# Unbedenklichkeitsbescheinigung

**Hersteller / Antragsteller:** **KACO new energy GmbH**
Werner-von-Siemens-Allee 1
74172 Neckarsulm
**Deutschland**

| | | |
|---|---|---|
| **Typ Erzeugungseinheit:** | **Photovoltaikwechselrichter** | |
| **Name der EZE:** | KACO blueplanet 60.0 TL3 (Photovoltaik Wechselrichter, PV), unter Bezugnahme auf die folgenden Typen: | |
| | KACO blueplanet 60.0 TL3 M1 WM OD IIGB,<br>KACO blueplanet 60.0 TL3 M1 WM OD IIGM<br>KACO blueplanet 60.0 TL3 M1 WM OD IIGX,<br>KACO blueplanet 60.0 TL3 M1 WM OD FRGX<br>KACO blueplanet 60.0 TL3 M1 WM OD TWGB,<br>KACO blueplanet 60.0 TL3 M1 WM OD KRGB | KACO blueplanet 50.0 TL3 M1 WM OD IIGM;<br>KACO blueplanet 50.0 TL3 M1 WM OD IIGB,<br>KACO blueplanet 50.0 TL3 M1 WM OD IIGX,<br>KACO blueplanet 50.0 TL3 M1 WM OD IIGS,<br>KACO blueplanet 50.0 TL3 M1 WM OD FRGX |
| **Wirkleistung (Nennleistung bei Nennbedingungen) [kW]:** | 60 | 50 |
| **Bemessungsspannung:** | 220 / 380; 230 / 400; 240 / 415 (3/N/PE – 3/PEN); 42 – 68 Hz | 220 / 380; 230 / 400; 240 / 415 (3/N/PE – 3/PEN); 42 – 68 Hz |
| **Firmware Version:** | **ab V5.74** | |

**Netzanschlussregel:** **TOR Erzeuger: Anschluss und Parallelbetrieb von Stromerzeugungsanlagen des Typs B** (Maximalkapazität ≥ 250 kW und < 35 MW und Nennspannung < 110 kV); Version 1.1

**Mitgeltende Normen / Richtlinien:**

**OVE-Richtlinie R25:2020-03**

Prüfanforderungen an Erzeugungseinheiten (Generatoren) vorgesehen zum Anschluss und Parallelbetrieb an Niederspannungsverteilnetzen

**Technische Richtlinien: FGW TR3 Rev. 25, FGW TR4 Rev. 9**

Bestimmung der elektrischen Eigenschaften von Erzeugungseinheiten und -anlagen, Speichern sowie für deren Komponenten am Mittel-, Hoch- und Höchstspannungsnetz

Anforderungen an Modellierung und Validierung von Simulationsmodellen der elektrischen Eigenschaften von Erzeugungseinheiten und -anlagen, Speicher sowie Komponenten

Die im Zertifikat aufgeführte Erzeugungseinheit wurde nach den, in der Netzanschlussregel referenzierten, technischen Richtlinien geprüft und zertifiziert. Die in der Netzanschlussregel geforderten elektrischen Eigenschaften werden erfüllt hinsichtlich:

- Frequenzhaltung
- Robustheit und dynamischer Netzstützung
- statischer Spannungshaltung
- Netzmanagement und Systemschutz (auf Einheitenebene)
- Synchronisierung und Netzwiederaufbau
- Netzrückwirkungen

Anmerkung (Einschränkung und Abweichung): Eine Prüfklemmleiste ist bei Bedarf separat nachzurüsten.

**Das Zertifikat beinhaltet folgende Angaben:**

- technische Daten der Erzeugungseinheit, der eingesetzten Hilfseinrichtungen und der verwendeten Softwareversion
- schematischen Aufbau der Erzeugungseinheit
- Referenz-Prüfberichte

**Projektnummer:** **15TH0250-OVE-directive R25_0**
**15TH0250_TR3_Rev.25_4**

**Zertifizierungsprogramm:** **NSOP-0032-DEU-ZE-V01**

**Zertifikatsnummer:** **U21-0324**

**Ausstellungsdatum:** **2021-04-13**

**Zertifizierungsstelle**

Thomas Lammel

*Zertifizierungsstelle der Bureau Veritas Consumer Products Services Germany GmbH Akkreditiert nach DIN EN ISO/IEC 17065*

*Eine auszugsweise Darstellung des Zertifikats bedarf der schriftlichen Genehmigung der Bureau Veritas Consumer Products Services Germany GmbH*

## Anhänge im Zertifikat U21-0324

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## 1. Anhang 1 – Referenzen

Dieses Zertifikat beruht auf folgenden Dokumenten:

| Referenz | Richtlinien |
|---|---|
| A.1 | TOR Erzeuger: Anschluss und Parallelbetrieb von Stromerzeugungsanlagen des Typs A und von Kleinsterzeugungsanlagen (Maximalkapazität < 250 kW und Nennspannung < 110 kV)<br>Version 1.1, 2019-12-12 |
| A.2 | TOR Erzeuger: Anschluss und Parallelbetrieb von Stromerzeugungsanlagen des Typs B<br>(Maximalkapazität ≥ 250 kW und < 35 MW und Nennspannung < 110 kV)<br>Version 1.1, 2019-12-12 |
| A.3 | OVE-Richtlinie R 25: 2020-03-01<br>Prüfanforderungen an Erzeugungseinheiten (Generatoren) vorgesehen zum Anschluss und Parallelbetrieb an Niederspannungs-Verteilernetzen |
| A.4 | Technische Regeln für den Anschluss von Kundenanlagen an das Mittelspannungsnetz und deren Betrieb (TAR Mittelspannung), VDE-AR-N 4110:2018-11 |
| A.5 | Technische Regeln für den Anschluss von Kundenanlagen an das Hochspannungsnetz und deren Betrieb (TAR Hochspannung), VDE-AR-N 4120:2018-11 |
| A.6 | 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 |
| A.7 | 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 |
| A.8 | EN 50549-2:2019 Anforderungen für zum Parallelbetrieb mit einem Verteilnetz vorgesehene Erzeugungsanlagen - Teil 2: Anschluss an das Mittelspannungsverteilnetz für Erzeugungsanlagen bis einschließlich Typ B |

| Referenz | Zertifikate |
|---|---|
| B.1 | U21-0248<br>Unbedenklichkeitsbescheinigung (U21-0248) nach TOR Erzeuger Typ A:2019-12, ausgestellt von Bureau Veritas Consumer Products Services Germany GmbH am 20.08.2020 |
| B.2 | 20-0296_6<br>Einheitenzertifikat nach VDE-AR-N 4110:2018-11 und VDE-AR-N 4120:2018-11, ausgestellt von Bureau Veritas Consumer Products Services Germany GmbH am 24.04.2020 |
| B.3 | U20-0266<br>Unbedenklichkeitsbescheinigung EN 50549-2:2019 Anforderungen für zum Parallelbetrieb mit einem Verteilnetz vorgesehene Erzeugungsanlagen - Teil 2: Anschluss an das Mittelspannungsverteilnetz für Erzeugungsanlagen bis einschließlich Typ B |

| Referenz | Prüfberichte |
|---|---|
| C.1 | 15TH0250-OVE-directive R25_0<br>Prüfbericht gemäß OVE-Richtlinie R 25: 2020-03-01, ausgestellt von Bureau Veritas Consumer Products Services Germany GmbH, Businesspark A96 86842 Türkheim Germany am 16.03.2021 |
| C.2 | 15TH0250_TR3_Rev.25_4<br>TR3 Prüfbericht gemäß FGW TR3 Rev.25, ausgestellt von Bureau Veritas Consumer Products Services Germany GmbH am 23.04.2020 |
| C.3 | 15TH0250_TR4_Rev9_2<br>15TH0250_BP60_TR4_Rev9_0<br>TR4 Prüfberichte gemäß FGW TG4 Rev.09, ausgestellt von Bureau Veritas Consumer Products Services Germany GmbH am 22.04.2020 |
| C.4 | 15TH0250-EN50549-2_0<br>Prüfbericht zum Nachweis der Konformität mit EN 50549-2:2019, ausgestellt von Bureau Veritas Consumer Products Services Germany GmbH am 17.04.2020 |

## 2. Anhang 2 – Technische Eigenschaften der Erzeugungseinheiten

### 2.1. Beschreibung der Erzeugungseinheiten

| | | | | |
|---|---|---|---|---|
| **Hersteller / Antragsteller:** | KACO new energy GmbH<br>Werner-von-Siemens-Allee 1<br>74172 Neckarsulm<br>Deutschland | | | |
| **Typ Erzeugungseinheit:** | Photovoltaikwechselrichter | | | |
| **Name der EZE:** | KACO blueplanet 50.0 TL3 | KACO blueplanet 60.0 TL3 | -- | -- |
| **Wirkleistung [kW]:** | 50 nom. / 52 max. | 60 | -- | -- |
| **Scheinleistung [kVA]:** | 50 nom. / 52 max. | 60 | -- | -- |
| **Bemessungsspannung [V]:** | 220 / 380; 230 / 400; 240 / 415 (3/N/PE – 3/PEN); 42 – 68 Hz | 220 / 380; 230 / 400; 240 / 415 (3/N/PE – 3/PEN); 42 – 68 Hz | -- | -- |
| **Bemessungsstrom (AC) $I_r$ [A]:** | 3 x 76,5 | 3 x 90 | -- | -- |
| **Firmware Version:** | ab V5.74 | | | |
| **Messzeitraum:** | 2021-01-12 – 2021-03-15, | | | |
| **Wirk- / Scheinleistungsbereich**<br>(ermittelte Messwerte bei Nennspannung) | | | | |
| Name der EZE: | KACO blueplanet 50.0 TL3 | KACO blueplanet 60.0 TL3 | -- | -- |
| $P_{Emax}$ [kW] bei cos φ = 1 | 50241 | 59504 | -- | -- |
| $S_{Emax}$ [kVA] bei cos φ = 1 | 50241 | 59507 | -- | -- |
| $P_{Emax}$ [kW] bei cos $\varphi_{untererregt}$ = 0,9 | 44620 | 54532 | -- | -- |
| $S_{Emax}$ [kVA] bei cos $\varphi_{untererregt}$ = 0,9 | 49827 | 60238 | -- | -- |
| $P_{Emax}$ [kW] bei cos $\varphi_{übererregt}$ = 0,9 | 45471 | 54532 | -- | -- |
| $S_{Emax}$ [kVA] bei cos $\varphi_{übererregt}$ = 0,9 | 50430 | 60816 | -- | -- |
| Anmerkung:<br>Bei cos φ = 1 entspricht die Wirkleistung der Bemessungsscheinleistung.<br>Für die Umsetzung einer Blindleistungssollwertvorgabe wird bei Bedarf die Wirkleistung reduziert. | | | | |

