Transmission Design Definition Report

MidWest Energy Project

Substations

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1	19/1/2011	4	C Schouten	Draft for review
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Documents Referenced In This Document

DM#	Title of Document
DM and other document reference in this document are indicated in blue underlined text.	

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APPENDICES

1 EXECUTIVE SUMMARY

Western Power is undertaking a major project for the construction of a 330 kV double circuit transmission line between Perth and Three Springs, a new terminal switchyard at Three Springs and a number of changes to existing 132 kV lines and substation terminals between Pinjar and Three Springs.

Construction of the Mid West Energy Project will allow for growth in the Mid West region of Western Australia. The project will improve the reliability and stability of electricity supply and facilitate connection of proposed wind generation and mine loads to the South West Interconnected Network.

This report captures the essence of the project Substation designs and will be used for future Asset Management and augmentation reference.

This document outlines the design characteristics for the substation components within the Mid West Energy Project (MWEP). A separate report (DM# 7075162) covers the design of the 330 kV double circuit line from Pinjar Terminal (PJR) to Eneabba Terminal site (ENT). Another document (DM# 7170020) provides the scope statement for the project.

A brief outline of the substation scope within the Mid West Energy Project follows:

- Environmental and Community Requirements
- Construct a new Three Springs Terminal 330/132 kV
- Add a new 330 kV line circuit at the existing Neerabup Terminal 330 kV switchyard
- Add a new 132 kV line circuit at the existing Three Springs Substation 132/33 kV
- Upgrade 132 kV line Protection systems at Pinjar Terminal (PJR), Regan (RGN), Cataby (CTB), Emu Downs Windfarm (EMD), Eneabba (ENB), Three Springs (TS), Mungarra Terminal (MGA), Geraldton (GTN) and Chapman (CPN)
- Protection upgrades to improve fault tripping times and North Country voltage stability
- Replacing legacy protection relays with digital relays to allow fast setting changes as the 132 kV line characteristics alter during the project execution – existing wood pole 'cricket wicket' line → split phase line on 330 kV towers → single circuit line on 330 kV towers
- SCADA works at all 132kV substations
- Communication works at Three Springs Terminal and modifications to optical fibre cable run-ins at some 132 kV substations

Proposed Three Springs Terminal 330 kV detail to meet scope are as follows:

- The yard will be constructed as a 330 kV breaker and a half layout
- Initially Three Springs Terminal will be configured as a three switch mesh comprising of two line circuits (NBT91 and KRA91) and one transformer
- It will have two 330 kV busbars and two bays

- One iron cored three phase shunt reactor will be connected to the Neerabup 330 kV line (NBT91) for voltage regulation during line energisation and low load conditions
- Two air cored shunt reactors will be connected to the transformer 22 kV tertiary for energisation of the 330kV line to Karara and steady state voltage control
- The Three Springs 132 kV line circuit (TS81) will initially be located within the 330 kV yard to minimise initial capital cost. This circuit will later be relocated once the Three Springs 132 kV Terminal is developed
- A concrete panel relay building will house all secondary equipment and ablutions
- Future Network Requirements include possible 330 kV connections from Three Springs Terminal to Karara mine site, Moonyoonooka (stage 2 of the North Country Reinforcement) and Extension Hill mine site. Allowance has been made for a future 132 kV yard at Three Springs Terminal
- Refer to Appendix E for the project single line diagrams

This report clarifies the ultimate design requirements for the above components, as well as future network requirements. Further information is contained in the remainder of the report.

2 GENERAL REQUIREMENTS

2.1 PROJECT SCOPE

Western Power identified and evaluated a number of options to increase the power transmission capacity for the Mid-West region of Western Australia to meet the forecast increased demand for electricity, together with a forecast increase in electricity generation in the region.

The overall scope for the project includes the following (from the Planning Definition Report DM# 7170020):

- New 330 kV line circuit at Neerabup Terminal
- Protection modifications at Pinjar Terminal, Regans, Cataby, Emu Downs Windfarm, Eneabba, Three Springs, Mungara, Geraldton and Chapman
- New 330/132 kV Terminal at Three Springs
- New 132 kV line circuit at Three Springs Substation
- New double circuit 330 kV line construction between Pinjar and Eneabba Terminal site (NBT-TST91). ***Note that the 330 kV line between Eneabba Terminal site and Three Springs Terminal will be constructed by Karara Mining Limited***
- New double circuit 132 kV line TST-TS81

The last two items above are outside the scope of this document – refer to the Lines Design report (DM# 7075162).

2.2 PLANNING CRITERIA

The designs for this project are to comply with the Technical Rules (DM# 3605551) and the plant and equipment ratings given in the appendices of Western Power's Transmission Planning Criteria (DM# 1195855). The main body of the Planning Criteria document has been superseded by the Technical Rules (DM# 3605551).

2.3 REGULATORY REQUIREMENTS

The designs for this project to comply with the following regulatory requirements:

- Western Powers Technical Rules (Approved by the ERA);
- Electricity Act 1945;
- Energy Coordination Act 1994;
- WA Occupation Safety and Health Act 1984 and Regulations 1996;
- Electricity (Supply Standards and System Safety) Regulations 2001;
- Electricity Industry Act 2004;
- Electricity Corporations Act 2005 (WA);
- Electricity Industry (Network Quality and Reliability of Supply) code 2005;
- Energy Safety Act 2006;
- Environmental Protection Act 1986;
- Environmental Protection (Noise) Regulations 1997;
- Environmental Protection and Biodiversity Conservation Act 1999;

- Australian and relevant international standards;
- Building Code of Australia;
- ESAA guidelines;
- Contaminated Site Act 2003; and
- Contaminated Site Regulations 2006.

For further details refer to the Transmission Standard Design Policy requirements and design guidelines, DM# 3377089.

2.4 RELIABILITY REQUIREMENTS

As per the Mid West Energy Project System Study – Internal Report (DM# 6346456), for a load of 95 MW at Karara in January 2012, system reinforcement is required under the new generation schedule.

The Technical Rules (DM# 3605551) require, at a minimum, the project to meet N-1 criterion.

At times during the 330 kV line construction, Regans Substation (RGN) will be on a single 132 kV supply. Various options were explored with respect to maintaining N-1 supply to RGN but have not been included in the Mid West Energy Project estimate.

3 DESIGN INPUTS FOR THIS PROJECT

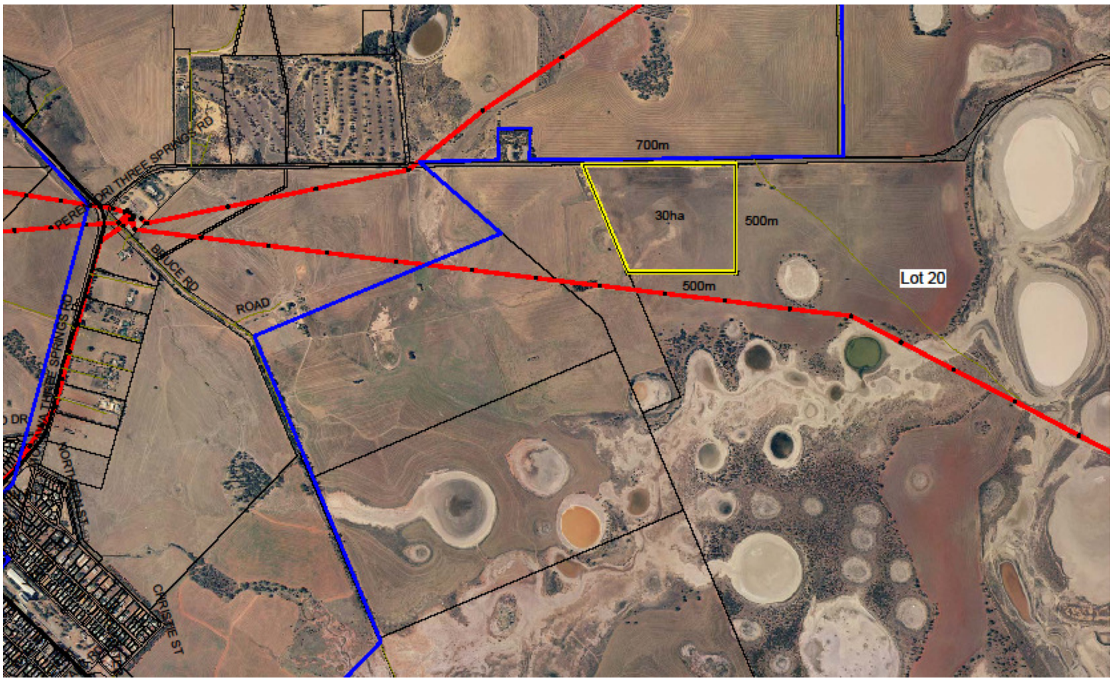
3.1 PROJECT DESIGN INPUTS

The following is a summary of the key substation design aspects for this project:

Network Requirements (Minimum):		
Factor		
Network nominal voltage	330 kV	132 kV
Normal operating range	±10%	±10%
Equipment highest voltage	362 kV	145 kV
Rated 1 minute power frequency withstand	520 kV	275 kV
Minimum Rated lightning / Surge Impulse withstand	1175 kV_p	650 kV_p
Continuous rating	2500 A / 3150 A (busbar)	2500 A / 3150 A (busbar)
Substation one second short time current rating	50 kA (initially 15 kA)	50 kA (initially 15 kA)
Maintenance requirements	Outage required	
Design life	50 years	
Reliability	High	

Rated Physical Environment:		
Factor	**Minimum**	**Maximum**
Shaded air temperature (no solar radiation)	0 °C	+45 °C
Solar radiation (horizontal surface)	Nil	1,000 W/m^2
Wind Region	A1	B
Regional Wind Speed	V_R = 46 m/s	V_R = 60 m/s
Terrain category	2.0	2.0
Relative humidity – outdoor	30%	90%
Assessed Topographic multiplier Mt	1.0	1.0
Geographic Area	Inland	
Pollution level per D(b)19-1975 ESAA Pollution Guide	Heavy	
Earthquake Design Category	II	
Earthquake Hazard Factor (Z)	0.15	
Solar / UV Levels	1100 W/m^2	
Altitude	Less than 1000 metres above sea level	
Keraunic level (thunder days per year –DM# 5534120)	10	
Termite activity	High	
Thermal resistivity for special backfill used	1 °C -m/W	
Soil temperature (1 m deep)	30 °C	

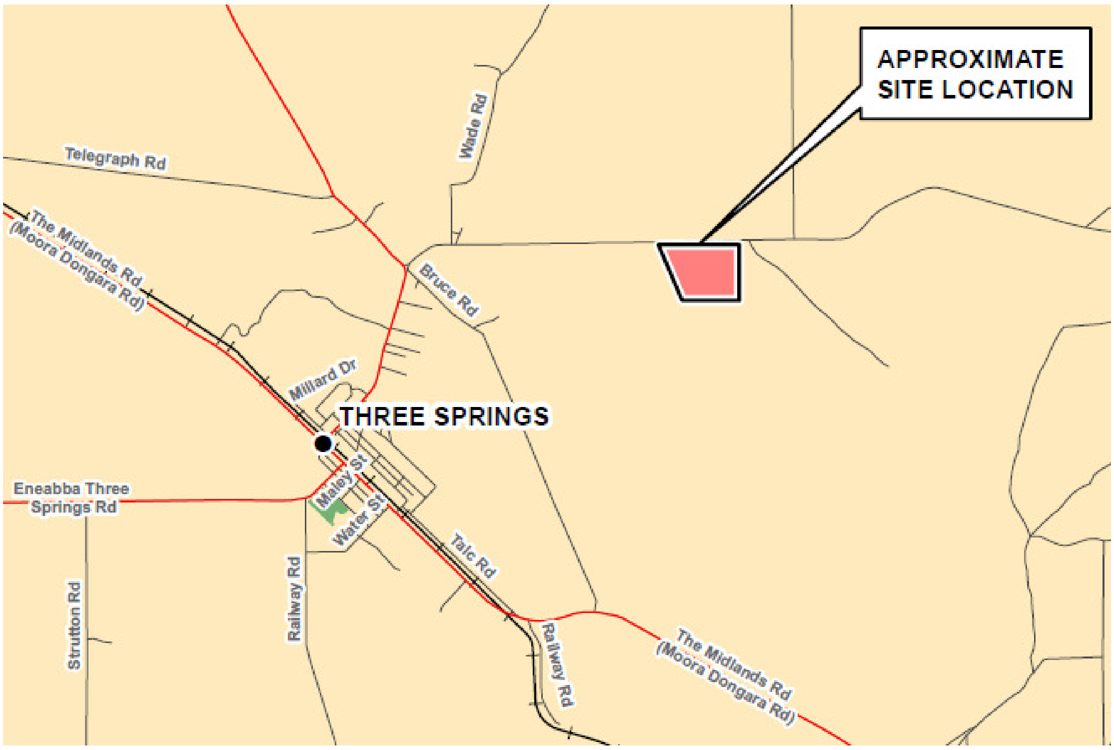
3.2 SITE SELECTION – THREE SPRINGS TERMINAL



Aerial view – Three Springs Terminal site shown in yellow box

Three Springs Terminal has been optimally located with respect to community, aesthetic, environmental, line route and access issues.

Acquisition of the Three Springs Terminal site was carried out by Western Power's Environment, Community Engagement and Approvals (ECEA) officers based in Geraldton. The selected site is located on the south side of the Three Springs – Perenjori Road approximately 3 km east of Three Springs town. Three Springs town is located in the Mid West 313 km north of Perth WA and 172 km south of Geraldton. Three Springs Terminal lies outside the Three Springs Water Reserve and is subject to Water Quality Protection Notes.



