WRL CCG

Undergrounding report

Western Renewables Link | Delivered by AusNet

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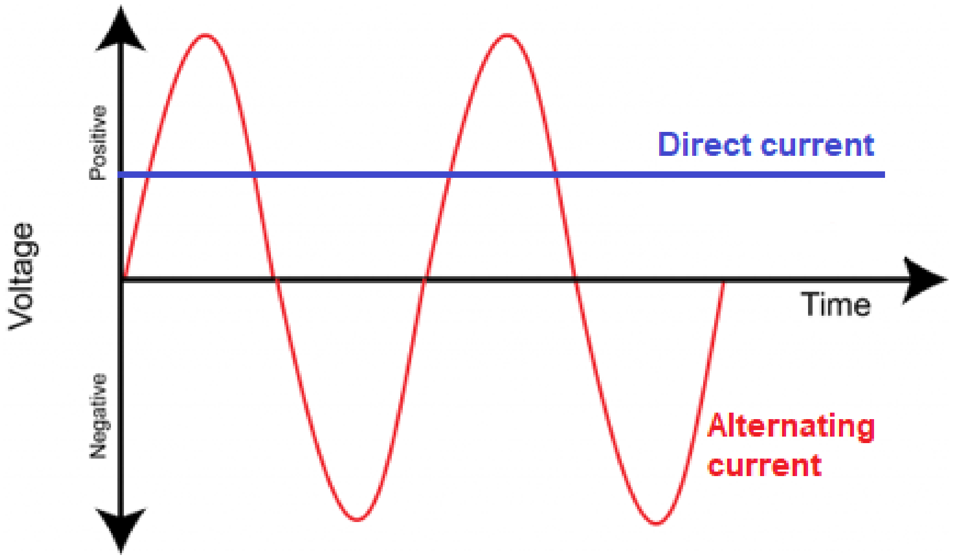
01 Electricity transmission fundamentals

Electric power transmission

- Electrical power (watts) is the product of voltage (volts) by current (amperes) (P = V * I)
- Higher voltages have less losses
- Electricity can be generated and transmitted as direct current (DC) or alternating current (AC)
- Solar panels generate DC which is converted to AC using inverters
- Wind turbines, and thermal (coal), gas and hydro power stations generate AC
- DC is difficult to transform into higher or lower voltages
- DC transmission losses are less than losses when using AC
- **AC is more flexible and can be easily transformed into higher or lower voltages**. For this reason, AC is widely used in transmission and distribution networks and appliances