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

### 2.2. Description of the power generating unit

**Description of the power circuit (Figure 3)**

The photovoltaic (PV) converters KACO blueplanet 50.0 TL3 M1 WM OD IIGM, KACO blueplanet 50.0 TL3 M1 WM OD IIGB, KACO blueplanet 50.0 TL3 M1 WM OD IIGX, KACO blueplanet 50.0 TL3 M1 WM OD FRGX, KACO blueplanet 50.0 TL3 M1 WM OD IIGS, KACO blueplanet 50.0 TL3 M1 WM OD HUGM and KACO blueplanet 50.0 TL3 M1 WM OD HUGX as well as KACO blueplanet 60.0 TL3 M1 WM WM OD IIGB, KACO blueplanet 60.0 TL3 M1 WM OD IIGM, KACO blueplanet 60.0 TL3 M1 WM OD IIGX and KACO blueplanet 60.0 TL3 M1 WM OD FRGX convert DC voltage, generated by photovoltaic modules, into AC voltage.

The units are three-phase.

Powador-protect:

The Powador-protect is an interface protection relay and controls the breakers that connect the inverter/generator with the grid. The device serves as disconnection facility for illegitimate frequency and voltage over- or undershooting. Two digital outputs provide a disconnection signal for external circuit breakers. So two external circuit breakers can be controlled. If these breakers are connected in series the opening of the output circuit will even operate in case of a malfunction of one of the breakers.

KACO blueplanet 50.0 / 60.0 TL3 M1- XL

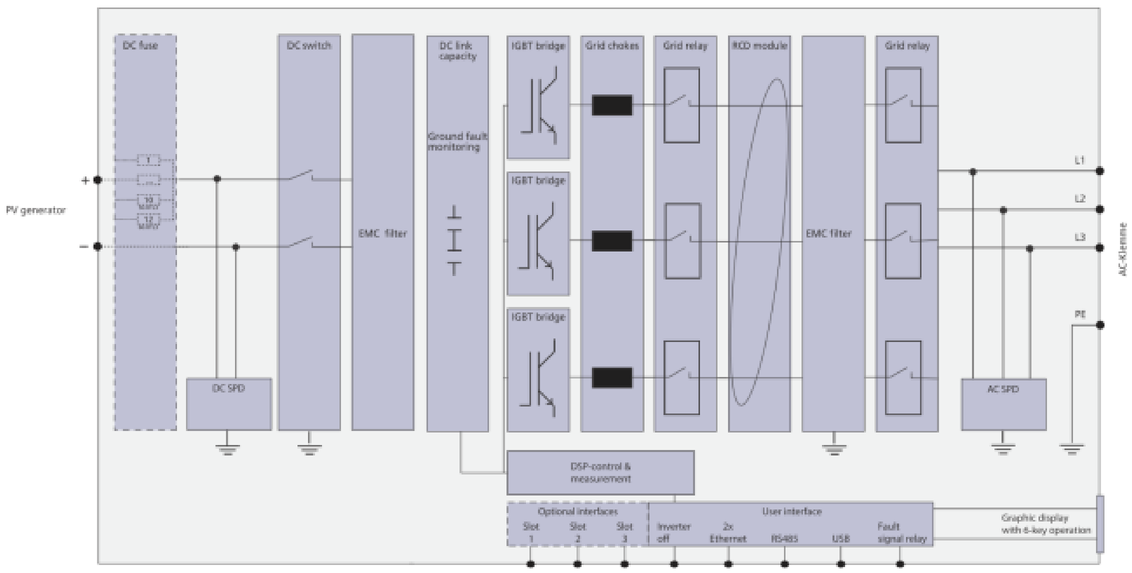


**Figure 3 – Block diagram of the power circuit 1 (PV)**

**Description of the differences of the models within a series:**

The units of the series are identical hardware platforms [7].

The implemented control and firmware are identical in all units. There is no difference regarding AC behavior between the PGU-types apart from the power rating deviation and current limitation of each unit.

If not stated otherwise the test results of the KACO blueplanet 50.0 TL3 can be applied directly to the KACO blueplanet 60.0 TL3.

**Description of the remote control in a typical installation (Figure 4)** *(Manufacturer's data)*:

Up to 31 KACO blueplanet inverters are connected to an individual Powador-proLOG XL box via RS485. One control box is defined as Master and up to 20 Powador-proLOG XL boxes can be connected as Slaves via Ethernet. Visualization and parameterization is adjusted via the web interface.

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

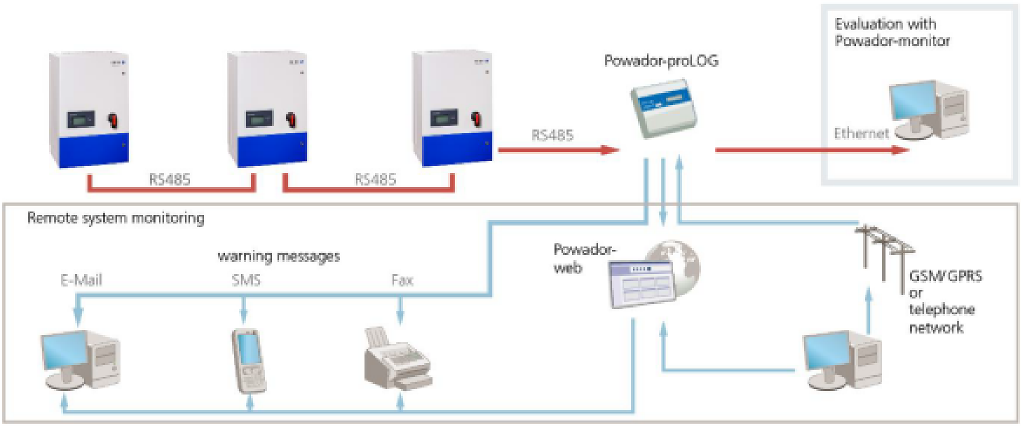


**Figure 4 – Scheme of an installation**

**Description of the connection to the remote control receiver (Figure 5)** *(Manufacturer's data)*:

The ripple signal controller is connected to the Powador-proLOG XL box. The four digital inputs can be parameterized. The control box sends the set-point commands via RS485 to the inverters directly. Optionally the set-point signals of the Powador-proLOG XL can be sent via the Powador-protect to the inverters.

The ripple signal is sent in 2 minutes intervals typically. If the there is no new signal within 5 minutes, the inverters' outputs are reset to 100% $P_n$.

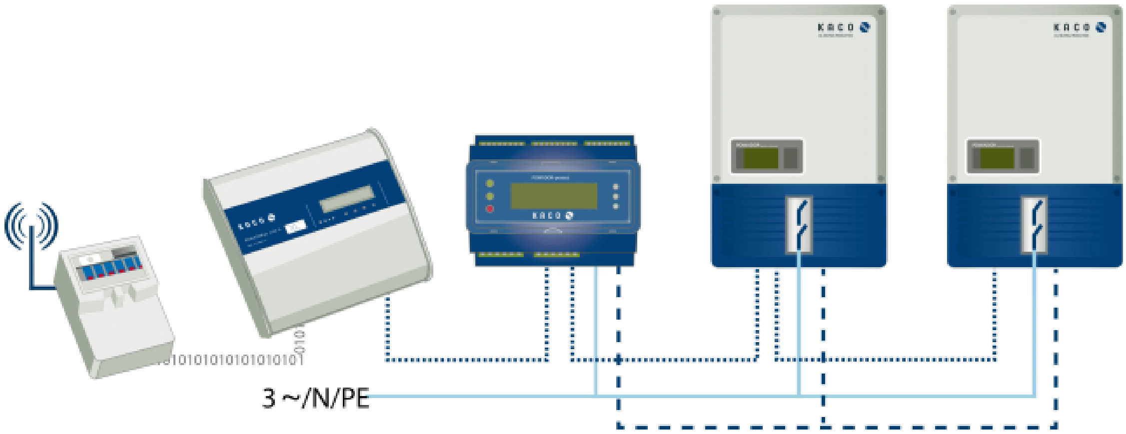


**Figure 5 – Connection of the remote control receiver in an installation**

## 2. Anhang 2 – Technische Eigenschaften der Erzeugungseinheiten

### 2.2. Beschreibung der Schnittstellen zur Regelung von Wirk- und Blindleistung

# 4 Control - modes

The inverters listed above make use of the following functions in order to control the reactive power. These are described in the following section:

- cos-ϕ const.
- Q const.
- cos ϕ/(p/pn)
- Q(U) 10 nodes

Reactive power is prioritised in all modes. The maximum possible active power that can be fed in is reduced in line with the P-Q operating range in accordance with Figure 1 to Figure 8 subject to the reactive power operating point.

