CONTROLLED DISCLOSURE

GENERATION CONNECTION CAPACITY ASSESSMENT OF THE 2016 TRANSMISSION NETWORK (GCCA-2016)

REVISION 2

June 2014

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EXECUTIVE SUMMARY

The Intergraded Resource Plan (IRP 2010-2030) has allocated 17 800 MW of solar and wind generation projects in line with the Governmentõs commitment to reducing emissions. One of the challenges for the integration of renewable energy (RE) generation has always been the cost of integration and the time-lines for creating grid capacity to accommodate RE generation, therefore the location of the RE plants in relation to the grid is very important. However, the proximity of the plant on its own is not sufficient if the grid does not have the capacity to connect the RE generated. This study was commissioned to determine the gridõs capacity to connect all types of generation plant at high-voltage (HV) bus bars of the Main Transmission System (MTS) substations in 2016. Although most RE connections will be at Distribution level, the lack of capacity in the Transmission network may delay the connection of new generation.

MTS substations supply specific geographic areas, and this fact was taken into account when considering the connection capacity, based on the assumption that RE plant in a supply area will probably be connected to the MTS substation supplying that area. The MTSs are divided into 27 supply areas located in all nine provinces.

Reasons for GCCA 2016 Revision 2

The initial generation connection capacity assessment (GCCA 2016 Rev1) that was done in 2013 had to be revised for the following reasons:

- The assumed network used for 2016 was changed due to capital constraints in line with the lower than expected tariff determination by NERSA. This resulted in a number of projects being deferred and thus some of the results in the GCCA 2016 rev1 report are no longer valid.
- The naming convention for voltages levels at MTS substations was changed to align with common industry practice. HV (400,275, 220 kV) was replaced with EHV, and LV (Ò 132 kV) was replaced HV; this aligns with industry understanding of the voltage.

- The study used the transformer N-1 capacity as a limitation of the maximum new generation that can be connected at HV assuming a connected load at low-load conditions of 30% of peak load. This is valid for any generation that might be generating at night. However in the case of PV plant that will be generating during daylight the connected load will be higher, thus increasing the capacity that can be connected. Thus more PV plant (day low-load at 70% of peak) can be connected than wind plant (night low-load at 30% of peak) at an individual substation.
- The previous document indicated that Eskom could provide a free (non-binding) cost estimate letter, but this is no longer the case as all Cost Estimate Letters can be only be produced upon payment of a Cost Estimate fee.
- A section providing the description of the titles used in the GCCA tables was added.
- Future transmission substations which do not have transformation in 2016 (e.g. Kronos), were excluded from the original GCCA simulations but these were included to provide an indication of the capacity at EHV level in a supply area.

This updated GCCA 2016 will provide an indication of the available capacity only up to 2016, and future GCCA documents will be drafted which will provide capacity beyond 2016.

LIST OF ABBREVIATIONS

CSP	Concentrating Solar Power
DoE	Department of Energy (Government of South Africa)
GCCA	Grid Connection Capacity Assessment
EHV bus bar	Extra High Voltage bus bar (> 132 kV at Transmission level)
IPP	Independent Power Producer
HV bus bar	High Voltage bus bar (<=132 kV at Transmission level)
MTS	Main Transmission System
MEC	Maximum exporting capacity
NERSA	National Energy Regulator of South Africa
NTC	National Transmission Company
PV	Photovoltaic
POC	Point of Connection
RE	Renewable energy
TNSP	Transmission Network Service Provider

CONTENTS

1 INTRODUCTION

1.1 Context of the Generation Connection Capacity

Eskom Holdings is the biggest producer of electricity in South Africa; it is also the sole transmitter of electricity via a transmission network which supplies electricity at high voltages to a number of key customers and distributors. Eskom is a vertically integrated company licensed to generate, transmit and distribute electricity. The transmission licence is held by Eskom Transmission, the transmission network service provider (TNSP). Planning the transmission network is the responsibility of the Grid Planning Department in the Transmission Division.

The intention of this document is to provide an indication of the available capacity for the connection of new generation at the Main Transmission System (MTS) substations on the Eskom transmission network that will be in service by 2016. The capacity specifies the substation limit as well as the transmission backbone limit for simultaneous generation connection at an HV bus bar of a MTS substation in a specific area. The grid is divided into 27 load supply areas, and these supply areas are used as generation connection areas to assess how much generation can be connected in each area. The capacities specified are for both steady-state and transient power system conditions. The transient stability limit represents the technically feasible integration limit, especially with regard to area limits. The provided values are not intended to be fixed specific connection capacities as each connection is unique, but rather to be used as a guideline to indicate the potential for connecting to a specific point or area in the transmission network, and also to identify the network strengthening required to unlock the network capacity to integrate more IPPs in areas which have high generation resources available.

The steady-state results provide the available capacity at MTS substations and also at an area level. All areas in the Cape have been combined to test the capacity of the Cape corridor. In the transient study, the focus of the results is on area limits, and the corridors supplying a number of areas are also tested by combining a number of areas into one large area. The results of this study can be used to assess the capacity (MW) that can be connected at each MTS substation for N-1 Grid Code reliability level, and also the total capacity that an area or a group of areas can handle without violating the limits of network stability.

1.2 Structure of the document

The document is structured as follows:

Chapter 2 provides the background to the study and the scope of the study

Chapter 3 gives the definition of the generation connection capacity and typical layouts of how new plant can be connected to the MTS substation.

Chapter 4 gives the supply areas on a provincial basis

Chapter 5 outlines the methodology employed in the study and how the results should be interpreted.

Chapter 6 provides the generation connection capacity at MTS substations per supply area, giving both the supply area steady-state (N-1) and the stability limit.

Chapter 7 explains a process which could be followed to obtain high-level cost estimations for generation integration.

1.3 Revision History

Date	Revision	Remarks
May 2013	First issue	New document
October 2013	Revision 1	Minor changes; substation names etc
June 2014	Revision 2	Major changes ï connection capacities and evaluation criteria. The list of abbreviations was also updated. Reasons for revision 2 changes are listed below.

Reasons for GCCA 2016 Revision 2

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- The assumed network used for 2016 was changed due to capital constraints in line with the lower than expected tariff determination by NERSA. This resulted in a number of projects being deferred and thus some of the results in the GCCA 2016 rev1 report are no longer valid.
- The naming convention for voltages levels at MTS substations was changed to align with common industry practice. HV (400,275, 220 kV) was replaced with EHV, and LV (Ò132 kV) was replaced HV; this aligns with industry understanding of the voltage.
- The study used the transformer N-1 capacity as a limitation of the maximum new generation that can be connected at HV assuming a connected load at low load conditions of 30% of peak load. This is valid for any generation that might be generating at night. However in the case of PV plant that will be generating during daylight the connected load will be higher, thus increasing the capacity that can be connected. Thus more PV plant (day low-load at 70% of peak) can be connected than wind plant (night low-load at 30% of peak) at an individual substation.
- The previous document indicated that Eskom could provide a free (non-binding) cost estimate letter, but this is no longer the case as all Cost Estimate Letters can be only be produced upon payment of a Cost Estimate fee.
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This updated GCCA 2016 will provide an indication of the available capacity only up to 2016, and future GCCA documents will be drafted which will provide capacity beyond 2016.

