UMBONO ENGINEERING

TETRA4 PHASE 2 GAS PROCESSING FACILITY NETWORK INTEGRATION AND INJECTION STUDIES

TECHNICAL REPORT

REV. 1

Compiled by: UMBONO Engineering (Pty) Ltd

REVISION CONTROL

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1 INTRODUCTION

Phase 2 is a new facility designed to handle up to 30MMSCFD feed gas supply. This will be implemented in two parts; Phase 2A and Phase 2B both of equal capacity at 15MMSCFD. 2A will become operational in Q2 2023 and 2B in 2025.

All infrastructure associated with Phase 2 will be new build. Tetra4 is currently going through our feasibility and EPC schedule build. The feasibility (including Level III AACE cost estimate) is due 31 March 2021. The final EPC schedules are due 30 June 2021.

Tetra4 have two contractors currently developing the plant side of the scope of work: Saipem on the LNG/LHe process plant and EPCM on the gas pipeline system. Saipem have indicated a power requirement of approximately 12MW for the Phase 2A facility. However, Tetra4 wants to future-proof our work to allow for a potential 24MW from Phase 2A and 2B.

The scope of work, however, requires the supply of power as follows:

1. Power Supply from grid
    a. Process plant contractor shall consider a single power line of 132 kV
    b. Dedicated to Phase 2 Plant. All the connections to the grid will be managed by Tetra4, so the battery limit will be at the gantry of HV Switch Yard.
    c. Process plant contractor will consider a HV Switch Yard with all the equipment needed (circuit breakers, measurements equipment, bus bars, plus control/protection equipment) and the downstream 132/11 kV transformer.
    d. Location of this HV Switch Yard will probably be where it is currently foreseen the Phase 1 Switch Yard.
    e. From the HV Switch Yard a MV (11 kV) cable will run to the Phase 2 Plant substation that will include also a 33 kV switchgear
2. Power Generation:
    a. Tetra4 would like to investigate the feasibility of power generation for the Plant, in order to have a cost estimate only at this stage.
    b. The power generation will cover the power needs of Phase 2 Plant (2A and 2B), plus export.
    c. For 2A an open cycle is foreseen to cover the 2A power needs only, while for 2B conversion to combined cycle will be foreseen allowing also export (final configuration ~60 MW).
    d. Part of the produced LNG will be used for this power generation.
    e. This investigation shall not be considered in the current design documents by the Process plant contractor, that will consider the base option of power supply from grid. This investigation is for cost estimate purpose only at this stage.

What Tetra4 needs is a feasibility and cost estimates associated with Item 1 above. **This is needed this by 31 March 2021**.

2 NETWORK INFORMATION

2.1 Existing Network

The proposed location for the Planned Gas Processing Plant facility (Virginia Site Location) is given in Figure 1 where the 44kV (Pink), some 132kV (blue) and 400kV (Green), lines can be seen.

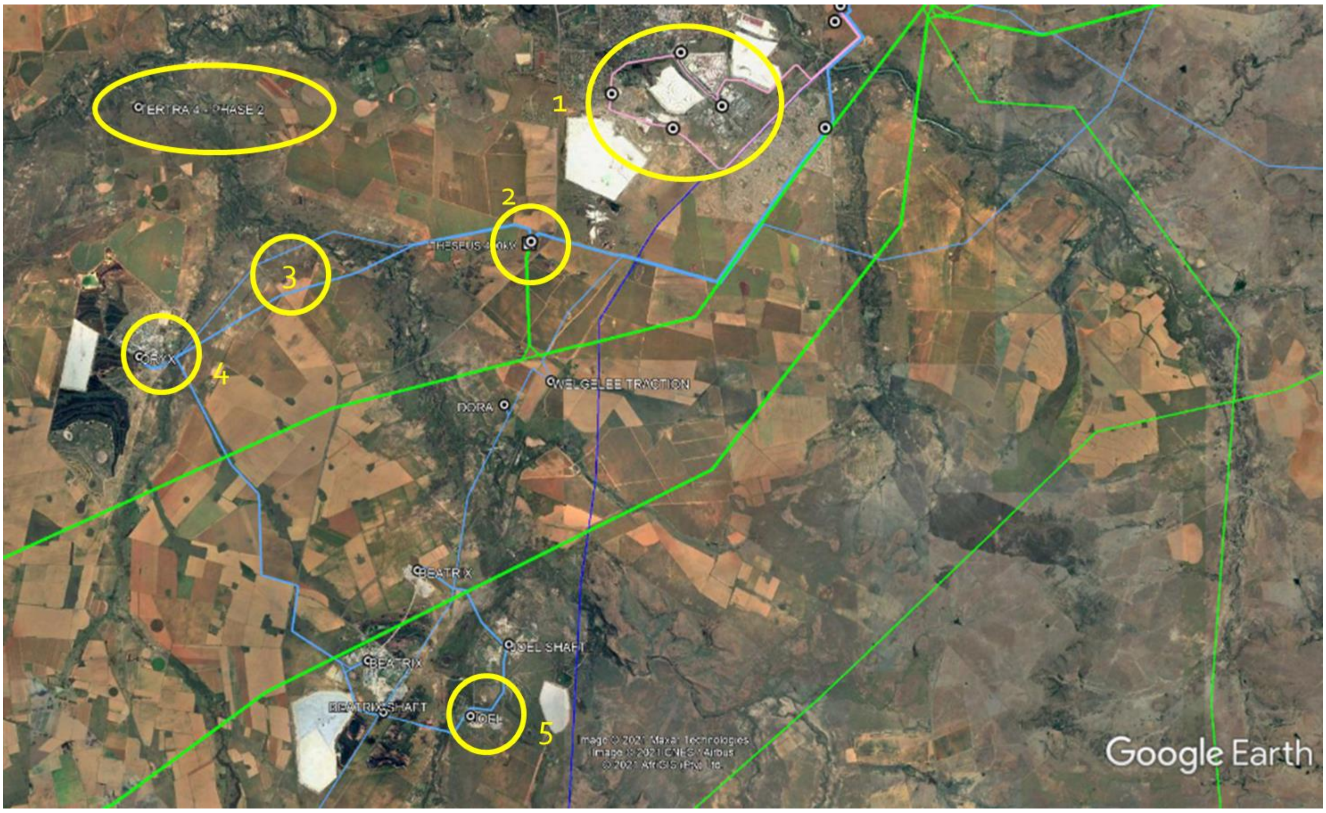


Figure 1: Location of Tetra4 Planned Gas Processing Plant Facility and existing electrical network

2.2 Supply Sources

The following table highlights the possible supply sources which have been identified in proximity to the planned Tetra4 Phase 2 Gas Processing Plant.

Table 1: High level Supply Options in proximity to the Planned Gas Processing Facility

SOURCE	VOLTAGE (kV)	LINE DISTANCE (km)	ADVANTAGES	DISADVANTANGES
1 (Mining Area)	44	15 -20	None	The 44kV network in this identified area is supplying existing mine; For a fixed power (60 MW) and line size, this voltage represents the least efficient option (low transfer capacity and high losses after 33 kV)

2 (Theseus Substation)	400	14	Strongest source of all in the area Two voltage sources (400 and 132 kV); High reliability (Transmission substation); Highest power transfer capacity (for a given line size)	Transmission substation is more stringent; Requires construction off 2x400 kV feeder bays; Requires a double circuit 400 kV line and a 400 kV stepdown substation at Tetra4; 400 kV connection is more expensive and requires more space.
2 (Theseus Substation)	132	14	Strongest source of all in the area Two voltage sources (400 and 132 kV) High reliability (Transmission substation)	Transmission substation is more stringent; Requires construction of 2x132 kV feeder bays and substation expansion
3 (Theseus - Oryx 132kV lines)	132	7	Does not require feeder bays at Theseus or Oryx; Requires a distribution substation; Has the shortest line requirement;	Could be the most demanding in terms of protection cost (may require works at Theseus and at Oryx for protection reliability and operation)
4 (Oryx Substation)	132	10	Second shortest line	Requires additional 2x132 kV feeder bays at Oryx Substation
4 (Oryx Substation)	33	10	Second shortest line	For a fixed power (60 MW) and line size, this voltage represents the least efficient option (low transfer capacity and high losses)
5 (Joel Substation)	132	30	There could be capacity at Joel and the possibility of being supplied at 132kV voltage means a strong source	Longest Distance, Requires additional 2x132 kV feeder bays at Joel Substation

Notes:

- Eskom Distribution's most reliable network is 132kV and because this is their backbone system voltage, they prefer ensuring that it operates in a ring formation, so that they can guarantee the reliability of supply that they charge their premium clients.
- Due to this, they always consider either a loop in loop out arrangement for a Premium supply or a double circuit line supplying their clients.
- This also means that both at the client's and at the sending substation, there will be a requirement for 2 x 132kV line bays as well.

2.3 Site Visits

The idea behind the site visits was to ensure that, prior to the studies being undertaken, to investigate the various connection options, a physical site visit would help in confirming certain information. There are also site-specific issues that can be seen and understood through being on site instead of use of drawings or information from Eskom Engineers.

At this stage, the 44kV network, which is represented by Source 1 (Mining Area) was discarded from the options for a site visit, primarily because, 44kV is not a strong enough voltage source for Tetra4's Phase 2 development to be fed with. This system voltage would have presented voltage drop problems for Tetra4's Phase 2 substation, given the size of the load and the distances to transmit the power at 44kV.

The site visits were planned for the following substations:

- Theseus Substation (400kV and 132kV)
- Joel Substation (132kV)
- Oryx Substation (132kV and 33kV) (Already Visited numerous times as part of Tetra 4 Phase 1)

2.3.1 Theseus Substation

Theseus Substation is a Main Transmission Substation and due to this, its considered a National Key point. Eskom has very strict requirements and visitation rules regarding accessing of these substations which are National Key points.

Due to Theseus Substation being a National Key Point, Umbono Engineering was not granted access to the substation due to the laborious process of application to get access to the substation. Also, Eskom Transmission highlighted that, access could only be granted if Umbono Engineering was working on an actual project, not doing an investigation for a planned project.

So Umbono Engineering sourced information from Google Earth to get a view of the layout of the substation and also get to see the infrastructure (powerlines and available High Voltage Bays). Figure 2 below shows Theseus substation equipment layout.

Figure 2: Google Earth Picture of Theseus Substation

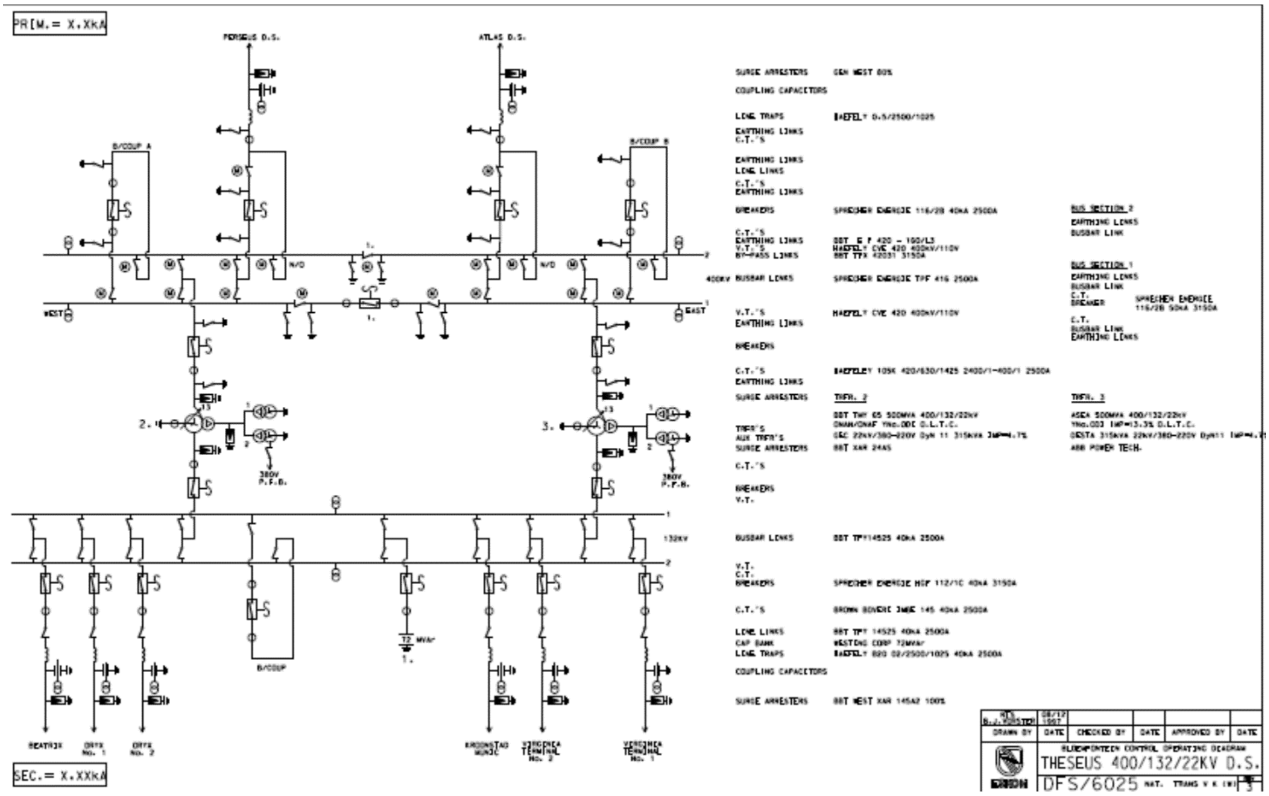


Figure 3: Theseus Substation Single Line Diagram

The Chief Planner for Eskom Transmission was contacted and information was sourced from them regarding the available capacity at Theseus substation, as means of understanding whether it would be feasible to integrate Tetra4 Phase 2's plant and supply its power requirements from here with also the possibility of injecting power generated from the plant into Theseus.

The answer given was that there was plenty of capacity to either have Theseus Substation as an exporter or importer of power to Tetra4's planned plant. This capacity was available both at 400kV or at 132kV. Figure 3 above also shows connected on the 132kV busbar are 2 x 500MVA transformers to confirm the availability of capacity at this substation.

The other aspect which was identified from doing a visual inspection of the substation and confirmed by Google earth was that, line crosses outside of the substation, should the connection to Tetra4 come from the 132kV bay, were inevitable. Line crosses outside a substation are not a preferred manner in which to exit of enter a substation. At Theseus there will be a minimum of 3 x 132kV crosses which will pose some technical and financial challenges.

2.3.2 Joel Substation

Joel Substation is a Distribution Substation that is a dedicated substation built to supply Harmony mine's (or one of) operations in the Virginia area. The incoming voltage at Joel substation is 132kV and hence the interest to possibly supply Tetra4's Phase 2. Figures 4 and 5 show both the Google Earth, the Single Line Diagram for Joel substation. The site visit pictures are shown in Appendix A: Joel Substation site pictures.

