Eskom	Standard	Transmission/System Operator/Ancillary Services

Title: **Certification and Performance Monitoring for Generators Capable of Operating in a Synchronous Condenser Mode**

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1. Introduction

Reactive power support from generators is managed via the procurement of services that are specified in the Ancillary Services Technical Requirements (ASTR). These services are comprised of synchronous condenser operation (SCO) and generator voltage control, wherein this standard would focus only on generating units capable of providing SCO capability, as outlined in Section 2.1 below. The South African Grid Code (SAGC) requires that the service providers / generators connected to the network, adhere to the stipulated codes whilst the System Operator will contract additional reactive power services from capable generators for system voltage control. Service providers shall be required to adhere to the generator voltage control certification and performance requirements to ensure SO achieves minimum system reliability targets as defined in the Grid Code.

2. Supporting Clauses

2.1 Scope

This document outlines the procedure for testing, certification, de-certification, and performance monitoring for generators capable of operating in a synchronous condenser mode. The document focuses on the generator reactive power and voltage control requirements to support acceptable power system voltage profiles.

2.1.1 Purpose

The aim of this standard is to ensure that voltage levels, reactive power flows and reactive power support from generators are monitored, maintained, and controlled within acceptable limits. This is done in real-time for the purpose of protecting equipment and for reliability and stability of the Eskom network.

2.1.2 Applicability

This document shall apply throughout Eskom Holdings Limited, its divisions, subsidiaries, entities wherein Eskom has a controlling interest, as well as all independent power producers connected to the national grid.

2.1.3 Effective date

This document is effective from date of authorisation.

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] South African Grid Code (SAGC)

[2] 240-159838031 Ancillary Services Technical Requirements for 2023/24 – 2027/28

2.2.2 Informative

[3] ISO 9001 Quality Management Systems.

2.3 Definitions

Definition	Description
Ancillary Services	As per the SAGC, these are services supplied to the NTC by generators, distributors, or end-use customers, necessary for the reliable and secure transport of power from generators to distributors and other customers, as defined in the System Operation Code, section 4.
National Transmission Company	As per the SAGC, this is the South African legal entity licensed to execute the national transmission responsibility. It consists of a System Operator and a national transmission network service provider.
Declared Voltage	Declared by the licensee as the voltage at the point of supply.
Facility	A generation facility which converts primary energy to electrical energy which consists of one or more Power Generating Modules connected to a network at one or more Connection Points.
Generator	As per the SAGC, this is a legal entity licensed to engage in the production of electricity through a unit or power station.
Maximum Continuous Rating (MCR)	TAs per the SAGC, this is the sent-out capacity that a unit is rated to produce continuously under normal conditions.
Reactive Power (RP)	Described as the background energy movement in an alternating current system arising from the production of electric and magnetic fields. The total complex power is defined as S = P + jQ. Were Q is the imaginary part and P is the real power.
Service Provider	A legal entity who contracts to provide ancillary services and operates one or more units or one or more facilities that supply power or capabilities to the Transmission or Distribution System.

Synchronous Condenser Operation (SCO)	A mode of operation whereby a capable generator is disengaged from the turbine and runs without mechanical load such that it can generates or absorb reactive power.
System Operator	A legal entity licensed to be responsible for short term reliability of the interconnected power system (IPS), which oversees controlling and operating the transmission system (TS) and dispatching generation (or balancing the supply and demand) in real time basis.
Under Voltage Event	An event where the voltage supplied reduces to a value of less than 0,85 p.u. of the standard or declared voltage for more than 3seconds on one or more phases.
Voltage Control	The ability of a power system to maintain steady acceptable voltages at all buses in the system under normal operating conditions and after being subjected to a disturbance.

2.4 Abbreviations

Unit – As defined in the Grid Code

Abbreviation	Explanation
AS	Ancillary Services
AVR	Automatic Voltage Regulator
CO	Commercial Operation
EL1	Emergency Level One
EOD	Electrical Operating Desk
EMS	Energy Management System
GC	Grid Code
GCM	Grid Code Management
GCR	Grid Code Requirement
IPP	Independent Power Producer
IPS	Interconnected Power System
MCR	Maximum Continuous Rating
MW	Megawatt
NC	National Control
PCC	Point of Common Coupling
PPA	Power Purchase Agreement
RP	Reactive Power
SAGC	South African Grid Code
SCO	Synchronise Condenser Operation
SO	System Operator

Abbreviation	Explanation
SP	Service Provider
TS	Transmission System
VC	Voltage Control