2 BACKGROUND

Eskom released the document on Generation Connection Capacity Assessment for the 2012 Transmission Grid (GCCA-2012) early in 2011 in response to the Governmentôs REBID programme and the large number of renewable generation applications and enquiries received by Eskom. This document only covered the Cape provinces because of time constraints and the prioritisation of the locations where enquiries were made.

The GCCA-2012 focused on the connection at the Lower Voltage (LV) bus bars of the Main Transmission System (MTS) substations and took into account the limitation of the transformers, as the emphasis was on connecting to the existing transmission infrastructure.

This version of the CGGA document not only considers the Transmission Grid that is expected to be in place by 2016 but now also includes the entire country. The focus is not on the generation that can be connected to the High Voltage (HV) bus bar at the MTS substation without the limitations of the transformers but on what can be first absorbed for supplying the local MTS supply area and what in addition can be transported into the Transmission Grid to supply more distant loads. The requirement is that the Transmission grid should still meet the single condition (N-1) criteria of the Grid Code.

The Transmission Grid is divided into 27 Transmission supply areas which contain a number of MTS substations to supply the demand in the area. These supply areas are grouped into the nine provinces of the country. The supply areas have been analysed to determine the generation connection capacities of the MTS substations within each supply area. An overview of each province and the provincesô supply areas is given in Section 5. An alphabetical list of MTS substations and their connection capacities per supply area is provided in Chapter 6.

3 DEFINITION OF TRANSMISSION CONNECTION CAPACITY

A ñTransmission Connectionò is defined for the purposes of this document as the direct or indirect connection to an MTS substation at either the HV or the EHV bus bar.

A direct connection at the EHV bus bar would require the construction of a Transmission voltage level line (400 kV, 275 kV or 220 kV) from the generation plant directly to the MTS substation. The connection to the MTS substationôs HV bus bar can be made in number of ways, namely:

- Direct connection from the generation plant substation to the MTS substation via a dedicated transmission line.
- Looping in an existing distribution line which is connected to the MTS substation into the generation plant substation.
- Direct connection from the generation plantôs substation to a Distribution substation which is supplied by the MTS substation.

The three LV bus bar connection options are shown diagrammatically in Figure 3.

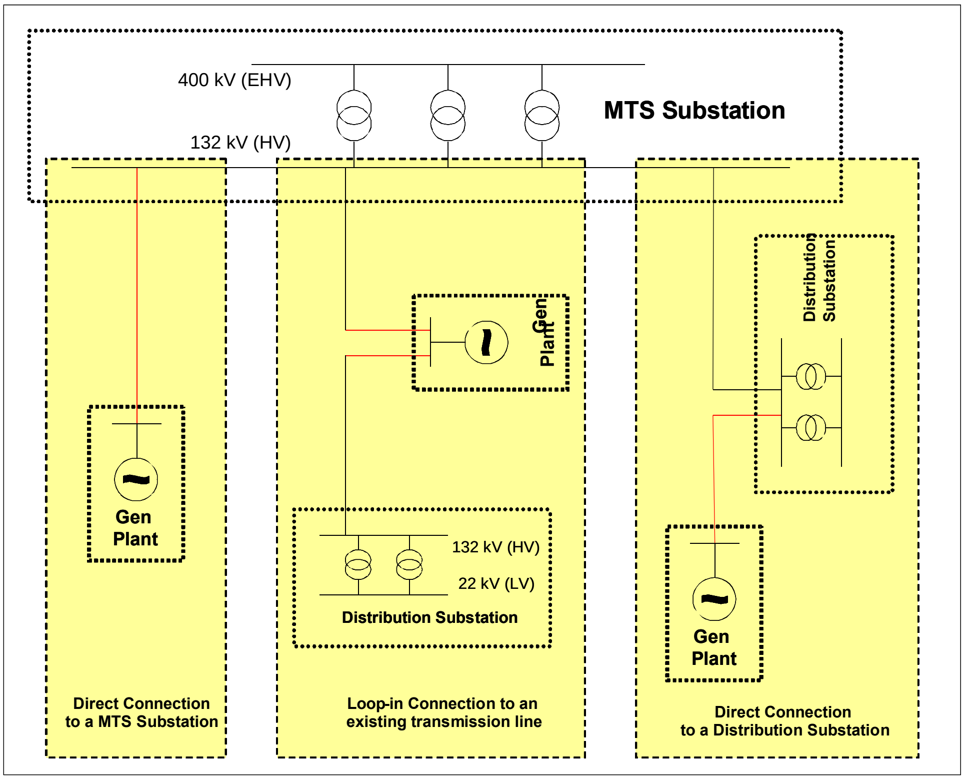

Figure 3 *Generation plant connection to the HV bus bar options*

4 SUPPLY AREAS BY PROVINCE

The Grid is divided into 27 supply areas that are used for conducting the load forecast, and these areas have a certain number of MTS substations supplied by them. The supply areas do cross the provincial boundaries in some cases because these areas are related to the networks from which they are supplied.

Figure 4 displays the grid layout with all supply areas.