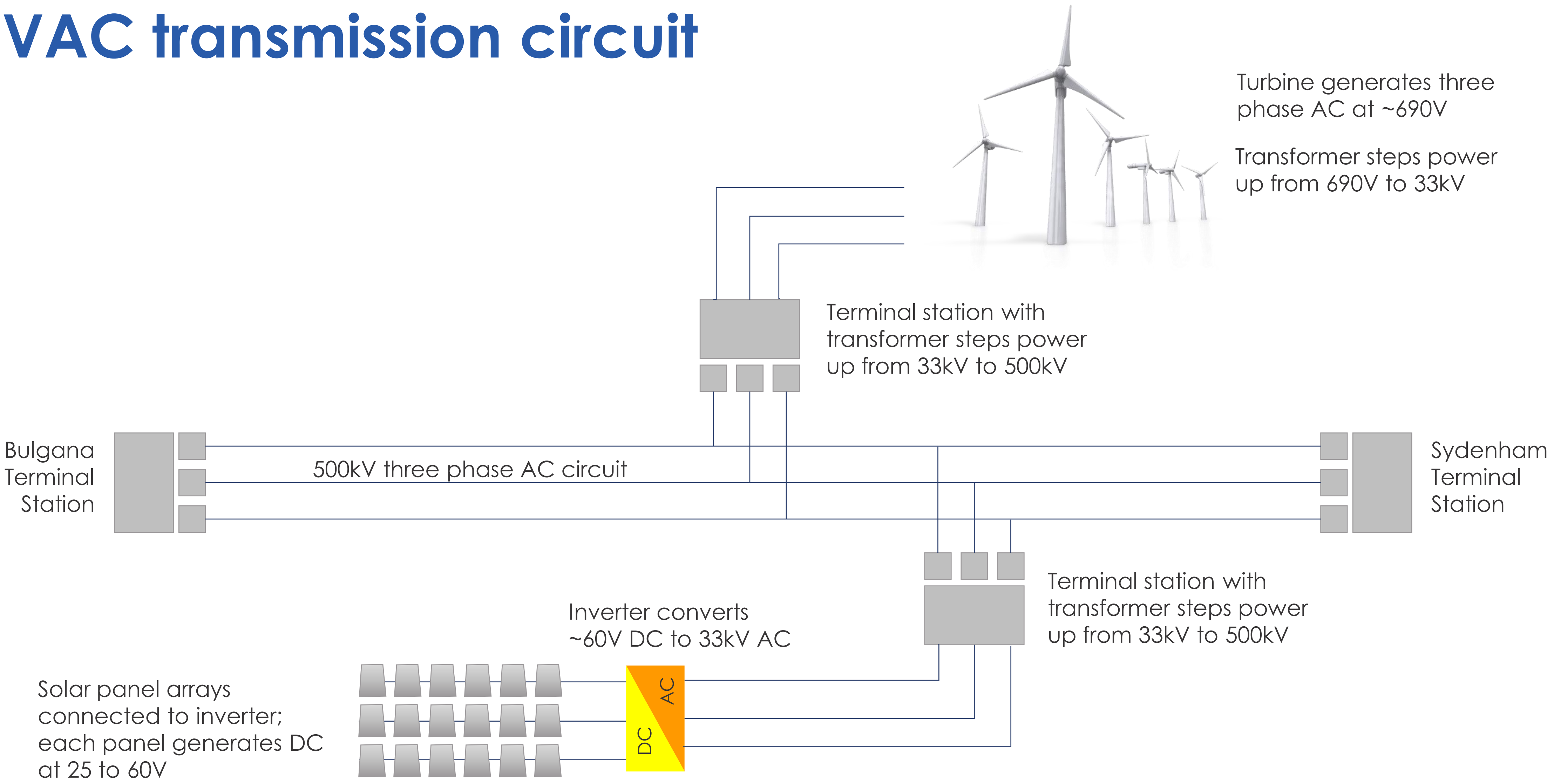
Technology options

- Electricity can be transmitted as AC or DC, overhead or underground
- AC is generated in three phases, with the phases making up a circuit
- DC is generated in a single phase (+ ve) with a return (- ve), with the phase making up a circuit
- AC and DC underground cable configurations are different
- AC requires at least one cable per phase, a minimum of three cables per circuit
- DC requires at least one cable, two if a metallic return is used instead of the earth
- DC transmission lines (overhead or underground) can be configured in different ways:
    - Asymmetrical monopole comprising one pole cable and one metallic return cable
    - Symmetrical monopole comprising two pole cables with one acting as the metallic return cable
    - Bipole comprising two pole cables and a metallic return cable
- DC circuits require converter stations to convert AC to DC and DC to AC at each end of the transmission circuit