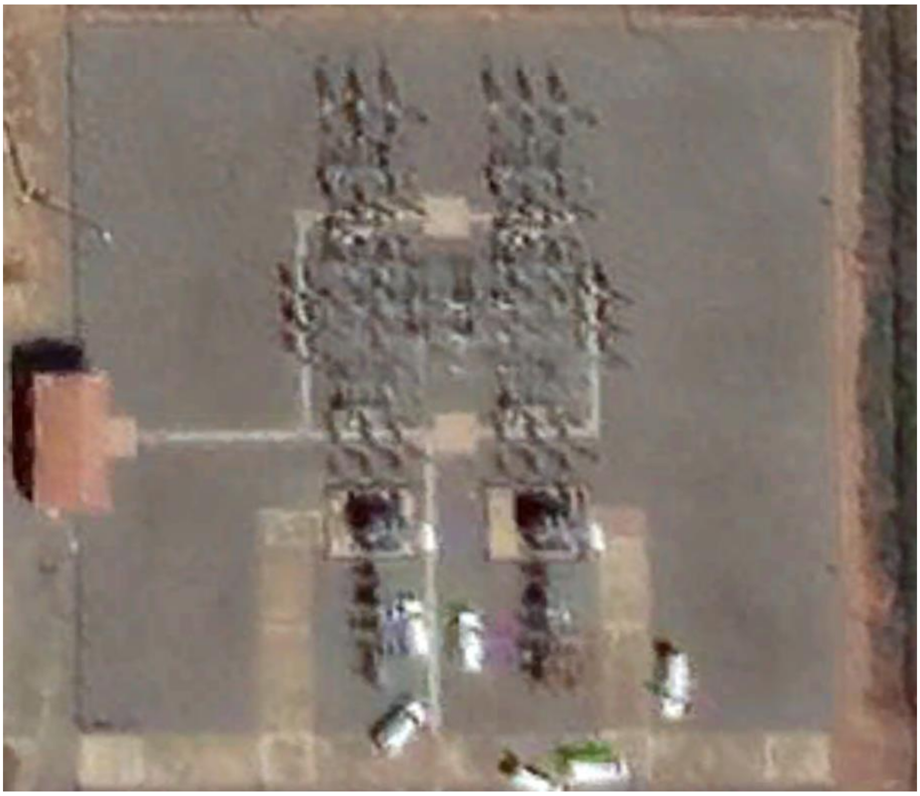


Figure 4: Google Earth Picture of Joel Substation

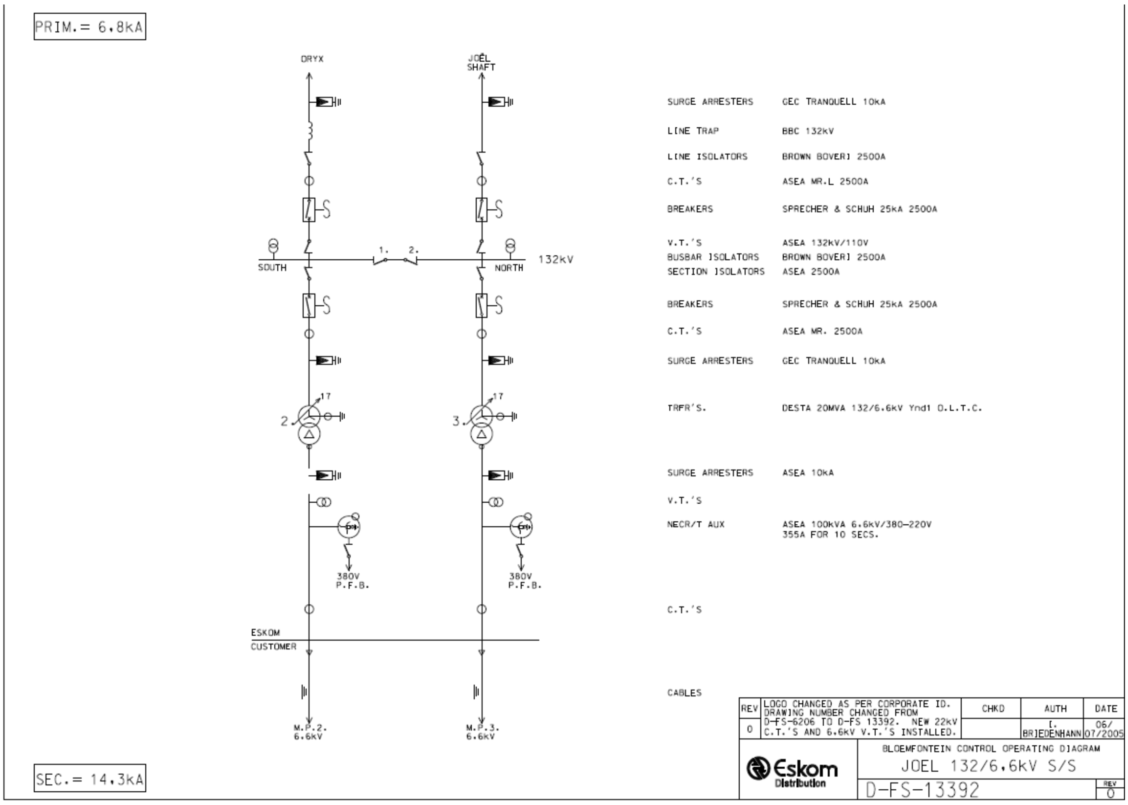


Figure 5: Joel Substation Single Line Diagram

It was identified that there are very limited options with regards to the possibility of either getting supply from this substation of injecting power into it. The substation is a customer dedicated substation as a result, the capacity of the transformers is tailored to the customer needs along with the size of the substation. Outside of the substation there are overhead lines which will also lead to powerline crossings immediately outside the substation. The addition of 2 x 132kV line bays will also require that the substation be extended along with its control room.

The existing capacity of 20MVA firm is only for the existing loads at the substation. Should it be considered, it would be more for a loop-in loop-out arrangement not for consumption or supply at the substation itself.

2.3.3 Oryx Substation

Figure 6: Oryx Substation Google Earth Picture

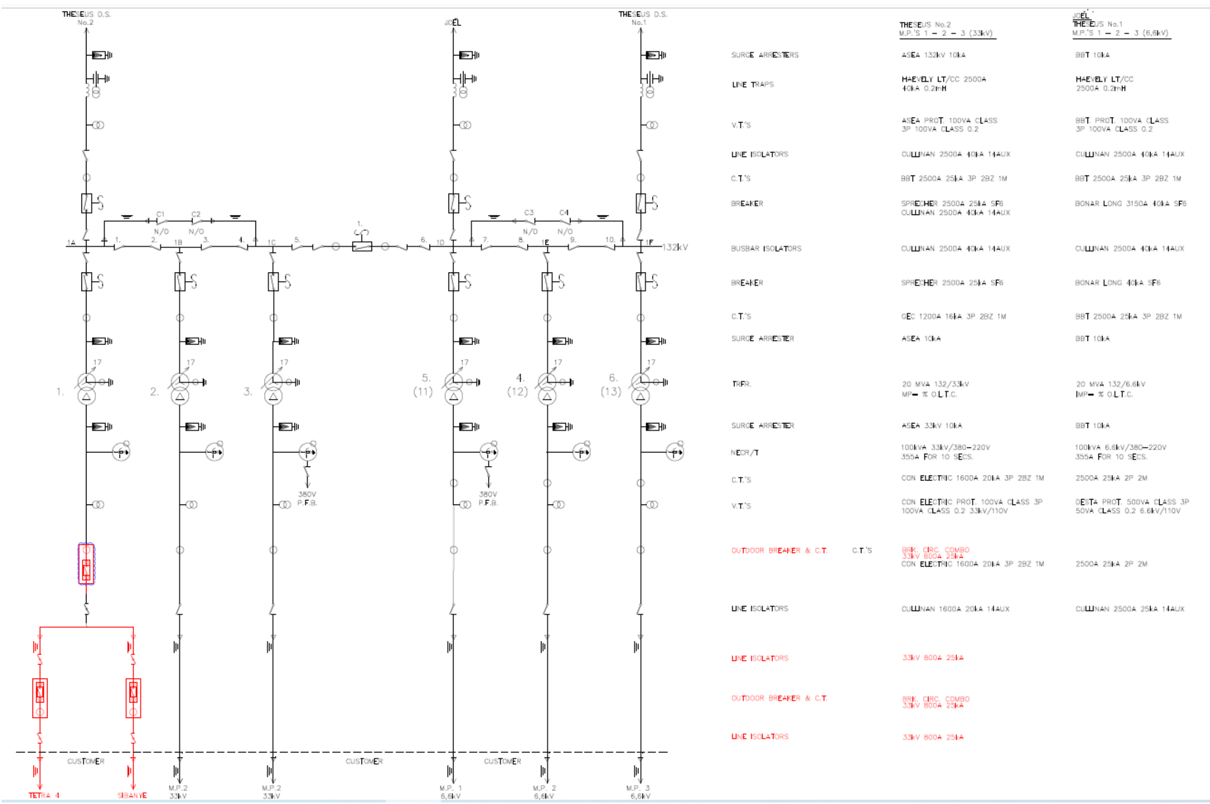


Figure 7: Oryx Substation Single Line Diagram

Oryx substation is already a substation where work is being done at, where the power supply for phase 1 of Tetra4's Gas Processing Plant. This information we already have on this substation already highlights some of the challenges and of advantages of being supplied from Oryx substation.

The biggest drawback is the fact that should an expansion take place, it would require 2 x 132kV completely new line bays, an extension to the existing control room and also possible underpasses or crossings of the existing 132kV lines coming into the substation.

Should the supply be coming from the 33kV busbar, there would be some difficulties coming out of the substation and additional transformers would have to be added to inject the power from the new plant into the grid, or to make capacity available for supply of the new Tetra4 development.

3 DESIGN INFORMATION

3.1 Overhead Line Design Information

The key area of interest was the Theseus Substation, Oryx Substation and Joel Substation (But this also was not an attractive option because of the distance). This led to the interest in acquiring the design information for the existing powerlines connecting these above-mentioned substations, with the possibility of also looking at looping in these powerlines, should those options be technical and financially more attractive than others.

Table 2 below presents the design information of the powerlines of interest.

Table 2: Design information for powerlines of interest

Line Name	Theseus-Oryx 132kV Line 1	Theseus-Oryx 132kV Line 2	Joel-Oryx 132kV Line
Phase Conductor:	Single ACSR Bear Conductor	Twin ACSR Bear Conductor	Single ACSR Bear Conductor
Shield Wire:	2 x 7/3.35 steel shield wire	2 x 7/3.35 steel shield wire	2 x 7/3.35 steel shield wire
Tower Type:	Tower Type: 226A Lattice Portal Suspensions towers; 226B Lattice Portal guyed strain towers; Variety of self-supporting Lattice strain towers	224 Self Supporting Lattice Tower Series	Tower Type: 226A Lattice Portal Suspensions towers; 226B Lattice Portal guyed strain towers; Variety of self-supporting Lattice strain towers
Length:	11.8km	12.4km	16.3km

4 NETWORK STUDIES

4.1 Study Area

Figure 8 below shows the study area and the following table shows why certain options were rejected and why others were taken through to modelling.

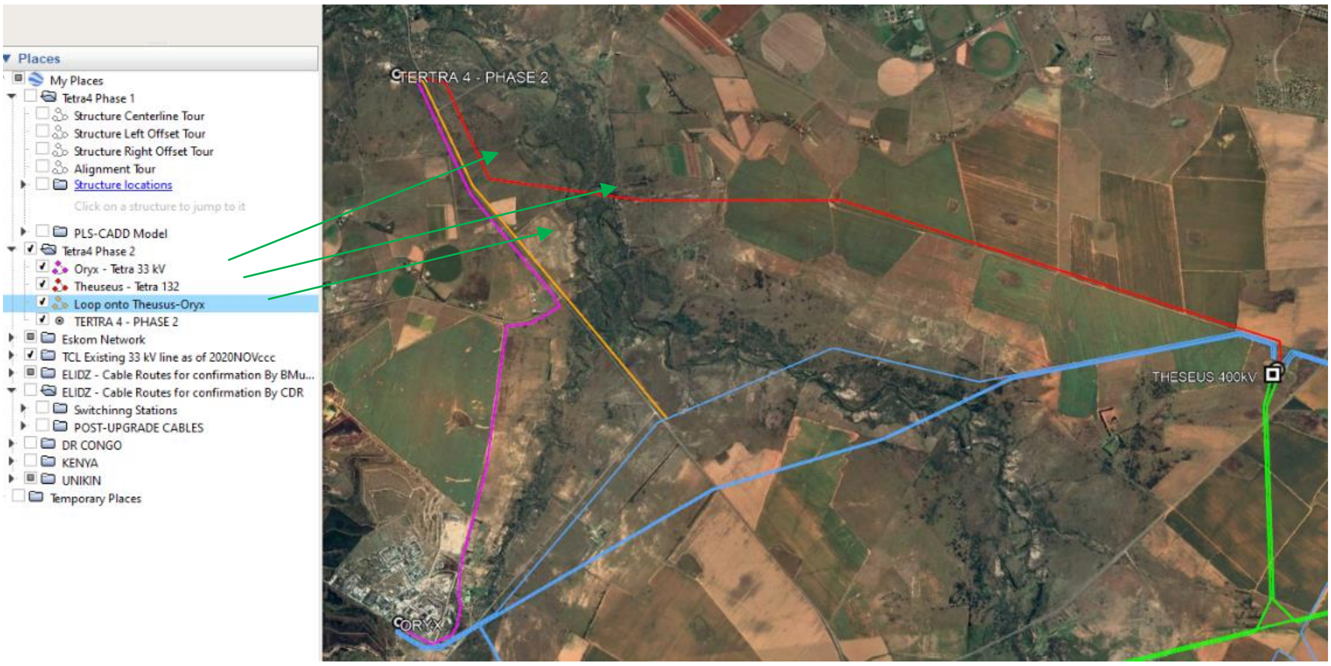


Figure 8: Study Area for Modeling

Table 3: Source options and why they are rejected or Supported

SOURCE	VOLTAGE (kV)	LINE DISTANCE (km)	ADVANTAGES	DISADVANTANGES	REJECTED/CONSIDERED FOR NEXT PHASE?
1	44	15 -20	None	Supplying existing mine; For a fixed power (60 MW) and line size, this voltage represents the least efficient option (low transfer capacity and high losses after 33 kV)	**REJECTED** Due to the low transfer capacity of the 44kV lines versus what is required for the phase 2 operations. This option was not considered further in the studies
2	400	14	Strongest source of all in the area Two voltage sources (400 and 132 kV);	Transmission substation is more stringent; Requires construction off 2x400 kV feeder bays;	**REJECTED** The connection on the 400kV busbar side has much higher cost implications for the establishment of the 2 x 400kV

			High reliability (Transmission substation); Highest power transfer capacity (for a given line size)	Requires a double circuit 400 kV line and a 400 kV stepdown substation at Tetra; 400 kV connection is more expensive and requires more space.	line bays for the lines going to Tetra4's phase 2 site. The difficulty to get permission to do self-build works at a Transmission substation on the Transmission Voltage side, makes this exercise even more unattractive. Also, on the Tetra4's site, there will be a need to establish a 400kV to 6.6kV transformation substation, which will have very high cost implications.
2	132	14	Strongest source of all in the area Two voltage sources (400 and 132 kV) High reliability (Transmission substation)	Transmission substation is more stringent; Requires construction off 2x132 kV feeder bays;	**CONSIDERED FOR NEXT PHASE** This option is a better option than 1 and 2 due to the fact that it will be a connection on the 132kV side of the Substation. The only option is to extend the 132kV busbar which will necessitate either and underpass or an overpass over the existing powerlines coming out of the 132kV side of the substation. This will have both high cost implications and constructability challenges and there may be requirements for outages and working in proximity to live powerlines. Also, there are costs of establishing 2 x 132kV line bays and costs of building 14km long 132kV Double circuit line to get to Tetra4's Phase 2 site.