Locality map – Three Springs Terminal

Other drivers of the Three Springs Terminal site selection included:

1. Minimum required terminal site dimensions of 500 m x 500 m (WP guideline)
2. Willing seller (WP prefers not to compulsorily acquire land)
3. Proximity to the proposed 330 kV NBT-TST91 line route which passes south and east of Three Springs town
4. The site lies south of the existing 132 kV TS-GGV81 line (to allow the proposed 330 kV TST-KRA91 line to be strung on the south side of the proposed double circuit towers)
5. Easy access for future 330 kV lines to Extension Hill mine to the east and Moonyoonooka [Geraldton] to the north
6. Avoid the existing 132 kV MOR-TS81 line just south of Three Springs Terminal
7. Avoid congestion of existing 132 kV lines west of Three Springs Substation
8. Relatively flat topology to minimise cost of Terminal earthworks and drainage
9. Suitable geotechnical conditions
10. Social / aesthetic considerations – away from Three Springs town
11. Maximise distance from salt lakes (ie maximise height above 100 year flood level and avoid corrosive soil)
12. Existing tree screening on the road verge
13. Road safety – WP access road crossover sight line distance from Three Springs – Perenjori Road horizontal and vertical curves
14. Avoid flora / fauna reserves and Aboriginal Heritage sites

4 ELECTRICAL DESIGN

4.1 GENERAL

This section describes in more detail the primary and secondary electrical design of the Terminals and Substations within the scope of the Mid West Energy Project. These sites are all brownfield except Three Springs Terminal:

- Neerabup Terminal 330 kV
- Three Springs Terminal 330/132 kV
- Pinjar Terminal 132 kV
- Regans Substation 132/33/22 kV
- Cataby Substation 132/ kV
- Emu Downs Substation 132/ kV
- Eneabba Substation 132/33 kV
- Three Springs Substation 132/33 kV
- Mungarra Terminal 132kV
- Geraldton Substation 132/33 kV
- Chapman Substation 132/22 kV

The Neerabup (NBT) and Three Springs Terminal (TST) designs are based on Western Power's standard 330/132 kV terminal outdoor air insulated designs/guidelines (refer DM# 7442120 and 3619979). The Three Springs Substation design is based on Western Power's standard 132/22 kV substation outdoor air insulated designs/guidelines (DM# 3470476 and 3493930). These have been peer reviewed by Hydro Tasmania [DM# 7442038] and deemed to be "Australian electrical utility best practice".

Since Three Springs Terminal is located within Wind Region B with a wind speed of 60 m/s, the standard terminal structures and foundations, which suit Region A wind speed of 46 m/s, will be upgraded as required. The average recurrence interval of 1000 years has been selected to achieve the high reliability required for a Terminal.

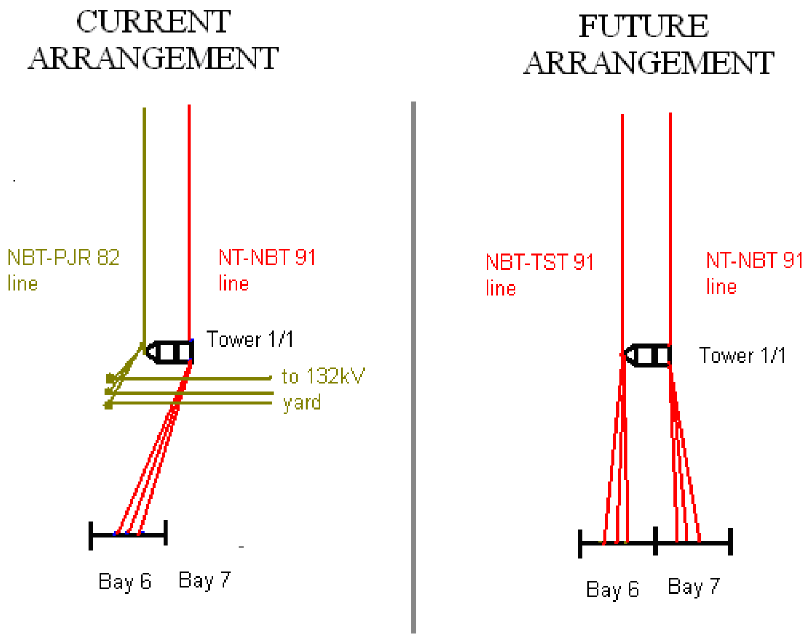
4.2 ELECTRICAL STANDARDS

Substation design will comply with all relevant Australian and international standards.

4.3 NEERABUP TERMINAL

4.3.1 General

A new circuit is required at Neerabup Terminal for the Three Springs 330 kV (TST91) line. The existing Northern Terminal 330 kV (NT91) line landing span must be swung across from the existing bay 6 gantry to a new bay 7 gantry so that the new TST91 line can be connected to bay 6. Careful consideration needs to be given to the constructability of bay 7 with respect to the outages required and the safety of workers. The existing NT91 line is the sole Neerabup Terminal 330 kV connection to the South West Interconnected Network (SWIN). A peaking gas turbine power station (Newgen Neerabup GNN) is also connected to Neerabup Terminal 330 kV, placing further constraints on outage planning.



NBT 330kV – bay 6 and 7 line entries

4.3.2 Scope

The scope of work in the 330 kV yard at Neerabup Terminal is as follows:

- Add a new part bay 7 which includes a line circuit to Northern Terminal (4 electromagnetic voltage transformers, 1 disconnector with 2 earth switches and 3 surge arrestors)
- Move the existing Northern Terminal line from bay 6 to bay 7 (see sketch above)
- Modify the existing line circuit in bay 6 to cater for the new line to Three Springs Terminal (TST). Additions in bay 6 including 1 circuit breaker (NBT961 which has high speed single phase auto reclose [HSSPAR] and point on wave [POW] capability), 3 current transformers, 1 disconnector with 1 earth switch and 1 disconnector with 2 earth switches.
- Secondary modifications to the existing NBT963 circuit breaker to allow for high speed single phase auto reclose [HSSPAR] and point on wave [POW] operation
- Extension of the ‘A’ busbar for bay 7
- Add one phase electromagnetic voltage transformer onto the ‘A’ busbar
- Replace the existing capacitive voltage transformer on the bay side of the 964.5 disconnector with an electromagnetic voltage transformer.

Some of this design work has already been undertaken under the earlier North Country Reinforcement Project.

4.3.3 Bus zone

Installation of bus zone protectors is not included in the Mid West Energy Project scope. As development progresses at Neerabup and Three Springs Terminals, it will require outages to install bus zone later. However the cost of installing bus zone could not be justified at this stage.

4.3.4 Secondary Design

Line protections:
One new cubicle will be installed containing protection 1 and protection 2 for the new line circuits.

Circuit Breakers:

- A new cubicle will be installed for the new NBT961 circuit breaker.
- The existing NBT963 circuit breaker will be modified to allow for high speed single phase auto reclose (HSSPAR) and point on wave (POW) operation.

DC supply:
At Neerabup Terminal the 50 V battery bank capacity is 102 AH and each of the two 110 V battery banks capacity are 400 AH. These are adequate and hence no changes are required.

AC supply:
The AC changeover board at Neerabup is designed to allow for three AC supplies in future, with two supplies currently installed. Currently one supply is from the T2 earthing compensator (in bay 6) and the backup supply is from the distribution network via a 315 kVA distribution transformer. No changes are required.

Wiring and cabling:
Wiring and cabling will only be replaced where necessary

Fault recorder:
A fault recorder is already installed at Neerabup Terminal. The new Three Springs 330 kV line circuit will be added to the recorder.

Air conditioning:
Four split-system air conditioning units are installed in the Neerabup 330 kV relay room to maintain appropriate conditions (around 28 degrees C) for sensitive electronic equipment and to maintain comfort levels for personnel working within the substation. This arrangement is satisfactory for the additional Mid West Energy Project works.

4.3.5 Design outputs

Design drawings for the primary and secondary modifications will be produced along with a scope of work and technical specification.

Assumptions

- Standard terminal plant will be used and hence standard/template drawings will be able to be utilised, with the exception of electromagnetic voltage transformers (EMVTs) and point on wave (POW) requirements
- New electromagnetic voltage transformers will be of similar size to the capacitive voltage transformers (CVTs) and hence standard primary plant spacing will be able to be utilised.

Identified Risks

- WP Plant section is currently reviewing term contracts for primary equipment. Some Plant changes have recently been announced eg voltage transformers and surge arrestors. More changes may be announced. Associated Western Power standard drawings will need to be revised.
- Delays in plant manufacturer drawings for electromagnetic voltage transformers and surge arrestors may mean either a delay in the drafting start date or drafting rework

4.4 THREE SPRINGS TERMINAL 330/132 KV

4.4.1 General

The Three Springs Terminal is required to step down the Neerabup-Three Springs 330 kV line via a 490 MVA transformer and connect into the existing Geraldton area 132 kV network via Three Springs Substation and Mungarra Terminal. This arrangement caters for the 'n-1' reliability criteria with respect to adding future customers. Initially, for the Karara Interim Supply, the transformer will step up 132 kV from Eneabba Substation to 330 kV to supply the Karara mine site.

For the initial development of the 330 kV terminal site there will be two 330 kV line circuits, and one 330/132 kV transformer, thus only parts of two bays will be populated as a three switch mesh.

The ultimate Site Utilisation for the Three Springs 330 kV terminal includes eight lines and two transformers over five bays in breaker and a half configuration. Additional spare circuits have been shown due to uncertainty regarding the geographic dispersion of future lines.

The ultimate Site Utilisation for the Three Springs 132 kV terminal includes eighteen line circuits, two transformer circuits and three capacitor banks over twelve bays in breaker and a half configuration.

The initial site utilisation drawing SS350/10/1/2 and ultimate site utilisation drawing SS350/10/1/1 are shown in Appendix C.

4.4.2 Site utilization

A rigorous evaluation procedure was carried out to arrive at the optimum site utilisation. Four ultimate configurations of 330 kV and 132 kV switchyard layout within the 30 hectare Three Springs Terminal site were considered.

The key deciding factors for site configuration were:

- Steeper topography in the north-west corner of the site was avoided in order to minimise earth works costs
- Since the main 330 kV line routes are approximately north-south, the 330 kV switchyard bays are arranged in a north-south orientation. 'Turning in' lines were avoided because of the high cost of 330 kV line 90° deviation towers.
- Spare room has been allowed for a possible future static VAr compensator (SVC) yard or drainage sump
- Separating the 330 kV and 132 kV yards allowed fairly unrestricted 330 kV line access

- Site access off the Three Springs – Perenjori Road was influenced by the public road vertical curve 80 km/hr sight line (traffic safety), site drainage issues and minimizing the length of the access road to the future 132 kV switchyard.
- Planning envisage a five bay ultimate 330 kV switchyard development. However, the site utilization shows eight bays to allow for varied expansion of the initial two bays either westward or eastward. There is much uncertainty with respect to the number and geographic dispersion of future 330 kV loads and generators.
- Forty meters has been allowed between the ultimate switchyard fence and the eastern site boundary – for possible landscaping or another bay.

Design considerations as an outcome of the site configuration are:

- Some internal switchyard roads were widened to cater for delivery of the 330 kV 50 MVAr reactor to the southern end of the yard (note that the main transformer is at the northern end).
- One of the 132 kV transformer interconnectors to the future 132 kV switchyard passes under two 330 kV lines. The 132 kV route passes close to the 330 kV termination towers providing maximum vertical clearance between the two. Line crossings are acceptable provided that high quality line construction (eg concrete footings, steel poles and porcelain insulators) is adopted.
- Landing spans of 80m were adopted to allow space for the 330 kV reactor circuit under the NBT91 line, to keep the KRA91 termination tower outside the switchyard fence (ie segregation of different contractors) and to minimize the loads on the strain structures.
- The initial two bay switchyard arrangement represents a reasonable minimum cost of earth works, fencing, site surfacing and earth grid.
- The two transformers are located in non-adjacent bays to minimise fire risk as recommended in AS2067.

4.4.3 Configuration options - breaker and a half versus mesh

Three Springs Terminal will be laid out as a breaker and a half switchyard:

1. Transmission Planning and Projects sections have determined that a breaker and a half layout is more economical in the longer term than a mesh layout when more than five circuits are envisioned for the ultimate development. Refer to discussion in DM# 7988057.
2. The Three Springs Terminal 330 kV yard will be laid out as a breaker and half layout but configured as a three switch mesh to accommodate one transformer, one line circuit and one line/reactor circuit. This minimizes initial establishment costs and allows for ease of future expansion beyond six circuits.
3. A complete suite of standard drawings are available for a 1.5 CB layout but not for a mesh layout (although the availability of drawings does not substantially affect the choice of switchyard layout)

4.4.4 Power transformer

Western Power has used a 490 MVA transformer for TST to allow for variability of future development in the Mid West, economies of procurement, interchangeability and uniform maintenance requirements across multiple terminals. The large 22 kV tertiary winding allows for lower cost air cored reactors for system voltage control.

The power auto transformer will be 550/490/60 MVA Oil-Directed Air-Forced circulation type (ODAF), three phase, 330/132/22 kV, three winding complete with on-load tap changer (OLTC) and the vector group of YNa0d11.

