Eskom	GUIDELINE	Transmission/System Operator/ GCM

Title: **GUIDANCE NOTE – GRID CODE REQUIREMENTS FOR HYBRID POWER PLANTS**

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Compiled by	Supported by	Functional Responsibility	Authorized by
J Mekwa	**T Khoza**	**P Moshodi**	**I Fick**
Senior Engineer	**Chief Engineer**	**Senior Manager**	**General Manager**
GCM	**GCM**	**GCM**	**System Operator**
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1. Introduction

Hybrid Power Plants are required to comply to the requirements of the South African *Grid Code* (SAGC).

These plants could use a variety of technologies, such as *alternators* and grid-following inverters based on wind energy, solar irradiation and/or battery energy storage. As a result, it may not always be clear which of the connection conditions should apply – those from the Network Code, the RPP Code and/or the BESF Code.

This guideline is intended to guide the *Generators* in applying the requirements of the SAGC, where two or more *Codes* have different capability requirements under similar *operating scenarios*. It is not intended to cover all requirements of these plants. The full set of requirements must be taken from the relevant *Codes*. Some general statements about the applicability of the existing *Codes* follow:

- The Network Code shall apply in the case of *Hybrid Power Plants* that have at least one grid-connected *alternator* that does not use a renewable energy source.
- The RPP Code shall apply in the case of *Hybrid Power Plants* that have at least one inverter-based technologies and/or *alternators* that use a renewable energy source.
- The BESF Code shall apply to all plants that have at least one battery energy storage facility.
- Depending on the technologies used, more than one of three *Codes* (Network Code, RPP Code and/or BESF Code) may be applicable.
- In the event of differing requirements that are not addressed by this document, the *Generators* must consult the *System Operator* (SO).

2. Supporting Clauses

2.1 Scope

This Guidance Note provides clarification on Grid Code requirements set out in the Network Code, RPP Code and BESF Code in a case of *Hybrid Power Plants,* where there are differing requirements under similar *operating scenarios*.

2.1.1 Purpose

The purpose of this document is to guide *Generators* in the application of the approved *Codes*, where two or more *Codes* have different capability requirements under similar *operating scenarios*.

2.1.2 Applicability

The requirements of the SAGC (latest version) shall be applicable to all *Hybrid Power Plants* subject to the qualifications and clarifications listed in this Guidance Note.

2.1.3 Effective date

01 September 2023

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] ISO 9001 Quality Management Systems

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

[3] Applicable version of the SAGC Network Code, available from www.nersa.org.za

[4] Applicable version of the SAGC Requirements for Battery Energy Storage Facilities, available from www.nersa.org.za

[5] Applicable version of the SAGC Preamble, available from www.nersa.org.za

[6] Applicable version of the SAGC The Information Exchange Code from www.nersa.org.za

2.2.2 Informative

None

2.3 Definitions

For this Guidance Note, the following definitions are applicable.

Alternators:

As defined in the Codes.

Ancillary Services:

As defined in the Codes.

Codes:

As defined in the Codes.

Droop:

As defined in the Codes.

Generator:

As defined in the Codes.

Grid Code (GC):

As defined in the Codes.

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

Maximum Continuous Rating (MCR):

As defined in the Codes.

Network Service Provider:

As defined in the Codes.

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 (refer to Appendix A).

Point of Connection (POC):

As defined in the Codes.

Primary Frequency Control:

As defined in the Codes.

Renewable Energy Technical Evaluation Committee (RETEC):

RETEC is a technical team within the *System Operator* established to validate or verify compliance to the *SAGC* as demonstrated by the *RPP Generator* in respect of his/her *RPP*.

System Operator (SO):

As defined in the Codes.

Unit:

As defined in the Codes.

2.4 Abbreviations

Abbreviation	Explanation
BESF	Battery Energy Storage Facility
GC	Grid Code
MCR	Maximum Continuous Rating
NSP	Network Service Provider
POC	Point of Connection
PV	Photovoltaic
RETEC	Renewable Energy Technical Evaluation Committee
RPP	Renewable Power Plant
SAGC	South African Grid Code
SO	System Operator

2.5 Roles and Responsibilities

2.5.1 *Generator* Responsibilities

It is the responsibility of the *Generator* to ensure that their *Hybrid Power Plant* complies with all applicable requirements of the *SAGC* (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 *GC* 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 the *Generator* in order to assess *GC* compliance status of the *Hybrid Power Plant*, and to provide feedback to the *Generators* on the *GC* compliance status of their *Hybrid Power Plant* and issue a *GC* compliance notification letter once the *Generator* has successfully demonstrated compliance to all applicable SAGC requirements.

