SYSTEM OPERATOR

Ancillary Services Technical Requirements for 2022/23 – 2026/27

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ANCILLARY SERVICES TECHNICAL REQUIREMENTS FOR 2021/22 – 2025/26

1. INTRODUCTION

This document specifies the technical requirements for ancillary services for the financial year period 2022/23 till 2026/27. Its purpose is to make known the technical requirements of the System Operator with respect to ancillary services. The technical requirements as specified in this document will be used to develop a medium-term view of requirements for ancillary services in the 5-year time horizon, and to contract for the forthcoming financial year, 2022/23.

The following requirements are defined as ancillary services:

- Reserves
- Black-Start
- Unit Islanding
- Reactive Power Supply and Voltage Control
- Constrained Generation

2. METHODOLOGY

The methodologies on which the 2022/23 – 2026/27 ancillary services technical requirements are based are captured in the Ancillary services technical requirements methodologies document [1].

3. RESERVES

3.1 INTRODUCTION

The definitions of the five reserve categories included in ancillary services are given in the Glossary of Reserve Related Terms [2] document and the South African Grid Code [3]. The minimum requirement for each reserve category is revised annually. Each reserve category has its own requirement and is exclusive, that is capacity reserved for one category cannot be used for another category. National Control will dispatch reserves according to the scheduling and dispatch rules as far as possible while adhering to the relevant guideline [5].

3.2 INSTANTANEOUS RESERVE

3.2.1 Description

Instantaneous reserve is generating capacity or demand side managed load that must be fully available within 10 seconds to arrest a frequency excursion outside the frequency dead-band. This reserve response must be sustained for at least 10 minutes. It is needed to arrest the frequency at an acceptable level following a contingency, such as a generator trip, or a sudden surge in load. Generators contracted for instantaneous reserve are also expected to respond to high frequencies (above 50.15 Hz) as stipulated in the South African Grid Code.

3.2.2 Technical Requirements

The Instantaneous reserve requirement was determined through a dynamic simulation study by establishing the effect of governing on system frequency [6]. The study considered various scenarios, which included various levels of generation and demand side capacity. Renewables (RE) were included in the study. Their impact was assessed during off peak periods, i.e. when demand was at its lowest, representing a low inertia scenario. RE impact is noticeable during off peak but overall the impact on reserves was not significant. The study results are valid for

2022/23 due to significantly high RE integration from 2023 as per 2019 IRP[4]. More studies will be conducted to validate requirements from 2023. The minimum requirements, which are based on only **generators providing instantaneous reserves**, are shown in

Table 1.

Table 1: Instantaneous reserve requirements

Season	Period	2022/23 MW	2023/24 MW	2024/25 MW	2025/26 MW	2026/27 MW
Summer/ Winter	Peak	650	650	650	650	650
	Off peak	850	850	850	850	850

The study has indicated that less instantaneous reserve is required over peak periods, due to higher system inertia during peak compared to off peak. Instantaneous reserve can also be provided by loads i.e. demand response. The optimum split between generators and loads, based on the dynamic study conducted by SO [6], is as follows:

Peak periods		Off peak periods		Reserve provider
Generators MW	Demand Response MW	Generators MW	Demand Response MW	
650	0	850	0	Generators only
600	200	800	200	Generators and loads
550	400	750	400	Generators and loads
500	600	700	600	Generators and loads
450	800	650	800	Generators and loads
400	1000	600	1000	Generators and loads

3.3 REGULATING RESERVE

3.3.1 Description

Regulating reserve is generating capacity or demand side managed load that is available to respond within 10 seconds and is fully activated within 10 minutes. The purpose of this reserve is to make enough capacity available to maintain the frequency close to scheduled frequency and keep tie line flows between control areas within schedule.

3.3.2 Technical Requirements

The IPS needs sufficient regulating range up and down every hour of the day to keep the frequency and tie line flows within schedule while meeting the peak load within the peak hour. The optimum regulating up and down reserve requirement is based on catering for variability of load and renewables for 95% of the time and also compliance with SAPP CPS performance criterion requirements.

A) Variability study

The purpose of this study was to determine the minimum regulating reserve capacity to ensure that load and renewables variability do not compromise frequency control requirements. A production simulation study was undertaken to determine the optimum reserve capacity. Various demand and generation performance scenarios were considered i.e. Low demand low performance and moderate demand moderate performance. Figure 1 below depicts simulation results for 2022, 2025 and 2026.

