GRID CODE REQUIREMENTS FOR WIND TURBINES CONNECTED TO DISTRIBUTION OR TRANSMISSION SYSTEMS IN SOUTH AFRICA

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# Content

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Objective</td>
<td>3</td>
</tr>
<tr>
<td>2. Scope</td>
<td>3</td>
</tr>
<tr>
<td>3. Definitions and Abbreviations</td>
<td>3</td>
</tr>
<tr>
<td>4. WEF Connection Requirements at the PCC</td>
<td>4</td>
</tr>
<tr>
<td>4.1 Frequency</td>
<td>4</td>
</tr>
<tr>
<td>4.1.1 Power-frequency response curve</td>
<td>6</td>
</tr>
<tr>
<td>4.1.2 Procedure for setting and changing the power-frequency response curves</td>
<td>7</td>
</tr>
<tr>
<td>4.2 Voltage requirements</td>
<td>7</td>
</tr>
<tr>
<td>4.2.1 Voltage control requirements</td>
<td>8</td>
</tr>
<tr>
<td>4.3 Power factor control</td>
<td>8</td>
</tr>
<tr>
<td>4.4 Active Power Curtailment</td>
<td>9</td>
</tr>
<tr>
<td>4.4.1 Ramp Rates</td>
<td>9</td>
</tr>
<tr>
<td>4.5 Low Voltage Ride Through (LVRT) Requirements</td>
<td>10</td>
</tr>
<tr>
<td>5. Metering Requirements</td>
<td>12</td>
</tr>
<tr>
<td>6. Earthing Requirements</td>
<td>12</td>
</tr>
<tr>
<td>7. Provision of Data and Dynamic Models</td>
<td>12</td>
</tr>
<tr>
<td>8. Signals, Communications &amp; Control</td>
<td>14</td>
</tr>
<tr>
<td>8.1 Signals from the WEF to SO</td>
<td>14</td>
</tr>
<tr>
<td>8.1.1 Signals List #1</td>
<td>14</td>
</tr>
<tr>
<td>8.1.2 Signals List #2</td>
<td>15</td>
</tr>
<tr>
<td>8.1.3 Signals List #3</td>
<td>15</td>
</tr>
<tr>
<td>8.1.4 Signals List #4</td>
<td>15</td>
</tr>
<tr>
<td>8.1.5 Signals List #5</td>
<td>16</td>
</tr>
<tr>
<td>8.2 Update Rates</td>
<td>16</td>
</tr>
<tr>
<td>8.3 Control Signals Sent from SO to the WEF</td>
<td>16</td>
</tr>
<tr>
<td>8.3.1 Active-Power Control</td>
<td>16</td>
</tr>
<tr>
<td>8.3.2 Connection Point CB Trip facility</td>
<td>17</td>
</tr>
<tr>
<td>8.4 MW Forecast</td>
<td>17</td>
</tr>
<tr>
<td>8.5 Wind Energy Facility MW availability declaration</td>
<td>17</td>
</tr>
<tr>
<td>8.6 Data Communications Specifications</td>
<td>17</td>
</tr>
<tr>
<td>9. Protection facilities</td>
<td>18</td>
</tr>
<tr>
<td>10. Compliance Monitoring</td>
<td>18</td>
</tr>
</tbody>
</table>
1. Objective

(1) The primary objective of this document is to establish technical connection conditions for wind energy facilities (WEFs) connected to the South African electricity transmission or distribution networks. It sets out rules and obligations to which participants must comply in order to connect WEFs to the South African electricity networks.

(2) This document shall be used, together with the requirements of the Grid Code and the Distribution Code, as compliance criteria applicable to WEFs in South Africa. This document shall take precedence whenever there is a conflict between requirement in this document and those in the Grid Code or Distribution Code.

(3) WEF generators shall demonstrate compliance to the requirements of this document and any other applicable code before being allowed to connect to the distribution system (DS) or the transmission system (TS) and operate commercially.

2. Scope

(1) The requirements in this document shall apply to a WEF connected to the DS or TS in South Africa as well as the respective DS and TS service providers.

(2) Any replacement of and/or radical changes to an existing WEF shall also be required to demonstrate compliance to these requirement before commercial operation.

(3) Matters relating to wind energy procurement and applicable tariffs are excluded from this document.

3. 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.

Available Active Power
The amount of Active Power (MegaWatts) that the WEF could produce based on current wind conditions.

