Eskom National Transmission Company South Africa ™	**Guideline**	**NTCSA/System Operator/ Grid Code Management**

Title: **RPP, BESF and Hybrid Power Plants Grid Code Compliance Test Guideline**

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1. Introduction

This document describes the testing procedure guideline to be followed by the Renewable Power Plant (RPP), Battery Energy Storage Facility (BESF) and Hybrid Power Plant *generators* to verify the compliance to GRID CONNECTION CODE FOR RPP and/or the GRID CONNECTION CODE FOR BESF CONNECTED TO THE ELECTRICITY TRANSMISSION SYSTEM (TS) OR THE DISTRIBUTION SYSTEM (DS) IN SOUTH AFRICA.

2. Supporting Clauses

2.1 Scope

2.1.1 Purpose

The purpose of this test procedure guideline is to guide the RPP, BESF and Hybrid Power Plant *generators* to cover all aspects of the RPP and/or BESF Code requirements. The RPP and/or BESF *generator* shall ensure compliance to Section 14 of the RPP Code and/or Section 13 of the BESF Code respectively. The South African Grid Codes take precedence over this document.

2.1.2 Applicability

This document shall be applicable to the Grid Code Management department, within the System Operator (SO); as well as to all RPP, BESF and Hybrid Power Plant connected to TS and DS.

2.1.3 Effective date

The effective date is as per authorization date.

2.2 Normative/Informative References

Parties using this document shall apply the most recent edition of the documents listed in the following paragraphs.

2.2.1 Normative

[1] Latest version of the RSA Grid Code, available from www.nersa.org.za.

[2] Latest version of the RSA Distribution Code, available from www.nersa.org.za.

[3] Latest version of the SAGC Requirements for Renewable Power Plants, available from www.nersa.org.za.

[4] Latest version of the SAGC Requirements for BESF, available from www.nersa.org.za.

2.2.2 Informative

[1] ISO 9001 Quality Management Systems.

2.3 Definitions

2.3.1 Alternator

As defined in the Codes.

2.3.2 Codes

All electricity codes as approved and published by the NERSA. These shall include RPP grid connection code, The RSA code and the BESF code.

2.3.3 Distribution System (DS)

As defined in the Codes.

2.3.4 Hybrid Power Plant

A Facility that has a combination of two or more of the following technologies connected to the same POC and operate as a single entity:

- PV
- Wind
- Energy storage
- Alternator

2.3.5 Network Service Provider (NSP)

As defined in the Codes.

2.3.6 Operating Scenario

Operation of a Hybrid Power Plant such that one or more technologies (e.g., PV, Wind, BESF and/or Alternator) are in operation at the same time.

2.3.7 Point Of Connection (POC)

As defined in the Codes.

2.3.8 Renewable Energy Technical Evaluation Committee (RETEC)

RETEC is a technical team within the System Operator, established to validate or verify compliance to the codes as demonstrated by the RPP, BESF and Hybrid Power Plants generators.

2.3.9 Renewable Power Plant (RPP)

As defined in the Codes.

2.3.10 RPP generator

As defined in the Codes.

2.3.11 System Operator (SO)

As defined in the Codes.

2.3.12 Transmission System (TS)

As defined in the Codes.

2.4 Abbreviations

Abbreviation	Explanation
BESF	Battery Energy Storage Facility
DS	Distribution System
GC	Grid Code
HMI	Human Machine Interface
IPP	Independent Power Producers
kV	Kilovolt
MCR	Maximum Continuous Rating
MW	Megawatt
MVar	Megavar
NERSA	National Energy Regulator of South Africa
NSP	Network Service Provider
P	Active Power
PF	Power Factor
POC	Point of Connection
PPC	Power Plant Controller
PV	Photovoltaic

Abbreviation	Explanation
Q	Reactive Power
RE	Renewable Energy
RETEC	Renewable Energy Technical Evaluation Committee
RPP	Renewable Power Plant
SCADA	Supervisory Control and Data Acquisition
SO	System Operator
SOA	System Operating Agreement
TS	Transmission System
WTG	Wind Turbine Generator

2.5 Roles and Responsibilities

2.5.1 RPP, BESF and Hybrid Power Plant *generator* Responsibilities

It is the responsibility of the RPP, BESF and Hybrid Power Plant *generators* to ensure that their RPP, BESF and/or Hybrid Power Plant complies with all applicable requirements of the Codes (including but not limited to, those set out in this document) by timeously submitting the required information (data, equipment specifications, tests data and/or reports) to RETEC for Grid Code compliance validation.