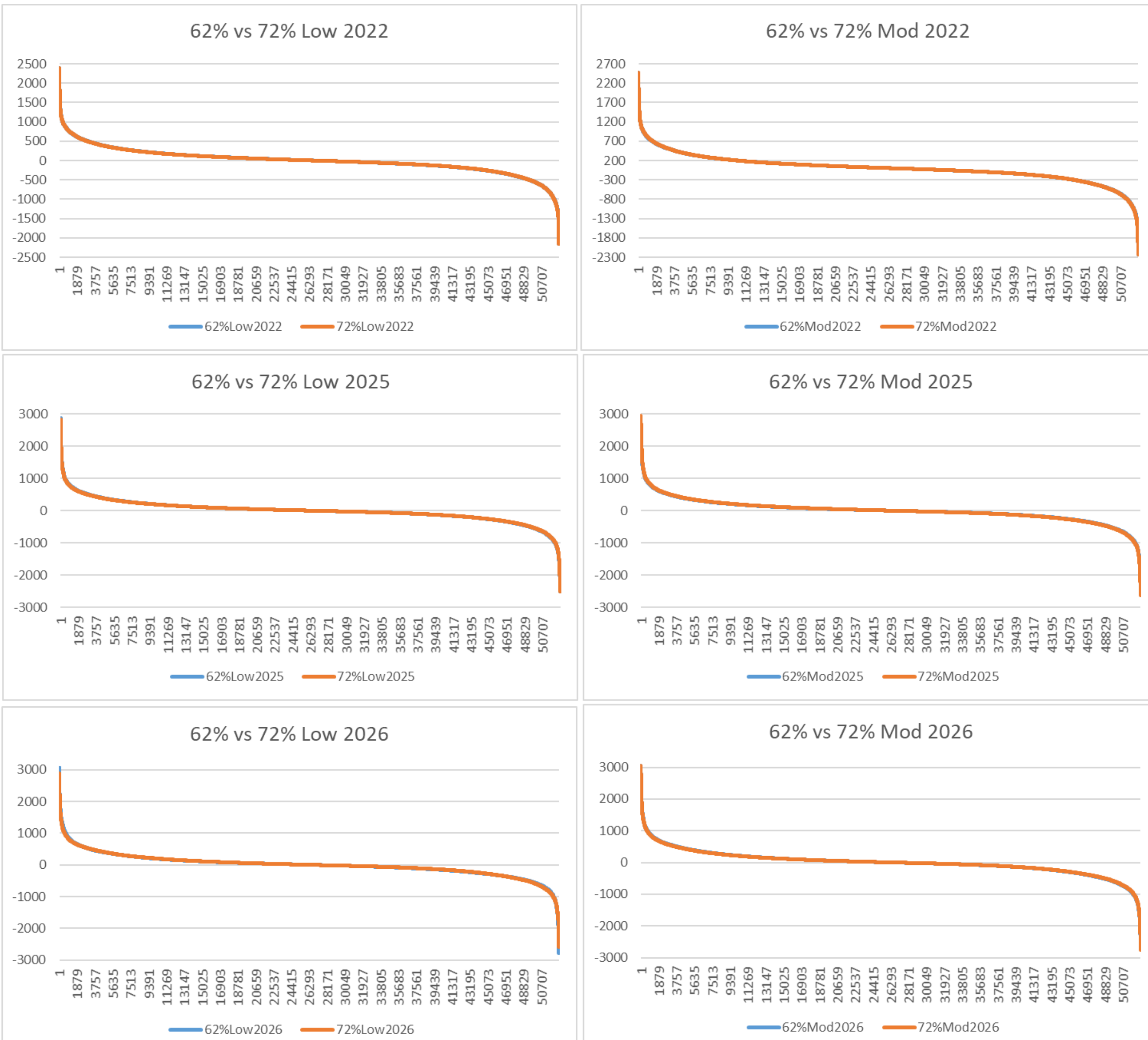


Figure 1: 2022, 2025 and 2026 variability study results

Using Figure 1 above, recommended regulating up/down reserve requirements are 530 MW in 2022 and 600 MW in 2026.

