GRID CONNECTION CODE FOR RENEWABLE POWER PLANTS (RPPs)
1.0 GRID CONNECTION CODE BASIS

1.1 LEGISLATION

1.1.1 The legal basis for this RPP Code (RPP Code) is specified in terms of the [Electricity] Act 2016 section 20A (d) on dispatch of generation.

1.1.2 This document shall be used together with other applicable requirements of the Malawi Grid Code – November 2015.

1.2 OBJECTIVES

1.2.1 The primary objective of this RPP Code is to specify minimum technical and design grid connection requirements for Renewable Power Plants (RPPs) connected to or seeking connection to the Electricity Transmission System (TS) or Distribution System (DS) in Malawi.

1.3 SCOPE

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

1.3.2 This RPP Code shall, at minimum, apply to the following RPP technologies:

(a) Photovoltaic
(b) Concentrated Solar Power
(c) Small Hydro
(d) Biomass
(e) Biogas
(f) Wind

1.3.3 The RPP Code shall take precedence on matters of Renewable Power Plants whenever there is a conflict between this RPP Code and other codes.

1.3.4 Compliance with this RPP Code shall be applicable to the RPP depending on its rated power and, where indicated, the nominal voltage at the POC. Accordingly, RPPs are grouped into the following three categories:

(a) Category A: Up To 1 MVA: This category includes RPPs with rated power of less than 1 MVA that are connected to the distribution system. This category shall further be divided into 3 sub-categories:
• **Category A1: 0 - 20 kVA:** This sub-category includes RPPs of Category A with rated power in the range of 0 to 20kVA that are connected to the 230 or 400V networks.

• **Category A2: 20 kVA – 100 kVA:** This sub-category includes RPPs of Category A with rated power in the range greater than 20 kVA but less than 100 kVA that are connected to the 400V.

• **Category A3: 100 kVA – 1 MVA:** This sub-category includes RPPs of Category A with rated power in the range 100 kVA but less than 1 MVA, Typically connected to 11kV or 33kV systems.

  This category also includes RPPs of Category A1 and A2 with a rated power less than 100kVA that are connected to the 11kV or 33kV networks.

**Note:** RPPs with a rated power greater than 10kVA must be balanced three-phase.

(b) **Category B: 1 MVA – 20 MVA and RPPs less than 1 MVA connected to the TS or DS:** This category includes RPPs with rated power in the range equal or greater than 1 MVA but less 20 MVA and RPPs with rated power less than 1 MVA c.

(c) **Category C: 20 MVA or higher:** This category includes RPPs with rated power equal to or greater than 20 MVA, typically connected to the TS.

2.0 The NSP shall supply the RPP Generator with a reasonable detail of their TS or DS that is sufficient to allow an accurate analysis of the interaction between the RPP and the Interconnected Power System (IPS), including other generation facilities.

3.0 **DEFINITIONS AND ABBREVIATIONS**

Unless otherwise indicated, words and terminology in this document shall have the same meaning as those in the Grid Codes. The following definitions and abbreviations are used in this document.

• **Active Power Curtailment Set-point:** The limit set by the SMO, NSP or their agent 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 (MW), measured at the POC, that the RPP could produce based on plant availability as well as current renewable primary energy conditions (e.g. wind speed, solar radiation).

• **Code:** The Malawi Grid Code Final Version – November 2015 or any other Code approved by MERA.

• **Connection Agreement:** As defined in the Grid Code (not currently defined in the Malawi Grid Code)

• **Communication Gateway Equipment:** As defined in the Grid Code

• **Curtailed Active Power:** The amount of Active Power that the RPP is permitted to generate by the SMO, NSP or their agent subject to network or system constraints.
• **Distribution System (DS):** As defined in the Grid Code

• **Distributor:** As defined in the Grid Code

• **Droop:** A percentage of the frequency change required for an RPP to move from no-load to rated power or from rated power to no-load.

• **Frequency control:** The control of active power with a view to stabilising frequency of the IPS.

• **Generator:** As defined in the Grid Code

• **Maximum voltages (Umax):** Maximum continuous operating voltage

• **Minimum voltages (Umin):** Minimum continuous operating voltage

• **Interconnected Power Systems (IPS):** As defined in the Grid Code

• **Transmission Licensee (TL):** As defined in the Grid Code.

• **Network Service Provider (NSP):** Either Transmission Licensee or Distribution Licensee (As defined in the Grid Code) who is operating a particular network

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

• **Participant:** As defined in the Grid Code,

• **Point of Common Coupling (PCC):** As defined in the Grid Code.