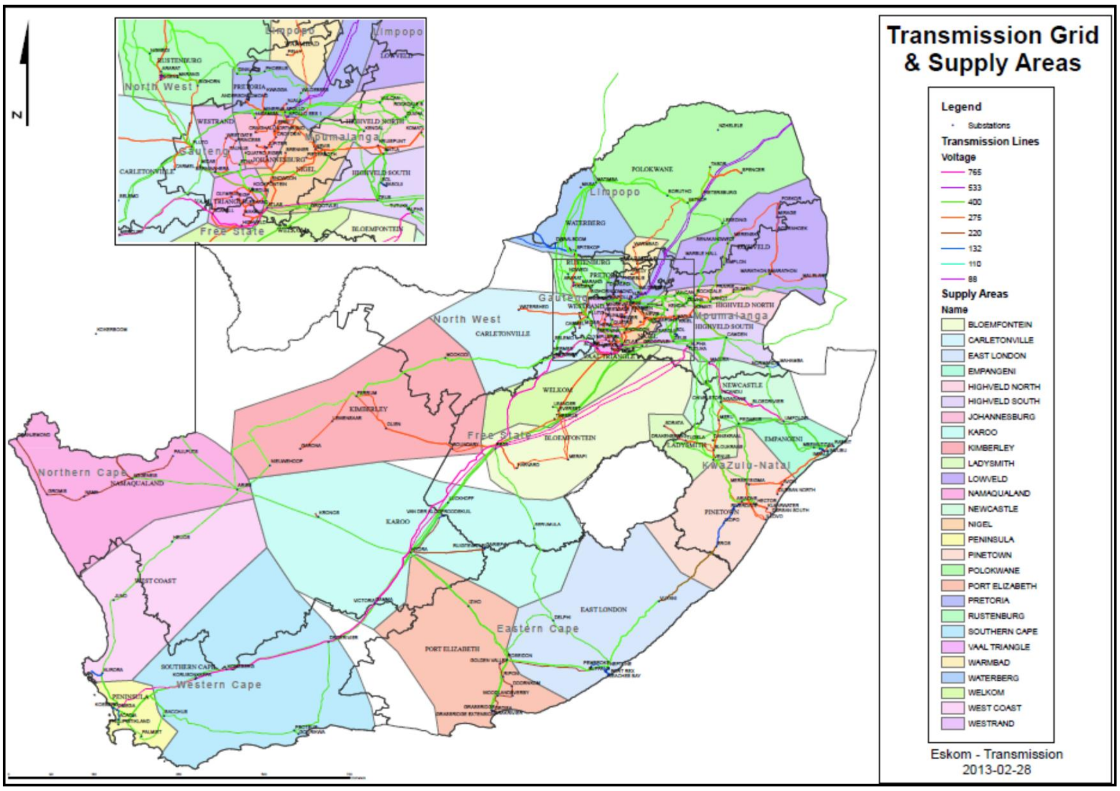

Figure 4 *Main Transmission System with supply areas*

The provincial maps give two figures for each supply area, which represent the steady-state (N-1) limit in MW and the stability limit in MW for that particular supply area.

5 METHODOLOGY AND INTERPRETATION

This chapter explains how the generation connection capacities were calculated for the MTS substations and how this value can be interpreted.

5.1 Methodology of determining the connection capacity

Connection capacity is determined by the available Transmission infrastructure in service to which a proposed generation project can connect and then transport the generated power to the loads. The document considers the connection capacity that will be available on the Transmission grid for the year 2016, taking into account the Transmission infrastructure that is expected to be in service in 2016, based on the approved Transmission Development Plan for the period 2013 to 2022.

The Distribution infrastructure is not considered in this document because of the sheer volume of infrastructure and the rapid changes that can be implemented at the lower voltages. All generation integration requirements will have to be considered at a local level and the direct connections can in general be implemented relatively quickly. The real issue that this document addresses is how much generation can be integrated and transported to the point where it is required at the Transmission level.

The Transmission Connection Capacity provides the overall capacity that can be absorbed at a specific MTS connection point without requiring any reinforcement, either directly connected to the MTS substation or via the distribution network supplied by the MTS substation. In other words, it is the indicative capacity for connecting new generation within the geographical supply area of that particular MTS substation.

Certain assumptions were made regarding the potential allocation of the downstream load in order to determine the connection capacity at the MTS substations:

- Essentially, the new generation will first supply the local load (low-load) within the supply area of the MTS substation and send the excess into the Transmission network via the MTS substation transformers and connecting Transmission lines.
- The low load assumption will be 30% and 70% of the peak load, for Wind and PV plants respectively.

The MTS substation is connected within a Transmission load supply area system, however, and in total there are 27 such areas, and the limit of the supply area dictates the potential limit at the individual MTS substation. The limit at each MTS substation within a supply area provides an indication of the proportional allocation of the supply area limit to the substations. The studies are then rerun, increasing the generation of the supply area with each substation at their relative proportional contribution until the area's N-1 limit is reached. This is then the generation connection capacity value for each MTS substation in the supply area.

The capacities are determined for both steady-state and transient power system conditions. Area limits, steady-state or transient stability, provide the total MW that can be evacuated from an area at EHV without a need to strengthen the network.

It must be noted that the GCCA values are based on N-1 compliance at EHV, but the Grid Code does not require N-1 compliance at POC for generation below 1000 MW. The fact that the GCCA is based on N-1 compliance (at EHV) will limit the available capacity of radial networks. But since Grid Code compliance only required N-0 up to the POC the possible connection capacity can result in a higher value that the GCCA value at substation level. The GCCA is thus a good guide to indicate areas where there are evacuation challenges, but then it should not be used to stop generation connection.

5.2 Interpretation of the connection capacity value

Based on the connection capacity of a specific MTS substation, a developer is able to make a high level assessment of what is likely to be required to connect his/her generation project to this point on the Eskom Transmission network.

This would be done by first identifying in which MTS substation supply area the generation project will be located and relating it to the approximate distance to that MTS substation or the nearest Distribution substation within that supply area. The map indicating the supply areas is in Chapter 5.

Using the proposed total MW output of the generation plant, the connection requirements and timing assessment can be done as follows:

Project MW output less than MTS connection capacity

The generation project should be able to connect to the Transmission network without requiring any additional deep transformation reinforcement. Only shallow connection works should be required, either via the distribution network or by connecting directly to the HV or LV bus bar of the MTS substation.

Project MW output is around MTS connection capacity

If the MW output of the generation project is of the same order as the MTS substation's connection capacity, around a ± 10% variation, then it may be possible to connect the project without requiring any additional deep reinforcement and only shallow connection works will be required.

Project MW output greater than MTS connection capacity

The generation project will not be able to connect without requiring some form of additional deep Transmission reinforcement (e.g. Transmission line, transformer) in addition to the shallow connection works. The deep reinforcement is likely to place a time constraint on connecting the generation plant project, depending on the nature and size of the transmission reinforcement works required.