The minimum Regulating Reserve requirements, taking load variation and renewable energy unpredictability into consideration, are given in Table 2 below:

Table 2: Regulating up and down reserve requirements

Reserve	Period	2022/23 MW	2023/24 MW	2024/25 MW	2025/26 MW	2026/27 MW
Regulating up	Summer (Pk/off pk)	530	545	560	575	600
	Winter (Pk/off pk)	530	545	560	575	600
Regulating down	Summer (Pk/off pk)	530	545	560	575	600
	Winter (Pk/off pk)	530	545	560	575	600

Regulating reserve capacity (regulating up + regulating down) is determined by AGC high and low limits set at the generator such that the generator will regulate up and down.

3.4 TEN-MINUTE RESERVE

3.4.1 Description

Ten minute reserve is generating capacity or demand side managed load that can respond within 10 minutes when called upon. It may consist of offline quick start generating plant (e.g. hydro or pumped storage) or demand side load that can be dispatched within 10 minutes. The purpose of this reserve is to restore Instantaneous and Regulating reserve to the required levels after an incident. Ancillary Services requires Ten minute reserve resources which may be used for up to 600 hours per year (assuming a usage over 50 weeks, 4 days and 3 hours per day). In addition, if the cost of any potential Ten minute reserve resource is close to or higher than gas turbines, it must be used as an emergency reserve resource. Any new Ten minute reserve resource must have no onerous energy restrictions since this reserve may be required to be used every day.

3.4.2 Technical Requirements

A) Credible multiple contingency requirement

A credible multiple unit contingency trip is defined in the SA grid code as a typical loss of three coal fired units. To ensure reliability it was assumed that the total operating reserve should be sufficient to replace the loss of the three biggest coal fired units. Thus, from 2022/23 to 2026/27, the biggest three units have a capacity of 3 x 722 = 2166 MW. The Ten minute reserve requirement = Total Operating – Instantaneous – Regulating

B) SAPP Requirement

SAPP Operating Guidelines state that a minimum of 950 MW of total operating reserve is currently required from the Eskom control area.

The credible multiple contingency criterion yields a higher requirement for Ten minute reserves. The Ten minute reserve requirements are shown in Table 3 below:

Table 3: Ten-minute reserve requirements

Period	2022/23 MW	2023/24 MW	2024/25 MW	2025/26 MW	2026/27 MW
Peak (Summer/ Winter)	1020	1005	990	975	950
Off-Peak (Summer/ Winter)	820	805	790	775	750

3.5 EMERGENCY RESERVE

3.5.1 Description

Emergency reserves should be fully activated within 10 minutes. Emergency reserves are utilised in accordance with the guideline [5]. Emergency reserves include interruptible loads, generator emergency capacity (EL1), and gas turbine capacity. Emergency reserve capacity is required less often than Ten minute reserve. The reserve must also be under the direct control of National Control. These requirements arise from the need to take quick action when any abnormality arises on the system.

3.5.2 Technical requirements

The technical requirement is based on the total average of unplanned capacity losses from the entire generation fleet. The optimum emergency reserve requirement is based on catering for forced outages or generator trips for 95% of the time.

A) Contingency study

The purpose of this study was to determine the minimum emergency reserve capacity to ensure that the power system is returned to normal conditions following disturbances. A production simulation study was undertaken to determine the optimum reserve capacity. Various demand and generation performance scenarios were considered i.e. Low demand-low performance and moderate demand-moderate performance. Figure 2 below depicts simulation results for 2022, 2025 and 2026.