• **Point of Connection (POC):** As defined in the Grid 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 the RPP):** The highest active power measured at the POC, which the RPP is designed to continuously supply.

• **Rated wind speed:** The average wind speed at which a wind power plant achieves its rated power. The average renewable speed is calculated as the average value of renewable speeds measured at hub height over a period of 10 minutes.

• **Regulator:** Means MERA

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

In this RPP 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.). An RPP can use different kinds of primary energy source. If an RPP consists of homogeneous types 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) or (CSP):** 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.

**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. This is also referred to as a wind energy facility (WEF)

- **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 forma part of the RPP.
- **RPP Generator:** Means a legal entity that is licensed to develop and operate a RPP.
- **System Operator (SMO):** As defined in the Grid Code
- **Transmission System (TS):** As defined in the Grid 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 operating 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).

### 4.0 TOLERANCE OF FREQUENCY AND VOLTAGE DEVIATIONS

4.1 The RPP shall be able to withstand frequency and voltage deviations at the POC and under normal and abnormal operating conditions described in sections 5.1 and 5.2 of this RPP Code.
5.0 OPERATING CONDITIONS
The RPP shall be able to support network frequency and voltage stability in line with the requirements of this RPP Code.

5.1 NORMAL OPERATING CONDITIONS

5.1.1 Unless otherwise stated, requirements in this section shall apply to all categories of RPPs.

5.1.2 RPPs of Category A shall be designed to be capable of operating continuously within the voltage range of -15% to +10% around the nominal voltage at the POC.

5.1.3 RPPs of Category B and C shall be designed to be capable of operating continuously within the POC voltage range specified by $U_{min}$ and $U_{max}$ as shown in table 1 below, measured at the POC.

Table 1: Minimum and maximum operating voltages at POC

<table>
<thead>
<tr>
<th>Nominal (Un) [kV]</th>
<th>$U_{min}$ [pu]</th>
<th>$U_{max}$ [pu]</th>
</tr>
</thead>
<tbody>
<tr>
<td>132</td>
<td>0.90</td>
<td>1.1</td>
</tr>
<tr>
<td>66</td>
<td>0.90</td>
<td>1.1</td>
</tr>
<tr>
<td>33</td>
<td>0.90</td>
<td>1.1</td>
</tr>
<tr>
<td>11</td>
<td>0.90</td>
<td>1.1</td>
</tr>
</tbody>
</table>

5.1.4 The nominal frequency of the IPS 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).

5.1.5 When the frequency on the IPS is higher than 51.5 Hz for longer than 4 seconds (see Figure 2), the RPP shall be disconnected from the grid.

5.1.6 When the frequency on the IPS is less than 47.0 Hz for longer than 200ms, the RPP may be disconnected (see Figure 2).

5.1.7 The RPP shall remain connected to the IPS 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 RPP (Cumulative over the life of the RPP)
5.1.1 Synchronising to the IPS

(a) RPPs of Category A shall only be allowed to connect to the IPS, at the earliest, 60 seconds after:
   (i) The voltage at the POC is in the range -15% to +10% around the nominal voltage,
   (ii) Frequency in the IPS is within the range of 49.0Hz and 50.2Hz, or otherwise as agreed with the SMO.

(b) RPPs of Category B and C shall only be allowed to connect to the IPS, at the earliest, 3 seconds after:
   (i) the voltage at the POC is within $U_{\text{max}}$ and $U_{\text{min}}$, as specified in Table 1, around the nominal voltage,
   (ii) frequency in the IPS is within the range of 49.0Hz and 50.2Hz, or otherwise as agreed with the SMO.

5.2 ABNORMAL OPERATING CONDITIONS

5.2.1 Tolerance To Sudden Voltage Drops And Peaks

(a) RPPs of Category A1 and A2

Figure 3: Voltage Ride Through Capability for the RPPs of Category A1 and A2

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

**Table 2: Maximum disconnection times for RPPs of Categories A1 and A2.**

<table>
<thead>
<tr>
<th>Voltage range (at 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 Categories A3, B and C shall be designed to withstand and fulfill, at the POC, voltage conditions described in this section and illustrated in Figures 4 and 5 below. The Area D is only applicable to category C RPPs.