5.3 Description of supply areas tables

The tables provide the substationsôtransformation and voltage levels, the 2016 installed transformer capacity, the N-1 transformer MVA level and the simulated EHV bus bar generation limit in MW. The tables for supply areas have eleven categories, and they are all explained in the Table 1 below. Here is what each category represents:

Table 1 *Explanation of GCCA tables*

Category	Description
Supply Area	This is the area supplied by the transmission substations
Substation	Substation name and transformation voltage levels
No. Trfr	Number of transformers
Single Trfr MVA	Size of transformer
Total Trfr MVA	Total sum of transformation at the substation
Firm N-1 MVA	Transformation capacity with the loss of one transformer
Gen MEC MW Allocated	This is the generation Maximum Exporting Capacity (MEC) in MW allocated and committed to be connected at the specific substation
Gen Available HV - undiversified (MW) in 2016	This is the generation connection capacity available at a substation, taking into account load[(2)] and the allocated MEC. This figure is per substation on an individual basis. This is the value that is of interest to the IPP who want to connect at the substation. A negative value indicates that substation level capacity has been exceeded, however, a detailed network study will provide the true limit. Therefore a negative (or low) value will need to be subject to a more detailed study before more generation can be connected at the substation.
EHV Capacity-diversified (MW)	The maximum that each substation can evacuate when generators are connected simultaneously at all substation in an area. This is the indicative value at the substation of the diversified component of the Supply Area steady state limit.
Supply Area steady-state limit (MW)	This is the maximum MW that can be connected in the whole area if all substations in that area have generation connected. This is the sum of all ñEHV capacity-diversified (MW)ò values in the area, and they are limited by thermal and voltage constraints.
Supply Area transient stability limit (MW)	This is the maximum MW that can be connected in the whole area before the network becomes transiently unstable (angular stability)
Year in service	This indicates the year in service of the new transformation for the substation. The year and quarter (Q) in which commissioning will take place in given. The new capacities for the year in service is given in brackets ()[(2)].

Note:

1. *In the tables the figure provided is the one with the load assumed when calculating the capacity values (Gen available HV) to be the night low-load at 30% of the peak load.*
2. *Numbers inside brackets () indicate future or new capacity that will be added at the substation in relevant year; the number outside the brackets is the existing installed capacity.*

5.4 Calculation of the generation connection capacity

Then the available generation connection capacity of each substation is given in MW, referred to as the *“Gen Limit HV - undiversified (MW) in 2016” in* the table, taking into account the transformation capacity, low-load and the committed generation.

*“Gen Available HV-undiversified (MW) in 2016” = [“Trfr N” or (“Trfr N-1 limit” + “Low load”) – [*Gen MEC MW Allocated*]*

However, if a substation has transformation (firm N-1) capacity that exceeds 1000 MVA, the available capacity will be limited to 1000 MW.

It is important to note that in a supply area, if the sum total of *“Gen Available HV-undiversified (MW) in 2016”* exceeds that supply areasô stead-state or transient stability limit, then there could be a problem with EHV evacuation in that area if these limits are exceeded.

In some substations, transformers will have to be introduced to either increase the capacity or to introduce an HV voltage (e.g.132 kV) for IPP integration. The total steady-state (N-1) limit and the system transient stability limit for a supply area indicate the following:

- If the *total area steady-state (N-1) limit > stability limit* then the supply area network has stability constraints and therefore the areaôs stability studies will be critical before a large amount of generation is connected in the entire area.
- If *the total area steady-state (N-1) limit < stability limit* then the supply area has thermal or voltage limits which have to be resolved in order to connect more generation and the area does not have stability constraints.

The supply area tables are listed alphabetically. Please note than in the case of 765/400-kV substations, the HV bus bar generation limit refers to the 400-kV bus bar

Here is an example of how to use the table for the Bloemfontein area;

- At Harvard (HV 132 kV), the ñGen Availableò shows that 619 MW can be connected. The 546 MW ñEHV capacity-diversifiedò is applicable if all other substations have their maximum possible generation connected simultaneously. If the other substation do not have any generation connected, the EHV (546 MW) capacity can be much higher. But generally, if the ñEHV capacity-diversifiedò is much lower that the ñGen Availableò, it shows a possibility of EHV evacuation challenges.

- The sum total of either the ñGen MEC Allocatedò (0 MW) should not exceed the lower of the ñSupply Area EHV steady-state limitò or the ñSupply Area EHV transient stability limitò, the lower of the two is 4745 MW. Eskom is responsible for ensuring that IPPs that are allocated do not exceed these limits unless there are other strengthening plans to increase the available capacity.
- The sum total of the ñGen Available HV ï undiversifiedò (2637 MW) should ideally not exceed the lower of the ñSupply Area EHV steady-state limitò or the Supply Area EHV transient stability limit. But if it does, care should be taken that the allocation in that area does not exceed the 4745 MW limit. If 4745 MW is exceeded, then then there must be a plan to strengthen the network to accommodate capacities greater than 4745 MW.

6 GENERATION CONNECTION CAPACITY BY SUPPLY AREA

The MTS substations are grouped by supply area and listed alphabetically in a single table for each supply area.

6.1 Bloemfontein area

Substation	No. Trfrs	Single Trfr MVA	Total Trfr MVA	Firm N-1 MVA	Gen MEC MW Allocated	Gen Available HV - undiversified (MW) in 2016	EHV Capacity-diversified (MW)	Supply Area EHV steady-state limit (MW)	Supply Area EHV transient stability limit (MW)	Year in Service
Beta 765/400 kV	2	2000	4000	2000	0	1000	2038	5127	4745	Existing
Harvard 275/132 kV	2	500	1000	500	0	619	546			Existing
Perseus 400/275 kV	2	400	800	800	0	800	2181			Existing
Perseus 400/275 kV	1	800	800							
Merapi 275/132 kV	2	180	360	180	0	218	362			Existing
Merapi 275/132 kV	0(1)	0(250)	0(250)	0(0)		0(250)				2016, 2nd Q

6.2 Carltonville area

Substation	No. Trfrs	Single Trfr MVA	Total Trfr MVA	Firm N-1 MVA	Gen MEC MW Allocated	Gen Available HV - undiversified (MW) in 2016	EHV Capacity-diversified (MW)	Supply Area EHV steady-state limit (MW)	Supply Area EHV transient stability limit (MW)	Year in Service
Mercury 400/132 kV	2	500	1000	500	0	601	284	1322	2300	Existing
Carmel 275/132 kV	2	500	1000	500	0	553	92			Existing
Midas 400/132 kV	2	500	1000	500	0	647	172			Existing
Pluto 400/275 kV	2	750	1500	750	0	828	311			Existing
Hermes 132/88 kV	3	180	540	360	0	409	291			Existing
Hermes 400/132 kV	3	500	1500	1000	0	1000				Existing
Watershed 275/132 kV	1	250	250	0	0	250	172			Existing
Watershed 275/88 kV	2	315	630	315	0	389				Existing

6.3 East London Bisho area

Substation	No. Trfrs	Single Trfr MVA	Total Trfr MVA	Firm N-1 MVA	Gen MEC MW Allocated	Gen Available HV - undiversified (MW) in 2016	EHV Capacity-diversified (MW)	Supply Area EHV steady-state limit (MW)	Supply Area EHV transient stability limit (MW)	Year in Service
Delphi 400/132kV	2	120	240	120	97	45	1228			Existing
Neptune 400/132kV	2	500	1000	500	0	605	852			Existing
Pembroke 220/132kV	2	250	500	250	20.6	223	306	3370	3898	Existing
Pembroke 220/66kV	2	90	180	90	0	114				Existing
Vuyani 400/132kV	2	250	500	250	0	298	984			Existing