2.5.2 RETEC Responsibilities

It is the responsibility of *RETEC* to review and analyse information (data, equipment specifications, tests data or reports) submitted by RPP, BESF and Hybrid Power Plant generator in order to validate Grid Code compliance status. Furthermore provide feedback to the *generators* on the Grid Code compliance status of their RPP, BESF and Hybrid Power Plant and issue a Grid Code compliance notification letter once the RPP, BESF and Hybrid Power Plant *generator* has successfully demonstrated compliance to all applicable codes requirements.

2.6 Process for Monitoring

This Guideline shall be reviewed as and when necessary.

2.7 Related/Supporting Documents

Refer to Section 2.2.1.

3. Pre-requisites for RETEC Site Tests Witnessing

3.1 Minimum Requirements for RPP, BESF and Hybrid Power Plant Grid Code Compliance Test Scheduling

The following documents shall be submitted at least two weeks before the proposed Grid Code compliance tests dates:

a) RPP, BESF and Hybrid Power Plant *generator* shall provide the test procedure guideline, which will be approved by RETEC.

b) Dry Run Tests report and the raw data (as per this test guideline).

c) A signed Regional and National document for SCADA (signal and Functionality) testing.

d) As built signed protection settings document.

e) Power Park Controller and generator (Inverter/ Turbine) settings.

f) Weather forecast expressed in active power output (MW). This forecast shall be updated daily until the day of testing (starting two weeks before the scheduled Grid Code Compliance test dates). Hybrid power plants to submit the weather forecast and load profile.

g) Fully completed checklist for inspections of substations/transformers station, minimum but not limited to the RETEC test procedure guideline.

3.2 Format of Data

a) RPP, BESF and Hybrid Power Plant *generator* shall submit all data in the following file formats, unless otherwise agreed with the SO/NSP.

- Specifications, Statements, Agreements and Technical Reports in PDF format.
- Signed final documents in scanned PDF format.
- Test result data points in CSV (comma separated values) format (e.g. Excel ®) and comtrade.
- Performance Charts/Plots in PDF and/or XLS format.
- Drawings in PDF or DWG format that can be opened with Bentley View.

b) Where documents and diagrams are provided as supporting information, they shall be legible and shall include all relevant data assumptions (for example generator base, p.u, percentage values, etc.).

c) Where testing and monitoring results are provided, they shall be legible, appropriately sized, scaled and labelled.

3.3 Minimum Document Submission on the Day of Testing

Unless otherwise agreed, the following documents shall be provided on the day of testing.

- Raw Data of Grid Code Compliance Tests.
- All tests data must be saved separately (clear definition of signal ID).
- Protection settings downloads for all inverters/turbines/alternators.

- Protection settings downloads of the POC.

3.4 RPP, BESF and Hybrid Power Plant Grid Code Compliance Tests Requirements

a) Grid Code Compliance testing shall only be performed on fully commissioned and operational generating units. Before any test can be performed, all turbines/inverters/alternators shall be online and generating MW.

b) If there is a turbine/Inverter/alternator unit trip during the test, this will be rendered as non-compliance to the South African Grid Code.

c) The available power (MW) shall be at least 50% for RPP and Hybrid Power Plants and 70% for BESF, for all tests.

d) The Grid Code Compliance tests shall be performed from the NSP SCADA unless agreed otherwise with RETEC. Setpoints shall be changed by an engineer/technician on site if local SCADA testing is required by RETEC.

e) The lowest sampling rate of the raw data must be at least of 1-second average values.

f) Each setpoint for all the tests shall be maintained for 2 minutes, unless stated otherwise.

g) No optimisation of the RPP, BESF and Hybrid Power Plant during Grid Code compliance testing will be allowed. If optimization is necessary, the whole set of Grid Code compliance tests shall be repeated

h) RPP's with synchronous generators are required to perform active power tests at minimum of 70% of MCR and reactive power tests at maximum output (MCR).

i) RPPs with synchronous generators must conduct RETEC and GCR 3 tests, should any of the tests be unsuccessful, both the RETEC and GCR 3 tests shall be repeated.