3	132	3.5	Does not require feeder bays at Theseus or Oryx; Requires a distribution substation; Has the shortest line requirement;	Could be the most demanding in terms of protection cost (may require works at Theseus and at Oryx for protection reliability and operation)	**CONSIDERED FOR NEXT PHASE** This option considers use of a very stable voltage at 132kV as the source, these powerlines are coming from a main transmission substation which has been confirmed to have the required transfer capacity. This option eliminates the need to establish 2 x 132kV busbars at Theseus substation, but only at Tetra4 substation. The length of the powerlines to be constructed is the shortest of all the options. This Option has 2 powerlines for consideration, not just 1.
4	132	10	Second shortest line	Requires additional 2x132 kV feeder bays	**CONSIDERED FOR NEXT PHASE** This option, as much as it will be connecting on the 132kV busbar side of Oryx Substation, it will require 2 x 132kV busbars, which will require a major extension of Oryx substation, not only its HV Yard, but also its control room, which would be a very costly exercise.
4	33	10	Second shortest line	For a fixed power (60 MW) and line size, this voltage represents the least efficient option (low transfer capacity and high losses)	**REJECTED** Extremely low transfer capacity at 33kV and the available capacity at the substation has been maxed out by phase 1 and this option would require a massive upgrade of the substation, with new transformers to create the required capacity and it would be extremely expensive.

4.2 Existing Network Design Parameters

The following figure and tables highlight the design parameters for setting up the models.

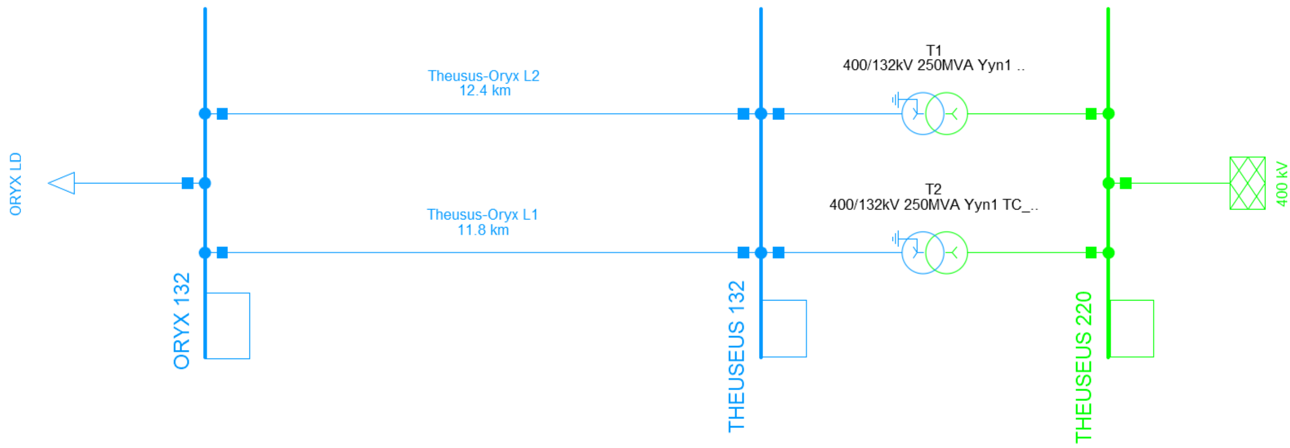


Figure 9: Base Case Model

The base case model looked at the two lines between Theseus substation and Oryx substation, namely Theseus-Oryx L1cand Theseus-Oryx L2. Their modeling parameters are as presented in table 4 below.

Table 4: Modeling parameters for the simulated powerlines

	Unit	Theseus – Oryx L1	Theseus – Oryx L2
Distance	*km*	11.8	12.4
Conductor	*ACSR*	1xBEAR	2xBEAR
Current @70deg.	*A*	770	1540
Voltage	*kV*	132	132
Thermal Limit	*MVA*	176	352

The total installed and modelled capacity at Oryx Substation is as follows:

- 132/6.6 kV – 3x20 MVA ➔ 60 MVA;
- 132/33 kV – 3x20 MVA ➔ 60 MVA;
- **TOTAL: 120 MVA**

4.3 Modelled Scenarios and Results without Tetra4 Phase 2

The following Modelling is meant to establish the transfer capacity of each of the two powerlines, when the other powerline is off. This model doesn't cater to the creation and supply of Tetra4 Phase 2 yet.

4.3.1 Loss of Theseus-Oryx L1

Figure 10 below shows the model and its results when loss of Theseus-Oryx L1 is modelled.

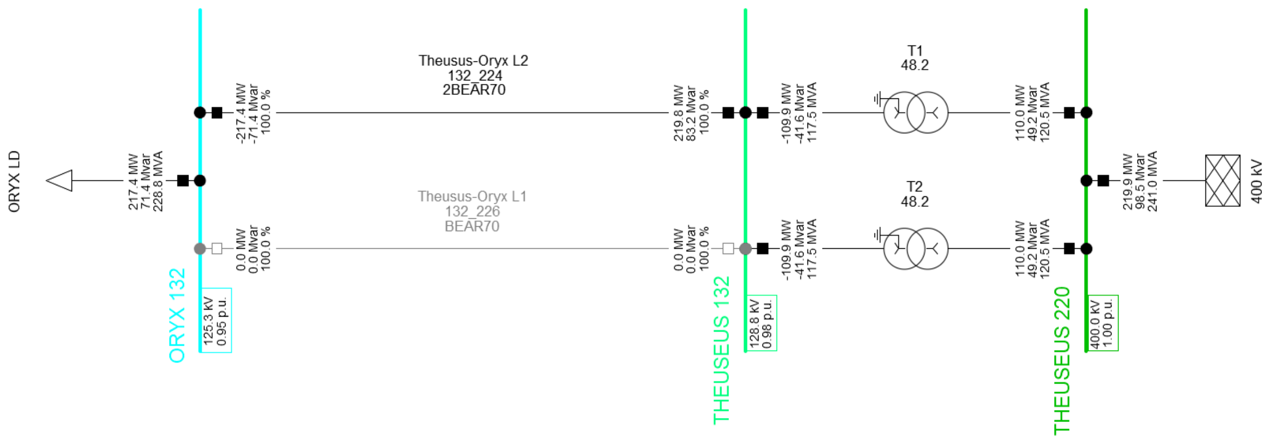


Figure 10: Loss of Theseus-Oryx L1 Modelled

Table 5 below shows the results of the modelled loss of Theseus-Oryx L1.

Table 5: Modeling results for the Loss of Theseus-Oryx L1

	Unit	L1	L2
Distance	*km*	11.8	12.4
Conductor	*ACSR*	1xBEAR	2xBEAR
Current	*A*	770	1540
Voltage	*kV*	132	132
Thermal Limit	*MVA*	176	352
Actual Limit at 0.95 p.u.	*MVA*	176	229

The modelled scenario is as follows:

- Theseus-Oryx L1 is out of service and Oryx is supplied by Theseus-Oryx L2 only.
- Theseus-Oryx L2 alone can supply up to 229 MVA (more than Oryx's 120 MVA installed capacity);
- Some of Theseus-Oryx L2 capacity probably used to back-feed (when needed) to Beatrix, Joel, etc.

4.3.2 Loss of Theseus-Oryx L2

Figure 11 below shows the model and its results when loss of Theseus-Oryx L2 is modelled.

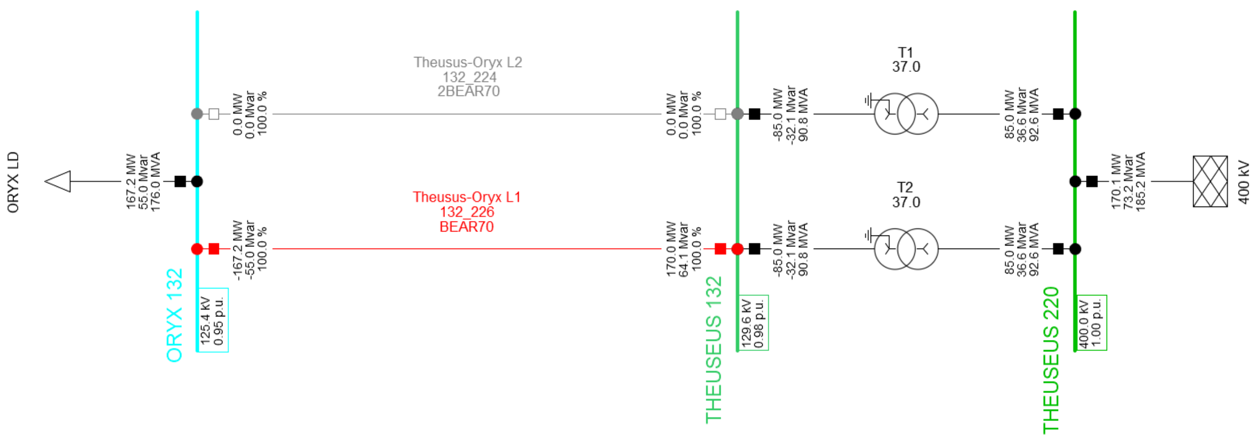


Figure 11: Loss of Theseus-Oryx L2 Modelled

Table 6 below shows the results of the modelled loss of Theseus-Oryx L2.

Table 6: Modeling results for the Loss of Theseus-Oryx L2

	Unit	L1	L2
Distance	*km*	11.8	12.4
Conductor	*ACSR*	1xBEAR	2xBEAR
Current	*A*	770	1540
Voltage	*kV*	132	132
Thermal Limit	*MVA*	176	352
Actual Limit at 0.95 p.u.	*MVA*	176	

The modelled scenario is as follows:

- L2 is out of service and Oryx is supplied by L1 only.
- L1 alone can supply up to 176 MVA (more than Oryx's 120 MVA installed capacity);
- Some of L1 capacity probably used to back-feed (when needed) to Beatrix, Joel, etc.

4.4 Modelled Scenarios and Results with Tetra4 Phase 2

The following Modelling is meant to establish the transfer capacity of each of the two powerlines, when the other powerline is on and off, while catering to the creation and supply of and or generation from Tetra4 Phase 2.

4.4.1 Supply of Tetra4 from Theseus-Oryx L2 (No Generation at Tetra4 and Both Lines (L1 and L2) in Service)

The modelled scenario is as follows:

- Fixed load at Oryx at 120 MVA (full capacity)
- Tetra: Load at 25MVA, No generation

Loop in – loop out line parameters

- Tower: 247 (double circuit)
- Phase conductor: 2xBEAR;
- Earth wire: 2x7/3.35 steel

Figure 12 below shows the model and its results when Tetra4 is supplied from Theseus-Oryx L2 shown in figure 13.

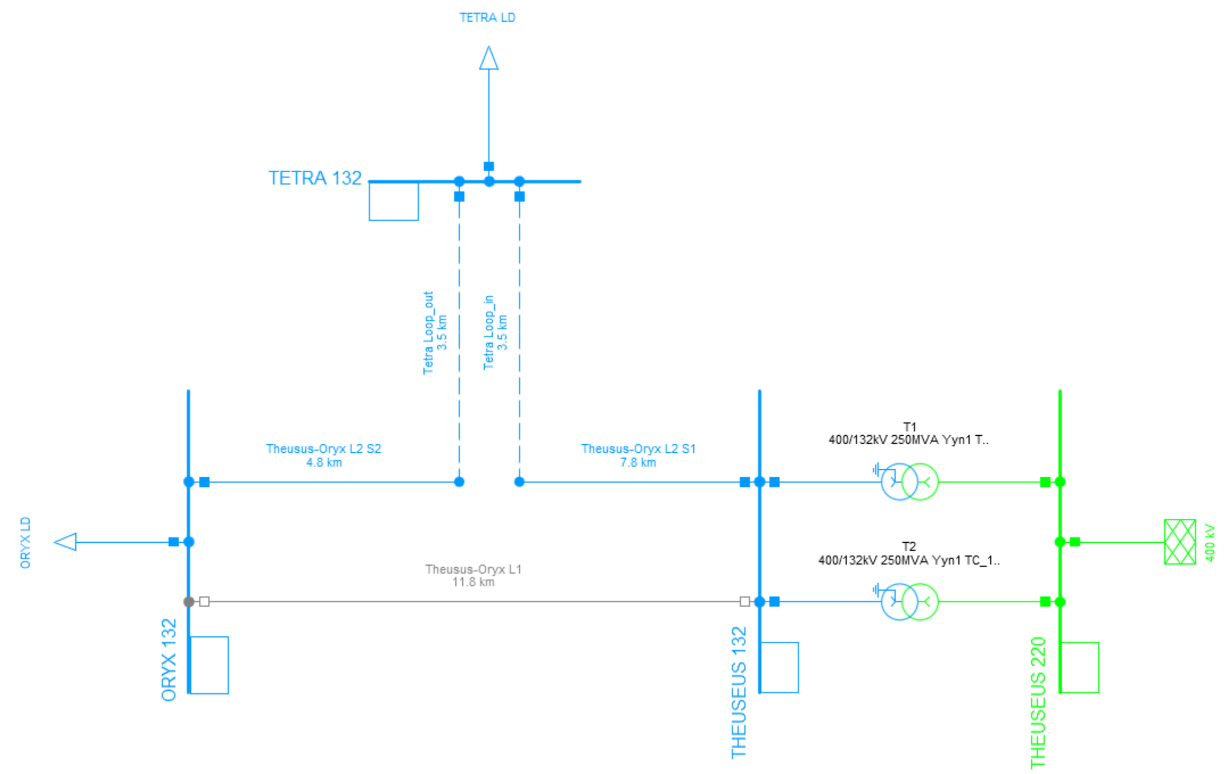


Figure 12: Tetra4 supplied from Theseus-Oryx L2

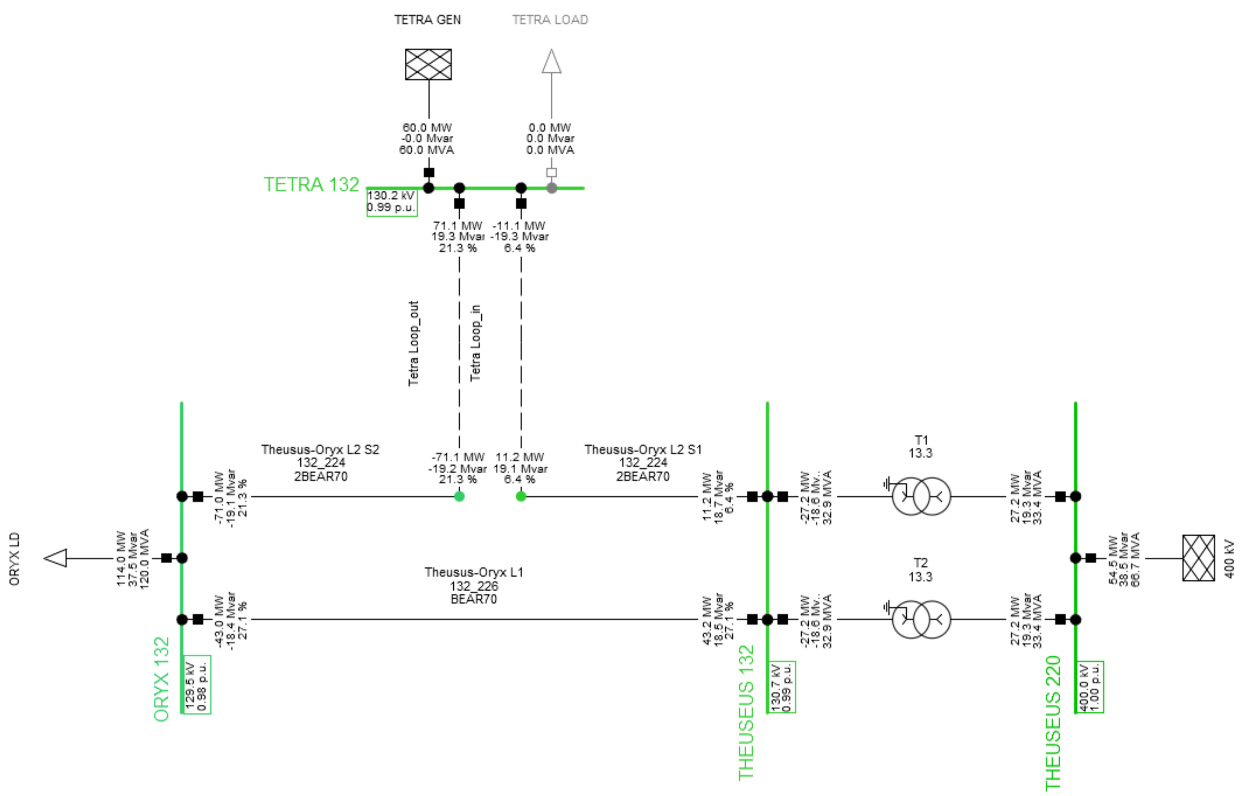


Figure 13: Tetra4 supplied from Theseus-Oryx L2, and Theseus-Oryx L1 is online

Table 7 below shows the results of the modelled supply of Tetra4 from Theseus-Oryx L2.

