Renewable energy generation connection capacity assessment

Information from Eskom

There is a move towards introducing renewable energy (RE) sources into the South African energy mix. At present developers of RE generation projects do not have a clear idea of the available capacity for connection of projects to the transmission network. To address this situation a study was undertaken by Eskom to determine the available connection capacity for new generation at the different MTS substations. This article gives a brief summary of the results of the study.

The introduction of REFIT has seen a flood of RE applications and enquiries. Currently the majority of these are for wind generation. The wide range of potential installed capacities per site results in developers either requesting quotations for multiple locations or multiple requests for quotations connecting to the same transmission connection points. This provides information from the study to enable stakeholders to make informed assessments of the likely requirements to connect their generation projects to the Eskom transmission network.

The transmission licence granted to Eskom provides that the planning of the transmission network is the responsibility of Transmission System Planning (TSP). The purpose of this document is to provide an indication of the available capacity for the connection of new generation projects at main transmission system (MTS) substations on the transmission network that will be in service by 2012. The values provided 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 on the transmission network.

In this document only the available capacity at the MTS substations in the Western Cape, Eastern Cape and Northern Cape provinces are presented. The detailed studies that have been undertaken have only considered these provinces based on the significant potential for renewable energy (RE) generation and the timing of the REFIT process. Future generation capacity connection studies will be extended to include the rest of the country and the results will be published in a later version of this document.

Due to time constraints and the urgency of the impending REFIT process the studies were completed only for the areas where the most potential for RE sources are located. Based on the RE generation applications and enquiries received by Eskom the connection capacity study covered the transmission networks in the Western Cape, Eastern Cape and Northern Cape.

A similar exercise for distribution networks is impractical due to the large number of networks. Direct connection to the distribution networks will be considered on a case-by-case basis. However, all the distribution networks are supplied by a MTS substation and the connection capacity will provide an indication of how much generation can be connected within the supply area of that MTS substation. Based on the connection capacity of a specific MTS substation, a developer will be able to make a high level assessment of what is likely to be required to connect generation projects to this point on the transmission network and the likely time it would take to be connected.

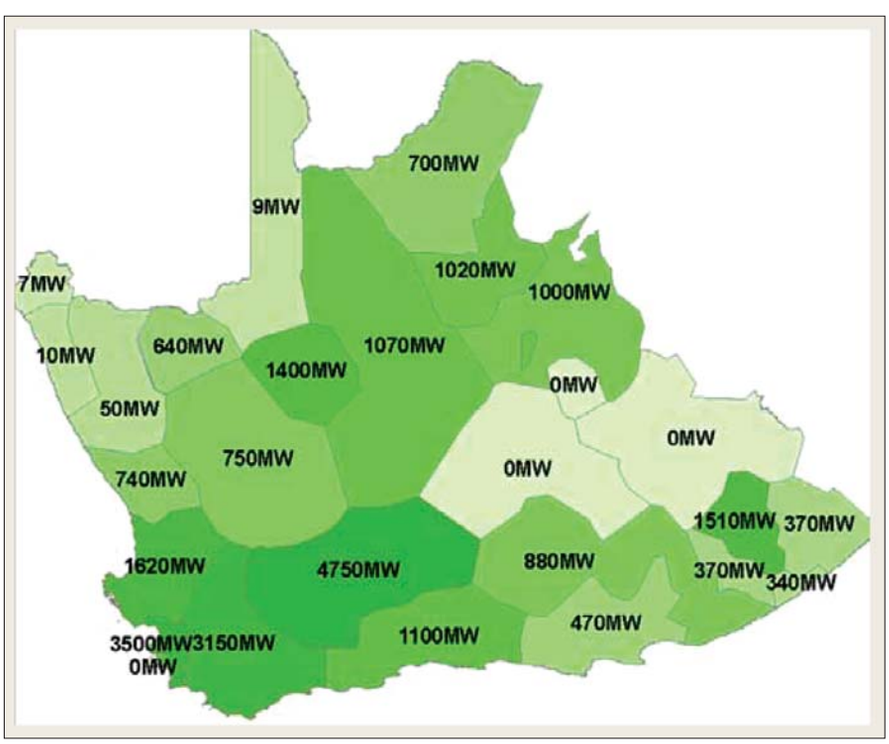

Fig. 1: Spatial map of level 2 local N-1 connection capacities for the 2012 transmission network.