## 4.1 cos φ constant

In cos φ constant mode, the specified displacement factor cos φ is set permanently by the inverter. In doing so, the reactive power level is set according Q=P*tan φ dependent on power output which produces the specified displacement factor cos φ continuously. If the specification is changed, the new value is adopted attenuated by a filter. The transient time is 1s with the transient response of a first-order filter (PT-1) with a time constant of Tau=200ms. The specified displacement factor may be configured in the display or via communication, via KACO RS485 protocol and MODBUS/SunSpec.

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



Parameter:

| Parameter name | Setting | Description |
|---|---|---|
| Displacement factor cos φ | 1-0,3 | Specified displacement factor |
| Excitation | Over-excited \| under-excited | Reactive power operating type, under-excited corresponds to inductive load, over-excited corresponds to capacitive load |

If the applicable grid code requires the cos φ response to set point by a defined gradient or settling time slower than the configured Tau=200ms, this gradient or settling time must be implemented in the plant control system.

### 4.2 Q constant

In Q constant mode, the specified reactive power value is set permanently by the inverter. If the specification is changed, the new value is adopted attenuated by a filter. The transient time is 1s with the transient response of a first-order filter (PT-1) with a time constant of Tau=200ms. The specified reactive power may be configured in the display or via communication, via KACO RS485 protocol and MODBUS/SunSpec.

Parameter:

| Parameter name | Setting | Description |
|---|---|---|
| Reactive power Q | 0-100 [% $S_{max}$] | Specification as a % of the maximum power |
| Excitation | Over-excited \| under-excited | Reactive power operating type, under-excited corresponds to inductive load, over-excited corresponds to capacitive load. |

If the applicable grid code requires the reactive power response to set point by a defined gradient or settling time slower than the configured Tau=200ms, this gradient or settling time must be implemented in the plant control system.

### 4.3 cos ϕ(p/pn)

In cos ϕ(p/pn) mode, the set value of cos ϕ and, derived from this, the set value of the reactive power is calculated continuously as a function of the actual power level. This function ensures that grid support is provided by the reactive power when a significant voltage increase is anticipated due to a high feed-in level. A characteristic curve is specified which can be used to configure up to 10 nodes, value pairs for active power and cos ϕ. The active power is entered as a % in relation to the nominal power. Other parameters allow to limit functionality and to limit activation to certain voltage ranges.

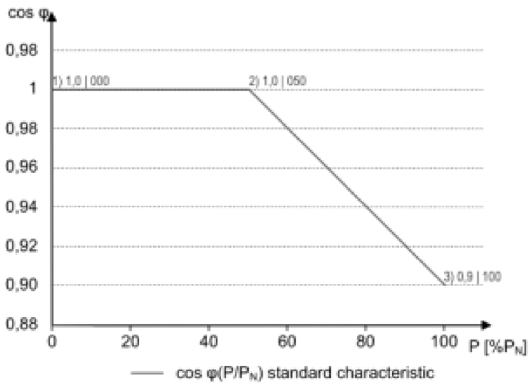


*Figure 11: Standard characteristic curve with 3 nodes*

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



Parameter:

| Parameter name | | Setting | Description |
|---|---|---|---|
| Settling time | | 200 – 30000 [ms] | Specifies the dynamic behaviour at change of cos ϕ set point. On an active power change, or at lock in or lock out, the cos ϕ is changed according a PT-1 characteristic with a settling time equal to 5 Tau. |
| Lock-in voltage | | 23 – 287 [V] | Control is activated above this voltage. |
| Lock-out voltage | | 23 – 287 [V] | Control is deactivated below this voltage |
| Number of support nodes | | 2 – 10 | Specify the number of nodes for the cos ϕ/(p/pn) characteristic curve |
| Nodes | Power | 0 – 100 [%$S_{max}$] | Power of the node as a percentage of the maximum power<br>For the 1st node, the power must be 0%; for the last node, the power must be 100%. The power values of the nodes must increase continuously.<br>Note: Storage inverter only in in-feed mode |
| | cos ϕ | 1 – 0,3 | cos ϕ of the node |
| | Excitation | Over-excited \| under-excited | Reactive power operating type, under-excited corresponds to inductive load, over-excited corresponds to capacitive load. |

### 4.4 Q(U) 10 nodes

In Q(U) 10 nodes mode, the set value of the reactive power is calculated continuously as a function of the grid voltage. This function ensures that grid support is provided by reactive power as soon as the voltage actually deviates from the target voltage. In this case, a characteristic curve is specified which can be used to configure up to 10 nodes, value pairs for voltage and reactive power. Other parameters allow to limit functionality and to limit activation to certain power levels as well as parametrise the transient response.

The positive sequence voltage is used to calculate the reactive power target value for three-phase units.

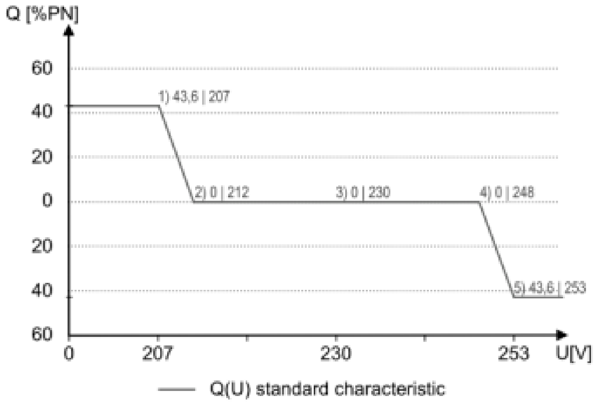


*Figure 12: Standard characteristic curve with 5 nodes*

Parameter:

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

### Application note - functional description

for grid support functions of TL3 series KACO inverters

Reactive Power - Operating range and control methods - SW: 5.5x / 1.2x / 3.1x

KACO new energy.

| Parameter name | | Setting | Description |
|---|---|---|---|
| Lock-in power | | 0 – 100 [% $S_{max}$] | Active power threshold above which the function is activated. |
| Lock-out power | | 0 – 20 [% $S_{max}$] | Active power threshold below which the function is deactivated. |
| Lock-in time | | 0 – 60 [s] | The length of time that the active power must remain above the lock-in power level before control is activated |
| Lock-out time | | 0 – 60 [s] | The length of time that the active power must remain below the lock-out power level before control is deactivated |
| Settling time | | 1 – 120 [s] | Transient time in the event of a step in the reactive power target value (e.g. caused by a voltage jump). The transient behaviour corresponds to a first-order filter (PT-1) with settling time = 5Tau.<br>Note: The settling time is superimposed with the increase and decrease gradient. |
| Dead time | | 0 – 10 [s] | If the voltage switches from a characteristic curve section with Q=0 to a characteristic curve section with Q≠0, the reactive power setting process is delayed by the set dead time. Once the dead time has elapsed, the control circuit is no longer delayed and the settling time determines the dynamic behaviour. |
| Output gradient limitation | | | In addition to configuring the dynamic behaviour using the settling time corresponding to a first-order filter, the reactive power setting can be determined by a maximum gradient - maximum change in the reactive power per time period |
| | increase | 1 – 60000 [% $S_{max}$ /min] | Maximum change in the reactive power %$S_{max}$/min in the event of a change to over-excited mode<br>Note: The gradient is superimposed with the settling time. |
| | decrease | 1 – 60000 [% $S_{max}$ /min] | Maximum change in the reactive power %$S_{max}$/min in the event of a change to under-excited mode<br>Note: The gradient is superimposed with the settling time. |
| Minimum cos φ | | | In the event of a significant voltage deviation, the maximum reactive power adjustment range can be limited by a minimum cos φ in order to prevent an excessive reactive power supply and, as a result, a significant reduction in the maximum active power that can be fed in. |
| | Q1 | 0\|0.3 – 1 | Minimum cos φ in over-excited operating mode (in-feed). |
| | Q4 | 0\|0.3 – 1 | Minimum cos φ in under-excited operating mode (in-feed). |
| | Q2 | 0\|0.3 – 1 | Only for storage inverter:<br>Minimum cos φ in over-excited operating mode (charge). |
| | Q3 | 0\|0.3 – 1 | Only for storage inverter:<br>Minimum cos φ in under-excited operating mode (charge). |

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

### Application note - functional description

for grid support functions of TL3 series KACO inverters

KACO new energy.

Reactive Power - Operating range and control methods - SW: 5.5x / 1.2x / 3.1x

| | | | |
|---|---|---|---|
| Priority mode | | Q priority \| P priority | P priority can be selected as an alternative to the standard setting Q priority. In P priority, the reactive power adjustment range is limited subject to the apparent power limitation of the inverter and the active power that is currently available and fed in. |
| Active curve | | 1 – 4 | Up to 4 characteristic curves can be configured independently and one of them can be activated for regulation each time. |
| Reset curve | | | Reset the active curve to the factory setting, depends on configured country setting. |
| Number of nodes | | 2 – 10 | Specify the number of nodes for the Q(U) characteristic curve |
| Nodes | Voltage | 0 – max. voltage in continuous operation | Voltage of the node in volts.<br>The voltage values of the nodes must increase continuously. For voltages below the 1st node and voltages above the last node, the reactive power value of the 1st or last node is used each time. |
| | Reactive power | 0 – 100 [% $S_{max}$] | Reactive power of the node as a percentage of the maximum power |
| | Excitation | Over-excited \| under-excited | Reactive power operating type, under-excited corresponds to inductive load, over-excited corresponds to capacitive load. |

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**Figure 7 – Interfaces provided for active and reactive power setting from** [21]

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

Following are the interfaces provided for active power setting [20]:

# 2 Regulating active power

Methods for controlling the active power of feed-in inverters may be necessary for local management of load flows, for voltage stability in the distribution network and for ensuring the stability of the interconnected network.