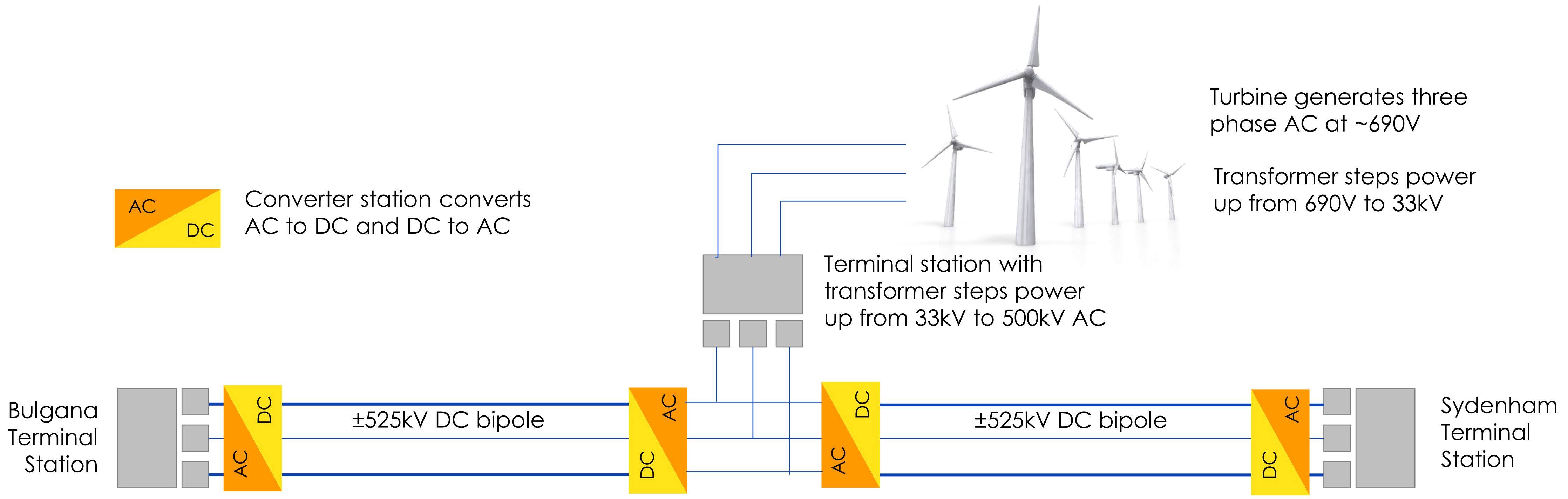
Overhead transmission line conductor

Underground transmission line cable

HVAC transmission circuit

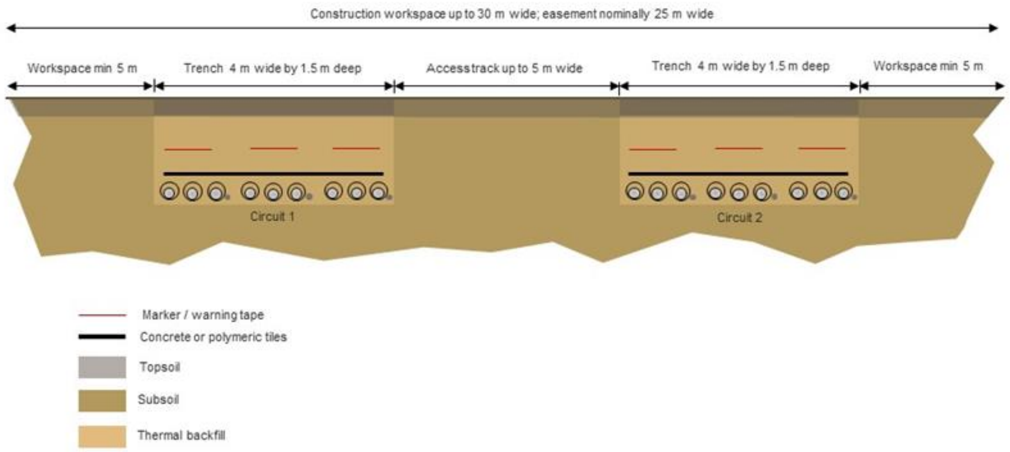


HVDC transmission circuit



02 Full and partial underground components

HVAC underground components

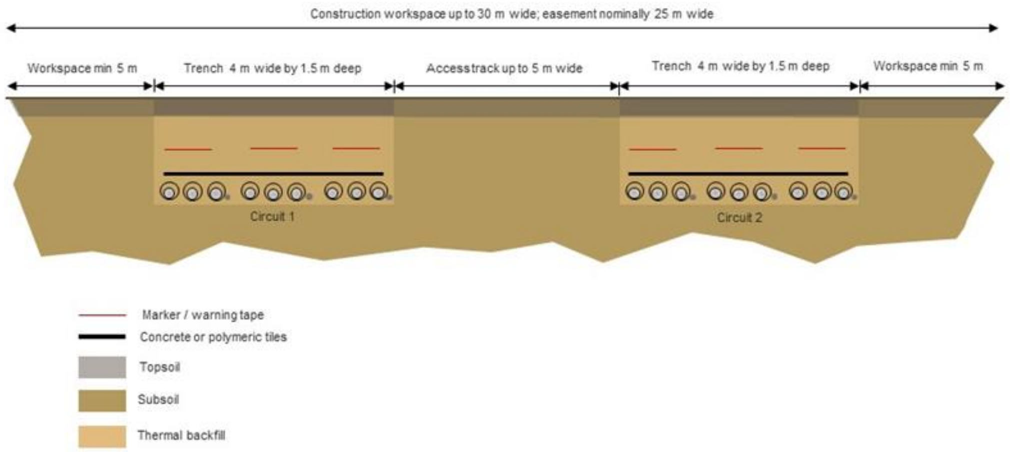


High-capacity single circuit cable trench

Typical cable joint pit

Reactive compensation station

HVAC partial underground components

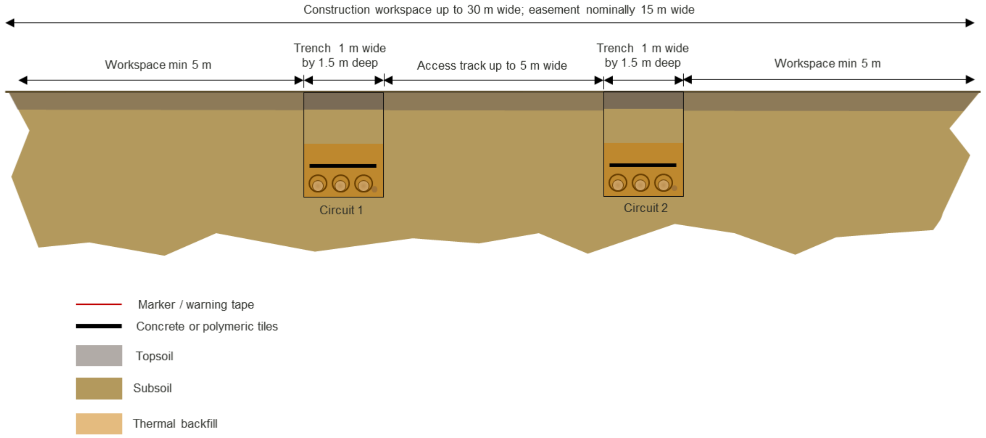



High-capacity single circuit cable trench


Typical cable joint pit

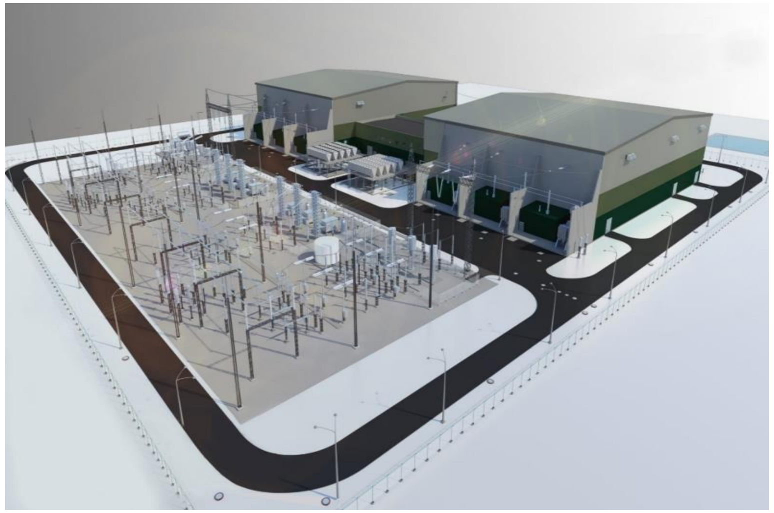

Kingwell transition station Source: Corrie Construction

HVDC underground components



Basslink single circuit converter station and switchyard

HVDC cable trench



Double circuit converter stations and switchyard

03

Underground construction

Underground route and construction considerations

- Terrain is a significant constraint
- Route perpendicular to slope to reduce exposure to landslip hazard
- Avoid tight bends; higher capacity cables have larger bending radius
- HDD duct lengths limited by length of cable on a drum
- Friction when pulling cable through duct can damage cable affecting its integrity
- Joints must be outside duct to enable access for repairs
- Rail and transmission line crossings perpendicular
- Cable joint pits should be above water table and flood levels
- Separation from third party assets

Underground construction

Typical HDD rig set up (long bores)

Source: WWW Vermeer Australia


Excavated trench with conduits

Source: WWW BR24 Suedlink courtesy Transnet BW


Typical cable drum

Source: WWW TenneT Suedlink


Cable joining facilities

Source: WWW TenneT Nordlink

04 Underground project examples

HVDC underground | MurrayLink
Berri, South Australia to Red Cliffs, Victoria


Construction corridor (8 to 10m wide)