2.5 Roles and Responsibilities

a) Ancillary Services, System Operator

The Ancillary Services section is responsible for managing the testing, certification, budgeting, contracting and compensation for all generators that can provide the voltage control via synchronous condenser operation, as well as determining technical requirements and minimum standards applicable to all service providers. In addition, AS certifies, decertifies, and ensures compliance to the SAGC by contracting sufficient facilities, defining minimum compliance standards, and managing the performance of service providers.

b) National Control, System Operator

National Control (NC) is responsible for managing the operation of the Power System in a safe, economical, and secure manner, while maintaining reliability and quality of supply. NC maintains the system voltages within the statutory limits by switching the reactive power equipment and utilising generators to support the system.

c) National Control System Support, System Operator

National Control System Support (NCSS) is responsible for providing operational support, EMS data support and relevant SO system/s software support during certification and performance monitoring of service providers.

d) Grid Code Management, System Operator

Grid Code Management is responsible for approving all the GCR compliance tests including reactive power and voltage control before a unit is approved for commercial operation (CO).

e) Service Providers

Service providers that are contracted to provide SCO are responsible for providing these services to the System Operator, as stipulated in their respective contracts in line with minimum performance standards. Where SO highlights poor performance, service providers are responsible for ensuring that performance is improved as soon as possible. The service providers are responsible for acknowledging and responding National Control requests as required on a real time basis, as well as providing a dynamic response to system voltage changes under abnormal conditions (which requires that service providers ensure that plant or systems that are required to enable SCO capability are in working order when generating units are in service).

2.6 Process for Monitoring

The process for testing/certification and performance monitoring of units capable of operating in a synchronous condenser is discussed in this standard.

2.7 Related/Supporting Documents

N/A

3. SCO CAPABILITY TESTING/CERTIFICATION AND PERFORMANCE MONITORING REQUIREMENTS

The contents of this document cover SCO requirements about AS testing, certification and performance monitoring processes. The Grid Code and the ASTR also guide the contents.

3.1 SYNCHRONOUS CONDENSER OPERATION (SCO) TESTING REQUIREMENTS

According to the SAGC, gas turbines (units build after the Grid Code implementation) shall be capable of SCO (synchronous condenser operation), unless otherwise agreed with the System Operator and approved by NERSA.

Other technologies that have similar mechanisms and can offer synchronous condenser operation are also considered (e.g., conventional, and pumped storage hydroelectric power stations).

3.1.1 SCO Prototype Testing

Prototype tests are conducted on new generators as part of Grid Code compliance in preparation to achieve commercial operation (CO). If the test is successful (in conjunction will all other required tests being completed successfully), the SCO capable generator is given the CO letter of confirmation by the Grid Code Management and a certificate from Ancillary Services (AS).

3.1.2 Routine SCO Testing

Once certified for SCO, the generator is obliged to conduct a routine test every six years or after the next general overhaul (GO) that may affect the SCO capability on the generator, whichever comes first. If the routine test is not successful, the generator is required to retest until the test is successful. After three consecutive unsuccessful tests, the generator will be decertified.

3.1.3 SCO Testing Methodology

Generators shall carry out routine and prototype response tests to demonstrate SCO capability.

The test shall be performed at 0 % of MCR active power and at least 100% of maximum reactive power in both lagging (capacitive/exporting to IPS -) and leading (inductive/importing from IPS) operating modes.

For testing in over-excited operation, while in SCO mode, the operating point shall be such that the machine is at maximum reactive power output or until the boundary value of the effective capability diagram is reached, whichever occurs earlier. This operating point shall be maintained until the machine temperatures have stabilized. It shall be verified that the temperatures of the machine and generator transformer remained within limits that are acceptable for continuous operation.

For testing in under-excited operation, while in SCO mode, the operating point shall be as close as possible to the under-excitation limiter. It shall be verified that the machine temperatures remained within limits that are acceptable for continuous operation.

The synchronous generator shall calculate the reactive capability at rated machine voltage from the measurements taken during the test (for both over-excited and under-excited operations), which may have been performed at off-nominal conditions.

3.1.4 SCO Testing Arrangement

The Service Provider shall apply formally, in writing (e-mail), to the Ancillary Services department stating the intent to get tested for certification and contracting. The start of the test period will be agreed upon between the Service Provider and SO. The facility/unit will be expected to start at least 10 working days after the request was received to enable the unit to be registered on the relevant SO system/s. The generator will be tested for one hour in leading and one hour in lagging operating modes.

To ensure plant reliability, prior arrangements must be done between the Service Provider, AS, NC and GCM (if it's a prototype tests) to choose the suitable date and time for the test. The unit/facility will be certified provided that the test was declared a success by AS and a certificate will be issued few days later.