The device makes use of the following functions in order to control the active power. These are described in the following section:

- P set (MPPT/communication)
- P limit (communication)
- P(U) (characteristic)
- P(f) (characteristic)

## 2.1 P set

### 2.1.1 PV inverter

The function P set is intrinsically integrated in PV inverters in the MPP-tracking of the inverter. The P set value is constantly recalculated based on the MPP tracking algorithm to ensure maximum yield of the PV generator.

### 2.1.2 Storage inverter

The function P set is available via MODBUS/SunSpec communication, inverter model 64201 WSetPct only. The function is available for managing load flows of the battery and in a plant. If the set value is changed the new value is adopted by way of a filter and a gradient limitation.

**Parameters:**

| Parameter name | Setting | Description |
|---|---|---|
| **P set**<br>[WSetPct] | -100 – 100<br>[% $S_{max}$] | Specifies the set point of active power. |
| **Settling time**<br>[WparamRmpTms] | 200 – 60000<br>[ms] | Specifies the dynamic behaviour at change of active power set point. The active power is changed according a PT-1 characteristic with a settling time equal to 5 Tau.<br>Note: the settling time is superimposed with the increase and decrease gradient. |
| **Increasing output gradient**<br>[WparamRmpDecTmm]<br>and<br>**Decreasing output gradient**<br>[WparamRmpIncTmm] | 1 – 65534<br>[% $S_{max}$ / min] | Specifies the dynamic behaviour at change of active power set point. The active power is changed with the specified gradient.<br>Note: The gradient is superimposed with the settling time. |

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

Application note - functional description

for grid support functions of TL3 series KACO inverters

Active power control functions SW: 5.5x / 1.2x / 3.1x

KACO new energy.

### 2.2 P limit

The function "P limit" is available limiting the maximum in-feed power. If necessary, this can be used to reduce the in-feed of an inverter e.g. for congestion management of the distribution system operator.

P limit is available via MODBUS/SunSpec inverter model 123 WMaxLimPct and RS485 communication only. For detailed information on the communication protocol please refer to the download section at www.kaco-newenergy.de subsection "software".

At reception of a P limit set value, the output power of the inverter is limited to the specified power value. If the limit value is changed, the new value is adopted by way of a filter and a gradient limit. The actual power of the inverter may vary freely below this limit based on possible fluctuation of the available power or set point, but will never increase above the absolute power limit. Depending on the inverter series, the settling time and gradient limit are adjustable.

Parameters:

| Parameter name | Setting | Description |
|---|---|---|
| Fallback power | 0 – 100 [% $S_{max}$ ] | Specifies the default power in case of loss of communication. If no active power command is received for the configured timeout, the inverter adapts the power to the configured fallback power. |
| Timeout | 3 – 100000 [s] | Specifies the timeout period until the inverter reverts to fall back power in case of loss of communication. |
| Increasing output gradient<br>and<br>Decreasing output gradient | 1 – 65534 [% $S_{max}$ / min] | Only available in blueplanet 87.0 TL3 – 165 TL3 and blueplanet gridsave<br>In all other inverters the gradient limitation is deactivated.<br>Specifies the dynamic behaviour at change of active power set point. The active power is changed with the specified gradient.<br>Note: The gradient is superimposed with the settling time. |
| Settling time | 200 – 60000 [ms] | Only available in blueplanet 87.0 TL3 – 165 TL3 and blueplanet gridsave<br>In all other inverters 1 s is set unconfigurable.<br>Specifies the dynamic behaviour at change of active power set point. The active power is changed according a PT-1 characteristic with a settling time equal to 5 Tau.<br>Note: The settling time is superimposed with the increase and decrease gradient. |

If the applicable grid code requires the active power response to a set point by a defined gradient or settling time, blueplanet 87.0 TL3 – 165 TL3 and blueplanet gridsave can be configured to comply with this gradient. It is also possible to implement the gradient in the plant control system. This second solution must be applied for all other inverters.

### 2.3 Voltage-dependent power reduction P(U)

If it is not possible to compensate adequately for voltage increase in the upstream distribution network by consumption of reactive power, it may be necessary to curtail the active power. In this case, P(U) control is available for making optimum use of the capacity of the upstream grid.

P(U) control reduces the active power that is fed-in as a function of the grid voltage using a prescribed characteristic curve as a basis. The P(U) control is implemented as an absolute power limit. The actual power of the inverter may vary freely below this limit based on possible fluctuation of the available power or set point, but will never increase above the absolute power limit.

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

### Application note - functional description

for grid support functions of TL3 series KACO inverters

Active power control functions SW: 5.5x / 1.2x / 3.1x

KACO new energy.

Figure 1 and Figure 2 are two example configurations. In case of the Figure 1 without hysteresis the function is activated once the voltage exceeds the configured voltage of data point 1 (dp1). The power limit follows the characteristic, a straight line between dp1 and dp2. The function is deactivated once the voltage falls below dp1. In case of Figure 2 the function is activated once the voltage exceeds the configured voltage of dp2. dp1 is not activating the function in this case as the power limit remains at 100%. The power limit follows the characteristic, a straight line between dp2 and dp3, but due to the activated hysteresis, the power limit is not increased at falling voltage. The function is deactivated once the voltage falls below dp1.

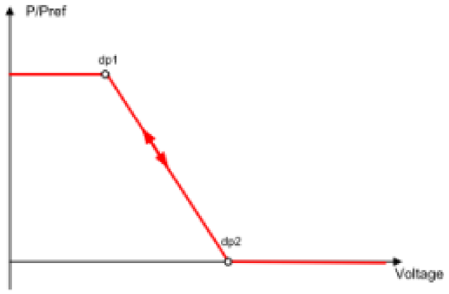


*Figure 1: example characteristic without hysteresis*

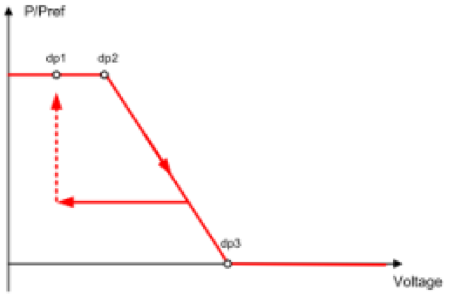


*Figure 2: example characteristic with hysteresis and a deactivation threshold lower than the activation threshold.*

In case of storage inverters, the function is only available in discharge, grid feed-in mode, not in battery-charge mode.

Parameters:

| Parameter name | Setting | Description |
|---|---|---|
| Mode | On \| Off | Enable or disable function |
| Reference Power | Actual power \| Nominal power | Specifies the power reference for the characteristic. 100 % to be the nominal power or the actual power at the instant of activation of the function, the instant when the voltage passes the configured node. |
| Evaluated voltage | Positive sequence voltage \| Maximum phase voltage | Specifies which voltage in a three phase system is evaluated. |
| Hysteresis mode | On \| Off | Off: In Non-Hysteresis mode, the active power is increase immediately in cases of falling voltage.<br>On: In Hysteresis mode the power is not increased in case of falling voltage. |
| Deactivation gradient | 1 – 65534 [% $S_{max}$/ min] | If available power is above actual power at the instant of deactivation, the power increase back to maximum power is restricted. The restriction is implemented by an absolute power limit that is increasing with a continuous gradient up to maximum power. The actual power of the inverter may vary freely below this limit based on possible fluctuation of the available power or set point, but will never increase above the absolute power limit. |
| Deactivation time | 0 – 60.000.000 [ms] | Only evaluated in Hysteresis mode On: Observation time for voltage to remain below lowest configured node before function is deactivated. |

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



| | | |
|---|---|---|
| Output gradient limitation increase | 1 – 65534 [% $S_{max}$ / min] | Specifies the dynamic behaviour at change of active power change for power increase. On a voltage change, the active power is changed with the specified gradient.<br>Note: The gradient is superimposed with the settling time. |
| Output gradient limitation decrease | 1 – 65534 [% $S_{max}$ / min] | Specifies the dynamic behaviour at change of active power change for power decrease. On a voltage change, the active power is changed with the specified gradient.<br>Note: The gradient is superimposed with the settling time. |
| Settling time | 200 – 120000 [ms] | Specifies the dynamic behaviour at change of active power set point. On a voltage change, the active power is changed according a PT-1 characteristic with a settling time equal to 5 Tau.<br>Note: The settling time is superimposed with the increase and decrease gradient. |
| Characteristic | Voltage: 80 – 125 [% $U_{nom}$]<br>Power: 0 – 100 [% $P_{ref}$] | Up to 5 nodes configurable for voltage [V] and power [% $P_{ref}$]. The power-value of the first and the last value pair is also used as maximum, minimum respectively active power value which is valid beyond the limits of the characteristic. |

## 2.4 P(f) Active power response to overfrequency of PV inverters

Feed-in inverters must assist with frequency stability in the grid. If the grid frequency leaves the normal tolerance range (e.g. ±200 mHz), the grid is in a critical state. In the event of overfrequency, there is a generation surplus, in the event of underfrequency, there is a generation deficit.

PV-Systems must adapt their active feed-in power in relation to the frequency deviation. In case of overfrequency the adaption of power is defined by a maximum feed-in limit. The actual power of the inverter may vary freely below this limit based on possible fluctuation of the available power or set point, but will never increase above the absolute power limit.

