2015 Review of the Transmission Integration of the Nuclear 1 Power Station Options

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BACKGROUND

Three sites were identified and assessed through an Environmental Impact Assessment (EIA) process phase for the establishment of a nuclear power station for the Nuclear-1 project and subsequent phases as part of a nuclear fleet, namely Thyspunt, Bantamsklip and Duynefontein. The integration of a nuclear power station of between 3,000MW and 5,000MW at each site into the main transmission systems was investigated by Grid Planning between 2006 and 2009. Subsequent to these studies there have been a number of major developments regarding the future generation in South Africa as well as changes in the expected load demand in the country.

One of the main developments was the issuing of the 2010 Integrated Resource Plan (IRP) and the commitment to the large scale development of renewable generation by the Government of South Africa, including the introduction of the Renewable Energy Independent Power Producer Procurement Programme (REIPPPP) which has already completed three Bid Windows of the Renewable Energy Bid (REBID) process. This has resulted in a completely new geographical spread of generation, specifically a potentially large amount of new generation in the Cape provinces, which will impact on the integration of the proposed nuclear plants. The proposed date for the Nuclear-1 power station was pushed back to 2023 by the IRP and the integration plans have been reviewed periodically for the three selected sites.

In 2014 the long term strategic "2040 Eskom Transmission Network Study" was completed, the location of Renewable Energy Development Zones (REDZ) identified and preparation work for a large gas fired generation IPP programme undertaken. These all have an impact on the nuclear transmission integration plans.

This 2015 review provides an updated high level assessment of the impact of these changes on the transmission integration of the three Nuclear-1 project site options. Final detailed transmission studies will only be undertaken once there is firm commitment of the target date of the Nuclear-1 power station.

MAJOR DEVELOPMENTS AND CHANGES

Generation Developments

Subsequent to the integration studies for the Nuclear-1 power station, the 2010 Integrated Resource Plan (2010 IRP) was issued which detailed the expected mix of generation types for the country up until 2030. Most significant was the commitment to the large scale development of renewable generation by the Government of South Africa. This included the introduction of the REIPPPP and the implementation of the REBID process for renewable generation which after the first three Bid Windows up to end 2014, is envisaged to continue with a regular rollout program with invitations for bids of a specified MW amount on a regular basis every 12 to 18 months. This will result in a completely new geographical spread of the future generation, specifically a potentially large amount of new generation in the Cape provinces where the wind and solar resources are the most abundant.

Similarly there is a potential for gas generation to be introduced at a number of locations along the coastline of the country. All of these new generation potentials will impact on the transmission integration of the proposed nuclear plants.

Identification of the REDZ areas

One of the components of the National Development Plan (NDP) is the Strategic Infrastructure Project (SIP) regarding the promotion of renewable energy, known as SIP 8. As part of this project the CSIR was tasked to identify preferred areas for the development of wind and solar PV generation, known as RE Development Zones or REDZ. Eight areas were identified, all in the Eastern, Northern and Western Cape Provinces which adds to the amount of generation which must be exported out of the Greater Cape area with the establishment of Nuclear-1. These will have an impact on the deep reinforcement transmission integration requirements.

Load Developments

The local and global economic conditions have resulted in the load forecasts changing with lower starting points and slower growth rates. However this really only impacts on the timing of generation and transmission projects to meet the future loads rather than a change in the need for these projects. From a transmission network aspect the spatial location of the future loads has not changed significantly and the same transmission projects will be required to deliver the power into the main load centres, only the timing is not certain.

Therefore regarding the integration of the Nuclear-1 power station, the changing load forecasts do not impact the transmission requirements. The only major change has been the cancellation of the large 1000MW smelter project scheduled for the Port Elizabeth area in the COEGA development zone included in the initial Nuclear-1 integration studies. However it is expected that a considerable amount of this load will be replaced with alternative large MW load projects as part of the COEGA development drive to establish a major industrial centre within this economic zone. This will only impact the Thyspunt site as the remaining excess power will have to be exported out of the COEGA zone.