3.1.5 SCO Testing Template

The SCO testing template serves as a guide to the Service Provider on how to test the capability and what data and information is required to enable SO to analyse the test results to declare whether the test is successful or not. The SCO testing template is found in the appendix B.

3.1.6 SCO Success/Acceptance Criteria

The SCO test will be declared successful if the generator can;

i) Operate at machine maximum continuous Mvar (under-excited) at rated voltage and nominal tap for 1 hour.

ii) Operate at machine maximum continuous Mvar (over-excited) at rated voltage and nominal tap for 1 hour.

It shall be verified that the machine temperatures remained within limits that are acceptable for continuous operation.

3.1.7 Certification Process

The Service Provider will perform the test as per the requirements of this standard and the SAGC and issue the completed SCO testing template (as per 3.1.5) to AS within 5 working days. AS will then evaluate and analyse the results before confirming whether the test was successful or not. If the test is declared successful, AS will issue a certificate which is valid for 6 years and if not, the Service Provider will have to repeat the test. Any costs incurred by the Service Provider in the certification process will be for the account of the Service Provider.

3.2 SCO PERFORMANCE MONITORING

The performance monitoring of SCO units is conducted monthly to ensure that the SCO capability is available to support National Control whenever the need arises. The SCO capability performance monitoring will be based on the daily average availability percentage of the generator in a month. This will be achieved by the Service Provider declaring availability daily, irrespective of whether they are used or not.

In the event of unavailability of any duration, written justification should form part of each period of unavailability.

Thus, Performance Availability = Average availability percentage of the SCO capability of all contracted SCO units at a power station/facility throughout a month.

Acceptable performance will be declared if the contracted Service Provider had SCO capability available for eighty percent (80%) or more throughout the month.

Monthly performance will be rated as follows;

- Eighty percent and above – Good
- Between fifty percent (50%) and eighty percent (80%) – Ok
- Below fifty (50%) – Poor

The performance monitoring will be analysed as seen in table 1 below.

3.2.1 SCO Performance Factor

The performance factor is derived based on the available SCO capability irrespective of whether the Service Provider is used or not. This is to ensure that the Service Provider's capability is available whenever the system need arise. Thus;

The performance factor is the daily average availability percentage of all contracted SCO units at a power station/facility in a month.

Table 1: SCO Performance Factor

Synchronous Condenser Operation Performance Factor (AFSCO)		
PF < 50%	50% ≤ PF < 80%	PF ≥ 80%
Poor	Ok	Good

3.2.2 SCO Utilization Factor (UF)

The utilisation factor is the average percentage of the hours when the Service Provider was used in SCO mode in a month across all contracted SCO units at the power station/facility. This measure is included to track the monthly SCO usage of a unit (and facility) and to ensure that the this is separated from usage in other modes of operation.

3.3 DECERTIFICATION

If the SCO percentage performance is rated less than the acceptable SCO performance, then the Service Provider shall provide a written report to the SO/AS detailing the reasons within one (1) month and rectify the performance. If the performance is not rectified within three (3) months, then:

- The Unit/Service Provider shall be decertified, and the Ancillary Service certificate withdrawn in respect of SCO provision.

The Unit/Service Provider shall be permitted to apply to the SO for recertification and issuance of the Ancillary Service certificate in respect of SCO for the Unit following decertification, based on the following:

- The recertification and issuance of the Ancillary Service certificate in respect of SCO for the Unit shall only be permitted if the Unit/Service Provider is retested successfully.

The Seller shall notify SO if the Unit can no longer provide SCO as certified and provide detailed technical description of the problem. If solving the problem will take more than three months, then

the unit is advised to apply for a temporary exemption and there will be no compensation to the Unit until the problem is sorted and retested successfully.

The Unit shall be tested every 6 years and any violation will lead to decertification.

