GRID CONNECTION CODE REQUIREMENTS FOR RENEWABLE POWER PLANTS (RPPs) CONNECTED TO THE TRANSMISSION SYSTEM (TS) OR THE DISTRIBUTION SYSTEM (DS) IN SOUTH AFRICA

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Comments to this document can be forwarded to:
RSA Grid Code Secretariat
Attention: Mr. Themba Khoza or Mr. Bernard Magoro
Eskom Transmission Division
P.O Box 103, Germiston 1400
Tell: +27 (0)11 871 2368 / 2774
Fax: +27 (0)86 663 8418
Email: themba.khoza@eskom.co.za or magorotb@eskom.co.za

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1. Grid Connection Code Basis

1.1 Legislation

(1) The legal basis for this grid connection code is specified in terms of the Electricity Regulation Act (Act 4 of 2006), as amended.

1.2 Handling of Non-compliances and Deviations

(1) Amendments, derogations or exemptions shall be processed as specified in the RSA Grid Code, as amended.

2. Objectives

(1) The primary objective of this grid connection code is to specify minimum technical and design grid connection requirements for Renewable Power Plants (RPPs) connected to or seeking connection to the South African electricity transmission system (TS) or distribution system (DS).

(2) This document shall be used together with other applicable requirements of the Grid Code, the Distribution Code and the Scheduling and Dispatch Rules (SDR), as compliance criteria applicable to RPPs connected to the TS and the DS.

3. Scope

(1) The grid connection requirements in this document shall apply to all RPPs connected or seeking connection to the TS or DS, the SO, as well as to the respective electrical Network Service Providers (NSPs).

(2) This grid connection code shall, at minimum, apply to the following RPP technologies:
   
   (a) Photovoltaic
   (b) Concentrated Solar Power
   (c) Small Hydro
   (d) Landfill gas
   (e) Biomass
   (f) Biogas
   (g) Wind

(3) All thermal and hydro units shall also comply with the design requirements specified in the SA Grid Code (specifically section 3.1. of the Network Code). This RPP grid connection
code shall take precedence whenever there is a conflict between this code and other parts of the Grid Code.

(4) Unless otherwise stated, the requirements in this grid connection code shall apply equally to all RPP technologies and categories.

(5) The RPP shall, for duration of its generation licence issued by NERSA, comply with the provisions of this grid connection code and all other applicable codes, rules and regulations approved by NERSA.

(6) Where there has been a replacement of and/or major modification to an existing RPP, the RPP shall also be required to demonstrate compliance to these requirements before commercial operation.

(7) Compliance with this grid connection code shall be applicable to the RPP depending on its total rated capacity and, where indicated, the nominal voltage at the POC. Accordingly, RPPs are grouped into the following three categories:

(a) Category A: 0 – 1 MVA (Only LV connected RPPs)
This category includes RPPs with a maximum power output range at the POC of less than 1 MVA and connected to the LV voltage (typically called 'small or micro turbines'). This category shall further be divided into 3 sub-categories:

(i) Category A1: 0 - 13.8 kVA
This sub-category includes RPPs of Category A with a nominal capacity rating in the range of 0 to 13.8 kVA.

(ii) Category A2: 13.8 kVA – 100 kVA
This sub-category includes RPPs of Category A with a nominal capacity rating in the range greater than 13.8 kVA but less than 100 kVA.

(iii) Category A3: 100 kVA – 1 MVA
This sub-category includes RPPs of Category A with a nominal capacity rating in the range 100 kVA but less than 1 MVA.

Any RPP larger than 4.6 kVA must be balanced three-phase.

(b) Category B: 1 MVA – 20 MVA and RPPs less than 1 MVA connected to the MV
This category includes RPPs with a maximum power output range of 1 MVA but less 20 MVA and RPPs with maximum power out of less than 1 MVA but connected to the MV.

(c) Category C: 20 MVA or higher
This category includes RPPs with a maximum power output at the POC equal to or greater than 20 MVA.

(8) The requirements of this grid connection code are organized according to above defined categories. Unless otherwise stated, requirements in this grid connection code shall apply equally to all categories of RPPs.

(9) Compliance with the Grid Code will depend on the interaction between the RPP and the grid to which it is connected. The NSP shall supply the RPP Generator with a reasonable detail of their grid. The grid information shall be sufficient to allow an accurate analysis of the interaction between the RPP and the grid, including other Generation Facilities, to be made.

4. Definitions and Abbreviations

(1) Unless otherwise indicated, words and terminology in this document shall have the same meaning as those in the RSA Grid Code and Distribution Code. The following definitions and abbreviations are used in this document.

Active Power Curtailment Set-point
The limit set by the SO, NSP or another Network Operator for the amount of Active Power that the RPP is permitted to generate. This instruction may be issued manually or automatically via a tele-control facility. The manner of applying the limitation shall be agreed between the parties.

Available Active Power
The amount of Active Power (MegaWatts) that the Renewable Power Plant (RPP) could produce at POC based on current renewable primary energy conditions.

Code
The Distribution Code, the Grid Code or any other Code, published by NERSA.

Connection Agreement
As defined in the Code.

Curtained Active Power
The amount of Active Power that the RPP is permitted to generate by the SO, NSP or other Network Operator subject to network or system constrains.

**Distribution System (DS)**
As defined in the Code

**Distributor**
As defined in the Code

**Extra High Voltage (EHV)**
The set of nominal voltage levels greater than 220 kV.

**Frequency control**
The control of active power with a view to stabilising the grid frequency.

**Generator**
As defined in the Code

**High voltage (HV)**
The set of nominal voltage levels greater than 33 kV and up to and including 220 kV.

**Low voltage (LV)**
Nominal voltage levels up to and including 1 kV.

**Medium voltage (MV)**
The set of nominal voltage levels greater than 1 kV and up to and including 33 kV.

**National Energy Regulator of South Africa (NERSA)**
The legal entity established in terms of the National Energy Regulator Act, 2004 (Act 40 of 2004), as amended.

**National Interconnected Power Systems (NIPS)**
The electrical network comprising components that have a measurable influence on each other as they are operating as one system, this includes:

- the TS;
- the DS;
- assets connected to the TS and DS;
- power stations connected to the TS and DS;
- international interconnectors;
- the control area for which the SO is responsible.
National Transmission Company (NTC)
As defined in the Code

Network Service Provider (NSP)
As defined in the Code

Nominal voltage
The voltage for which a network is defined and to which operational measurements are referred.

Participants
As defined in the Code,

Point of Common Coupling (PCC)
As defined in the Code.

Point of Connection (POC)
As defined in the Code.

Power Quality
Characteristics of the electricity at a given point on an electrical system, evaluated against a set of reference technical parameters. These characteristics include:

- voltage or current quality, i.e. regulation (magnitude), harmonic distortions, flicker, unbalance;
- voltage events, i.e. voltage dips, voltage swells, voltage transients;
- (supply) interruptions;
- frequency of supply.

Rated power of a RPP
The highest active power which the RPP is designed to continuously supply.

Rated wind speed
The average wind speed at which a wind turbine generator system achieves its rated power, see IEC 60050-415-03-04. The average renewable speed is calculated as the average value of renewable speeds measured at hub height over a period of 10 minutes.

Renewable Power Plant (RPP)
One or more unit(s) and associated equipment, with a stated total rated power, which has been connected to the same POC and operating as a single power plant.
Notes:
It is therefore the entire RPP that shall be designed to achieve requirements of this code at the POC. A RPP has only one POC.

In this code, the term RPP is used as the umbrella term for a unit or a system of generating units producing electricity based on a primary renewable energy source (e.g. wind, sun, water, biomass etc.). A RPP can use different kinds of primary energy source. If a RPP consists of a homogeneous type of generating units it can be named as follows:

- **PV Power Plant (PVPP)**
  A single photovoltaic panel or a group of several photovoltaic panels with associated equipment operating as a power plant.