Equation 1defines the maximum limit with ΔP according to Equation 2, $P_M$ the actual power at the moment of activation and $P_{ref}$ the reference power. In KACO PV inverters $P_{ref}$ is defined as $P_M$, the actual power at the moment of activation. f is the actual frequency and $f_1$ is the activation threshold as configured.

$$P_{max-limit} = P_M + \Delta P \qquad \text{Equation 1}$$

$$\Delta P = g \cdot P_{ref} \cdot (f_1 - f). \qquad \text{Equation 2}$$

In some standards the power adaption is not defined by a gradient – g but by a droop – s as in Equation 3. The droop s can be converted to a gradient g according to Equation 4.

$$\Delta P = \frac{1}{s} \times \frac{(f1 - f)}{fn} \times Pref \qquad \text{Equation 3}$$

$$g = \frac{1}{s \cdot f_n} \qquad \text{Equation 4}$$

During an overfrequency event the frequency f is above the activation threshold $f_1$. Therefore the term $(f_1 - f)$ is negative and ΔP is a in-feed power reduction.

The measurement accuracy of the frequency is better than 10mHz.

The specific mode of operation of the function is specified by the grid operator or by applicable standards or grid codes. The configurability of the function makes it possible to meet a wide variety of standards and grid codes.

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

### Application note - functional description

for grid support functions of TL3 series KACO inverters

Active power control functions SW: 5.5x / 1.2x / 3.1x

KACO new energy.

Certain configuration options are not available in some country settings because the applicable standards or grid codes prohibit adjustments.

Parameters:

| Parameter name | Setting | Description |
|---|---|---|
| Mode | Off \| Mode 1 \| Mode 2 | Enable or disable function.<br>Mode 1: enable with hysteresis. See Figure 4.<br>Mode 2: enable without hysteresis. See Figure 3. |
| Activation threshold ($f_1$) | 45 – 65 [Hz] | Specifies the frequency threshold to activate the function if Mode is enabled. |
| Deactivation range lower limit | 45 – Activation threshold [Hz] | Only evaluated in Mode 1.<br>The function is deactivated if the frequency re-enters the deactivation range and remains there for the duration of the deactivation time. |
| Deactivation range upper limit | Deactivation range lower limit – Activation threshold [Hz] | Only evaluated in Mode 1.<br>The function is deactivated if the frequency re-enters the deactivation range and remains there for the duration of the deactivation time. |
| Deactivation time | 0 – 3600 [s] | Only evaluated in Mode 1.<br>The function is deactivated if the frequency re-enters the range between minimum and maximum deactivation threshold and remains there for the duration of the deactivation time. |
| Gradient | 0 – 200 [% $P_{ref}$ /Hz] | Specifies the active power change as function of the frequency according Equation 2 and Equation 3. |
| Intentional delay | 0 – 5 [s] | The activation of the function based on the activation threshold is delayed by the configured time.<br>Note 1: This function is considered critical for transmission system stability and is therefore prohibited by several national grid codes.<br>Note 2: This function is required in some national grid code to avoid negative effect on the island detection. P(f) has no negative effect on KACO enhanced island detection. |
| Settling time | 200 – 2000 [ms] | Specifies the dynamic behaviour at change of active power set point. On a frequency change, the active power is changed according a PT-1 characteristic with a settling time equal to 5 Tau.<br>Note: the settling time is superimposed with the increase and decrease gradient. |
| Output gradient increase | 1 – 65534 [% $S_{max}$ / min] | Specifies the dynamic behaviour at change of active power change for power increase. On a frequency change, the active power is changed with the specified gradient.<br>Note: the gradient is superimposed with the settling time. |
| Output gradient decrease | 1 – 65534 [% $S_{max}$ / min] | Specifies the dynamic behaviour at change of active power change for power decrease. On a frequency change, the active power is changed with the specified gradient.<br>Note: the gradient is superimposed with the settling time. |
| Deactivation | 1 – 65534 | If available power is above actual power at the instant of deactivation, |

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



| | | |
|---|---|---|
| gradient | [% $S_{max}$ / min] | the power increase back to maximum power is restricted. The restriction is implemented by an absolute power limit that is increasing with a continuous gradient up to maximum power. The actual power of the inverter may vary freely below this limit based on possible fluctuation of the available power, but will never increase above the absolute power limit. |

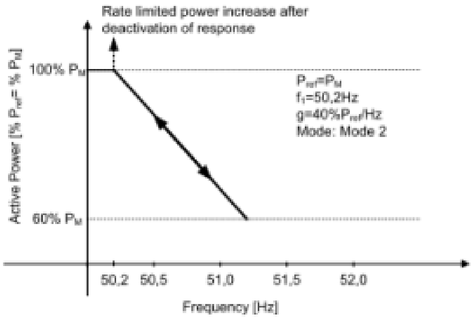


*Figure 3: example behaviour without hysteresis (Mode 2)*

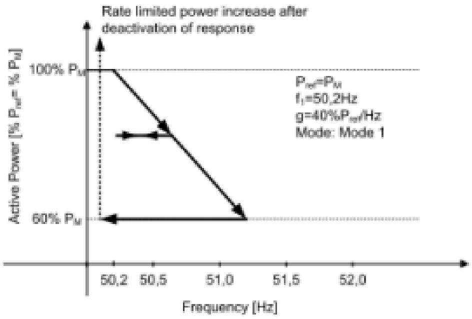


*Figure 4: example behaviour with hysteresis (Mode 1)*

## 2.5 P(f) Active power response to underfrequency of PV inverters

Some grid codes also require P(f) active power response to underfrequency. As PV plants typically operate at maximum power point there is no available power reserve to increase power in case of underfrequency.

However, in case of curtailment of the Plant due to market control, active power increase up to the available power is possible. As the inverter is not able to distinguish P constant set values between mandatory congestion management of the grid operator and market control, this needs to be implemented in the site specific plant control infrastructure.

## 2.6 P(f) Active power response to over and underfrequency of storage inverters

Feed-in inverters must assist with frequency stability in the grid. If the grid frequency leaves the normal tolerance range (e.g. ±200 mHz), the grid is in a critical state. In the event of overfrequency, there is a generation surplus, in the event of underfrequency, there is a generation deficit.

Electrical storage systems must adapt their active feed-in power in relation to the frequency deviation. The adaption of power is defined by a maximum feed in limit in case of overfrequency and by a maximum charging limit in case of underfrequency. The actual power of the inverter may vary freely below this limit based on possible fluctuation of the available power or set point, but will never increase above the absolute power limit.

Equation 6 defines the maximum limit with ΔP according to Equation 6, $P_M$ the actual power at the moment of activation and $P_{ref}$ the reference power as configured.

$$P_{max-limit} = P_M + \Delta P$$ Equation 5

$$\Delta P = g \cdot P_{ref} \cdot (f_1 - f).$$ Equation 6

In some standards the power adaption is not defined by a gradient – g but by a droop – s as in Equation 7. The droop s can be converted to a gradient g according to Equation 8.

$$\Delta P = \frac{1}{s} \times \frac{(f1 - f)}{fn} \times Pref$$ Equation 7

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



$$g = \frac{1}{s \cdot f_n}$$ Equation 8

During an overfrequency event the frequency f is above the activation threshold $f_1$. Therefore the term $(f_1 - f)$ is negative and ΔP is an in-feed power reduction or charging power increase. During an underfrequency event the frequency f is below the activation threshold $f_1$. Therefore the term $(f_1 - f)$ is positive and ΔP is an in-feed power increase or charging power decrease.

Depending on the point of operation of the inverter at the instant of activation of the function, the configured power reference and configured gradient, the inverter may change from charging to in-feed mode in case of underfrequency or from in-feed mode to charging mode in case of overfrequency (see also Figure 5).

The measurement accuracy of the frequency is better than 10mHz.

The specific mode of operation of the function is specified by the grid operator or by applicable standards or grid codes. The configurability of the function makes it possible to meet a wide variety of standards and grid codes. Certain configuration options are not available in some country settings because the applicable standards or grid codes prohibit adjustments.

Parameters:

| Parameter name | Setting | Description |
|---|---|---|
| Mode | Off \| Mode 1 \| Mode 2 | Enable or disable function.<br>Mode 1: enable with hysteresis. See Figure 4.<br>Mode 2: enable without hysteresis. See Figure 3. |
| Power reference at overfrequency | Actual Power \| Nominal Power | Power reference for power adaption as in Equation 6 and Equation 7 for overfrequency events. |
| Power reference at underfrequency | Actual Power \| Nominal Power | Power reference for power adaption as in Equation 6 and Equation 7 for underfrequency events. |
| Activation threshold ($f_1$) overfrequency | Activation threshold ($f_1$) underfrequency – 70 [Hz] | Specifies the frequency threshold to activate the function for overfrequency events. Active power adaption is activated if the frequency increases above the configured value and Mode 1 or 2 is enabled.<br>In Mode 2 the function is deactivated if the frequency falls below the configured value. |
| Activation threshold ($f_1$) underfrequency | 40 – Activation threshold ($f_1$) overfrequency [Hz] | Specifies the frequency threshold to activate the function for underfrequency events. Active power adaption is activated if the frequency falls below the configured value and Mode 1 or 2 is enabled.<br>In Mode 2 the function is deactivated if the frequency increases above the configured value. |
| Gradient at overfrequency (feed-in) | 0 – 200 [% $P_{ref}$ /Hz] | Specifies the active power change as function of the frequency according Equation 6 and Equation 7.<br>Gradient for overfrequency events if the event starts during feed-in mode. |
| Gradient at underfrequency (feed-in) | 0 – 200 [% $P_{ref}$ /Hz] | Specifies the active power change as function of the frequency according Equation 6 and Equation 7.<br>Gradient for underfrequency events if the event starts during feed-in mode. |
| Gradient at overfrequency (charge) | 0 – 200 [% $P_{ref}$ /Hz] | Specifies the active power change as function of the frequency according Equation 6 and Equation 7.<br>Gradient for overfrequency events if the event starts during charge mode. |
| Gradient at | 0 – 200 | Specifies the active power change as function of the frequency according |