The tap changer has 16 positions, from –16% to +4% with 1.25% steps. Transformers with an impedance of 8-12% on a 490 MVA base are expected. Western Power requires a bag type conservator and vacuum on load tap changer (OLTC) as standard features.

The 22 kV winding will be earthed via an Earthing Compensator. The 330 kV winding will be solidly earthed.

The transformer will be specified with the "Reduced sound level" of Figure AA1 of AS 2374-6. Although TST is located in an isolated country area, the reduced sound level allows for future development adjacent the switchyard or relocation of the transformer to a more populated area. The power transformer will be mounted on anti-vibration pads and secured with holding down bolts. Associated protection, control and indication equipment will be installed.

Further discussion on the 490MVA 330/132kV Transformer is included in MWEP-planning considerations DM # 7988057.

4.4.5 330 kV shunt reactor on NBT91 line

Planning studies have determined that a 330 kV 50 MVAr (at 330 kV) three phase oil insulated shunt reactor is required on the NBT91 line circuit (refer to DM# 7988057). The 120 MVAr capacitance of the Neerabup – Three Springs 330 kV line will raise the receiving voltage at Three Springs Terminal to 1.15 per unit under light load conditions (ie due to the Ferranti effect). Connection of the shunt reactor will reduce the receiving voltage to 1.04 per unit under low load conditions and reduce line switching transients.

Energisation of the 330 kV line from Neerabup Terminal will occur in two stages - firstly with the 330 kV reactor connected and secondly by closing onto the transformer 22 kV shunt reactors before energisation to the Karara 330kV line. The 330 kV shunt reactor will be switched off during higher North Country load conditions. The Shunt Reactor circuit will have a dedicated 330 kV circuit breaker. For a Shunt reactor fault, the breaker will be tripped by protection so that the NBT-TST91 line can remain in operation.

4.4.6 22 kV reactors

Planning studies show a requirement for two smaller shunt reactors on the transformer tertiary energisation to Karara and for maintaining steady state voltage control.

The transformer tertiary winding is rated at 60 MVA and it is proposed that 2 x 25 MVAr 22 kV reactors will be connected to the transformer through 72 kV circuit breakers. Western Power standard 72 kV circuit breakers will cope with the onerous switching duty associated with connection of the reactor banks.

For comparison, Karara have adopted three x 20 MVAr 33 kV busbar connected reactors to manage steady state voltages at their mining site.

2 x 25 MVAr reactors on the transformer 22 kV tertiary allow stepped switching (using 2 x CBs) for voltage control during steady state conditions and energisation of the TST-KRA91 line (but not for energisation of the NBT-TST91 line)

1. Reactors will be air cored and chainmesh fences will be located outside the magnetic clearance zone specified by the manufacturer and incorporate gaps in the horizontal railing (to prevent circulating currents). Gates will be mechanically interlocked with the CBs.
2. The 22 kV tertiary also supplies a combined earthing compensator (EC) and 500 kVA station transformer
3. A 22 kV bus zone scheme is proposed by Protection. Surge arrestors will also be installed

Further discussions on the use and operation of the 330kV and 22kV reactors is included in MWEP-Planning Considerations DM # 7988057

4.4.7 Point on wave switching (NBT and TST 330 kV)

System studies show that point on wave (POW) switching of 330 kV high speed single phase auto reclose (HSSPAR) circuit breakers (CBs) are required to cope with the switching transients caused by the Ferranti Effect on a long line (~ 280 km).

Point on wave switching is easily achieved by purchasing a special relay to supplement the existing Western Power standard specification CB. A budget price increase for a POW feature is $30 k per CB. Six POW CBs are deemed necessary – two at Neerabup Terminal and four at Three Springs Terminal (including two to cater for the future Moonyoonooka lines). This cost is less than adopting pre-insertion resistor CBs or a static VAr compensation (SVC) system.

Pre insertion resistor CBs were considered however the additional cost of approximately $70k per CB and the larger physical size compared to standard Western Power CBs (ie doubts about electrical safety clearances if used in a standard template layout) led to the selection of POW CBs. Note that the issue of available space was particularly pertinent to an existing CB at Neerabup Terminal which would require replacing if pre insertion resistor CBs were selected.

4.4.8 Circuit breakers (NBT and TST)

Circuit Breakers (CB) will be 362 kV or 145 kV outdoor SF6 live-tank three-pole type with 110 V DC motor-charged spring operating mechanism. The CBs will comply with AS 2006 and AS 2650 per the following:

• Rated normal current:	3150 A
• Rated short circuit breaking current:	50 kA
• Rated short-time withstand current:	50 kA for 1 second
• DC component X/R ratio	14(curve I)
• Rated short circuit making current:	125 kA peak
• Operating sequence:	O-0.3sec-CO-3min-CO

4.4.9 132 kV line circuit (TST-TS81)

To minimize the initial capital costs, the 132 kV TS81 line circuit will be built adjacent to the 490 MVA transformer in the 330 kV switch yard. This will save the cost of developing the Three Springs Terminal 132 kV switch yard with its attendant earthworks, roads, control building, fencing and so on.

4.4.10 Earthing

Three Springs Terminal will be designed for an initial fault level of 15 kA with respect to earth potential rise (EPR), step and touch voltages. The ultimate development earthing system will be rated for 50 kA.

The earth grid conductors and primary plant will be rated for 50 kA / 0.31 sec. Initially, the number and depth of earth electrodes will be designed to provide satisfactory electro potential rise (EPR) and touch/step voltages for a 15 kA fault. As the switchyard grows over time the larger earth grid footprint and additional electrodes will safely cater for the incremental increase to the ultimate design fault current.

4.4.11 Disconnectors (NBT and TST)

Disconnectors will be provided for off-load, live operation and will be capable of switching the charging current of open busbars and connections or currents from parallel circuits. Disconnectors will be 2500 A continuous and 50 kA/1 sec short circuit withstand rated, three-pole outdoor, double break type complying with AS1306: High voltage AC switchgear and control gear - Disconnectors (isolators) and earthing switches and complete with insulators and associated operated mechanism. Integral manual earthing switches will be included as required. All 330 kV disconnectors and the 132 kV line disconnector will be motorised.

4.4.12 Current transformers (NBT and TST)

A thorough investigation by Protection Design determined that WP standard specification current transformers were suitable for this project. Long 330 kV lines with Line Shunt Reactors experience long lasting DC transients during energisation. Such transients may lead to saturation of, and remanence in, any CTs they pass through. Any DC component present in fault currents greatly affects the onset of core saturation, and becomes a major consideration in the CT design.

4.4.13 Voltage transformers (NBT and TST)

Voltage transformers (VT) will be oil insulated, capacitive or inductive, class CL 1.0, 3P and comply with AS 60044: Instrument Transformers. Capacitive voltage transformers are usually used for 330 kV because they are $7 k cheaper than inductive units, however inductive voltage transformers are required in selected locations (refer to single line diagrams in Appendix C) to cope with the transients associated with a 280 km long line and reactors.

A marshalling box will be mounted adjacent to each VT set and will be used to link VT output terminals to the substation protection, control and metering panels within the substation building. Facilities will be provided for grounding one side of the VT secondaries and fusing the other. Secondary output is 100 VA at 110/ √3 V

4.4.14 Surge arrestors (NBT and TST)

Surge arresters will be of the metal-oxide gapless type and comply with AS 1307.2, with a nominal discharge current of 10 kA and line discharge class 3. Surge arrestors will be located on all 132 kV and 330 kV line circuits, close to the transformer bushings and the 330 kV shunt reactor. Western Power has recently adopted polymeric units as standard. The standard drawing templates, which are based on porcelain surge arrestors, will be updated.

4.4.15 Lightning protection (NBT and TST)

The Lightning Protection System will provide shielding for substation equipment and personnel from direct strike by lightning. A combination of overhead earth wires (OHEW), lightning rods on strain structures and lightning masts will be used. The design of the lightning protection systems will be in accordance with Western Power standard 'Lightning Protection for Substations' based on IEEE 998 (refer DM# 4724906). The rolling sphere diameter now varies with respect to the Basic Insulation Level (BIL) of the protected equipment. The masts will be located to minimise their impact on maintenance access to other equipment, maintain safety clearances to live conductors and be directly connected to the earth grid.

4.4.16 Outdoor busbars and connections

The 330 kV switch will have two main busbars to provide the high security of supply required of a Terminal. As Three Springs Terminal develops beyond five circuits the mesh configuration will become a breaker and a half arrangement.

Design parameters, including current ratings, solar radiation and pollution performance, are tabulated in section 3.1. Mechanical support is provided by porcelain station post insulators. The maximum allowable conductor operating temperature is limited to 85 degrees C.

Overhead and low level stranded conductors will be twin all aluminium (AAC) fitted with spacers at suitable centres to minimise clashing and intra-phase pinch forces. Venus and Triton are the standard conductors for 330 kV and 132/22 kV respectively.

Corona and radio interference are mitigated by the selection of appropriate conductor diameters, smooth edges and corona rings which are standard design features.

Power cables between the transformer tertiary and the 22 kV shunt reactors will be three or four per phase, 500 or 630 mm2 (Ratings to confirm size/number) copper conductor, copper screened, cross linked polyethylene (XLPE) insulated and poly vinyl chloride (PVC) sheathed. Terminations will be shrink type polymeric outdoor type with rain sheds. Proprietory aluminium cable clamps will support the cables onto support structures above ground. Cables will be direct buried to maximise heat transfer into the soil.

4.4.17 Earthing compensator / station transformer

The earthing compensator (EC) will have a short-time current rating of 1200A for 10 seconds and have a zero-sequence impedance of 35 Ω per phase. An auxiliary winding is rated for 500 kVA and is the main supply to the terminal 440 volt AC distribution board. Oil containment is provided by locating the EC in the main transformer bund.

4.4.18 Station transformer

A standby 440V AC supply will be provided by a 33000/440 V 315 kVA mineral oil insulated, core type construction transformer (modular packaged substation) utilising cable 33 kV connections installed by WP Distribution.

4.4.19 440 V AC auxiliary supplies

Three Springs Terminal will initially have two 440 V AC auxiliary supplies (is N-1 reliability) feeding the main change-over board. In the future, once a second main power transformer is installed, a third 440 V AC supply will be connected to the change-over board.

4.4.20 Maintenance / Access Requirements

The TST 330 kV yard is designed to provide full and ready access to all its major plant and equipment for planned and unplanned maintenance without the need for customer outage or load curtailment.

The annualised maintenance costs for the complete terminal yard should not exceed a target of 1% of the establishment cost. The design of the terminal yard allows for online condition monitoring of the plant and equipment.

The area enclosed within the terminal yard security fence will have sufficient area and clearance from high voltage equipment to allow light cranes and vertically extendable work platforms to access all HV plant.

The terminal is designed to operate automatically and will generally be unmanned. There will be requirements for certified personnel to work within the terminal yard premises, either in the switchyard or within the terminal buildings for operational or maintenance purposes.

4.4.21 Construction Risks

To reduce the initial capital cost the Three Springs Terminal earthworks bench area and fence length have been minimized.

4.4.22 Substation Electrical Design Outputs

The following tables provide a summary of the key design decisions and outputs for the Three Springs terminal site:

330kV / 132kV Terminal Item	Output/Decision	Comment
Ultimate Capacity / Utilisation SS350/10/1/1, SS350/10/1/2	5 x 330 kV bays and 12 x 132 kV bays required	The number of bays that were required in each yard for the ultimate arrangement affected the size and positioning of the two yards and hence the site utilisation
Single Line - 132 kV,	Breaker and a half configuration (future)	Breaker and a half configuration offers the high reliability required (future)
Single Line - 330kV SSTTV/15/1/1	Two lines, three circuit breakers and a transformer	This arrangement minimizes the upfront plant requirements. It can be extended in future stages to breaker and a half arrangement.

Initial Capacity	Single 490 MVA transformer to be installed initially	The load forecast around the Geraldton/The Springs area was such that only one transformer would be needed initially.
Site Layout SS350/10/1/1, SS350/10/1/2	Orientation of the 330 kV yard to the SE of the 132 kV yard.	The site layout minimized the length of initial line cut-ins, reduced the number of crossings and provided clear exit routes for all future lines.
Site Development	To develop 132 kV Bays 1-4 (eastern side) initially	The topography of the block dictated that the access road had to be on the northern side of the terminal.

4.5 132KV SUBSTATIONS

4.5.1 General

The existing 'cricket wicket' line (CWL) will be demolished for the 330 kV tower line to be built. This line currently cuts in and out of Pinjar, Regans, Cataby and Eneabba Substations and tees into Emu Downs Substation. The 330 kV tower line will be energised on one side at 132 kV to replace this existing 132 kV line. Regans is only supplied by this 'cricket wicket' line so there is a need to maintain 132 kV supply to Regans throughout the line build.

Protection upgrade works at Geraldton, Mungarra and Chapman are required to reinforce the system as advised by system analysis and solutions.

DC supply:
Western Power's standard battery capacity for terminal substations is sized to supply standard and emergency loads for up to 24 hours upon loss of 440 V AC supplies. Two 110 V DC and one 50 V DC systems are specified to meet protection and scada requirements.

AC supply:
Western Power standards require a minimum of two AC supplies, one being the main supply, and the other a standby supply, complete with a change over board. This changeover board feeds into the AC distribution board, which must contain adequately rated moulded case circuit breakers (MCCBs), miniature circuit breakers (MCBs), under voltage devices and fuses

Air conditioning:
Split-system air conditioning units are installed in relay buildings to maintain appropriate conditions (around 28 degrees C) for sensitive equipment and to maintain comfort levels for personnel working within the substation.