2.6 Process for Monitoring

It will be possible to monitor the effective use of this guideline by *RETEC* and *Generators*. As soon as the *Generator* submits the required information for *GC* compliance assessment to commence, *RETEC* shall evaluate the submitted information and provide feedback to the *Generator*. *RETEC* shall also motivate for the issuing of Commercial Operation certificates at project completion.

2.7 Related/Supporting Documents

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

[2] Applicable version of the SAGC The Network Code, available from www.nersa.org.za

[3] Applicable version of the SAGC Requirements for Battery Energy Storage Facilities, available from www.nersa.org.za

[4] Applicable version of the SAGC Preamble, available from www.nersa.org.za

[5] Applicable version of the SAGC The Information Exchange Code from www.nersa.org.za

3. Connection Requirements

3.1 *Hybrid Power Plants* Categories

The requirements of the SAGC are applicable to *Hybrid Power Plants* depending on the rated capacity as specified in Table 1 below.

Table 1: *Hybrid Power Plants* Categories

Category	***Hybrid Power Plant's MCR***		
A	>0	to	< 1 MW
A1	>0	to	≤ 13.8 kW
A2	>13.8 kW	to	<100 kW
A3	≥100 kW	to	<1 MW
B	≥1 MW	to	<20 MW
B1	≥1 MW	to	<5 MW
B2	≥5 MW	to	<20 MW
C	≥20 MW	to	<800MW
C1	≥20 MW	to	<100 MW
C2	≥100MW	to	<800 MW
D	≥800 MW		

3.2 Voltage and Frequency Operating Range

3.2.1 Voltage Operating Range

(1) The voltage range, within which the *Hybrid Power Plants* shall be capable of operating are as shown in Table 2.

(2) *Hybrid Power Plants* shall be capable of operating continuously, at any power between Minimum Generation and *MCR*, as per the respective *Codes*, within the voltage range at the *POC* specified in Table 2 below.

Table 2: Minimum and maximum operating voltages at *POC*

Nominal voltage, Un [kV]	U_{min} [pu]	U_{max} [pu]
765	0.95	1.05
400	0.95	1.05
275	0.95	1.05
220	0.95	1.05
132	0.90	1.0985
88	0.90	1.0985
66	0.90	1.0985
44	0.90	1.08
33	0.90	1.08
22	0.90	1.08
11	0.90	1.08
6.6	0.90	1.08
3.3	0.90	1.08

3.2.2 Frequency Operating Range

(1) The frequency operating ranges are defined in all relevant *Codes* for Generator Connection conditions. The requirements shall also apply to *Hybrid Power Plants*.

3.3 Frequency Response

3.3.1 Primary Frequency Response

(1) *Hybrid Power Plants* shall be capable of primary frequency response in accordance with the relevant *Codes*, i.e., Network Code, RPP Code and/or BESF Code.

(2) The response shall only be required if the *Hybrid Power Plant* has been contracted for this *ancillary service*. If the *Hybrid Power Plant has* not been contracted by the SO to provide *primary frequency control* (instantaneous reserve), the primary frequency support function shall be deactivated.

3.3.2 Mandatory Response to High and Low Frequencies

(1) *Hybrid Power Plants* shall be capable of mandatory response in accordance with the relevant *Codes*, i.e., Network Code, RPP Code and/or BESF Code.

3.4 Active Power Constraint Functions

(1) *Hybrid Power Plants* shall be capable of active power constraint functions as in the RPP Code and/or BESF Code. These include *absolute production constraint*, *delta production constraint* and *power gradient constraint*, as applicable.

3.5 Reactive Power Capability

(1) Reactive power capability requirements, as specified in the RPP Code, shall be applied to *Hybrid Power Plants* without BESF.

(2) Reactive power capability requirements, as specified in the RPP Code and BESF Code, shall be applied to *Hybrid Power Plants* with both the RPP and BESF, whether with the *alternator* or not.

(3) The continuous operating area of the *alternator* may be further constrained by the *Minimum Generation* of the *unit*, which could be higher than the 20% of *MCR* as specified on both the RPP Code and BESF Code.

3.6 Reactive Power and Voltage Control

(1) Inverter-based *Hybrid Power Plants* shall follow the requirements of the RPP Code and/or the BESF Code. Therefore, they shall be equipped with power plant controllers for the automatic control of voltage (with *droop*), power factor and reactive power at the *POC*.

(2) *Hybrid Power Plants* with alternator/s shall be equipped with excitation systems control at the *alternator* level as described in GCR3 of the Network Code.

3.7 Disturbance Withstand-Capability and Response

3.7.1 Fault Ride-Through (FRT) Requirements

(1) *Hybrid Power Plants* shall be capable of riding through faults regardless of the *operating scenario*. The requirements in the RPP Code for the inverter-based technologies and *alternators* shall apply. *Hybrid Power Plants* with BESF shall comply to the requirements of both the RPP Code and BESF Code.

