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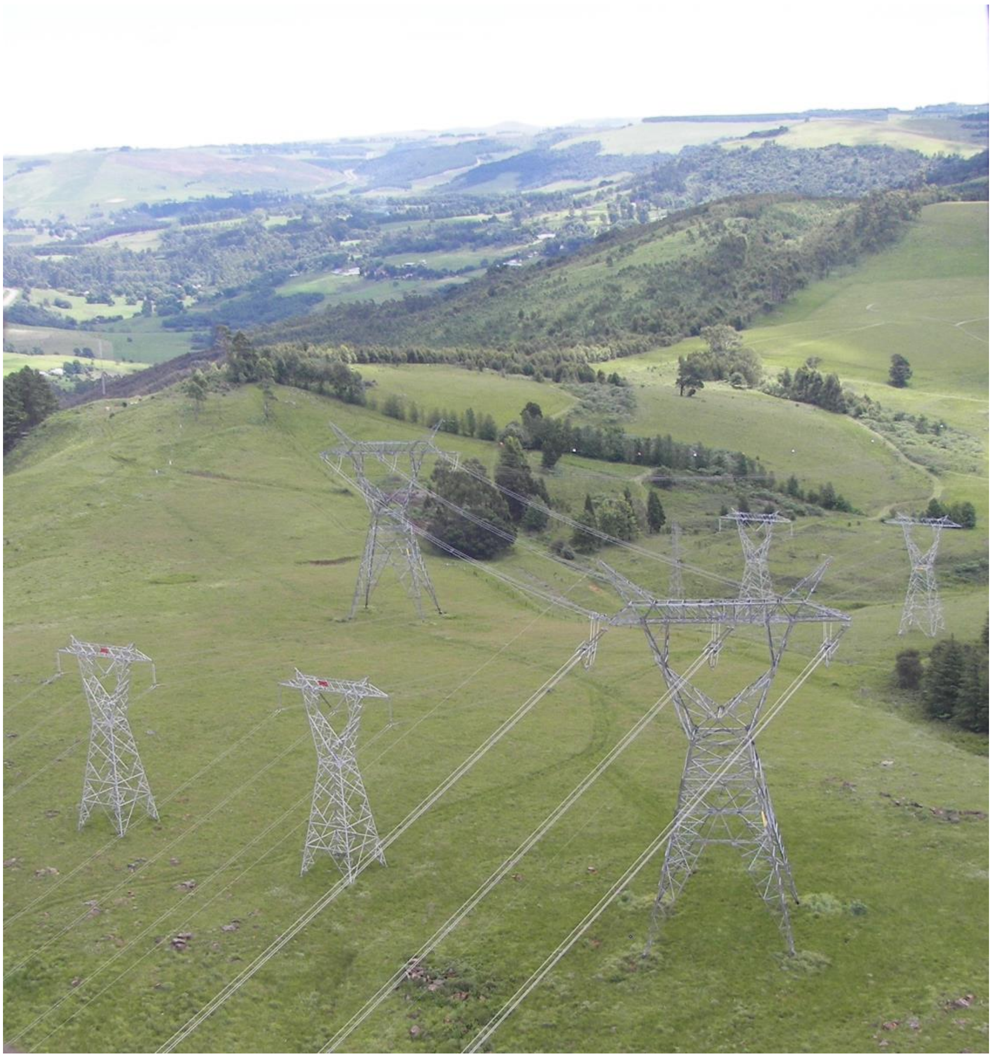

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REVISION CONTROL

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1	May 2017	First issue	R. Vajeth

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1 BACKGROUND

The Free State Grid requested LES to assist with the replacement of damaged tower members on tower 226 on the Grootvlei-Theseus 1 400kV line. LES conducted a ground inspection to establish the extent of the damage and to propose a solution to the problem. The tower is situated in an active farming area and the damage was due to a heavy impact load by farming equipment. Table 1.1 below lists the line details.