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



| | | |
|---|---|---|
| underfrequency (charge) | [% $P_{ref}$ /Hz] | Equation 6 and Equation 7. Gradient for underfrequency events if the event starts during charge mode. |
| Intentional delay | 0 – 5 [s] | The activation of the function based on the activation threshold is delayed by the configured time. Note 1: This function is considered critical for transmission system stability and is therefore prohibited by several national grid codes. Note 2: This function is required in some national grid code to avoid negative effect on the island detection, however P(f) has no negative effect on KACO enhanced island detection. |
| Deactivation range lower limit | Activation threshold ($f_1$) underfrequency – Deactivation range upper limit [Hz] | Only evaluated in Mode 1. The function is deactivated if the frequency re-enters the deactivation range and remains there for the duration of the deactivation time. |
| Deactivation range upper limit | Deactivation range lower limit– Activation threshold ($f_1$) overfrequency [Hz] | Only evaluated in Mode 1. The function is deactivated if the frequency re-enters the deactivation range and remains there for the duration of the deactivation time. |
| Deactivation time | 0 – 3600 [s] | Only evaluated in Mode 1. The function is deactivated if the frequency re-enters the range between minimum and maximum deactivation threshold and remains there for the duration of the deactivation time. |
| Deactivation gradient | 1 – 65534 [% $S_{max}$ / min] | If available power is above actual power at the instant of deactivation, the power increase back to maximum power is restricted. The restriction is implemented by an absolute power limit that is increasing with a continuous gradient up to maximum power. The actual power of the inverter may vary freely below this limit based on possible fluctuation of the available power or power set point, but will never increase above the absolute power limit. |
| Dynamic gradient mode | On \| Off | If dynamic gradient mode is enabled, the gradients for over- and underfrequency as described above are not used. The gradient is calculated dynamically at the moment of activation. The gradient is calculated to a value to guarantee linear power adaption up to maximum power. In case of overvoltage active power is adapted to maximum charging power, in case of underfrequency active power is adapted to maximum in-feed power. |
| Dynamic gradient maximum frequency | Activation threshold ($f_1$) overfrequency – 70 | If dynamic gradient mode is enabled the gradient is calculated to guarantee linear power adaption to reach maximum charging power if the frequency increases to the configured maximum frequency. |
| Dynamic gradient minimum frequency | Activation threshold ($f_1$) underfrequency – 40 | If dynamic gradient mode is enabled the gradient is calculated to guarantee linear power adaption to reach maximum in-feed power if the frequency decreases to the configured minimum frequency. |
| Settling time | 200 – 2000 | Specifies the dynamic behaviour at change of active power limit. On a frequency change, the active power is changed according a PT-1 |

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

Application note - functional description

for grid support functions of TL3 series KACO inverters

Active power control functions SW: 5.5x / 1.2x / 3.1x

| | | |
|---|---|---|
| | [ms] | characteristic with a settling time equal to 5 Tau.<br>Note: the settling time is superimposed with the increase and decrease gradient. |
| Output gradient increase | 1 – 65534<br>[% $S_{max}$ / min] | Specifies the dynamic behaviour at change of active power limit for power increase. On a frequency change, the active power is changed with the specified gradient.<br>Note: the gradient is superimposed with the settling time. |
| Output gradient decrease | 1 – 65534<br>[% $S_{max}$ / min] | Specifies the dynamic behaviour at change of active power limit for power decrease. On a frequency change, the active power is changed with the specified gradient.<br>Note: the gradient is superimposed with the settling time. |

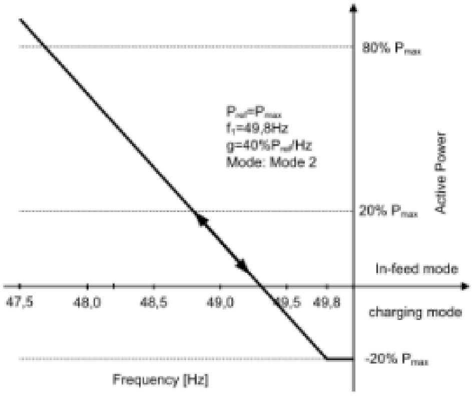


*Figure 5: example behaviour without hysteresis (Mode 2). At the instant of activation, the inverter is in charging mode with 20% charging power.*

# 3 Other grid support functions effective on active power

## 3.1 Permanent Power Limitation

The maximum active and apparent power to be installed in a generating plant is agreed between the grid operator and plant operator. Depending on the used inverters and the agreed value it might not be possible to exactly match the agreed generating plant power with the inverter power. The exact match can be reached by using the $S_{lim}$ and $P_{lim}$ settings. $S_{lim}$ and $P_{lim}$ can be used to down rate the power of the inverter precisely to the needed value, so that the sum of the inverter power matches exactly the agreed generating plant power. To ensure that the load on the devices in the plant is uniform, we recommend distributing the performance reduction evenly across all devices.

Some applicable standards or grid codes require that the agreed apparent power is also delivered in case of undervoltage. KACO TL3 inverters provide a certain current reserve to provide full power at undervoltage, the exact values are provided in the manual (clause 10) or in the application note "reactive power control functions". If the under voltage capability requirement exceeds the ability of the inverter, the function $S_{lim}$ can be used to permanently down rate the maximum apparent power and thus increase the current reserve.

Some applicable standards or grid codes require that the agreed reactive power can be provided from every active power operating point of the plant without a reduction of the actual active power.

As stated in the manual (clause 10) or in the application note "reactive power control functions" respectively, all KACO TL3 inverters operate with a (semi-)circular P-Q operating range. If the inverter is operating at maximum active

## 2. Anhang 2 – Technische Eigenschaften der Erzeugungseinheiten



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



The soft start is implemented as an absolute power limit that is increasing with a continuous gradient up to maximum power. The actual power of the inverter may vary freely below this limit based on possible fluctuation of the available power or set point, but will never increase above the absolute power limit.

Parameters:

| Parameter name | Setting | Description |
|---|---|---|
| Gradient | 1 – 600 [% $S_{max}$ / min] | Gradient of power limit. The maximum power limit increase to 100% of nominal power with the gradient specified. |
| After every connect | Check to enable | Soft start ramp up is activated for every connection of the inverter to the grid. |
| After first connect | Check to enable | Soft start ramp up is activated for the first connection of the inverter to the grid on a particular day or after complete reboot of the inverter (AC and DC disconnected). |
| After grid error | Check to enable | Soft start ramp up is activated for connection of the inverter to the grid after trip of the internal interface protection or via the external grid protection port (powador-protect) |

### 3.3 Normal operation power gradient (only available in bp87.0TL3 – 165TL3)

In the case of very large generating plants, it may also be necessary to restrict the change in power level during normal operation. If the set value (for increase and decrease in power level) and the solar irradiation change (for increase in power level), then the grid feed-in power is increased or decreased in line with the configured gradient. A limitation is not possible if the solar irradiation is reduced.

The function is not active for power changes defined by other grid support function such as power recovery after fault ride through, P(f) and P(U) as the dynamic of the power change is configured separately in each function.

Parameters:

| Parameter name | Setting | Description |
|---|---|---|
| Operation mode | On \| Off | Enable, disable normal operation power gradient limitation. |
| Increasing gradient | 1 – 65534 [% $S_{max}$ / min] | Active power change is limited to configured gradient for power increase. |
| Decreasing gradient | 1 – 65534 [% $S_{max}$ / min] | Active power change is limited to configured gradient for power decrease. |



**Figure 8 – Interfaces provided for active power setting from [20]**

## 1. Anhang 3 – Zusammenfassung des Prüfberichts OVE-Richtlinie R 25

Die im Zertifikat aufgeführten Erzeugungseinheiten wurden nach der technischen OVE-Richtlinie R25 geprüft. Die in der Netzanschlussregel TOR Erzeuger „Anschluss und Parallelbetrieb von Stromerzeugungsanlagen des Typs A und von Kleinsterzeugungsanlagen (Maximalkapazität < 250 kW und Nennspannung < 110 kV)" geforderten elektrischen Eigenschaften für Anschluss und Parallelbetrieb an Niederspannungs-Verteilernetzen werden erfüllt:

5.1 Prüfung der Netzrückwirkungen

5.2 Prüfung des Symmetrieverhaltens von Drehstromumrichtern

5.3 Prüfung des Verhaltens der Erzeugungseinheit am Netz

5.4 Prüfung der selbsttätig wirkenden Freischaltstelle

5.5 Prüfung der Zuschaltbedingungen und Synchronisierung

5.6 Nachweis der Robustheit und dynamischen Netzstützung

## 2. Anhang 4 – Zusammenfassung der Prüfberichte Technische Richtlinien: FGW TR3 Rev. 25, FGW TR4 Rev. 9

Das der Netzanschlussregel TOR Erzeuger „Anschluss und Parallelbetrieb von Stromerzeugungsanlagen des Typs B (Maximalkapazität ≥ 250 kW und < 35 MW und Nennspannung < 110 kV)“ konforme Verhalten bezüglich FRT-Fähigkeit mit Anschluss an das Mittelspannungsnetz der Erzeugungseinheiten ist durch die Ergebnisse im TR3-Prüfbericht (nach der technischen Richtlinie TR3, Test 4.6) belegt.