Cable laying equipment


Cable laying (direct burial)

HVDC underground | Viking Link

Bicker Fen, England to Revsing, Denmark

Construction corridor (30 to 50m wide)

Cable joint pits (cable joining in progress)

HDD under canal

Comparison to WRL

Parameter	MurrayLink	VikingLink	WRL	
Purpose	Network interconnection	Network interconnection	Network augmentation	
Connections	No, point-to-point interconnector	No, point-to-point interconnector	Yes, renewable energy generators	No, point-to-point interconnector
Capacity	220MW	1400MW	4500MW	3000MW
Voltage	±150kV	±525kV	500kV	±525kV
Technology	HVDC	HVDC	HVAC	HVDC
Configuration	Symmetrical monopole	Bipole or symmetrical monopole	Double circuit	Two bipole systems
Length	~180km	765km (620km subsea, 145km land)	~190km	~190km
Construction method	Underground	Underground	Overhead	Underground
Construction corridor width	~6m	30-50m	80-100m	~35m
Easement width	Unknown	Unknown	80-100m	25-35m

05 WRL requirements

WRL technical specification (by AEMO)

HVAC transmission line

- Double circuit transmission line
- Nominal voltage 500kV
- Power transfer capacity of each circuit 2,250MW
- Single contingency event 600MW

HVDC transmission line

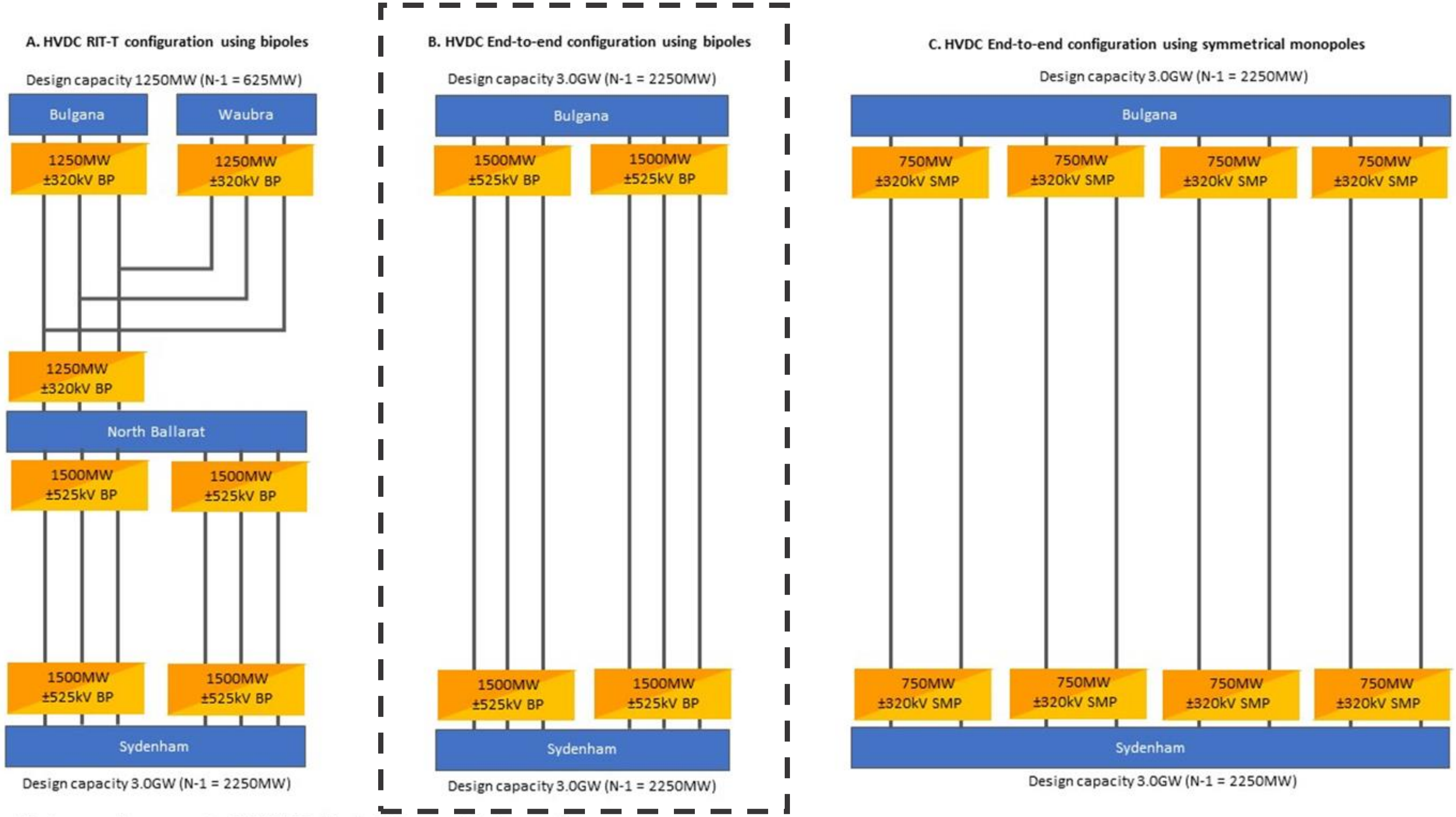
- Double circuit transmission line
- Nominal voltage ±525kV
- Power transfer capacity of each circuit 1,500MW
- Single contingency event 750MW