Table 7: Modeling results for the supply of Tetra4 from Theseus-Oryx L2

	Unit	L1	L2
Distance	*km*	11.8	**12.4**
Conductor	*ACSR*	1xBEAR	**2xBEAR**
Current	*A*	770	**1540**
Voltage	*kV*	132	**132**
Thermal Limit	*MVA*	176	**352**
Actual Limit at 0.95 p.u.	*MVA*	176	**229**

All lines in service

Observe network:

- ✓ **All voltages higher that 0.95 p.u.;**
- ✓ **All line and transformer loading <100%**

4.4.2 Supply of Tetra4 from Oryx-Tetra L2 (No Generation at Tetra4 and Loss of Theseus-Tetra4 L2)

The modelled scenario is as follows:

- Fixed load at Oryx at 120 MVA (full capacity)
- Tetra: Load at 25MVA, No generation

Loop in – loop out line parameters

- Tower: 247 (double circuit)
- Phase conductor: 2xBEAR;
- Earth wire: 2x7/3.35 steel

Figure 14 below shows the model with Theseus-Tetra4 L2 out of service and its results when Tetra4 is supplied from Oryx-Tetra L2 shown in figure 15.

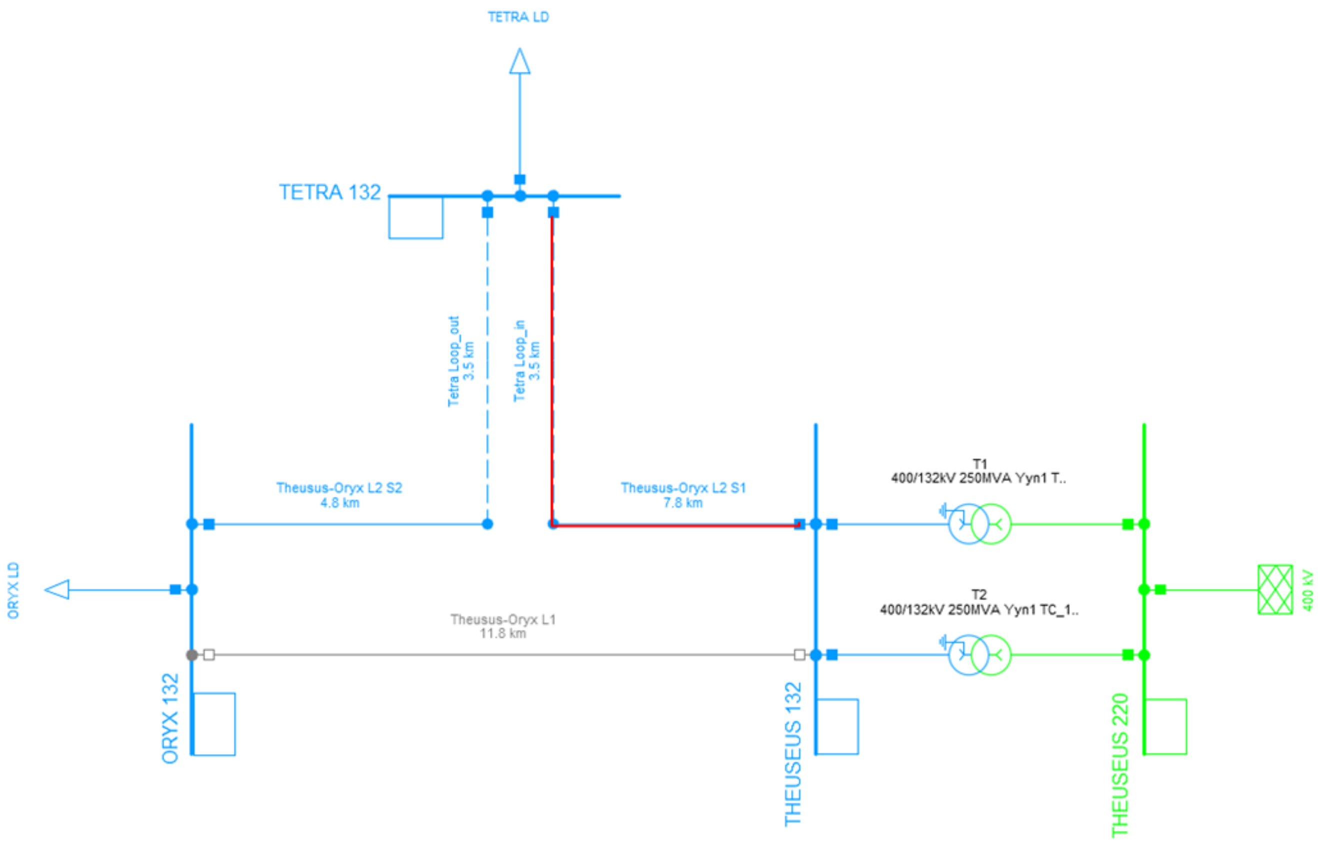


Figure 14: Tetra4 supplied from Oryx-Tetra L2 and Theseus-Tetra4 L2 is Out of Service

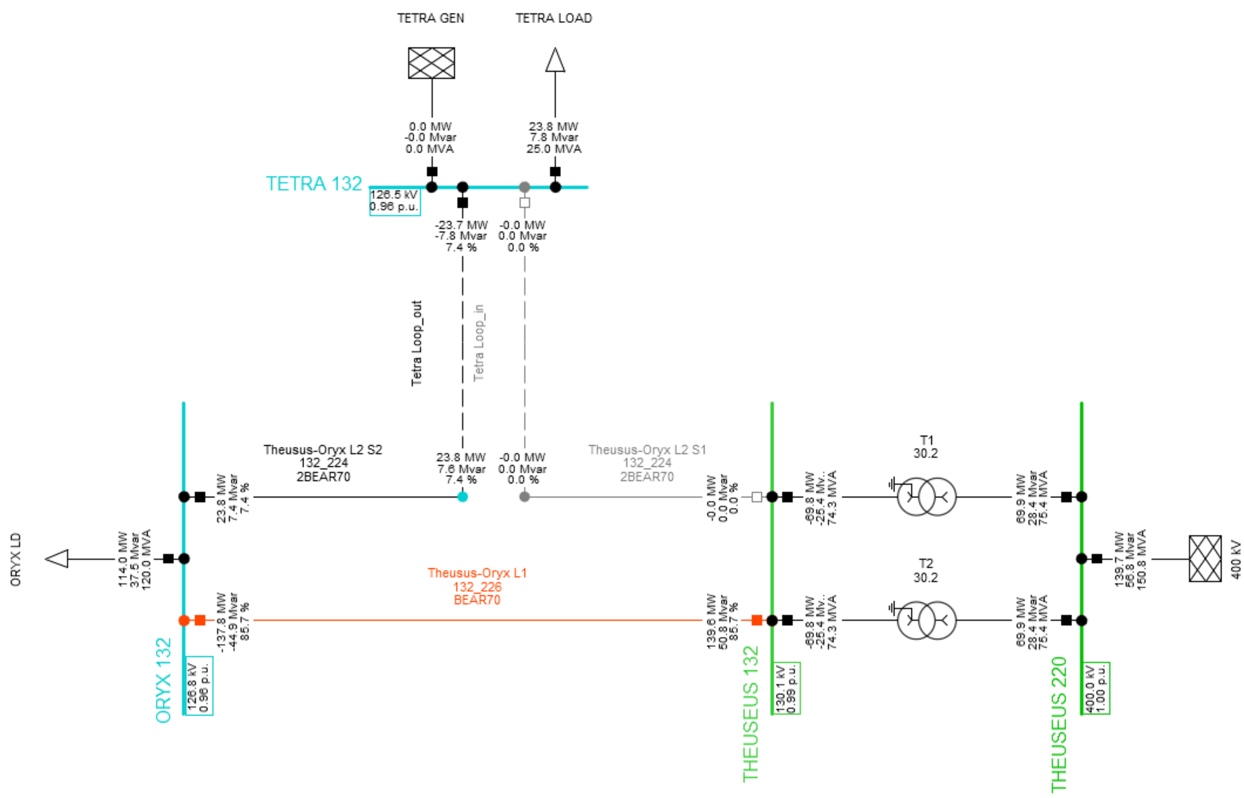


Figure 15: Tetra4 supplied from Oryx-Tetra L2, and Theseus-Tetra4 L2 is out of service (Full Load at Tetra4 and No Generation)

All lines in service

Observe network:

- ✓ **All voltages higher that 0.95 p.u.;**
- ✓ **All line and transformer loading <100%**

4.4.3 Supply of Tetra4 from Oryx-Tetra L2 (60MW Generation, no load at Tetra4 and Loss of Theseus-Tetra4 L2)

The modelled scenario is as follows:

- Fixed load at Oryx at 120 MVA (full capacity)
- Tetra: No Load, Generation at 60 MW

Loop in – loop out line parameters

- Tower: 247 (double circuit)
- Phase conductor: 2xBEAR;
- Earth wire: 2x7/3.35 steel

Figure 16 below shows the model with Theseus-Tetra4 L2 out of service and its results when Tetra4 is supplied from Oryx-Tetra L2 shown in figure 17.

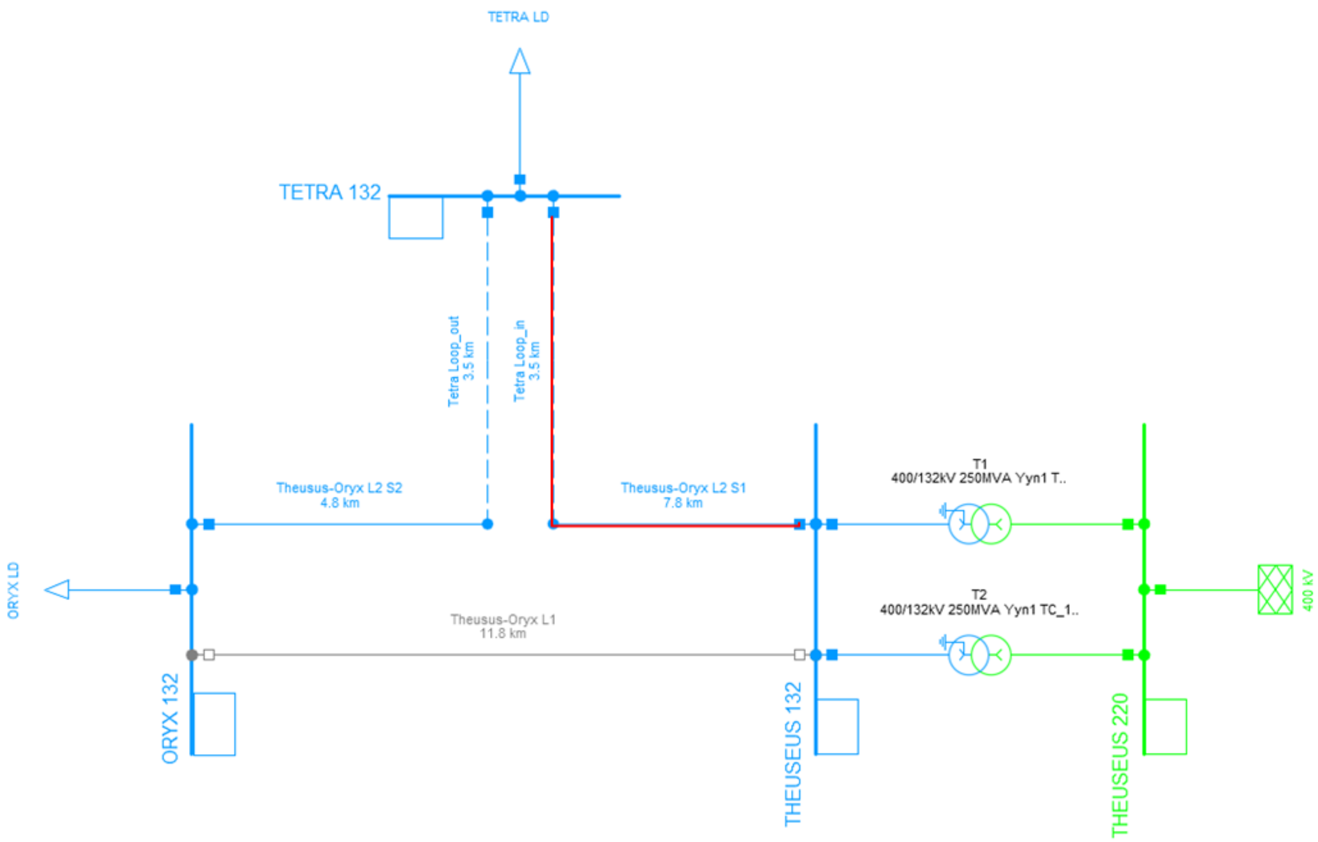


Figure 16: Tetra4 supplied from Oryx-Tetra L2 and Theseus Tetra4 L2 is Out of Service