4. Acceptance

This document has been seen and accepted by:

Name	Designation
Gavin Hurford	National Control Manager
Louis Du Plessis	National Operations Manager
Lawrence Padachi	Integrated Power System Reliability Services Senior Manager
Maite Sako	Grid Code Management Chief Engineer
Themba Khoza	Grid Code Management Chief Engineer
Lyle Naidoo	Ancillary Services Chief Engineer
Andries Steenkamp	Manager Performance & Development Gx Division (Peaking Operating Unit)

5. Revisions

Date	Rev.	Compiler	Remarks
March 2024	1	SJ Malakapatlo	First issue

6. Development Team

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

1. Ike Tshwagong
2. Selaelo Malakapatlo

7. Acknowledgements

N/A

APPENDIX A: SYSTEM VOLTAGE AND POWER FACTOR LIMITS INCLUDING VC FLOW CHART

Table 2: System voltage limits and generator power factor limits

Transmission		
Voltage	**Normal Conditions**	**Disturbance Conditions**
88kV, 132kV, 400kV and 765kV	±5% of nominal	±5% of nominal
Generators/Service Provider		
Power Factor	**Lagging**	**Leading**
Generators/IPPs	0.85	0.95
Renewables	0.95	0.95

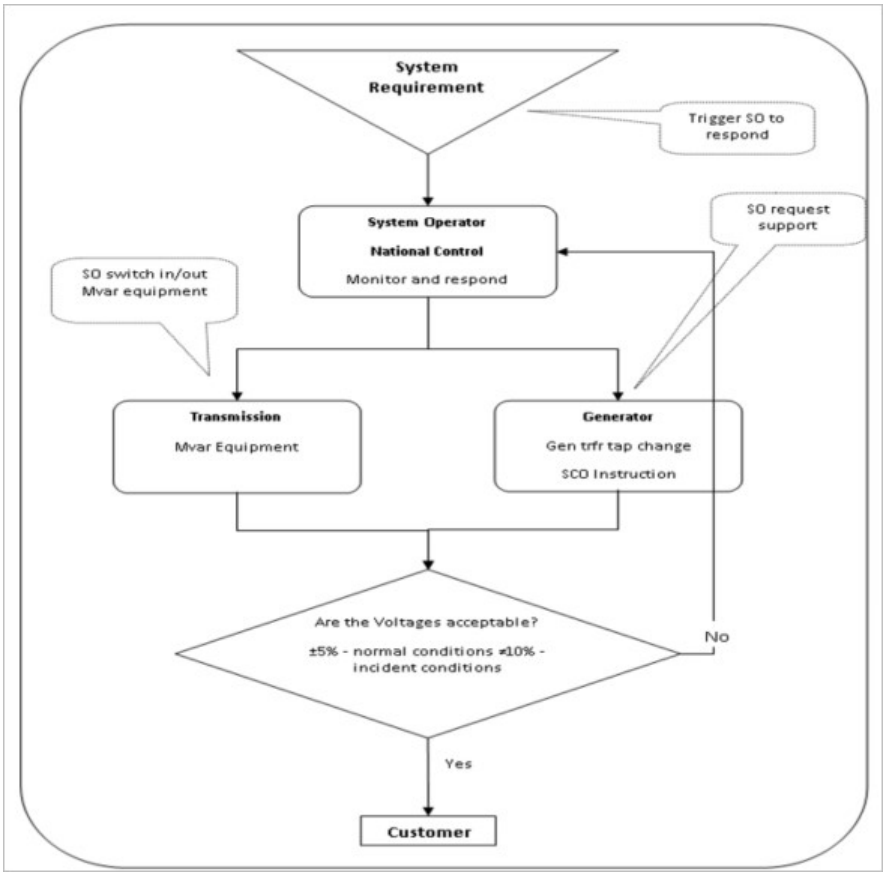

Figure 1: National Control voltage control process

Figure 1 above shows how National Control manages the voltage control process by utilising Transmission reactive power equipment and this also shows how they request support from Generators.

APPENDIX B: CERTIFICATION TEMPLATE

SYSTEM OPERATOR

Testing Template for Synchronous Condenser Operation (SCO) Certification

Compiled by	Functional Responsibility
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Date: ---	Date: ---

1. Basic Information

Service Provider	……	**Test Date**	……	**Start Time**	……
				End Time	……

2. Process

Certification	X	Decertification	

3. Product

Instantaneous Reserves		Black Start	
Regulating Reserves		Unit Islanding	
Ten-minute Reserves		Voltage Control	
Emergency Level 1		Synchronous Condenser Operation	X
Instantaneous Demand Response		Self-start	
Supplemental Demand Response		Constrained Generation	

4. Reason for Certification

Service Provider conducted SCO capability tests as per this standard for SCO certification.

5. Test Results/Supporting Information

- Leading (inductive/importing from IPS) and Lagging (capacitive/exporting to IPS) SCO Testing
  - The test shall be performed at 0 % of MCR active power and at least 100% of maximum reactive power in both leading (capacitive/exporting to IPS) and lagging (inductive/importing from IPS) operating modes.
  - Each SCO mode either leading or lagging shall be tested for a period of 1 hour.