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

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

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

(v) Figure 4 shall apply to all types of faults (symmetrical and asymmetrical i.e. one-, two- or three-phase faults) and the bold line shall represent the minimum voltage of all the phases.
Figure 4: Voltage Ride Through Capability for the RPPs of Category A3, B and C

(vii) 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 approach area C, disconnection is allowed, see Figure 4.

(viii) In the area C (Figure 4): disconnection of the RPP is allowed.

(ix) In connection with symmetrical fault sequences in areas B and D of Figure 4, the RPP (other than synchronous generating units) shall have the capability of controlling the reactive current, as illustrated in Figure 5. The following requirements shall be complied with:

**Area A:** The RPP shall stay connected to the network and uphold normal production.

**Area B:** The RPP shall stay connected to the network and in addition:

- *RPPs of category A3* shall not inject any reactive current into the network;

- *RPPs of category B and category C* shall provide maximum voltage support by supplying a controlled amount of reactive current so as to ensure that the RPP assists in stabilising the voltage as shown in Figure 5.

- Inverter driven *RPPs of category B and category C* shall be able to disable reactive current support functionality at the request of SMO or
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.

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.

(x) Control shall follow Figure 5 so that the reactive current follows the control characteristic with a tolerance of ±20% after 60 ms.

(xi) The supply of reactive power has first priority in area B, while the supply of active power has second priority. Active power shall be maintained during voltage drops, but a reduction in active power within the RPP’s design specifications is required in proportion to voltage drop for voltages below 85%.

(xii) Upon clearance of fault each RPP shall restore active power production to at least 90% of the level available immediately prior to the fault within 1 second.
Figure 5: Requirements for Reactive Power Support, IQ, during voltage drops or peaks at the POC

6.0 Power - Frequency Response

In case of frequency deviations in the IPS, RPPs shall be designed to be capable of providing power-frequency response in order to stabilise the grid frequency.

6.1 Power-frequency response curve for RPPs

6.1.1 During high frequency operating conditions, RPPs shall be able to meet a mandatory active power reduction requirement in order to stabilise the frequency in accordance with Figure 6 below. The metering accuracy for the grid frequency shall be ± 10 mHz or better.

6.1.2 When the frequency on the IPS exceeds 50.5 Hz, the RPP shall reduce the active power as a function of the change in frequency as illustrated in Figure 6 below.

6.1.3 Once the frequency exceed 52Hz for longer than 4 seconds the RPP shall be tripped to protect the IPS.

Figure 6: Power curtailment during over-frequency for RPPs

6.2 Power-frequency response curve for RPPs of Category C

(1) RPPs shall be designed to be capable of providing power-frequency response as illustrated in Figure 7.

(2) Except for the mandatory high frequency response (above 50.5 Hz), the RPP shall not perform any frequency response function (i.e. there shall be no PDelta, dead-band and control-band functions) without having entered into a specific agreement with the SMO.

(3) 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 \( f_6 \) to any value in the range of 47 - 52 Hz with a minimum accuracy of 10 mHz.
(4) The purpose of frequency points $f_1$ to $f_4$ is to form a dead band and a control band for RPPs contracted for primary frequency response. The purpose of frequency points $f_4$ to $f_6$ is to supply mandatory critical power/frequency response.

(5) 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%. The actual droop setting shall be as agreed with the SMO.

(6) The SMO 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.

(7) If the active power from the RPP is regulated downward below the unit’s design limit $P_{\text{min}}$, shutting-down of individual RPP units is allowed.

(8) The RPP (with the exception of PVPP) shall be designed with the capability of providing a PDelta of not less than 3% of $P_{\text{available}}$. PDelta is the amount of active power by which the available active power has been reduced in order to provide reserves for frequency stabilisation.

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

(10) The accuracy of the control performed (i.e. change in active power output) and of the setpoint shall not deviate by more than $\pm 2\%$ of the setpoint value or by $\pm 0.5\%$ of the rated power, depending on which yields the highest tolerance.

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**Figure 7: Frequency response requirement for RPPs of category C**
The default settings for \( f_{\text{min}}, f_{\text{max}}, f_4, f_5 \) and \( f_6 \) shall be as shown in Table 2, unless otherwise agreed upon between the SMO and the RPP generator. Settings for \( f_1, f_2 \) and \( f_3 \) shall be as agreed with the SMO.