Methodology and interpretation

This section explains how the generation connection capacities were calculated for the MTS substations and how this value is interpreted.

Methodology of calculation

Connection capacity is determined by the transmission and distribution infrastructure in service available for the proposed project to connect to and then transport the generated power to the loads. The appropriate year for consideration to facilitate the REFIT targets is the year 2012 as this is the year most of the RE projects would start to come online. The studies considered the entire transmission infrastructure that will be in service in 2012, based on the approved transmission development plan for the period 2010 to 2019.

Transmission connection capacity was thus determined for the expected 2012 Eskom transmission network. The capacity of the distribution networks to connect the generation will be evaluated on a

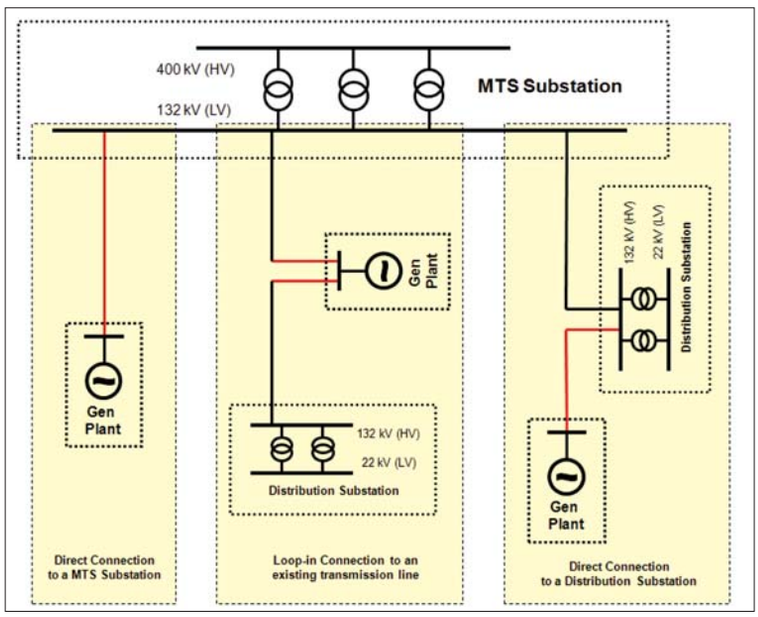

Fig. 2: Generation plant connection to the LV busbar options.

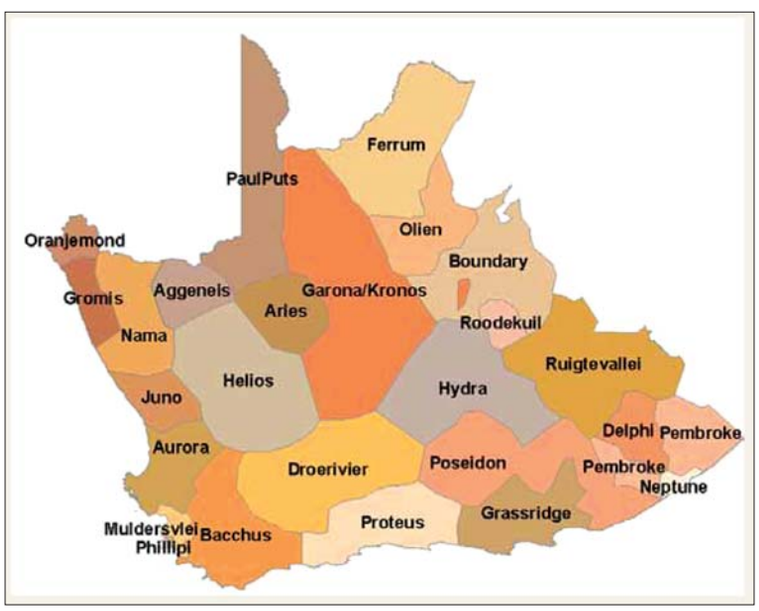

Fig. 3: Map showing MTS substations and their supply areas.

case-by-case basis after an application has been submitted. The transmission connection capacity provides the overall capacity that can be absorbed at a specific MTS connection point without any reinforcement required, either directly connected to the MTS substation or via the distribution network supplied by the MTS substation.