Anmerkung:

Die Implementierung der FRT Funktion für die Ländereinstellung „Austria“ ist identisch zu den Ländereinstellungen nach VDE AR-N 4110:2018 und VDE AR-N 4120:2018:

- für den Anschluss und Parallelbetrieb an Niederspannungs-Verteilernetzen können die Erzeugungseinheiten mit eingeschränkter dynamischen Netzstützung betrieben werden.
- Im Fall eines Anschluss an das Mittelspannungsnetz oder einer höheren Spannungsebene werden die symmetrischen Komponenten der Spannung während des Netzfehlers überwacht und das Mit- und Gegensystem des Stromes geregelt. Bei symmetrischen und unsymmetrischen Spannungseinbrüchen erfolgt eine definierte Blindstromeinspeisung im Mitsystem und Gegensystem entsprechend der K-Faktor-Kennlinie.

2.1. Die der Netzanschlussregel TOR Erzeuger „Anschluss und Parallelbetrieb von Stromerzeugungsanlagen des Typs B (Maximalkapazität ≥ 250 kW und < 35 MW und Nennspannung < 110 kV)“ konforme Blindleistungskapazität ist durch die Ergebnisse im TR3-Prüfbericht (nach der technischen Richtlinie TR3, Test 4.2.2 und 4.2.3) und die Herstellererklärung (dokumentiert im Prüfbericht und durch das Zertifikat VDE AR-N 4110:2018 und VDE AR-N 4120:2018 nachgewiesen.

2.2. Das der Netzanschlussregel konforme Verhalten des Erzeugungseinheitenmodells wird über den TR 4-Validierungsbericht nachgewiesen.

*Herstellererklärung*:

Bezüglich der Implementierung der FRT Funktion und der Blindleistungskapazität besteht zwischen der Firmware Version PKG: 5.74 ARM: 6.72(5C55) CFG: 6.4925(AE2C) DSP: 4.32 (635A) (Netzanschlussregel VDE AR-N 4110:2018 und VDE AR-N 4120:2018 konform) und ab V5.74 (Netzanschlussregel TOR Erzeuger: Anschluss und Parallelbetrieb von Stromerzeugungsanlagen des Typs A und von Kleinsterzeugungsanlagen (Maximalkapazität < 250 kW und Nennspannung < 110 kV) und TOR Erzeuger: Anschluss und Parallelbetrieb von Stromerzeugungsanlagen des Typs B (Maximalkapazität ≥ 250 kW und < 35 MW und Nennspannung < 110 kV) konform) kein Unterschied.

## 3. Anhang 5 – Bewertung der Konformität der Erzeugungseinheiten

Die im Zertifikat aufgeführten Erzeugungseinheiten wurden nach den technischen Richtlinien geprüft.

OVE-Richtlinie R 25: 2020-03-01
Prüfanforderungen an Erzeugungseinheiten (Generatoren) vorgesehen zum Anschluss und Parallelbetrieb an Niederspannungs-Verteilernetzen

Test report: 15TH0250-OVE-directive R25_0 (C.1)

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

Test report: 15TH0250_TR3_Rev.25_4 (C.2)

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

Test report: 15TH0250_TR4_Rev9_2 und 15TH0250_BP60_TR4_Rev9_0 (C.3)

EN 50549-2:2019 Anforderungen für zum Parallelbetrieb mit einem Verteilnetz vorgesehene Erzeugungsanlagen - Teil 2: Anschluss an das Mittelspannungsverteilnetz für Erzeugungsanlagen bis einschließlich Typ B

Test report: 15TH0250-EN50549-2_0 (C.4)

(*Herstellererklärung*)
Die Implementierung der Funktionen für die Ländereinstellung „Austria“ ist identisch zu den Ländereinstellungen nach VDE AR-N 4110:2018 und VDE AR-N 4120:2018.

## 3. Anhang 5 – Bewertung der Konformität der Erzeugungseinheiten

Im Folgenden der Bewertungsumfang:

| Anforderung (aus Kapitel von A.1) | Bewertung |
|---|---|
| 5 Verhalten der Stromerzeugungsanlage am Netz | --- |
| 5.1 Anforderungen an die Frequenzhaltung | --- |
| 5.1.1 Frequenzbereiche | Konform.<br>(*Herstellererklärung*) C.2:<br>(*Manufacturer's data*)<br>The unit can be continuously operated within the voltage / frequency range of 80%$U_n$ and 120%$U_n$ / 47.5 Hz and 52 Hz. The operating range of voltage and frequency can also be limited using the protection functions.<br>Prüfungen nach A.6,<br>*4.7 VERIFICATION OF THE WORKING RANGE WITH REGARD TO VOLTAGE AND FREQUENCY*<br>dokumentiert im C.2.<br>(*Herstellererklärung*):<br>Die EZE ist in der Lage, innerhalb des Frequenzbereiches zwischen 50,0 und 47,5 Hz die Verbindung mit dem Netz und den Betrieb ohne Leistungsverringerung aufrechtzuerhalten.<br>Prüfungen nach A.8,<br>*4.4.3 Minimal requirement for active power delivery at underfrequency*<br>dokumentiert im C.4. |
| 5.1.2 Frequenzgradienten | Konform.<br>(*Herstellererklärung*):<br>Die EZE ist in der Lage, bei Frequenzgradienten bis zu 2 Hz/s die Verbindung mit dem Netz und den Betrieb aufrechtzuerhalten. |
| 5.1.3 Wirkleistungsreduktion bei Überfrequenz (LFSM-O) | Konform.<br>Funktion auch auf EZE-Ebene implementiert. Die entsprechenden Schnittstellen sind im B.2 dokumentiert.<br>Bei Bedarf kann die Funktion im überlagerten EZA-Regler implementiert werden. Zur Info der entsprechenden Schnittstellen kann an Hersteller wenden.<br>(*Herstellererklärung*) C.2:<br>• Der Frequenzschwellenwert für den Beginn des LFSM-O-Modus ist einstellbar zwischen 40,00 und 60,00 Hz.<br>• Die Statik für den LFSM-O-Modus ist einstellbar zwischen 2% und 12%.<br>• Die Auflösung der Frequenzmessung <10 mHz.<br>• Die anfängliche Zeitverzögerung ist im SW auf 0 s eingestellt.<br>• Die Anforderung an die An- und Einschwingzeit kann erfüllt werden.<br>Prüfungen nach A.6,<br>*4.1.3 Active power feed-in as a function of grid frequency*<br>dokumentiert im C.2. |

## 3. Anhang 5 – Bewertung der Konformität der Erzeugungseinheiten

| Anforderung (aus Kapitel von A.1) | Bewertung |
|---|---|
| 5.1.4 Wirkleistungsabgabe gemäß Sollwert | Konform.<br>Funktion auch auf EZE-Ebene implementiert. Die entsprechenden Schnittstellen sind im B.2 dokumentiert.<br>Bei Bedarf kann die Funktion im überlagerten EZA-Regler implementiert werden. Zur Info der entsprechenden Schnittstellen kann an Hersteller wenden.<br>Prüfungen nach A.6,<br>*4.1.2 Operating power limited by grid operator*<br>dokumentiert im C.2. |
| 5.1.5 Verringerung der maximalen Wirkleistungsabgabe bei abnehmender Frequenz | Konform.<br>(*Herstellererklärung*):<br>Die EZE ist in der Lage, innerhalb des Frequenzbereiches zwischen 50,0 und 47,5 Hz die Verbindung mit dem Netz und den Betrieb ohne Leistungsverringerung aufrechtzuerhalten.<br>Prüfungen nach A.8,<br>*4.4.3 Minimal requirement for active power delivery at underfrequency*<br>dokumentiert im C.4. |
| 5.1.6 Wirkleistungserhöhung bei Unterfrequenz (LFSM-U) | Entfällt.<br>(Keine Anforderung vorgesehen)<br>Anmerkung:<br>Funktion auch auf EZE-Ebene implementiert. Die entsprechenden Schnittstellen sind im B.2 dokumentiert.<br>Bei Bedarf kann die Funktion im überlagerten EZA-Regler implementiert werden. Zur Info der entsprechenden Schnittstellen kann an Hersteller wenden.<br>(*Herstellererklärung*) C.2:<br>• Der Frequenzschwellenwert für den Beginn des LFSM-U-Modus ist einstellbar zwischen 40,00 und 60,00 Hz.<br>• Die Statik für den LFSM-U-Modus ist einstellbar zwischen 2% und 12%.<br>• Die Auflösung der Frequenzmessung <10 mHz.<br>• Die anfängliche Zeitverzögerung ist im SW auf 0 s eingestellt.<br>• Die Anforderung an die An- und Einschwingzeit kann erfüllt werden.<br>Prüfungen nach A.6,<br>*4.1.3 Active power feed-in as a function of grid frequency*<br>dokumentiert im C.2. |
| 5.1.7 Frequenzabhängiger Modus (Frequency Sensitive Mode, FSM) | Entfällt.<br>(Keine Anforderung vorgesehen)<br>Anmerkung:<br>Keine separate Funktion vorhanden, kann aber realisiert durch die LFSM-O in Kombination mit LFSM-U. |
| 5.1.8 Bereitstellung von synthetischer Schwungmasse | Entfällt.<br>(Nicht verpflichtend)<br>Anmerkung:<br>Bei Bedarf kann im überlagerten EZA-Regler implementiert werden. |
| 5.2 Anforderungen hinsichtlich Robustheit und dynamischer Netzstützung | Konform.<br>Prüfungen nach A.6,<br>*4.6 RESPONSE DURING GRID FAULTS (FRT)*<br>dokumentiert im C.2.<br>Anmerkung:<br>Der Nachweis der Stabilität bei Netzpendelungen wurde im Rahmen der dynamischen Netzstützung abgedeckt. |
| 5.2.1 FRT-Fähigkeit (fault ride through) von Stromerzeugungsanlagen | |
| 5.2.2 Wirkstrom- und Blindstromeinspeisung während und nach Netzfehlern | |
| 5.2.3 Stabilität bei Netzpendelungen | |