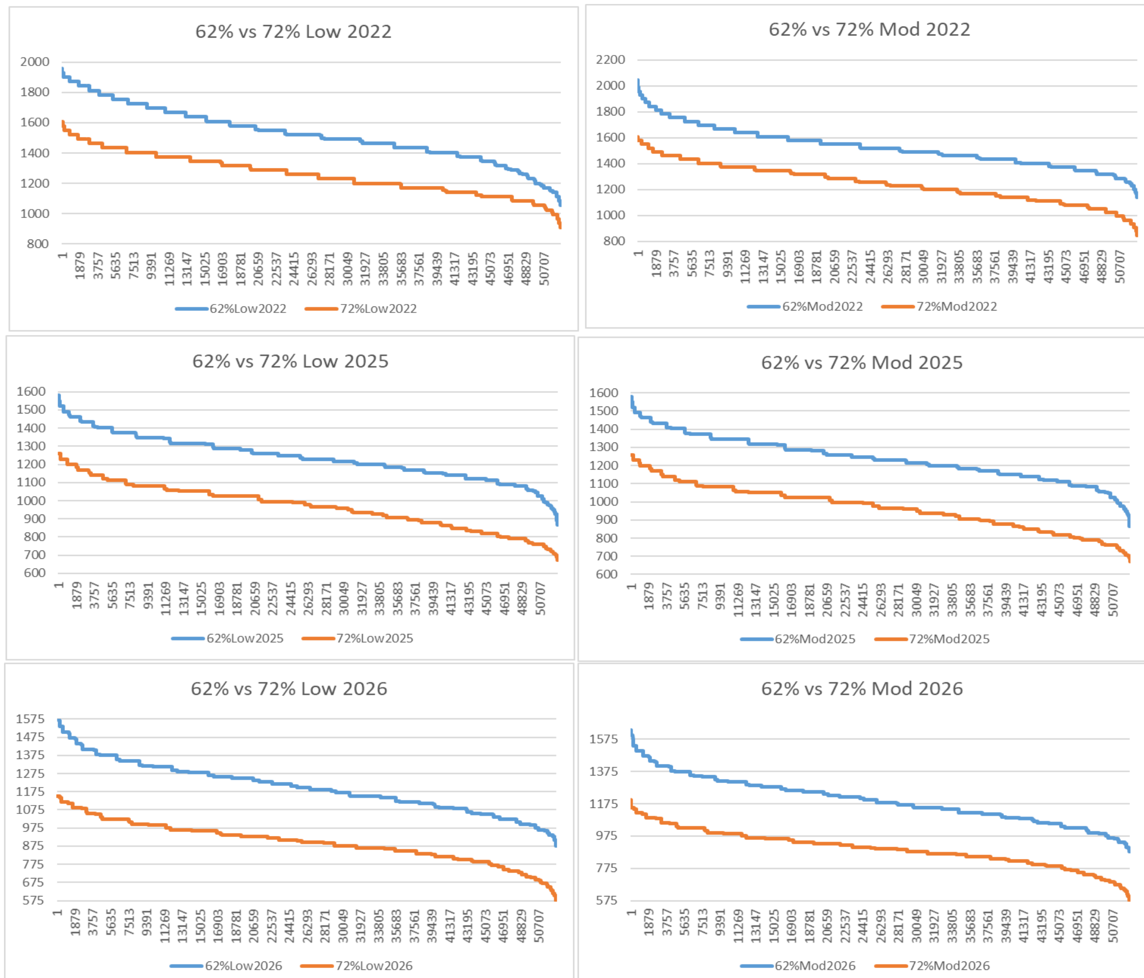


Figure 2: Figure 2: 2022, 2025 and 2026 contingency study results

Using Figure 2 above, recommended emergency reserve requirements are 1400 MW in 2022 and 1000 MW in 2026.

The emergency reserve requirements are given in Table 4 below:

Table 4: Emergency reserve requirements

Period	2022/23 MW	2023/24 MW	2024/25 MW	2025/26 MW	2026/27 MW
Winter Peak/ Off peak	1400	1300	1200	1100	1000
Summer Peak/ Off peak	1400	1300	1200	1100	1000

3.6 SUPPLEMENTAL RESERVE

3.6.1 Description

Supplemental reserve is generating or demand side load that can respond in 6 hours or less to restore operating reserves. This reserve must be available for at least 2 hours [2]. This capacity is used to ensure an acceptable day-ahead risk.

3.6.2 Technical requirements

The technical requirement is based on the average loss of coal fired power station capacity greater than 3000MW, which was calculated to be approximately 3800 MW. This capacity should be replaced by the sum of operating, emergency and supplemental reserve capacity. Thus, Supplemental capacity = Total PS capacity – Operating reserve - Emergency reserve. The supplemental reserve requirements are as follows:

Table 5: Supplemental reserve requirements

Period	2022/23 MW	2023/24 MW	2024/25 MW	2025/26 MW	2026/27 MW
Winter Peak/ Off peak	200	300	400	500	600
Summer Peak/ Off peak	200	300	400	500	600