3.5 Grid Code Compliance Tests Pass Criteria

a) The RPP, BESF and Hybrid Power Plant *generator* shall conduct tests to demonstrate that their RPP, BESF and/or Hybrid Power Plant complies with each of the requirements of the RPP or BESF Code.

b) The assessment criteria, not limited to, shall be based on reaction time and tolerance.

3.6 Post Site Testing Requirements

a) RETEC will submit a detailed Grid Code compliance verification letter to the Grid Code Secretariat within 10 working days from receipt of the RPP, BESF and/or Hybrid Power Plant Grid Code Compliance test report.

b) The Grid Code Secretariat shall provide a response to the RPP, BESF and/or Hybrid Power Plant *generator* indicating the outcome of the overall Grid Code compliance tests.

3.7 Checklist for inspections of Substations / transformer stations

RPP, BESF and/or Hybrid Power Plant Name:

Date:

Inspector:

Maximum Continuous Rating (MCR)	MW
P_{min}	MW

PPC information

Serial number	
Make and Model	
Firmware version	
PPC Settings	*Provide on separate document

All installed individual turbines/inverters/alternators information

Number of turbines/inverters/alternators	
Rating/Name plate	
Serial numbers	
Make and Model	
Firmware version	
turbines/inverters/alternators Settings Download (Format in PDF)	*Provide all individual inverter settings
turbines/inverters/alternators transformer name plate	*Provide on separate document

RPP, BESF and Hybrid Power Substation

POC Transformer Serial Number/s	
POC Transformer name plate	*Provide on separate document
POC Protection Settings Document	*Provide on separate document
Tap Changer name plate	*Provide on separate document

General information:	Name	Contact person	Telephone No.	Picture
Park Controller				--
Operator of Park Controller				--

Operator of Transformer Station				--
	House No.	Street / field yard	City / post code	--
Address of Transformer Station				--
Rating Plate Transformer Station				
Gauss Krueger Coordinates	RW: HW:			
Date of on-site Inspection				--
Name of Inspector				--
Name of Independent Engineers				

Notes: _____

_____

_____

_____

Technical information:				Picture	
		Type/serial no./installation point		Full view	Rating Plate
Park Controller					
Circuit Diagram of Substation/ Transformer Station					
Switchgear/ Circuit Breaker		HV: MV:			
Transformer					
Electric Meter					
Counting Point Designation					
		Serial No.	Ratio		
Transducer Main Grid Protection	Voltage L1				
	Current L1				
	Voltage L2				
	Current L2				
	Voltage L3				
	Current L3				
Transducer of Park Controller	Voltage L1				
	Current L1				
	Voltage L2				
	Current L2				
	Voltage L3				
	Current L3				

POC 1/SNo.:	Voltage protection							Frequency protection					Transformer Ratio:
	U>	U>>	U<	U<<	U<<<			f>	f>>	f<	f<<	RoCoF	
Tripping level													
Tripping time													

POC 2/SNo.:	Voltage protection							Frequency protection					Transformer Ratio:
	U>	U>>	U<	U<<	U<<<			f>	f>>	f<	f<<	RoCoF	
Tripping level													
Tripping time													

Inverter/WTG 1/SNo.:	Voltage protection							Frequency protection					Transformer Ratio:
	U>	U>>	U<	U<<	U<<<			f>	f>>	f<	f<<	RoCoF	
Tripping level													
Tripping time													

Inverter/WTG 2/SNo.:	Voltage protection							Frequency protection					Transformer Ratio:
	U>	U>>	U<	U<<	U<<<			f>	f>>	f<	f<<	RoCoF	
Tripping level													
Tripping time													