- **Concentrated Solar Power Plant (CSPP)**
  A group of aggregates to concentrate the solar radiation and convert the concentrated power to drive a turbine or a group of several turbines with associated equipment operating as a power plant.

- **Small Hydro Power Plant (SHPP)**
  A single hydraulic driven turbine or a group of several hydraulic driven turbines with associated equipment operating as a power plant.

- **Landfill Gas Power Plant (LGPP)**
  A single turbine or a group of several turbines driven by landfill gas with associated equipment operating as a power plant.

- **Biomass Power Plant (BMPP)**
  A single turbine or a group of several turbines driven by biomass as fuel with associated equipment operating as a power plant.

- **Biogas Power Plant (BGPP)**
  A single turbine or a group of several turbines driven by biogas as fuel with associated equipment operating as a power plant.

- **Wind Power Plant (WPP)**
  A single turbine or a group of several turbines driven by wind as fuel with associated equipment operating as a power plant.

**Renewable Power Plant (RPP) Controller**
A set of control functions that make it possible to control the RPP at the POC. The set of control functions shall form part of the RPP.

**RPP Generator**
A legal entity that is licensed to develop and operate a RPP.

**System Operator (SO)**
As defined in the Code

**Transmission Network Service Provider (TNSP)**
As defined in the Code

**Transmission System (TS)**
As defined in the Code

**Unit / Generation facility**
As defined in the Code

**Voltage Quality**
Subset of power quality referring to steady-state voltage quality, i.e. voltage regulation (magnitude), voltage harmonics, voltage flicker, voltage unbalance, voltage dips. The current drawn from or injected into the POC is the driving factor for voltage quality deviations.

**Voltage Ride Through (VRT) Capability**
Capability of the RPP to stay connected to the network and keep operation following voltage dips or surges caused by short-circuits or disturbances on any or all phases in the TS or DS.

**Wind Energy Facility (WEF)**
A single wind turbine connected to the TS or DS or a group of several wind turbines with associated equipment with common connection(s).

### 5. Tolerance of Frequency and Voltage Deviations

1. The RPP shall be able to withstand frequency and voltage deviations at the POC under normal and abnormal operating conditions described in this grid connection code while reducing the active power as little as possible.

2. The RPP shall be able to support network frequency and voltage stability in line with the requirements of this grid connection code.

3. Normal operating conditions and abnormal operating conditions are described in section 5.1 and section 5.2, respectively.
5.1 Normal Operating Conditions

(1) Unless otherwise stated, requirements shall apply to all categories of RPPs.

(2) RPPs of Category A shall be designed to be capable of operating within the voltage range of -15% to +10% around the nominal voltage at the POC. The actual operating voltage differs from location to location, and this shall be decided by the NSP in consultation with the affected customers (including the RPP Generator), and implemented by the RPP Generator.

(3) RPPs of Category B and C shall be designed to be capable of operating within the voltage range of ±10% around the nominal voltage at the POC. The actual operating voltage differs from location to location, and this shall be decided by the NSP in consultation with the affected customers (including the RPP Generator), and implemented by the RPP Generator.

(4) The nominal frequency of the National Integrated Power System (NIPS) is 50 Hz and is normally controlled within the limits as defined in the Grid Code. The RPP shall be designed to be capable of operating for the minimum operating range illustrated in Figures 1 (total cumulative over the life of the RPP) and Figure 2 (during a system frequency disturbance).

(5) When the frequency on the NIPS is higher than 52 Hz for longer than 4 seconds, the embedded generator shall be disconnected from the grid.

(6) When the frequency on the NIPS is less than 47.0 Hz for longer than 200ms, the RPP may be disconnected.

(7) The RPP shall remain connected to the NIPS during rate of change of frequency of values up to and including 1.5 Hz per second, provided the network frequency is still within the minimum operating range indicated in Figures 1 and 2.
Figure 1: Minimum frequency operating range for \textit{RPP} (Cumulative over the life of the \textit{RPP})

Figure 2: Minimum frequency operating range of a \textit{RPP} (during a system frequency disturbance)

5.1.1 Synchronising to the \textit{NIPS}

(1) \textit{RPPs} of \textit{Category A} shall only be allowed to connect to the \textit{NIPS}, at the earliest, 60 seconds after:

(a) The voltage at the \textit{POC} is in the range -15\% to +10\% around the nominal voltage,
(b) Frequency in the NIPS is within the range of 49.0Hz and 50.2Hz, or as agreed with the SO.

(2) RPPs of Category B and C shall only be allowed to connect to the NIPS, at the earliest, 3 seconds after:

(a) (for TS connected RPPs), the voltage at the POC is within ±5% around the nominal voltage,
(b) (for DS connected RPPs), the voltage at the POC is within ±10% around the nominal voltage,
(c) frequency in the NIPS is within the range of 49.0Hz and 50.2Hz, or as agreed with the SO.

5.2 Abnormal Operating Conditions

(1) The RPP shall be designed to withstand sudden phase jumps of up to 40° at the POC without disconnecting or reducing its output. The RPP shall after a settling period supply normal production not later than 5 sec after the operating conditions in the POC have reverted to the normal production conditions.

5.2.1 Tolerance to sudden voltage drops and peaks

(a) RPPs of Category A1 and A2

(1) RPPs of Categories A1 and A2 shall be designed to withstand and fulfil, at the POC, voltage conditions described in Figures 3 below.
(2) In addition, the maximum disconnection times for RPPs of Category A1 and A2 is given in Table 1 below.

Table 1: Maximum disconnection times for RPPs of Categories A1 and A2.

<table>
<thead>
<tr>
<th>Voltage range (at the POC)</th>
<th>Maximum trip time [Seconds]</th>
</tr>
</thead>
<tbody>
<tr>
<td>V &lt; 50 %</td>
<td>0.2 s</td>
</tr>
<tr>
<td>50 % ≤ V &lt; 85 %</td>
<td>2 s</td>
</tr>
<tr>
<td>85 % ≤ V ≤ 110 %</td>
<td>Continuous operation</td>
</tr>
<tr>
<td>110 % &lt; V &lt; 120 %</td>
<td>2 s</td>
</tr>
<tr>
<td>120 % ≤ V</td>
<td>0.16 s</td>
</tr>
</tbody>
</table>

(b) RPPs of Category A3, B and C

(1) RPPs of Categories A3, B and C shall be designed to withstand and fulfil, at the POC, voltage conditions described in this section and in Figures 4 and 5 below.

(2) The RPP shall be designed to withstand voltage drops and peaks, as shown in Figure 4, and supply or absorb reactive current as shown in Figure 5 without disconnecting.

(3) The RPP shall be able to withstand voltage drops to zero, at the POC, for a minimum period of 0.150 seconds without disconnecting, as shown in Figure 4.

(4) The RPP shall be able to withstand voltage peaks up to 120% of the nominal voltage at the POC for a minimum period of 2 seconds without disconnecting, as shown in Figure 4.

(5) Figures 4 shall apply to all types of faults (symmetrical as well as asymmetrical i.e. one-, two- or three-phase faults) and the bold line shall represent the minimum voltage of all the phases.

(6) In connection with symmetrical fault sequences in area B and D of Figure 4, the RPP shall have the capability of controlling the reactive power, as illustrated in Figure 5.

(7) Control shall follow Figure 5 so that the reactive power follows the control characteristic with a tolerance of ±20% after 100 ms.

(8) The supply of reactive power has first priority in area B, while the supply of active power has second priority. If possible, active power shall be maintained during voltage drops, but a reduction in active power within the RPP’s design specifications is acceptable.
(a) **Area A:** The RPP shall stay connected to the network and uphold normal production.

(b) **Area B:** The RPP shall stay connected to the network. In addition, the RPP shall provide maximum voltage support by supplying a controlled amount of reactive current so as to ensure that the RPP helps to stabilise the voltage, see Figure 5.

(c) **Area C (Figure 4):** Disconnecting the RPP is allowed.