**Table 2: Frequency Default Settings**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Magnitude (Hz.)</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>As agreed with SMO</td>
</tr>
<tr>
<td>( f_2 )</td>
<td>As agreed with SMO</td>
</tr>
<tr>
<td>( f_3 )</td>
<td>As agreed with SMO</td>
</tr>
<tr>
<td>( f_4 )</td>
<td>50.5</td>
</tr>
<tr>
<td>( f_5 )</td>
<td>51.5</td>
</tr>
<tr>
<td>( f_6 )</td>
<td>50.2</td>
</tr>
</tbody>
</table>
6.3 Procedure for setting and changing the power-frequency response curves for
RPPs of Categories C

(1) The SMO or its agent shall give the RPP generator a minimum of 2 weeks’ notice if changes to any of the frequency response parameters (i.e. f1 to f6) are required. The RPP generator shall confirm with the SMO or its agent that requested changes have been implemented within two weeks of receiving the SMO’s request.

7.0 REACTIVE POWER CAPABILITIES

7.1 RPPs OF CATEGORY A

7.1.1 RPPs of category A1 & A2 shall operate at unity power factor measured at the POC, unless otherwise specified by the NSP or the SMO.

7.1.2 RPPs of category A3 shall be designed with the capability to supply rated power (Pn) (MW) for power factors ranging between 0.95 lagging and 0.95 leading, measured at the POC available from 20% to 100% of rated power (Pn).

7.1.3 The RPP shall be designed to operate according to a power factor characteristic curve, which will be determined by the NSP or the SMO.

7.1.4 The default power factor setting shall be unity power factor, unless otherwise specified by the NSP or the SMO.

7.2 RPPs OF CATEGORY B

7.2.1 RPPs of category B shall be designed with the capability to operate in a voltage (V), power factor or reactive power (Q or Mvar) control modes as described in section 8 below. The actual operating mode (V, power factor or Q control) as well as the operating point shall be agreed with the NSP.

7.2.2 When operating between 5% and 100% of rated power Pn (MW) the RPP of category B shall have the capability of varying reactive power (Mvar) support at the POC within the reactive power capability ranges as defined by Figure 8a, where Qmin and Qmax are voltage dependent as defined by Figure 9.

7.2.3 At nominal voltage, the required RPP reactive power capability (measured at the POC) shall be as shown in Figure 8b.

7.2.4 When operating below 5% of rated power Pn (MW), there is no reactive power capability requirement, however the RPP can only operate within the reactive power tolerance range not exceeding + -5% of rated power; that is within Area A,B,C and D in Figure 8b.
Figure 8a: Reactive power requirements for RPPs of category B at the POC (Q_{min} and Q_{max} are voltage dependent as defined by Figure 9)

Figure 8b: Reactive power requirements for RPPs of category B (at nominal voltage at POC)
7.3 **RPPs OF CATEGORY C**

7.3.1 *RPPs* of category C shall be designed with the capability to operate in voltage, power factor or, reactive power (Q or Mvar) control modes. The actual control operating mode (V, power factor or Q control) as well as operating point shall be agreed with the NSP.

7.3.2 When operating between 5% and 100% of *rated power* $P_n$ (MW) the *RPP* of category C shall have the capability of varying reactive power (MVAr) support at the POC within the reactive power capability ranges as defined by Figure 10a, where $Q_{\text{min}}$ and $Q_{\text{max}}$ are voltage dependent as defined by Figure 11.

7.3.3 At nominal voltage, the required *RPP* reactive power capability (measured at the POC) shall be as shown in Figure 10b.

7.3.4 When operating below 5% of *rated power* $P_n$ (MW), there is no reactive power capability requirement, however the *RPP* can only operate within the reactive power tolerance range not exceeding $\pm 5\%$ of *rated power*; that is within Area A,B,C and D in Figure 10b.

*Figure 9: Requirements for reactive power and voltage control range for RPPs of category B.*
Figure 10a: Reactive power requirements for RPPs of category C at the POC (Qmin and Qmax are voltage dependent as defined by Figure 11)

Figure 10b: Reactive power requirements for RPPs of category C (at nominal voltage at POC)
8.0 REACTIVE POWER AND VOLTAGE CONTROL FUNCTIONS

(a) The following requirements shall apply to RPPs of category B and C.

(b) 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.

(c) 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.
   - Voltage control
   - Power Factor control
   - Q control

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

8.1 REACTIVE POWER (Q) CONTROL

8.1.1 Q control is a control function controlling the reactive power supply and absorption at the POC independently of the active power and the voltage. This control function is illustrated in Figure 12 as a vertical line.

8.1.2 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 maximum reactive power, depending on which yields the highest tolerance.