Distribution System (DS)
As defined in the RSA Grid Code, Preamble section

Generator
As defined in the RSA Grid Code, Preamble section

High voltage (HV)
The set of nominal voltage levels greater than 33 KV and up to and including 220 kV. [SANS 1019]

Low voltage (LV)
Nominal voltage levels up to and including 1 kV. [SANS 1019]

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1 Once adopted by the regulator, NERSA, this document will form part of the RSA Grid Code and the Distribution Code.
Low Voltage Ride Through (LVRT) Capability
Capability of the WEF to stay connected to the network and keep operation following voltage dips caused by a short-circuit or disturbances on any or all phases in the TS or DS.

Maximum Continuous Rating (MCR)
As defined in the RSA Grid Code, Preamble section

Maximum Export Capacity (MEC)
The contracted maximum export value (in MW) of an entire generation station in accordance with the generator’s connection agreement

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

National Transmission Company (NTC)
As defined in the RSA Grid Code, Preamble section

Point of Common Coupling (PCC)
As defined in the RSA Grid Code, Preamble section

System Operator (SO)
As defined in the RSA Grid Code, Preamble section

Transmission System (TS)
As defined in the RSA Grid Code, Preamble section

Wind Energy Facility (WEF)
A single wind turbine or a group of several wind turbines with associated equipment

4. WEF Connection Requirements at the PCC

(1) All wind turbine units within the WEF shall comply with the requirements of IEC Technical Specification Series, TS 61400. However, provisions of this document and the RSA Grid Code and Distribution Code shall take precedence whenever there is a conflict.

4.1 Frequency

(1) The WEF, when in operation, shall be capable of operation for specific periods as a function of system frequency in accordance with Figure 1 and Figure 2 below.
Figure 1: Minimum frequency operating range of a WEF (Cumulative over the life of the WEF)

Figure 2: Minimum frequency operating range of a WEF (during a system frequency disturbance)

(2) The tripping of the individual wind turbines within the WEF due to frequency excursions shall be staggered and the philosophy for tripping shall be approved by the SO.

(3) The WEF shall remain connected to the DS or TS during rate (for falling frequencies, but not rising) of change of frequency of values up to and including 0.5 Hz per second, provided the network frequency is still within the continuous frequency characteristic.

(4) The WEF shall include a Frequency Response System. The Frequency Response System shall provide the response as specified in 4.1.1 below.
4.1.1 Power-frequency response curve

(1) The Frequency Response System shall have the capabilities as displayed in the Power-Frequency Response Curve below.

(2) A frequency dead-band setting capable of being set between 0 and 0.5Hz shall be provided with each WEF. The actual setting to be implemented by the WEF shall be as specified in the Grid Code.

(3) Under continuous operation frequency range as shown in figure 1, the WEF shall be capable of operating continuously at a power output level of 95% available active power and above. The actual operating point shall be agreed with the SO.

(4) If the frequency rises to a level above 50.5Hz, then the WEF shall act to ramp down the WEF's active power output. The response rate of each available online WEF shall be a minimum of 1% of WEF rated capacity per second (MW/second).

(5) When the frequency is below the normal range and is recovering back towards the normal range, the Frequency Response System shall act to ramp down the WEF Active Power output in accordance with the Frequency/Active Power characteristic defined by the line ‘A’-‘B’.

(6) Once the frequency rises to a level above point ‘C’, the Frequency Response System shall act to ramp down the WEF Active Power output in accordance with the Frequency/Active Power characteristic defined by the line ‘C’-‘D’-‘E’.

(7) Points ‘A’, ‘B’, ‘C’, ‘D’ and ‘E’ shall depend on a combination of the frequency, Active Power and MW curtailment set-point settings. These settings may be different for each WEF depending on system conditions and WEF location. These settings are defined in Table 1, and needs to be agreed between the SO and the WEF generator.
Table 1: Frequency and % Available Active Power Settings for the Points A, B, C, D and E

<table>
<thead>
<tr>
<th>Point</th>
<th>Frequency</th>
<th>Wind Energy Facility Power output (% of available active power)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>FA</td>
<td>PA</td>
</tr>
<tr>
<td>B</td>
<td>FB</td>
<td>Minimum of : PB or MW Curtailment set-point</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(Converted to a % of Available active Power)</td>
</tr>
<tr>
<td>C</td>
<td>FC</td>
<td>Minimum of : PC or MW Curtailment set-point</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(Converted to a % of Available active Power)</td>
</tr>
<tr>
<td>D</td>
<td>FD</td>
<td>Minimum of : PD or MW Curtailment set-point</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(Converted to a % of Available active Power)</td>
</tr>
<tr>
<td>E</td>
<td>FE</td>
<td>PE = 0%</td>
</tr>
</tbody>
</table>