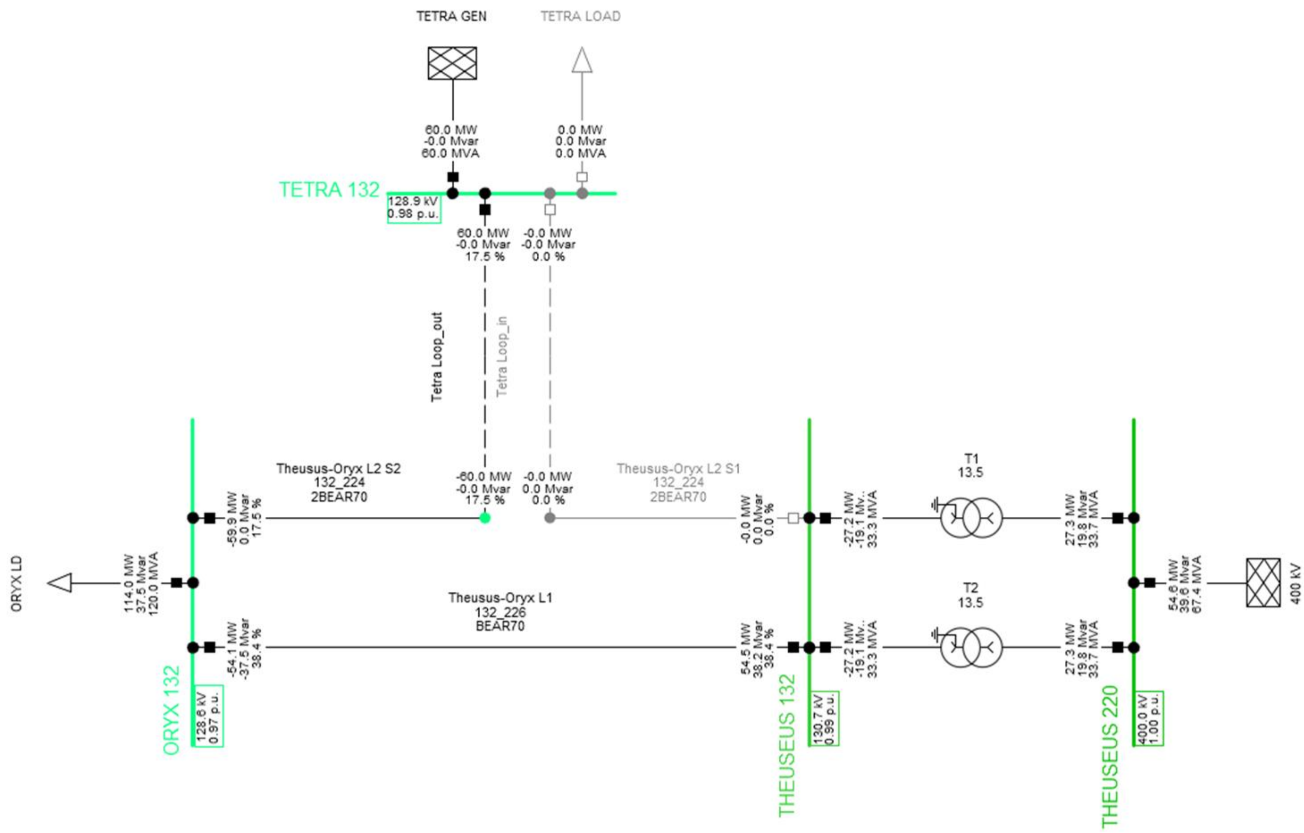


Figure 17: Tetra4 supplied from Oryx-Tetra L2, and Theseus-Tetra4 is out of service (No Load at Tetra4 but 60MW Generation)

All lines in service

Observe network:

- ✓ **All voltages higher that 0.95 p.u.;**
- ✓ **All line and transformer loading <100%**

4.4.4 Supply of Tetra4 from Theseus-Tetra L2 (60MW Generation, no load at Tetra4 and Loss of Oryx-Tetra4 L2)

The modelled scenario is as follows:

- Fixed load at Oryx at 120 MVA (full capacity)
- Tetra: No Load, Generation at 60 MW

Loop in – loop out line parameters

- Tower: 247 (double circuit)
- Phase conductor: 2xBEAR;
- Earth wire: 2x7/3.35 steel

Figure 18 below shows the model, with Oryx-Tetra4 L2 out of service and its results when Tetra4 is supplied from Theseus-Tetra L2 shown in figure 19.

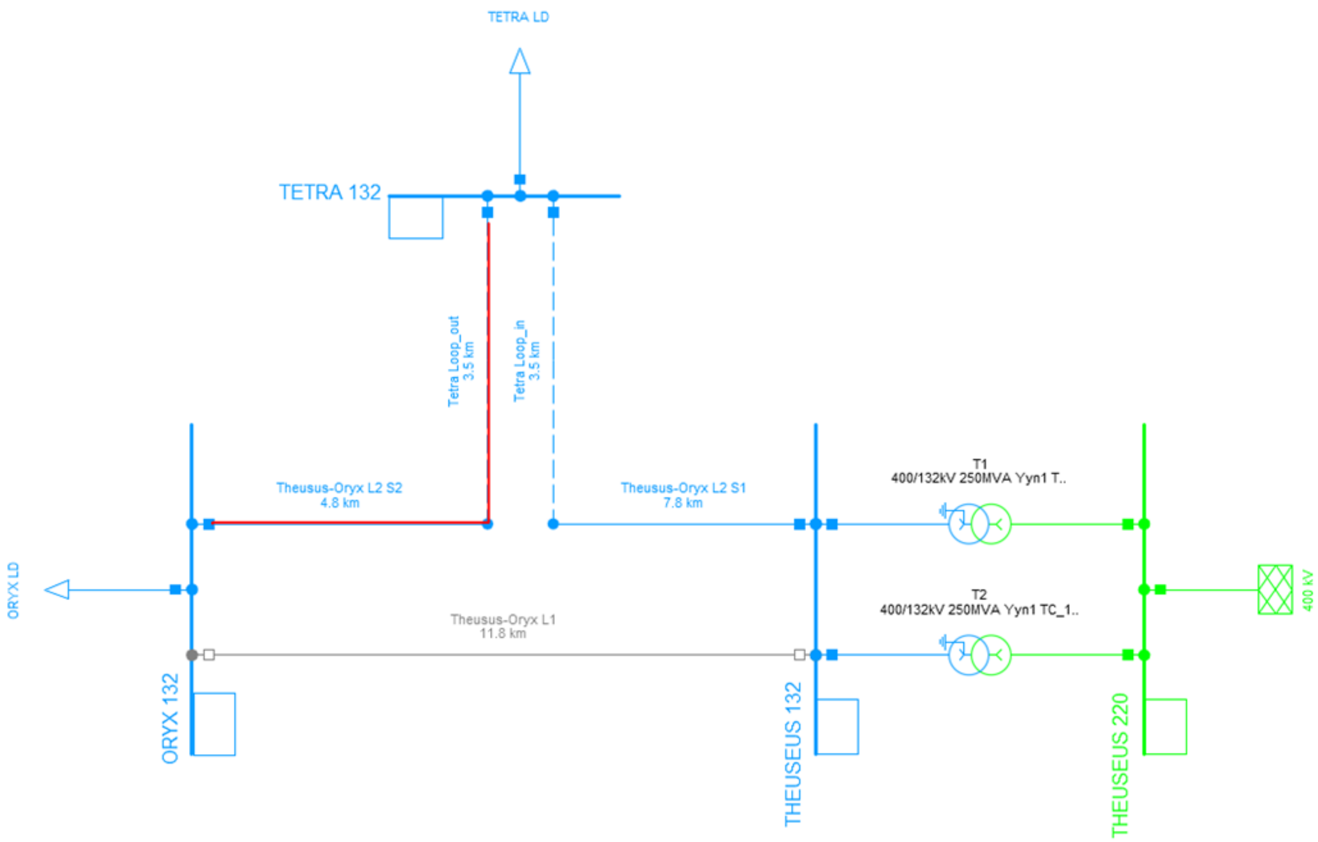


Figure 18: Tetra4 supplied from Theseus-Tetra L2 and Oryx-Tetra4 L2 is Out of Service

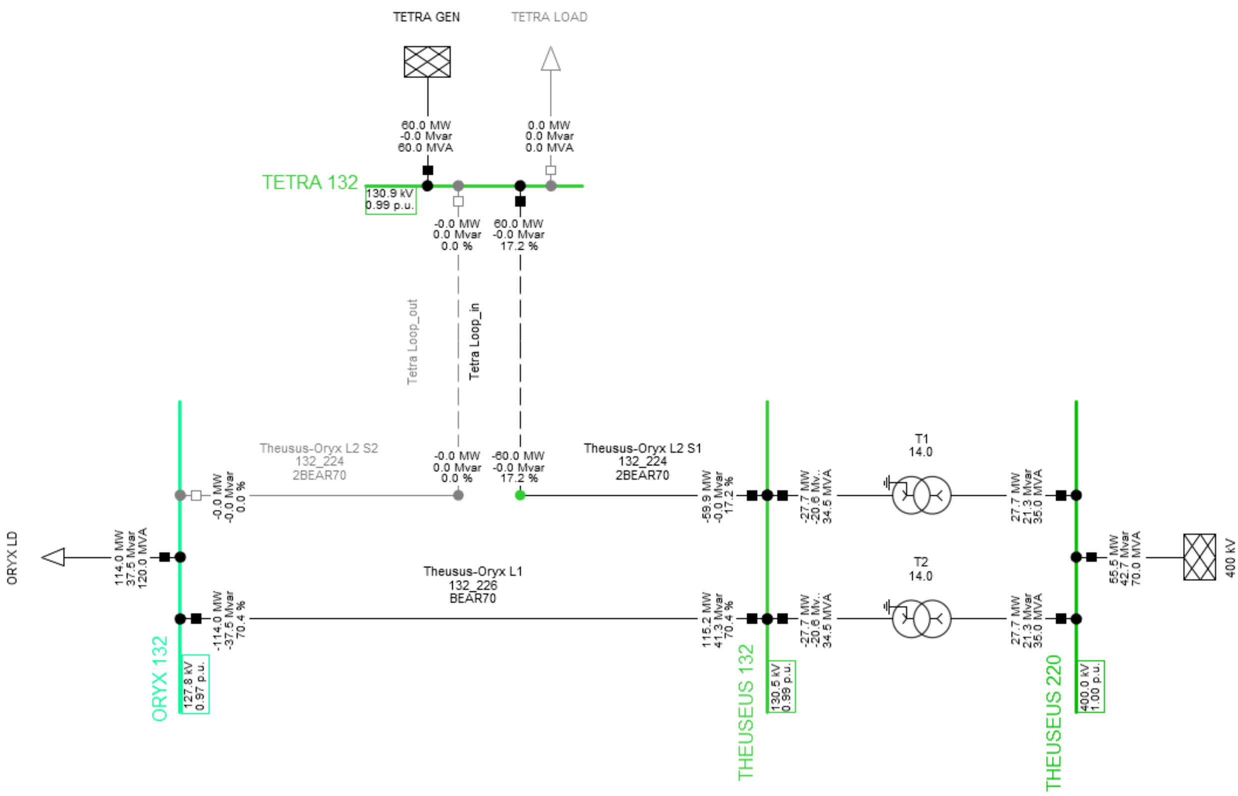


Figure 19: Tetra4 supplied from Theseus-Tetra L2, and Oryx-Tetra4 L2 is out of service (No Load at Tetra4 but 60MW Generation)

All lines in service

Observe network:

- ✓ **All voltages higher that 0.95 p.u.;**
- ✓ **All line and transformer loading <100%**

4.4.5 Supply of Tetra4 from Theseus-Oryx L1 (No Generation at Tetra4 and Both Lines (L1 and L2) in Service)

The modelled scenario is as follows:

- Fixed load at Oryx at 120 MVA (full capacity)
- Tetra: Load at 25MVA, No generation

Loop in – loop out line parameters

- Tower: 247 (double circuit)
- Phase conductor: 1xBEAR;

- Earth wire: 2x7/3.35 steel

Figure 20 below shows the model and its results when Tetra4 is supplied from L1 shown in figure 21.

