50,00	100	50,01		72,8		----	
	55,00	1	54,95		72,6		----	
Underfrequency protection / *Frequenzrückgangsschutz*: f<	45,00	1	45,00		80		----	
	50,00	100	49,95		171,8		----	
Underfrequency protection / *Frequenzrückgangsschutz*: f≪	47,50	1	47,60		84		----	
	50,00	100	50,05		176,8		----	
Operating time of circuit breaker / *Eigenzeit der Abschalteinheit* [ms] (Manufacturer's data / *Herstellerdaten*)	≤ 100	☒ by measurement / *aus Messung*		☐ by test certificate / *aus Prüfzertifikat*			☐ from manufacturer specification / *aus Herstellerangabe*	

Note / *Anmerkung*:
The following minimum / maximum threshold / trigger time were used for the testing /
Für die Prüfungen wurde die folgende minimale / maximale Schwelle / Auslösezeit verwendet:

3. Annex 3 – Extract from the test report

Extract from the test report - Part 3: Protection system

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	Trigger values / times			
	min. threshold	max. threshold	min. delay	max. delay
Overvoltage [U>]	1,00·U_n	1,30·U_n	1 ms	180 s
Overvoltage [U≫]	1,00·U_n	1,30·U_n	1 ms	100 ms
Undervoltage [U<]	0,10·U_n	1,00·U_n	1 ms	2,4 s
undervoltage [U≪]	0,10·U_n	1,00·U_n	1 ms	800 ms
Overfrequency [f>]	50,0 Hz	55,0 Hz	1 ms	5 s
Overfrequency [f≫]	50,0 Hz	55,0 Hz	1 ms	100 ms
Underfrequency [f<]	45,0 Hz	50,0 Hz	1 ms	100 ms
Underfrequency [f≪]	---	---	---	---

Note / *Anmerkung*:

The units monitor the phase-to-neutral voltages. / *Die Einheiten überwachen die Phase-Neutral-Spannungen.*

The results of the *REFUsol* 100K 880P100 can be applied to the and *REFUstor* 88K 420P088, REFUstor 100K 421P100 *REFUstor* 50K 420P050/REFUstor 50K 421P050 directly./
Die Ergbenisse des REFUsol 100K 880P100 *können auf den* REFUstor 88K 420P088,REFUstor 100K 421P100 *und* REFUstor 50K 420P050/REFUstor 50K 421P050 *direkt übertragen werden.*

3. Annex 3 – Extract from the test report

4.5 VERIFICATION OF CONNECTION CONDITIONS / *NACHWEIS DER ZUSCHALTBEDINGUNGEN*

4.5.1 Connection without previous protection trigger / *Zuschalten ohne vorherige Schutzauslösung*

REFUsol 100K 880P100			
	Range / Bereich [p.u. U_n] / [Hz]	Cut in occured within the given range / *Zuschaltung erfolgte im angegebenen Berich*	
Voltage / *Spannung*:	0,90 – 1,10	☒ Yes / *Ja*	☐ No / *Nein*
Frequency / *Frequenz*:	47,5 – 50,2	☒ Yes / *Ja*	☐ No / *Nein*

4.5.2 Connection after triggering of the decoupling protection / *Zuschalten nach Auslösung der Entkupplungsschutzes*

REFUsol 100K 880P100			
	Range / Bereich [p.u. U_n] / [Hz]	Cut in occured within the given range / *Zuschaltung erfolgte im angegebenen Berich*	
Undervoltage / Unter*spannung*:	< 0,95	☐ Yes / *Ja*	☒ No / *Nein*
Underfrequency / Unter*frequenz*:	≤ 49,9	☐ Yes / *Ja*	☒ No / *Nein*
Overfrequency / Über*frequenz*:	≥ 50,1	☐ Yes / *Ja*	☒ No / *Nein*

Note / *Anmerkung*:

The results of the *REFUsol* 100K 880P100 can be applied to the *REFUstor* 88K 420P088,REFUstor 100K 421P100and *REFUstor* 50K 420P050 / REFUstor 50K 421P050 directly./
Die Ergebnisse des REFUsol 100K 880P100 *können auf den REFUstor* 88K 420P088. REFUstor 100K 421P100 *und* REFUstor 50K 420P050 / REFUstor 50K 421P050 *direkt übertragen werden.*

Figure 13 – Results of grid protection from [11]

3. Annex 3 – Extract from the test report

Note (manufacturer's data):

The protection devices on the power generating units have been designed in such a way that the settings can be easily read without additional equipment or if additional equipment is required, the authenticity and identification of the data read out is ensured.

Gird-independent auxiliary energy is supplied to the protection equipment over DC-Supply.

Functionality of the protection functions within the operating ranges (Quasi Steady State ranges) shown can be provided.

An auxiliary energy loss of the protection equipment or the equipment control, respectively, causes the power generation to be switched off without delay.

The voltage transformers are installed at the power generating units on the network side of the of the power generating unit's circuit-breaker to monitor grid voltage.

Operability of the protection functions has been provided before the power generating units start feeding in power.

The coupling switch ensures three-pole galvanic separation.

The coupling switch is designed as specified by the manufacturer. The switching capacity of the coupling switch is stated according to the type label data (switch-off current is max. inverter current).

The sum of time elements of the protection and switching equipment does not exceed 100 ms.

Description of the interface for on-site testing

The PGU does not provide test terminals for on-site testing. For necessary on-site testing, an external monitoring relay with corresponding test terminals must be installed and the PGU's monitoring parameters must be set accordingly.

3. Annex 3 – Extract from the test report

3.5. Self-protection

The integrated self-protection in the power generating units, works independent of any control functions. The integrated protection functions are implemented in separate software modules and that they operate independent from control functions.

3. Annex 3 – Extract from the test report

3.6. Quasi-static operation

Manufacturer's data from [6]

The unit can be continuously operated within the voltage / frequency range of 85%U_n and 115%U_n / 47.5 Hz and 51,5 Hz. The entire power generating unit / component, respectively, including all its associated parts, (such as, i.a., control and protection equipment,) has been designed for the frequency and voltage ranges of quasi-steady-state operation (*Manufacturer's data*) [15].

3. Annex 3 – Extract from the test report

3.7. Fault ride through capability

Within the adjustable parameter ranges of the grid monitoring the PGU can ride through the symmetrical and asymmetrical faults according to the Fault Ride-Through (FRT) limit curve for a Type 2 power generating plant specified in [6].

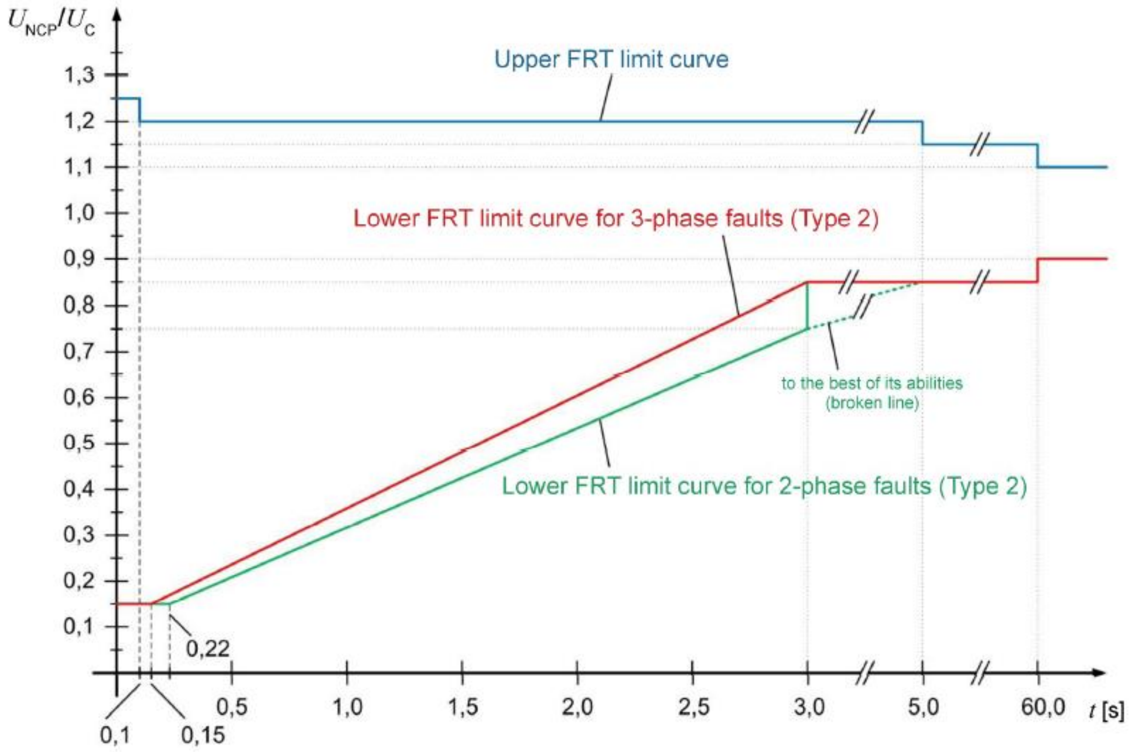


Figure 14 – Verified Fault Ride-Through (FRT) limit curve from [6]

3. Annex 3 – Extract from the test report

3.8. Short-circuit current contributions

In the following the test results are summarized:

REFUsol 100K 880P100

Ergebnis	0.1			0.2			0.3			0.4		
	A 1)	B 1)	C 1)	A 1)	B 1)	C 1)	A 1)	B 1)	C 1)	A 1)	B 1)	C 1)
16	-	-	-	-	-	-	-	-	-	-	-	-
17	-			-			-			-		
22	-			-			-			-		
23	-			-			-			-		
28 2)	-			-			-			-		
32	-			-			-			-		
51 - 53	-	-	-	-	-	-	-	-	-	-	-	-
54 - 56	-	-	-	-	-	-	-	-	-	-	-	-
57 - 59	-	-	-	-	-	-	-	-	-	-	-	-
60 - 62	-	-	-	-	-	-	-	-	-	-	-	-
63 - 65	-	-	-	-	-	-	-	-	-	-	-	-
66 - 68	-	-	-	-	-	-	-	-	-	-	-	-
69 - 71	-	-	-	-	-	-	-	-	-	-	-	-
74	-			-			-			-		

Ergebnis	25.1			25.2			25.3			25.4		
	A 1)	B 1)	C 1)	A 1)	B 1)	C 1)	A 1)	B 1)	C 1)	A 1)	B 1)	C 1)
16	0.251	0.251	0.251	0.251	0.251	0.251	Die EZE ist in der Lage, mehrfach aufeinanderfolgende Spannungseinbrüche durchzufahren. / *The PGU is able to ride through several consecutive voltage dips.*			0.543	0.997	0.544
17	0.251			0.251						0.624		
22	0.999			0.998						0.999		
23	0.002			0.002						0.002		
28 2)	-0.006			-0.002						-0.006		
32	-0.982			-0.199						-0.981		
51 - 53	74.1	63.6	39.4	77.7	64.3	43.2				98.2	53.9	55.2
54 - 56	0.175	0.126	0.102	0.183	0.154	0.143				0.242	0.034	0.209
57 - 59	0.939	0.942	0.940	0.938	0.937	0.940				0.923	0.460	0.463
60 - 62	0.938	0.939	0.940	0.941	0.943	0.946				0.922	0.460	0.463
63 - 65	0.940	0.939	0.941	0.939	0.941	0.941				0.923	0.460	0.463
66 - 68	0.938	0.939	0.939	0.938	0.940	0.940				0.923	0.460	0.463
69 - 71	0.936	0.939	0.940	0.937	0.937	0.939				0.922	0.460	0.463
74	0.230			0.175						0.218		

Ergebnis	25.5			50.1			50.2			50.5		
	A 1)	B 1)	C 1)	A 1)	B 1)	C 1)	A 1)	B 1)	C 1)	A 1)	B 1)	C 1)
16	0.544	0.997	0.544	0.502	0.500	0.501	0.502	0.500	0.500	0.498	0.498	0.497
17	0.624			0.501			0.501			0.497		
22	0.998			1.000			0.998			1.000		
23	0.002			0.002			0.002			0.000		
28 2)	-0.002			-0.006			-0.002			0.021		
32	-0.198			-0.984			-0.199			-0.995		
51 - 53	98.8	53.4	60.9	122.8	133.3	100.7	92.0	60.9	90.5	180.7	180.1	180.7
54 - 56	0.272	0.016	0.277	0.425	0.455	0.392	0.351	0.246	0.289	0.971	0.917	0.895
57 - 59	0.923	0.461	0.463	0.930	0.932	0.932	0.939	0.943	0.942	0.013	0.014	0.014
60 - 62	0.923	0.461	0.463	0.930	0.933	0.933	0.943	0.938	0.942	0.013	0.013	0.013
63 - 65	0.923	0.460	0.463	0.930	0.933	0.933	0.939	0.942	0.945	0.014	0.014	0.013
66 - 68	0.924	0.461	0.463	0.930	0.934	0.934	0.938	0.944	0.943	0.014	0.014	0.013
69 - 71	0.923	0.460	0.463	0.931	0.932	0.934	0.937	0.941	0.943	0.014	0.014	0.013
74	0.009			0.232			0.000			0.053		

Ergebnis	50.3			50.4			50.6			75.1		
	A 1)	B 1)	C 1)	A 1)	B 1)	C 1)	A 1)	B 1)	C 1)	A 1)	B 1)	C 1)
16	0.661	0.999	0.661	0.660	0.997	0.660	0.897	0.496	0.896	0.751	0.749	0.749
17	0.749			0.748			0.745			0.750		
22	1.000			0.998			1.000			0.999		
23	0.002			0.002			0.001			0.002		
28 2)	-0.006			-0.002			0.043			-0.006		
32	-1.003			-0.198			-0.993			-0.983		
51 - 53	138.1	42.7	109.8	124.9	44.3	81.7	214.0	244.5	172.0	171.8	168.2	167.4
54 - 56	0.413	0.189	0.406	0.329	0.115	0.336	0.661	0.849	0.715	0.893	0.864	0.906
57 - 59	0.948	0.467	0.482	0.943	0.463	0.480	0.026	0.018	0.016	0.936	0.937	0.937
60 - 62	0.949	0.466	0.482	0.943	0.463	0.479	0.026	0.018	0.017	0.937	0.938	0.937
63 - 65	0.948	0.465	0.483	0.942	0.462	0.480	0.026	0.018	0.017	0.936	0.937	0.937
66 - 68	0.949	0.466	0.483	0.943	0.461	0.482	0.026	0.018	0.017	0.936	0.936	0.936
69 - 71	0.950	0.462	0.488	0.942	0.461	0.481	0.026	0.018	0.017	0.933	0.935	0.934
74	0.224			0.002			0.045			0.181		

3. Annex 3 – Extract from the test report

Ergebnis	75.2			75.3			75.4			115.2		
	A 1)	B 1)	C 1)	A 1)	B 1)	C 1)	A 1)	B 1)	C 1)	A 1)	B 1)	C 1)
16	0.751	0.749	0.749	0.750	0.748	0.748	0.758	0.755	0.755	1.180	1.177	1.177
17	0.750			0.749			0.756			1.178		
22	0.998			0.997			1.007			0.999		
23	0.002			0.002			0.003			0.002		
28 2)	-0.002			0.540			-0.551			-0.002		
32	-0.199			-0.193			-0.203			-0.199		
51 - 53	87.8	75.1	88.9	118.7	85.1	117.9	170.6	172.4	157.5	66.9	66.4	65.7
54 - 56	0.351	0.272	0.357	0.396	0.339	0.414	0.781	0.831	0.770	0.230	0.206	0.249
57 - 59	0.523	0.524	0.524	0.228	0.228	0.225	0.975	0.973	0.980	0.365	0.369	0.371
60 - 62	0.525	0.526	0.526	0.227	0.227	0.227	0.974	0.972	0.980	0.368	0.369	0.370
63 - 65	0.525	0.526	0.526	0.227	0.226	0.227	0.974	0.972	0.980	0.369	0.369	0.369
66 - 68	0.522	0.525	0.524	0.227	0.227	0.227	0.976	0.974	0.980	0.368	0.369	0.369
69 - 71	0.517	0.519	0.519	0.229	0.229	0.226	0.975	0.973	0.980	0.363	0.366	0.367
74	0.000			0.000			0.009			0.168		