The 2040 Eskom Transmission Network Study

The Transmission Grid Planning department completed the strategic study of the potential future transmission network requirements by the year 2040, known as the 2040 Transmission Network Study. This study considered a number of future generation scenarios that would need to be integrated to supply the future load demands. These scenarios were based on the extension of the 2010 IRP from 2030 to 2040 as the base case and then variations to include either a larger renewable generation component or a larger imported power component.

The key to the study was the spatial allocation of these future generation power plants in relation to the load demand. From this it was possible to determine the demand balance around the county, i.e. where there would be future power excesses or power deficits. The transmission network would then need to transport the power from the areas with excess to the areas with deficit. Taking an overview of all the scenarios enable a number of common power corridors that would need to be

developed irrespective of which generation scenario unfolded, i.e. the future main power corridor routes.

Five main power corridor routes were identified and these were then incorporated in the SIP 10 initiative of the NDP which is focused on the development of transmission and distribution for the country. The Strategic Environmental Assessments (SEAs) of these routes is currently being undertaken for the Department of Environmental Affairs and is targeted to be completed by end 2015.

The map in Figure 1 shows the location of the three proposed -Nuclear-1 sites relative to the 2040 Transmission Power Corridors and the SIP 8 REDZs (pink areas labeled 1 to 8).