RESERVE REQUIREMENTS SUMMARY

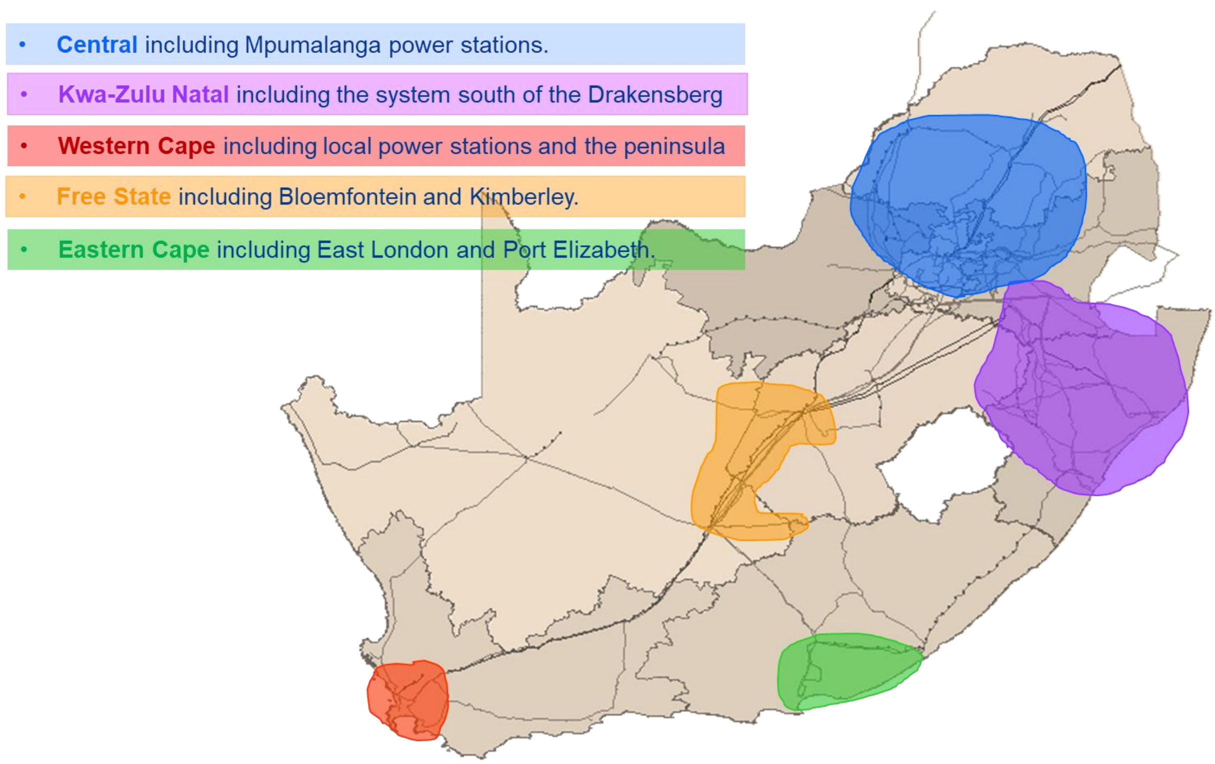
The overall reserve requirements may be summarised as follows:

Table 6: Summary of reserve requirements

Reserve	Season	Period	2022/23 MW	2023/24 MW	2024/25 MW	2025/26 MW	2026/27 MW
Instantaneous	Summer	Peak	650	650	650	650	650
		Off peak	850	850	850	850	850
	Winter	Peak	650	650	650	650	650
		Off peak	850	850	850	850	850
Regulating	Summer	Peak	530	545	560	575	600
		Off peak	530	545	560	575	600
	Winter	Peak	530	545	560	575	600
		Off peak	530	545	560	575	600
Ten-minute	Summer	Peak	1020	1005	990	975	950
		Off peak	820	805	790	775	750
	Winter	Peak	1020	1005	990	975	950
		Off peak	820	805	790	775	750
Operating	**Summer/ Winter**	**Peak/ Off peak**	**2200**	**2200**	**2200**	**2200**	**2200**
Emergency			**1400**	**1300**	**1200**	**1100**	**1000**
Supplemental			**200**	**300**	**400**	**500**	**600**
Total			**3800**	**3800**	**3800**	**3800**	**3800**

4. SYSTEM RESTORATION SERVICES

System restoration services are those services that are required in the unlikely event of a failure of the multiple system defence barriers protecting the IPS from a blackout condition. These services (i.e. unit islanding and black-start) form part of the national system restoration plan, which is a highly confidential document that details the sequence and steps required to restore the IPS for predefined blackout scenarios under the current network topology. As such, location is a key overarching requirement for both services. Consider the following geographical representation of generation resources:



For the current time horizon, a potential service provider would need to be able to provide their capability in the proximity of one of the highlighted areas to be considered as a restoration option. Outside of these areas, the reactive power generated by energising long, lightly-loaded transmission lines connected to major load centres and other generators will likely make voltage control extremely unstable, thus only facilities that are located in these regions will be considered. A generic version of this restoration strategy is available [9] which captures the high-level response required from black-start and unit islanding facilities in a restoration context. For both services, there is a requirement to provide their capability in the absence of an established grid, as would be the case under blackout conditions.