Ergebnis	75.5			75.6			75.7			80.1		
	A 1)	B 1)	C 1)	A 1)	B 1)	C 1)	A 1)	B 1)	C 1)	A 1)	B 1)	C 1)
16	0.751	0.750	0.751	0.820	0.999	0.818	0.820	0.998	0.817	0.804	0.804	0.804
17	0.751			0.874			0.874			0.804		
22	0.998			0.999			0.998			1.000		
23	0.001			0.002			0.002			0.000		
28 2)	-0.002			-0.006			-0.002			0.019		
32	-0.199			-0.981			-0.198			-0.994		
51 - 53	68.1	45.8	62.0	183.3	155.1	171.7	86.8	38.9	73.1	176.7	184.2	183.0
54 - 56	0.288	0.231	0.247	0.854	0.680	0.931	0.307	0.100	0.321	0.976	0.978	0.928
57 - 59	0.950	0.949	0.951	0.799	0.449	0.858	0.511	0.114	0.420	0.956	0.953	0.962
60 - 62	0.949	0.948	0.950	0.800	0.446	0.857	0.511	0.114	0.420	0.958	0.952	0.962
63 - 65	0.949	0.948	0.950	0.800	0.448	0.857	0.512	0.114	0.421	0.958	0.955	0.961
66 - 68	0.945	0.944	0.944	0.799	0.446	0.857	0.511	0.116	0.420	0.959	0.955	0.961
69 - 71	0.944	0.945	0.946	0.799	0.454	0.859	0.506	0.113	0.418	0.958	0.952	0.961
74	0.000			0.175			0.000			0.013		

Ergebnis	80.2			75.8			110.1			110.2		
	A 1)	B 1)	C 1)	A 1)	B 1)	C 1)	A 1)	B 1)	C 1)	A 1)	B 1)	C 1)
16	0.864	1.007	0.861	0.820	0.998	0.819	1.160	0.988	1.158	1.157	0.986	1.155
17	0.908			0.874			1.099			1.097		
22	1.009			0.998			0.999			0.995		
23	0.003			0.002			0.001			0.000		
28 2)	-0.006			0.004			0.022			0.005		
32	-0.983			-0.209			-1.001			-0.230		
51 - 53	179.2	174.2	172.7	160.1	64.4	127.6	168.9	167.3	170.1	41.8	42.4	40.4
54 - 56	0.969	0.963	0.963	0.829	0.287	0.542	0.872	0.927	0.886	0.172	0.217	0.187
57 - 59	0.837	0.586	0.925	0.931	0.372	0.559	0.796	0.863	0.495	0.451	0.382	0.092
60 - 62	0.839	0.588	0.925	0.932	0.372	0.560	0.795	0.865	0.499	0.453	0.383	0.094
63 - 65	0.839	0.589	0.925	0.928	0.369	0.560	0.799	0.861	0.500	0.450	0.382	0.092
66 - 68	0.839	0.590	0.925	0.929	0.370	0.560	0.801	0.862	0.500	0.450	0.382	0.091
69 - 71	0.836	0.587	0.925	0.916	0.360	0.556	0.795	0.863	0.495	0.451	0.382	0.092
74	0.015			0.164			0.165			0.006		

Ergebnis	85.1			110.3			115.1			-		
	A 1)	B 1)	C 1)	A 1)	B 1)	C 1)	A 1)	B 1)	C 1)	A 1)	B 1)	C 1)
16	0.880	0.878	0.879	1.121	1.118	1.117	1.181	1.178	1.177	-	-	-
17	0.879			1.119			1.178			-		
22	0.998			0.999			1.000			-		
23	0.001			0.002			0.002			-		
28 2)	-0.002			-0.002			-0.006			-		
32	-0.199			-0.199			-0.983			-		
51 - 53	54.0	51.0	46.1	48.3	52.1	52.5	99.0	97.3	91.6	-	-	-
54 - 56	0.229	0.234	0.213	0.187	0.199	0.194	0.434	0.385	0.389	-	-	-
57 - 59	0.291	0.288	0.290	0.271	0.273	0.275	0.546	0.546	0.545	-	-	-
60 - 62	0.287	0.288	0.287	0.272	0.273	0.273	0.545	0.545	0.546	-	-	-
63 - 65	0.291	0.289	0.290	0.272	0.273	0.273	0.545	0.546	0.547	-	-	-
66 - 68	0.289	0.290	0.290	0.272	0.272	0.272	0.544	0.545	0.548	-	-	-
69 - 71	0.286	0.286	0.286	0.269	0.272	0.274	0.544	0.544	0.542	-	-	-
74	0.000			0.163			0.245			-		

3. Annex 3 – Extract from the test report

Note:

Die Ergebnisse in der Tabelle sind anhand der Tabelle 4-70 in FGW TR3 (Rev.25) wie folgt durchnummeriert /
The results in the table are numbered according to Table 4-70 in FGW TR3 (Rev.25) as follows :

1) A / B / C kennzeichnen die Phase-Phase-Spannungen (L12, L23, L31) oder die Phasenströme (L1, L2, L3). /
A / B / C indicate the phase-phase voltages (L12, L23, L31) or the phase currents (L1, L2, L3).

2) Untererregter / induktiver Blindstrom hat ein negatives Vorzeichen, übererregter / kapazitiver Blindstrom hat ein positives Vorzeichen, das Vorzeichen der Blindleistung ist gleich wie Blindstrom. /
Under-excited / inductive reactive current has a negative sign, over-excited / capacitive reactive current has a positive sign, the sign of the reactive power is the same as the reactive current.

3) Test für Mehrfachfehler zu nachweisen, dass die EZE in der Lage ist, mehrfach aufeinanderfolgende Spannungseinbrüche durchfahren zu können. /
Test for mutiple faults to proven the PGU is able to ride through several consecutive voltage dips.

Nr.:	**Parameter**	**Phasenbezug, Bezugszeit, Wert [Einheit] /** ***Phase reference, Reference time, Value [unit]***
16	Istwert Spannungseinbruchtiefe / Spannungserhöhung / *Measeured value of voltage drop / increase* (L12, L23, L31)	Phase-Phase, t1 + 100ms … t2 zu t1 - 60s ... t1) [p.u. U_n]
17	Istwert Spannungseinbruchtiefe / Spannungserhöhung / *Measeured value of voltage drop / increase*	Mitsystem / *Pos. seq* ., Phase-neutral, t1 + 100ms … t2 zu t1 - 60s ... t1) [p.u. U_n]
22	Spannung / *Voltage*	Mitsystem / *Pos. seq* ., Phase-neutral, t1 - 60s bis t1) [p.u. U_n]
23	Spannung / *Voltage*	Gegensystem / *Neg. seq* , Phase-neutral, t1 - 60s bis t1) [p.u. U_n]
28 2)	Blindstrom / *Reactive current*	Mitsystem / *Neg. seq.* , t1 - 60s bis t1) [p.u. I_n]
32	Wirkleistung / *Active Power*	Gesamt / *Total* , t1 – 10s … t1 [p.u. P_n]
51 - 53	Kurzschlussströme Scheitelwerte / *Short-circuit currents, peak value* (L1,L2,L3)	t1 … t1 + 20ms [A]
54 - 56	Kurzschlussströme 1-Perioden-Effektivwert / *Short-circuit currents, 1-period RMS value* (L1,L2,L3)	t1 ... t1 + 20ms [p.u. I_n]
57 - 59	Kurzschlussströme 1-Perioden-Effektivwert / *Short-circuit currents, 1-period RMS value* (L1,L2,L3)	t1 + 80ms ... t1 + 100ms [p.u. I_n]
60 - 62	Kurzschlussströme 1-Perioden-Effektivwert / *Short-circuit currents, 1-period RMS value* (L1,L2,L3)	t1 + 130ms ... t1 + 150ms [p.u. I_n]
63 - 65	Kurzschlussströme 1-Perioden-Effektivwert / *Short-circuit currents, 1-period RMS value* (L1,L2,L3)	t1 + 280ms ... t1 + 300ms [p.u. I_n]
66 - 68	Kurzschlussströme 1-Perioden-Effektivwert / *Short-circuit currents, 1-period RMS value* (L1,L2,L3)	t1 + 480ms ... t1 + 500ms [p.u. I_n]
69 - 71	Kurzschlussströme 1-Perioden-Effektivwert / *Short-circuit currents, 1-period RMS value* (L1,L2,L3)	t1 + 980ms ... t1 + 1000ms [p.u. I_n]
74	Anschwingzeit Wirkstrom / *Response time of active current*	Mitsystem / *Pos. seq.* [s]

3. Annex 3 – Extract from the test report

REFUstor 88K 420P088 @ 200V

0.1			0.2			0.3			0.4		
A 1)	B 1)	C 1)	A 1)	B 1)	C 1)	A 1)	B 1)	C 1)	A 1)	B 1)	C 1)
-	-	-	-	-	-	-	-	-	-	-	-
-			-			-			-		
-			-			-			-		
-			-			-			-		
-			-			-			-		
-			-			-			-		
-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-
-			-			-			-		

25.1			25.2			25.3			25.4		
A 1)	B 1)	C 1)	A 1)	B 1)	C 1)	A 1)	B 1)	C 1)	A 1)	B 1)	C 1)
0.252	0.252	0.253	-	-	-	Die EZE ist in der Lage, mehrfach aufeinanderfolgende Spannungseinbrüche durchzufahren. / *The PGU is able to ride through several consecutive voltage dips.*			-	-	-
0.252			-						-		
1.000			-						-		
0.001			-						-		
0.009			-						-		
-1.015			-						-		
61.5	74.3	65.0	-	-	-				-	-	-
0.135	0.139	0.171	-	-	-				-	-	-
0.960	0.956	0.957	-	-	-				-	-	-
0.956	0.957	0.960	-	-	-				-	-	-
0.956	0.959	0.960	-	-	-				-	-	-
0.958	0.960	0.961	-	-	-				-	-	-
0.957	0.959	0.956	-	-	-				-	-	-
0.223			-						-		

25.5			50.1			50.2			50.5		
A 1)	B 1)	C 1)	A 1)	B 1)	C 1)	A 1)	B 1)	C 1)	A 1)	B 1)	C 1)
-	-	-	-	-	-	-	-	-	-	-	-
-			-			-			-		
-			-			-			-		
-			-			-			-		
-			-			-			-		
-			-			-			-		
-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-
-			-			-			-		

50.3			50.4			50.6			75.1		
A 1)	B 1)	C 1)	A 1)	B 1)	C 1)	A 1)	B 1)	C 1)	A 1)	B 1)	C 1)
-	-	-	-	-	-	-	-	-	-	-	-
-			-			-			-		
-			-			-			-		
-			-			-			-		
-			-			-			-		
-			-			-			-		
-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-
-			-			-			-		

3. Annex 3 – Extract from the test report

Ergebnis	75.2			75.3			75.4			75.5		
	A 1)	B 1)	C 1)	A 1)	B 1)	C 1)	A 1)	B 1)	C 1)	A 1)	B 1)	C 1)
16	-	-	-	0.000	0.000	0.000	-	-	-	-	-	-
17	-			0.000			-			-		
22	-			0.000			-			-		
23	-			0.000			-			-		
28 2)	-			0.000			-			-		
32	-			0.000			-			-		
51 - 53	-	-	-	0.0	0.0	0.0	-	-	-	-	-	-
54 - 56	-	-	-	0.000	0.000	0.000	-	-	-	-	-	-
57 - 59	-	-	-	0.000	0.000	0.000	-	-	-	-	-	-
60 - 62	-	-	-	0.000	0.000	0.000	-	-	-	-	-	-
63 - 65	-	-	-	0.000	0.000	0.000	-	-	-	-	-	-
66 - 68	-	-	-	0.000	0.000	0.000	-	-	-	-	-	-
69 - 71	-	-	-	0.000	0.000	0.000	-	-	-	-	-	-
74	-			0.000			-			-		

Ergebnis	75.6			75.7			75.8			80.1		
	A 1)	B 1)	C 1)	A 1)	B 1)	C 1)	A 1)	B 1)	C 1)	A 1)	B 1)	C 1)
16	-	-	-	-	-	-	0.820	0.998	0.822	-	-	-
17	-			-			0.875			-		
22	-			-			0.999			-		
23	-			-			0.001			-		
28 2)	-			-			-0.002			-		
32	-			-			-0.391			-		
51 - 53	-	-	-	-	-	-	132.1	72.5	102.8	-	-	-
54 - 56	-	-	-	-	-	-	0.490	0.146	0.517	-	-	-
57 - 59	-	-	-	-	-	-	0.909	0.261	0.653	-	-	-
60 - 62	-	-	-	-	-	-	0.906	0.256	0.656	-	-	-
63 - 65	-	-	-	-	-	-	0.906	0.251	0.662	-	-	-
66 - 68	-	-	-	-	-	-	0.903	0.242	0.670	-	-	-
69 - 71	-	-	-	-	-	-	0.903	0.242	0.671	-	-	-
74	-			-			0.007			-		

Ergebnis	80.2			85.1			110.1			110.2		
	A 1)	B 1)	C 1)	A 1)	B 1)	C 1)	A 1)	B 1)	C 1)	A 1)	B 1)	C 1)
16	-	-	-	-	-	-	-	-	-	-	-	-
17	-			-			-			-		
22	-			-			-			-		
23	-			-			-			-		
28 2)	-			-			-			-		
32	-			-			-			-		
51 - 53	-	-	-	-	-	-	-	-	-	-	-	-
54 - 56	-	-	-	-	-	-	-	-	-	-	-	-
57 - 59	-	-	-	-	-	-	-	-	-	-	-	-
60 - 62	-	-	-	-	-	-	-	-	-	-	-	-
63 - 65	-	-	-	-	-	-	-	-	-	-	-	-
66 - 68	-	-	-	-	-	-	-	-	-	-	-	-
69 - 71	-	-	-	-	-	-	-	-	-	-	-	-
74	-			-			-			-		

3. Annex 3 – Extract from the test report

Note:
Die Ergebnisse in der Tabelle sind anhand der Tabelle 4-70 in FGW TR3 (Rev.25) wie folgt durchnummeriert /
The results in the table are numbered according to Table 4-70 in FGW TR3 (Rev.25) as follows :

[1)] A / B / C kennzeichnen die Phase-Phase-Spannungen (L12, L23, L31) oder die Phasenströme (L1, L2, L3). /
A / B / C indicate the phase-phase voltages (L12, L23, L31) or the phase currents (L1, L2, L3).

[2)] Untererregter / induktiver Blindstrom hat ein negatives Vorzeichen, übererregter / kapazitiver Blindstrom hat ein positives Vorzeichen, das Vorzeichen der Blindleistung ist gleich wie Blindstrom. /
Under-excited / inductive reactive current has a negative sign, over-excited / capacitive reactive current has a positive sign, the sign of the reactive power is the same as the reactive current.

[3)] Test für Mehrfachfehler zu nachweisen, dass die EZE in der Lage ist, mehrfach aufeinanderfolgende Spannungseinbrüche durchfahren zu können. /
Test for mutiple faults to proven the PGU is able to ride through several consecutive voltage dips.