Date	**Time (Duration)**	**Generator Transformer 400kV Side**		
		Mvar	**PF**	
……	……	……	Lagging	……
……	……	……	Leading	……

Comments:

Testing in over-excited operation, while in SCO mode, the operating point shall be such that the machine is at maximum reactive power output or until the boundary value of the effective capability diagram is reached, whichever occurs earlier. This operating point shall be maintained until the machine temperatures have stabilized. It shall be verified that the temperatures of the machine and generator transformer remained within limits that are acceptable for continuous operation.

Testing in under-excited operation, the operating point shall be as close as possible to the under-excitation limiter. It shall be verified that the machine temperatures remained within limits that are acceptable for continuous operation. The Service Provider shall calculate the reactive capability at rated machine voltage from the measurements taken during the test, which may have been performed at off-nominal conditions.

6. Recommendations

Under recommendations the Service Provider is expected to state the following;

- Were the tests carried out in line with SCO Certification Standard?
- Did the generator reach the maximum reactive power output for both leading and lagging operation?
- What was the actual maximum reactive power output for both leading and lagging operations?
- Was the operating point maintained until the machine temperatures have stabilised?
    - It shall be verified that the temperatures of the machine and generator transformer remained within limits that are acceptable for continuous operation.

Yours sincerely

_____

Name Surname
GENERAL MANAGER: POWER STATION NAME
COMPANY/DIVISION

APPENDIX C: CERTIFICATION

POWER STATION NAME		
UNIT NUMBER		
DATE		
SCO		
Over-excited (lagging power factor):		
▪ Active power at which test performed (0% MCR)		MW
▪ Reactive power at rated real power output		Mvar
▪ Generator terminal voltage		kV
▪ Generator current		kA
▪ Voltage on HV side of main transformer		kV
▪ Tap setting of main transformer		
▪ Active power of auxiliaries		MW
▪ Reactive power of auxiliaries		Mvar
▪ Active power measured on HV side of main transformer		MW
▪ Reactive power measured on HV side of main transformer		Mvar
Under-excited (leading power factor):		
▪ Active power at which test performed (0% MCR)		MW
▪ Reactive power at which under-excitation limiter becomes active		Mvar
▪ Generator terminal voltage		kV
▪ Generator current		kA
▪ Voltage on HV side of main transformer		kV
▪ Tap setting of main transformer		
▪ Active power of auxiliaries		MW
▪ Reactive power of auxiliaries		Mvar
▪ Active power measured on HV side of main transformer		MW
▪ Reactive power measured on HV side of main transformer		Mvar

Certified reactive power range		
SCO		
Machine active power in SCO mode		MW
Unit active power in SCO mode		MW
Machine maximum continuous Mvar (over-excited) at rated voltage		Mvar
Machine maximum continuous Mvar (under-excited) at rated voltage		Mvar
Unit maximum continuous Mvar (over-excited) at rated voltage & nominal tap		Mvar
Unit maximum continuous Mvar (under-excited) at rated voltage & nominal tap		Mvar
POWER STATION NAME		
UNIT NUMBER		
DATE		

Certification form accepted	
Signed:	**Signed:**
(Generator)	**(System Operator)**
Date:	**Date:**

APPENDIX D: CERTIFICATION LETTER

(Power Station Manager Name and Surname)
(Power Station Manager)
(Power Station Name)
(Power Station Address)

Date:
dd-mm-yyyy
Enquiries:
Tel +27 11 XXX XXXX

Dear *(Power Station Manager Name)*

RE: CERTIFICATION OF *(POWER STATION NAME/SERVICE PROVIDER)*, UNIT (*UNIT NUMBER*) FOR REACTIVE POWER CAPABILITY TO OPERATE IN SCO MODE

This certification letter serves to confirm that … "Power Station Name" …, unit … ("*Unit Number*") … has verified its SCO capability range according to the standard "*Certification and Performance Monitoring of Generators Capable of Synchronous Condenser Operation (SCO)"*. **Ref "240-180300098"**. The unit is hereby certified according to the test held on …"XXXX-XX-XX", ("*date of test"*) for the SCO capability for the following range:

Date	Time (Duration)	Generator Transformer 400kV Side		
		Mvar	PF	
…….	…….	…….	…….	Lagging
…….	…….	…….	…….	Leading

The certification is valid for a period of 72 months from the date of the successful reactive power test, "XXXX-XX-XX, ("*from date"*) to "XXXX-XX-XX" ("*to date*").

Yours sincerely

_____

Name & Surname
GENERAL MANAGER: SYSTEM OPERATOR TRANSMISSION