Line rearrangements
Before the line section between Cataby and Eneabba is demolished, the tee into Emu Downs (EMD801 circuit) has to be moved onto the existing PJR- ENB81 line. To do this, the protection on the PJR-ENB line must be replaced with digital differential protection (7SD on P1, L90 on P2). The relays at Emu Downs on the 801 circuit also need to be replaced with digital differential protection (7SD on P1, L90 on P2).

Since Regans substation only supply is from the CWL, the order of the demolition and rebuild is important. The order of demolition/rebuild works:

- Demolish RGN – CTB and CTB – ENB
- Build and energise CTB-RGN (split phase)
- Build and energise CTB-ENB, demolish PJR-RGN
- Build and energise PJR-RGN

Assumptions
If new communications cubicles are required, it is assumed that they will fit within the existing relay rooms.

Identified Risks
When installing fibre optic cable from the termination pole outside the substation into the relay room, there is a risk of damaging existing buried cables or earth grid conductors.

4.5.2 Pinjar Terminal

Substation design work required at Pinjar Terminal:

- On circuit 814 PJR-ENB line: (a) remove 7SA522 relay from Protection 1 and replace with a new 7SD523 relay (b) remove existing SEL321 relay from Protection 2 and replace with a new L90 relay
- Install auto reclose on the PJR-RGN line by adding an auto reclose relay to the 821 circuit breaker (before demolishing RGN-CTB)
- New fibre optic cable will be direct buried from the termination pole outside the terminal into the relay room. Communications cubicles may need to be installed or replaced and in this case the relay room layout would need to be updated.

Line protections:
At Pinjar protection 1 and protection 2 for line circuits are installed in separate cubicles. This arrangement will be apply to the new arrangement as well. Relays in the 814 cubicles will be removed and replaced as detailed above. Terminals and links will be added to the 822 protection 1 and 2 cubicles, and new relays and links will be installed in the existing 821 circuit breaker cubicle.

DC supply:
Currently at Pinjar the battery capacity for 110 V batteries are 220 AH each and for the 50 V battery is 130 AH. This is deemed satisfactory for the MWEP.

AC supply:
At Pinjar there are three 440 V AC supplies with a changeover scheme. This is deemed satisfactory for the MWEP.

Wiring and cabling:
Wiring and cabling will only be replaced where necessary

Air conditioning:
Four split-system air conditioning units are installed in the relay building at Pinjar Terminal. This is deemed satisfactory for the MWEP.

Mimic Panel:

At Pinjar there is an existing mimic panel. Therefore the mimic panel will be updated with pushbuttons for auto reclose on/off.

4.5.3 Regans Substation 132/33/22 kV

Substation design work required at Regans:

- Update single line diagram to show multiple changes to line destinations
- New fibre optic cable will be direct buried from the termination pole outside the substation into the relay room. Communications cubicles may need to installed or replaced and in this case the relay room layout would need to be updated.

Line protections:
No line protection changes required at Regans

DC supply:
Since the load on the batteries will not increase due to works for this project, no upgrade is required.

AC supply:
No work is required.

Wiring and cabling:
No secondary wiring should be required

Air conditioning:
No change to the air conditioning system is required

4.5.4 Cataby Substation 132/33 kV

Substation design work required at Cataby Substation:

- Update single line diagram to show multiple changes to line destinations
- New fibre optic cable will be direct buried from the termination pole outside the substation into the relay room. Communications cubicles may need to installed or replaced and in this case the relay room layout would need to be updated.

Line protections:
No line protection changes required at Cataby Substation

DC supply:
No upgrade is required

AC supply:
No upgrade is required

Wiring and cabling:
No additional secondary wiring should be required at Cataby

Air conditioning:
No change to the air conditioning system is required

4.5.5 Emu Downs Substation 132 kV

Substation design work required at Emu Downs Substation:

- On the CTB-ENB81 line (circuit 801) remove a 7SA relay from Protection 2
- On circuit 801: (a) move L90 from Protection 1 to Protection 2 (b) install new 7SD on Protection 1
- New fibre optic cable will be direct buried from the termination pole outside the substation into the relay room. Communications cubicles may need to installed or replaced – this will be determined at the implementation stage.
- Update single line diagram to show circuit 801 as the PJR-ENB/EMD line (was the CTB-ENB81 line)

Line protections:
Relays in the 801 racks will be removed and replaced as detailed above.

DC supply:
No change required.

AC supply:
No change required.

Wiring and cabling:
Wiring and cabling will only be replaced where necessary.

Fault recorder:
A fault recorder is already installed at Emu Downs Substation.

Air conditioning:
No change to the air conditioning system is required

4.5.6 Eneabba Substation 132/33 kV

Substation design work required at Eneabba Substation:

- On circuit 802: (a) install new 7SD523 on Protection 1 (existing 7SA522 remains and is used for LBU, AR and CS) (b) remove existing SEL321 relay from Protection 2 and replace with a new L90 relay
- New fibre optic cable will be direct buried from the termination pole outside the substation into the relay room. Communications cubicles may need to installed or replaced – this will be determined at the implementation stage.
- Update the naming on the new circuit ENB801 (constructed as part of the Karara project) from TST to TS including updating the single line diagram

Line protections:
Relays in the 802 racks will be removed and replaced as detailed above.

DC supply:
No change required.

AC supply:
No change required.

Wiring and cabling:

Wiring and cabling will only be replaced where necessary

Fault recorder:
There is a fault recorder already installed at Eneabba.

Air conditioning:
No change required.

4.5.7 Geraldton Substation 132/33 kV

Substation design work required at Geraldton Substation:

- Install an under voltage load shedding scheme (UVLS)
- On circuit 803 (line to Mungarra), replace the existing line protection on Protection 1 and 2 with duplicated high speed protection ie digital differential relays

Line protections:
Relays in the 803 racks will be removed and replaced.

UVLS :
A new under voltage load shedding scheme will be installed in a separate panel.

DC supply:
No change required.

AC supply:
No change required.

Wiring and cabling:
Wiring and cabling will only be replaced where necessary.

Fault recorder:
There is a fault recorder already installed at Geraldton Substation.

Air conditioning:
No change required.

4.5.8 Mungarra Substation 132/11 kV

Substation design work required at Mungarra Substation:

- On circuit 842 (line to Geraldton), replace the existing line protection on Protection 1 and 2 with duplicated high speed protection ie digital differential relays

Line protections:
Relays in the 842 cubicles will be removed and replaced.

DC supply:
No change required.

AC supply:
No change required.

Wiring and cabling:
Wiring and cabling will only be replaced where necessary.

Fault recorder:
There is a fault recorder already installed at Mungarra Substation.

Air conditioning:
No change to the air conditioning system is required.

4.5.9 Chapman Substation 132/22kV

Substation design work required at Chapman Substation:

- Install UVLS

Line protections:
No line protection changes required at Chapman Substation.

UVLS:
A new under voltage load shedding scheme will be installed in a separate panel.

DC supply:
No change required.

AC supply:
No change required.

Wiring and cabling:
Wiring and cabling will only be replaced where necessary.

Fault recorder:
There is a fault recorder already installed at Chapman Substation.

Air conditioning:
No change required.

4.5.10 Three Springs Substation 132/33 kV

Substation design work required at Three Springs Substation:

- Design a 132 kV line circuit
- Update single line diagram to show new TS-TST 81 line, renumbering may be required.
- Replacing of existing TS-ENB 81 line protection relays with duplicated high speed protection ie digital differential relays
- Modify fault recorder with additional inputs from TS-TST 81 line
- Modification of existing "X" bus zone protection to accommodation the additional line
- New fibre optic cable will be direct buried from the termination pole outside the substation into the relay room. Communications cubicles may need to installed or replaced – this will be determined at the implementation stage.

Line protections:

Replace both line protections for TS-ENB 81 and install new line protections for TS-TST 81 at Three Springs.

DC supply:
No change is required.

AC supply:
At Three Springs, there is a main AC supply from the station transformer with no standby supply or changeover facility.

Wiring and cabling:
Secondary wiring is required for TS-ENB 81, TS-TST 81 and "X" bus zone protection at Three Springs due to retrofitting and modification of existing relay racks to make space for new line protection.
New/additional cables will be required for both TS-TST 81 and TS-ENB 81 lines.

Fault recorder:
The existing fault recorder at Three Springs needs to be modified to include TS-TST 81 line inputs.

Air conditioning:
Two split-system air conditioning units need to be installed.

Identified Risks
Outage of "X" bus is very difficult and will hinder the installation work at Three Spring. The design methodology will need to cater for outage duration.

4.6 SUBSTATION ELECTRICAL DESIGN METHODOLOGY

As part of the development of this project, Western Power needs to:

- Comply with relevant industry standards (particularly AS2067: Substations and high voltage installations exceeding 1 kV a.c.);
- Comply with relevant Western Power standards; and
- Follow proven Western Power guidelines and practices.

4.7 MAJOR PLANT REQUIRED FOR THIS PROJECT

Primary plant required for the Mid West Energy Project substations is listed in the table below:

Site	Transmission Plant Allocation Sheet (TPAS) DM#
Neerabup Terminal	7347554
Three Springs Terminal	7346957
Three Springs Substation	7347633

General remarks:
Some plant is already available, having been ordered for the North Country Reinforcement project.

4.8 IDENTIFIED RISKS

The key substation design risks have been identified - refer to estimate risk register DM# 7316699.

4.9 SAFETY IN ELECTRICAL DESIGN

Transmission Primary Engineering and Construction has developed a Safety in Design checklist [DM# 7673373]. Various design checklists are also utilized to enhance the rigour of the design process eg Substation design checklist [DM# 4251099].

4.10 DANGEROUS GOODS

Dangerous goods safety applies to road transport and storage/handling on site. The Three Springs Terminal transformer holds 103 m3 of insulating oil (Class 3 flammable liquid) which must be registered on a Western Power manifest. Similarly, 330 kV circuit beakers hold 40 kg of sodium hexa-fluoride (SF6) gas. Hazchem signage must be fixed to the main entrance gates and a site plan available for Fire and Emergency Authority (FESA). The Three Springs Terminal site must be licensed and details kept in the Substation Oil and SF6 register as described in WP's Dangerous Goods management guidelines.

5 CIVIL AND STRUCTURAL DESIGN

5.1 SCOPE

5.1.1 Neerabup Terminal 330 kV

The earthworks bench, roads, fencing, relay building and site surfacing already exist for the new Three Springs 330 kV line circuit. Two 19.3 m high gantries and the 'A' busbar require extensions. Additional low level structures and footings are required. Since Neerabup Terminal lies within wind Region A1, standard Western Power footings and structures have been adopted. All NBT civil and structural designs / drawings have been completed (for the original North Country project).

5.1.2 Three Springs Terminal 330 kV

Three Springs Terminal site - undeveloped

The civil scope for the green field TST site includes all earthworks, drainage, roads, hardstand, fences, footings, structures, transformer/reactor bunds, cable trenches, site surfacing and a relay building for a new 2 bay Terminal 1.5 circuit breaker yard. Existing standard 330 kV and 132 kV terminal footings for wind Region A1 need to be redesigned to suit the higher wind loads of Region B. Existing standard 330 kV and 132 kV terminal structures are already suitable for Region B. New designs will be required for the 22 kV reactor circuit footings and structures.

5.1.3 Three Springs Substation 132/33 kV

The existing earthworks bench and site surfacing require extension for the new 132 kV line circuit (TST81). A geotechnical investigation is necessary. Existing fencing lies well outside the proposed construction area and does not require modification.

Existing standard template zone substation footings and structures are suitable for this wind Region B site. No modifications are anticipated to the existing relay building except for the addition of air conditioning.

5.2 CIVIL AND STRUCTURAL DESIGN STANDARDS

A list of civil and structural standards pertaining to the Mid West Energy project may be found in DM# 7936677.