(8) Settings for each of FA, FB, FC, FD, FE, PA, PB, PC, PD and PE shall be specified by the SO. WEF shall be responsible for implementing the appropriate settings during commissioning. Alterations to the MW Curtailment Set-point shall be sent in real-time by the SO and these alterations shall be implemented by the WEF within one minute of receipt of the appropriate signal or instruction from the SO (operational limits and feedback response to the signal will be provided).

(9) Alterations to the WEF Active Power output, triggered by frequency changes outside the dead-band, shall be achieved by proportionately altering the Active Power output of all available WEF as opposed to switching individual WEF on or off, in so far as possible.

(10) No time delay other that those necessarily inherent in the design of the Frequency Response System shall be introduced. The response rate of each available online WEF shall be a minimum of 1% of WEF rated capacity per second (MW/second). The frequency Response System shall continuously monitor the frequency in order to continuously determine the WEF appropriate Active Power output by taking account of the WEF Available Active Power and Curtailed Active Power.

(11) If the frequency rises to a level above the line ‘D’-‘E’, as defined by the Power-Frequency Response Curve, SO recognises that WEFs may cease to generate. Any WEF which has ceased generation shall be brought back on load subject to SO requirements.

(12) After a failure in the local network where the WEF exists, the WEF shall be returned to service as soon as the conditions allow. Where manual reset of the WEF is required by the generator, this shall be achieved without undue delay.

4.1.2 Procedure for setting and changing the power-frequency response curves

(1) The SO shall give the WEF generator a minimum of 2 weeks if changes to any of the curve’s parameters (i.e. F_A, F_B, F_C, F_D, F_E, P_A, P_B, P_C, P_D or P_E) are required. The WEF generator shall confirm with the SO that requested changes have been implemented within two weeks of receiving the SO’s request.

4.2 Voltage requirements

(1) Voltage quality distortion levels emitted by the WEF at the PCC shall not exceed the apportioned levels as supplied by the relevant distributor or transmission network service.
provider. The calculation of these emission levels shall be based on the NERSA approved process.

4.2.1 Voltage control requirements

(1) The WEF shall have a continuously-variable and continuously acting closed loop voltage regulation system with manual adjustable telemetered set-point at PCC. The set-point shall be adjustable within 90% to 110% of nominal voltage at PCC.

(2) The maximum allowable voltage change at the PCC after a switching operation shall not be greater than 2%.

4.3 Power factor control

The WEF with MEC less than 20MW shall be designed to supply constant reactive power output (in Mvar) of not less than 0.975 lagging and 0.975 leading calculated at rated active power output (MW), available at the PCC under all operating conditions. This reactive power shall be available from minimum generation to full rated active power output. Figure 3 shows a typical power factor requirement at the PCC of a WEF with MEC less than 20MW. Power factor readings shall refer to the PCC.

![Figure 3: Reactive power requirement for WEF with MEC less than 20MW](image)

(1) The WEF with MEC equal to or greater than 20MW shall be designed to achieve a constant reactive power limit (in Mvar) of not less than 0.95 lagging and 0.95 leading calculated at rated MW output, available at the PCC under all operating conditions. This...
reactive power shall be available from minimum generation to full rated active power output. Figure 4 shows a typical power factor of a WEF with MEC equal to or greater than 20MW. Point A is equivalent (in MVar) to -5% rated MW output. Point B is equivalent (in MVar) to 5% rated MW output.

![Diagram of reactive power requirement for WEF with MEC equal to or greater than 20MW]

Figure 4: Reactive power requirement for WEF with MEC equal to or greater than 20MW

(2) No WEF will consume (import) reactive power from the network in order for it to start up.

### 4.4 Active Power Curtailment

(1) For system security reasons it may also be necessary for the SO or another network operator to constrain the WEF active power output.

(2) The WEF shall be capable of:

- operating the WEF at a reduced level if active power has been curtailed by the SO for system security reasons.
- 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.

#### 4.4.1 Ramp Rates

(1) The WEF 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.
(2) These ramp rate settings shall be applicable for all ranges of operation including start up, normal operation and shut down.