For unit islanding, this capability is defined in terms of a generating unit being able to disconnect from the transmission network and to control all necessary parameters such that the generator remains at speed and excited while supplying its auxiliary load – in a blackout scenario, they would need to maintain the islanded state for at least two hours and act as a start-up supply for other capacity to be synchronised as part of a process of restoring the power system .

For black-start, the capability is defined as the ability to self-start (i.e. start-up without external support), energise the surrounding transmission and distribution networks, supply load, and act as a start-up supply for other capacity to be synchronised as part of a process of restoring the power system.

The full testing requirements and process for system restoration service providers are detailed in [10]. However, the aim of this section is present the high-level requirements that a potential service provider would need to consider before approaching the System Operator for future certification.

4.1 BLACK-START REQUIREMENTS

First and foremost, all black-start service providers must meet the requirements specified in the Grid Code [3] [10]. However, potential service providers should be aware of the following selection of requirements from [11] that are necessary for consideration as a black-start facility:

1. Renewables and battery energy storage will not be considered for black-start until such time that the grid-forming inverter technology reaches maturity in a restoration context

2. As full system restoration can potentially last multiple weeks, a peaking facility will only be considered for black-start if it has the capability to provide start-up power for a base-load generator that can then provide power continuously throughout the restoration
3. Each contracted black-start facility must be operationally available to black-start for at least 90% of the year
4. Contracted black-start facilities must be positioned at different geographical locations to facilitate the safest possible restoration following a blackout
5. Base-load black-start facilities must be capable of starting at least one on-site base-load generator within 4 hours, following a system blackout
6. Peaking black-start facilities must be capable of starting a minimum of two or more on-site peaking generators (one unit in Generating mode, others in SCO mode) within 2 hours, following a system blackout. These facilities must then be capable of energising a defined portion of the transmission/distribution system, and enabling the start-up of a black-start support station from blackout conditions within 4 hours
7. Base-load black-start facilities and black-start support stations shall be capable of picking up instantaneous load blocks of up to 50 MW and/or ramping within their defined range
8. Peaking black-start facilities shall be capable of picking up instantaneous load blocks of up to 15 MW and/or ramping up within their defined range
9. All black-start facilities must be capable of controlling the frequency within the continuous operating range (49.0 – 51.0Hz), and maintaining voltage within acceptable limits (± 5% of nominal) during the grid reconnection and load pick-up process
10. Self-start equipment at all black-start facilities must be capable of supplying the inrush current of any transformers or motors required to be energised as part of the system restoration
11. The barring, lubrication, jacking and hydrogen seal oil facilities on the generating units must be independent from the main supply during a system blackout condition and these facilities must be able to operate for an extended period (i.e. at least two hours) after

loss of the external supply to ensure the safe run-down of the turbo-generators from nominal to barring speed

12. After black-starting, the facility must be capable of remaining synchronised and available long enough for subsequent base-load units to be started up and synchronised as part of the larger system restoration
13. Black-start facilities must be capable of attempting at least three consecutive start-ups. This implies that the facility must always maintain adequate emergency fuel/power for self-start equipment to enable three consecutive start-ups to provide start-up power for other generators
14. Adequate spares (agreed between SO and the black-start facility) must be maintained at all facilities to ensure that required maintenance or refurbishment can be completed as soon as possible such that black-start capability is not compromised
15. For base-load black-start facilities and black-start support stations, sufficient material supply (e.g. coal, diesel, fuel oil, propane gas, demineralised and potable water, hydrogen, etc.) must be maintained by the facility for the entire restoration process (i.e. three consecutive start-ups of a single unit, loading and grid restoration)