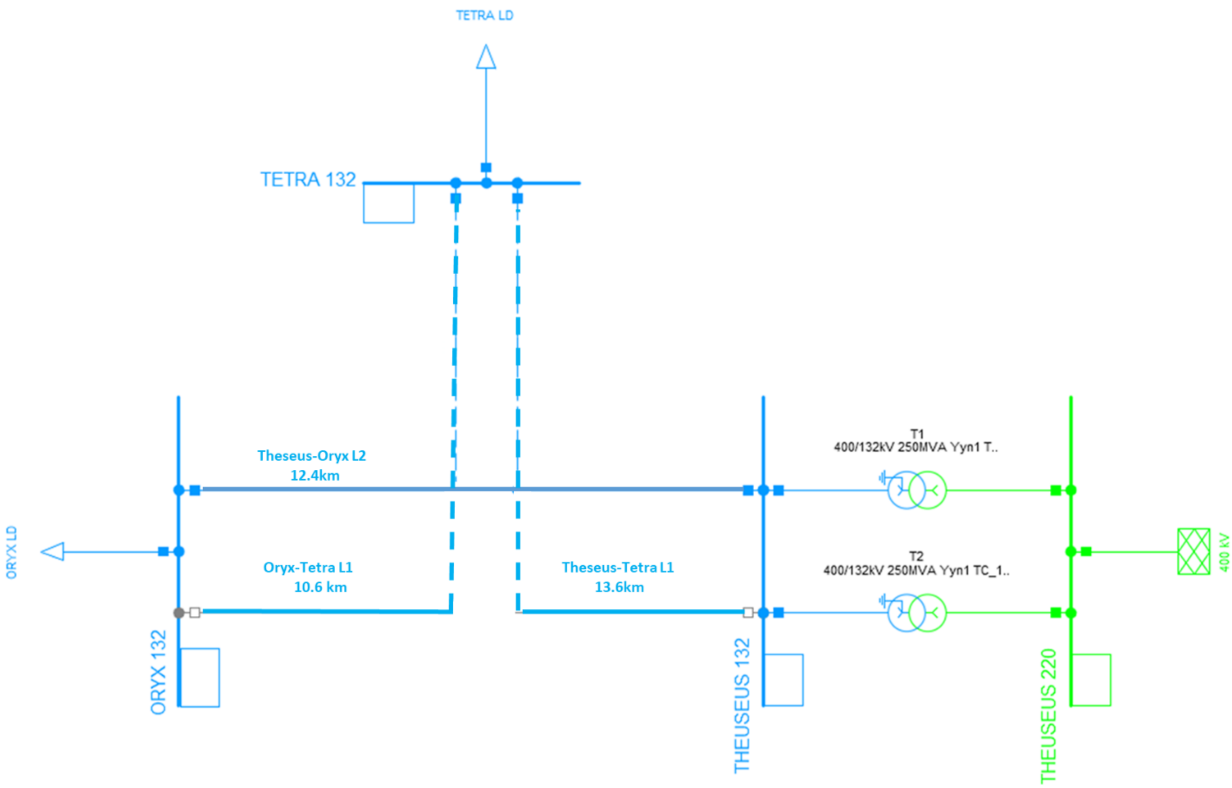


Figure 20: Tetra4 supplied from Theseus-Oryx L1

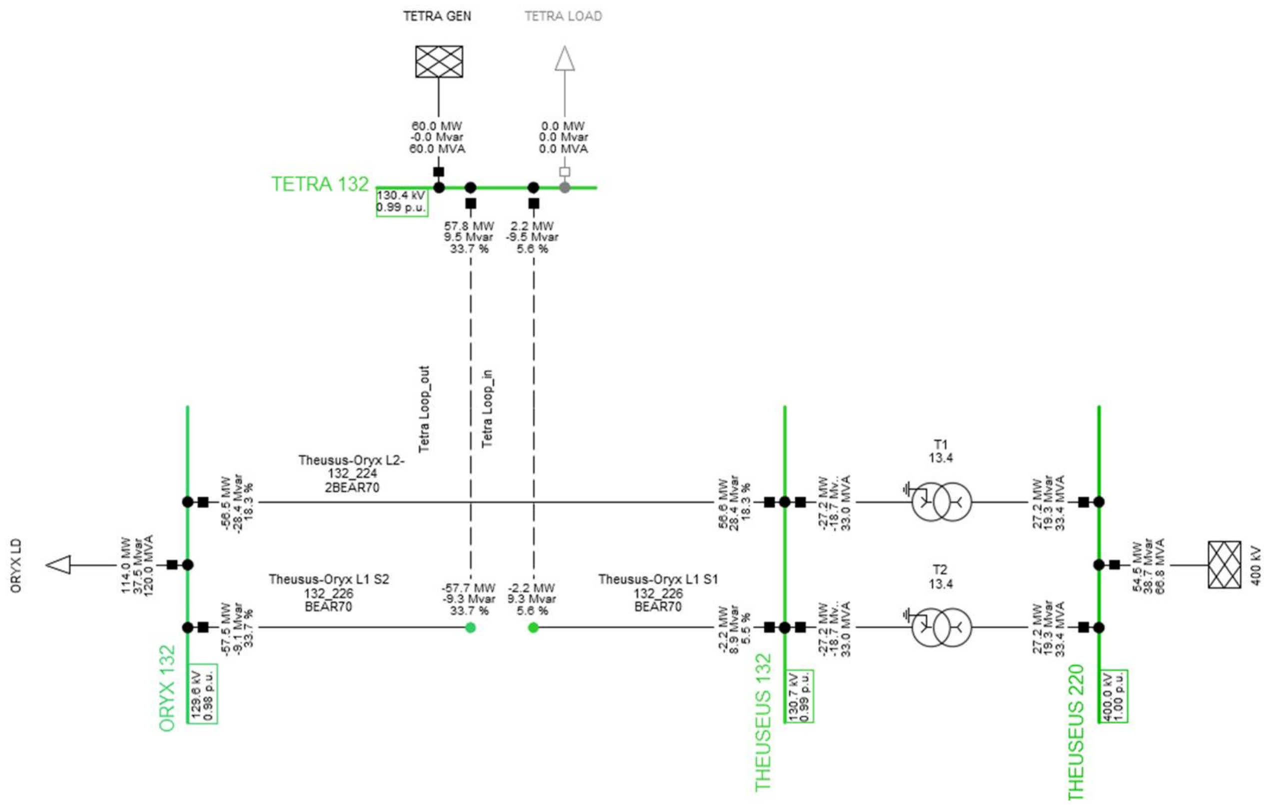


Figure 21: Tetra4 supplied from Theseus-Oryx L1, and Theseus-Oryx L2 is online

Table 8 below shows the results of the modelled supply of Tetra4 from L1.

Table 8: Modeling results for the supply of Tetra4 from Theseus-Oryx L1

	Unit	L1	L2
Distance	*km*	**11.8**	12.4
Conductor	*ACSR*	**1xBEAR**	2xBEAR
Current	*A*	**770**	1540
Voltage	*kV*	**132**	132
Thermal Limit	*MVA*	**176**	352
Actual Limit at 0.95 p.u.	*MVA*	**176**	229

All lines in service

Observe network:

- ✓ **All voltages higher that 0.95 p.u.;**
- ✓ **All line and transformer loading <100%**

4.4.6 Supply of Tetra4 from Oryx-Tetra L1 (No Generation at Tetra4 and Loss of Theseus-Tetra4 L1)

The modelled scenario is as follows:

- Fixed load at Oryx at 120 MVA (full capacity)
- Tetra: Load at 25MVA, No generation

Loop in – loop out line parameters

- Tower: 247 (double circuit)
- Phase conductor: 1xBEAR;
- Earth wire: 2x7/3.35 steel

Figure 22 below shows the model with Theseus-Tetra4 L1 out of service and its results when Tetra4 is supplied from Oryx-Tetra L1 shown in figure 23.

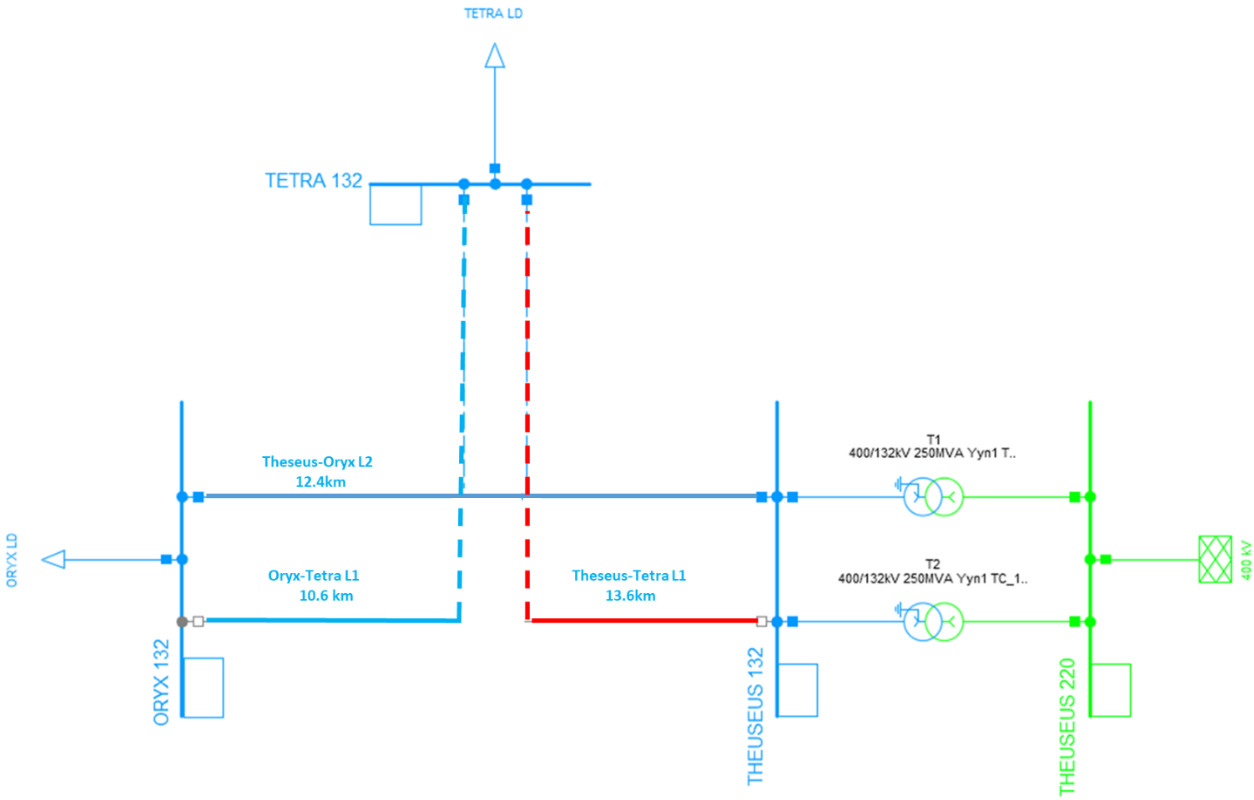


Figure 22: Tetra4 supplied from Oryx-Tetra L1 and Theseus-Tetra4 L1 is Out of Service

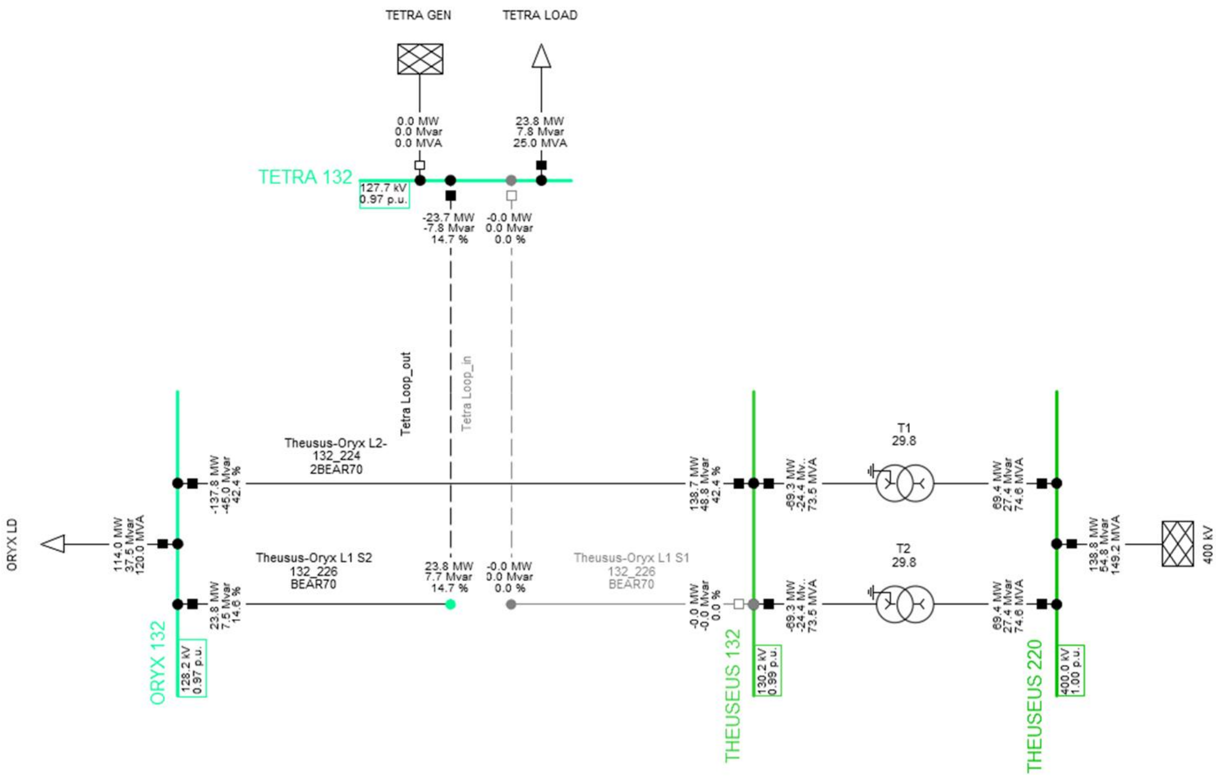


Figure 23: Tetra4 supplied from Oryx-Tetra L1, and Theseus-Tetra4 L1 is out of service (Full Load at Tetra4 and No Generation)

All lines in service

Observe network:

- ✓ **All voltages higher that 0.95 p.u.;**
- ✓ **All line and transformer loading <100%**

4.4.7 Supply of Tetra4 from Oryx-Tetra L1 (No Load, 60MW Generation at Tetra4 and Loss of Theseus-Tetra4 L1)

The modelled scenario is as follows:

- Fixed load at Oryx at 120 MVA (full capacity)
- Tetra: No Load, 60MW generation

Loop in – loop out line parameters

- Tower: 247 (double circuit)
- Phase conductor: 1xBEAR;
- Earth wire: 2x7/3.35 steel

Figure 24 below shows the model with Theseus-Tetra4 L1 out of service and its results when Tetra4 is supplied from Oryx-Tetra L1 shown in figure 25.

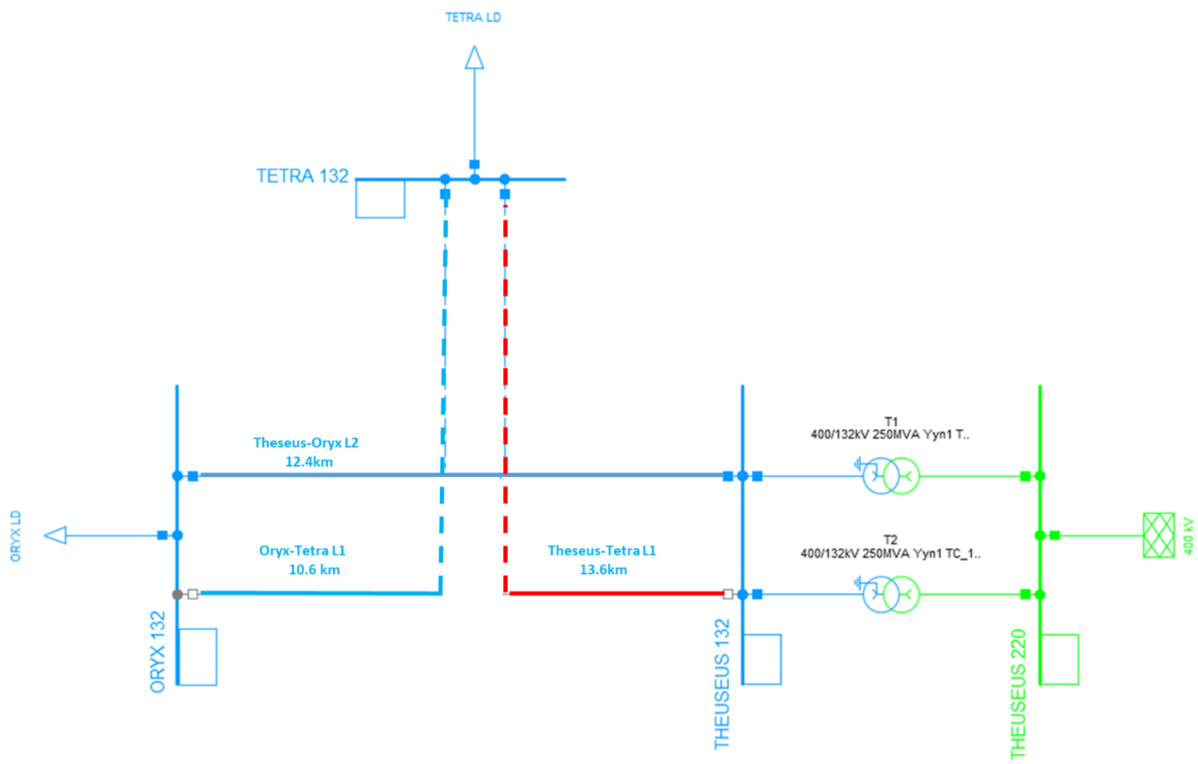


Figure 24: Tetra4 supplied from Oryx-Tetra L1 and Theseus-Tetra4 L1 is Out of Service