(d) **Area E (Figure 5):** Once the voltage at the POC is below 20%, the RPP shall continue to supply reactive current within its technical design limitations so as to ensure that the RPP helps to stabilise the voltage. Disconnection is only allowed after conditions of Figure 4 have been fulfilled.

(e) **Area D:** The RPP shall stay connected to the network and provide maximum voltage support by absorbing a controlled amount of reactive current so as to ensure that the RPP helps to stabilise the voltage within the design capability offered by the RPP, see Figure 5.

(9) If the voltage (U) reverts to area A during a fault sequence, subsequent voltage drops shall be regarded as a new fault condition. If several successive fault sequences occur within area B and evolve into area C, disconnection is allowed, see Figure 4.

![Figure 4: Voltage Ride Through Capability for the RPPs of Category A3, B and C](image-url)
6. Frequency Response

(1) In case of frequency deviations in the NIPS, RPPs shall be able to provide frequency control in order to stabilise the grid frequency. The metering accuracy for the grid frequency shall be at least ±10mHz.

6.1 Power-frequency response curve for RPPs of Category A

(1) During high frequency operating conditions RPPs of Category A shall be able to provide mandatory frequency control in order to stabilise the grid frequency according to Figure 6 below. The metering accuracy for the grid frequency shall be ± 10 mHz or better.
(2) When the frequency on the NIPS exceeds 50.5 Hz, the RPP shall reduce the output power as a function of the change in frequency as illustrated in Figure 6 below.

(3) Once the frequency exceed 52Hz for longer than 4 seconds the RPP shall be tripped to protect the grid.

![Power curtailment during over-frequency](image)

**Figure 6: Power curtailment during over-frequency for Category A RPPs**

6.2 Power-frequency response curve for RPPs of Categories B & C

(2) It shall be possible to set the frequency response control function for all frequency points shown in Figure 7. It shall be possible to set the frequencies $f_{\text{min}}$, $f_{\text{max}}$, as well as $f_1$ to $f_7$ to any value in the range of 47 - 52 Hz with a minimum accuracy of 10 mHz.

(3) The purpose of frequency points $f_1$ to $f_4$ is to form a dead band and a control band for primary frequency response. The purpose of frequency points $f_5$ to $f_7$ is to supply critical power/frequency response.

(4) The RPP shall be equipped with the frequency control droop settings as illustrated in figure 7. Each droop setting shall be adjustable between 0% and 10%.

(5) The SO shall decide and advise the RPP generator (directly or through its agent) on the droop settings required to perform control between the various frequency points. In this context, droop is the change in active power caused by a change in frequency.

(6) If the active power from the RPP is regulated downward below the unit’s design limit $P_{\text{min}}$, shutting-down of individual unit’s is allowed.
(7) The RPP (with the exception of RPPPV) shall be designed with the capability of providing a $P_{\Delta}$ of not less than 3% of $P_{\text{available}}$. $P_{\Delta}$ is the setpoint to which the available active power has been reduced in order to provide frequency stabilisation (primary frequency control) in the case of falling grid frequency.

(8) It shall be possible to activate the frequency response control function in the interval from $f_{\text{min}}$ to $f_{\text{max}}$.

(9) If the frequency control setpoint is to be changed, such change shall be commenced within two seconds and completed no later than 10 seconds after receipt of an order to change the setpoint.

(10) The accuracy of the control performed and of the setpoint shall not deviate by more than ±2% of the setpoint value or by ±0.5% of the rated power, depending on which yields the highest tolerance.

Figure 7: Frequency response requirement for RPPs of category B and C (drawing to be updated: IET agreed on the one droop = droop 1 for high frequency as well)
(11) The default settings for \( f_{\text{min}} \), \( f_{\text{max}} \) and \( f_1 \) to \( f_4 \) shall be as shown in Table 2, unless otherwise agreed upon between the SO and the RPP Generator. Settings for \( f_5 \) to \( f_7 \) shall be agreed to with the SO.

### Table 2: Frequency Default Settings

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Magnitude</th>
</tr>
</thead>
<tbody>
<tr>
<td>( f_{\text{min}} )</td>
<td>47</td>
</tr>
<tr>
<td>( f_{\text{max}} )</td>
<td>52</td>
</tr>
<tr>
<td>( f_1 )</td>
<td>49.5</td>
</tr>
<tr>
<td>( f_2 )</td>
<td>49.85</td>
</tr>
<tr>
<td>( f_3 )</td>
<td>50.15</td>
</tr>
<tr>
<td>( f_4 )</td>
<td>50.5</td>
</tr>
</tbody>
</table>

### 6.3 Procedure for setting and changing the power-frequency response curves for RPPs of Categories B & C

(1) The SO or its agent shall give the RPP Generator a minimum of 2 weeks if changes to any of the frequency response parameters (i.e. \( f_1 \) to \( f_7 \)) are required. The RPP Generator shall confirm with the SO or its agent that requested changes have been implemented within two weeks of receiving the SO’s request.

### 7. Reactive Power Capabilities

#### 7.1 RPPs of Category A

(1) The RPP shall be designed with the capability to supply rated power output (MW) for power factors ranging between 0.95 lagging and 0.95 leading available from 20% of rated power measured at the POC.

(2) The RPP shall be designed to operate according to a power factor characteristic curve, which will be determined by the NSP or the SO.

(3) The default power factor setting shall be unity power factor, unless otherwise specified by the NSP or the SO.

#### 7.2 RPPs of Category B

(1) The RPP shall be designed to supply rated power output (MW) for power factors ranging between 0.975 lagging and 0.975 leading available from 20% of rated power measured at the POC. This is illustrated in Figure 8 below.
(2) In addition the RPP shall be designed in such a way that the operating point can lie anywhere within the hatched area in Figure 8 & 9.

(3) The RPP shall be designed with the capability to operate in a voltage, power factor or, Mvar control modes as described in section 8 below. The actual operating mode (voltage, power factor or, Mvar control) and operating point shall be agreed with the NSP.

(4) Point A is equivalent (in MVar) to –5% rated MW output and Point B is equivalent (in MVar) to 5% rated MW output, and Point C is equivalent (in MW) to 5% rated MW output (see Figure 8).

Figure 8: Reactive power requirements for RPPs of category B

Figure 9: Requirements for voltage control range for RPPs of category B.
7.3  RPPs of Category C

(1) The RPP of Category C shall be designed to supply rated power output (MW) for power factors ranging between 0.95 lagging and 0.95 leading available from 20% of rated power measured at the POC.

(2) The RPP shall be designed in such a way that the operating point can lie anywhere within the hatched area in Figure 10 & 11.

(3) The RPP shall be designed with the capability to operate in a voltage, power factor or, Mvar control modes. The actual control operating mode (voltage, power factor or, Mvar control) and operating point shall be agreed with the NSP.

(4) Point A is equivalent (in MVar) to –5% rated MW output and Point B is equivalent (in MVar) to 5% rated MW output, and Point C is equivalent (in MW) to 5% rated MW output (see Figure 10).

![Figure 10: Reactive power requirements for RPPs of category C](image-url)
8. Reactive Power and Voltage Control Functions

(1) The following requirements shall apply to RPPs of Categories B and C.

(2) The RPP shall be equipped with reactive power control functions capable of controlling the reactive power supplied by the RPP at the POC as well as a voltage control function capable of controlling the voltage at the POC via orders using setpoints and gradients.

(3) The reactive power and voltage control functions are mutually exclusive, which means that only one of the three functions mentioned below can be activated at a time.
   (a) Q-control
   (b) Power Factor–control
   (c) Voltage-control

(4) The control function and applied parameter settings for reactive power and voltage control functions shall be determined by the NSP in collaboration with the SO, and implemented by the RPP generator. The agreed voltage control functions shall be documented in the operating agreement.

8.1 Q-Control
(1) Q control is a control function controlling the reactive power independently of the active power and the voltage at the *POC*. This control function is illustrated on Figure 12 as a vertical line.