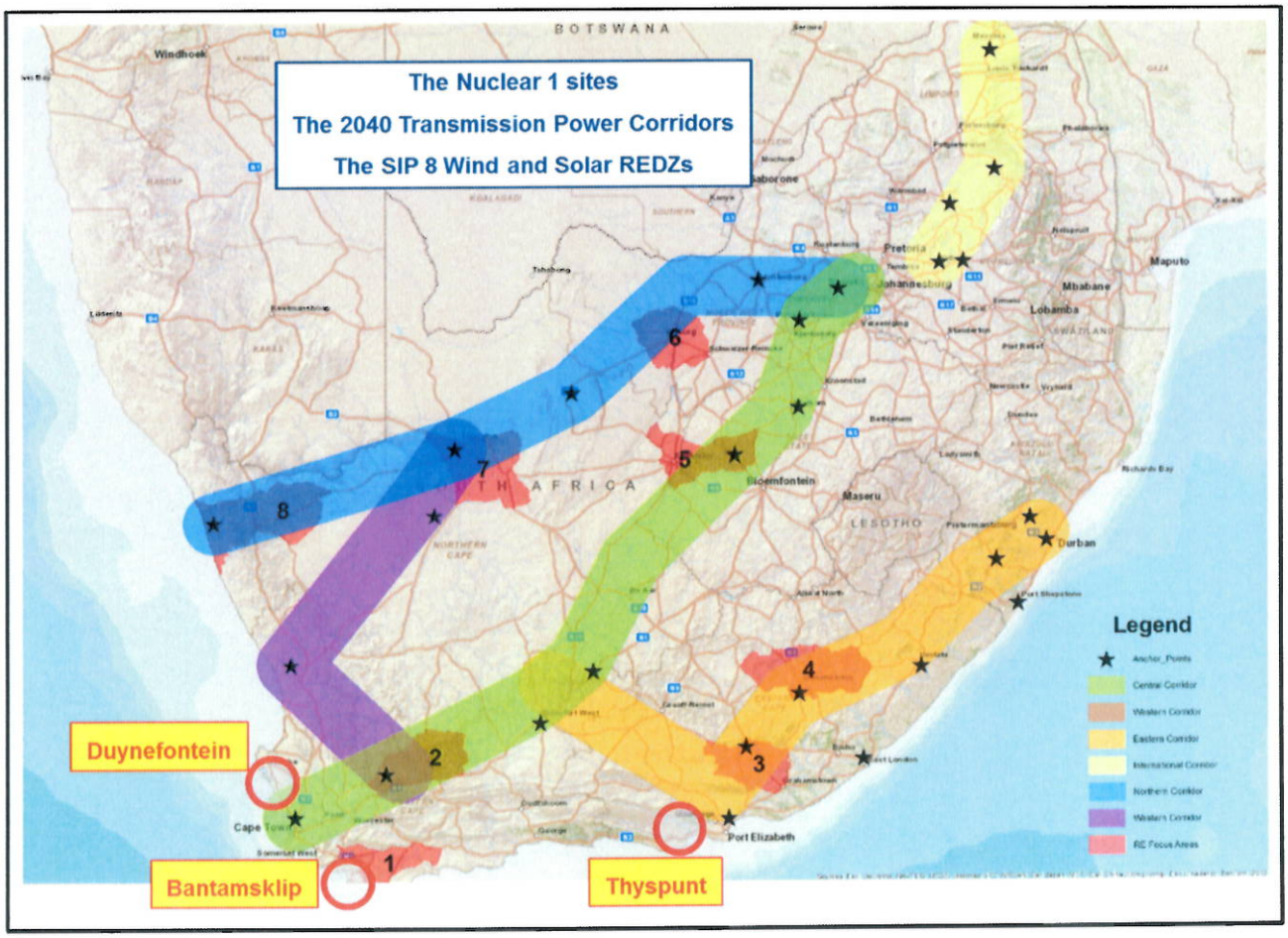

Figure 1: The Nuclear 1 sites, the 2040 Transmission Power Corridors and the SIP 8 REDZs

THE THYSPUNT SITE

Transmission Integration Plan

The integration of the -Nuclear-1 power station at the Thyspunt site is based on constructing up to five 400kV lines from the site towards Port Elizabeth and connecting to the 765kV network at the Grassridge substation. The 400kV lines will also integrate with the Dedisa substation and the new Port Elizabeth 400kV substation to be established to supply the growing loads in this area. These 400kV transmission lines form part of the development of the transmission networks to improve the security of supply in the Greater Port Elizabeth area and in particular the COEGA industrial development zone. The two 765kV lines between Gamma and Grassridge substation will be required to be constructed by the time Nuclear-1 at Thyspunt is commissioned in order to evacuate the excess power. The transmission network integration for Nuclear-1 at the Thyspunt site is shown in Figure 2.