Nr.:	**Parameter**	**Phasenbezug, Bezugszeit, Wert [Einheit] /** ***Phase reference, Reference time, Value [unit]***
16	Istwert Spannungseinbruchtiefe / Spannungserhöhung / *Measeured value of voltage drop / increase* (L12, L23, L31)	Phase-Phase, t1 + 100ms … t2 zu t1 - 60s ... t1) [p.u. U_n]
17	Istwert Spannungseinbruchtiefe / Spannungserhöhung / *Measeured value of voltage drop / increase*	Mitsystem / *Pos. seq*., Phase-neutral, t1 + 100ms … t2 zu t1 - 60s ... t1) [p.u. U_n]
22	Spannung / *Voltage*	Mitsystem / *Pos. seq*., Phase-neutral, t1 - 60s bis t1) [p.u. U_n]
23	Spannung / *Voltage*	Gegensystem / *Neg. seq*, Phase-neutral, t1 - 60s bis t1) [p.u. U_n]
28 [2)]	Blindstrom / *Reactive current*	Mitsystem / *Neg. seq.*, t1 - 60s bis t1) [p.u. I_n]
32	Wirkleistung / *Active Power*	Gesamt / *Total*, t1 – 10s … t1 [p.u. P_n]
51 - 53	Kurzschlussströme Scheitelwerte / *Short-circuit currents, peak value* (L1,L2,L3)	t1 … t1 + 20ms [A]
54 - 56	Kurzschlussströme 1-Perioden-Effektivwert / *Short-circuit currents, 1-period RMS value* (L1,L2,L3)	t1 ... t1 + 20ms [p.u. I_n]
57 - 59	Kurzschlussströme 1-Perioden-Effektivwert / *Short-circuit currents, 1-period RMS value* (L1,L2,L3)	t1 + 80ms ... t1 + 100ms [p.u. I_n]
60 - 62	Kurzschlussströme 1-Perioden-Effektivwert / *Short-circuit currents, 1-period RMS value* (L1,L2,L3)	t1 + 130ms ... t1 + 150ms [p.u. I_n]
63 - 65	Kurzschlussströme 1-Perioden-Effektivwert / *Short-circuit currents, 1-period RMS value* (L1,L2,L3)	t1 + 280ms ... t1 + 300ms [p.u. I_n]
66 - 68	Kurzschlussströme 1-Perioden-Effektivwert / *Short-circuit currents, 1-period RMS value* (L1,L2,L3)	t1 + 480ms ... t1 + 500ms [p.u. I_n]
69 - 71	Kurzschlussströme 1-Perioden-Effektivwert / *Short-circuit currents, 1-period RMS value* (L1,L2,L3)	t1 + 980ms ... t1 + 1000ms [p.u. I_n]
74	Anschwingzeit Wirkstrom / *Response time of active current*	Mitsystem / *Pos. seq.* [s]

3. Annex 3 – Extract from the test report

REFUstor 100K 421P100

Ergebnis	**25.1**			**25.2**			**25.3**			**25.4**		
	A [1]	**B** [1]	**C** [1]	**A** [1]	**B** [1]	**C** [1]	**A** [1]	**B** [1]	**C** [1]	**A** [1]	**B** [1]	**C** [1]
16	-	-	-	0,252	0,251	0,251	Die EZE ist in der Lage, mehrfach aufeinanderfolgende Spannungseinbrüche durchzufahren. / *The PGU is able to ride through several consecutive voltage dips.*			-	-	-
17	-			0,251						-		
22	-			0,999						-		
23	-			0,002						-		
28 [2]	-			-0,020						-		
32	-			0,199						-		
51 - 53	-	-	-	61,1	59,1	47,0				-	-	-
54 - 56	-	-	-	0,275	0,263	0,240				-	-	-
57 - 59	-	-	-	0,937	0,941	0,941				-	-	-
60 - 62	-	-	-	0,937	0,939	0,935				-	-	-
63 - 65	-	-	-	0,935	0,939	0,940				-	-	-
66 - 68	-	-	-	0,936	0,939	0,939				-	-	-
69 - 71	-	-	-	0,938	0,940	0,941				-	-	-
74	-			0,013						-		

Ergebnis	**25.5**			**50.1**			**50.2**			**50.5**		
	A [1]	**B** [1]	**C** [1]	**A** [1]	**B** [1]	**C** [1]	**A** [1]	**B** [1]	**C** [1]	**A** [1]	**B** [1]	**C** [1]
16	-	-	-	-	-	-	-	-	-	-	-	-
17	-			-			-			-		
22	-			-			-			-		
23	-			-			-			-		
28 [2]	-			-			-			-		
32	-			-			-			-		
51 - 53	-	-	-	-	-	-	-	-	-	-	-	-
54 - 56	-	-	-	-	-	-	-	-	-	-	-	-
57 - 59	-	-	-	-	-	-	-	-	-	-	-	-
60 - 62	-	-	-	-	-	-	-	-	-	-	-	-
63 - 65	-	-	-	-	-	-	-	-	-	-	-	-
66 - 68	-	-	-	-	-	-	-	-	-	-	-	-
69 - 71	-	-	-	-	-	-	-	-	-	-	-	-
74	-			-			-			-		

Ergebnis	**50.3**			**50.4**			**50.6**			**75.1**		
	A [1]	**B** [1]	**C** [1]	**A** [1]	**B** [1]	**C** [1]	**A** [1]	**B** [1]	**C** [1]	**A** [1]	**B** [1]	**C** [1]
16	-	-	-	0,661	0,998	0,661	-	-	-	-	-	-
17	-			0,749			-			-		
22	-			0,998			-			-		
23	-			0,002			-			-		
28 [2]	-			0,007			-			-		
32	-			0,199			-			-		
51 - 53	-	-	-	84,5	69,2	40,3	-	-	-	-	-	-
54 - 56	-	-	-	0,283	0,295	0,135	-	-	-	-	-	-
57 - 59	-	-	-	0,936	0,471	0,465	-	-	-	-	-	-
60 - 62	-	-	-	0,935	0,471	0,465	-	-	-	-	-	-
63 - 65	-	-	-	0,935	0,472	0,464	-	-	-	-	-	-
66 - 68	-	-	-	0,935	0,472	0,463	-	-	-	-	-	-
69 - 71	-	-	-	0,932	0,473	0,459	-	-	-	-	-	-
74	-			0,000			-			-		

3. Annex 3 – Extract from the test report

Ergebnis	75.2			75.3			75.4			75.5		
	A 1)	B 1)	C 1)	A 1)	B 1)	C 1)	A 1)	B 1)	C 1)	A 1)	B 1)	C 1)
16	0.751	0.749	0.749	-	-	-	-	-	-	-	-	-
17	0.750			-			-			-		
22	0.998			-			-			-		
23	0.002			-			-			-		
28 2)	-0.020			-			-			-		
32	0.199			-			-			-		
51 - 53	49.2	60.4	48.0	-	-	-	-	-	-	-	-	-
54 - 56	0.221	0.258	0.236	-	-	-	-	-	-	-	-	-
57 - 59	0.549	0.551	0.553	-	-	-	-	-	-	-	-	-
60 - 62	0.552	0.552	0.553	-	-	-	-	-	-	-	-	-
63 - 65	0.554	0.555	0.556	-	-	-	-	-	-	-	-	-
66 - 68	0.557	0.557	0.557	-	-	-	-	-	-	-	-	-
69 - 71	0.552	0.553	0.554	-	-	-	-	-	-	-	-	-
74	0.003			-			-			-		

Ergebnis	75.6			0			75.8			80.1		
	A 1)	B 1)	C 1)	A 1)	B 1)	C 1)	A 1)	B 1)	C 1)	A 1)	B 1)	C 1)
16	-	-	-	0.000	0.000	0.000	-	-	-	-	-	-
17	-			0.000			-			-		
22	-			0.000			-			-		
23	-			0.000			-			-		
28 2)	-			0.000			-			-		
32	-			0.000			-			-		
51 - 53	-	-	-	0.0	0.0	0.0	-	-	-	-	-	-
54 - 56	-	-	-	0.000	0.000	0.000	-	-	-	-	-	-
57 - 59	-	-	-	0.000	0.000	0.000	-	-	-	-	-	-
60 - 62	-	-	-	0.000	0.000	0.000	-	-	-	-	-	-
63 - 65	-	-	-	0.000	0.000	0.000	-	-	-	-	-	-
66 - 68	-	-	-	0.000	0.000	0.000	-	-	-	-	-	-
69 - 71	-	-	-	0.000	0.000	0.000	-	-	-	-	-	-
74	-			0.000			-			-		

Ergebnis	80.2			85.1			110.1			110.2		
	A 1)	B 1)	C 1)	A 1)	B 1)	C 1)	A 1)	B 1)	C 1)	A 1)	B 1)	C 1)
16	-	-	-	-	-	-	-	-	-	-	-	-
17	-			-			-			-		
22	-			-			-			-		
23	-			-			-			-		
28 2)	-			-			-			-		
32	-			-			-			-		
51 - 53	-	-	-	-	-	-	-	-	-	-	-	-
54 - 56	-	-	-	-	-	-	-	-	-	-	-	-
57 - 59	-	-	-	-	-	-	-	-	-	-	-	-
60 - 62	-	-	-	-	-	-	-	-	-	-	-	-
63 - 65	-	-	-	-	-	-	-	-	-	-	-	-
66 - 68	-	-	-	-	-	-	-	-	-	-	-	-
69 - 71	-	-	-	-	-	-	-	-	-	-	-	-
74	-			-			-			-		

Ergebnis	110.3			115.1			115.2			-		
	A 1)	B 1)	C 1)	A 1)	B 1)	C 1)	A 1)	B 1)	C 1)	A 1)	B 1)	C 1)
16	-	-	-	-	-	-	1.180	1.177	1.176	-	-	-
17	-			-			1.178			-		
22	-			-			0.999			-		
23	-			-			0.002			-		
28 2)	-			-			-0.020			-		
32	-			-			0.199			-		
51 - 53	-	-	-	-	-	-	42.3	61.7	54.7	-	-	-
54 - 56	-	-	-	-	-	-	0.157	0.196	0.212	-	-	-
57 - 59	-	-	-	-	-	-	0.353	0.353	0.353	-	-	-
60 - 62	-	-	-	-	-	-	0.355	0.354	0.354	-	-	-
63 - 65	-	-	-	-	-	-	0.357	0.358	0.358	-	-	-
66 - 68	-	-	-	-	-	-	0.355	0.359	0.357	-	-	-
69 - 71	-	-	-	-	-	-	0.353	0.354	0.353	-	-	-
74	-			-			0.015			-		

3. Annex 3 – Extract from the test report

Nr.:	Parameter	Phasenbezug, Bezugszeit, Wert [Einheit] / *Phase reference, Reference time, Value [unit]*
16	Istwert Spannungseinbruchtiefe / Spannungserhöhung / *Measeured value of voltage drop / increase* (L12, L23, L31)	Phase-Phase, t1 + 100ms … t2 zu t1 - 60s ... t1) [p.u. U_n]
17	Istwert Spannungseinbruchtiefe / Spannungserhöhung / *Measeured value of voltage drop / increase*	Mitsystem / *Pos. seq* ., Phase-neutral, t1 + 100ms … t2 zu t1 - 60s ... t1) [p.u. U_n]
22	Spannung / *Voltage*	Mitsystem / *Pos. seq* ., Phase-neutral, t1 - 60s bis t1) [p.u. U_n]
23	Spannung / *Voltage*	Gegensystem / *Neg. seq* , Phase-neutral, t1 - 60s bis t1) [p.u. U_n]
28 [2)]	Blindstrom / *Reactive current*	Mitsystem / *Neg. seq.* , t1 - 60s bis t1) [p.u. I_n]
32	Wirkleistung / *Active Power*	Gesamt / *Total* , t1 – 10s … t1 [p.u. P_n]
51 - 53	Kurzschlussströme Scheitelwerte / *Short-circuit currents, peak value* (L1,L2,L3)	t1 … t1 + 20ms [A]
54 - 56	Kurzschlussströme 1-Perioden-Effektivwert / *Short-circuit currents, 1-period RMS value* (L1,L2,L3)	t1 ... t1 + 20ms [p.u. I_n]
57 - 59	Kurzschlussströme 1-Perioden-Effektivwert / *Short-circuit currents, 1-period RMS value* (L1,L2,L3)	t1 + 80ms ... t1 + 100ms [p.u. I_n]
60 - 62	Kurzschlussströme 1-Perioden-Effektivwert / *Short-circuit currents, 1-period RMS value* (L1,L2,L3)	t1 + 130ms ... t1 + 150ms [p.u. I_n]
63 - 65	Kurzschlussströme 1-Perioden-Effektivwert / *Short-circuit currents, 1-period RMS value* (L1,L2,L3)	t1 + 280ms ... t1 + 300ms [p.u. I_n]
66 - 68	Kurzschlussströme 1-Perioden-Effektivwert / *Short-circuit currents, 1-period RMS value* (L1,L2,L3)	t1 + 480ms ... t1 + 500ms [p.u. I_n]
69 - 71	Kurzschlussströme 1-Perioden-Effektivwert / *Short-circuit currents, 1-period RMS value* (L1,L2,L3)	t1 + 980ms ... t1 + 1000ms [p.u. I_n]
74	Anschwingzeit Wirkstrom / *Response time of active current*	Mitsystem / *Pos. seq.* [s]

Figure 15 – Summary results of short-circuit current contributions

The following reference values are applied for calculation of the p.u. values specified in the table above:

	REFUstor 88K 420P088
Rated active power, P_n [kW]	88
Rated voltage (phase-to-phase), U_n [V]	400
Rated current, I_n [A]	128

The FRT behaviour of the REFUsol 100K 880P100 can be applied to REFUstor 88K 420P088, REFUstor 100K 421P100 and REFUstor 50K 421P050 / REFUstor 50K 420P050.

3. Annex 3 – Extract from the test report

Parameters necessary for calculating the short-circuit currents as specified in DIN EN 60909-0 (VDE 0102) [5] (*Manufacturer's data* from [15]):

Herstellerangabe erforderlich: /

Manufacturer specifications needed:

Table 12 – Extent of the information on short-circuit current contributions to be given in the unit certificate

Type of power generating unit	Information	Symbol
Power generating units with full-scale converters	R.m.s. value of the source current for three-phase fault	I_{skPF}
	R.m.s. value of the source current for two-phase fault	$I_{(1)sk2PF}$
	R.m.s. value of the source current for single-phase fault	$I_{(1)sk1PF}$
	Negative-sequence short-circuit impedance (manufacturer information for integer *k*-factors only)	$Z_{(2)PF}$

Maximum rms short-circuit current is 128 A.