6.4 Empangeni area

Substation	No. Trfrs	Single Trfr MVA	Total Trfr MVA	Firm N-1 MVA	Gen MEC MW Allocated	Gen Available HV - undiversified (MW) in 2016	EHV Capacity-diversified (MW)	Supply Area EHV steady-state limit (MW)	Supply Area EHV transient stability limit (MW)	Year in Service
Athene 400/132 kV	4	500	2000	1500	0	1000	395			Existing
Impala 275/132 kV	4	250	1000	750	16.5	843	404	1203	2115	Existing
Invubu 400/275 kV	3	800	2400	1600	0	1000	404			Existing

6.5 Highveld North area

Substation	No. Trfrs	Single Trfr MVA	Total Trfr MVA	Firm N-1 MVA	Gen MEC MW Allocated	Gen Available HV - undiversified (MW) in 2016	EHV Capacity-diversified (MW)	Supply Area EHV steady-state limit (MW)	Supply Area EHV transient stability limit (MW)	Year in Service
Prairie 275/132 kV	2	240	480	240	6.76	261	481			Existing
Rockdale 400/132 kV	2	500	1000	500	0	582	633			Existing
Rockdale 275/132 kV	2	500	1000	500	0	538	454	3010	4685	Existing
Vulcan 5&6 400/132 kV	2	500	1000	500	0	627	633			Existing
Gumeni 400/132 kV	0(1)	0(500)	0(500)	0(0)	0	500	633			2015, 2nd Q
Kruispunt 275/132 kV	4	250	1000	750	0	894	176			Existing

6.6 Highveld South area

Substation	No. Trfrs	Single Trfr MVA	Total Trfr MVA	Firm N-1 MVA	Gen MEC MW Allocated	Gen Available HV - undiversified (MW) in 2016	EHV Capacity-diversified (MW)	Supply Area EHV steady-state limit (MW)	Supply Area EHV transient stability limit (MW)	Year in Service
Sol 400/132 kV	4	500	2000	1500	0	1000	172	7819	7749	Existing
Zeus 765/400 kV	3	2000	6000	4000	0	1000	4300			Existing
Alpha 765/400 kV	3	2000	6000	4000	0	1000	3347			Existing

6.7 Johannesburg area

Substation	No. Trfrs	Single Trfr MVA	Total Trfr MVA	Firm N-1 MVA	Gen MEC MW Allocated	Gen Available HV - undiversified (MW) in 2016	EHV Capacity-diversified (MW)	Supply Area EHV steady-state limit (MW)	Supply Area EHV transient stability limit (MW)	Year in Service
Craighall 275/88 kV	3	315	945	630	0	797	324	2287	4315	Existing
Croydon 275/132 kV	3	250	750	500	0	589	280			Existing
Eiger 275/88 kV	3	315	945	630	0	778	393			Existing
Esselen 132/88 kV	2	315	630	315	0	337	293			Existing
Esselen 275/132 kV	2	180	360	360	0	451				Existing
Esselen 275/132 kV	1	250	250							
Jupiter 275/88 kV	3	180	540	360		425	280			Existing
Lepini 275/88 kV	4	315	1260	945	3.2	997	456			Existing
Lulamisa 400/88 kV	3	315	945	630	0	864	261			Existing

6.8 Karoo area

Substation	No. Trfrs	Single Trfr MVA	Total Trfr MVA	Firm N-1 MVA	Gen MEC MW Allocated	Gen Available HV - undiversified (MW) in 2016	EHV Capacity-diversified (MW)	Supply Area EHV steady-state limit (MW)	Supply Area EHV transient stability limit (MW)	Year in Service
Hydra 400/132 kV	0(1)	0(500)	0(500)	0(0)	426.4	0(74)	567	1025	2398	2018, 2nd Q
Hydra 400/132kV	2	240	480	240	278.15	-28				Existing
Hydra 400/220kV	2	315	630	315	0	366	63			Existing
Kronos 400/132 kV	0(1)	0(250)	0(250)	0(0)	169.9	0(80)	319			2016, 4th Q
Roodekuil 220/132kV	1	125	125	0	0	0	46			Existing
Ruigtvallei 132/66kV	2	20	40	20	0	0	30			Existing
Ruigtvallei 220/132kV	2	250	500	250	69.9	0				Existing

6.9 Kimberly area

Substation	No. Trfrs	Single Trfr MVA	Total Trfr MVA	Firm N-1 MVA	Gen MEC MW Allocated	Gen Available HV - undiversified (MW) in 2016	EHV Capacity-diversified (MW)	Supply Area EHV steady-state limit (MW)	Supply Area EHV transient stability limit (MW)	Year in Service
Boundary 275/132 kV	2	250	500	250	78.15	220	148	880	2580	Existing
Ferrum 275/132 kV	2	250	500	250	224	32	124			Existing
Ferrum 400/132 kV	0(2)	0(500)	0(1000)	0(500)	0	545	148			2014, 4th Q
Mookodi 400/132	0(2)	0(500)	0(1000)	0(500)	0	531	277			2014, 4th Q
Upington 400/132 kV	0(1)	0(500)	0(500)	0(0)	169.9	0(330)	0			2017, 4th Q
Garona 275/132 kV	1	125	125	0	50	75	84			Existing
Olien 275/132 kV	2	150	300	150	139	34	99			Existing

6.10 Ladysmith area

Substation	No. Trfrs	Single Trfr MVA	Total Trfr MVA	Firm N-1 MVA	Gen MEC MW Allocated	Gen Available HV - undiversified (MW) in 2016	EHV Capacity-diversified (MW)	Supply Area EHV steady-state limit (MW)	Supply Area EHV transient stability limit (MW)	Year in Service
Bloukrans 275/ 132 kV	2	250	500	250	0	320	530	2816	3261	Existing
Danskraal 275/ 132 kV	2	125	250	125	0	154	344			Existing
Tugela 275/132 kV	2	180	360	180	4	219	437			Existing
Venus 275 kV	0	0	0	0	0	0	641			Existing
Venus 400/275 kV	2	800	1600	800	0	1000	864			Existing