(3) The *WEF* control system shall have the capability to set the ramp rate in *MW* per minute averaged over both one and ten minutes.

(4) The maximum ramp rate of the *WEF* shall not exceed *50MW* per minute.

### 4.5 Low Voltage Ride Through (LVRT) Requirements

(1) All *WEF* equipment shall be designed with anticipation of voltage conditions at the point of connection as shown on Figure 5 below. The *WEF* shall not disconnect from the network for voltages above the bold line, provided power evacuation capability after the fault is maintained.

(2) Figure 5 shall apply to all types of faults and the bold line shall represent the minimum voltage of all the phases.

(3) Following a *WEF* disconnection due to low voltage below the bold line (defined by Figure 5), the *WEF* shall reconnect to the network within 1 second after the voltage has recovered to at least 0.9p.u of nominal voltage.
(4) In addition to remaining connected to the DS or TS for the duration shown above, the WEF shall have the technical capability to provide maximum voltage support by supplying a controlled amount of reactive power to stabilise the voltage at the PCC. This shall be achieved in the following manner:

(a) In case of significant voltage deviation (i.e. below 0.85 pu), the WEF shall back up the voltage at the PCC by adjusting (increasing) the reactive current, $I_Q$, in proportion to the relevant voltage deviation $\Delta U$ (i.e. $\Delta I_Q/I_N = k \cdot \Delta U/U_N$) as shown in Figure 7 below, where:

- $U_N$ is the reference voltage
- $I_N$ is the reference current

(b) $k$ is constant (defined by $0 \leq k \leq 10$). $k$ shall be set to 2, unless otherwise agreed with the SO or relevant Distributor or TNSP.
5. Metering Requirements

(1) Metering installations shall be provided in accordance with the requirements of Grid and the Distribution Metering Codes, as applicable.

6. Earthing Requirements

(1) Earthing at the PCC shall be done as per the earthing requirements of the Distributor or TNSP, as applicable.

7. Provision of Data and Dynamic Models

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

(2) WEF data exchange shall be a time-based process.
   • First stage (during the application for connection)
(a) The following information shall be submitted by the WEF to the SO and Distributor or TNSP, as applicable:

(i) physical location of WEF (including the GPS coordinates)
(ii) site plan
(iii) number of wind turbines to be connected
(iv) MW output per turbine
(v) expected capacity availability factor
(vi) operating power factor
(vii) output voltage
(viii) initial phase MW value
(ix) final phase MW value and the timelines
(x) any other information that the service provider may reasonably require.

(c) The network service provider shall, in return, provide the WEF generator with information such as:

(i) possible suitable voltage level for connection
(ii) adequacy of network to absorb the power
(iii) cost of connection quotation in line with the NERSA approved connection guidelines
(iv) any other information that WEF generator may reasonably require, including case files and data for modelling connection to the grid.

- **Second stage** (after detailed WEF designs have been completed but before commissioning the WEF).

  (a) During this stage, the WEF is compelled to provide information:

  (i) selected wind turbine technology as well as the detailed wind turbines dynamic modelling data.
  (ii) generic test model data per wind turbine model prior to WEF commissioning.

- **Third stage** (after commissioning and optimisation of the WEF)

  (a) During this stage, the WEF is compelled to provide information:

  (i) a validated turbine generator dynamic model using commissioning test measurements
(ii) test measurement data in the format agreed between the WEF and the Distributor, NC or SO, as applicable.

(3) The dynamic modelling data shall be provided preferably in DigSilent PowerFactory latest format, or any such other format as may be agreed between the WEF and the Distributor, NTC or SO, as applicable.

(4) In addition, the WEF shall provide the SO with operational data as prescribed in section 8 below.

8. Signals, Communications & Control

8.1 Signals from the WEF to SO

(1) Signals from the WEF to the SO or another network operator shall be broken up into a number of logical groups. There are different requirements for WEF depending on the WEF’s maximum sent out capacity or functionality.

(2) The following groups shall apply:

i) **Signals List #1** - applies to all WEFs

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

ii) **Signals List #2** - Wind Energy facility Availability Estimate;

iii) **Signals List #3** - Wind Energy facility MW Curtailment Data;

iv) **Signals List #4** - Frequency Response System Settings;

v) **Signals List #5** - Wind Energy facility Meteorological Data;

8.1.1 Signals List #1

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

- MegaWatt sent-out (MW) at the PCC
- Available Active Power Estimate (MW) at the PCC
- Reactive Power Import/Export (+/-Mvar) at the PCC
- On/off status indications for all Reactive Power devices exceeding 5 Mvar;
• Circuit-breaker positions indication. These may include indications from circuit-breakers on individual wind turbine circuits (in case of distribution this shall refer to the substation feeder breakers). The actual circuit-breaker signals and alarm indications required shall be specified by the SO and subsequently advised by the Distributor, where the WEF is connected to the DS.