$I_{skPF} = I_{(1)sk2PF} = I_{(2)sk1PF} = 128$ A

min. $Z_{(2)PF} = 0{,}54\ \Omega$

Figure 16 – Parameters necessary for calculating the short-circuit currents according to DIN EN 60909-0

4. Annex 4 – Validated simulation model

4.1. General information about the simulation model [7]:

Simulation environment used for creation of the PGU model:	PowerFactory 2020
Simulation environment used for conducting simulation/validation:	PowerFactory 2021 SP5 (x64)
Data format of the simulation model:	.pfd: PowerFactory model file .zip: Compressed file archive
Identification number of the validated model of the generating unit:	File name: REFU_TG4_09.08.2022.7z MD5 - Checksum: 582445af419417efa64b7a376de86b36 **Archive content:** File name: REFUsol/REFUstor_REFU_TR4.pfd MD5 - Checksum: 2628c18746c5ae8bbc3507abf2a47755
Certification the PGU according to:	☒ VDE-AR-N 4110:2018-11
Available model documentation:	Test Report_REFU_TG4 model REFUsol_20220809.pdf (09.08.2022)
Model type:	☐ EMT model ☒ RMS model
The model is suitable for	☒ static simulation ☒ dynamic simulation ☒ simulation of symmetrical and asymmetrical faults ☐ only simulation of symmetrical faults
Implemented FRT modes:	☒ Full dynamic grid support ☒ Limited dynamic grid support
Is k-factor adjustable?	☒ yes ☐ no
Further functions implemented in the model:	See *4.3 Model parameters [7]*
Is a simulation on a PGS configuration with SCR = 5 possible?	☒ yes ☐ no, for a stable simulation the SCR has to be limited to: ___

4. Annex 4 – Validated simulation model

A2. General information

2.1 Data format		
PowerFactory model file		
2.2 Explicit identification number of the computational model of the generating unit		
Name:	*REFU_TG4*.zip	
MD5 – Checksum:	582445af419417efa64b7a376de86b36	
Archive content:		
Name der Datei	**MD5 – Prüfsumme**	**Beschreibung**
REFUsol/REFUstor_REFU_TR4.pfd	2628c18746c5ae8bbc3507abf2a477 55	Encrypted PowerFactory model for inverter REFUsol/REFUstor.
2.3 Description of the simulation environment used for creation of the PGU model		
Name:	PowerFactory	
Software version:	2020	
Note (*manufacturer's information*): It is recommended that run the model in PowerFactory 2020 but newer version can be theoretically used. Solver setting for running the simulation model see *Annex 4 – Setting for calculation of initial conditions.*		
2.4 Description of the simulation environment used for conducting simulation/validation		
Name:	PowerFactory	
Software version:	2021 SP5 (x64)	
2.5 Description of the provided model documentation		
Name:	Test Report_REFU_TG4 model REFUsol_20220809.pdf (Issue: V3.0, date: 09.08.2022)	
Note: Other Documented Simulation model: REFUsol/REFUstor_REFU_Family.pfd MD5 – Checksum: e57e703968bde4b8794057a45089021f REFUsol/REFUstor_REFU_EZA.pfd MD5 – Checksum: cdb9c6a5c16047fca242369bf479f1c1		

4. Annex 4 – Validated simulation model

4.2. Description of the PGU simulation model [7]:

The simulation models of the REFUsol/REFUstor_REFU_TR4_20220420.pfd are implemented in DIgSILENT Power Factory Version 2020. In time-domain the static generator model acts as a current source and is suitable for RMS simulations. It is recommended that the integration step size to be set to 1 ms for the simulations.

Description of the main control circuit (Figure 17, Figure 18 & Figure 19):

The PV inverter is represented by the built-in Power Factory element Static Generator. The behaviour of dynamic model is determined by the DSL models connected to the Static Generator as showed in Figure 19.

- The measurement block measures the active-reactive power, the voltage, the frequency, and the cos(phi) at the PCC.
- The modeling of the dynamic behavior of the controller cannot be directly seen in the pane "RMS Simulation" because this modeling is more complex and was performed with a "Composite Model" named "Inverter Control".
- The "Power Controller-Details" in the Figure 6 is a complex control structure which model the behavior of the inverter controller in static and dynamic simulation. The Power Controller-Details DSL element consist of the active power controller, fault controller, reactive power controller and the limiter

4. Annex 4 – Validated simulation model

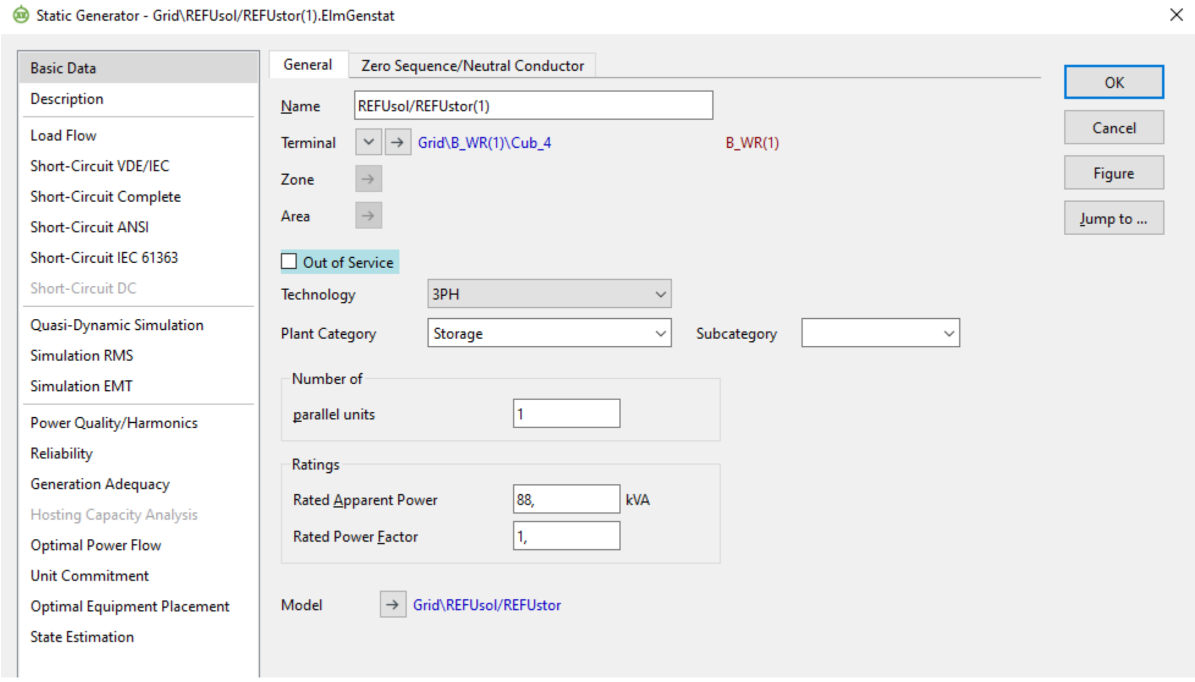


Figure 17 – Static Generator Dialogue window for *Basic Data*

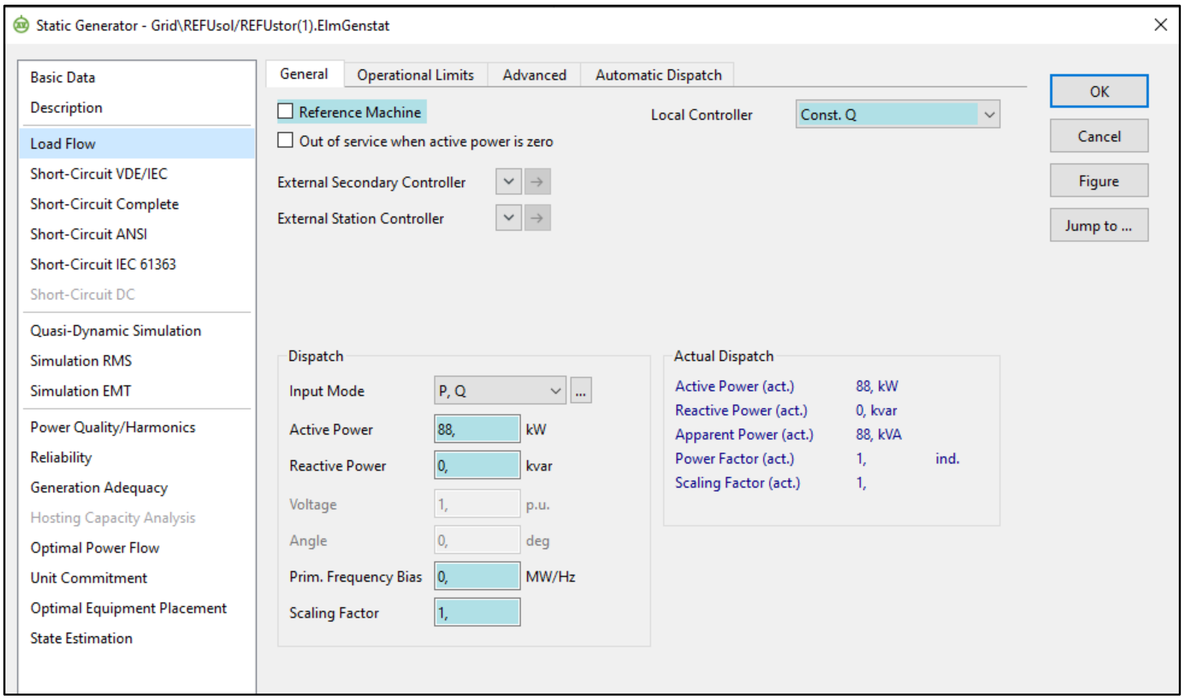


Figure 18 – Static Generator Dialogue window for *Load Flow – Operational Limits*

4. Annex 4 – Validated simulation model

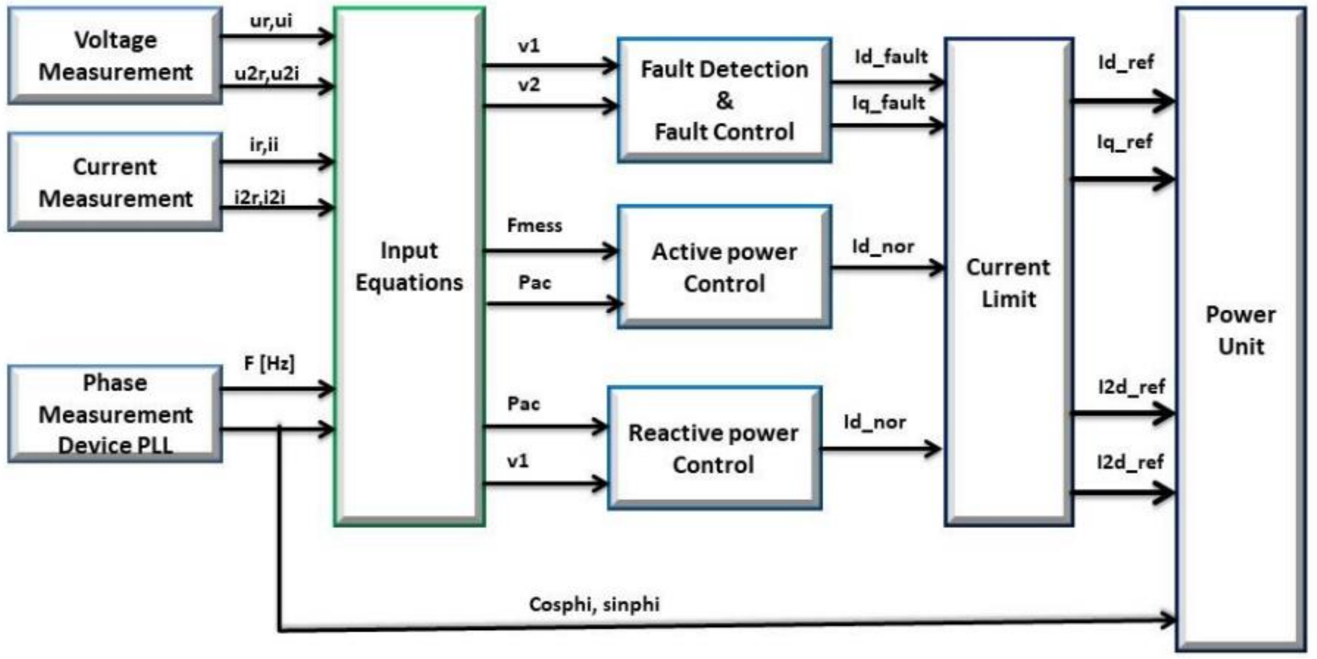


Figure 19 – Control frame of the simulation model

Description of the interface to DC input and AC output (Figure 20):

The PV converter is connected to AC mains via the 0,40 kV three phase busbar (which is the measuring point of the above-mentioned voltage measuring elements) and also contains the relays of the internal disconnection function.

In time-domain simulations the static generator model acts as a current source, no explicit primary energy conversion is implemented.

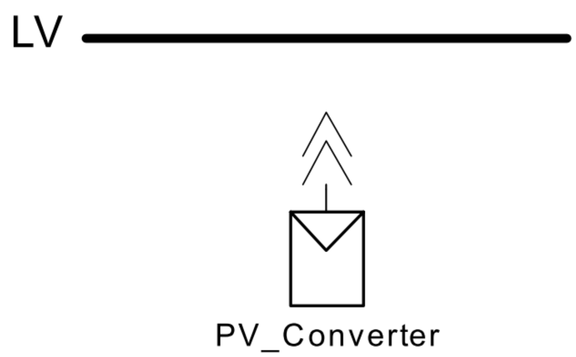


Figure 20 – Interface of the model towards the simulation environment

4. Annex 4 – Validated simulation model

4.3. Model parameters [7]

Description of the accessible parameterization of the model:

The ranges of the following parameters need to be selected in a sensible way: i.e. using the default values or parameter ranges stated in the TG 3 report 18TH0270_TR3_2*.*

Figure 21 shows the composite model *DynamicModel "REFUsol/Refustor.Elm.Comp"* which references to *Control_Frame* showed in Figure 21 and connects to the common model of

- *Power_Controloller*;.