(2) If the Q control setpoint is to be changed by the *NSP* or *SO*, then the *RPP* generator shall update its echo analog set point value in response to the new value from *NSP* or *SO* within two seconds. The *RPP* shall respond to the new set point within 30 seconds after receipt of an order to change the setpoint.

(3) The accuracy of the control performed and of the setpoint shall not deviate by more than ±2% of the setpoint value or by ±0.5%, depending on which yields the highest tolerance.

(4) The *RPP* shall be able to receive a Q setpoint with an accuracy of 1kVar.

![Figure 12: Reactive power control functions for the RPP](image)

### 8.2 Power Factor Control

(1) Power Factor Control is a control function controlling the reactive power proportionally to the active power in the *POC*, which is illustrated on Figure 12 by a line with a constant gradient.

(2) If the power factor setpoint is to be changed by the *NSP* or *SO*, then the *RPP* shall update its echo analog set point value to in response to the new value from *NSP* or *SO* within two seconds. The *RPP* shall respond to the new set point within 30 seconds after receipt of an order to change the setpoint.
(3) The accuracy of the control performed and of the setpoint shall not deviate by more than ±2% of the setpoint value or by ±0.5% of the rated power factor, depending on which yields the highest tolerance.

8.3 Voltage Control

(1) Voltage control is a control function controlling the voltage at the POC.

(2) If the voltage setpoint is to be changed, such change shall be commenced within two seconds and completed no later than 30 seconds after receipt of an order to change the setpoint.

(3) The accuracy of the voltage setpoint shall be within ±0.5% of nominal voltage, and the accuracy of the control performed shall not deviate by more than ±2% of the required injection of reactive power according to droop characteristics as defined in Figure 13, or ±0.5% of the nominal voltage.

(4) The individual RPP shall be able to perform the control within its dynamic range and voltage limit with the droop configured as shown in Figure 13. In this context, droop is the voltage change (p.u.) caused by a change in reactive power (p.u.).

(5) When the voltage control has reached the RPP’s dynamic design limits, the control function shall await possible overall control from the tap changer or other voltage control functions.

(6) Overall voltage coordination shall be handled by the NSP in collaboration with the SO.
9. Power Quality

(1) The following requirements shall apply to all categories of RPPs.

(2) Power quality and voltage regulation impact shall be monitored at the POC and shall include an assessment of the impact on power quality from the RPP concerning the following disturbances at the POC:

   (a) voltage fluctuations:
       i. rapid voltage changes
       ii. flicker

   (b) high-frequency currents and voltages:
       i. harmonics
       ii. inter-harmonics
       iii. disturbances greater than 2 kHz.

   (c) unbalanced currents and voltages:
       i. deviation in magnitude between three phases
       ii. deviation in angle separation from 120° between three phases.

   (d) RPP will generally follow the supply network frequency:
       i. Any attempt by the RPP to change the supply frequency may result in severe distortion of the voltage at the POC, PCC and other points in the network.

(3) Power quality and voltage regulation impact shall be monitored at the POC.
(4) Voltage and current quality distortion levels emitted by the RPP at the POC shall not exceed the apportioned limits as determined by the relevant NSP. The calculation of these emission levels shall be based on international (e.g. relevant parts of IEC 61000-series) and local specifications (e.g. NRS 048-4). The allocation shall be fair and transparent.

(5) The RPP Generator shall ensure that the RPP is designed, configured and implemented in such a way that the specified emission limit values are not exceeded.

(6) The maximum allowable voltage change at the POC after a switching operation by the RPP (e.g. of a compensation devices) shall not be greater than 2%.

(7) The RPP can assume that the network harmonic impedance at the POC will be less than 3 times the base harmonic impedance for the range of reference fault levels at the POC, i.e. the network harmonic impedance shall not exceed a harmonic impedance of:

\[ Z(h) = 3 \times \frac{V}{S} \times h \]

where \( h \) is the harmonic number, \( V \) is the nominal voltage in kV, and \( S \) is the fault level in MVA.

10. Protection and Fault levels

(1) Unless otherwise stated, requirements in this section apply to all Categories of RPPs.

(2) Protection functions shall be available to protect the RPP and to ensure a stable TS and DS.

(3) The RPP Generator shall ensure that a RPP is dimensioned and equipped with the necessary protection functions so that the RPP is protected against damage due to faults and incidents in the TS and DS.

(4) The RPP shall be equipped with effective detection of islanded operation in all system configurations and capability to shut down generation of power in such condition within 2 seconds. Islanded operation with part of the TS or DS is not permitted unless specifically agreed with the NSP.

(5) The RPP of Category A shall be equipped with effective detection of islanded operation in all system configurations and capability to shut down generation of power in such condition within 0.2 seconds. Islanded operation with part of the TS or DS is not permitted unless specifically agreed with the NSP.

(6) The NSP or the SO may request that the set values for protection functions be changed following commissioning if it is deemed to be of importance to the operation of the TS and DS.
However, such change shall not result in the RPP being exposed to negative impacts from the TS and DS lying outside of the design requirements.

(7) The NSP shall inform the RPP generator of the highest and lowest short-circuit current that can be expected at the POC as well as any other information about the TS and DS as may be necessary to define the RPP’s protection functions.

11. Active Power Constraint Functions

(1) This section shall apply to RPPs of categories A3, B & C

(2) For system security reasons it may be necessary for the SO or another network operator to curtail the RPP active power output.

(3) The RPP Generator shall be capable of:

(a) operating the RPP at a reduced level if active power has been curtailed by the NSP, SO or another network operator for system security reasons.

(b) receiving a telemetered MW Curtailment set-point sent from the SO and/or another network operator. If another operator is implementing power curtailment, this shall be in agreement with all the parties involved.

(4) The RPP shall be equipped with constraint functions, i.e. supplementary active power control functions. The constraint functions are used to avoid imbalances in the NIPS or overloading of the TS and DS in connection with the reconfiguration of the TS and DS in critical or unstable situations or the like, as shown in Figure 14. Activation of the active power constraint functions shall be agreed with the SO or NSP. The required constraint functions are as follows:

(a) Absolute production constraint
(b) Delta production constraint
(c) Power gradient constraint

(5) The required constraint functions are described in the following sections.

11.1 Absolute Production Constraint

(1) An Absolute Production Constraint is used to constrain the output active power from the RPP to a predefined power MW limit at the POC. An Absolute Production Constraint is typically used to protect the TS and DS against overloading.
(2) If the frequency control setpoint for the Absolute Production Constraint is to be changed, such change shall be commenced within two seconds and completed not later than 30 seconds after receipt of an order to change the setpoint.

(3) The accuracy of the control performed and of the setpoint shall not deviate by more than ±2% of the setpoint value or by ±0.5% of the rated power, depending on which yields the highest tolerance.

### 11.2 Delta Production Constraint

(1) A Delta Production Constraint is used to constrain the active power from the RPP to a required constant value in proportion to the possible active power.

(2) A Delta Production Constraint is typically used to establish a control reserve for control purposes in connection with frequency control.

(3) If the setpoint for the Delta Production Constraint is to be changed, such change shall be commenced within two seconds and completed no later than 30 seconds after receipt of an order to change the setpoint.

(4) The accuracy of the control performed and of the setpoint shall not deviate by more than ±2% of the setpoint value or by ±0.5% of the rated power, depending on which yields the highest tolerance.

### 11.3 Power Gradient Constraint

(1) A Power Gradient Constraint is used to limit the maximum ramp rates by which the active power can be changed in the event of changes in primary renewable energy supply or the setpoints for the RPP. A Power Gradient Constraint is typically used for reasons of system operation to prevent changes in active power from impacting the stability TS or the DS.

(2) If the setpoint for the Power Gradient Constraint is to be changed, such change shall be commenced within two seconds and completed no later than 30 seconds after receipt of an order to change the setpoint.