6.11 Lowveld area

Substation	No. Trfrs	Single Trfr MVA	Total Trfr MVA	Firm N-1 MVA	Gen MEC MW Allocated	Gen Available HV - undiversified (MW) in 2016	EHV Capacity-diversified (MW)	Supply Area EHV steady-state limit (MW)	Supply Area EHV transient stability limit (MW)	Year in Service
Acornhoek 275/132 kV	2(3)	125	250(375)	125(250)	0	297	296			2015, 4th Q
Foskor 275/132 kV	2	250	500	250	0	325	228			Existing
Merensky 275/132 kV	2	250	500	500	0	635	389			Existing
Merensky 400/132 kV	1	500	500				363			Existing
Merensky 400/275 kV	2	400	800	400	0	490				Existing
Senakangwedi 275/33 kV	3	180	540	360	0	409	143	2211	3250	Existing
Komatipoort 275/132 kV	2	125	250	125	0	141	160			Existing
MarathonB 400/132 kV	0(1)	0(800)	0(800)	0(0)	0	0(800)	15			2020, 4th Q
Marathon 132/66 kV	2	30	60	30	0	43				Existing
Marathon 275/132 kV	2	500	1000	500	0	589	525			Existing
Simplon 275/132 kV	2	250	500	250	0	318	92			Existing

6.12 Namaqualand area

Substation	No. Trfrs	Single Trfr MVA	Total Trfr MVA	Firm N-1 MVA	Gen MEC MW Allocated	Gen Available HV - undiversified (MW) in 2016	EHV Capacity-diversified (MW)	Supply Area EHV steady-state limit (MW)	Supply Area EHV transient stability limit (MW)	Year in Service
Aggeneis 220/66 kV	2	40	80	40	0	55	98			Existing
Aggeneis 400/220 kV	2	315	630	315	219.65	140	121			Existing
Aries 400/22 kV	1	40	40	0	9.65	30	116			
Gromis 220/66 kV	2	40	80	40	0	45	33			Existing
Nama 220/66 kV	2	80	160	80	0	86	37	471	1235	Existing
Oranjemond 220/66 kV	2	80	160	80	0	91	33			Existing
Paulputs 132/33 kV	1	10	10	0	10	0	33			Existing
Paulputs 220/132 kV	1	125	125	0	119.65	5				Existing
Paulputs 220/132 kV	0(2)	0(250)	0(500)	0(250)	100	0(33)				2019, 2nd Q

6.13 Newcastle area

Substation	No. Trfrs	Single Trfr MVA	Total Trfr MVA	Firm N-1 MVA	Gen MEC MW Allocated	Gen Available HV - undiversified (MW) in 2016	EHV Capacity-diversified (MW)	Supply Area EHV steady-state limit (MW)	Supply Area EHV transient stability limit (MW)	Year in Service
Bloedrivier 275/88 kV	2	160	320	160	0	195	155	1245	1498	Existing
Chivelston 400/275 kV	1	800	800	0	0	800	238			Existing
Incandu 400/132 kV	2	315	630	630	0	726	207			Existing
Incandu 400/132 kV	1	500	500							
Ingagane 275/88 kV	2	160	320	160	0	201	192			Existing
Umfolozi 400/88 kV	2	160	320	160	0	208	291			Existing
Normandie 132/88 kV	1	160	160	0	0	160				Existing
Normandie 400/132 kV	2	250	500	250	0	286	162			Existing
Normandie 400/88 kV	2	160	320	160	0	180				Existing

6.14 Nigel area

Substation	No. Trfrs	Single Trfr MVA	Total Trfr MVA	Firm N-1 MVA	Gen MEC MW Allocated	Gen Available HV - undiversified (MW) in 2016	EHV Capacity-diversified (MW)	Supply Area EHV steady-state limit (MW)	Supply Area EHV transient stability limit (MW)	Year in Service
Benburg 275/132	3	250	750	500	0	595	63	725	175	Existing
Brenner 275/88	3	315	945	630	0	802	231			Existing
Nevis 275/132	2	500	1000	500	0	662	80			Existing
Pieterboth 275/132	2	315	630	315	0	401	138			Existing
Snowdon 275/88	3	160	480	320	0	397	213			Existing

6.15 Peninsula area

Substation	No. Trfrs	Single Trfr MVA	Total Trfr MVA	Firm N-1 MVA	Gen MEC MW Allocated	Gen Available HV - undiversified (MW) in 2016	EHV Capacity-diversified (MW)	Supply Area EHV steady-state limit (MW)	Supply Area EHV transient stability limit (MW)	Year in Service
Acacia 400/132 kV	3	500	1500	1000	0	1000	729	3277	3251	Existing
Muldersvlei 132/66 kV	2	80	160	80	0	91	0			Existing
Muldersvlei 400/132 kV	2	240	480	240	0	0	729			Existing
Muldersvlei 400/132 kV	2(3)	500	1000(1500)	1000	135.2	865				2015, 2nd Q
Sterrekus (Omega) 765/400 kV	0(1)	0(2000)	0(2000)	0	0	0	562			2015, 4th Q
Philippi 400/132 kV	2	500	1000	500	0	692	729			Existing
Stikland 400/132 kV	2	500	1000	500	0	717	528			Existing

6.16 Pinetown area

Substation	No. Trfrs	Single Trfr MVA	Total Trfr MVA	Firm N-1 MVA	Gen MEC MW Allocated	Gen Available HV - undiversified (MW) in 2016	EHV Capacity-diversified (MW)	Supply Area EHV steady-state limit (MW)	Supply Area EHV transient stability limit (MW)	Year in Service
Ariadne 400/132 kV	2	500	1000	500	0	638	279	5080	5466	Existing
Avon 275/132 kV	3	250	750	500	0	586	522			Existing
Eros 400/132 kV	2	500	1000	500	0	601	688			Existing
Georgedale 275/132 kV	3	250	750	500	0	563	445			Existing
Klaarwater 275/132 kV	4	315	1260	945	0	1000	241			Existing
Hector 275 kV	0	0	0	0	0	0	152			Existing
Hector 400/275 kV	3	800	2400	1600	0	1000	663			Existing
Illovo 132/88 kV	1	80	80	0	0	80	484			Existing
Illovo 275/132 kV	2	250	500	250	0	288				Existing
Mersey 275/132 kV	2	250	500	250	0	333	535			Existing
Mersey 400/275 kV	3	800	2400	1600	0	1000	1071			Existing

6.17 Polokwane area

Substation	No. Trfrs	Single Trfr MVA	Total Trfr MVA	Firm N-1 MVA	Gen MEC MW Allocated	Gen Available HV - undiversified (MW) in 2016	EHV Capacity-diversified (MW)	Supply Area EHV steady-state limit (MW)	Supply Area EHV transient stability limit (MW)	Year in Service
Leseding 400/132 kV	2	500	1000	500	0	577	171	1762	735	Existing
Spencer 275/132 kV	2	250	500	250	0	322	370			Existing
Tabor 400/132 kV	1	500	500	0	0	500	304			Existing
Borutho 400/132 kV	0(2)	0(500)	0(1000)	0(500)	0	555	171			2015, 4th Q
Tabor 275/132 kV	2	250	500	250	28	256	337			Existing
Witkop 400/132 kV	3	500	1500	1000	30	970	409			Existing
Witkop 400/275 kV	2	400	800	400	0	548				Existing