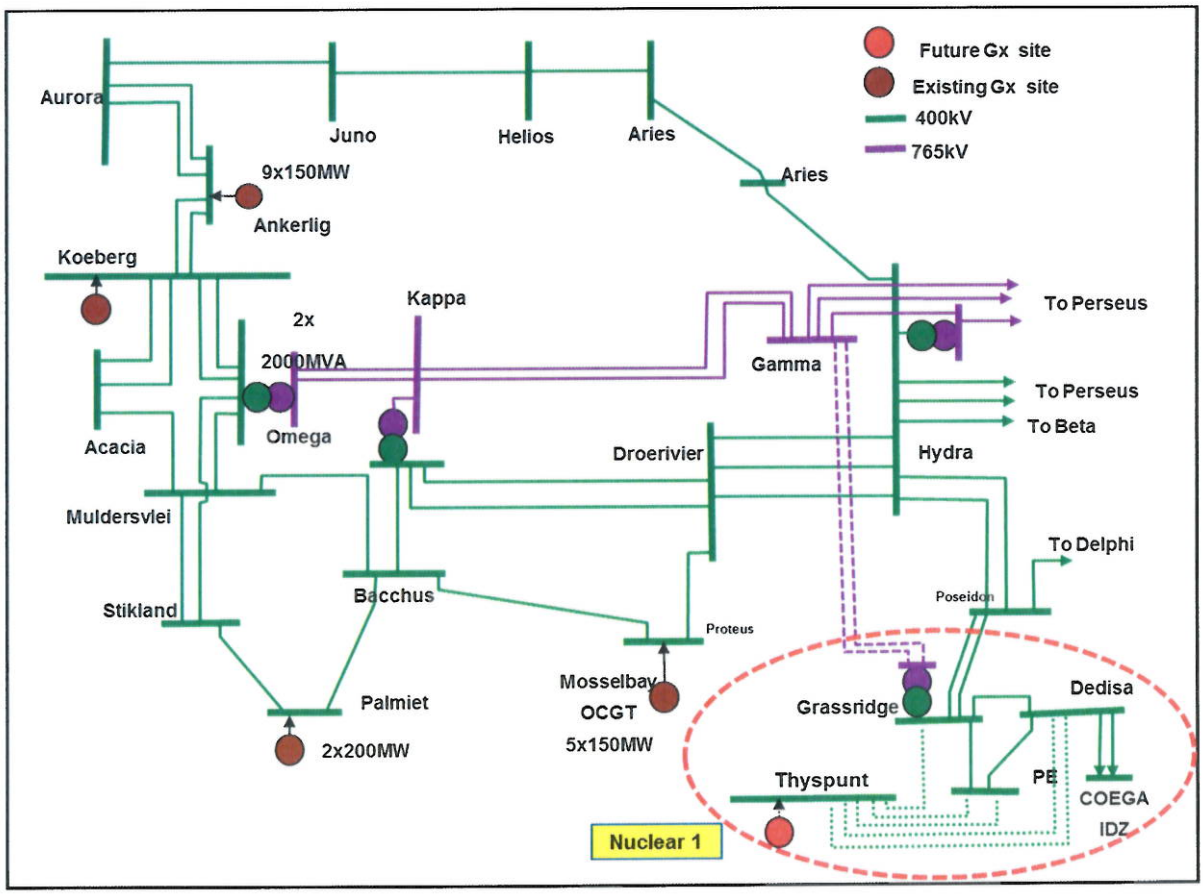

Figure 2: The transmission integration for Nuclear-1 at Thyspunt

External Impacts on Transmission Integration Plan

Regarding the cancellation of the 1000MW smelter project at COEGA, this could potentially affect the stability of the greater Cape network as this large load is not available to help dampen any oscillations after transient events. However, as already stated above a large portion of this load is anticipated to be replaced by a number of large MW load projects. The balance of the excess power will have to be exported and this will require the proposed two 765kV lines from Gamma to Grassridge to be completed to have sufficient capacity to cope with the power exports. This 765kV link is also required to provide network stability for the Eastern Cape. In addition the new 400kV interconnection to the north-east along the coast via Umtata into KwaZulu-Natal will also provide an output for the power and improve stability under contingency conditions.

There is a substantial potential for wind generation in the Eastern Cape, including the area around the Thuyspunt site, with two REDZ identified (REDZ 3 and 4) in the province. The 400kV integration plans for the Thuyspunt site will not be directly affected by the wind generation; on the contrary it may assist the wind projects by providing an additional injection point into the transmission system for wind projects in this area to connect at the 400kV substation. The REDZ 3 and 4 fall within the Eastern Power Corridor (orange corridor in Figure 1) and will be accommodated as this corridor is expanded. Therefore the impact of the IRP and the REBID program is minimal for the Thuyspunt site.

The additional risk to Nuclear-1 at Thyspunt that has materialized recently is the possible establishment of a 2000MW to 3000MW gas fired power station on the COEGA area. The large gas power station as an IPP or Eskom/IPP project is under consideration by the Department of Energy (DOE) as part of their update of the next IRP, due out later this year. Should this project start to be commissioned before Nuclear-1 this would take up most of the capacity of the two Gamma-Grassridge 765kV lines and additional 765kV or 400kV lines will be required to evacuate the Thyspunt Nuclear-1 power. However this can be considered a deep reinforcement transmission project and will be required if both Nuclear-1 and a large gas power station are established in this area, i.e. a common works project, irrespective of which project is established first.

Overall Assessment of Site

The transmission direct connection integration plan for the Thyspunt site at 400kV is still adequate and appropriate. Additional deep strengthening transmission lines at either 400kV or 765kV will be required if other large generation projects such as the gas are established in this area, but these will be common cost projects. **No delay in integrating Nuclear-1 is expected from the transmission integration plan at Thyspunt**.