| 3. Anhang 5 – Bewertung der Konformität der Erzeugungseinheiten | |
|---|---|
| **Anforderung (aus Kapitel von A.1)** | **Bewertung** |
| 5.3 Anforderungen hinsichtlich statischer Spannungshaltung | --- |
| 5.3.1 Spannungsbereiche | Konform.<br>(*Herstellererklärung*) C.2:<br>(*Manufacturer's data*)<br>The unit can be continuously operated within the voltage / frequency range of 80%$U_n$ and 120%$U_n$ / 47.5 Hz and 52 Hz. The operating range of voltage and frequency can also be limited using the protection functions.<br>Prüfungen nach A.6,<br>*4.7 VERIFICATION OF THE WORKING RANGE WITH REGARD TO VOLTAGE AND FREQUENCY*<br>dokumentiert im C.2. |
| 5.3.2 Trennung der Stromerzeugungsanlage vom Netz | Konform.<br>Anforderung kann durch Einsatz der EZE-integrierten Schutzfunktion erfüllt werden.<br>Prüfungen nach A.6,<br>*4.4 PGU DISCONNECTION FROM THE GRID*<br>dokumentiert im C.2. |
| 5.3.3 Blindleistungskapazität | Anmerkung:<br>Standardmäßig ist die AC-Wirkleistung der Einheiten auf max. Scheinleistung begrenzt. In dieser Standard-PQ-Betriebsmodus ist die Blindleistung bei Volllast ($P = P_{max} = S_{max}$) Null (Leistungsfaktor = 1).<br>Die AC-Nennwirkleistung $P_n$ ist ein vom Hersteller definierter Nennwert. Diese muss bei Bedarf zusätzlich mit den Parametern *Plimit* und *Pmaxref* eingestellt werden. Mit dieser Einstellung ist eine Blindleistungsbereitstellung entspricht<br>• cosφ = 0,905 bei Volllastbetrieb ($P_n$) und bei $U \geq U_n$<br>oder<br>• cosφ = 0,995 bei Volllastbetrieb ($P_n$) und bei $U = 0{,}9 \cdot U_n$<br>möglich.<br>Die Parameter *Plimit* und *Pmaxref* ermöglichen eine Reduzierung der Wirkleistung zugunsten der Blindleistungsbereitstellung der Einheiten.<br>Dies muss auf Projektebene berücksichtigt werden.<br><br>Die Blindleistungskapazität der EZE dokumentiert im B.2.<br>Prüfungen nach A.6,<br>*4.2.2 Meassuring the maximum reactive power range (PQ diagram)*<br>und<br>*4.2.3 Meassuring separate operating points in the voltage dependent PQ diagram*<br>dokumentiert im C.2. |

| 3. Anhang 5 – Bewertung der Konformität der Erzeugungseinheiten | |
|---|---|
| **Anforderung (aus Kapitel von A.1)** | **Bewertung** |
| 5.3.4 Verfahren zur Blindleistungsbereitstellung | Konform.<br>Die geforderten Verfahren zur Blindleistungsbereitstellung sind auch auf EZE-Ebene implementiert (siehe B.2 und C.4). Die entsprechenden Schnittstellen sind im B.2 dokumentiert.<br>Bei Bedarf können die Funktionen im überlagerten EZA-Regler implementiert werden. Zur Info der entsprechenden Schnittstellen kann an Hersteller wenden.<br>Prüfungen nach A.6,<br>*4.2.4 Reactive power following setpoint;*<br>*4.2.5 Q(U) control;*<br>*4.2.6 Q(P) control;*<br>*4.2.7 Reactive power Q with voltage limitation function.*<br>dokumentiert im C.2.<br>Prüfungen nach A.8,<br>*4.7.2.3 Control modes*<br>dokumentiert im C.4 |
| 5.3.5 Spannungsregelung synchroner Stromerzeugungsanlagen | Entfällt.<br>(Anforderung nur für Synchrone Stromerzeugungsanlagen) |
| 5.3.6 Spannungsgeführte Wirkleistungsabregelung | Entfällt.<br>(keine Anforderungen vorgesehen)<br>Anmerkung:<br>Funktion auch auf EZE-Ebene implementiert.<br>Bei Bedarf kann die Funktion im überlagerten EZA-Regler implementiert werden. Zur Info der entsprechenden Schnittstellen kann an Hersteller wenden.<br>Prüfungen nach A.3,<br>*5.3.6 Spannungsgeführte Wirkleistungsabregelung*<br>dokumentiert im C.1. |
| 5.4 Anforderungen hinsichtlich Netzmanagement und Systemschutz | --- |
| 5.4.1 Wirkleistungsvorgabe durch den Netzbetreiber | Konform.<br>Funktion auch auf EZE-Ebene implementiert. Die entsprechenden Schnittstellen sind im B.2 dokumentiert.<br>Bei Bedarf kann die Funktion im überlagerten EZA-Regler implementiert werden. Zur Info der entsprechenden Schnittstellen kann an Hersteller wenden.<br>Prüfungen nach A.6,<br>*4.1.2 Operating power limited by grid operator*<br>dokumentiert im C.2. |

## 3. Anhang 5 – Bewertung der Konformität der Erzeugungseinheiten

| Anforderung (aus Kapitel von A.1) | Bewertung |
|---|---|
| 5.4.2 Simulationsmodelle und Simulationsparameter | Konform. |

Validiertes Simulationsmodell sowie die entsprechenden Parameter vorhanden. (Siehe B.2 und C.3).

Anmerkung:

- Funktionen implementiert im Modell gemäß Modellhandbuch (siehe B.2):

The model includes the following functions:
1. Converter current control and current limiting
2. Reactive current injection during grid faults (voltage support)
3. Reactive power control: according to fixed reference, power factor control, power factor as function of active power or QU curve
4. Active power control: according to fixed reference or percentage setting
5. Protection function with disconnection from the grid

- Anwendungsbereich des Modells (siehe B.2):

| | | |
|---|---|---|
| Model type: | ☐ EMT model | ☒ RMS model |
| The model is suitable for | ☒ static simulation<br>☒ simulation of symmetrical and asymmetrical faults | ☒ dynamic simulation<br>☐ only simulation of symmetrical faults |
| Implemented FRT modes: | ☒ Full dynamic grid support<br>☒ Limited dynamic grid support | |
| Is k-factor adjustable? | ☒ yes | ☐ no |
| Further functions implemented in the model: | See *4.3 Model parameters [8]* | |
| Is a simulation on a PGS configuration with SCR = 5 possible? | ☒ yes | ☐ no,<br>for a stable simulation the SCR has to be limited to:<br>___ |

- Umfang der Validierungs- und Plausibilitätstests nach A.7 dokumentiert in C.3 (siehe B.2):

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**4. Annex 4 – Validated simulation model**

**4.5. Scope of the validation and plausibility tests [8]**

The simulation model was checked for validity and plausibility according to TG 4 for following test scenarios:
- Validating all TG3 FRT tests (chapter 5 in [4])
- Plausibility tests on single model for different
  - fault types;
  - voltage depth;
  - pre-fault voltages
  - pref-fault active powers
  - pref-fault reactive powers
  - k-factors

  (chapter 5.5.2 in [4])
- Validating the P-Q diagram measured according to TG3 Chapters 4.2.2 and 4.2.3 (chapter 5.5.2.1 in [4])
- Plausibility checks of the steady-state operation (chapter 5.5.2.2 in [4])
- Plausibility tests for typical PGS configuration (SCR = 8) for different
  - fault types;
  - voltage depth;
  - pre-fault voltages
  - pref-fault active powers
  - pref-fault reactive powers
  - k-factors

  (chapter 5.5.3.1 in [4])
- Simulating of unsuccessful automatic reconnection on the PGS configuration with SCR = 5 (chapter 5.5.3.2 in [4])
- Active power reduction with over-frequency on single model (chapter 5.5.4.1 in [4])

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

| 3. Anhang 5 – Bewertung der Konformität der Erzeugungseinheiten | |
|---|---|
| **Anforderung (aus Kapitel von A.1)** | **Bewertung** |
| 5.4.3 Systemschutz | Anmerkung:<br>Genaue Betrachtung auf Anlagenebene notwendig.<br>Siehe Punkt 5.3.4. |
| 5.5 Anforderungen hinsichtlich Synchronisierung und Netzwiederaufbau | --- |
| 5.5.1 Synchronisierungsvorrichtungen | Entfällt.<br>Anmerkung:<br>Genaue Betrachtung auf Anlagenebene notwendig. |
| 5.5.2 Zuschaltbedingungen | Anmerkung:<br>Genaue Betrachtung auf Anlagenebene notwendig.<br>Funktion auch auf EZE-Ebene implementiert.<br>Prüfungen nach A.6,<br>*4.5 VERIFICATION OF CONNECTION CONDITIONS*<br>dokumentiert im C.2. |
| 5.5.3 Schwarzstartfähigkeit | Entfällt.<br>(keine Anforderungen vorgesehen) |
| 5.5.4 Inselbetriebsfähigkeit | Entfällt.<br>(keine Anforderungen vorgesehen) |
| 5.5.5 Schnelle Neusynchronisierung | Entfällt.<br>(keine Anforderungen vorgesehen)<br>Anmerkung:<br>Funktion auch auf EZE-Ebene implementiert.<br>Prüfungen nach A.6,<br>*4.5 VERIFICATION OF CONNECTION CONDITIONS*<br>dokumentiert im C.2. |
| 5.6 Anforderungen hinsichtlich Datenaustausch | Entfällt.<br>Anmerkung:<br>Genaue Betrachtung auf Anlagenebene notwendig. |
| 6 Ausführung der Anlage und Schutz | Entfällt.<br>Anmerkung:<br>Genaue Betrachtung auf Anlagenebene notwendig. |