(3) The accuracy of the control performed and of the setpoint shall not deviate by more than ±2% of the setpoint value or by ±0.5% of the rated power, depending on which yields the highest tolerance.

(4) The active power constraint functions are illustrated on Figure 14.
12. Control Function Requirements

(1) RPPs of category A shall only be capable of power factor control.

(2) RPPs of category B and C shall be equipped with the control functions specified in Table 3. The purpose of the various control functions is to ensure overall control and monitoring of the RPP’s generation.

(3) The RPP control system shall be capable of controlling the ramp rate of its active power output with a maximum MW per minute ramp rate set by SO or NSP.

(4) These ramp rate settings shall be applicable for all ranges of operation including positive ramp rate during start up, positive ramp rate only during normal operation and negative ramp rate during controlled shut down. They shall not apply to frequency regulation.

(5) The RPP generator shall not perform any frequency response or voltage control functions without having entered into a specific agreement to this effect with the NSP.

(6) The specifications and regulation functions specified shall comply with the international standard IEC 61400-25-2

Table 3: Control functions required for RPPs

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Page 29
13. Signals, Communications & Control

(1) All signals shall be made available at the POC by the RPP generator.

(2) Requirements for the exchange of signals between RPPs of Category A and the NSP or SO shall be limited to a start and stop signals.

(3) Requirements for the exchange of signals between RPPs of Categories B and C, and the NSP or SO are described in the following sections.

13.1 Signals from the RPP available at the POC

(1) This section shall apply to RPPs of Categories B and C.

(2) Signals from the RPP to the SO or NSP shall be broken up into a number of logical groups. There are different requirements for RPP depending on the RPP's maximum sent out capacity or functionality.

(3) The following groups shall apply:

(a) Signals List #1 – General

In addition, the RPP shall be required to provide certain signals from Signals Lists 2, 3, 4 and 5. These lists relate to:

(b) Signals List #2 - RPP Availability Estimate;
(c) Signals List #3 - RPP MW Curtailment Data;
(d) Signals List #4 - Frequency Response System Settings;
(e) Signals List #5 - RPP Meteorological Data.
13.1.1 **Signals List #1 – General**

(1) The *RPP Generator* shall make the following signals available at a *Distributor* or *TNSP* designated communication gateway facility located at the *RPP* site:

(a) Actual sent-out (MW) at the *POC*
(b) Ramp rate of the entire *RPP*
(c) Reactive Power Import/Export (+/- Mvar) at the *POC*
(d) Reactive power range upper and lower limits
(e) Power Factor
(f) Voltage output
(g) Echo MW set point
(h) Echo Mvar set point
(i) Echo Voltage set point

13.1.2 **Signals List #2 – RPP Availability Estimates**

(1) *RPP Generator* shall make available the following signals at a *Distributor* or *TNSP* designated communication gateway facility located at the *RPP* site:

(a) Available MW and forecast MW for the next 6 hours updated hourly on the hour.
(b) Available Mvar and forecast Mvar for the next 6 hours updated hourly on the hour.

13.1.3 **Signals List #3 – Frequency Response System Settings**

(1) The *RPP Generator* shall make the following signals available at a designated Gateway facility located at the *RPP* site:

(a) *RPP* MW Curtailment facility status indication (ON/OFF) as a double bit point. This is a controllable point which is set on or off by the SO. When set “On” the *RPP* shall then clarify initiate the curtailment based on the curtailment set point value below.
(b) Curtailment in progress digital feedback. This single bit point will be set high by the *RPP* while the facility is in the process of curtailing its output.
(c) *RPP* MW Curtailment Set-point value (MW- feedback).

(2) In the event of a curtailment, the SO will pulse the curtailment set point value down. The *RPP* response to the changed curtailment value will be echoed by changing the corresponding echo MW value. This will provide feedback that the *RPP* is responding to the curtailment request.
13.1.4 Signals List #4 – Frequency Response System Settings

(1) The RPP Generator shall make the following signals available at a Distributor designated communication gateway facility located at the RPP site:
   (a) Frequency Response System mode status indication (ON/OFF) as a double bit point

13.1.5 Signals List #5 – RPP Meteorological Data.

(1) RPP Generator shall make the following signals available at a Distributor or TNSP designated Gateway facility located at the RPP site:
   (a) Wind speed (within 75% of the hub height) – measured signal in meters/second (for WPP only)
   (b) Wind direction within 75% of the hub height) – measured signal in degrees from true north(0-359) (for WPP only)
   (c) Air temperature- measured signal in degrees centigrade (-20 to 50);
   (d) Air pressure- measured signal in millibar (800 to 1400).
   (e) Air density (for WPP only)
   (f) Solar radiation (for PVPP only)

(2) The meteorological data signals shall be provided by a dedicated Meteorological Mast located at the RPP site or, where possible and preferable to do so, data from a means of the same or better accuracy.

(3) Energy resource conversion data for the facility (e.g. MW/ wind speed) for the various resource inputs to enable the SO to derive a graph of the full range of the facilities output capabilities. An update will be sent to the SO following any changes in the output capability of the facility.

(4) For RPP where the wind turbines are widely dispersed over a large geographical area and rather different weather patterns are expected for different sections of the RPP, the meteorological data shall be provided from a number of individual Meteorological Masts, or where possible and preferable to do so, data from a source of the same or better reliability for groups of wind turbines. It is expected that wind turbines within an individual group shall demonstrate a high degree of correlation in Active Power output at any given time. The actual signals required shall be specified by the SO. There shall be at least one Meteorological Mast for every 10x10 square km area of the facility

13.2 Update Rates

(1) Signals shall be updated at the following rates:
(a) Analog Signals at a rate of 2 seconds.
(b) Digital Signals at the rate of 1 second.
(c) Meteorological data once a minute

13.3 Control Signals Sent from SO to the RPPs

(1) The control signals described below shall be sent from SO to the RPP. The RPP shall be capable of receiving these signals and acting accordingly.

13.3.1 Active-Power Control

(1) An Active-Power Control set-point signal shall be sent by SO to the RPP control system. This set-point shall define the maximum Active Power output permitted from the RPP. The RPP control system shall be capable of receiving this signal and acting accordingly to achieve the desired change in Active Power output. See (a) in Figure 14 below

(2) This value is controlled by raise or lower pulses.

(3) The RPP Generator shall make it possible for the SO to remotely enable/disable the Active-Power control function in the RPP control system.

13.3.2 Connection Point CB Trip facility

(1) A facility shall be provided by the NSP to facilitate the disconnection of the RPP. It shall be possible for SO or another network operator to send a trip signal to the circuit breaker at the HV side of the POC. This is currently implemented via the breaker shown as (b) in Figure 14 below.

13.4 MW Forecast

(1) This section applies only to Category C RPPs.

(2) The RPP generator shall have the capability to produce and submit to the SO the day-ahead and week-ahead hourly MW production forecast.

(3) The forecasts shall be provided by RPP generator. These forecasts shall be provided at 10:00 a.m. on a daily basis for the following 48 hours for each 1 hour time-period, by means of an electronic interface in accordance with the reasonable requirements of SO’s data system. This is shown as (c) in Figure 14 below.
13.5 RPP MW availability declaration

(1) The RPP Generator shall submit RPP MW availability declarations whenever changes in MW availability occur or are predicted to occur. These declarations shall be submitted by means of an electronic interface in accordance with the requirements of SO's data system. This is shown as (c) in Figure 14 below.

13.6 Data Communications Specifications

(1) The RPP shall have an external communication gateway facility that can communicate with a minimum of three simultaneous SCADA Masters, independently from what is done inside the RPP.

(2) The location of the communication gateway facility shall be agreed between affected participants in the connection agreement.

(3) The necessary communications links, communications protocol and the requirement for analogue or digital signals shall be specified by the SO as appropriate before a connection agreement is signed between the RPP Generator and the Distributor or TNSP.