• Ramp rate

8.1.2 Signals List #2

(1) The WEF, with Maximum Export Capacity (MEC) in excess of 10 MW, shall make available the following signals at a Distributor or TNSP designated communication gateway facility located at the WEF site:

• WEF availability estimate (0 - 100%) and the number of units by type available for generation;
• Indication of the number of units by type that are shutdown due to high wind speed conditions;
• Indication of the number of units by type that are shutdown due to low wind speed conditions;
• Indication of the number of units by type that are shutdown due to maintenance.

(2) Where the WEF is widely dispersed over a large geographical area and rather different weather patterns are expected for different sections of the WEF site, the above data set shall be provided for a number of groups of WEF (e.g. 1 signal for each group of wind turbines within the WEF site). The actual signals required shall be specified by the SO and subsequently advised by the Distributor or TNSP, as applicable.

8.1.3 Signals List #3

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

• WEF MW Curtailment facility status indication (ON/OFF).
• WEF MW Curtailment Set-point value (MW- feedback)

8.1.4 Signals List #4

II. The WEF shall make the following signals available at a Distributor designated communication gateway facility located at the WEF site:
• Frequency Response System mode status indication (ON/OFF)

8.1.5 Signals List #5

(1) The WEF, with an MEC in excess of 10 MW, shall make the following signals available at a Distributor or TNSP designated Gateway facility located at the WEF site:

• Wind speed (at hub height) – measured signal;
• Wind direction (at hub height) – measured signal;
• Air temperature – measured signal;
• Air pressure – measured signal.

(2) The meteorological data signals shall be provided by a dedicated Meteorological Mast located at the WEF site or, where possible and preferable to do so, data from a means of the same or better accuracy. For WEF where the wind turbines are widely dispersed over a large geographical area and rather different weather patterns are expected for different sections of the WEF, 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.

8.2 Update Rates

(1) Signals shall be updated at the following rates:

• Analog Signals at a rate of 2 seconds
• Digital Signals at the rate of 1 second.

8.3 Control Signals Sent from SO to the WEF

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

8.3.1 Active-Power Control

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

(2) The WEF shall make it possible for the SO to remotely enable/disable the Active-Power control function in the WEF control system

8.3.2 Connection Point CB Trip facility

(1) A facility shall be provided by the network service provider to facilitate the disconnection of the WEF. It shall be possible for SO or another network operator to send a trip signal to the circuit breaker at the HV side of WEF PCC

8.4 MW Forecast

(3) MW forecasts shall be provided by WEF 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.

8.5 Wind Energy Facility MW availability declaration

(1) The WEF generator shall submit WEF 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.

8.6 Data Communications Specifications

(1) The WEF shall have an external communication gateway facility that can communicate with both the SO and the Distributor or TNSP systems (as applicable), independently from what is done inside the WEF.

(2) The location of the communication gateway facility shall be agreed between the Distributor or TNSP and the WEF before a connection agreement is signed between the WEF generator and the Distributor or TNSP.

(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 WEF generator and the Distributor or TNSP.
(4) If MW Curtailment, Frequency Response or Voltage Regulation facilities at the WEF become unavailable, the WEF generator shall contact SO without undue delay.

(5) Where signals or indications required to be provided by the WEF become unavailable or do not comply with applicable standards due to failure of the WEF equipment or any other reason under the control of the WEF, the WEF generator shall restore or correct the signals and/or indications as soon as possible.

9. Protection facilities

(1) The WEF generator shall install suitable protection systems to protect the WEF plant from damage due to short circuits and any other abnormal conditions that may occur on the DS or TS.

10. Compliance Monitoring

(1) The WEF shall be required, prior to commercial operation, to demonstrate to the SO and the relevant Distributor or TNSP full compliance to all requirements of this code and related sections in the Distribution Code and the Grid Code.

(2) While in operation the WEF generator shall report any material deviation from the requirement of this code to the SO and the local network operator within 2 days after being aware of such deviation.