THE DUYNEFONTEIN SITE

Transmission Integration Plan

The integration of the -Nuclear-1 power station at the Duynefontein site is based on constructing 400kV lines from the site towards Cape Town and connecting to the 765kV network at the new Sterrekus (Omega) 765/400kV substation. The 400kV lines will be integrated with the Stikland and Acacia substations in the Cape Town area. These 400kV transmission lines form part of the development of the transmission networks to improve the security of supply in the Greater Cape Town and Peninsula area. The second Gamma-Kappa-Sterrekus 765kV line which has been delayed due to budget constraints will have to be completed for the establishment of Nuclear-1 at Duynefontein to provide the evacuation capacity for the excess power and the necessary network stability. The transmission network integration for Nuclear-1 at the Duynefontein site is shown in Figure 3.

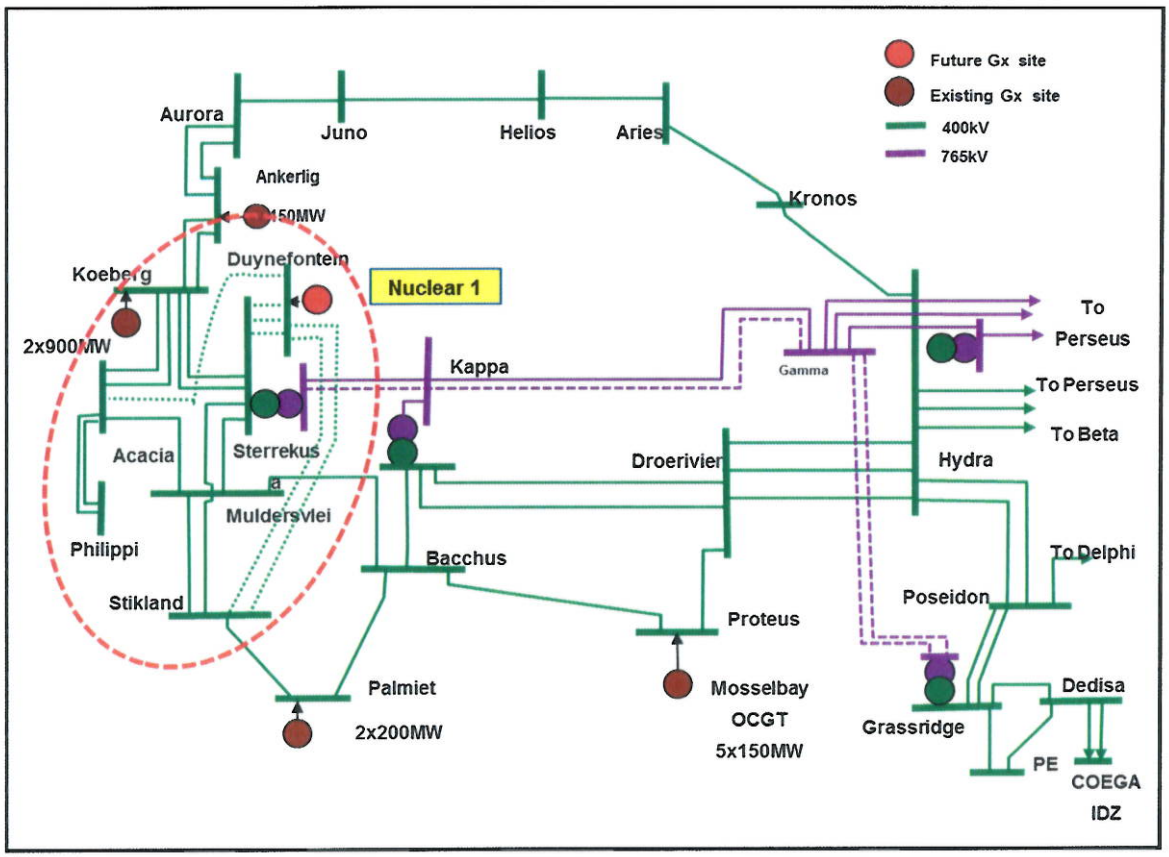

Figure 3: The transmission integration for Nuclear-1 at Duynefontein

External Impacts on Transmission Integration Plan

There is a large potential for wind generation in the Western Cape, however the potential is limited in the area around the Duynefontein site itself with the wind generation anticipated to be much further up the West Coast (REDZ 8) and inland (REDZ 2). The 400kV integration plans for the Duynefontein site will not be affected by the wind generation and therefore the impact of the IRP and the REBID program is minimal for the Duynefontein site.