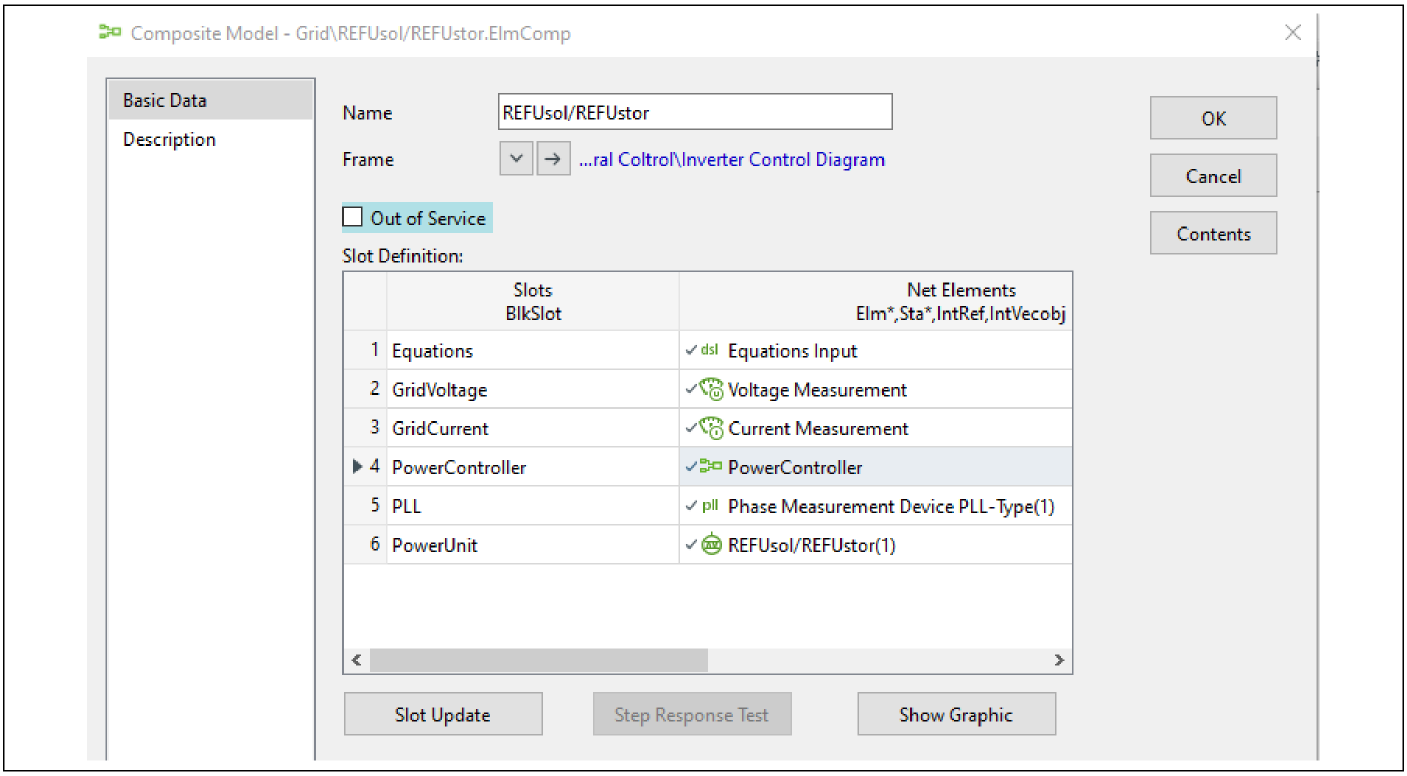
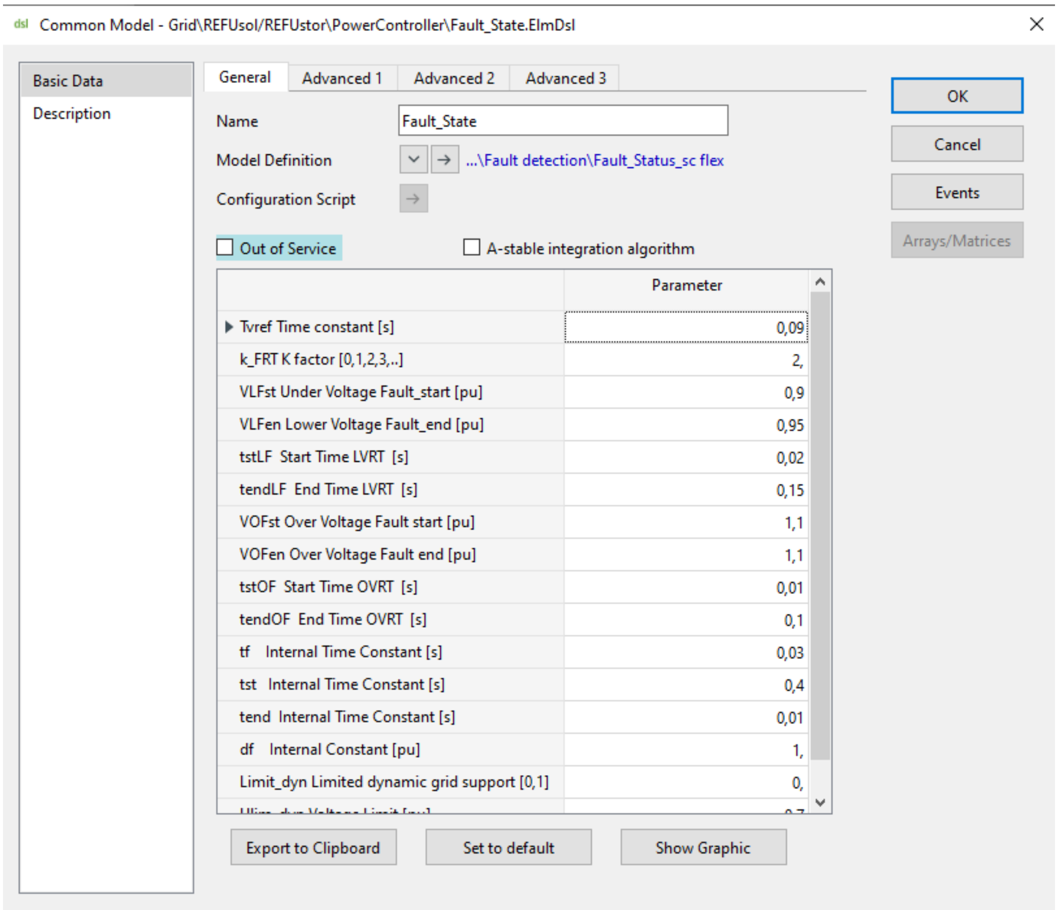
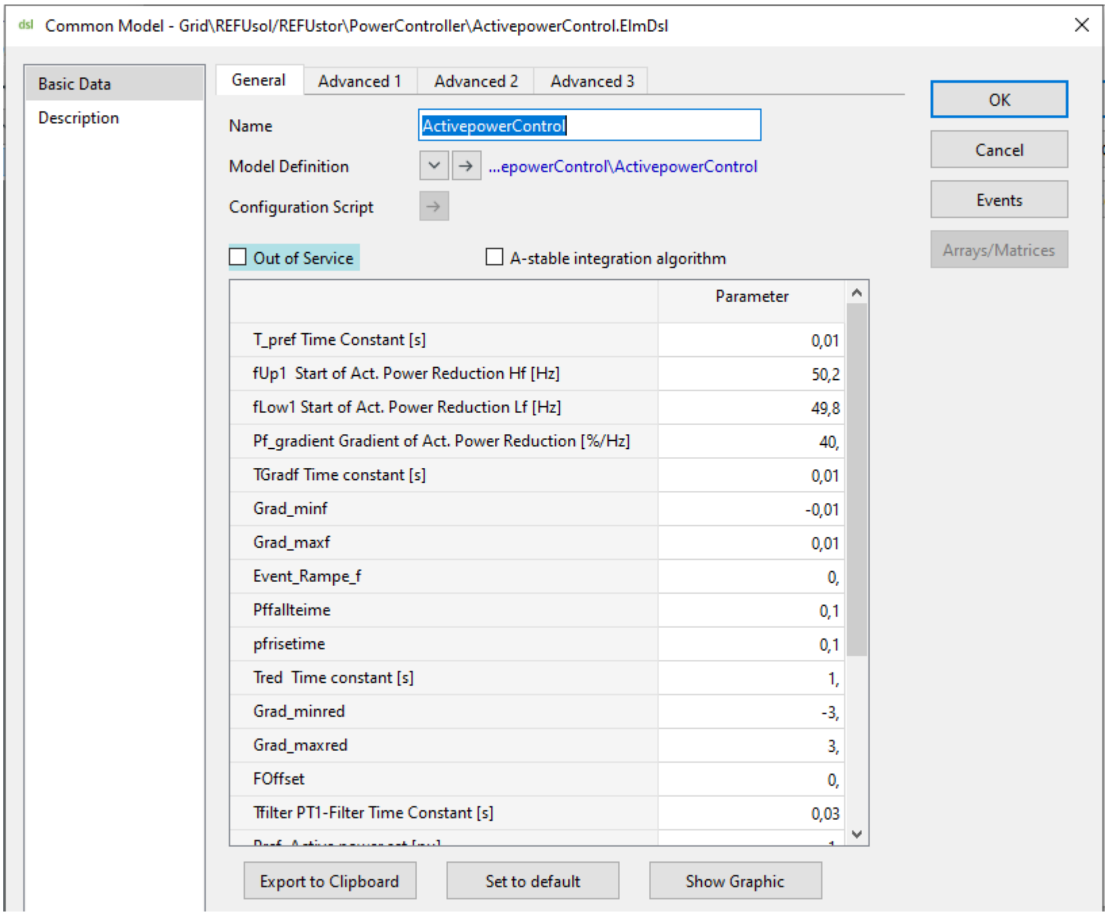


Figure 21 – Composite model *DynamicModel* references to *Control_Frame*

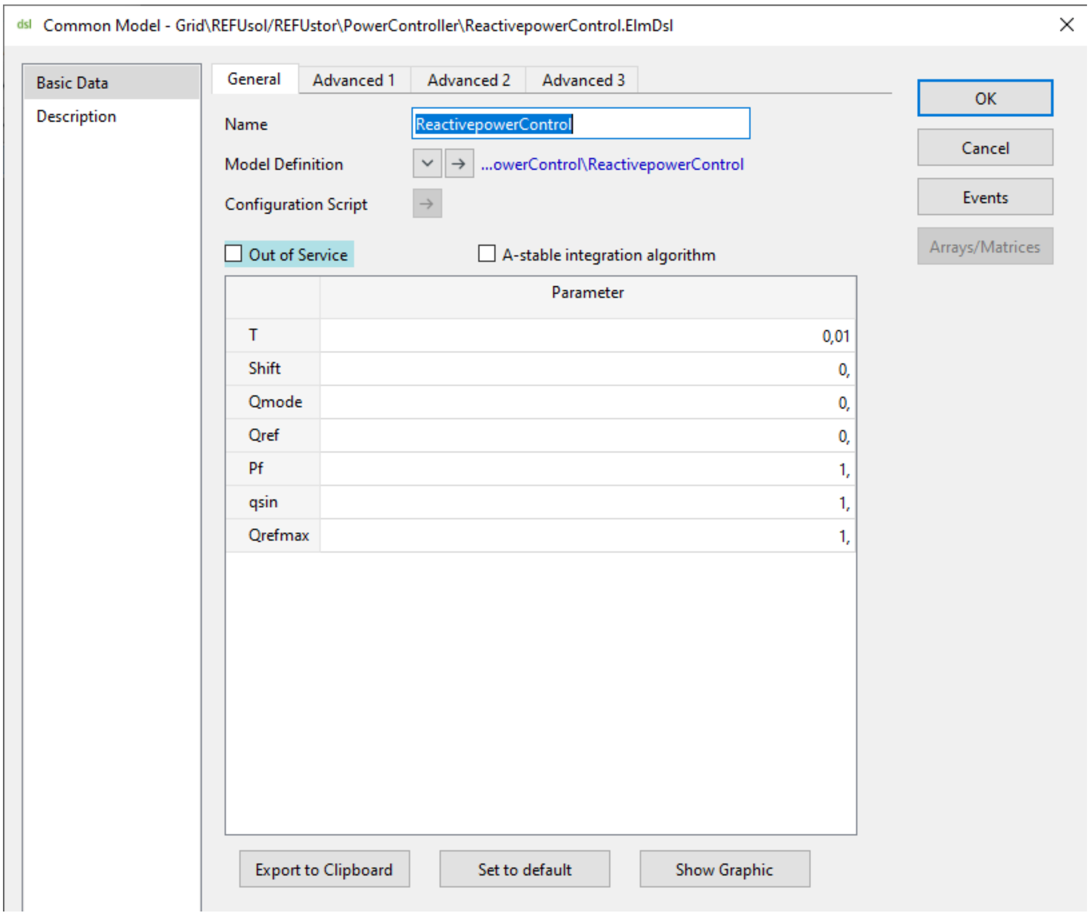
4. Annex 4 – Validated simulation model

Via the common models the parameters of the controllers are accessible and can be set:





4. Annex 4 – Validated simulation model



Common Model - Grid\REFUsol/REFUstor\PowerController\ReactivepowerControl.ElmDsl

Basic Data | Description

General | Advanced 1 | Advanced 2 | Advanced 3

Name: ReactivepowerControl

Model Definition: ...owerControl\ReactivepowerControl

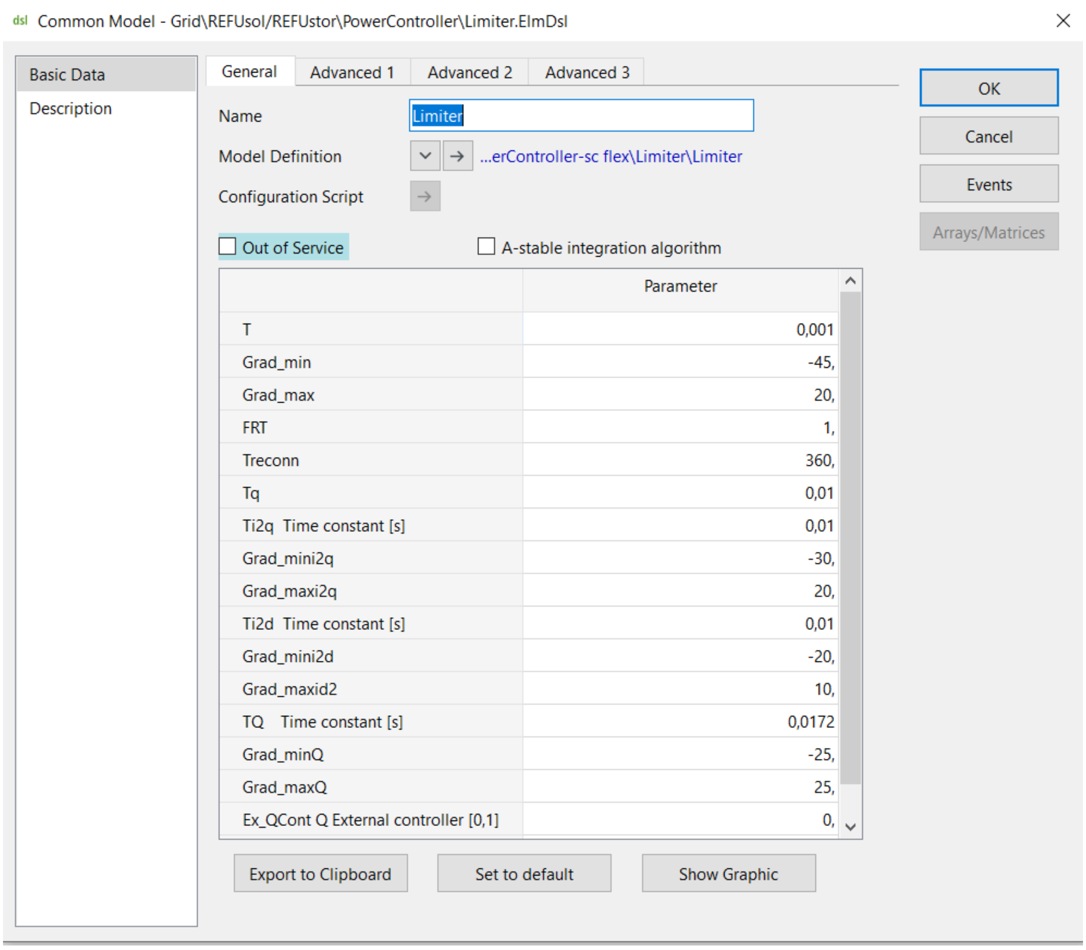
Configuration Script

Out of Service | A-stable integration algorithm

	Parameter
T	0,01
Shift	0,
Qmode	0,
Qref	0,
Pf	1,
qsin	1,
Qrefmax	1,

Export to Clipboard | Set to default | Show Graphic

OK | Cancel | Events | Arrays/Matrices



Common Model - Grid\REFUsol/REFUstor\PowerController\Limiter.ElmDsl

Basic Data | Description

General | Advanced 1 | Advanced 2 | Advanced 3

Name: Limiter

Model Definition: ...erController-sc flex\Limiter\Limiter

Configuration Script

Out of Service | A-stable integration algorithm

	Parameter
T	0,001
Grad_min	-45,
Grad_max	20,
FRT	1,
Treconn	360,
Tq	0,01
Ti2q Time constant [s]	0,01
Grad_mini2q	-30,
Grad_maxi2q	20,
Ti2d Time constant [s]	0,01
Grad_mini2d	-20,
Grad_maxid2	10,
TQ Time constant [s]	0,0172
Grad_minQ	-25,
Grad_maxQ	25,
Ex_QCont Q External controller [0,1]	0,