(4) Active Power Curtailment or Voltage Regulation facilities at the RPP shall be tested once a month. It is essential that facilities exist to allow the testing of the functionality without tripping the actual equipment.

(5) Where signals or indications required to be provided by the RPP Generator become unavailable or do not comply with applicable standards due to failure of the RPP equipment or any other reason under the control of the RPP, the RPP Generator shall restore or correct the signals and/or indications within 24 hours.
14. Testing and Compliance Monitoring

(1) All RPP generators shall demonstrate compliance to the requirements specified in this document and any other applicable codes or standard approved by NERSA, as applicable depending on the connection point, before being allowed to connect to the DS or the TS and operate commercially.

(2) The RPP Generator shall review, and confirm to the SO and NERSA, compliance by the RPP with every requirements of this code.

(3) The RPP Generator shall conduct tests or studies to demonstrate that each RPP complies with each of the requirements of this code.

(4) The RPP Generator shall continuously monitor its compliance in all material respects with all the connection conditions of this code.

(5) Each RPP Generator shall submit to the SO a detailed test procedure, emphasising system impact, for each relevant part of this code prior to every test.
(6) If RPP Generator determines, from tests or otherwise, that the RPP is not complying with one or more sections of this code, then the RPP Generator shall (within 1 hour of being aware):

(a) notify the SO of that fact
(b) advise the SO of the remedial steps it proposes to take to ensure that the relevant RPP can comply with this code and the proposed timetable for implementing those steps
(c) diligently take such remedial action to ensure that the relevant RPP can comply with this code; the RPP Generator shall regularly report in writing to the SO on its progress in implementing the remedial action, and
(d) after taking remedial action as described above, demonstrate to the reasonable satisfaction of the SO that the relevant RPP is then complying with this code.

(7) The SO may issue an instruction requiring the RPP Generator to carry out a test to demonstrate that the relevant RPP complies with the code requirements. A RPP Generator may not refuse such an instruction, provided it is issued timeously and there are reasonable grounds for suspecting non-compliance.

(8) The RPP Generator shall keep records relating to the compliance of the RPP with each section of this code, the Grid Code or the Distribution Code and the Dispatch Rules, applicable to that RPP, setting out such information that the SO reasonably requires for assessing power system performance, including actual RPP performance during abnormal conditions. Records shall be kept for a minimum of 5 years (unless otherwise specified in the Grid Code) commencing from the date the information was created.

15. Reporting to NERSA

(1) The RPP Generator shall design the system and maintain records so that the following information can be provided to the Energy Regulator on a monthly basis in an electronic spreadsheet format:

(a) Non-renewable/supplementary fuel used by the power plant as outlined under Supplementary Fuel Specification schedule of the PPA during the month.
(b) Day ahead forecast output energy to the grid and hourly availability as specified in 13.4 and 13.5 above.
(c) Actual hourly availability and output energy to the grid that occurred and the average primary resource for that hour (i.e. Wind speed for wind generators and solar radiation for solar generation)
(d) Actual hourly electricity imports from all sources as applicable.
(e) Direct monthly emissions per unit of electricity generated by the RPP (tCO2/kWh).
(f) Any curtailed energy during the month.

(2) These reports are to be submitted before the 15\textsuperscript{th} of the following month to IPSreports@nersa.org.za

(3) These reports should also include details of incidents relating any unavailability of the network which prevented the RPP from generating and any incidents where their right to self-dispatch was impinged upon where the PPA gives them a right to self-dispatch.

16. Provision of Data and Electrical Dynamic Simulation Models

(1) The SO, Distributors and TNSPs require suitable and accurate dynamic models, in the template specified by the requesting party applying for a connection to the DS or TS, in order to assess reliably the impact of the RPP proposed installation on the dynamic performance and security and stability of the power system.

(2) The required dynamic models must operate under RMS and EMT simulation to replicate the performance of the RPP facility or individual units for analysis of the following network aspects:

(a) \textit{RPP} impact on network voltage stability
(b) \textit{RPP} impact on QOS at POC
(c) \textit{RPP} switching transients impact on network performance
(d) \textit{RPP} impact on breakers TRV (Transient Recovery Voltage)
(e) \textit{RPP} impact on network insulation co-ordination requirements
(f) \textit{RPP} impact on network protection co-ordination
(g) \textit{RPP} FRT (Fault Ride Through) capability for different types of faults and positions
(h) \textit{RPP} response to various system phenomena such as:
   (i) switching on the network
   (ii) power swings
   (iii) small signal instabilities

(3) \textit{RPP} data exchange shall be a time-based process.
   (a) First stage (during the application for connection)

   (i) The following information shall be submitted by the \textit{RPP Generator} to the SO and Distributor or TNSP, as applicable:

   - Physical location of the \textit{RPP} (including the GPS coordinates)
   - Site Plan
• Number of wind turbines or units to be connected
• MW output per turbine or unit
• Initial phase MW value
• Final phase MW value and timelines
• Any other information that the service provider may reasonably require

(ii) For the detailed RPP design, the NSP shall make available to the RPP generator or its agent at least the following information:

• Point of Connection and the Point of Common Coupling including the nominal voltages,
• Expected fault levels
• The network service provider’s connection between the Point of connection and the RPP,
• The busbar layout of the Point of Common Coupling and POC substations,
• The portion of the network service provider’s grid that will allow accurate and sufficient studies to design the RPP to meet the Grid Code. This information shall include:
  o Positive and zero sequence parameters of the relevant network service provider’s transmission and distribution, transformers, reactors, capacitors and other relevant equipment
  o The connection of the various lines transformers, reactors and capacitors etc.

(b) Second stage (after detailed RPP designs have been completed but before commissioning the RPP).

(i) During this stage, the RPP Generator is compelled to provide information on:

• Selected wind turbine technology data.
• LVRT capability and harmonic studies test report
• Generic test model and dynamic modelling data per wind turbine or unit as from the type approval and tests result

(c) Third stage (after commissioning and optimisation of the RPP)
(i) During this stage, the *RPP Generator* is compelled to provide information on:

- A validated *RPP* electrical dynamic simulation model using commissioning test data and measurements
- Test measurement data in the format agreed between the *RPP Generator* and the *Distributor, NTC* or *SO*, as applicable.

(4) The dynamic modelling data shall be provided in a format as may be agreed between the *RPP Generator* and the *Distributor, NTC* or *SO*, as applicable.

(5) In addition, the *RPP Generator* shall provide the SO with operational data as prescribed in *Appendix 8*. 
Appendices
Appendix 1 - Wind

A1.1 High Wind Curtailment

(1) It shall be possible to continuously downward regulate the active power supplied by the RPP to an arbitrary value in the interval from 100% to at least 40% of the rated power. When downward regulation is performed, the shutting-down of individual wind turbine generator systems is allowed so that the load characteristic is followed as well as possible.

(2) The wind power plant shall stay connected to the TS and DS at average wind speeds below a predefined cut-out wind speed. The cut-out wind speed shall as a minimum be 25 m/s, based on the wind speed measured as an average value over a 10-minute period. To prevent instability in the TS and DS, the wind power plant shall be equipped with an automatic downward regulation function making it possible to avoid a temporary interruption of the active power production at wind speeds close to the cut-out wind speed.

(3) Downward regulation shall be performed as continuous or discrete regulation. Discrete regulation shall have a step size of maximum 25% of the rated power within the hatched area shown in Figure 16. When downward regulation is being performed, the shutting-down of individual wind turbine generator systems is allowed. The downward regulation band shall be agreed with the NSP upon commissioning of the wind power plant.

Figure 16: Downward regulation of active power at high renewable speeds
Appendix 2 - Photovoltaic

(1) A Photovoltaic RPP of category A shall be provided with functionality to continuously downward regulate the active power supplied by the power plant according to a droop characteristic as illustrated in Figure 17. The trigger frequency and the droop shall be agreed with the NSP upon commissioning of the power plant.