6.18 Port Elizabeth area

Substation	No. Trfrs	Single Trfr MVA	Total Trfr MVA	Firm N-1 MVA	Gen MEC MW Allocated	Gen Available HV - undiversified (MW) in 2016	EHV Capacity-diversified (MW)	Supply Area EHV steady-state limit (MW)	Supply Area EHV transient stability limit (MW)	Year in Service
Dedisa 400/132kV	2	500	1000	500	0	619	524	2225	3523	Existing
Grassridge 220/132kV	2	360	720	360	26.19	346	272			Existing
Grassridge 400/132kV	2	500	1000	500	506.39	109	594			Existing
Poseidon 220/132kV	2	125	250	125	158.86	-19	249			Existing
Poseidon 220/66kV	1	40	40	0	0	40				Existing
Poseidon 220/66kV	1	80	80	0	0	80				Existing
Poseidon 400/132 kV	0(1)	0(500)	0(500)	0(0)	233.6	266	586			2016, 2nd Q
Poseidon 400/220kV	2	500	1000	500	0	539				Existing

6.19 Pretoria area

Substation	No. Trfrs	Single Trfr MVA	Total Trfr MVA	Firm N-1 MVA	Gen MEC MW Allocated	Gen Available HV - undiversified (MW) in 2016	EHV Capacity-diversified (MW)	Supply Area EHV steady-state limit (MW)	Supply Area EHV transient stability limit (MW)	Year in Service
Apollo 400/275 kV	1	800	800	0	0	800	1008	6108	6345	Existing
Apollo 400/275 kV	2	1000	2000	1000	0	1000				Existing
Apollo 275 kV	0	0	0	0	0	0	649			Existing
Njala 275/132 kV	3	250	750	500	0	617	544			Existing
Verwoedburg 400/132 kV	2	250	500	250	0	364	396			Existing
Kwagga 275/132 kV	4	300	1200	900	0	1000	544			Existing
Minerva 275 kV	0	0	0	0	0	0	1104			Existing
Minerva 400/275 kV	4	800	3200	2400	0	1000	818			Existing
Lomond 275/88 kV	2	315	630	315	0	434	227			Existing
Dinaledi 400/132 kV	2(3)	500	100(1500)	500(1000)	0	1000	818			2015, 2nd Q

6.20 Rustenburg area

Substation	No. Trfrs	Single Trfr MVA	Total Trfr MVA	Firm N-1 MVA	Gen MEC MW Allocated	Gen Available HV - undiversified (MW) in 2016	EHV Capacity-diversified (MW)	Supply Area EHV steady-state limit (MW)	Supply Area EHV transient stability limit (MW)	Year in Service
Ararat 275/88 kV	3	315	945	630	0	746	143	1289	1580	Existing
Bighorn 275/88 kV	3	315	945	630	0	755	143			Existing
Ngwedi (Mogwase) 400/132 kV	0(2)	0(500)	0(1000)	0(500)	0	559	350			2015, 3rd Q
Bighorn 400/132kV	2	500	1000	500	6.76	612	299			Existing
Marang 400/88 kV	4	315	1260	945	0	1000	205			Existing
Trident 275/88 kV	2	315	630	315	0	394	149			Existing

6.21 South Cape area

Substation	No. Trfrs	Single Trfr MVA	Total Trfr MVA	Firm N-1 MVA	Gen MEC MW Allocated	Gen Available HV - undiversified (MW) in 2016	EHV Capacity-diversified (MW)	Supply Area EHV steady-state limit (MW)	Supply Area EHV transient stability limit (MW)	Year in Service
Bacchus 400/132 kV	2	500	1000	500	62.19	594	924	3270	1580	Existing
Droerivier 400/132 kV	2	120	240	120	0	153	951			Existing
Vryheid 400/132 kV	0(2)	0(500)	0(1000)	0(500)	0	0(500)	0			2019, 2nd Q
Kappa 765/400 kV	1	2000	2000	0	0	0	910			2016, 2nd Q
Proteus 132/66 kV	2	80	160	80	0	103	0			Existing
Proteus 400/132 kV	2	500	1000	500	0	676	485			Existing

6.22 Vaal Triangle area

Substation	No. Trfrs	Single Trfr MVA	Total Trfr MVA	Firm N-1 MVA	Gen MEC MW Allocated	Gen Available HV - undiversified (MW) in 2016	EHV Capacity-diversified (MW)	Supply Area EHV steady-state limit (MW)	Supply Area EHV transient stability limit (MW)	Year in Service
Makalu 275/88	4	160	640	480	0	584	278	2803	2990	Existing
Makalu B 275/88	0(2)	0(315)	0(630)	0(315)	0	0				2019, 4th Q
Scafell 275/132	2	135	270	135	0	158	374			Existing
Glockner 400/275	3	800	2400	1600	0	1000	554			Existing
Kookfontein 275/88	3	315	945	630	0	763	445			Existing
Olympus 275/132	2	250	500	250	0	332	527			Existing
Rigi 275/88	3	315	945	630	0	764	264			Existing
Verdun 275/88	2	315	630	315	0	355	361			Existing

6.23 Warmbaths area

Substation	No. Trfrs	Single Trfr MVA	Total Trfr MVA	Firm N-1 MVA	Gen MEC MW Allocated	Gen Available HV - undiversified (MW) in 2016	EHV Capacity-diversified (MW)	Supply Area EHV steady-state limit (MW)	Supply Area EHV transient stability limit (MW)	Year in Service
Pelly 275/132 kV	2	250	500	250	0	291	33	47	1262	Existing
Warmbad 132/66 kV	2	40	80	40	0	52	14			Existing
Warmbad 275/132 kV	2	125	250	125	0	144				Existing

6.24 Waterberg area

Substation	No. Trfrs	Single Trfr MVA	Total Trfr MVA	Firm N-1 MVA	Gen MEC MW Allocated	Gen Available HV - undiversified (MW) in 2016	EHV Capacity-diversified (MW)	Supply Area EHV steady-state limit (MW)	Supply Area EHV transient stability limit (MW)	Year in Service
Spitskop 275/88 kV	2	315	630	315	0	362	496	1641	560	Existing
Spitskop 400/132 kV	2	250	500	500	0	500	1145			Existing
Spitskop 400/132 kV	1	500	500							Existing
Spitskop 400/275 kV	2	800	1600	800	0	1000				Existing

6.25 Welkom area

Substation	No. Trfrs	Single Trfr MVA	Total Trfr MVA	Firm N-1 MVA	Gen MEC MW Allocated	Gen Available HV - undiversified (MW) in 2016	EHV Capacity-diversified (MW)	Supply Area EHV steady-state limit (MW)	Supply Area EHV transient stability limit (MW)	Year in Service
Everest 275/132 kV	2	500	1000	500	0	548	1460	4720	4765	Existing
Leander 400/132 kV	2	500	1000	500	0	574	1630			Existing
Theseus 400/132 kV	2	500	1000	500	0	630	1630			Existing