4.2 UNIT ISLANDING REQUIREMENTS

As with black-start, all unit islanding service providers must meet the requirements specified in the Grid Code [3] [10]. However, as unit islanding capability cannot be provided by all technologies, it is important to define the selection criteria [12] that will be applied in considering potential unit islanding service providers:

1. All unit islanding facilities must have a fully commissioned and operational AVR
2. Apart from monitoring equipment, no special modifications to the plant must be made for the purpose of islanding i.e. must be part of the normal capability of the facility

3. Peaking plant will not be considered for unit islanding certification – these stations should have self-start capability. If self-start capability is permanently unavailable, a proposal for islanding certification can be made based on location, rating and load factor
4. Renewable energy sources will not be considered for unit islanding certification – this will be re-evaluated when grid-forming inverters reach sufficient maturity such that inverter-based resources do not need an established grid to connect to
5. Battery energy storage will not be considered for unit islanding certification
6. Only 100 MVA generators and larger will be considered for islanding certification
7. Only remote generators with insufficient local load will be automatically disregarded for unit islanding certification based on location i.e. all adequately-sized generators of the appropriate technology will be considered
8. The System Operator shall define all minimum criteria (not limited to the above) that is deemed necessary to select a generator/facility as a potential service provider

5. REACTIVE POWER AND VOLTAGE CONTROL

Reactive power supply and voltage control form part of the ancillary services required by the System Operator to efficiently perform its main function of supplying electrical power.

5.1 TECHNICAL REQUIREMENTS

The technical requirements for reactive power and voltage control include requirements from the Grid Code, Renewables Grid Code and System Operator.

A) Grid Code Requirements for Conventional Generation

1. As required by the Grid Code, Network Code, all units greater than 100 MW shall be capable of supplying rated power output (MW) at any point between the limits of 0.85 power factor lagging and 0.95 power factor leading at the HV side of the generator transformer.
2. Reactive power output shall be fully variable between these limits under AVR, manual or other controls.
3. SO shall control power station export/import of reactive power through TEMSE or telephone.
4. When a unit is in pumping or generating, reactive power supply is mandatory in full operating range
5. Voltages shall not deviate by more than ±5% from declared voltages under normal operating conditions.
6. Gas Turbine units built after the implementation of the Grid Code shall be capable of operating in SCO.
7. Generators shall conduct prototype and routine tests to demonstrate reactive capability.

All units built after the implementation of the South African Grid Code shall be equipped with power system stabilisers as defined in IEC 60034, IEEE42. Reactive output shall be fully variable so as to achieve acceptable levels of voltage (± 5%) under automatic or manual control.

B) Grid Code Requirements for Renewables Power Plants (RPP)

1. During start-up / energising, the Renewables Power Plants (RPP) may only consume or export not more that 5% of rated reactive power from the transmission system.

2. Different power factor categories (A – C) depending on the output power are specified in the RPP Code.
3. The RPP shall be equipped with reactive power control functions capable of controlling the reactive power supplied by the IPP at the point of connection (POC) as well as a voltage control function capable of controlling the voltage at the POC via orders using set points.

4. The RPP shall ensure that they can function/operate under any of the three different modes mentioned below. Furthermore, 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:
    a. Q-control
    b. Power Factor–control
    c. Voltage-control

5. The applied parameter settings for reactive power and voltage control functions shall be determined before commissioning by the Network Service Provider (NSP) in collaboration with the SO.

C) System Operator (SO) Requirements

1. SO shall use peaking stations (pump storage and OCGTs) in SCO for voltage control.
2. All installed thermal and peaking stations will be used for voltage control at the discretion of the SO.
3. All generators shall have automatic voltage regulators (AVR)/converters in an automatic voltage control mode.
4. All generators shall inform/update SO of any restriction that might affect the reactive power support.

5. All generators capable of voltage control shall be required to do reactive capability tests as stipulated in Eskom Work Instruction 240-88425452, “Generating unit reactive power and voltage control certification procedure”.

6. CONSTRAINED GENERATION

6.1 INTRODUCTION

The Grid Code [3] requires that the System Operator manage real-time system constraints within safe operating limits, using constrained generation as one of the ancillary services as required. In particular, it requires multiple outages of a credible nature to be studied to ensure that the operation of the system protects against cascading outages for such an event, wherever practical. To support the MYPD, this requires the System Operator to identify national system constraints over a 5 year horizon, define relevant system problems by establishing those constraints affecting the capacity to meet demand, and draw conclusions on the need for this service. An input in establishing the need for this service includes determining the constraints with duration beyond a few hours that have a significant impact and high probability. This requirement excludes the long duration planned transmission maintenance outages that are coincident with full generation at Matimba from the list of national constraints requiring constrained generation where they can be avoided, for example, as such planned outages can be coordinated with Matimba generation outages where possible.