8.1.3 The RPP shall be able to receive a Q setpoint with an accuracy of at least 1kVar.
8.2 POWER FACTOR CONTROL

8.2.1 Power Factor Control is a control function controlling the reactive power proportionally to the active power at the POC. This is illustrated in Figure 12 by a line with a constant gradient.

8.2.2 The accuracy of the control performed and of the setpoint shall not deviate by more than ±0.02.

8.3 VOLTAGE CONTROL

8.3.1 Voltage control is a control function controlling the voltage at the POC.

8.3.2 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.

8.3.3 The accuracy of the voltage set point 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 or absorption of reactive power according to droop characteristics as defined in Figure 13.

8.3.4 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.).

8.3.5 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.

8.3.6 Overall voltage coordination shall be handled by the NSP in collaboration with the SMO.
Figure 13: Voltage control for the RPP
9.0 POWER QUALITY

9.1 The following requirements shall apply to all categories of RPPs.

9.2 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) The 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.

9.3 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 and local specifications. The allocation shall be fair and transparent.

9.4 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.

9.5 Voltage changes under normal operating conditions shall be limited according to the values provided in Table 3 below. These limits apply at the full range of fault levels at the POC of the RPP where full generation is possible.
Table 3: maximum voltage change permitted at different voltage levels as a function of the frequency of these voltage changes.

<table>
<thead>
<tr>
<th>Number of changes per hour</th>
<th>Percentage Change in the Voltage at POC</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>nominal voltage at POC</td>
</tr>
<tr>
<td></td>
<td>nominal voltage at POC</td>
</tr>
<tr>
<td></td>
<td>□44kV</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>r&lt;1</td>
<td>4</td>
</tr>
<tr>
<td>1&lt;r&lt;=10</td>
<td>3</td>
</tr>
<tr>
<td>10&lt;r&lt;=100</td>
<td>2</td>
</tr>
<tr>
<td>100&lt;r&lt;100</td>
<td>1,25</td>
</tr>
</tbody>
</table>

9.6 The RPP can assume that the network harmonic impedance at the POC will be less than three (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:

\[
Z(h) = 3 \cdot \frac{V^2}{S} \cdot h
\]

where h is the harmonic number, V is the nominal voltage in kV, and S is the fault level in MVA. The angle of the network harmonic impedance may range from fully inductive to fully capacitive.

9.7 In order to assist with the maximum resonance of 3 times as per clause (6) above, no RPP may connect equipment, e.g. shunt capacitor banks, that will cause a resonance of more than 3 times at the POC at any frequency. If this condition can’t be met, then an agreement between the RPP and the NSP shall be made.

9.8 The NSP shall use their reasonable endeavours to furnish the RPP with a reliable and continuous connection for the delivery of electrical energy up to the POC. The network operators do not guarantee that the continuity and voltage quality of the connection will always be maintained under all contingencies. It is therefore incumbent upon the RPP to take adequate measures to protect the RPP Facility against any losses and/or damage arising from frequency deviations, connection/supply interruptions, voltage variations (including voltage dips), voltage harmonics, interharmonics, voltage flicker, voltage unbalance, voltage swells and transients, undervoltages and overvoltages in the connection. It is also incumbent upon the RPP to take such necessary measures so as not to cause any damage to the TS and DS.

10. **PROTECTION AND FAULT LEVELS**

10.1 Unless otherwise stated, requirements in this section apply to all categories of RPPs.

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

10.3 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.

10.4 The RPP of Category A shall be equipped with effective detection of islanded operation in all system configurations and the 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.

10.5 The RPP of Category B and C 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.

10.6 The NSP or the SMO 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.

10.7 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**

11.1 This section shall apply to RPPs of categories A3, B & C

11.2 For system security reasons it may be necessary for the SMO, NSP or their agent to curtail the RPP active power output.

11.3 The RPP generator shall be capable of:

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

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

11.4 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 IPS 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 illustrated in Figure 14.

11.5 Activation of the active power constraint functions shall be agreed with the SMO or NSP. The required constraint functions are as follows:

   (c) Absolute production constraint
The required constraint functions are described in the following sections.

11.6.1 **ABSOLUTE PRODUCTION CONSTRAINT**

(a) An Absolute Production Constraint is used to constrain the output active power from the RPP to a predefined power MW limit at the POC. This is typically used to protect the TS and DS against overloading.

(b) If the 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.

(c) 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.

11.6.2 **DELTA PRODUCTION CONSTRAINT**

(a) 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.