6.26 West Coast area

Substation	No. Trfrs	Single Trfr MVA	Total Trfr MVA	Firm N-1 MVA	Gen MEC MW Allocated	Gen Available HV - undiversified (MW) in 2016	EHV Capacity-diversified (MW)	Supply Area EHV steady-state limit (MW)	Supply Area EHV transient stability limit (MW)	Year in Service
Aurora 400/132 kV	4	250	1000	750	245.2	616	1633	2665	2616	Existing
Helios 400/132 kV	0(1)	0(500)	0(500)	0	275.9	0(224)	580			2017, 2nd Q
Helios 400/22 kV	1	40	40	0	0	40				Existing
Juno 132/66 kV	2	40	80	40	8.8	48	452			Existing
Juno 400/132 kV	2	120	240	120	108.8	30				Existing
Juno 400/132 kV	0(2)	0(500)	0(1000)	0(500)	0	0(500)				2019, 2nd Q

6.27 West Rand area

Substation	No. Trfrs	Single Trfr MVA	Total Trfr MVA	Firm N-1 MVA	Gen MEC MW Allocated	Gen Available HV - undiversified (MW) in 2016	EHV Capacity-diversified (MW)	Supply Area EHV steady-state limit (MW)	Supply Area EHV transient stability limit (MW)	Year in Service
Bernina 275/132	4	240	960	720	0	821	699	2912	4686	Existing
Etna 275/88	2	315	630	315	1	445	746			Existing
Hera 400/275	2	800	1600	800	0	1000	508			Existing
Princess 275/88	3	315	945	630	0	738	183			Existing
Taunus 275/132	3	500	1500	1000	4.8	995	555			Existing
Westgate 275/132	2	500	1000	500	0	646	221			Existing

6.28 Large-Area Integration Stability limits

The simultaneous integration of generation at EHV bus bars in the areas that are grouped together as indicted in the tables below, was simulated to derive a stability limit for wide-area integration. Simulations were done for each area individually. The stability limit given is a good indicator of the highest possible integration limit if no restrictions are imposed by network overloading in an area.

Larger area	Transmission supply areas	Stability limit (MW)
KwaZulu-Natal	Empangeni, Ladysmith, Newcastle, Pinetown	17 000
Cape	Kimberley, East London, Karoo, Port Elizabeth, Peninsula, Namaqualand, Southern Cape and West Coast	15 000
Limpopo and North West	Polokwane, Waterberg, Warmbaths, Rustenburg and Carltonville	10 000

The geographic locations of the larger areas are shown in Figure 6.28.

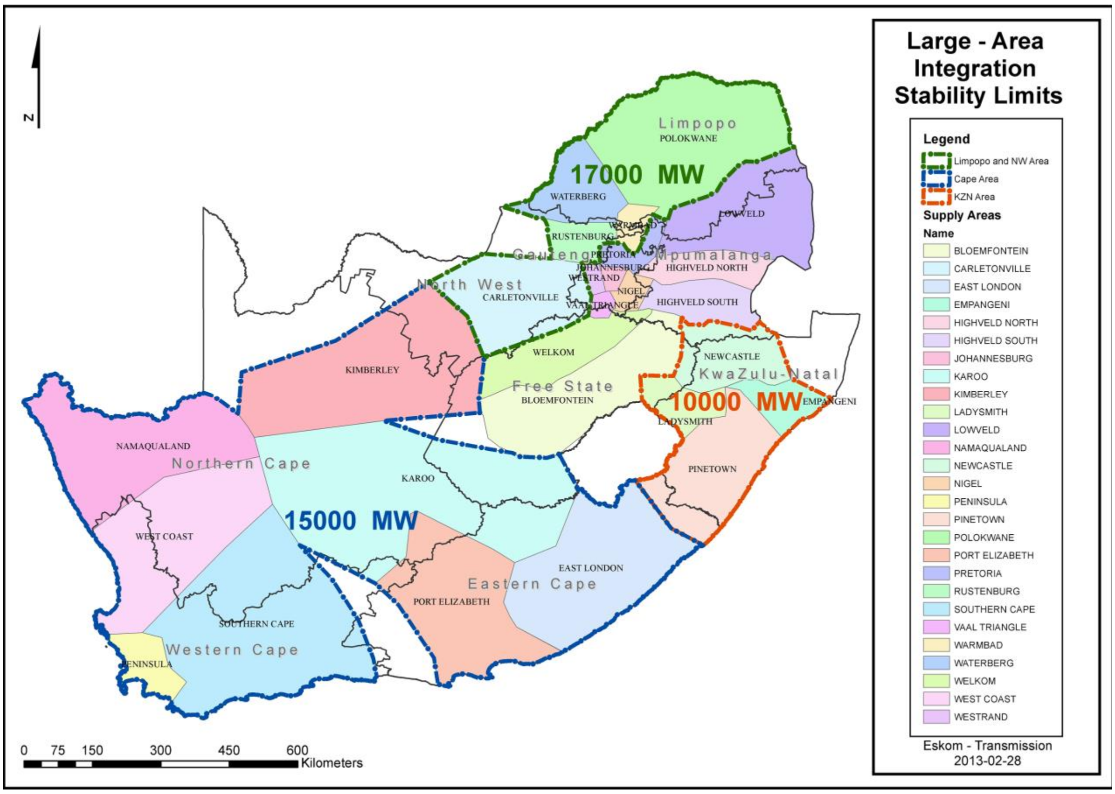

Figure 6.28 *Geographic location of larger areas and the stability limits*

7 HIGH-LEVEL CONNECTION ESTIMATES

The location and Generation Connection Capacity of the closest MTS substation will give a developer some indication of what will be required to connect his/her proposed generation plant to the Eskom Transmission Grid. If the MW output of the generation plant is less than or about the same as the Generation Connection Capacity of the relevant MTS substation, the connection requirements would probably be only a shallow connection. If the MW output exceeds the Generation Connection Capacity, some form of transmission reinforcement would probably be required and Eskom should be engaged to discuss the potential integration requirements of the project.

Consulting engineers and equipment manufacturers or suppliers can provide some unit costs of the transmission infrastructure for the simple calculation of estimates, so as to provide an order-of-magnitude value of the cost of a possible shallow connection. Eskom can also provide a Cost Estimate Letter at a fee for IPPs that apply to Eskom for connection. The cost-estimate letter will provide an indicative cost which is non-binding, but will give the IPP a good indication of cost of major works to for connecting the IPP to the grid.