To determine connection capacity certain assumptions were made regarding the potential allocation of the downstream load. Essentially the new generation will first supply the local load within the supply area of the MTS substation and the excess would be sent into the transmission network via the MTS substation transformers.

The first set of calculations considered that the new generation would be connected to the LV busbar of the MTS substation (132 or 66 kV) and increased until the grid code criteria was breached for the single contingency (N-1) criteria, i.e. the loss of a single transmission element, the substation transformer in this case. This provided the local N-1 connection capacity at the LV busbar with no transmission reinforcement considered. This is referred to as the Level 1 connection capacity.

Consideration was then given to allowing limited local transmission reinforcement to enable greater access for RE generation. In this case this means that either transmission voltage level lines (400, 275 or 220 kV) are constructed to enable connection directly at the HV busbar of the substation or additional transformers are installed to allow for additional connections at the LV busbar. As before the generation connected was increased until the grid code criteria were breached for the single contingency (N-1) condition. This provided the local N-1 connection capacity at the HV busbar that could be possible with the limited downstream transmission reinforcements. This is referred to as the Level 2 connection capacity.

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 a generation project to this point. This would be done by first identifying in which MTS substation supply area the generation project will be located and relate it to the approximate distance to that MTS substation or the nearest Distribution substation within that supply area. Then 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 any additional deep transformation reinforcement required. Only shallow connection works should be required, either via the distribution network or connecting directly to the HV or LV busbar of the MTS substation. No time constraints for connecting the project anticipated provided the EIA requirements for the transmission lines connecting to the agreed connection point are completed with sufficient time to allow construction.
- Project MW output is around MTS connection capacity: If the generation project MW output is of the same order as the MTS substation connection capacity, around ±10% variation, then the project may be able to be connected without any additional deep reinforcement required. Thus only shallow connection works may be required, either via the distribution network or connecting directly to the HV or LV busbar of the MTS substation. However, there may be some form of reinforcement required further upstream on the Eskom network or at the MTS substation. This may introduce a time constraint for connecting the generation project.
- Project MW output greater than MTS connection capacity: The generation project will not be able to connect

without some form of additional deep reinforcement required in addition to the shallow connection works. It is unlikely that the generation project can be connected via the distribution network and will have to be directly connected to the MTS substation. The deep reinforcement will place a time constraint for connecting the generation plant project depending on the nature and size of the transmission reinforcement works required.

It must be noted that the connection capacity values have been calculated based on steady state loadflow studies. No dynamic simulations have been considered as the actual generators to be used and their location are not known at present. Once these details are known and studies undertaken possible dynamic instability problems may be encountered. These will have to be addressed at this stage and they may have a time and cost implication.

Definition of transmission connection capacity

A "transmission connection" is defined for the purposes of this document as the direct or indirect connection to a MTS substation at either the LV or the HV busbar. A direct connection at the HV busbar would require the construction of a transmission voltage level line (400, 275 or 220 kV) from the generation plant directly to the MTS substation. However the transmission voltage level is considered a shared network asset and connection at the HV busbar is very much dependant on the meshed network and possible interactions with the rest of the system. The connection to the MTS substation LV busbar can be done 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 plant substation to a distribution substation which is supplied by the MTS substation

The three LV busbar connection options are shown diagrammatically in Fig. 2.

Making an allowance for absorption of some of the new generation by the local loads the connection capacity of the MTS substation is the amount of MW power that can be safely connected to the HV and LV busbar and still meet the grid code criteria for single contingency (N-1) conditions. This includes only the local network loading, voltage and thermal ratings of installed equipment at the MTS substation.This is referred to as the local transmission substation N-1 Generation Capacity. However the connection capacity of a MTS substation also has to consider capacity of the regional network to which it is connected. In the case of the three Cape provinces there are three regional zones which represent the regional transmission networks. The zones are closely aligned to the provincial boundaries with minor deviations.