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

(c) 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.

(d) 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.

11.6.3 **POWER GRADIENT CONSTRAINT**

(a) 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, taking into account the availability of primary energy to support these gradients. A Power Gradient Constraint is typically used for reasons of system operation to prevent changes in active power from impacting the stability of the TS or the DS.

(b) 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.
(c) 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.

(d) The active power constraint functions are illustrated on Figure 14.

![Figure 14: Active power control functions for a Renewable Power Plant](image)

12. **CONTROL FUNCTION REQUIREMENTS**

12.1 *RPPs* shall be equipped with the control functions specified in Table 4. The purpose of the various control functions is to ensure overall control and monitoring of the *RPP’s* generation.

12.2 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 *SMO* or *NSP*.

12.3 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.

12.4 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*. 
The specifications and regulation functions specified shall comply with the international standard IEC 61400-25-2

Table 4: Control functions required for RPPs

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<td>Voltage control</td>
<td>-</td>
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<td>X</td>
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</table>
13. SIGNALS, COMMUNICATIONS & CONTROL

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

(b) Requirements for the exchange of signals between RPPs of category A and the NSP or SMO shall be limited to start and stop signals.

(c) Requirements for the exchange of signals between RPPs of Category B and C, and the NSP, SMO or their agent are described in the following sections.

13.1 SIGNALS FROM THE RPP AVAILABLE AT THE POC

13.1.1 This section shall apply to RPPs of category B and C.

13.1.2 Signals from the RPP to the SMO or NSP or their agent shall be broken up into a number of logical groups depending on functionality.

13.1.3 The following signal list groups shall apply:

(a) **Signals List #1 – General**

The RPP generator shall make the following signals available at a SMO or NSP designated communication gateway equipment located at the RPP site:

(i) Actual sent-out (MW) at the POC
(ii) Active Power Ramp rate of the entire RPP
(iii) Reactive Power Import/Export (+/-MVAr) at the POC
(iv) Reactive power range upper and lower limits
(v) Power Factor
(vi) Voltage output
(vii) Echo MW set point
(viii) Echo Mvar set point
(ix) Echo Voltage set point

(b) **Signals List #2 – RPP Availability Estimates**

(1) RPP generator shall make available the following signals at an MSMO or NSP designated communication gateway equipment located at the RPP site:

(a) Available MW and forecast MW for the next 6 hours updated hourly on the hour.
(b) Available range of MVAR capability for the next 6 hours updated hourly on the hour.
(c) **Signals List #3 – RPP MW Curtailment Data**

(c.1) The *RPP generator* shall make the following signals available at a designated *communication gateway equipment* located at the *RPP site*:

(i) *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 *SMO*. When set “On” the *RPP* shall then clarify and initiate the curtailment based on the curtailment set point value below.

(ii) 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.

(iii) *RPP MW Curtailment Set-point value (MW - feedback)*.

(c.2) In the event of a curtailment, the *SMO* 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.

(d) **Signals List #4 – Frequency Response System Settings**: The *RPP generator* shall make the following signals available at an *SMO or NSP designated communication gateway equipment* located at the *RPP site*:

(i) *Frequency Response System mode status indication (ON/OFF)* as a double bit point

(e) **Signals List #5 – RPP Meteorological Data**:

(e.1) The *RPP generator* shall make the following signals available at a *SMO or NSP designated communication gateway equipment* located at the *RPP site*:

(i) Wind speed (within 75% of the hub height) – measured signal in meters/second (for *WPP only*)

(ii) Wind direction within 75% of the hub height – measured signal in degrees from true north (0-359) (for *WPP only*)

(iii) Air temperature- measured signal in degrees centigrade (-20 to 50);

(iv) Air pressure- measured signal in millibar (800 to 1400).

(v) Air density (for *WPP only*)

(vi) Solar radiation (for *PVPP only*)

(e.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.

(e.3) Energy resource conversion data for the facility (e.g. MW/ solar radiation) for the various resource inputs to enable the *SMO* to derive a graph of the full range of the facilities output capabilities. An update will be sent to the *SMO* following any changes in the output capability of the facility.
For an RPP where the units 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 units. It is expected that units 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 SMO. There shall be at least one Meteorological Mast for every 10x10 square km area of the facility.

13.2 UPDATE RATES

(a) 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 SMO TO THE RPPS

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

13.3.1 Active-Power Control

(b) An Active-Power Control set-point signal shall be sent by SMO 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 15 below.