Export to Clipboard | Set to default | Show Graphic

OK | Cancel | Events | Arrays/Matrices

4. Annex 4 – Validated simulation model

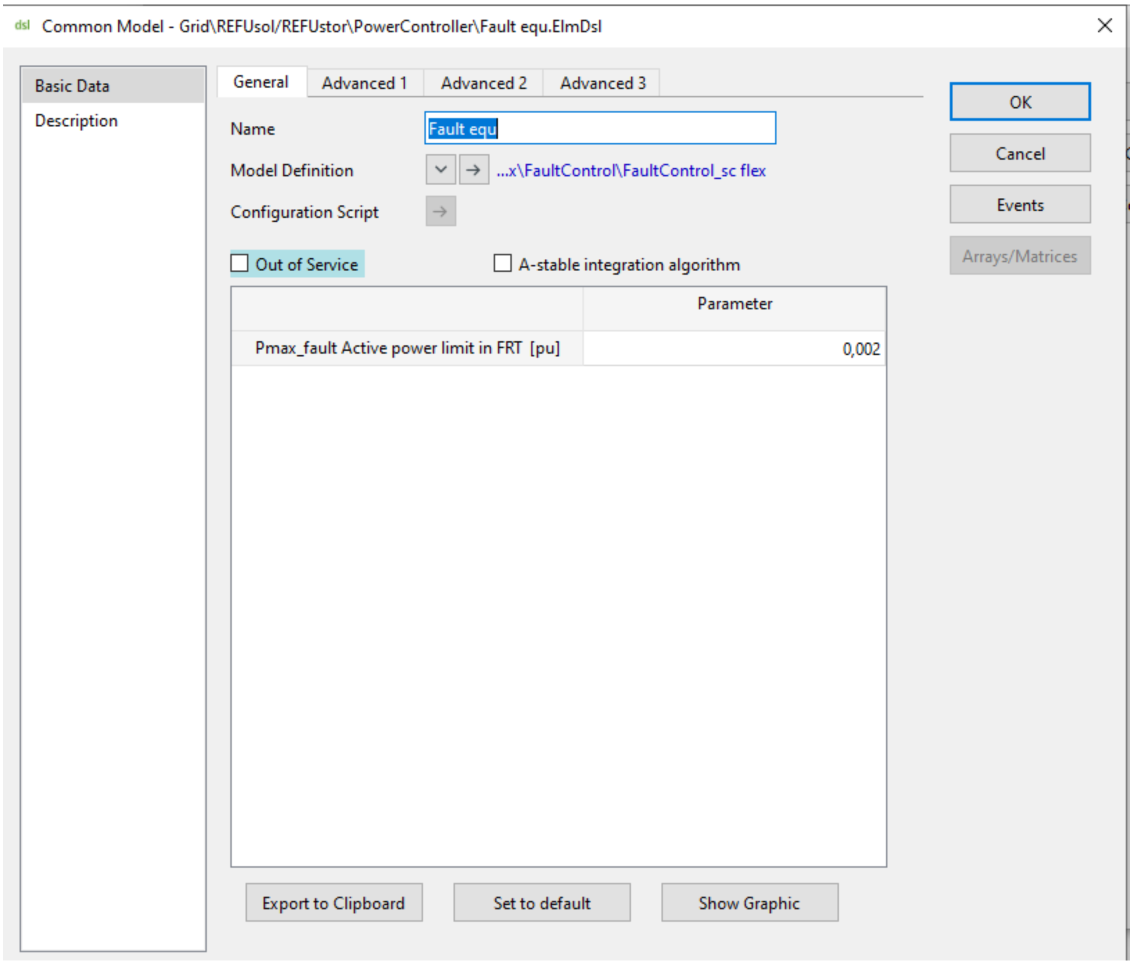


Figure 22 – Common models from [7]

4. Annex 4 – Validated simulation model

TG4 model for an inverter Controller

Fraunhofer ISE

TestLab Power Electronics

Manufacturer: REFU Storage Systems GmbH
Type: TG4 model REFUsol/REFUstor
Model Version: 20220420

5.1.5 List of model parameters

Name	Unit	Default Value	Range	Description
Fault State parameters				
Tvref	[s]	0.09	0 to 100	Time constant
k_FRT	[0,1,2,3, ...]	2	0 to 10	K factor
VLFst	[pu]	0.9	0 to 1	Under Voltage Fault_start
VLFen	[pu]	0.95	0 to 1	Lower Voltage Fault_end
tstLF	[s]	0.02	0 to 100	Start Time LVRT
tendLF	[s]	0.15	0 to 100	End Time LVRT
VOFst	[pu]	1.1	0 to 1.15	Over Voltage Fault_start
VOFen	[pu]	1.1	0 to 1.15	Over Voltage Fault end
tstOF	[s]	0.01	0 to 100	Start Time OVRT
tendOF	[s]	0.1	0 to 100	End Time OVRT
tf	[s]	0.03	0 to 100	Internal Time Constant
tst	[s]	0.4	0 to 100	Internal Time Constant
tend	[s]	0.01	0 to 100	Internal Time Constant
df	[pu]	1	0 to 100	Internal Constant
Limit_dyn	[0,1]	0	0 or 1	Limited dynamic grid support
Ulim_dyn	[pu]	0.7	0 to 1	Voltage Limit
Active Power control parameters				
T_pref	[s]	0.01	0 to 100	Time Constant
fUp1	[Hz]	50.2	50.2 to 50.5	Start of Act. Power Reduction Hf
fLow1	[Hz]	49.8	94.5 to 49.8	Start of Act. Power Reduction Lf
Pf_gradient	[%/Hz]	40	0 to 500	Gradient of Act. Power Reduction
TGradf	[s]	0.01	0 to 100	Time constant
Grad_minf	[pu]	-0.01	-100 to 0	Gradient of min
Grad_maxf	[pu]	0.01	-100 to 0	Gradient of max
Event_Rampe _f	[0 or 1]	0	0 or 1	Event ramp function
Pffallteime	[s]	0.1	0 to 100	Time constant
pfrisetime	[s]	0.1	0 to 100	Time constant
Tred	[s]	1	0 to 100	Time constant
Grad_minred	[pu]	-3	-100 to 0	Gradient of min
Grad_maxred	[pu]	3	0 to 100	Gradient of max
FOffset	[pu]	0	0 to 100	F Set
Tfilter	[s]	0.03	0 to 100	PT1-Filter Time Constant

4. Annex 4 – Validated simulation model

TG4 model for an inverter Controller

Fraunhofer ISE

TestLab Power Electronics

Manufacturer: REFU Storage Systems GmbH
Type: TG4 model REFUsol/REFUstor
Model Version: 20220420

Pref	[pu]	0.2	-1 to 1	Active power set
Exp	[pu]	0	-1 to 1	Active power set from extern
T	[s]	0	0 to 100	Time constant
TPGradient_back	[s]	0.01	0 to 100	Time constant
PfGradient_back	[pu]	16	0 to 100	Gradient of Act. Power Reduction with p(f)
Pf_function	[0 or 1]	0	0 or 1	P(F) Status (Set zero for REFUstor devices)
imin	[pu]	-1.1	-1 to 0	Min. Current
imax	[pu]	1.1	0 to 1	Max. Current
Reactive Power control parameters				
T	[s]	0,01	0 to 100	Time constant
Shift	[pu]	0	-1 to 1	Shift of the Q(U) control
Qmode	[0,1,2,3]	0	0,1,2, or 3	reactive power controller Qref,Q_Pf,Q_U,Q_P
Qref	[pu]	0	-1 to 1	Reactive power set
Pf	[cos phi]	1	0 to 1	power factor
qsin	1 or -1	1	1 or -1	inductive or Capacitive
Qrefmax	[pu]	1	-1 to 1	Max reactive power
Limiter parameters				
T	[s]	0.001	0 to 100	Time constant
Grad_min	[pu]	-45	-10000 to 0	Gradient min of Act. Power
Grad_max	[pu]	20	0 to 10000	Gradient max of Act. Power
FRT	[0 or 1]	1	0 or 1	FRT function
Treconn	[s]	360	0 to 1000	Reconnection time of Act. Power after voltage less
Pf_min	[-]	0	0 to 1	Minimum cosphi
Tq	[s]	0.01	0 to 100	Time constant
Ti2q	[s]	0.001	0 to 100	Time constant
Grad_mini2q	[pu]	-100	-10000 to 0	Gradient min of i2q
Grad_maxi2q	[pu]	50	0 to 10000	Gradient max of i2q
Ti2d		0.01	0 to 100	Time constant
Grad_mini2d	[pu]	-20	-10000 to 0	Gradient min of i2d
Grad_maxi2d	[pu]	10	0 to 10000	Gradient max of i2d
TQ		0.02	0 to 100	Time constant
Grad_minQ	[pu]	-25	-10000 to 0	Gradient min of reactive power

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Grad_maxQ	[pu]	25	0 to 10000	Gradient max of reactive power
Ex-QCont	[0 or 1]	0	0 or 1	External set Q
imax2	[pu]	1	0 to 1	Max current
Fault equ. parameters				
Pmax_fault	[pu]	0.002	0 to 1	Active power limit in FRT
Equations Input parameters				
T	[s]	0	0 to 100	Time constant
TGrad	[s]	0	0 to 100	Time constant
Grad_min	[pu]	-20	-10000 to 0	Gradient min
Grad_max	[pu]	20	0 to 10000	Gradient max
Tf	[s]	0	0 to 100	Time constant

Reactive power control Q(U) characteristic		
Q	**U**	**Unit**
0	0	[pu]
-0.15	0.97	[pu]
0,08	1	[pu]
0.277	1.033	[pu]
0.3	2	[pu]
Reactive power control Q(P) characteristic		
Q	**P**	**Unit**
0.038	0.55	[pu]
0.2	0.7	[pu]
0.43	0.95	[pu]
0.43	1	[pu]

Note:

The Q(P)- and Q(U)-curve can be defined under
"*Common Model – Grid\DynamicModel\Power controller_Control.ElmDsl\reactive power control - Basic Data\Advanced 1*"

Name	**Unit**	**Default Value**	**Description**
Frequency Protection			
f>	Hz	49,5	
tf>	s	60	
f> activated	0/1	0	out of service = 0
f>>	Hz	50,05	
tf>>	s	2	
f>> activated	0/1	0	out of service = 0
f<	Hz	49,65	
tf<	s	3	
f< activated	0/1	0	out of service = 0

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Voltage Protection			
U>	p.u.	1,091	
tU>	s	0	
U> aktiviert	0/1	0	out of service = 0
U>>	p.u.	1,091	
tU>>	s	0,4	
U>> aktiviert	0/1	0	out of service = 0
U<	p.u.	0,909	
tU<	s	0	
U< aktiviert	0/1	1	out of service = 0
U<<	p.u.	0,8	
tU<<	s	0,4	
U<< aktiviert	0/1	0	out of service = 0
Current Protection			
I>>	p.u.	2,99	
tI>>	s	1	
I>> aktiviert	0/1	0	out of service = 0

Figure 23 – Accessible parameters of the model from [7]

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4.4. Model application guide [7]

Adaption of model parameters for different PGU types

(The other devices of the same series with the nominal power of 50kW, 88kW and 100kW (in which case the limit is to be set in the software of the inverter) and which are therefore technical identical to the base model can be modelled by adapting the base model. This simple adaptation is only possible for the devices with identical topology and the same control. For example, a device with a nominal power of 50 kW and AC nominal voltage 400 V. It should only adjust the nominal values in the template model.

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Description of the steps for integration of the simulation model in a power generating system project (Manufacturer's information) [7]

1. Import the project "REFUsol/REFUstor_REFU_TR4.pfd" into PowerFactory 2020 (or later version).
2. Activate the power plant project. Copy the model template in the project "REFUsol_REFUstor_REFU_TR4" under the folder Library\Templates\ into the folder Library\Templates\ of power plant project.
3. Select the imported model template from the Drawing Tools tool-window (which appears by default on the left-hand side of the graphic window in the PowerFactory 2021) and place the inverter model into the single-line diagram.
4. Select the corresponding Capability Curve of the PGU type in Static Generator \ Load Flow \ Operational Limits page (see Figure 19).
5. Edit the parameters in the DLS models under guidance of manufacturer.
6. Edit the active and reactive power operating point on the Load Flow page of the static generator.
7. Calculate the load flow and ensure that there are no warnings or error messages.
8. Calculate the initial conditions (RMS simulation, symmetrical or unsymmetrical network representation, recommended integration step size: 1 ms constant step size).
9. Define network events and select the variables to be recorded.
10. Start the simulation, plot result variables and observe the converter behaviour.

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4.5. Scope of the validation and plausibility tests [7]

The simulation model was checked for validity and plausibility according to TG 4 for following test scenarios:

- Validating P setpoint control measured according to TG3 Chapters 4.1.1, 4.1.2 (chapter 3.1.1, 3.1.2 in [3])
- Validating the P-Q diagram measured according to TG3 Chapters 4.2.2 (chapter 3.2.1 in [3])
- Validating the Q measured according to TG3 Chapters 4.2.4 (chapter 3.2.2 in [3])
- Validating all TG3 FRT tests (chapter 3.3, 3.5 and 5 in [3])
- Plausibility tests on single model for different
    - fault types;
    - voltage depth;
    - pre-fault voltages
    - pre-fault active powers
    - pre-fault reactive powers
    - k-factors

  (chapter 5.5.2 in [3])
- Plausibility tests for typical PGS configuration for different
    - fault types;
    - voltage depth;
    - pre-fault voltages
    - pre-fault active powers
    - pre-fault reactive powers
    - k-factors

  (chapter 5.5.3.1 in [3])
- Simulating of unsuccessful automatic reconnection for typical PGS configuration (chapter 5.5.3.2 in [3])

For all the test scenarios the simulation ran stably without any error messages and showed satisfying behaviour.

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4.6. Results of Validating simulation models (PGU) [7]