Inverter/WTG 3/SNo.:	Voltage protection							Frequency protection					Transformer Ratio:
	U>	U>>	U<	U<<	U<<<			f>	f>>	f<	f<<	RoCoF	
Tripping level													
Tripping time													

3.8 Grid Code Compliance Tests

- Disclaimer: Depending on the weather conditions on site, RETEC shall determine the reference test starting point and may change the setpoints at their own discretion.
- Before the commencement of all tests, the internal RPP SCADA shall be tested by switching the plant off (Open POC Breaker/ MV Breakers). Circuit breakers can be opened at any MW generation.
- Table 1 below show the tests required for RPP, BESF and Hybrid Power plants and Table 2 shows an example of the different operation scenarios.

Table 1: Tests required for RPP, BESF and Hybrid Power Plant

Requirements	PV	Wind	BESF (Charging and Discharging)	CSP/Biomass/Landfill Gas/Biogas/Small Hydro	Hybrid (All operating scenarios)
Absolute	√	√	√	√	√
Gradient	√	√	√	Subject to agreement with the SO or NSP	√
Delta	N/A	√	N/A	Subject to agreement with the SO or NSP	√
Frequency Response	√	√	√	√	√
Reactive power control	√	√	√	√	√
Power factor control	√	√	√	√	√
Voltage Control	√	√	√	√	√

Table 2: Example of Operation Scenarios

Scenario	BESF discharging	PV	BESF charging	Description
A	√	X	X	Only BESF available to meet dispatch instruction prior to sunrise
B	√	√	X	BESF supplements PV to meet dispatch instruction
C	X	√	√	PV alone meets dispatch instruction and excess PV charges BESF
D	X	√	X	PV curtailed to MCR, BESF fully charged

3.8.1 Absolute Active Power Constraint

Note:

- The test can only be performed if the primary energy supply is sufficient to reach the set active power output.
- Reference power ($P_{reference}$) is the value, which the parties on site agree upon.
- Declare Rated Power and P_{min} values.

Signals for the site testing to be available on the HMI:

- P (Available)
- P (Actual)
- P (Setpoint)

Default value by SO or by the RPP						
Before the start, the available power is measured and a reference value must be agreed between the parties. $P_{reference}$: ____MW						
Reduction/limit	**Setpoint value P [MW]**	**Start value P [MW]**	**Actual P [MW] at 30s after setting the value**	**Measured Accuracy [kW]**	**Accuracy Max allowed [kW]**	**Comment**
$P_{reference}$						
1st test to 80% $P_{reference}$						
2nd test to 40% $P_{reference}$						
3rd test to 20% $P_{reference}$						
4th test to 10% $P_{reference}$						
5th test to 30% $P_{reference}$						
6th test to 50% $P_{reference}$						
7th test to 80% $P_{reference}$						
8th test to 100% $P_{reference}$						
After the 8th test the RPP shall go back to normal operation						

Remarks:

_____
_____
_____

3.8.2 Delta Production Active Power Constraint

- The parameter of set value (P_{delta}) from the commission protocols has to be checked if available (optional Request Screenshot remote system).
- Readings from the display of the Power Park Controller have to be captured and documented with photos. A comparison of the actual values can be processed on site.
- In the testing procedure, the P_{delta} has to be set high enough that the absolute delta value is at least 1 MW and at least 3% of available power ($P_{available}$). P_{delta} is a percent value according to the RPP Grid Code.
- After setting this value in the Power Park Controller, the RPP, BESF and/or Hybrid Power Plant shall operate in this condition for at least 10 minutes.