5.3 CIVIL AND STRUCTURAL DESIGN - TST

5.3.1.1 GENERAL

As part of the development of this project, Western Power needs to:

- Comply with relevant industry standards
- Comply with relevant Western Power standards
- Follow proven Western Power guidelines and practices
- Comply with Main Roads WA, AUSTROADS and Shire guidelines / specifications

5.3.1.2 ASSUMPTIONS

- For shallow pad footings, the allowable bearing pressure was calculated assuming a minimum depth of 0.5 m of approved fill material over the underlying clayey soils
- Information provided by the relevant authorities on the availability and location of existing services is correct and up to date

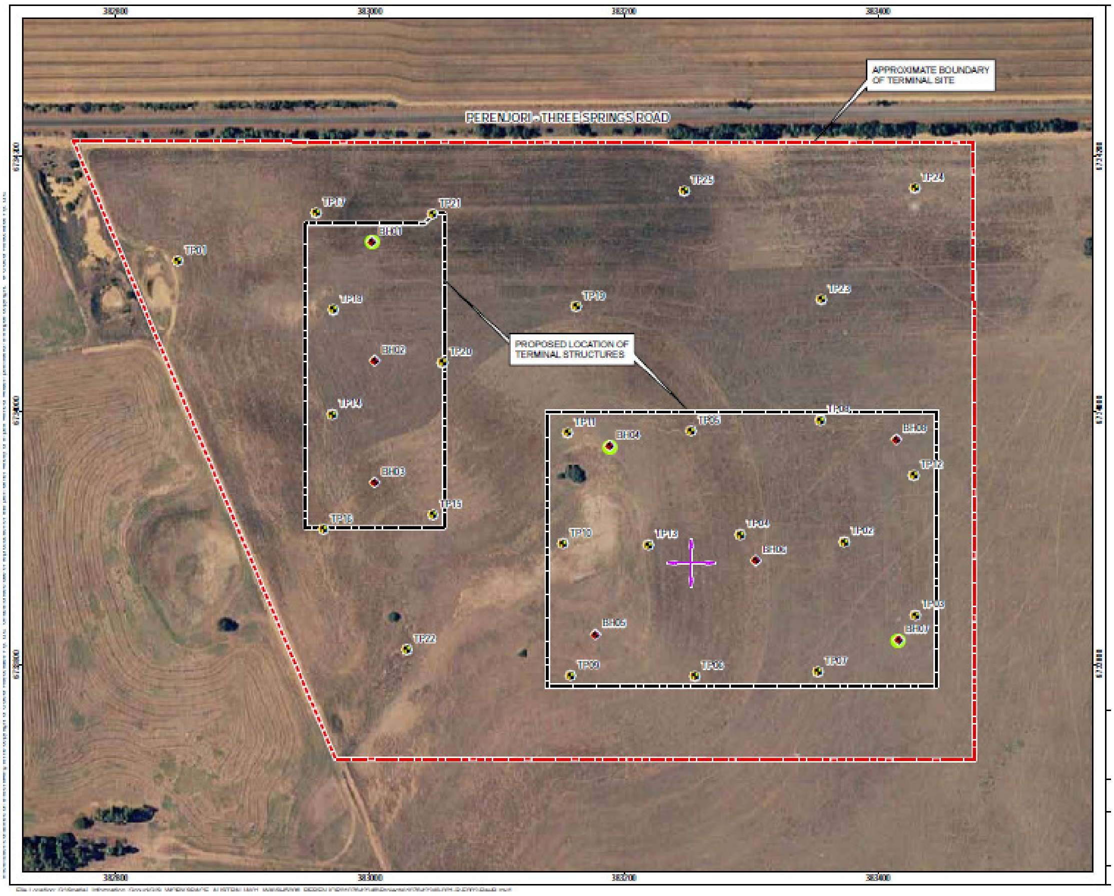
5.3.1.3 FLOOD LEVEL

Golder Associates have completed a local flood study to determine the 100 year flood level for the TST site. Hydrological concentration has been based on the contours provided on the aerial photogrammetric survey. The proposed earthwork bench will be elevated 600 mm above this flood level.

Note that a regional flood study is being conducted in May 2011. The results of this study are required before the start of TST earthworks. There is a small risk that the earthworks bench may need to be raised if the regional flood level exceeds the local flood level.

The terminal site is within the catchment known as the Yarra Yarra salt lake system which is an area of internal drainage and does not have any outlet to the ocean. Anecdotal information from the Shire indicates that the terminal site was not inundated in the 1999 Moora floods.

5.3.2 Geotechnical Investigation



Location of TST geo-technical test pits and bore holes

The geotechnical investigation indicates that the TST subsurface conditions comprise the following:

- Loose to medium dense SAND, extending from the surface to depths of between 0.45 m to over 2.5 m; overlying
- Clayey SAND/ Sandy CLAY, medium to high plasticity, stiff to very stiff or loose to dense, extending to depths of between about 1.1 m and 2.4 m; cemented in parts, becoming weakly cemented with depth and generally causing refusal or termination of the test pits where encountered; overlying
- Clayey Sandy GRAVEL, well iron cemented, extending to depths of between 0.7 m to over 2.5 m, encountered at some locations.

The depth of sand overlying the clayey soils was highly variable. Shallower depths of sand were encountered within the low-lying area in the south-west of the site.

Groundwater was encountered in five of the test pits at depths ranging between 1.3 m and 1.9 m. Groundwater inflow was generally in the form of minor seepage of water perched on top of the clayey soils.

The Acid Sulphate Soil (ASS) risk maps indicate that the terminal site is located close (within 500 m) to an area of high risk of AASS and PASS. Therefore assessment of

Acid Sulphate Soils (ASS) was combined with the geotechnical investigation. Moderate to high risk of Acid Sulphate Soil (ASS) was identified.

Allowable soil bearing pressures are stated in the geotechnical report & suit the standard footing designs.

The following is a summary of the key design decisions and outputs:

- Shallow pad footings are considered appropriate for TST structures
- Drainage of the TST site by means of soak wells was considered appropriate
- Cable trenches are to be drained

5.3.3 Earthworks, Roads and Drainage Design

5.3.3.1 GENERAL

- Further detailed studies, such as regional flood level modelling, existing road intersection design (seal levels, cross-falls, drainage requirements etc) with Shire of Three Springs sign-off needs to be undertaken to be able to produce the final Approved for Construction drawings.
- Drainage design for the bench is based on a 5 minute rainfall of 1 in 20 years return period
- Stage 1 TST earthworks design is based on the ultimate site utilization plan

5.3.3.2 IDENTIFIED RISKS

- The TST regional flood level study has yet to be completed and this may change the final bench level
- Geotechnical investigations cannot cover the entire bench so there is a possibility of encountering difficult soil conditions

5.3.4 Services

5.3.4.1 DESIGN METHODOLOGY

As part of the development for terminal or substation project, Western Power needs to liaise and obtain approval with utility services company (such as Water Corporation, Telstra and the Shire) for the connections to their existing services. However, if there are no utility services within the vicinity, portable/in-situ arrangement to be made. Allowance has been made for a rain water tank and a septic system on site.

5.3.4.2 DESIGN OUTPUTS

All connection detail design will comply with the relevant authorities' specifications.

5.3.5 Low Level Structures

5.3.5.1 DESIGN OUTPUTS

The following footings and structures were selected for 330, 132 and 22 kV circuits and analysed for the Region B wind force to determine their suitability. Changes necessary to the standard footings were based on preliminary designs for estimating purposes only. Actual conductor loads will inform the final footing designs.

Description	Footing drawing	Structure drawing	Remark
Neerabup Terminal 330kV			
Adopt standard terminal footings and structures designed for wind region A			
Three Springs Terminal 330kV			
Circuit breaker	SS1/18/9/502/1	Supplied by manufacturer	Footing size to be increased
Disconnector	SS1/18/9/501/2	SS1/20/9/502/2	OK
Current transformer	SS1/18/9/503/1	SS 1/19/9/502/1	Footing size to be increased
Capacitive voltage transformer	SS1/18/9/504/1	SS1/19/9/503/1	Footing size to be increased
Electromagnetic voltage transformer	Similar to SS1/18/9/504/1	Similar to SS1/19/9/503/1	Await supplier's drawings
Surge arrestor	SS1/18/9/505/1	SS1/19/9/504/1	Footing size to be increased
Busbar support	SS1/18/9/506/1	SS1/19/9/508/1	Footing size to be increased
Tee off support	SS1/18/9/507/1	SS1/19/9/509/1	Footing size to be increased
Three Springs Terminal 132kV			
Circuit breaker	SS1/18/8/513/1	Supplied by manufacturer	Footing width increased to 2400
Disconnector	SS1/18/8/501/1	SS1/20/8/501/2	Beam size to be increased
Current transformer	SS1/18/8/501/1	SS1/20/8/509/1	Footing size to be increased
Voltage transformer 3ph	SS1/18/8/501/1	SS1/20/8/505/1	Footing size to be increased
Voltage transformer 1ph	SS1/18/8/511/1	SS1/20/8/508/1	OK
Surge arrestor	SS1/18/8/501/1	SS1/20/8/503/1	Footing size to be increased
Three Springs Terminal 22kV			
Circuit breaker	SS1/18/5/507/1	Supplied by manufacturer	Adopt 66 CB
Disconnector	SS1/18/0/15/2	SS1/20/5/90/4	New designs
Current transformer	SS1/18/5/507/1	SS1/20/5/76/2	New designs
Voltage transformer 1ph	SS1/18/0/15/2	SS1/20/5/76/2	New designs
Surge arrestor	-	-	New designs
Cable termination	SS1/18/5/502/1	SS1/20/5/33/6	Check suits 500-630 mm2 cables
Reactor	New design	Supplied by manufacturer	
Three Springs Substation 132/22kV			
Adopt standard zone substation footings and structures which suit wind region B			

5.3.5.2 PARAMETERS

The following structural design parameters have been adopted for TST:

Design parameter	Value
Allowable soil bearing pressure	200 kPa
Concrete grade	N25 or N32
Steel grade	300 MPa
Bolts	PC 4.6 snug tightened

5.3.6 Gantries

5.3.6.1 DESIGN METHODOLOGY

Western Power has developed a number of standard gantry structures that are commonly used in its network. These structures comply with all the relevant Australian Standards but are designed for wind loading for Region A1. Three Springs Terminal is located in Wind Region B and therefore the wind pressure is approximately 70% more than Region A1. For this reason a review and partial redesign is required.

The predominant design loads for strain structures are wind pressure and conductor tension due to short circuit loads. As per Western Power current design practice, wind loads are computed according to AS1170.2:2002 while short circuit electromechanical loads on conductors are derived using in-house Gload software written according to AS3865:1991 (consistent with IEC 865-1).

5.3.6.2 DESIGN OUTPUTS

A preliminary design only has been completed with the following findings:

- The 330 kV 19.3 m high, double bay gantries need to be redesigned with an increase in size for leg and beam members. Foundation pad dimensions also will be increased.
- The 132 kV gantry structures (both 7.3 and 12 m high) are capable of withstanding the increased load within acceptable deflection limits; in both cases foundations need to be increased. Also the 7.3 m gantries at Three Springs Terminal and Substation may require a lateral prop.

5.3.6.3 ASSUMPTIONS

Conductor type and stringing tensions impact the gantry loadings and values adopted for the preliminary design are tabulated below:

Span length(m)	Phase conductor	Overhead earth	Tension Insulator set
Neerabup Terminal 330 kV landing span (TST91)			

60	Twin Silicon 61/3.5 AAAC 5% EDT	Lemon / OPGW 30/7/3.0 ACSR/GZ 5% EDT	Double porcelain
Three Springs Terminal 330 kV landing span (NBT91 and KRA91)			
80	Twin Hurdles 54/7/3.5 ACSR/AC 5% EDT	Darts / OPGW 30/7/3.0 ACSR/AC 4% EDT	Double porcelain
Three Springs Terminal 330 kV internal bays			
68	Twin Venus 54/3.75 AAC 5% EDT	Neptune 19/3.25 AAC 5% EDT	Single porcelain
Three Springs Terminal 132 kV internal bay over transformer T2			
46	Twin Venus 54/3.75 AAC 5% EDT	Neptune 19/3.25 AAC 5% EDT	Single porcelain
Three Springs Terminal 132 kV landing span (TS81)			
22	Venus 54/3.75 AAC 4% EDT	Lemon OPGW 30/7/3.0 ACSR 4% EDT	Polymeric
Three Springs Substation 132 kV landing span (TST81)			
tba	Venus 54/3.75 AAC 4% EDT	Lemon OPGW 30/7/3.0 ACSR 4% EDT	Polymeric

5.3.6.4 IDENTIFIED RISKS

From a safety in design perspective, Western Power will review the contractor's gantry erection procedure.

5.3.7 Building and Fire Protection

5.3.7.1 BUILDING DESIGN METHODOLOGY

Standard relay building for 330 kV and 132 kV Terminals

A standard concrete tilt-up precast wall panel, steel roof frame building has been chosen for Three Springs terminal. The plan footprint is approximately 24 m x 12 m and standard drawings are already available. Compliance with the more onerous Region B wind pressures is ensured by selecting a heavier steel reinforcing fabric from a table in the drawings. Roof sheeting is Colorbond profiled sheeting Tek screwed to cold formed Zed purlins.

The building will be elevated above finished surface level to ensure that stormwater does not enter the cable space under the equipment floor.

The standard relay room for terminal substation is suitable for being used in Three Springs. It complies with the current relevant Australian standard and with the Building Code of Australia 2010 (class 8 building as per AS 2067:2008).

The building will be divided into four segregated areas to accommodate:

- Relay/Control room buildings will contain Protection Relay Racks, SCADA equipment, communication equipment, 415V AC distribution boards, 110V and 50V DC paralleling boards, batteries and chargers
- 110 and 50 volt batteries
- A washroom and toilet
- A store room

The buildings will be equipped with air-conditioning units, an AC lighting and small power system, emergency lighting, battery room eyewash equipment, battery room ventilation, fire extinguishers and a Vesda smoke detection system.

5.3.7.2 DESIGN OUTPUTS

The standard terminal building can be used as it is for Three Springs Terminal. Site specific arrangements are required for plumbing and stormwater management eg rainwater tank / pressure pump, septics and soakwells

5.3.8 Transformer Foundations and Bunds

5.3.8.1 DESIGN OUTPUTS

The following is a summary of the key design decisions and outputs:

- The design of transformer foundation and bund is similar to the approved design template drawing
- The design of the 330 kV shunt reactor foundation and bund is a preliminary design for estimation purposes only
- No fire walls are required in this Terminal due to adequate separation distances between transformers [AS2067 Table 6.1]

5.3.8.2 ASSUMPTIONS

The following key assumptions have been made:

- Main transformer is physically identical to Neerabup Terminal T2
- The 330 kV shunt reactor type is adopted from ABB reactor document 2ZSE 460010-A2291

5.3.8.3 IDENTIFIED RISKS

The 330 kV shunt reactor could be larger than expected resulting in changes to the TST layout

5.3.9 Fences

The following is a summary of the key design decisions and outputs:

- Following a risk assessment, a chainmesh fence has been adopted for TST, which was deemed to be a low security risk site
- A low boundary fence will enclose the property
- There are no screen walls required in this substation.