6.2 NATIONAL SYSTEM CONSTRAINTS

The SA Grid Code System Ops Code, section 4.3 specifies that any power stations run out of schedule to respect operational limits be compensated for the resulting financial loss so suffered as a consequence of the lack of IPS capacity and related market rules, as part of constrained generation. The power station must be financially compensated for the opportunity cost, loss of profit or additional cost not recovered from the tariff for this operation.

6.2.1 Cape Constraint

Consistent with the System Operator's obligations outlined in the Grid Code to operate the IPS and security monitoring on a system-wide basis to ensure safe, reliable and economic operation of the IPS, the risk to meeting local demand while refuelling Koeberg Nuclear Power Station (KNPS) was assessed. Given the increasing renewable generation in the region outlined in IRP2019, a production simulation study using the latest production plan for KNPS refuelling during winter was used to establish the associated cost for peaking generation of such a proposition. From this, the following OCGT constrained generation requirements were determined:

Table 7: Summary of OCGT energy requirements for refuelling of KNPS

Financial year	Study category	Max units required	OCGT energy needed (GWh)
2022/23	Planned operation (N-0)	0	0
	Non-refuel (N-1)	0	0
	Refuel (N-1-1)	0	0
2023/24	Planned operation (N-0)	0	0
	Non-refuel (N-1)	0	0
	Refuel (N-1-1)	0	0
2024/25	Planned operation (N-0)	0	0
	Non-refuel (N-1)	0	0
	Refuel (N-1-1)	0	0
2025/26	Planned operation (N-0)	0	0
	Non-refuel (N-1)	0	0
	Refuel (N-1-1)	0	0
2026/27	Planned operation (N-0)	0	0
	Non-refuel (N-1)	0	0
	Refuel (N-1-1)	0	0

Based on these results, the System Operator chooses to continue to not impose any restriction on when KNPS may be refuelled.

Regarding the operation of Palmiet Pumped Storage Scheme, the System Operator maintains the minimum top dam level at 5 unit generating hours (UGH). The restriction on Palmiet not to be on planned maintenance during refuelling outages at KNPS remains.

7. ACCEPTANCE

This document has been seen and accepted by:

Name	Designation
Bonginkosi Sibeko	National Operations, Chief Engineer
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8. REVISIONS

Date	Rev.	Compiler	Remarks
November 2020	1.0	VG Smith	New document

9. DEVELOPMENT TEAM

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

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- Marathon Ntusi
- Musa Gumede
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10. SUPPORTING CLAUSES

10.1 Scope

This document specifies the technical requirements for ancillary services for financial years 2022/23 to 2026/27.

The purpose of the document is to make the System Operator's requirements known to ensure a reliable network and provide optimal usage of ancillary services for the next five financial years.

All suppliers of ancillary services need to meet all aspects of the South African Grid Code relating to these services.

10.2 Abbreviations and Definitions

CPS: Control Performance Standard

GX: Generation division

IRP: Integrated Resource Plan (for Electricity)

IPS: Interconnected Power System

KNPS: Koeberg Nuclear Power Station

OCGT: Open cycle gas turbine

OP: Operating Procedure

OS: Operating Standard

Peak and Off-peak: Peak periods are considered only during weekdays. There are two peak periods in the daily system load profile, morning peak and evening peak, occurring at different times of the day during winter and summer months. Public holidays are treated the same as weekends with no peak periods. In winter, identified as May to August, the morning peak occurs from 06:00 to 09:00 and the evening peak occurs from 17:00 to 20:00. In summer, covering the remainder of the year outside winter, the morning peak occurs from 09:00 to 12:00 and the evening peak from 18:00 to 21:00. Thus the peak periods occur for six hours of the day every weekday.

Residual load: That portion of the load not met by renewable generation

RE: Renewable energy (generation)

SAPP: Southern African Power Pool

SO: System Operator

SOG: System Operator Guideline

UGH: Unit generating hours

10.3 Roles and Responsibilities

The provision of these requirements is monitored regularly via the monthly performance reports.

10.4 REFERENCES

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