Summary of validation results REFUsol 100K 880P100

Test label according to TG3, chapter 4.6 - Behavior during grid disturbance - Table 4-68 and 4-69		Positive Sequence												Negative Sequence											
		P			Q			I_w			I_b			P			Q			I_w			I_b		
		MXE	ME	MAE	MXE	ME	MAE	MXE	ME	MAE	MXE	ME	MAE	MXE	ME	MAE	MXE	ME	MAE	MXE	ME	MAE	MXE	ME	MAE
U_rest < 0,05	Pre	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
0.1 according to IEC	Fault	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3ph / Full Load / Kp = 2, Kn=2	Post	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
U_rest < 0,05	Pre	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
0.2 according to IEC	Fault	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3ph / Partial Load / Kp = 2, Kn=2	Post	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
U_rest < 0,05	Pre	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
0.3 according to IEC	Fault	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2ph / Full Load / Kp = 2, Kn=2	Post	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
U_rest < 0,05	Pre	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
0.4 according to IEC	Fault	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2ph / Partial Load / Kp = 2, Kn=2	Post	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
0,20 ≤ U_rest ≤ 0,30	Pre	0.018	0.018	0.018	0.007	-0.006	0.006	0.011	0.010	0.010	0.007	-0.006	0.006	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.001	0.000	0.000
25.1 according to IEC	Fault	0.009	0.007	0.002	0.015	0.011	0.014	0.035	0.018	0.010	0.065	0.052	0.061	0.000	0.000	0.000	0.000	0.000	0.000	0.004	-0.002	0.001	0.004	0.001	0.001
3ph / Full Load / Kp = 2, Kn=2	Post	0.024	0.015	0.019	0.008	-0.005	0.009	0.017	0.008	0.012	0.008	-0.004	0.009	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001	0.001	0.000	0.001
0,20 ≤ U_rest ≤ 0,30	Pre	0.002	0.001	0.001	0.002	-0.002	0.002	0.001	0.001	0.001	0.002	-0.002	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
25.2 according to IEC	Fault	0.006	0.002	0.001	0.035	0.031	0.034	0.024	0.009	0.007	0.066	0.053	0.061	0.000	0.000	0.000	0.000	0.000	0.000	0.004	-0.001	0.001	0.004	0.001	0.002
3ph / Partial Load / Kp = 2, Kn=2	Post	0.002	0.000	0.002	0.004	-0.001	0.005	0.001	0.000	0.002	0.004	-0.001	0.005	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.001	0.000	0.000	0.000
0,20 ≤ U_rest ≤ 0,30	Pre	0.019	0.019	0.019	0.007	-0.006	0.006	0.017	0.017	0.017	0.007	-0.006	0.006	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000
25.4 according to IEC	Fault	0.028	0.020	0.013	0.009	0.006	0.009	0.043	0.030	0.020	0.005	-0.009	0.005	0.036	0.033	0.035	0.014	-0.011	0.012	0.108	0.097	0.105	0.086	-0.076	0.080
2ph / Full Load / Kp = 2, Kn=2	Post	0.020	0.015	0.020	0.008	-0.005	0.009	0.018	0.013	0.019	0.008	-0.004	0.009	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.002	0.001	-0.001	0.002
0,20 ≤ U_rest ≤ 0,30	Pre	0.003	0.002	0.002	0.002	-0.002	0.002	0.002	0.002	0.002	0.002	-0.002	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
25.5 according to IEC	Fault	0.025	0.013	0.012	0.011	0.009	0.011	0.040	0.020	0.020	0.012	0.008	0.011	0.025	0.022	0.024	0.020	-0.017	0.019	0.073	0.064	0.070	0.091	-0.082	0.088
2ph / Partial Load / Kp = 2, Kn=2	Post	0.002	0.000	0.003	0.003	0.000	0.005	0.002	0.000	0.003	0.003	0.000	0.006	0.000	0.000	0.000	0.000	-0.001	0.001	0.000	0.001	0.001	0.000	-0.002	0.002
0,45 ≤ U_rest ≤ 0,60	Pre	0.018	0.018	0.018	0.006	-0.006	0.006	0.011	0.010	0.010	0.006	-0.006	0.006	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.001	0.000	0.000
50.1 according to IEC	Fault	0.045	-0.006	0.021	0.033	0.027	0.031	0.091	-0.016	0.042	0.030	0.019	0.026	0.000	0.000	0.000	0.000	0.000	0.000	0.009	-0.001	0.002	0.011	0.000	0.002
3ph / Full Load / Kp = 2, Kn=2	Post	0.024	0.013	0.020	0.008	-0.005	0.008	0.017	0.006	0.014	0.008	-0.005	0.008	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001	0.001	0.000	0.001
0,45 ≤ U_rest ≤ 0,60	Pre	0.001	0.001	0.001	0.002	-0.002	0.002	0.001	0.000	0.000	0.002	-0.002	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
50.2 according to IEC	Fault	0.061	-0.007	0.028	0.038	0.029	0.032	0.118	-0.019	0.057	0.041	0.023	0.028	0.000	0.000	0.000	0.000	0.000	0.000	0.010	-0.001	0.001	0.011	0.001	0.002
3ph / Partial Load / Kp = 2, Kn=2	Post	0.002	0.002	0.003	0.004	-0.001	0.007	0.001	0.001	0.003	0.004	-0.001	0.007	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.001	0.000	0.000	0.000
0,45 ≤ U_rest ≤ 0,60	Pre	0.003	-0.002	0.002	0.006	-0.006	0.006	0.004	-0.003	0.003	0.006	-0.006	0.006	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.001	0.000	0.000
50.3 according to IEC	Fault	0.035	0.022	0.018	0.025	0.020	0.023	0.047	0.029	0.025	0.037	0.030	0.034	0.033	0.031	0.032	0.002	0.002	0.002	0.121	0.112	0.116	0.046	0.044	0.043
2ph / Full Load / Kp = 2, Kn=2	Post	0.005	-0.005	0.006	0.013	-0.006	0.011	0.006	-0.006	0.007	0.013	-0.006	0.011	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001	0.001	0.000	0.001
0,45 ≤ U_rest ≤ 0,60	Pre	0.002	0.002	0.002	0.002	-0.002	0.002	0.002	0.002	0.002	0.002	-0.002	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
50.4 according to IEC	Fault	0.071	-0.012	0.014	0.030	0.025	0.027	0.095	-0.016	0.019	0.042	0.034	0.038	0.029	0.027	0.028	0.006	0.005	0.005	0.109	0.102	0.105	0.054	0.049	0.048
2ph / Partial Load / Kp = 2, Kn=2	Post	0.002	0.001	0.004	0.003	-0.001	0.005	0.002	0.001	0.003	0.003	0.000	0.006	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001	0.000	-0.001	0.001
0,45 ≤ U_rest ≤ 0,60	Pre	0.005	0.005	0.005	0.021	0.021	0.021	0.002	-0.002	0.002	0.021	0.021	0.021	0.000	0.000	0.000	0.000	0.000	0.000	0.003	0.000	0.002	0.006	-0.006	0.006
50.5 according to IEC	Fault	0.002	0.008	0.002	0.007	-0.006	0.007	0.005	0.015	0.005	0.013	-0.013	0.013	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3ph / Full Load / Kp = 2, Kn=2 / Limited Mode	Post	0.011	-0.004	0.010	0.018	0.015	0.015	0.017	-0.010	0.010	0.018	0.015	0.015	0.000	0.000	0.000	0.000	0.000	0.000	0.003	0.000	0.002	0.006	-0.005	0.006
0,45 ≤ U_rest ≤ 0,60	Pre	0.008	0.007	0.007	0.044	0.043	0.043	0.007	0.007	0.007	0.044	0.043	0.043	0.000	0.000	0.000	0.000	0.000	0.000	0.021	-0.020	0.020	0.009	-0.001	0.005
50.6 according to IEC	Fault	0.001	0.003	0.001	0.015	-0.016	0.014	0.002	0.004	0.002	0.020	-0.022	0.019	0.000	0.000	0.000	0.002	-0.001	0.002	0.001	0.001	0.001	0.006	-0.005	0.006
2ph / Full Load / Kp = 2, Kn=2 / Limited Mode	Post	0.010	0.001	0.009	0.042	0.040	0.041	0.010	0.000	0.009	0.042	0.040	0.041	0.000	0.000	0.000	0.000	0.000	0.000	0.021	-0.020	0.020	0.012	0.001	0.005
0,70 ≤ U_rest ≤ 0,80	Pre	0.018	0.017	0.017	0.006	-0.006	0.006	0.011	0.010	0.010	0.006	-0.006	0.006	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.001	0.000	0.000
75.1 according to IEC	Fault	0.012	0.012	0.011	0.018	0.007	0.008	0.001	0.000	0.001	0.015	0.000	0.006	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.000	0.000	0.001	0.000	0.000
3ph / Full Load / Kp = 2, Kn=2	Post	0.024	0.016	0.019	0.008	-0.006	0.008	0.017	0.009	0.012	0.008	-0.006	0.008	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001	0.001	0.000	0.000

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Test label according to TG3, chapter 4.6 - Behavior during grid disturbance - Table 4-68 and 4-69		Positive Sequence												Negative Sequence											
		P			Q			I_w			I_b			P			Q			I_w			I_b		
		MXE	ME	MAE	MXE	ME	MAE	MXE	ME	MAE	MXE	ME	MAE	MXE	ME	MAE	MXE	ME	MAE	MXE	ME	MAE	MXE	ME	MAE
0,70 ≤ U_rest ≤ 0,80	Pre	0.002	0.001	0.001	0.002	-0.002	0.002	0.001	0.000	0.000	0.002	-0.002	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000
75.2 according to IEC	Fault	0.006	0.005	0.005	0.026	0.013	0.015	0.004	0.003	0.003	0.027	0.011	0.013	0.000	0.000	0.000	0.000	0.000	0.000	0.003	-0.001	0.001	0.002	0.001	0.001
3ph / Partial Load / Kp = 2, Kn=2	Post	0.002	0.001	0.002	0.004	-0.002	0.005	0.001	0.000	0.001	0.004	-0.002	0.005	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000
0,70 ≤ U_rest ≤ 0,80	Pre	0.008	0.007	0.007	0.019	0.014	0.014	0.010	0.009	0.009	0.015	0.010	0.010	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.000	0.001	0.002	0.000	0.001
75.3 according to IEC	Fault	0.018	0.018	0.018	0.023	0.013	0.015	0.024	0.024	0.024	0.031	0.018	0.020	0.000	0.000	0.000	0.000	0.000	0.000	0.002	-0.001	0.001	0.001	0.000	0.000
3ph / Partial Load / Kp = 2, Kn=2	Post	0.008	0.008	0.008	0.018	0.015	0.015	0.010	0.009	0.009	0.014	0.011	0.011	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.000	0.001	0.003	0.000	0.001
0,70 ≤ U_rest ≤ 0,80	Pre	0.008	0.007	0.007	0.014	-0.014	0.014	0.008	0.007	0.007	0.014	-0.013	0.013	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.001	0.001	0.001
75.4 according to IEC	Fault	0.002	0.002	0.002	0.047	0.044	0.046	0.003	0.002	0.002	0.065	0.061	0.064	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.000	0.001	0.001	0.001	0.001
3ph / Partial Load / Kp = 2, Kn=2	Post	0.008	0.007	0.008	0.015	-0.013	0.014	0.008	0.008	0.008	0.014	-0.012	0.014	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.001	0.001	0.001
0,70 ≤ U_rest ≤ 0,80	Pre	0.002	0.001	0.001	0.002	-0.002	0.002	0.001	0.001	0.001	0.002	-0.002	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000
75.5 according to IEC	Fault	0.015	0.001	0.005	0.044	0.021	0.024	0.015	-0.004	0.008	0.035	0.006	0.013	0.000	0.000	0.000	0.000	0.000	0.000	0.003	0.000	0.000	0.004	0.001	0.001
3ph / Partial Load / Kp = 4, Kn=4	Post	0.002	0.002	0.002	0.004	-0.001	0.006	0.001	0.001	0.001	0.004	-0.001	0.006	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000
0,70 ≤ U_rest ≤ 0,80	Pre	0.019	0.019	0.019	0.007	-0.006	0.006	0.018	0.017	0.017	0.007	-0.006	0.006	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000
75.6 according to IEC	Fault	0.015	-0.004	0.006	0.018	0.009	0.012	0.015	-0.003	0.006	0.022	0.011	0.014	0.012	0.012	0.012	0.010	-0.009	0.009	0.079	0.077	0.078	0.025	-0.017	0.017
2ph / Full Load / Kp = 2, Kn=2	Post	0.019	0.017	0.019	0.008	-0.005	0.008	0.017	0.015	0.018	0.008	-0.005	0.008	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001	0.000	0.000	0.000
0,70 ≤ U_rest ≤ 0,80	Pre	0.002	0.002	0.002	0.002	-0.002	0.002	0.002	0.002	0.002	0.002	-0.002	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
75.7 according to IEC	Fault	0.003	-0.002	0.002	0.025	0.017	0.019	0.003	-0.002	0.002	0.029	0.021	0.022	0.012	0.011	0.012	0.010	-0.009	0.010	0.075	0.074	0.075	0.028	-0.020	0.021
2ph / Partial Load / Kp = 2, Kn=2	Post	0.003	0.002	0.002	0.003	-0.001	0.004	0.002	0.001	0.002	0.003	-0.001	0.004	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.000	0.000	0.001
0,70 ≤ U_rest ≤ 0,80	Pre	0.010	-0.009	0.009	0.005	0.003	0.003	0.010	-0.009	0.009	0.005	0.003	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.007	-0.004	0.004	0.003	0.001	0.001
75.8 according to IEC	Fault	0.019	-0.006	0.008	0.021	0.001	0.007	0.022	-0.007	0.008	0.025	0.002	0.008	0.023	0.022	0.022	0.022	-0.019	0.020	0.150	0.142	0.146	0.071	-0.047	0.053
2ph / Partial Load / Kp = 4, Kn=4	Post	0.010	-0.010	0.010	0.006	-0.001	0.007	0.010	-0.010	0.010	0.006	0.000	0.008	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.002	0.000	-0.003	0.003
0,75 ≤ U_rest ≤ 0,85	Pre	0.007	0.006	0.006	0.019	0.019	0.019	0.000	0.000	0.000	0.019	0.019	0.019	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.000	0.001	0.003	-0.003	0.003
80.1	Fault	0.005	0.002	0.002	0.052	0.042	0.045	0.012	-0.007	0.008	0.060	0.048	0.051	0.000	0.000	0.000	0.000	0.000	0.000	0.006	0.002	0.002	0.006	-0.002	0.003
3ph / Full Load / Kp = 2, Kn=2, Limited Mode	Post	0.013	0.004	0.006	0.019	0.014	0.014	0.007	-0.001	0.002	0.019	0.014	0.014	0.000	0.000	0.000	0.000	0.000	0.000	0.004	-0.001	0.002	0.005	-0.003	0.003
0,75 ≤ U_rest ≤ 0,85	Pre	0.017	0.017	0.017	0.007	-0.006	0.006	0.019	0.019	0.019	0.007	-0.006	0.006	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.001	0.000	0.000
80.2	Fault	0.229	0.224	0.226	0.187	-0.178	0.180	0.257	0.251	0.254	0.206	-0.197	0.199	0.001	0.000	0.000	0.020	0.019	0.019	0.007	-0.005	0.005	0.197	0.193	0.195
2ph / Full Load / Kp = 2, Kn=2, Limited Mode	Post	0.018	0.018	0.018	0.010	-0.009	0.009	0.020	0.020	0.020	0.010	-0.009	0.009	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.001	0.001	0.001	0.001
0,85 ≤ U_rest ≤ 0,90	Pre	0.002	0.001	0.001	0.002	-0.002	0.002	0.001	0.001	0.001	0.002	-0.002	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
85.1 according to IEC	Fault	0.040	0.001	0.002	0.018	0.004	0.005	0.017	0.000	0.002	0.019	0.004	0.005	0.000	0.000	0.000	0.000	0.000	0.000	0.003	0.000	0.000	0.003	0.000	0.000
3ph / Partial Load / Kp = 2, Kn=2	Post	0.002	0.002	0.002	0.008	-0.005	0.010	0.001	0.002	0.002	0.008	-0.005	0.010	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000
U_rest ≥ 1,10	Pre	0.001	-0.001	0.001	0.023	0.022	0.022	0.008	-0.008	0.008	0.023	0.022	0.022	0.000	0.000	0.000	0.000	0.000	0.000	0.002	-0.001	0.001	0.004	-0.004	0.004
110.1 according to IEC	Fault	0.017	-0.010	0.010	0.035	0.029	0.028	0.012	-0.006	0.006	0.031	0.025	0.025	0.001	0.000	0.000	0.021	0.020	0.020	0.027	0.022	0.022	0.135	0.129	0.130
2ph / Full Load / Kp = 2, Kn=2	Post	0.001	-0.002	0.002	0.023	0.022	0.022	0.008	-0.009	0.009	0.023	0.022	0.022	0.000	0.000	0.000	0.000	0.000	0.000	0.003	-0.001	0.002	0.004	-0.003	0.005
U_rest ≥ 1,10	Pre	0.030	-0.030	0.030	0.005	0.005	0.005	0.032	-0.032	0.032	0.005	0.005	0.005	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.001	-0.001	0.001
110.2 according to IEC	Fault	0.038	-0.037	0.037	0.032	0.022	0.021	0.034	-0.033	0.033	0.028	0.019	0.019	0.002	0.002	0.002	0.020	0.020	0.020	0.036	0.033	0.034	0.130	0.127	0.128
2ph / Partial Load / Kp = 2, Kn=2	Post	0.030	-0.031	0.031	0.005	0.004	0.005	0.032	-0.032	0.032	0.005	0.004	0.005	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.001	0.001	0.000	0.002
U_rest ≥ 1,10	Pre	0.001	0.001	0.001	0.002	-0.002	0.002	0.001	0.000	0.000	0.002	-0.002	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
110.3 according to IEC	Fault	0.013	0.002	0.002	0.011	0.000	0.003	0.005	0.002	0.002	0.011	-0.001	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.004	0.000	0.001	0.001	0.000	0.000
3ph / Full Load / Kp = 2, Kn=2	Post	0.002	0.001	0.002	0.005	0.000	0.004	0.001	0.001	0.001	0.005	0.000	0.004	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000
U_rest ≥ 1,15	Pre	0.018	0.017	0.017	0.006	-0.006	0.006	0.012	0.011	0.011	0.006	-0.006	0.006	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.001	0.000	0.000
115.1 according to IEC	Fault	0.023	0.023	0.023	0.028	-0.010	0.011	0.021	0.021	0.020	0.024	-0.009	0.010	0.000	0.000	0.000	0.000	0.000	0.000	0.003	0.001	0.001	0.001	0.000	0.000
3ph / Full Load / Kp = 2, Kn=2	Post	0.019	0.014	0.019	0.004	-0.002	0.003	0.013	0.008	0.013	0.004	-0.002	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001	0.001	0.000	0.000
U_rest ≥ 1,15	Pre	0.001	0.001	0.001	0.002	-0.002	0.002	0.001	0.000	0.000	0.002	-0.002	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
115.2 according to IEC	Fault	0.011	0.010	0.010	0.027	-0.010	0.012	0.010	0.009	0.009	0.024	-0.010	0.011	0.000	0.000	0.000	0.000	0.000	0.000	0.003	0.001	0.001	0.001	0.000	0.000
3ph / Partial Load / Kp = 2, Kn=2	Post	0.001	0.001	0.001	0.006	0.002	0.003	0.001	0.001	0.001	0.006	0.002	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000

5. Annex 5 – Certification-relevant parameters

Parameter list of PGU or series

1. General information regarding the Parameter list

Manufacturer:	REFU Storage Systems GmbH
Created by:	Ronald Kiebler
Created on:	2020-01-29
Revised on:	2023-01-16

2. Information regarding the power generating unit

Type designation (clear identification of the type)	Rated power [kW] @400V	Rated active current [A] (with statement of displacement factor at which the current is valid)
421P100.010 REFUstor 100K	**88**	**128 A / PF = 1**
420P088.020 REFUstor 88K	**88**	**128 A / PF = 1**
421P050.010 REFUstor 50K	**50**	**128 A / PF = 1**
420P050.020 REFUstor 50K	**50**	**128 A / PF = 1**
880P100.020 REFUsol 100K	**88**	**128 A / PF = 1**

3. Parameter set during the measurement

File name:	Implemented in Firmware
Clear identification: (e.g. MD5 checksum)	

☒ No adaptations to the standard parameter set were carried out during the measurement.