(2) The trigger frequency and the droop shall be agreed with the NSP upon commissioning of the power plant.

![Figure 17: Downward regulation of active power at grid frequency increase](image-url)
Appendix 3 - Concentrated Solar Power

No special requirements except the general requirement specified in this code shall be applied for solar CSP.
Appendix 4 - Small Hydro

No special requirements except the general requirement specified in this code shall be applied for Small Hydro.
Appendix 5 - Landfill Gas

No special requirements except the general requirement specified in this code shall be applied for Landfill Gas.
Appendix 6 - Biomass

No special requirements except the general requirement specified in this code shall be applied for Biomass.
Appendix 7 - Biogas

No special requirements except the general requirement specified in this code shall be applied for Biogas.
### A8.1 Master Data

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## A8.2 Technical Documentation

### A8.2.1 Step-Up Transformer

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<td>Nominal apparent power (1 p.u.)</td>
<td>$S_n$</td>
<td>MVA</td>
<td></td>
</tr>
<tr>
<td>Nominal primary voltage (1 p.u.)</td>
<td>$U_p$</td>
<td>kV</td>
<td></td>
</tr>
<tr>
<td>Nominal secondary voltage</td>
<td>$U_s$</td>
<td>kV</td>
<td></td>
</tr>
<tr>
<td>Coupling designation, eg Dyn11</td>
<td>-</td>
<td>-</td>
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</tr>
<tr>
<td>Step switch location</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Step switch, additional voltage per step</td>
<td>$dU_{tp}$</td>
<td>%/trin</td>
<td></td>
</tr>
<tr>
<td>Step switch, phase angle of additional voltage per step:</td>
<td>$\phi_{tp}$</td>
<td>degree/step</td>
<td></td>
</tr>
<tr>
<td>Step switch, lowest position</td>
<td>$n_{tp\min}$</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Step switch, highest position</td>
<td>$n_{tp\max}$</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Step switch, neutral position</td>
<td>$n_{tp0}$</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Short-circuit voltage, synchronous</td>
<td>$u_k$</td>
<td>%</td>
<td></td>
</tr>
<tr>
<td>Copper loss</td>
<td>$P_{cu}$</td>
<td>kW</td>
<td></td>
</tr>
<tr>
<td>Short-circuit voltage, zero system</td>
<td>$u_{k0}$</td>
<td>%</td>
<td></td>
</tr>
<tr>
<td>Resistive short-circuit voltage, zero-sequence system</td>
<td>$u_{kr0}$</td>
<td>%</td>
<td></td>
</tr>
<tr>
<td>No-load current</td>
<td>$I_0$</td>
<td>%</td>
<td></td>
</tr>
<tr>
<td>No-load loss</td>
<td>$P_0$</td>
<td>%</td>
<td></td>
</tr>
</tbody>
</table>
A8.2.2 Single Line Diagram Representation

(1) This applies to all RPPs of category B and C. The SO, NSP or local network operator may request that a single-line diagram representation be provided for RPPs of category A.

(2) A single-line diagram representation of the plant shall be created, with indication of POC, metering points, including settlement metering, limits of ownership and operational supervisor limits/limits of liability. In addition, the type designation for the switchgear used shall be stated so as to make it possible to identify the correct connection terminals.

(3) In instances when a single-line diagram representation is included in the grid use agreement between RPP Generator and SO, the grid connection agreement can be enclosed as documentation.

A8.2.3 PQ Diagram

(1) This applies to all RPPs of category B and C. The SO, NSP or local network operator may also request that a PQ diagram representation be provided for RPPs of category A.

A8.2.4 Short-circuit data

Application: This applies to all RPPs of category B and C.

For the purposes of static calculations, the RPP generator shall provide short-circuit data at different voltage drops in the TS and DS, using the requirements in section 5.2.1 as starting point. Voltage drops in connection with faults shall be stated with a short-circuit time of 150 ms.

The fault sequence is logged through simulation in the 0-500 ms time interval. Short-circuit data shall be provided in the following tables.

Assumptions for the calculation of short-circuit data:

- All generator in the RPP are connected
- The RPP produces rated power
- Current values are calculated in the POC
- Symmetrical voltage drop is indicated as a percentage (dU) of the output voltage
- The RPP’s protection functions/settings are included
- The short-circuit power in the POC is set to 10 x Pn with an X/R of 10
- 50 Hz component of the active current, I_{active}
- 50 Hz component of the reactive current, I_{reactive}
- Total current incl. DC component and harmonics, I_{peak}

\[ dU = 20\% \]
<table>
<thead>
<tr>
<th>Time [ms]</th>
<th>$I_{active}$ [A]</th>
<th>$I_{reactive}$ [A]</th>
<th>$I_{peak}$ [A]</th>
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</table>

$dU=30\%$

<table>
<thead>
<tr>
<th>Time [ms]</th>
<th>$I_{active}$ [A]</th>
<th>$I_{reactive}$ [A]</th>
<th>$I_{peak}$ [A]</th>
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<tr>
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</table>

$dU=50\%$

<table>
<thead>
<tr>
<th>Time [ms]</th>
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<th>$I_{reactive}$ [A]</th>
<th>$I_{peak}$ [A]</th>
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<tr>
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</tbody>
</table>

$dU=80\%$

<table>
<thead>
<tr>
<th>Time [ms]</th>
<th>$I_{active}$ [A]</th>
<th>$I_{reactive}$ [A]</th>
<th>$I_{peak}$ [A]</th>
</tr>
</thead>
<tbody>
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</tbody>
</table>
A9.1 Introduction
This section specifies the procedures to be followed in carrying out testing to verify compliance with this Code.

A9.2 Test procedures

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Reference</th>
<th>Description</th>
</tr>
</thead>
</table>
| Protection function and settings | Section 10 | **APPLICABILITY AND FREQUENCY**
All new RPPs coming on line or at which major refurbishment or upgrades of protection systems have taken place.  

**Routine review:** All generators to confirm compliance every six years.  

**PURPOSE**
To ensure that the relevant protection functions in the RPP are coordinated and aligned with the system requirements.

**PROCEDURE**
1. Establish the system protection function and associated trip level requirements from the SO or relevant NSP.
2. Derive protection functions and settings that match the RPP and system requirements.
3. Confirm the stability of each protection function for all relevant system conditions.
4. Document the details of the trip levels and stability calculations for each protection function.
5. Convert protection tripping levels for each protection function into a per unit base.
6. Consolidate all settings in a per unit base for all protection functions in one document.
7. Derive actual relay dial setting details and document the relay setting sheet for all protection functions.
8. Document the position of each protection function on one single line diagram of the generating unit and associated connections.
9. Document the tripping functions for each tripping function on one tripping logic diagram.
10. Consolidate detail setting calculations, per unit setting sheets, relay setting sheets, plant base information on which the settings are based, tripping logic diagram, protection function single line diagram and relevant protection relay manufacturers’ information into one document.
11. Submit to the SO or relevant NSP for its acceptance and update.

**Review:**
1. Review Items 1 to 10 above.
2. Submit to the SO or relevant NSP for its acceptance and update.
3. Provide the SO or relevant NSP with one original master copy and one working copy.

**ACCEPTANCE CRITERIA**
All protection functions are set to meet the necessary
protection requirements of the RPP with a minimal margin, optimal fault clearing times and maximum plant availability.