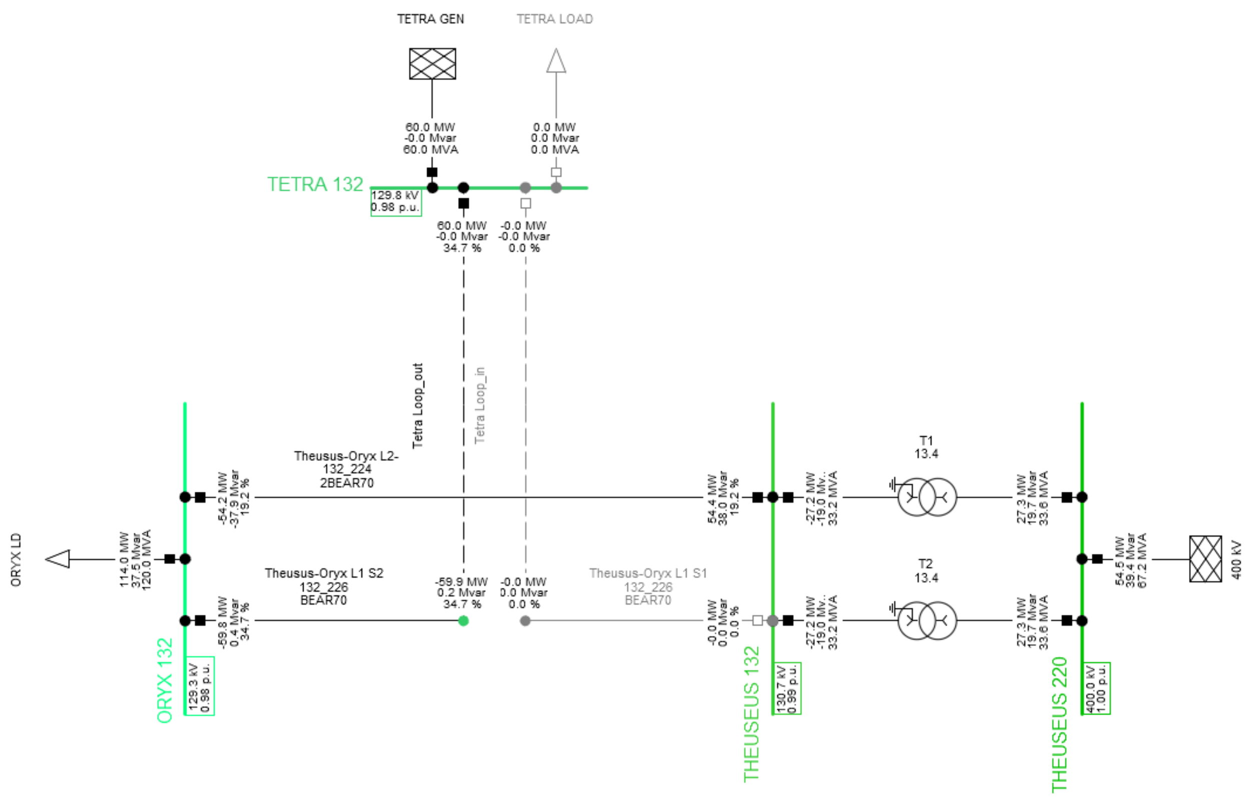


Figure 25: Tetra4 supplied from Oryx-Tetra L1, and Theseus-Tetra4 L1 is out of service (No Load at Tetra4 and 60MW Generation)

All lines in service

Observe network:

- ✓ **All voltages higher that 0.95 p.u.;**
- ✓ **All line and transformer loading <100%**

4.4.8 Supply of Tetra4 from Theseus-Tetra L1 (No Load, 60MW Generation at Tetra4 and Loss of Oryx-Tetra4 L1)

The modelled scenario is as follows:

- Fixed load at Oryx at 120 MVA (full capacity)
- Tetra: No Load, 60MW generation

Loop in – loop out line parameters

- Tower: 247 (double circuit)
- Phase conductor: 1xBEAR;
- Earth wire: 2x7/3.35 steel

Figure 26 below shows the model with Oryx-Tetra4 L1 out of service and its results when Tetra4 is supplied from Theseus-Tetra L1 shown in figure 27.

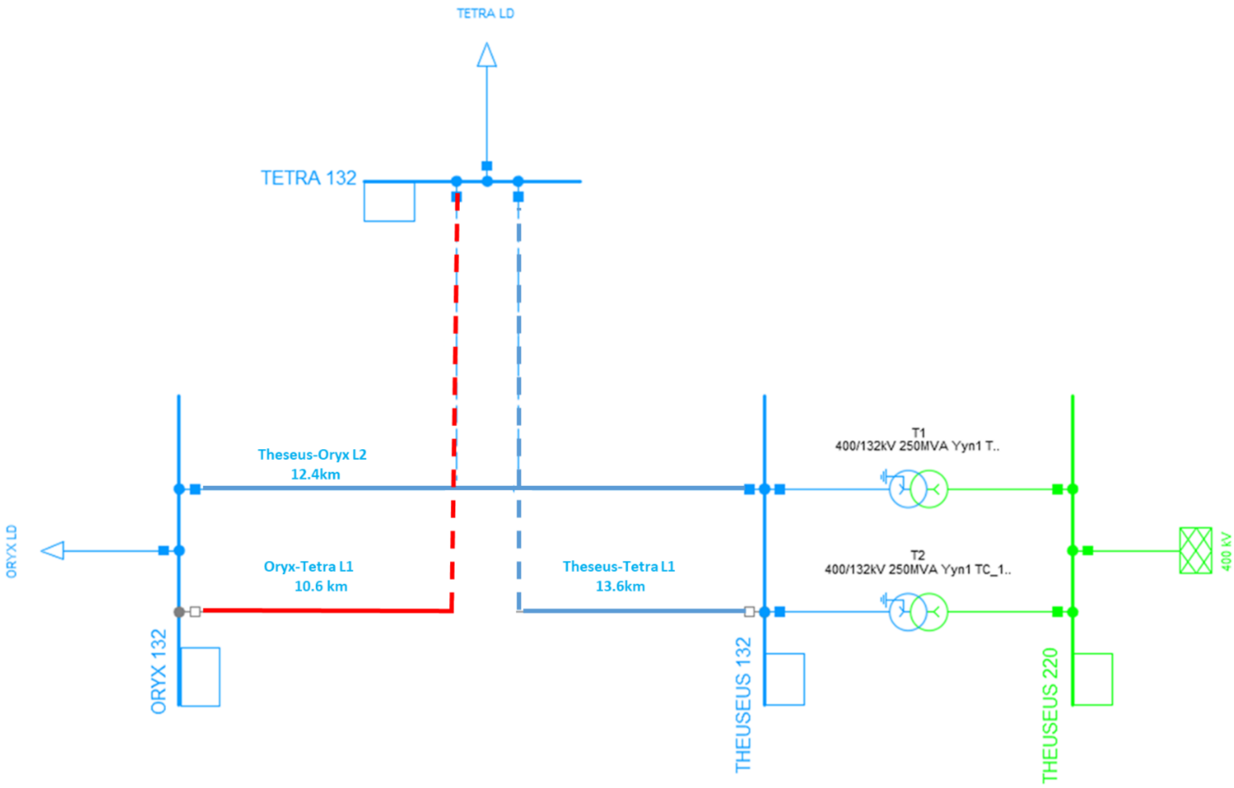


Figure 26: Tetra4 supplied from Theseus-Tetra L1 and Oryx-Tetra4 L1 is Out of Service

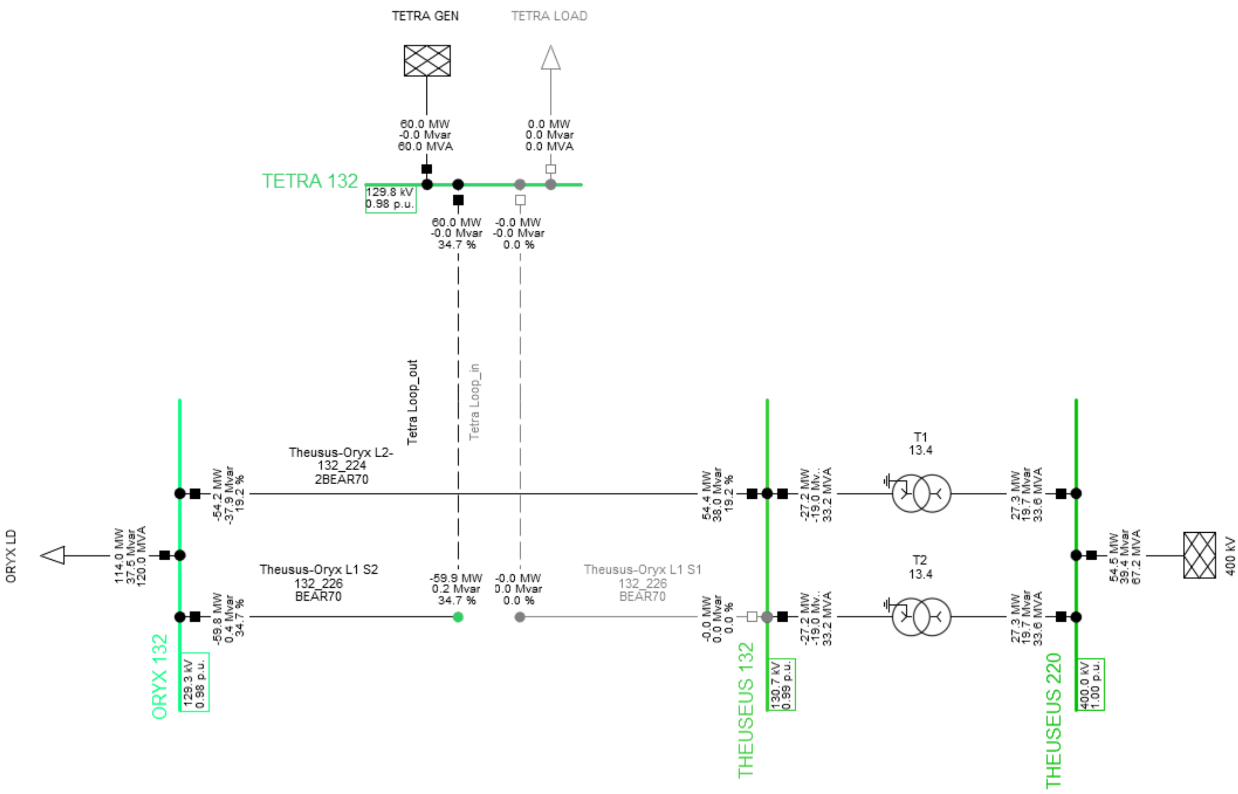


Figure 27: Tetra4 supplied from Oryx-Tetra L1, and Theseus-Tetra4 L1 is out of service (No Load at Tetra4 and 60MW Generation)

All lines in service

Observe network:

- ✓ **All voltages higher that 0.95 p.u.;**
- ✓ **All line and transformer loading <100%**

4.5 Summary of Modelling and the results Discussion

The various scenarios modelled were primarily looking at the following 2 scenarios:

- To ascertain the transfer capacity of the two possible loop-in and loop-out powerlines viz: Theseus-Oryx Line 1 and Line 2 during loss of either Line 1 or Line 2
- To Model the capability and the impact of loss of 1 line on the other line's capability to integrate Tetra4's Planned Gas Processing plant, both when it Generates and when it is on full load.

The outcome of the above-mentioned modelling showed that there are no impacts on both the system voltages and the actual loading conditions of the existing powerlines in all the scenarios modelled.

Secondly, the modelling also investigates various scenarios when Tetra4's planned Gas Processing Plant, with regards to it either generating or in full load mode, while, one of the loop-in lines is out of service. Again, these scenarios have proven that the loop-in loop-out scenario is a technically feasible solution.

4.6 Conceptual Design for the Tetra4 Gas Processing Plant Substation

The premise for the conceptual design for the Tetra4 Phase 2 substation is that, Eskom will be supplying the substation at 132kV. Due to the fact that this is the backbone network for Eskom Distribution, they expect that clients should be connected as part of the ring network configuration. This configuration ensures that there is an N-1 contingency scenario for the Distribution network. This means that there has to be redundancy built into the network at all times. this helps with security of supply to the clients being supplied at this voltage. This N-1 contingency scenario also allows for expansion of the network by Eskom.

The above N-1 scenario has lead to the substation having to have 1 x 132kV incoming feeders, as 2 x 132kV powerlines will be supplying the substation. Figures 28 to below shows the high-level conceptual design critical components for the Planned Tetra4 Gas processing Plant Substation.