Signals for the site testing trends and final report:

- P (Available)
- P (Actual)
- P_{delta} (Setpoint)

DELTA CONTROL – ($P_{available}$ >20% of P_{max}) Time for test: 10min		
Ref No	**Description**	**Comments**
SETUP		
1.	Check $P_{available}$ at least 50% P_{max}	_____ MW
2.	Check PPC control ready	
TEST		
3.	Check P_{delta} control enabled	
4.	Send ___e.g. 10% of $P_{available}$ (> 1 MW)	____% of $P_{available}$
5.	Check if power reduces to setpoint value on Park Controller, SCADA or better measurement system.	OK?
6.	Hold for at least 10 min	
7.	Further tests are optional, e.g. longer period if the primary energy do not change during the 10 min test period or other setting like P_{delta} of 3% would be tested	
8.	Send 0% P_{delta} setpoint	
9.	Hold for 2 min	
10.	Disable P_{delta} control	

Remarks:
_____
_____
_____

3.8.3 Active Power Gradient Constraint

Note:

- Reference power ($P_{reference}$) is the value, which the parties on site agree upon.
- During dry run tests, establish and test your minimum and maximum ramp rates.

Signals for the site testing trends and final report:

- P (Available)
- P (Actual)
- P (Setpoint)

Before the start of the tests the available power is measured and used for all test as a fixed reference value: $P_{reference}$ =____MW			
Reduction/limit	**Setpoint value P [MW]**	**Start value P [MW]**	**Actual P [MW] at 2 min after setting the value**
1st test: Down ramp rate has to be set to: (0.4 x Preference)/min			
1st test from $P_{reference}$ to 20% $P_{reference}$	20% $P_{reference}$	$P_{reference}$	
2nd test: Up ramp rate has to be set to: (0.4 x $P_{reference}$)/min			
2nd test from 20% $P_{reference}$ to $P_{reference}$	$P_{reference}$	20% $P_{reference}$	
Reduction/limit	**Setpoint value P [MW]**	**Start value P [MW]**	**Actual P [MW] at 4 min after setting the value**
3rd test: Down ramp rate has to be set to: (0.2 x $P_{reference}$)/min			
3rd test from $P_{reference}$ to 20% $P_{reference}$	20% $P_{reference}$	$P_{reference}$	
4th test: Up ramp rate has to be set to: (0.2 x Preference)/min			
4th test from 20% $P_{reference}$ to $P_{reference}$	$P_{reference}$	20% $P_{reference}$	
After the last test the RPP is allowed to go back to normal operation			

Remarks:

_____

_____

3.8.4 Power Curtailment during Frequency

- For Ancillary services capability test (if applicable) - Please ensure the plant is tested for primary frequency response as per the latest version of the RPP and BESF Codes.

3.8.4.1 Frequency Controller Response Performance: Under-frequency

Note:

- It is recommended to simulate a grid frequency in the Power Park Controller to make the control independent of the real grid frequency.

Signals for the site testing trends and final report:

- P (Available)
- P (Actual)
- Simulated Frequency

Set value of P_{delta}:				_____% of $P_{available}$		
Set value of Droop 1:				4%		
	at start; direct before setting			at 10 s after setting the new frequency value		
	Actual P [MW]	**Frequency [Hz]**	**$P_{available}$ [MW]**	**Actual P [MW]**	**Frequency [Hz]**	**$P_{available}$ [MW]**
1st test Frequency from 50 Hz to 49.85 Hz						
2nd test Frequency from 49.85 Hz to 49.5 Hz						
3rd test Frequency from 49.5 Hz to 49 Hz						
4th test Frequency from 49 Hz to 48 Hz						
5th test Frequency from 48 Hz to 47 Hz						
6th test Frequency from 47 Hz to 50 Hz						

Remarks:
_____
_____
_____
_____

3.8.4.2 Frequency Controller Response Performance: Over-frequency

Signals for the site testing trends and final report:

- P (Available)
- P (Actual)
- Simulated Frequency

Set value of P_{delta}:				_____ MW		
Set value of Droop 2:				_____MW/Hz		
	at start; direct before setting			at 10 s after setting the new frequency value		
	Actual P[MW]	**Frequency [Hz]**	**$P_{available}$ [MW]**	**Actual P[MW]**	**Frequency [Hz]**	**$P_{available}$ [MW]**
1st test Frequency from 50 Hz to 50.15 Hz						
2nd test Frequency from 50.15 Hz to 50.5 Hz						
3rd test Frequency from 50.5 Hz to 51 Hz						
4th test Frequency from 51 Hz to 51.5 Hz						
5th test Frequency from 51.5 Hz to 51.98 Hz						
6th test Frequency from 51.98 Hz to 51.5 Hz						
7th test Frequency from 51.5 Hz to 51 Hz						
8th test Frequency from 51 Hz to 50.5Hz						
9th test Frequency from 50.5 Hz to 50.15Hz						
10th test Frequency from 50.15 Hz to 50Hz						