Submit a report to the SO or relevant NSP one month after commissioning and six-yearly for routine tests.
## A.9.2.2 - RPP protection integrity verification

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Reference</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protection integrity</td>
<td>Section 10</td>
<td><strong>APPLICABILITY AND FREQUENCY</strong>&lt;br&gt; All new RPPs coming on line and all other power stations after major works of refurbishment of protection or related plant. Also, when modification or work has been done to the protection, items 2 to 5 must be carried out. This may, however, be limited to the areas worked on or modified. <strong>Routine review:</strong> All RPPs on:&lt;br&gt; item 1 below: Review and confirm every 6 years&lt;br&gt; Item 2, and 3 below: at least every 12 years. <strong>PURPOSE</strong>&lt;br&gt; To confirm that the protection has been wired and functions according to the specifications. <strong>PROCEDURE</strong>&lt;br&gt; 1. Apply final settings as per agreed documentation to all protection functions.&lt;br&gt; 2. With the unit off load and de-energized, inject appropriate signals into every protection function and confirm correct operation and correct calibration. Document all protection function operations.&lt;br&gt; 3. Carry out trip testing of all protection functions, from origin (e.g. Buchholz relay) to all tripping output devices (e.g. HV breaker). Document all trip test responses.&lt;br&gt; 4. Apply short-circuits at all relevant protection zones and with generator at nominal speed excite generator slowly, record currents at all relevant protection functions and confirm correct operation of all relevant protection functions. Document all readings and responses. Remove all short-circuits.&lt;br&gt; 5. With the RPP at nominal production. Confirm correct operation and correct calibration of all protection functions. Document all readings and responses. <strong>Review:</strong>&lt;br&gt; Submit to the SO or relevant NSP for its acceptance and update. <strong>ACCEPTANCE CRITERIA</strong>&lt;br&gt; All protection functions are fully operational and operate to required levels within the relay OEM allowable tolerances. Measuring instrumentation used shall be sufficiently accurate and calibrated to a traceable standard. Submit a report to the SO or relevant NSP one month after test.</td>
</tr>
</tbody>
</table>
A9.2.3  - RPP active power control capability verification

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Reference</th>
<th>Description</th>
</tr>
</thead>
</table>
| Active power control function and operational range | Section 11 depending on category | **APPLICABILITY**

All new RPPs coming on line and after major modifications or refurbishment of related plant components or functionality.

**Routine test/reviews**: Confirm compliance every 6 years.

**PURPOSE**

To confirm that the active power control capability specified is met.

**PROCEDURE**

The following tests shall be performed within an active power level range from 0.2 p.u. to 0.6 p.u.

1. The *RPP* will be required to regulate the active power to a set of specific setpoints within the design margins.
2. The *RPP* will be required to obtain a set of active power setpoints within the design margins with minimum two different gradients for ramping up and two different gradients for ramping down.
3. The *RPP* will be required to maintain as a minimum two different set levels of spinning reserve within the design margins.
4. The *RPP* will be required to operate as a minimum to limit active power output according to two different absolute power constraint set levels within the design margins.
5. The *RPP* will be required to verify operation according to as a minimum two different parameter sets for a frequency response curve within the design margins.

**ACCEPTANCE CRITERIA**

1. The *RPP* shall maintain the set output level within ±2% of the capability registered with the *SO, NSP or another network operator* for at least one hour.
2. The *RPP* shall demonstrate ramp rates with precision within ±2% of the capability registered with the *SO, NSP or another network operator* for ramp up and down.
3. The *RPP* shall maintain a spinning reserve set level within ±2% of the capability registered with the *SO, NSP or another network operator* for at least one hour.
4. The *RPP* shall maintain an absolute power constraint set level within ±2% of the capability registered with the *System Operator* for at least one hour.
5. The *RPP* shall demonstrate that the requested frequency response curves can be obtained.

Submit a report to the *SO, NSP or another network operator* one month after the test.
### A9.2.4 - RPP reactive power control capability verification

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Reference</th>
<th>Description</th>
</tr>
</thead>
</table>
| Reactive power control function and operational range | Sections 7 and 8 depending on category | **APPLICABILITY**
All new RPPs coming on line and after major modifications or refurbishment of related plant components or functionality.  
**Routine test/reviews:** Confirm compliance every 6 years.  
**PURPOSE**
To confirm that the reactive power control capability specified is met.  
**PROCEDURE**
The following tests shall be performed within a minimum active power level range from 0.2 p.u. to 0.6 p.u.  
1. The RPP will be required to regulate the voltage at the PCC to a set level within the design margins.  
2. The RPP will be required to provide a fixed Q to a set level within the design margins.  
3. The RPP will be required to obtain a fixed PF within the design margins.  
**ACCEPTANCE CRITERIA**
1. The RPP shall maintain the set voltage within ±5% of the capability registered with the SO, NSP or another network operator for at least one hour.  
2. The RPP shall maintain the set Q within ±2% of the capability registered with the SO, NSP or another network operator for at least one hour.  
3. The RPP shall maintain the set PF within ±2% of the capability registered with the SO, NSP or another network operator for at least one hour.  
Submit a report to the SO, NSP or another network operator one month after the test.
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Reference</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power quality calculations</td>
<td></td>
<td></td>
</tr>
<tr>
<td>for:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Rapid voltage changes</td>
<td></td>
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<tr>
<td>2. Flicker</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Harmonics</td>
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<td></td>
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<tr>
<td>4. Inter-harmonics</td>
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<tr>
<td>5. High frequency disturbances</td>
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</tr>
</tbody>
</table>

**APPLICABILITY**

All new RPPs coming on line and after major modifications or refurbishment of related plant components or functionality.

**Routine test/reviews:** Confirm compliance every 6 years.

**PURPOSE**

To confirm that the limits for all power quality parameters specified is met.

**PROCEDURE**

The following tests shall be calculated within a minimum active power level range from 0.2 p.u. to 1.0 p.u.

1. Calculate the levels for rapid voltage changes are within the limits specified over the full operational range.
2. Calculate the flicker levels are within the limits specified over the full operational range.
3. Calculate the harmonics are within the limits specified over the full operational range.
4. Calculate the interharmonics are within the limits specified over the full operational range.
5. Calculate the disturbances higher than 2 Hz are within the limits specified over the full operational range.

**ACCEPTANCE CRITERIA**

1. The calculations shall demonstrate that the levels for rapid voltage changes are within the limits specified over the full operational range.
2. The calculations shall demonstrate that the flicker levels are within the limits specified over the full operational range.
3. The calculations shall demonstrate that the harmonics are within the limits specified over the full operational range.
4. The calculations shall demonstrate that the interharmonics are within the limits specified over the full operational range.
5. The calculations shall demonstrate that the disturbances higher than 2 Hz are within the limits specified over the full operational range.

Submit a report to the *System Operator* one month after the test.
### A.13.2.6 - RPP fault ride through simulations

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Reference</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>Simulations of fault ride through voltage droops and peaks.</td>
<td>Section 5.2.1 for category B and C</td>
<td><strong>APPLICABILITY</strong>&lt;br&gt;All new RPPs coming on line and after major modifications or refurbishment of related plant components or functionality.</td>
</tr>
<tr>
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<td><strong>Routine test/reviews:</strong> None.</td>
</tr>
<tr>
<td></td>
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<td><strong>PURPOSE</strong>&lt;br&gt;To confirm that the limits for all power quality parameters specified is met.</td>
</tr>
<tr>
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<td><strong>PROCEDURE</strong>&lt;br&gt;By applying the electrical simulation model for the entire RPP it shall be demonstrated that the RPP performs to the specifications.&lt;br&gt;1. Area A - the RPP shall stay connected to the network and uphold normal production.&lt;br&gt;2. Area B - the RPP shall stay connected to the network. The RPP shall provide maximum voltage support by supplying a controlled amount of reactive power within the design framework offered by the technology, see Figure 6.&lt;br&gt;3. Area C - the RPP is allowed to disconnect.&lt;br&gt;4. Area D - the RPP shall stay connected. The RPP shall provide maximum voltage support by absorbing a controlled amount of reactive power within the design framework offered by the technology, see Figure 6.</td>
</tr>
<tr>
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<td><strong>ACCEPTANCE CRITERIA</strong>&lt;br&gt;1. The dynamic simulations shall demonstrate that the RPP fulfills the requirements specified.</td>
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<td>Submit a report to the SO, NSP or another network operator three month after the commission.</td>
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</tbody>
</table>