	Grootveli-Theseus 1 400kV
Construction year	1983
Phase conductor type	Dinosaur
Phase conductor configuration	Twin
Earthwire	19/2.6
Tower Types	501, 510, 515, 517 tower series
Affected Tower Type	501A Self Supporting Suspension
Line length (km)	252

Table 1.1: Basic Line information (TxSiS)

A desktop study was conducted to confirm that the tower wind and weight spans are within limit. See the table below showing the As-built data and the original design parameters of the 501A tower.

	Design Parameters	Gro-The 1 400kV
Wind Span (m)	396	325
Weight Span (m)	450	390
Conductor Bundle	Twin Dinosaur	Twin Dinosaur
Earthwire	19/2.6	19/2.6

Table 1.2: Design data vs. As-built data

As seen on Table 1.2, the wind and weight spans are within the design parameters. This confirms that the tower was damaged due to external loads.

The affected tower members are on the main leg and on the diaphragm of the tower. Figure 1.1 and 1.2 shows the affected leg.

Figure 1.1: Damaged tower members on leg A

Figure 1.2: Damaged tower members on leg B

2 PROPOSED SOLUTIONS

The following three options are considered below

I. Installation of a new tower (10m-20m away from the damaged tower)
II. Replacement of bent members only
III. Add bracings to the affected tower members

2.1 Installation of a new tower (10m-20m away from the damaged tower)

This method requires the existing tower to be dismantled in order to make way for a new tower. A new similar tower type with the same height as the original tower will be required. A new tower will be constructed 10-20m away from the existing tower.

ADAVANTAGES

- New tower (Uncompromised tower strength)
- Short line outage would be required

DISADVANTAGES

- Costly i.e. new steel, new foundations, dismantling costs, new conductor
- Requires a lot of time: - casting of new foundations, assembly and erection, dismantling of the damaged tower, conductor stringing.

2.2 Replacement of bent members only

This method involves the replacement of the damaged tower members and the reinforcement the affected stubs. A crane would be required to support the tower during the replacement procedure.

Tower type	Weight (Tons)	Conductor (Tons)	Earthwire	Total Weight (Tons)
501A	9 (Approx.)	2x361x3x2.489/1000 =5.5	2x361x0.857=0.6	15.1

The maximum weight as seen on the table above is 15 tons. To account for the construction and wind loads a factor of about 2.5 is applied. A minimum of 38 ton crane is required to temporarily support the structure during refurbishment.

Figure 2.2.1: Tower rigging (For illustration)

ADVANTAGES

- Short duration for an outage (Line can be off ARC).
- Cost minimal when compared to method 2.1 i.e. only few steel members are required, low labour costs and a saving on conductor and foundation costs.

DISADVANTAGES

- Requires an experienced contractor.
- High risk activity since the line will be live.

Figure 2.2.2: Proposed stub reinforcement

2.2.1 BOM

The table below list the members to be replaced.

Quantity	Description	Size (in mm)	Member Number	Weight (kg)
2	Stub (Leg A & B)	100x100x10	XA1001	300
3	Stabilise Member (Leg A & B)	75x65x6	XA2002	45
2	Main Leg Member	100x100x10	XA2001	300
4	Member	45x45x3	XA2003	25.56
4	Member	45x45x3	XA2004	25.56
4	Member	45x45x3	XA2005	25.56
2	Member	45x45x3	XA2006	12.78
1	Member	45x45x3	XA2007	6.39
1	Member	45x45x3	XA3002	6.39
1	Member	45x45x3	XA3005	6.39
1	Member	45x45x3	XA3008	6.39

The total weight is 760kg.

2.3 Adding Bracings to the Tower

This method would require LES to run models on PLS tower in order to determine strategic positions and correct member sizes to provide the original design tower stability.