(c) This value is controlled by raise or lower pulses.
(d) The RPP generator shall make it possible for the SMO to remotely enable/disable the Active-Power control function in the RPP control system.

### 13.3.2 Connection Point CB Trip facility

(a) A facility shall be provided by the NSP to facilitate the disconnection of the RPP. It shall be possible for SMO, NSP or their agent 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 15 below.

### 13.4 MW FORECAST

13.4.1 This section applies only to RPPs of category B and C.

13.4.2 The RPP generator shall have the capability to produce and submit to the SMO the day-ahead and week-ahead hourly MW production forecast.

13.4.3 The forecasts shall be provided by RPP generator. These forecasts shall be provided by 10:00 a.m. on a daily basis for the following 24 hours and 7 days for each 1 hour time-period, by means of an electronic interface in accordance with the reasonable requirements of SMO’s data system.

### 13.5 RPP MW AVAILABILITY DECLARATION

13.5.1 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 SMO’s data system.

### 13.6 DATA COMMUNICATIONS SPECIFICATIONS

13.6.1 The RPP shall have external communication gateway equipment that can communicate with a minimum of three simultaneous SCADA Masters, independently from what is done inside the RPP.

13.6.2 The location of the communication gateway equipment shall be agreed between affected participants in the connection agreement.

13.6.3 The necessary communications links, communications protocol and the requirement for analogue or digital signals shall be specified by the SMO as appropriate before a connection agreement is signed between the RPP generator and the Distributor or TNSP.

13.6.4 Active Power Curtailment or Voltage Regulation facilities at the RPP shall be tested
once every 6 months. It is essential that facilities exist to allow the testing of the functionality without tripping the actual equipment.

13.6.5 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 a time agreed with the SMO or NSP.

Figure 15: Example of one line Human Machine Interface layout

14. TESTING AND COMPLIANCE MONITORING

14.1 All RPP generators shall demonstrate compliance to all applicable requirements specified in this RPP Code and any other applicable code or standard approved by MERA, as applicable, before being allowed to connect to the DS or the TS and operate commercially.

14.2 The RPP generator shall review, and confirm to the SMO and MERA, compliance by the RPP with every requirements of this RPP Code.

14.3 The RPP generator shall conduct tests or studies to demonstrate that the RPP complies with each of the requirements of this RPP Code.

14.4 The RPP generator shall continuously monitor its compliance in all material respects with all the connection conditions of this RPP Code.
14.5 Each RPP generator shall submit to the SMO a detailed test procedure, emphasising system impact, for each relevant part of this RPP Code prior to every test.

14.6 If the RPP generator determines, from tests or otherwise, that the RPP is not complying with one or more sections of this RPP Code, then the RPP Generator shall (within 24 hours of being aware):
(a) notify the SMO of that fact
(b) advise the SMO of the remedial steps it proposes to take to ensure that the relevant RPP can comply with this RPP 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 RPP Code; the RPP generator shall regularly report in writing to the SMO on its progress in implementing the remedial action, and
(d) after taking remedial action as described above, demonstrate to the reasonable satisfaction of the SMO that the relevant RPP is then complying with this RPP Code.

14.7 The SMO may issue an instruction requiring the RPP generator to carry out a test to demonstrate that the relevant RPP complies with the Grid Code requirements. An RPP generator may not refuse such an instruction, provided it is issued timeously and there are reasonable grounds for suspecting non-compliance.

14.8 The RPP generator shall keep records relating to the compliance of the RPP with each section of this RPP Code, or any other code applicable to that RPP, setting out such information that the SMO 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. PROVISION OF DATA AND ELECTRICAL DYNAMIC SIMULATION MODELS

15.1 The SMO, 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.

15.2 The required dynamic models must operate under RMS simulation to replicate the performance of the RPP facility or individual units for analysis of the following network aspects:
(a) RPP impact on thermal rating of connected DS or TS equipment
(b) RPP impact on network voltage stability
(c) RPP impact on system frequency stability
15.3 Generic instead of type tested models can be accepted

15.4 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 RPP generator to the SMO and Distributor or TNSP, as applicable:

- Physical location of the 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:

- PCC and the POC including the nominal voltages
- Expected fault levels
- The NSP's connection between the POC and the RPP,
- The busbar layout of the PCC 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:
  - Positive and zero sequence parameters of the relevant network service provider’s transmission and distribution, transformers, reactors, capacitors and other relevant equipment
  - 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 shall provide information on:

- Selected RPP technology data.
- Fault ride through capability and harmonic studies test report
- Generic test model and dynamic modelling data per 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, TNSP or SMO, as applicable.