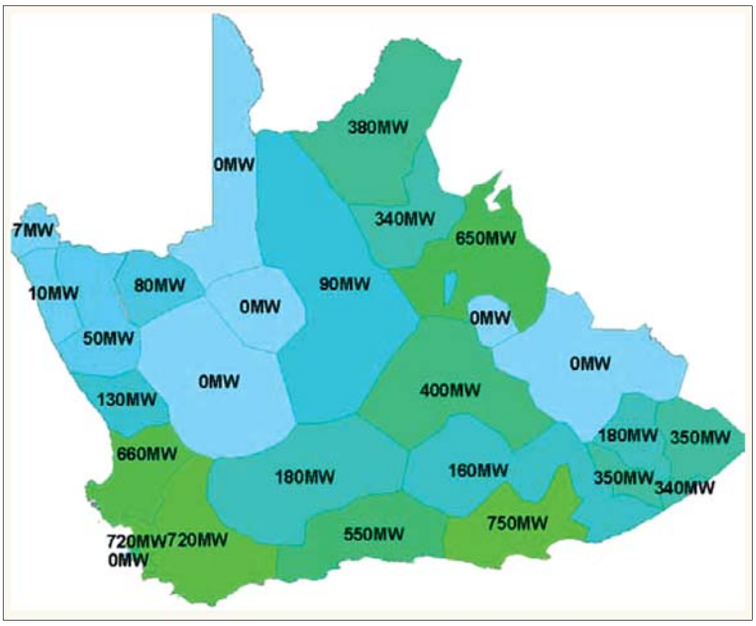

Fig. 4: Spatial map of Level 1 Local N-1 Generation connection capacities.

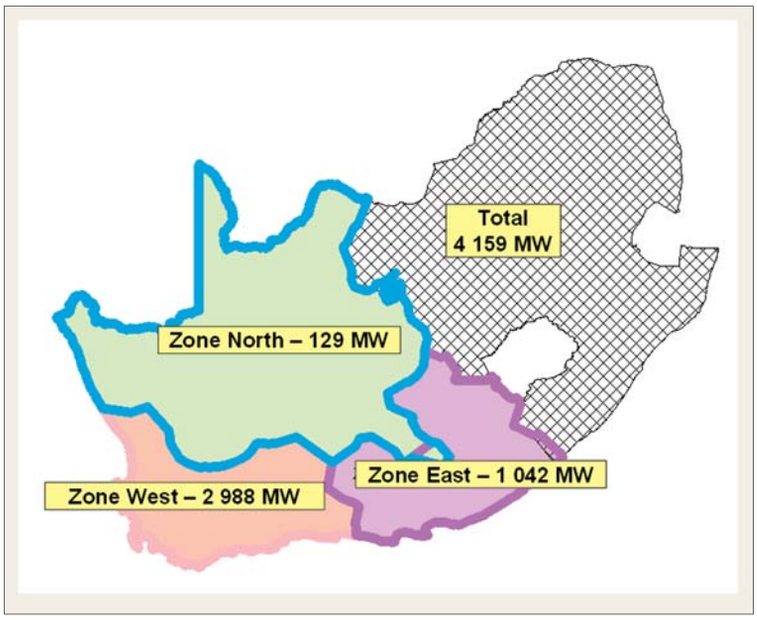

Fig. 5: Map of Level 1 System N-1 Generation connection capacities per zone.

MTS substation details

This section gives an overview of all of the MTS substations that are addressed in this document.

The map given in Fig. 3 indicates the relative location of the MTS substations and their supply areas which are the shaded areas on the map. The shaded supply area indicates the approximate spatial area that the sub-transmission or distribution networks which are supplied by the relevant MTS substation cover.

Developers should plot the location of their proposed generation project onto the map. Whichever shaded area the generation project falls in will give an indication of which MTS substation the project is likely to be the connected to. Based on the possible MW output of the generation project it is possible to determine if more than a simple shallow connection may be required.