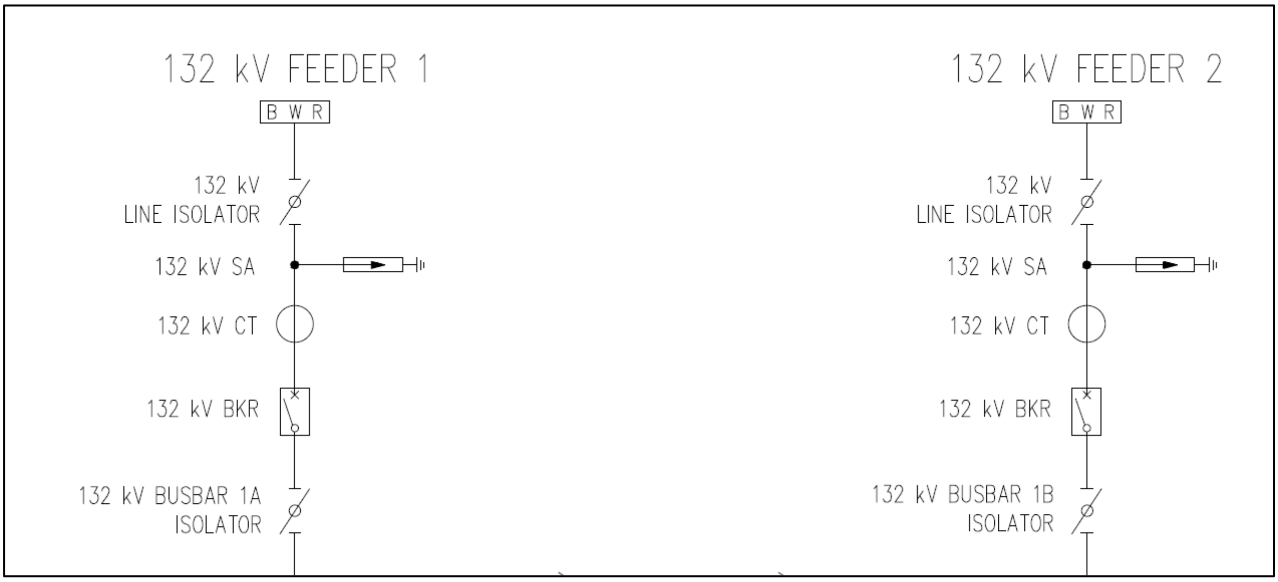


Figure 28: 2 x 132kV Incoming Feeder bays

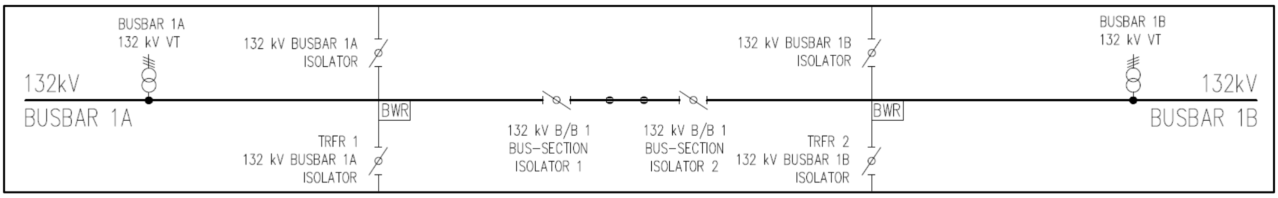


Figure 29: 132kV Busbar with Bus-Sections and Isolators

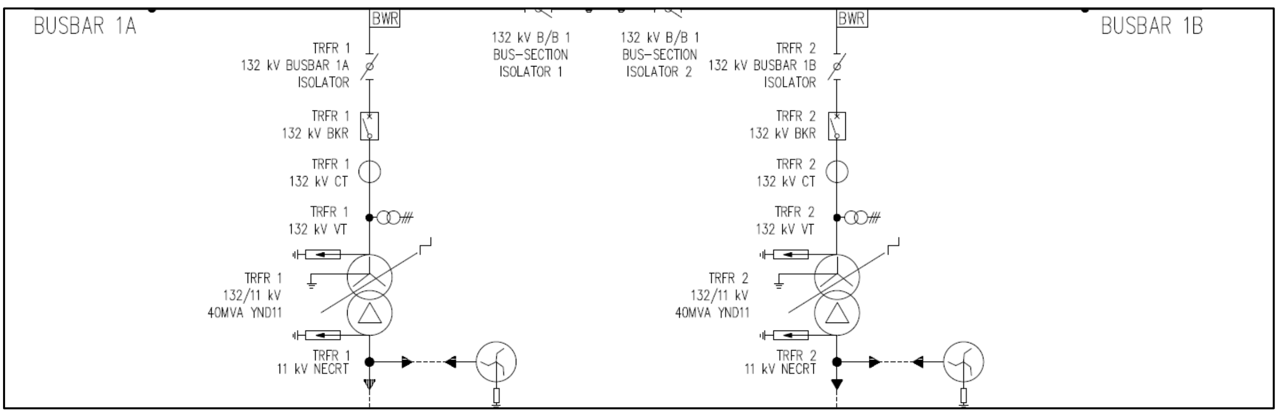


Figure 30: 2 x 132/11kV 40MVA Transformer Bays

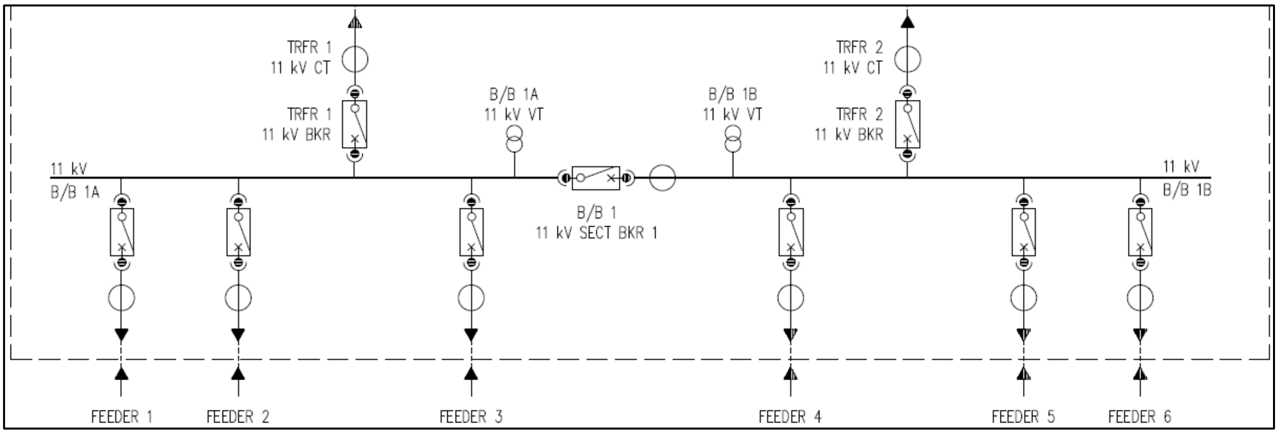


Figure 31: 11kV Switchgear, allowing for 6 x 11kV Feeders

The critical components of the proposed substation, are standard components in most Eskom Substations.

5 FINANCIAL ANALYSIS

The financial analysis that is presented in this section of the report, is meant to compare all the various scenarios that have been investigated, and whose information has been captured though engagements with Eskom personnel, as well as contactors who do construct similar infrastructure as the ones being proposed on this study, as well as Engineering judgement applied by Umbono Engineering based on the simulations and powerline and substation design experience.

The following, are the scenarios whose costing has been done and will be presented in a table format for comparative analysis:

- **132kV** double circuit line connecting Tetra4 phase 2 to **Theseus Substation**
- Loop-In and Loop-Out of **Theseus-Oryx 132kV Line 1**
- Loop-In and Loop-Out of **Theseus-Oryx 132kV Line 2**
- 132kV double circuit line connecting Tetra4 phase 2 to **Oryx Substation**
- 132kV double circuit line connecting Tetra4 phase 2 to **Joel Substation**

These options were the most technically feasible options from the various connection and supply options which were discussed at the beginning of the report.

The following are aspects of the cost comparison exercise:

1. 132kV Feeder Bay – All the supplies from the substations, will need 2 x 132kV Feeder Bays
2. 1xBear and 7/3.35 on Double Circuit line on 247 Structures (See Appendix C) – The existing Theseus – Oryx 132kV line 1 is designed with this specification
3. 2 x Bear and 7/3.35 on Double Circuit line on 247 Structures (See Appendix C) – The existing Theseus – Oryx 132kV line 2 is designed with this specification

4. Integration with Communication and SCADA – All the supplies from existing substations to Tetra4 will require that this work gets conducted at the existing substation's control rooms
5. Overhead Line Overpass – The substations where existing powerlines have been identified as possibly giving rise to a crossing outside of the substation
6. 132kV Feeder Bay Control Panels – The substations where Feeder bays are being built, their switchgear will need to be integrated into the existing substation's control room

The cost comparison of the various options, is presented in table 9 below.

Table 9: Modeling results for the supply of Tetra4 from L1

Item No:	COST DESCRIPTION	Unit	Unit Cost	Connection to Theseus		Connection to THES-ORY L1		Connection to THES-ORY L2		Connection to Oryx SS		Connection to Joel SS	
				Qty	Total	Qty	Total	Qty	Total	Qty	Total	Qty	Total
1	132 kV Feeder Bay	Sum	2,800,000	2	5,600,000	0	0	0	0	2	5,600,000	2	5,600,000
2	1xBEAR and 7/3.35 on DC 247 Tower	km	2,200,000	14	30,800,000	4.5	9,900,000	0	0	10	22,000,000	30	66,000,000
3	2xBEAR and 7/3.35 on DC 247 Tower	km	2,600,000	0	0	0	0	3.5	9100000	0	0	0	0
4	132 kV Feeder bay control Panels	Each	1,370,000	4	5,480,000	2	2,740,000	2	2740000	4	5,480,000	4	5,480,000
5	Line overpass	Each	500,000	3	1,500,000	0	0	0	0	4	2,000,000	2	1,000,000
6	Integration with communication and SCADA	Sum	350,000	1	350,000	0	0	0	0	1	350,000	1	350,000
7													
8	TOTAL				43,730,000		12,640,000		11,840,000		35,430,000		78,430,000
9	Costs of Tetra4 132kV/11kV Transformation Substation (2 x 40MVA)	Each	65,500,000	1	65,500,000	1	65,500,000	1	65,500,000	1	65,500,000	1	65,500,000
10	**Grand Total**				**109,230,000**		**78,140,000**		**77,340,000**		**100,930,000**		**143,930,000**
			Ranking		**4**		**2**		**1**		**3**		**5**

Noteworthy Exclusions

- Annual Price Escalations
- Cost of Land Acquisition, along with wayleave negotiations and assessment of other possible impacted services and their possible relocations, should these be needed
- Cost of Environmental Impact Assessments
- Contingencies

6 CONCLUSIONS AND RECOMMENDATIONS

The purpose of the report was to investigate a range of possible options for the power supply (24MW when fully operational) and possible opportunity for Tetra4 phase 2 project to inject up to 60MW into the grid. Umbono Engineering's approach was to the Grid Injection Studies approach, when an estimate of the costs associated with connecting an IPP into the power grid, or the bulk power application approach, where a bulk power user is intending to be connected to the power grid. This latter approach is what Tetra4's phase 1 project with Umbono Engineering is about.

The investigation of the available power infrastructure within reasonable proximity to the phase 2 location, along with site visits, interactions with Eskom personnel, and power system simulations have yielded a range of options which have been presented in table 9 for consideration.

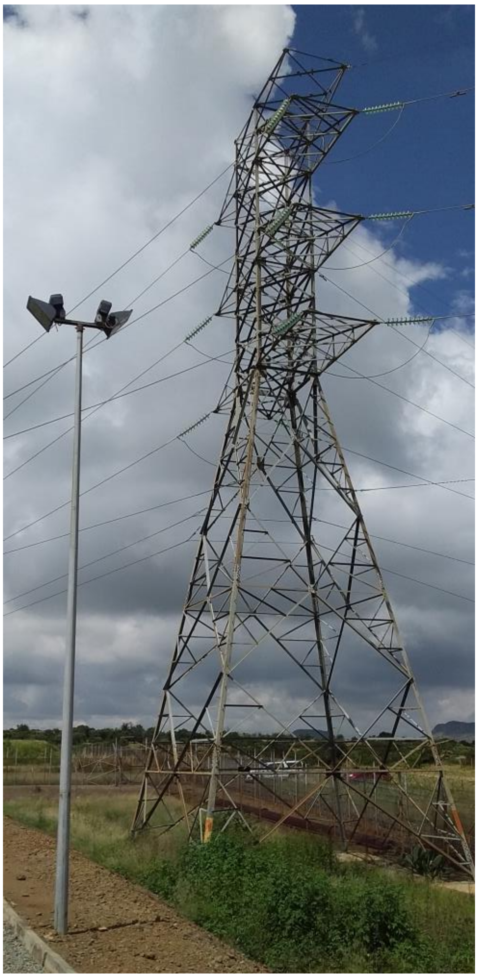
These options have also been ranked in terms of not only their financial but also technical feasibility.

- The most preferred option is the Option of Looping-In the Theseus-Oryx 132kV line no 2. The cost associated with this option is **R 77 340 000 (Excluding VAT)**
- The second most preferred option is the Option of Looping-In the Theseus-Oryx 132kV line no 1. The cost associated with this option is **R 78 140 000 (Excluding VAT)**
- The Third Most preferred option is the option of building a double circuit line and connecting at Oryx substation at 132kV at a cost of **R 100 930 000 (Excluding VAT)**
- The second least preferred option is the option of connecting Tetra4 from Theseus substation at 132kV with a double circuit line at a cost of **R 109 230 000 (Excluding VAT)**
- The least attractive option is connecting Tetra4 from Joel substation using a double circuit 132kV line at a cost of **R 143 930 000 (Excluding VAT)**

Umbono Engineering's recommendation is that Tetra4 considers Option 1. It**s advantages span beyond costs and the following are some of the additional advantages:**

- The **land negotiations and servitude acquisitions costs will not be exorbitant** as the length of the line is only 3.5km (Using Google Earth information)
- There will only be **2 major work packages** (3.5km long double circuit line and Tetra4's 40MVA substation). This is more attractive than most other options that also require work at the source substations, which brings about complications in the project coordination and further interdependencies which are outside of our control)
- **Execution time** will be the shortest for this project as its scope is the simplest
- **EIA and EMP processes should be very quick** as well as the length of the overhead line isn't that long

APPENDIX A: JOEL SITE VISIT

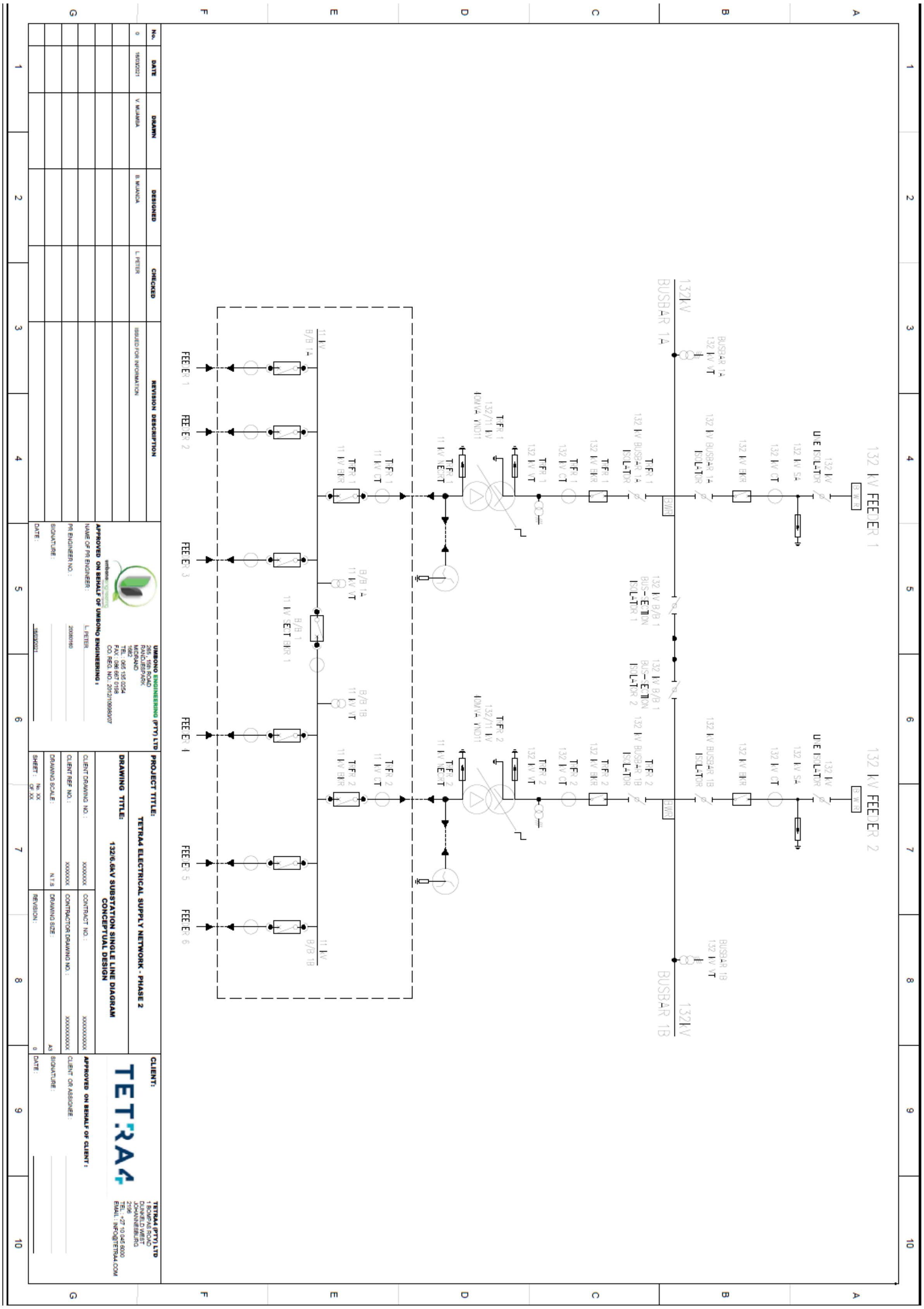



JOEL S/S
ABB
132kV ORYX FDR

132kV BUSZONE

BATTERY CABINET

APPENDIX B: Tetra4's Planned Phase 2 Gas Processing Plant's Conceptual Substation Design



APPENDIX C: 247 Tower OUTLINE DRAWING