☐ The following adaptations were made to the standard parameter set during the measurement:

Parameter (clear identification)	No. in *5*	Change	Justification as to why the change does not have an influence on the previous measurement results and these can be used as the result for the certification

4. Main Components of the regulating system

Main components of the control system with firmware and software	
Main component(s) of the control system (Hardware on which the control software is operated)	SR36300.2
Firmware version (clear identification of the firmware)	310-01-06-42-S
Software version (clear identification of the software)	
Parameter set (clear identification of the parameter set)	Implemented in FW-package

5. Relevant parameters for the electrical behaviour

General parameter settings (rated values or reference values)	
Parameter set for the default values	

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No.	Name	Description	Unit	Setting range		Default value (acc. to parameter set)
				Min.	Max.	
	1450.0	Rated active power	W			50000/88000/ 100000
	1450.1	Max. active power	W			50000/88000/ 100000
		Rated/max. apparent power				See active power
	601.0	Rated voltage (phase-to-earth)	V			230
	1451.0	Rated current	A			128
	979.0	Max. FRT current	A			128 (420P088, 421P100, 880P100) 73 (420P050, 421P050)
	602.0	Rated frequency	Hz			50
	1070.0	Operating mode				Sol: 1 = MPPT Stor: 0=power setpoint by 1071 or 1076
	1071.0	Active Power setpoint (saved)	W	-100000	100000	0
	1076.0	Active Power setpoint (unsaved)	W	-100000	100000	0
	1136.0	Active power pos. gradient (only when controlled by P-setpoint P1071/P1076)	$\%P_N/s$			0,6 (PGU) 100 (batt. Inverter)
	1136.1	Active power neg. gradient (only when controlled by P-setpoint P1071/P1076)	$\%P_N/s$			0,6 (PGU) 100 (batt. Inverter)
Active power peaks						
	1450.1	Maximum active power limit	W			50000/88000/ 100000
Operating power limited by grid operator						
	1171.0	Active power ramp in case of grid operator specification (increase) by P1162.0	%Pmax/s			0,6 (PGU) 1e+07 (batt. Inverter)
	1171.1	Active power ramp in case of grid operator specification (decrease) by P1162.0	%Pmax/s			0,6 (PGU) 1e+07 (batt. Inverter)
	1162.0	Ext. power limitation	%Pn*10			1000
	1216.0	If no new parameterization takes place for some time, the power limitation is withdrawn to this value.	W			1000
	1217.0	After this time, when no updated setpoint is available, the power limiting is set to the value of P1216.0	s			600
	1770.0	Extern communication controller heartbeat	s			0
	1772.0	Extern communication HeartBeat timeout	s			0
Active power feed-in as a function of grid frequency (PGU and battery inverter)						
	1232.0	Start frequency P(f) (Start of frequency regulation - power reduction) (only PGU)	Hz			50,2

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	1232.1	Start frequency P(f) (Start of frequency regulation - power increase) (only PGU)	Hz			49,8
	1231.0	Decrease factor for power reduction dP/Pmom (only PGU)	-			20
	1231.1	Increase factor for power increase dP/Pmom (only PGU)	-			20
	1234.0	Active power gradient with P(f) during critical grid status (only PGU)	$\%P_N$/min			9
	1553.0	Start frequency P(f) (Start of frequency regulation - power reduction) (only Battery storage)	Hz			50,2
	1553.1	Start frequency P(f) (Start of frequency regulation - power increase) (only Battery storage)	Hz			49,8
	1554.0	Static of P(f) in overfrequency (only Battery storage)	%			2
	1554.1	Static of P(f) in underfrequency (only Battery storage)	%			2
	1555	Waiting time (in critical grid status) (only Battery storage)	s			600
	1138.0	Ramp-up power gradient in critical grid status (only Battery storage)	$\%P_N$/s			0,15
	1138.1	Ramp-down power gradient in critical grid status (only Battery storage)	$\%P_N$/s			0,15
	1139.0	Ramp-up power gradient in P(f) mode (only Battery storage)	$\%P_N$/s			1000
	1139.1	Ramp-down power gradient in P(f) mode (only Battery storage)	$\%P_N$/s			1000
	1229	DC-charge-current limit (only Battery storage)	A		< 0	-200
	1230	DC-discharge-current limit (only Battery storage)	A	> 0		200
Active power gradient following disconnection from the grid						
	1201.0	start up ramp time to P_N after grid failure	ms			150000
	1201.1	start up ramp time to P_N after normal connection	ms			1000
Reconnection time following disconnection from the grid						
	1501.0	Time until reconnection	s	0	3600	30
	1501.1	Time until reconnection after grid fault	s	0	3600	600
Reactive power provision						
	1459.0	Cos phi specifications; minimum cos phi	-			0,3
	See P-Q-Diagram	Q specifications				
	1164.0	Q(U) characteristic (add -3% P_N with every value for Q acc. to the given characteristic)	-			15 VDE-AR-N4110 (Bild 8)
	1164.0	Q(U) characteristic (with voltage limiting)	-			13 VDE-AR-N4110 (Bild 10)
	1164.0	Q(P) characteristic	-			14 VDE-AR-N4110 (Bild 9)

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	1164.0	Cos phi (P) characteristic (bidirectional)	-			16
	1164.0	Cos phi (phi)	°			2 VDE-AR-N4110 (10.2.2.4)
	See P-Q-Diagram	Q limit overexcited				
	See P-Q-Diagram	Q limit underexcited				
	1451.0	Apparent current limit	A			128
	See P-Q-Diagram	Q limit at U110% underexcited				
	1402.0	Active power gradient (rise)	A/s			10000
	1402.1	Active power gradient (fall)	A/s			10000
	1402.2	Reactive power gradient (rise)	A/s			10000
	1402.3	Reactive power gradient (fall)	A/s			10000
	1030.1	Reactive power transfer function activation cos phi saved	-			0=off 1= PT1 (Standard) 2=linear
	1030.2	Reactive power transfer function activation cos phi unsaved	-			0=off 1= PT1 (Standard) 2=linear
	1030.13	Reactive power transfer function activation Q(U) with voltage limitation	-			0=off 1= PT1 (Standard) 2=linear
	1030.14	Reactive power transfer function activation Q(P)	-			0=off 1= PT1 (Standard) 2=linear
	1030.15	Reactive power transfer function activation Q(U)	-			0=off 1= PT1 (Standard) 2=linear
	1031.0	PT1 (3tau) of reactive power transfer function	s			10
	1273.0	Q(P) characteristic Node 1 P	%Pinst			0,1
	1274.0	Q(P) characteristic Node 1 Q	$\%P_N$			0
	1273.1	Q(P) characteristic Node 2 P	%Pinst			0,2
	1274.1	Q(P) characteristic Node 2 Q	$\%P_N$			0
	1273.2	Q(P) characteristic Node 3 P	%Pinst			0,3
	1274.2	Q(P) characteristic Node 3 Q	$\%P_N$			0
	1273.3	Q(P) characteristic Node 4 P	%Pinst			0,4
	1274.3	Q(P) characteristic Node 4 Q	$\%P_N$			0
	1273.4	Q(P) characteristic Node 5 P	%Pinst			0,5
	1274.4	Q(P) characteristic Node 5 Q	$\%P_N$			0
	1273.5	Q(P) characteristic Node 6 P	%Pinst			0,6
	1274.5	Q(P) characteristic Node 6 Q	$\%P_N$			0,05
	1273.6	Q(P) characteristic Node 7 P	%Pinst			0,7
	1274.6	Q(P) characteristic Node 7 Q	$\%P_N$			0,143
	1273.7	Q(P) characteristic Node 8 P	%Pinst			0,8
	1274.7	Q(P) characteristic Node 8 Q	$\%P_N$			0,236
	1273.8	Q(P) characteristic Node 9 P	%Pinst			0,9

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	1274.8	Q(P) characteristic Node 9 Q	%P_N			0,33
	1273.9	Q(P) characteristic Node 10 P	%Pinst			1
	1274.9	Q(P) characteristic Node 10 Q	%P_N			0,33
	1276.0	Q(U) characteristic node 1 U	%P_N			0,96
	1276.1	Q(U) characteristic node 2 Q	%P_N			0,33
	1276.2	Q(U) characteristic node 3 U	%P_N			1,04
	1276.3	Q(U) characteristic node 4 Q	%P_N			-0,33
	1277.0	Q(U) voltage deviation	%P_N			0
	1278.0	Q(U) voltage deadband	%U_N			0
	1164.0	Q(U) with voltage limiting characteristic	-			13
	1270.0	Q(U) characteristic node 1 U	%Uc			0,94
	1270.1	Q(U) characteristic node 1 Q	%P_N			-0,33
	1270.2	Q(U) characteristic node 2 U	%Uc			0,96
	1270.3	Q(U) characteristic node 2 Q	%P_N			0
	1270.4	Q(U) characteristic node 3 U	%Uc			1,04
	1270.5	Q(U) characteristic node 3 Q	%P_N			0
	1270.6	Q(U) characteristic node 4 U	%Uc			1,06
	1270.7	Q(U) characteristic node 4 Q	%P_N			0,33
	1271.0	Q-deviation	%P_N			0
	Implemented, not configurable	Reactive power-prioritised active power reduction				
System perturbations						
	1501.0	Time until reconnection	s	0	3600	30
	1501.1	Time until reconnection after grid fault	s	0	3600	600
PGU disconnection from the grid						
	902.0	U>> protection	%U_N	100	200	125
	903.0	t_u >> protection	S	0,000	3600,000	0,1
	902.1	U> protection	%U_N	100	200	0
	903.1	t_u > protection	S	0,000	3600,000	0,000
	900.0	U< protection	%U_N	0	100	80
	901.0	t_u < protection	S	0,000	3600,000	1,5
	900.1	U<< protection	%U_N	0	100	30
	901.1	t_u<< protection	s	0,000	3600,000	0,8
	906.0	f>>frequency	Hz (df)	0,00	50,00	2,5
	907.0	t_f>> frequency	s	0,000	3600,000	0,1
	906.1	f>frequency	Hz (df)	0,00	50,00	1,5
	907.1	t_f> frequency	s	0,000	3600,000	5
	904.0	f< frequency	Hz (df)	-50,00	0,00	-2,5
	905.0	t_f< frequency	s	0,000	3600,000	0,1
	904.1	f<< frequency	Hz (df)	-50,00	0,00	0,00

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	905.1	t_f<< frequency	s	0,000	3600,000	0,000
	910.0	U>> protection (p-to-p)	%U_N	100	200	125
	911.0	t_u >> protection (p-to-p)	s	0,000	3600,000	0,1
	908.0	U< protection (p-to-p)	%U_N	0	100	80
	909.0	t_u < protection (p-to-p)	s	0,000	3600,000	1,5
	908.1	U<< protection (p-to-p)	%U_N	0	100	30
	909.1	t_u<< protection (p-to-p)	s	0,000	3600,000	0,8
Connection conditions						
	1502.1	Limit value connection U>	%U_N	100	200	110
	1502.0	Limit value connection U<	%U_N	0	100	90
	1503.1	Limit value connection f>	Hz (df)	0,00	50,00	0,2
	1503.0	Limit value connection f<	Hz (df)	-50,00	0,00	-2,5
	1503.2	Limit value connection f> (after grid failure)	Hz (df)	0,00	50,00	0,1
	1503.3	Limit value connection f< (after grid failure)	Hz (df)	-50,00	0,00	-0,1
	1502.3	Limit value connection U> (after grid failure)	%U_N	100	200	110
	1502.2	Limit value connection U< (after grid failure)	%U_N	0	100	95
		…				
Response during grid faults						
	976.1	UVRT trigger threshold	%U_N			0,9
	974.0	k factor	-	0,000	10,000	2
	978.0	No reactive power feed-in no active power feed-in	-			0
	980.0	factor of Un; below this grid voltage threshold, the FRT current is equal to zero (limited dynamic grid support)	-	0	1	0,15
Dynamic response for fault ride-through (FRT) in the case of overvoltage						
	976.0	OVRT trigger threshold	%U_N			1,1
	974.0	k factor	-	0,000	10,000	2
	978.0	No reactive power feed-in no active power feed-in	-			0
Self-protection						
	1453.0	U>>> protection	V			332,4
	Hardware	I> overcurrent protection	A			229
	947.0	Temperature protection (heatsink)	°C			125
	947.1	Temperature protection (air)	°C			100

6. Relevant parameters for the electrical behaviour

Reading out the parameters

☒ The parameters can be read out using the following software.

Name:	REFUvis
Version:	1.8.0.23

☐ The parameters can be read out using the display in the control system.

7. Interfaces

7.1. Active power specification

Interfaces for the active power reduction by defined setpoint	
Analogue interfaces for active power specification (e.g. 0 V – 10 V, 4 mA – 20 mA)	n/a
Digital interfaces for active power specification (e.g. potential-free inputs, protocol IEC 60870-5-104)	n/a
Measured interface(s)	n/a

7.2. Reactive power specification

Interfaces for the provision of reactive power	
Analogue interfaces for the specification of reactive power (z.B. 0 – 20 mA, 4 - 20 mA, 0 – 10 V or -10 - 10 V, Q or cosφ)	n/a
Digital interfaces for reactive power specification (e.g. protocol IEC 60870-5-104)	n/a
Permanently adjustable, not variable via external setpoints (e.g. cosφ fixed value and Q fixed value, Q(U) characteristic, cosφ(P) characteristic)	φ fix, Q fix
Types of reactive power specification (e.g. cosφ and Q, Q(U) characteristic, cosφ(P) characteristic)	φ, Q, Q(U), Q(P)
Measured interface(s) and type of reactive power specification	
External actual value capture possible? (for example for control at the PCC)	n/a
Measured interface(s)	

Figure 24 – Parameter list from [14]