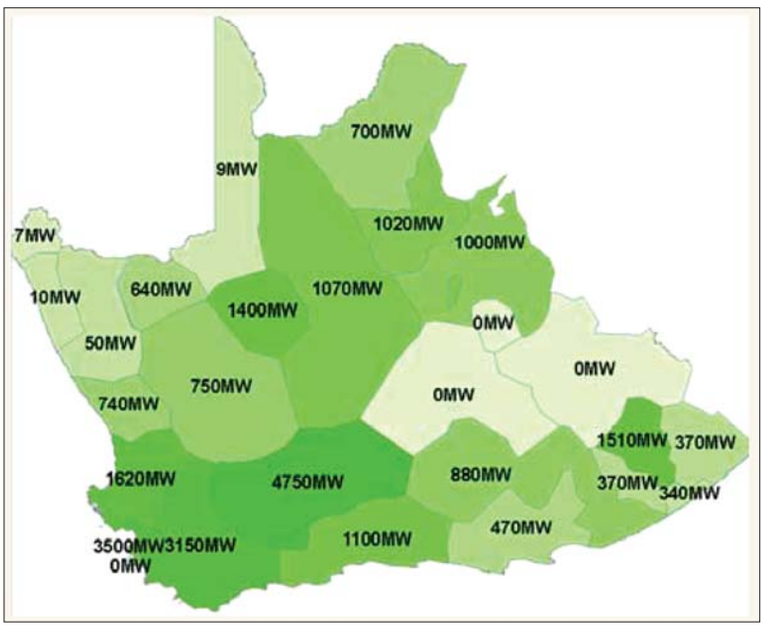

Fig. 6: Spatial map of Level 2 Local N-1 Generation connection capacities.

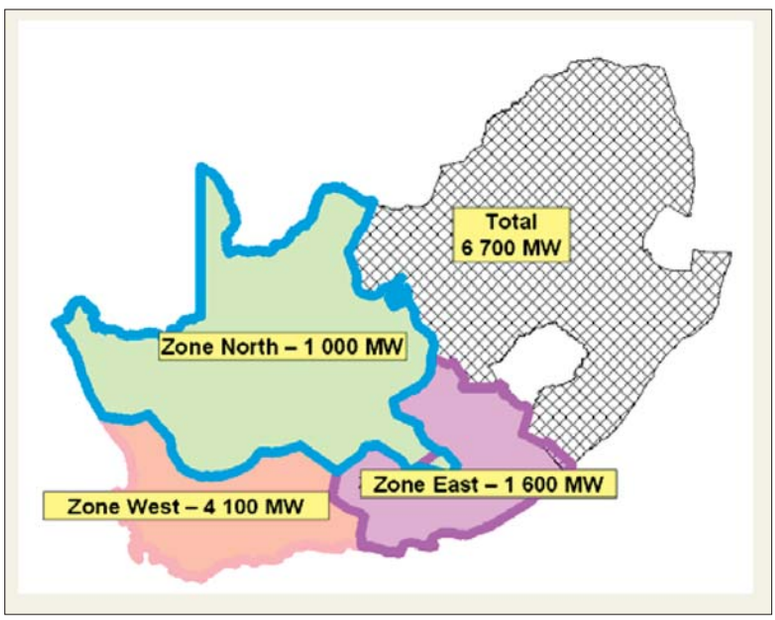

Fig. 7: Map of Level 2 system N-1 Generation connection capacities per zone.

The generation connection capacity at the MTS substations have been calculated under two conditions for the 2012 transmission network, referred to as Level 1 and Level 2. Level 1 considers only the existing 2012 network infrastructure with no transmission network strengthening. Connection is only considered at the LV busbar of the MTS substation (132 or 66 kV). Level 2 considers that limited local transmission network strengthening could be undertaken to enable greater access for new generation. Connection capacity is considered as the total seen by the HV busbar of the MTS substation (400 kV, 275 or 220 kV). No reinforcement of the main power corridors is considered. Reinforcement of the main transmission power corridors to enable access to potential generation, RE or other, is considered to be a more strategic planning exercise and beyond the scope of this document.