5.4 SAFETY IN DESIGN REPORT

Civil and structural 'safety in design' reports may be referred to in DM# 7358146 and #7359543.

6 TRANSMISSION LINE DESIGN

Refer to Mid West Energy Project Line Design Report DM# 7075162.

7 DISTRIBUTION WORKS

Refer to Mid West Energy Project Distribution Design Reports DM# 6114296 (PNJ-RGN), 5026445 (RGN-CTB) and 5104612 (CTB-ENB).

8 ENVIRONMENTAL AND COMMUNITY REQUIREMENTS

The following key risks for the Three Springs terminal site have been addressed by Western Power environmental and community engagement section:

- No issues arose from WP consultation with the Shire of Three Springs and the local community
- Visual amenity is acceptable
- A Section 18 Ministerial permission to disturb an Aboriginal heritage site is not required
- An adequate firebreak will be provided around the substation fence
- The site was previously farmland so does not require any vegetation removal
- If disturbance of greater than 100 m3 of material from below the water table becomes necessary or dewatering is required, some additional acid sulphate soil (ASS) investigation may be required.
- Three Springs terminal lies just outside a country drinking water source area for Three Springs.

A summary of the above issues may be found in email DM# 7942882.

Environmental and community issues associated with Lines are addressed in the Lines Design Report [DM# 7075162].

9 SECONDARY SYSTEMS REQUIREMENTS

9.1 COMMUNICATIONS

Protection upgrades & Line reconfigurations on the existing 132 kV lines between Pinjar & Three Springs will necessitate new underground optical fibre lead-ins at various substations. Where line lengths exceed 100 km optical amplifier systems will be installed.

Since the Dampier Natural Gas Pipeline communications microwave bearer is being upgraded to digital, substation analogue Tele Protection Services will be replaced with digital equipment where required to eliminate pink noise.

A new OPGW will be installed between TST & TS. OPGW splice boxes have been allowed for adjacent the future Badgingarra Terminal site.

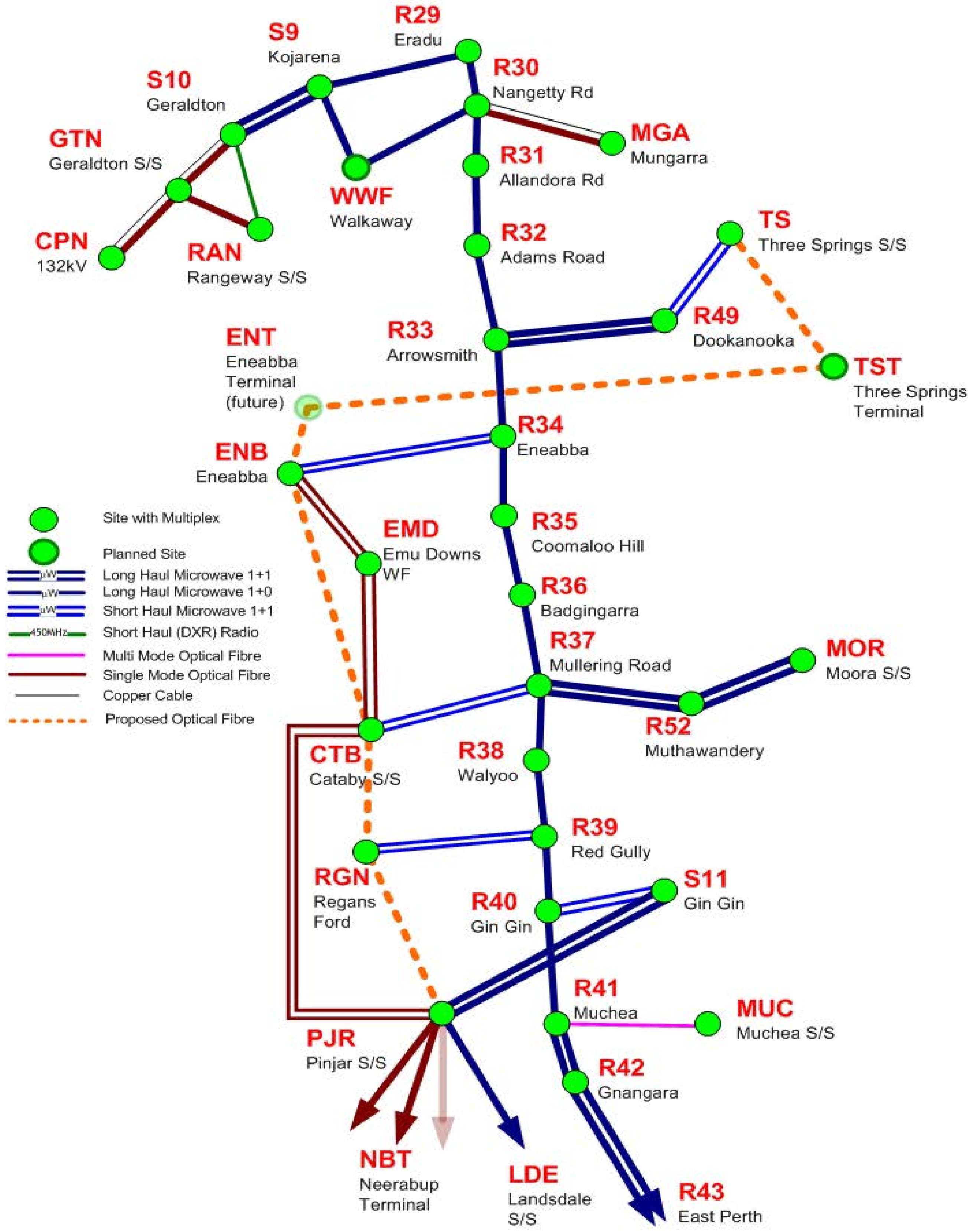
At some substations the additional communication equipment lowers the battery standby time below the required 48 hour limit – new batteries have been allowed for.

At present the SEAL Gigabit backbone extends only to PJR. However the existing Midwest SEAL backbone will be upgraded up to Three Springs.

A dedicated phone line will be provided at TST for operators to contact System Operations Control Centre.

Communications works will also facilitate an Ethernet connection for a datastore at TST and allow for new fault recorders at Cataby & TST.

Refer to Communications Design Report [DM# 7319450]. See the bearer plan below


R29
Eradu
S9
Kojarena
R30
Nangetty Rd
S10
Geraldton
MGA
Mungarra
GTN
Geraldton S/S
R31
Allandora Rd
WWF
Walkaway
CPN
132kV
RAN
Rangeway S/S
R32
Adams Road
TS
Three Springs S/S
R49
Dookanooka
ENT
Eneabba
Terminal
(future)
R33
Arrowsmith
TST
Three Springs
Terminal
R34
Eneabba
ENB
Eneabba
Site with Multiplex
Planned Site
Long Haul Microwave 1+1
Long Haul Microwave 1+0
Short Haul Microwave 1+1
Short Haul (DXR) Radio
Multi Mode Optical Fibre
Single Mode Optical Fibre
Copper Cable
Proposed Optical Fibre
EMD
Emu Downs
WF
R35
Coomaloo Hill
R36
Badgingarra
R37
Mullering Road
MOR
Moora S/S
R52
Muthawandery
CTB
Cataby S/S
R38
Walyoo
R39
Red Gully
RGN
Regans
Ford
R40
Gin Gin
S11
Gin Gin
R41
Muchea
MUC
Muchea S/S
PJR
Pinjar S/S
R42
Gnangara
NBT
Neerabup
Terminal
LDE
Landsdale
S/S
R43
East Perth

9.2 SCADA

The scope of the MWEP SCADA work involves:

- Upgrade of the SCADA RTU at Three Springs S/S (TS)
- Establishing a new SCADA facility at Three Spring 330kV Terminal
- Expanding the existing SCADA facilities at Neerabup 330kV Terminal, Pinjar, Regans, Cataby, Emu Downs, Eneabba, Mungarra, Chapman and Geraldton Substations.

RTU and master station databases will be modified, installed and commissioned to reflect the Protection changes. Intelligent electronic devices (IEDs) will be connected to remote terminal units (RTUs) using DNP3, whilst protection defective alarms will be hardwired.

A GPS clock will be installed at Cataby S/S to synchronise alarm events with the Fault Recorder.

At TST allowance has been made to create operational procedures for the reactors & to procure / install a human machine interface (HMI).

Further details may be found in the Scada Design Report [DM# 6480305] and estimate memo [DM# 7345093].

9.3 PROTECTION SYSTEMS

The Technical Rules stipulates the requirements for protection systems on the South-West Interconnected System and thus has an influence on protection design. Protection design is also carried out with consideration of efficiency in using standard designs, enhanced supply security with minimal marginal cost difference and future expansion.

All 330 kV circuits have duplicated line protections which are both high-speed duplicated digital differential protection schemes. System Analysis & Solutions section has requested HSSPAR for the NBT-TST 330 kV line and point-on-wave (POW) switching for its associated circuit breakers. An existing 330 kV CB at NBT must be rewired for HSSPAR & POW.

AT TST the 330 kV line shunt reactor will be installed in bay 947 with a dedicated circuit breaker fitted with duplicated high-speed protections. The two TST 22 kV reactors will each have a CB with single protections.

Existing 132 kV line protections will be upgraded to high speed unit type if required, say to meet critical fault clearance times. Under-voltage protections are required to maintain stability of the mid west 132 kV transmission system. Temporary settings will be required when some lines are operated in split-phase configuration.

Due to the long line route and adjacent line impedances on the CTB-ENB 132 kV line, installation of jumpers along the line may not be sufficient to provide adequate protection and maintain coordination during split-phase operation. To overcome this problem, the existing blocking distance protection scheme will be replaced with a digital differential protection scheme. New relays will be required at both ends of the line.

The TST 415 V AC standby supply is derived from the TS Latham feeder. Feeder settings & sensitivity will be reviewed.

Secondary works resulting from protection requirements have been largely outlined in section 4 of this report.

Refer also to the Protection Scope DM# 7360520, estimate memo DM# 7333241, staging diagram DM# 7310177 & 330 kV reactor issues DM# 7329042.

9.4 IDENTIFIED RISKS

The following key risks have been identified:

- Reactor switching
- CT and/or VT saturation (switching transients)
- Control of NBT-TST91 and TST-KRA91 line energisation … voltage stability etc
- Multiple protection changes eg 132 kV line as split phase line then not (staging)

10 MITIGATION STUDY REQUIREMENTS

10.1 SUBSTATION EARTHING

The preliminary Three Springs terminal earthing design has assumed three soil resistivity scenarios - poor, average and good resistivity. Shallow resistivity test results from the TST geotechnical investigation and the earth grid resistance for the nearby existing Three Springs Substation were also used to somewhat refine the earth grid design. Final earthing design will follow MWEP approval.

Western Power uses CDEGS software to perform earthing, electro-magnetic field (EMF) and low frequency induction (LFI) design.

10.2 SUBSTATION LIGHTNING AND LIGHTING

10.2.1 Scope

The lightning design of substations is carried out using Caligari software trueSpace7. Lighting design is performed using AGi32 software developed by Lighting Analysts.

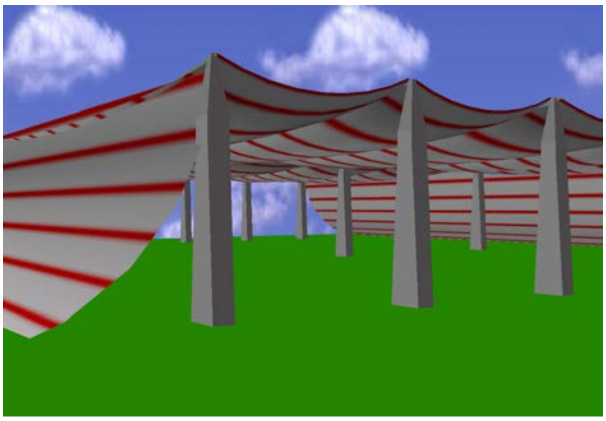
10.2.2 Lightning protection

The lightning protection systems will be designed in accordance with AS1768: Lightning Protection. For the 330/132 kV Terminal Yards standard design lightning shielding of the outdoor switchyard will be provided by a combination of lightning rods on the line termination towers, earth wire strung between gantries and lightning poles within the switchyard area.

Strategically placed lightning masts, directly connected to the terminal yards earth grid and positioned so that they do not obstruct maintenance access to other equipment in the switchyard, are to be located in the switchyard to cover the initial and final location of equipment. The masts may also be used to mount light fittings for yard lighting.

Earth wires will be strung between the gantries. These earth wires will form part of the lightning protection scheme and will be considered during the lightning design.

An example of a lightning design for a Terminal Yard using the rolling sphere method is included below:



In calculating the shielded area, the "Rolling Sphere" method as described in AS1768: Lightning Protection is to be used. The Australian Standard states that a sphere of radius between 20 and 60m can be used, depending on the protection level required.

The Western Power standard Lightning Protection of Substations (DM# 4724906) states that a radius of 24m shall be used. The 24m radius is the outcome of an iterative process of calculating the risk due to lightning strikes and comparing this with the tolerable value of risk. This value is widely used in the power industry.

The height of the masts is to be 15 metres. The distribution of lightning masts is to provide sufficient cover to protect the future bays. The masts will be based on Western Power's standard design.