Remarks:

_____

_____

_____

3.8.5 Reactive Power Control Function Category B and C

Note:

- During the reactive power test, the full capability of Q has to be checked. Followed by repeating the test at 20% of P_{max}.
- It is not recommended to jump from full reactive power overexcited to full reactive power under excited and vice versa due to resulting imbalances in the grid.

Signals for the site testing trends and final report:

- P (Actual)
- V (Actual)
- Q (Actual)
- Q (Setpoint)

3.8.5.1 Reactive Power Control at at P_{max}

	Setpoint	Actual value		Response time
	Q [MVar]	Q [MVar]	P [MW]	[s]
Q = 0 MVar				
$-Q_{min}$ over excited				
Q = 0 MVar				
$+Q_{max}$ under excited				
Q = 0 MVar				

3.8.5.2 Reactive Power Control at Fixed Power of 20%P_{max}

	Setpoint	Actual value		Response time
	Q [MVar]	Q [MVar]	P [MW]	[s]
Q = 0 MVar				
$-Q_{min}$ over excited				
Q = 0 MVar				
$+Q_{max}$ under excited				
Q = 0 MVar				

Remarks:

_____
_____
_____

3.8.6 Power Factor Control

Note:

- It is not recommended to jump from full reactive power overexcited to full reactive power under excited and vice versa due to resulting imbalances in the grid.

Signals for the site testing trends and final report:

- P (Actual)
- V (Actual)
- Q (actual)
- PF (Actual)
- PF (Setpoint)

PF Setpoint	Actual value Q [MVar]	Actual value P [MW]	Actual value cos φ	Response time[s]
PF= 1				
PF_Leading (min)				
PF= 1				
PF_Lagging (max)				
PF= 1				

Remarks:
_____
_____
_____
_____

3.8.7 Voltage Control Function

Signals for the site testing trends and final report:

- P (Actual)
- V (Actual)
- Q (Actual)
- V (Setpoint)

3.8.7.1 Test 1: Set the Droop to 4%: (Q_{max})/4% U_n

Reactive Power Control – Q (U) Characteristic					
Voltage setpoint at the PPC	Setpoint		Actual value		Response time
	U [kV]	Q [MVar]	U [kV]	Q [MVar]	
Reference voltage					
1.02 of U_{ref}					
Reference voltage					
0.98 of U_{ref}					
Reference voltage					

3.8.7.2 Test 2: Set the Droop to 8%: (Q_{max})/8% U_n

Reactive Power Control – Q (U) characteristic					
Voltage setpoint at the PPC	Setpoint		Actual value		Response time
	U [kV]	Q [MVar]	U [kV]	Q [MVar]	
Reference voltage					
1.04 of U_{ref}					
Reference voltage					
0.96 of U_{ref}					
Reference voltage					

Remarks:
_____
_____
_____
_____

4. Acceptance

This document has been seen and accepted by:

Name	Designation
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Nothando Mdletshe	Engineer
Bruce Siavhe	Chief Engineer
Thabo Modisane	Chief Engineer
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5. Revisions

Date	Rev.	Compiler	Remarks
13 May 2022	0.1	Sureshan Naidoo	First Draft
27 June 2022	1	Sureshan Naidoo	First Issue
23 October 2024	2	Sureshan Naidoo	Inclusion of Hybrid Power Plants

6. Development Team

The following people were involved in the development of this document:

- Themba Khoza
- Sureshan Naidoo
- Nompilo Mkhonza
- Zesizwe Ncane
- Jesse Mekwa

7. Acknowledgements

None.