15.5 The dynamic modelling data shall be provided in a format as may be agreed between the RPP generator and the Distributor, TNSP or SMO, as applicable.

15.6 In addition, the RPP Generator shall provide the SMO with operational data as prescribed in Appendix 2.
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. 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 speed](image-url)
A2.1 Master Data

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### A2.2 Technical Documentation

#### A2.2.1 Step-Up Transformer

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<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>
A2.2.2 Single Line Diagram (SLD) Representation

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

(2) An SLD 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 SLD representation is included in the grid use agreement between RPP Generator and SMO, the grid connection agreement can be enclosed as documentation.

A2.2.3 PQ Diagram

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

A2.2.4 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 RPP unit nominal output.
Appendix 3 – Compliance test specifications

A3.1 Introduction
This section specifies the procedures for testing to verify compliance with this RPP Code.

A3.2 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 SMO 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. Consolidate detailed setting calculations, per unit setting sheets, relay setting sheets, tripping logic diagram, protection function SLD and relevant protection relay manufacturers’ information into one document.
10. Submit to the SMO or relevant NSP for its acceptance and update.

**Review:**
1. Review Items 1 to 10 above.
2. Submit to the SMO or relevant NSP for its acceptance and update.
3. Provide the SMO 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 SMO or relevant NSP one month after commissioning and six-yearly for routine tests.
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Reference</th>
<th>Description</th>
</tr>
</thead>
</table>
| Protection integrity         | Section 10| **APPLICABILITY AND FREQUENCY**
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.

**Routine review:** All RPPs on:
item 1 below: Review and confirm every 6 years
Item 2, and 3 below: at least every 12 years.

**PURPOSE**
To confirm that the protection has been wired and functions according to the specifications.

**PROCEDURE**
1. Apply final settings as per agreed documentation to all protection functions.
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.
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.
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.
5. With the RPP at nominal production. Confirm correct operation and correct calibration of all protection functions. Document all readings and responses.

**Review:**
Submit to the SMO or relevant NSP for its acceptance and update.

**ACCEPTANCE CRITERIA**
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 SMO or relevant NSP one month after test.
### A3.2.3 - RPP active power control capability verification

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Reference</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Active power control function and operational range</td>
<td>Section 11 depending on category</td>
<td></td>
</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 active power control capability specified is met.

**PROCEDURE**
The following tests shall be performed within an active power level range of at least 0.2p.u. or higher:

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 SMO, 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 SMO, 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 SMO, 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 SMO, NSP or another network operator one month after the test.
### A3.2.4 - 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**<br>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**<br>To confirm that the reactive power control capability specified is met.  
**PROCEDURE**<br>The following tests shall be performed within a minimum active power level range of at least 0.2 p.u. or higher  
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**<br>1. The RPP shall maintain the set voltage within ±5% of the capability registered with the SMO, 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 SMO, 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 SMO, NSP or another network operator for at least one hour.  
Submit a report to the SMO, NSP or another network operator one month after the test.
### A3.2.5 - RPP power quality calculations

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Reference</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power quality calculations for:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Rapid voltage changes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Flicker</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Harmonics</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Interharmonics</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. High frequency disturbances</td>
<td></td>
<td></td>
</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 0.2p.u. to 1.0p.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
A.3.2.6 - RPP fault ride through simulations

Parameter | Reference | Description
--- | --- | ---
Simulations of fault ride through voltage droops and peaks. | Section 5.2.1 for category B and C | **APPLICABILITY**

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

**Routine test/reviews:** None.

**PURPOSE**

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

**PROCEDURE**

By applying the electrical simulation model for the entire RPP it shall be demonstrated that the RPP performs to the specifications.

1. Area A - the RPP shall stay connected to the network and uphold normal production.
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 5.
3. Area C - the RPP is allowed to disconnect.
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 5.

**ACCEPTANCE CRITERIA**

1. The dynamic simulations shall demonstrate that the RPP fulfils the requirements specified.

Submit a report to the SMO, NSP or another network operator three months after the commission.

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**DATE THIS  5TH DAY OF OCTOBER 2017**

**Rt. Rev. Dr. Joseph P. Bvumbwe**

**BOARD CHAIRPERSON**

**MALAWI ENERGY REGULATORY AUTHORITY**