Increased gas generation at the existing Ankerlig site and potential sites further up the West Coast will have to be taken into account, particularly with regard to the resultant increased fault levels which may exceed the fault current ratings of the installed transmission and distributed equipment in the connected substations. Saldanha is considered as an alternative gas power station site to the COEGA gas generation project, adding between 1000MW and 1500MW in addition to the Ankerlig generation. The fault level issues are expected to be resolved by internal reconfiguration of the 400kV line connections and not necessarily with additional

transmission lines. If the gas generation is increased significantly a reconfiguration of the 765kV may be required with an additional 765/400kV substation closer to Saldanha established with new 765kV and 400kV transmission lines to help integrate and evacuate all the generation in the area rather than trying to link it all through the Sterrekus 765/400kV substation.

Combing the gas generation and Nuclear-1 generation may require additional lines at either 400kV or 765kV up along the West Coast and then through the Northern Cape towards Gauteng. This is in line with the Western and Northern Power Corridors (the purple and blue corridors in Figure 1) in line with the expected future development of the transmission network. This can only be studied in detail and the appropriate solution identified when there is more clarity and certainty of the timing and size of these new generation projects.

The load demand forecast for the Western Cape has not shown any significant deviations with regard to spatial distribution. As for the national forecast the issue is rather timing due to the changing load growth rate than where it will be. Thus the transmission integration for the Duynefontein Nuclear-1 site is still adequate and appropriate.

Overall Assessment of Site

The transmission direct connection integration plan for the Duynefontein site at 400kV and linked to the Sterrekus 765/400kV substation is still adequate and appropriate. Additional deep strengthening transmission lines at either 400kV or 765kV will be required if other large generation projects such as the gas are established in this area, but these will be common cost projects. **No delay in integrating Nuclear-1 is expected from the transmission integration plan at Duynefontein.**

THE BANTAMSKLIP SITE

Transmission Integration Plan

The Bantamsklip site is a very remote location with respect to both the existing transmission network and any large load centre. There is no large concentrated load development expected in the surrounding areas of the site in the foreseeable future. A number of integration options were considered; using only 400kV lines; a combination of 400kV and 765kV lines and lastly only using 765kV lines. However the network stability studies and the need for an N-2 contingency capability (i.e. the generators remain stable after the loss of two transmission lines in the area) in order to be Grid Code compliant have indicated that only the 765kV option with four long 765kV lines to Kappa substation will be able to meet the requirements in the Nuclear-1 timeframe.

Therefore if Bantamsklip is selected for the site for Nuclear-1 four 765kV transmission lines of around 250km in length each will have to be constructed from the site to the Kappa 765kV substation, giving a total of around 1000km of 765kV lines required. To put this on context the Thuyspunt site is less than 100km from the main substations and around 450km of 400kV lines will be required. Duynefontein is less than 10km from the nearest main substation and less then 50km from the substations around Cape Town requiring a total of around 120km of 400kV lines. The cost of 400kV lines is around 60% of the cost of 765kV lines which combined with the total length of lines required at over twice that for Thyspunt indicates that this transmission integration will be significantly more expensive than the other two,

The power station will be linked to the 765kV substation at the Kappa site and will not be able to provide a 400kV injection to support the network in this part of the Western Cape for future development. The 400kV transmission support will have to come from somewhere else. The transmission network integration for Nuclear-1 at the Bantamsklip site is shown in Figure 4.