ADVANTAGES

- No outage (line can be off ARC)
- Cost minimal when compare to method 2.1 i.e. only few steel members are required, low labour costs and a saving on conductor and foundation costs.
- Crane not necessary

DISADVANTAGES

- Requires an experienced contractor
- Requires a lot of design work e.g. modelling on PLS tower
- The repaired tower will not have 100% of the original design strength taking into consideration the flow of forces.

The table below summarizes the differences between the three options based on risk during construction, outage required and construction costs.

Option	Risks	Outage Required	Costs (Rands)
1	Standard line construction risks	4-5 days to take down existing conductor, erect tower to full height and to string a new conductor	+/- 1.5million
2	Standard line construction risks	2-3 days outage required (off Arc)	R300 000
3	Low since this is reinforcement. The structural integrity remains compromised	None (off ARC)	R300 000

Table 2.3.1 Risks and mitigation

2.4 Method Statement

The contractor is to supply a detailed method statement on all activities for the refurbishment of the bent members and reinforcing of the stub.

Baseline Method statement

1. Attach the tower to the crane (min 38 ton) using adequately rated and tested slings. Ensure that is symmetrically supported by the crane in both longitudinal and

transverse directions. Enough tension can now be applied to the slings enough to just support the tower

2. Excavate around the tower leg to expose the foundation cap and to ensure enough space to carry out work.
3. Remove the bent members on the leg and cut off the bent portion of the stub.
4. Take measurements, mark off and drill members on site. The hole pattern on the main leg is be maintained on all the new joints.
5. Where there are no lengths of the members given, the contractor is required to measure the required length on site. The stub must be reinforced first followed by the main leg member, crossing diagonals and ultimately the redundant bracings.
6. All nuts must be punched and painted with a calcium based paint to prevent corrosion.
7. The tower members must be galvanised to a minimum of 85µm (SANS121:2000)
8. All tower members to be fabricated using S355JR grade of steel
9. Bolts for the lattice structure shall be metric to SABS 136-1991 grade 6.8 with length as per SABS135-1991. All steel members within 5m from the ground level in lattice structure shall be fitted with anti-theft fasteners in at least one hole per side of the member. The anti-theft fasteners will be of minimum 8.8 grade strength bolts and shall involve metal deformation during installation.
10. After the members have been replaced, the concrete cap will be casted with the top surface chamfered at an angle to prevent water collection.
11. Ensure suitable back filling material after completion of the foundation construction. The material shall be mechanically compacted to a minimum of 90% of the dry density of the undisturbed material.

2.5 Risk and mitigations

The following high level risks were identified with recommended mitigations. It is important to note that the contractor still needs to identify and analyse the risks specific to each activity.

Risks	Mitigations
Tower damage/twist when relieving the compression on the loads	Conduct operation under still air conditions and properly back stay the structure
Disturbing the tower foundation	A proper method statement must be submitted to LES for approval on the method of how the contractor intends to carry out the tasks
Member cut and drilling of holes	The drawings of the tower are old and hard to read. The contractor will have to cut and drill members on site
Electrocution	An outage will be required to carry out the stub reinforcement procedure.

2.6 Discussion and recommendations

All three possible solutions are viable, however solution 1 should be ruled out completely due to cost implication. Although greater risks with option 2 and 3, proper measures will be put in place to control the risk associated with the various activities entailed by these options.

Since adding additional bracings to the tower will require a bit of work (modelling of the new bracings on PLS tower to confirm the tower capacity) it is therefore recommended that a suitable contractor is appointed to replace the bent members with new members, hence option 2 is the recommended solution.

2.7 Conclusion

A conclusive bill of material needs to be drawn up on site to identify all affected tower members and associated weights. The contractor is to submit a detailed method statement for approval by Eskom LES before conducting any work. The contractor will conduct a detailed risk analysis, management and mitigation for the associated activities. The stub reinforcing members and the replacement tower members can be cut and drilled on site.

The proposed solution requires no design change. The contractor is to submit a detailed risk assessment and Safe Working Procedure (SWP) to Eskom for acceptance.