Level 1 with no transmission strengthening

The network studies determined the local transmission substation N-1 generation capacity at the MTS substations which considered only the local substation loading, voltage and thermal ratings of installed equipment at or connected to the MTS substation. The MW value is the amount of generation that could be connected to the LV busbar at that specific MTS substation. It does not evaluate the aggregated network capacity impact.

The local generation connection capacities are displayed on the map shown in Fig. 4. The MW value within the shaded areas indicates the connection capacity of the supply area of the relevant MTS substation.

When the regional transmission network constraints are taken into account there is a maximum N-1 generation capacity that the network can absorb before contravening the grid code. These regional networks have been divided into three zones based on the transmission configuration, namely the East, West and North Zones. These zones correspond closely to the provincial boundaries with minor deviations. A maximum N-1 capacity has been determined for each zone and the aggregated substation generation integration cannot exceed this limit. This zone limit is referred to the system N-1 generation capacity.

The level 1 system N-1 generation capacity limits are as follows:

- East Zone: 1042 MW
- West Zone: 2988 MW
- North Zone: 129 MW

This presents an overall Level 1 limit for the three Cape provinces of 4159 MW.

The three zones are indicated on a spatial basis with their N-1 generation capacity limits marked in the map in Fig.5.

Level 2 with limited local transmission strengthening

Level 2 considers only the existing 2012 network infrastructure with limited local transmission network strengthening to enable greater access for new generation. In this case the connection capacity is considered at the HV busbar of the MTS substation (400, 275 or 275 kV) whether the connection is directly to the HV busbar or via the substations transformers at the LV busbars. The network studies determined the local transmission substation N-1 generation capacity at the MTS substations which considered only the local substation loading, voltage and thermal ratings of installed equipment at or connected to the MTS substation, the same as in Level 1. The MW value is the amount of generation that can be absorbed at the HV busbar of that specific MTS substation. It does not evaluate the aggregated network capacity impact.

The local generation connection capacities at Level 2 are displayed on the map shown in Fig. 6. The MW value

within the shaded areas indicates the connection capacity of the supply area of the relevant MTS substation. As in the Level 1 case there is a maximum N-1 generation capacity that the network can absorb for the Level 2 case before contravening the Grid Code when taking into account the regional transmission network constraints.

The Level 2 System N-1 Generation Capacity limits are as follows:

- East Zone:1042 MW
- West Zone:2988 MW
- North Zone:129 MW

This presents an overall Level 2 limit for the three Cape provinces of 6700 MW.

The three Zones are indicated on a spatial basis with their N-1 generation capacity limits marked in the map in Fig. 7.

High level connection cost estimating

The location and generation connection capacity of the closest MTS substation will provide a developer with some indication of what will be required to connect their proposed generation plant to the transmission network. If the output of the generation plant is less than or of the order of the generation connection capacity of the relevant MTS substation then the connection requirements are likely to be only a shallow connection. If the output exceeds the generation connection capacity then some form of transmission reinforcement is likely to be required and TSP should be engaged to discuss the potential integration requirements of the project.

There are three likely connection configurations for the new generation plant to be connected to the transmission network:

- The most expensive would be a direct connection from the generation plant substation to the MTS substation via a dedicated transmission line
- The next most expensive option would be a direct connection from the generation plant substation to a closer distribution substation which is supplied by the MTS substation
- The least expensive would be looping in an existing transmission line which is connected to the MTS substation and is at an appropriate voltage level with sufficient network capacity, into the generation plant substation. The TSP would have to be contacted directly to discuss this option.

Based on the length of transmission line required to facilitate one of the above connection configuration options and the two line bays at the end of the transmission lines a high level estimate of the connection cost can be made. Consulting engineers or the manufacturers of the transmission equipment and components can be contacted to provide unit or per km costs to use to calculate the expected shallow connection cost. They should also be able to provide an estimated time of delivery, construction and commissioning of the connecting transmission lines. However this does not imply or commit that Eskom will be able to connect within these time frames.

Full details of the study can be found in the document "Generation Connection Capacity Assessment of the 2012 Transmission Network (GCCA-2012)" which can be obtained from Eskom at www.eskom.co.za on the media publications page.

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