10.2.3 Lighting design

The lighting system will provide light for safe access and operation in the terminal site with minimal disturbance to the surrounding area, as per Western Power Substation Lighting Standard (DM# 741783) and Western Power Lighting Procedure (DM# 4479054). The lighting systems secondary function is security, as stipulated by the IEEE. The lighting is designed in compliance to:

AS4282: Control of the obtrusive effects of outdoor lighting;
IEEE1127: Guide for the Design, Construction and Operation of Electric Power Substations for Community Acceptance and Environmental Compatibility; and
AS60598: Luminaries – General requirements and tests.

Interior building lighting is required to allow the safe movement of personnel and the safe operation of equipment. Emergency lighting will also be fitted within buildings in accordance with AS2293: Emergency escape lighting and exit signs for buildings and the Building Code of Australia (BCA).

Outdoor lighting will be as per the figures listed in Table 1 of the CIE Publication No. 68 'Guide to the lighting of exterior work areas'. Halogen type lamps are required and will be mounted on lightning protection masts or dedicated light poles with a minimum height of 6m above ground level.

11 SPECIFIC SITE REQUIREMENTS AND CONDITIONS

11.1 FIRE PROTECTION

As per Western Power standard designs (refer DM# 3619983 / 3619979), the Relay Room will be equipped with a Vesda smoke detection and alarm system. Extinguishers will be provided externally and within the Terminal Yard buildings.

The standard building design has been produced by external consultants and architects in compliance with the latest building codes and fire requirements.

External fire risk to the relay building is minimal due to the considerable distance between it and the transformer (70 m), 330 kV reactor (93 m) and 'bush land' (24 m) [AS3959]. Also the CBs are SF6 insulated and CT / VTs contain small volumes of oil.

The fire response at Three Springs Terminal may be very limited eg Shire of Three Springs bush fire brigade. The closest larger regional centre may be Geraldton 172 km away.

11.2 STAGING OF WORKS

Refer to staging information in the Protection Design Report DM# 7360520 & the Scope for MWEP estimate DM# 7170020.

11.3 SITE CONSTRAINTS

- Mains water availability – a mains pipe runs along the public road
- Sewerage disposal on site
- Nearest three phase 33 kV supply is near TS ~2.5 km away

11.4 DEMOLITION WORKS

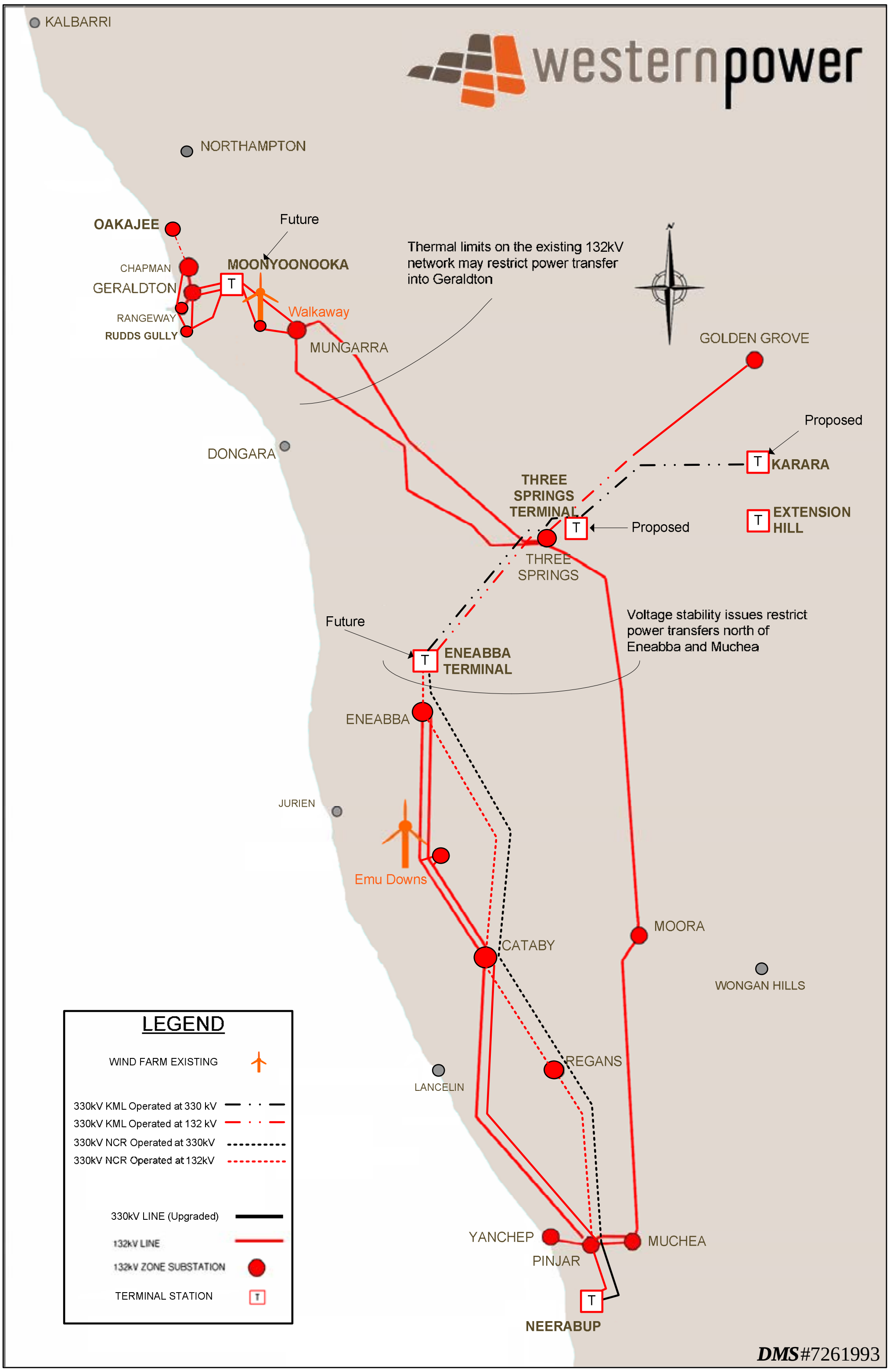
There is no demolition work envisioned in the substation component of the Mid West Energy Project.

Appendix A : ABBREVIATIONS

In this document the follow abbreviations refer to:

Abbreviation	Description
AS	Australia Standard
ASS	Acid sulphate soil
ASCE	American Society of Civil Engineers
AVC	Analytical Voltage Calculator
BCA	Building Code of Australia
CASA	Civil Aviation Safety Authority
DEC	Department of Environment and Conservation
DM	Document Management System
ECEA (was ELMB)	Environmental, Community Engagement and Approvals (was Environmental and Land Management Branch)
EDT	Every Day Tension (15º C)
ENA	Energy Networks Australia
EPA	Environmental Protection Authority
GPS	Global Position System
IEC	International Electro-technical Commission
ESAA	Electricity Supply Association of Australia
HDPE	High Density Polyethylene
HMI	Human Machine Interface
LFI	Low Frequency Induction
NENS	National Electricity Network Safety Code
OHEW	Over Head Earth Wire
OPGW	Optical Ground Wire
PLSCADD	Power Line System Computer Aided Design and Drafting
RTU	Remote Terminal Unit
SCADA	System Control and Data Acquisition
SOE	Sequence of events
SWIN	South West Interconnected Network
TBL	Triple Bottom Line
HSSPAR	High Speed Single Pole Auto-reclosing
UWA	University of Western Australia
WC	Water Closet
WP	Western Power
XLPE	Cross Linked polyethene