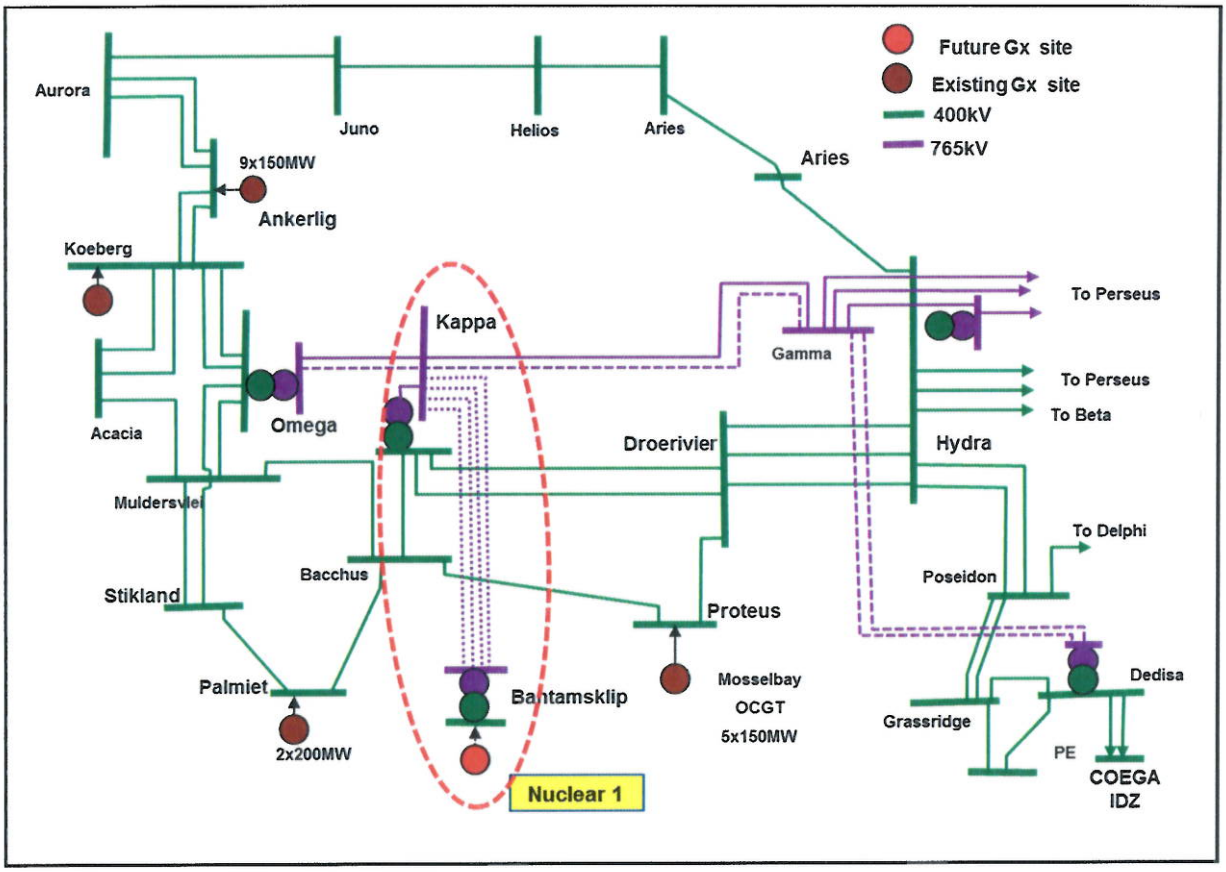

Figure 4: The transmission integration for Nuclear-1 at Bantamsklip

External Impacts on Transmission Integration Plan

A recent factor as a result of the IRP and REBID program is that there is the potential for renewable generation in this part of the Western Cape, specifically wind generation. Although not a lot of potential is located around the Bantamsklip site itself, there is significant potential to the north towards the Kappa site and to the north-east. The SIP 8 project has identified REDZ 1 in this area as indicated on the map in Figure 1. This REDZ 1 area is expected to potentially contain between 600MW and 2000MW of wind generation over time, requiring 400kV transmission. This introduces the potential to integrate part or all of the nuclear generation at Bantamsklip at 400kV, should REDZ 1 be developed with wind generation facilities and dependent on the network stability of this new 400kV and 765kV combination configuration. At this stage the location and certainty of the wind generation is not known and therefore there is no specific 400kV network plan for this area in place yet.