3.7.2 Voltage Support during Faults

(1) The Network Code includes requirements for excitation systems, which significantly impact the response of *alternators* during faults.

(2) The inverter-based technologies shall respond to voltage support as specified in the RPP Code and/or BESF Code.

3.8 Power Quality

(1) *Hybrid Power Plants* shall meet the power quality requirements specified in the RPP Code and/or the BESF Code. The requirements shall apply to all *operating scenarios*.

3.9 Protection

(1) All the *Codes* include requirements for the electrical protection systems. The Network Code includes protection functions which may or may not be required depending on “IPS requirements”. The *SO* may specify whether these functions are required.

(2) *Hybrid Power Plants* shall demonstrate compliance in accordance with the requirements specified in the respective *Codes*.

4. Testing and Compliance Monitoring

4.1 General

(1) *Generators* of the *Hybrid Power Plants* shall demonstrate compliance through the provision of design information, type tests, dynamic simulations (part of a grid compliance report), measurements, on-site tests and model validation.

4.2 Studies and Tests

(1) All *Hybrid Power Plants* shall perform simulation studies and tests as required and as specified in any part of the *Codes* (refer to Appendix A).

(2) The type testing of the main components (i.e., *Units*, *inverters*, *alternators*, *transformers* etc.) shall be done according to best international practices.

4.3 Non-compliance suspected by the System Operator

(1) If at any time the SO or responsible NSP suspects that a *Hybrid Power Plant* is not complying with a requirement in the respective *Codes*, then the *SO* and/or *NSP* shall notify the relevant *Generator* of such non-compliance by issuing a *non-conformance* report (as referred to in the Governance Code), specifying the requirement concerned and the basis for the *SO's* or *NSP's* suspicion.

4.4 Modifications

(1) If a *Generator* proposes to change or modify the *Hybrid Power Plant* in a manner that could reasonably be expected to either affect its ability to comply with the *Codes*, or changes the performance, information supplied, settings, etc., then that *Generator* shall prove compliance to the requirements of the respective *Codes*.

5. Acceptance

This document has been seen and accepted by:

Name	Designation
Isabel Fick	General Manager – System Operator
Phokoane Moshodi	Senior Manager – Grid Code Management
Themba Khoza	Chief Engineer – Grid Code Management
Maite Sako	Chief Engineer – Grid Code Management
Target Mchunu	Chief Engineer – Grid Code Management

6. Revisions

Date	Rev.	Compiler	Remarks
July 2023	0	J Mekwa	Draft
August 2023	1	J Mekwa	First Issue

7. Development Team

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

- Phokoane Moshodi
- Themba Khoza
- Maite Sako
- Target Mchunu
- Ndamulelo Tshivhase
- Sureshan Naidoo
- Jesse Mekwa
- Zesizwe Ncane
- Yaaseen Akhalwaya
- Tumelo Motsei
- Keneilwe Seleme
- Olebogeng Katametsi
- Nompilo Mkhonza
- Matabase Makena

8. Acknowledgements

- Peter Lilje – GIZ

Appendix A – Hybrid Plant Requirements

A.1 Studies and Tests Requirements

Requirements	Pre-connection study	GCC Tests	RMS Model validation
Reactive power capability	All operating scenarios		All operating scenarios (Updated)
20 degree phase jump	All hybrid operating scenarios (more than one technology in operation)		All hybrid operating scenarios (more than one technology in operation) (Updated)
Frequency trips (Under and Over)	All hybrid operating scenarios (more than one technology in operation)		All hybrid operating scenarios (more than one technology in operation) (Updated)
Fault ride through	All operating scenarios		All operating scenarios (Updated)
Absolute		All operating scenarios unless otherwise agreed with the system operator	All operating scenarios as per the site testing
Gradient		All operating scenarios unless otherwise agreed with the system operator	All operating scenarios as per the site testing
Delta		All operating scenarios unless otherwise agreed with the system operator	All operating scenarios as per the site testing
Frequency Response		All operating scenarios unless otherwise agreed with the system operator	All operating scenarios as per the site testing
Reactive power control		All operating scenarios unless otherwise agreed with the system operator	All operating scenarios as per the site testing
Power factor control		All operating scenarios unless otherwise agreed with the system operator	All operating scenarios as per the site testing
Voltage Control		All operating scenarios unless otherwise agreed with the system operator	All operating scenarios as per the site testing

A.2 Operating Scenarios Example

Scenario	BESS disch.	PV	BESS charging	Description
A	✓	✗	✗	Only BESS available to meet dispatch instruction prior to sunrise
B	✓	✓	✗	BESS supplements PV to meet dispatch instruction
C	✗	✓	✓	PV alone meets dispatch instruction and excess PV charges BESS
D	✗	✓	✗	PV curtailed to MEC, BESS fully charged

A.3 Generation Forecast Example