Appendix B : PROJECT LOCATION



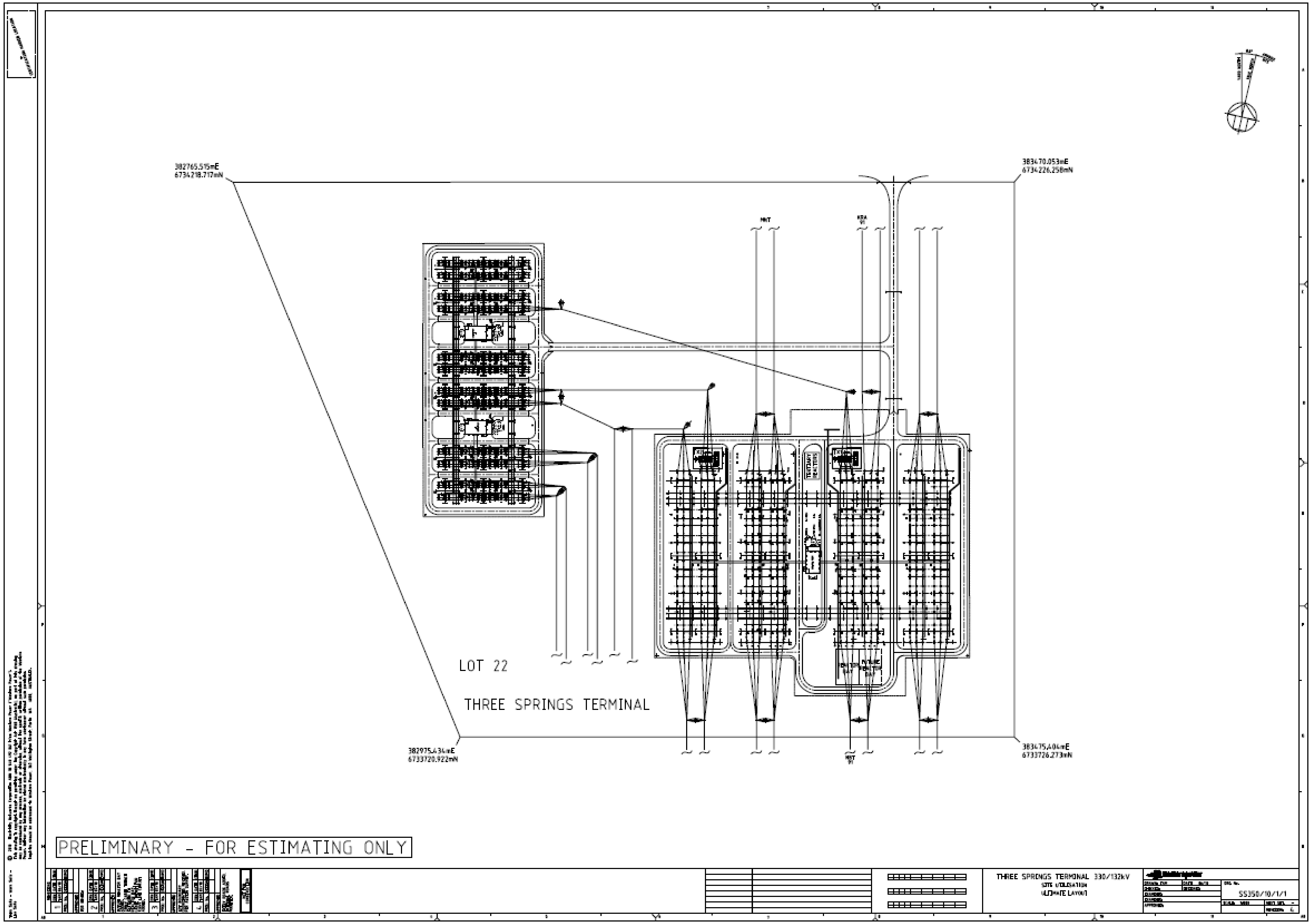


Figure C.1TST 330/132 kV Ultimate Site Utilisation

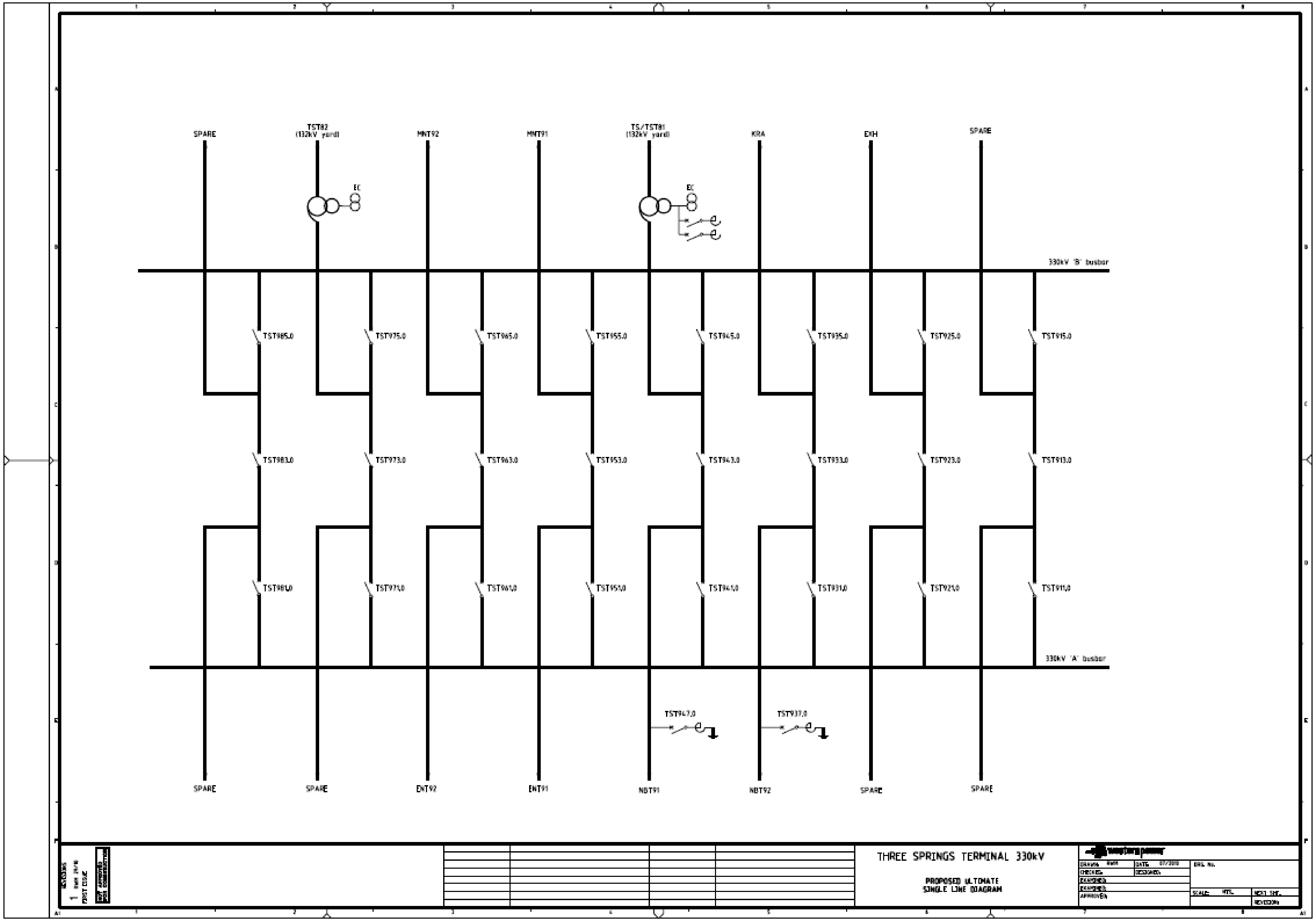


Figure C.2 TST 330 kV Ultimate Single Line Diagram

Appendix D : PROJECT SITE UTILISATION AND SINGLE LINE DIAGRAM

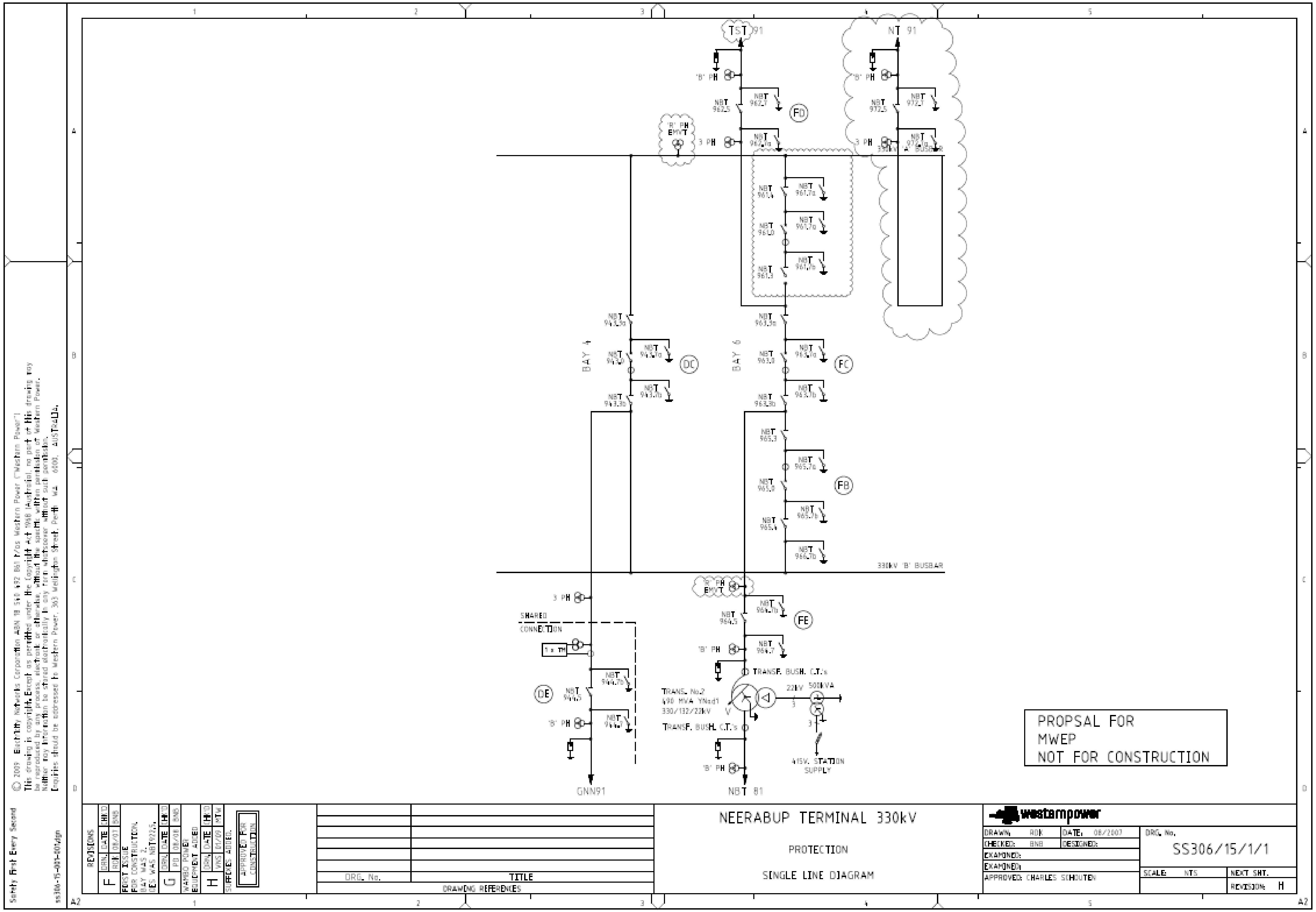


Figure D.1 NBT 330 kV Single Line Diagram (MWEP work shown clouded)

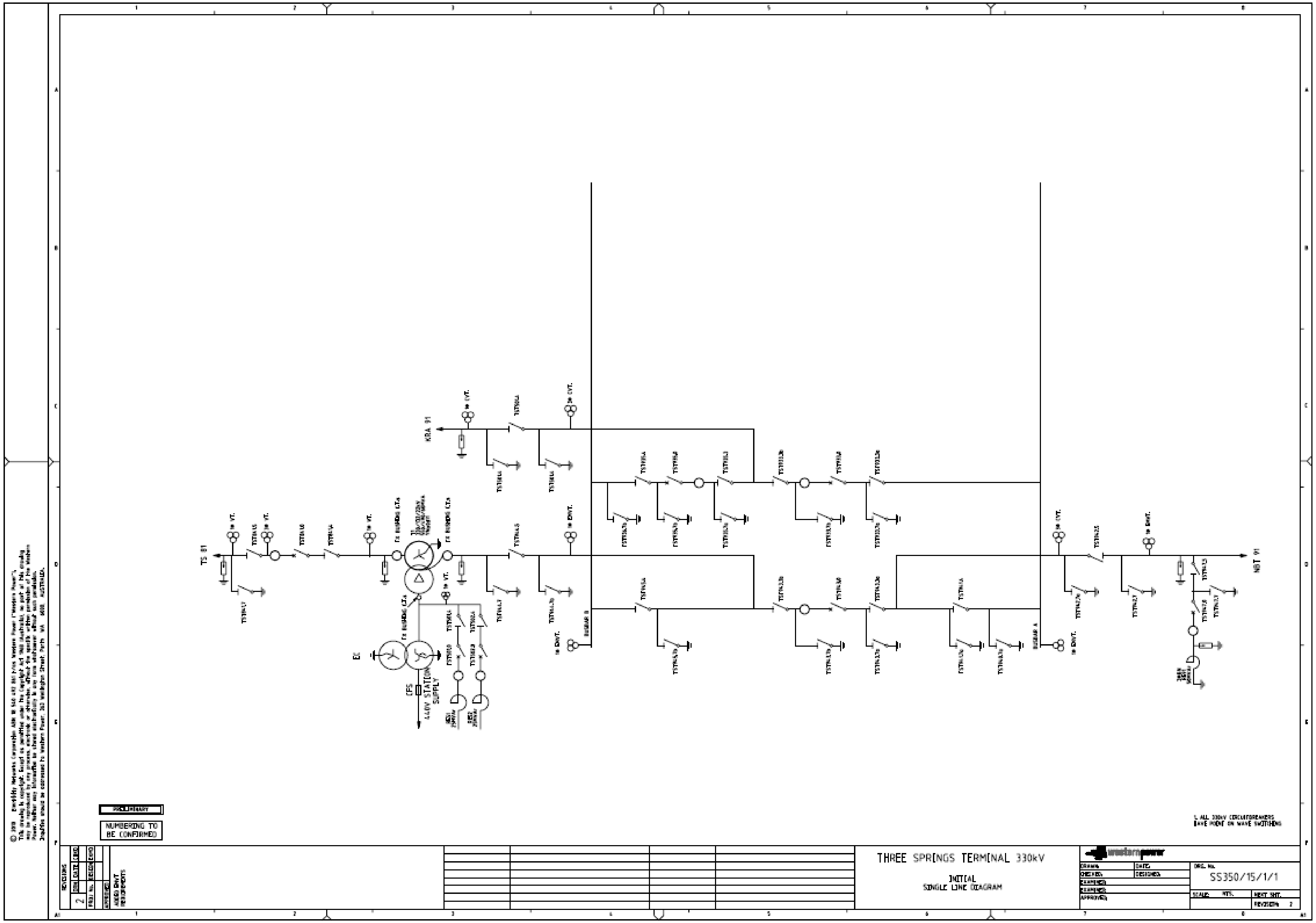


Figure D.2 TST 330 kV Single Line Diagram (including TS81 line)

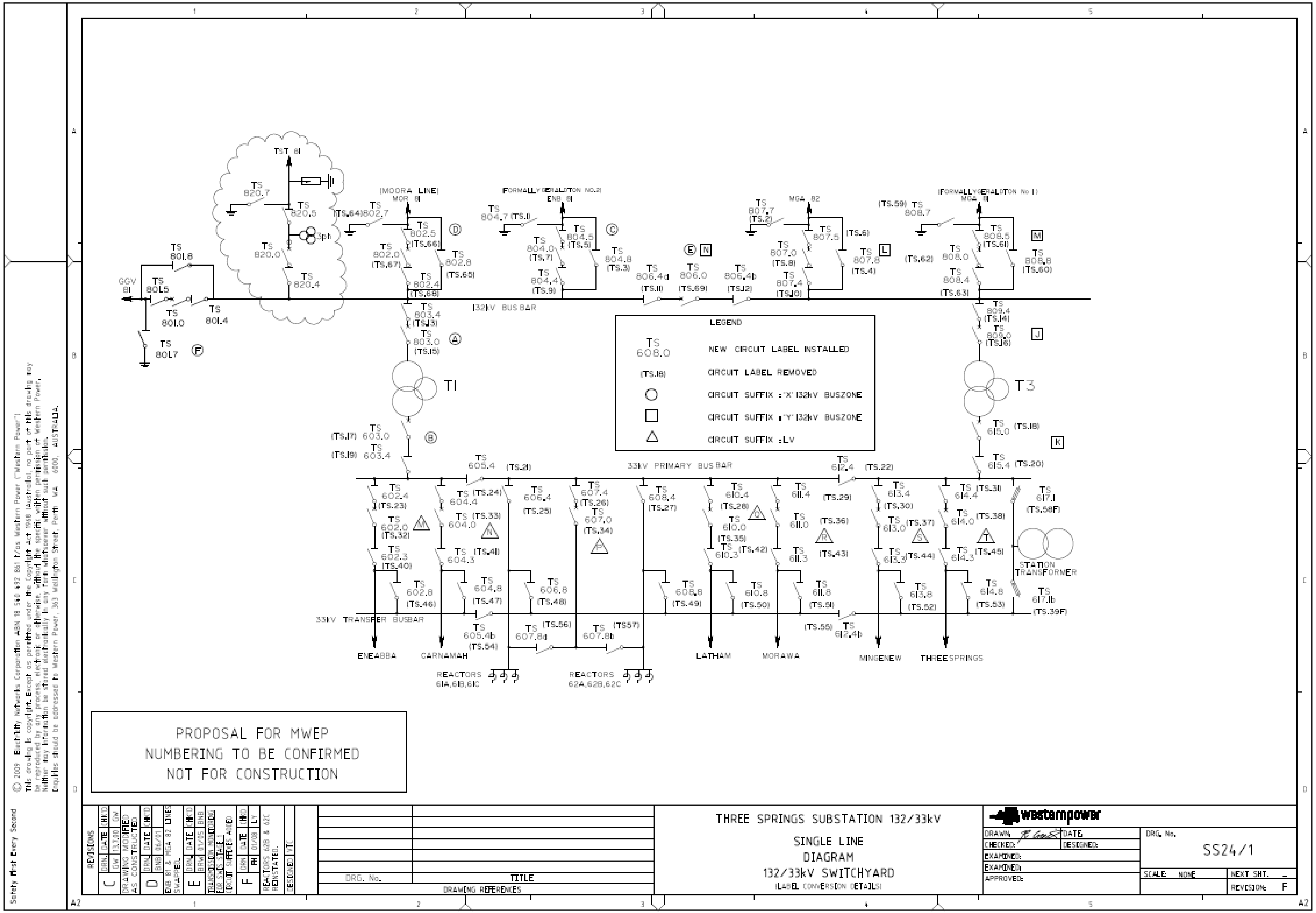


Figure D.3 TS 132/33 kV Single Line Diagram (showing new TST81 line)