A further potential option to integrate the power station at Bantamsklip would be the establishment of a High Voltage Direct Current (HVDC) scheme, particularly if Bantamsklip is selected for the later phases of the nuclear fleet. This would require a new EIA for the HVDC line route. All the new generation of all types in the Cape will require the Central Power Corridor (green corridor in Figure 1) to be reinforced. One of the reinforcement options would be to use an HVDC scheme to overlay the Central Corridor, but this is only viable at a later stage. However if HVDC is used then Bantamsklip could be integrated with a combination of 400kV and an HVDC which may prove more cost effective solution from an overall transmission system aspect. However the HVDC is not appropriate for the Nuclear-1 implementation timeframe.

The terrain that the 765kV lines will have to cross to get to the Kappa site is very mountainous with steep slopes making it difficult to traverse and will require significant numbers of strengthened strain towers to negotiate the routes. Besides increasing the costs of lines, the construction of the lines will be difficult and thus the option of siting the first of the nuclear units at Bantamsklip will present transmission challenges in terms of project scheduling. **It is the most difficult and longest of the three transmission integration options and has the highest risk in terms of time to complete to meet the Nuclear-1 target date**. It is also the most expensive in terms of the direct transmission connection costs, at around three times the cost of the other two integration options.

Overall Assessment of Site

The renewable generation potential has introduced an additional level of uncertainty for the transmission integration of the Bantamsklip site. The most beneficial plan may now be a combination of 765kV and 400kV transmission or a combination of HVDC and 400kV transmission or still remain an entirely 765kV transmission plan. Until there is more certainty regarding the combination and amount of generation that will have to be integrated in this part of the Western Cape, the optimum integration plan cannot be identified.

The Bantamsklip site has the highest level of uncertainty of the three sites. However if required for the Nuclear-1 power station then it will have to be integrated into the power system with the current recommended 765kV transmission integration plan.

OVERVIEW OF THE THREE SITES

The transmission integration plans for the Nuclear-1 power station at the Thyspunt and Duynefontein sites are not affected by the potential of other generation developments in the relevant provinces, specifically renewable energy generation. The planned 400kV transmission lines form part of the development of the transmission networks to improve the security of supply in their respective areas. Although the large smelter load near the Thyspunt site has been cancelled the connection to the 765kV network and the new 400kV interconnection with KwaZulu Natal will largely mitigate this risk. Large new gas generation at COEGA or near Ankerlig combined with the nuclear and renewable generation may trigger an additional 400kV and 765kV transmission lines to evacuate the excess power, but these are in line with the identified strategic 2040 Transmission Network Power Corridors. However, no delay in integrating Nuclear-1 at these two sites is expected from the transmission plans based on current generation plans in the areas.

There is a higher level of uncertainty on the appropriate transmission integration plan for the Bantamsklip site. If required to integrate Nuclear-1 at this site the four 765kV transmission lines will be required to safely integrate the power station. No additional transmission lines will be required, although a new detailed study with more confirmed generation commitments may indicate a different configuration and voltage level combination. However an improved or detailed integration plan in terms of the overall national power system for a nuclear power station at Bantamsklip site can be developed or established if Bantamsklip is selected for the later phases of a nuclear fleet.

The transmission integration plans for the three sites are still adequate for the safe connection of the Nuclear-1 power station to the power system, despite the generation and load forecast changes that have occurred. **However, although all**

three sites can be integrated into the national grid, Bantamsklip is not preferred for the siting of Nuclear-1 from a transmission point of view due to the reasons outlined in the discussion on the Bantamsklip site above.

Selection of the Bantamsklip site for Nuclear-1 is likely to result in a delay in commissioning due to late completion of the transmission infrastructure as well as significant over investment in the inappropriate transmission solution for the long term development of the national transmission grid. It is the recommendation from Transmission that the Bantamsklip site should only be considered for the later phases of the roll out of a potential nuclear fleet.

Furthermore, until there is more clarity on the future generation in the Cape regarding the generation source, timing and location, there is no value added to undertake more detailed transmission integration studies at this time. These studies would have to be repeated once there is certainty and commitment on the authorization and timing of Nuclear-1 and more certainty regarding the other generation in the Cape provinces.