Underground technology requirements

- **HVAC solution requires**
  - Two 500kV 2,250MW circuits (3 cables per phase, 9 cables per circuit, 18 cables in total)
  - Reactive compensation stations at approximately 30km intervals
  - Two 4m-wide trenches at least 5 m apart in a 30m wide construction corridor

- **HVDC solution requires**
  - Two ±525kV 1,500MW circuits (bipoles) (3 cables per circuit, 6 cables in total)
  - Four ±320kV 750MW circuits (symmetrical monopoles) (2 cables per circuit, 8 cables in total)
  - Converter stations at each end of each circuit
  - One 1.5m-wide trench per circuit with at least 5m separation between trenches in a 30 to 40m wide construction corridor
    - Two trenches for bipole configuration
    - Four trenches for symmetrical monopole configuration

RIT-T and optimal HVDC underground solutions



Maximum contingency event = 750MW BP = bipole SMP = symmetrical monopole

- RIT-T and optimised HVDC solutions prepared by Mott McDonald and endorsed by Amplitude (on behalf of Moorabool Shire Council)
- RIT-T solution not practicable
- Optimised solution appropriate for end-to-end transmission
- Bipoles or symmetrical monopoles dependent on system requirements
- Bipoles provide greater security hence preferred solution

06 Full underground

HVDC full underground routes

- Underground cable routes different to overhead transmission line routes
- Topographic and land use constraints key issues
- Parallel to Ballarat to Horsham 220kV transmission line where practicable
- Follow property boundaries where practicable
- Use plantation and forest road firebreaks where practicable
- Parallel to Ballarat to Bendigo 220kV transmission line where practicable
- Use Diggers Rest - Coimadai Road to cross Merrimu Reservoir dam wall
- Use road reserves for short sections where practicable

HVDC full underground route (Western Freeway)

Source: Google Maps (Street view) Image capture 2018 © 2021 Google

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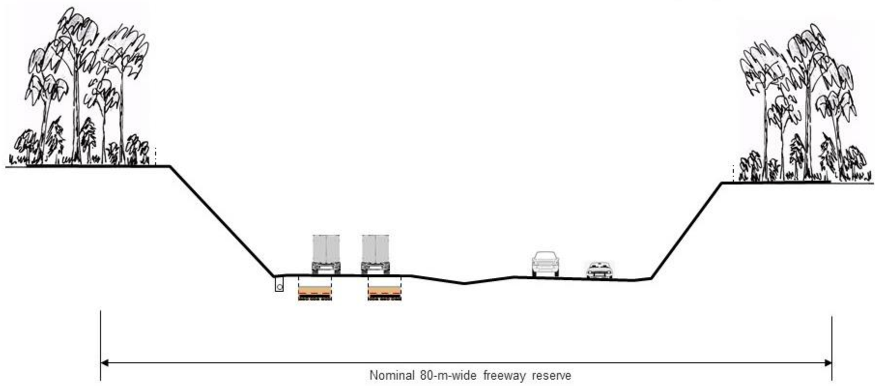
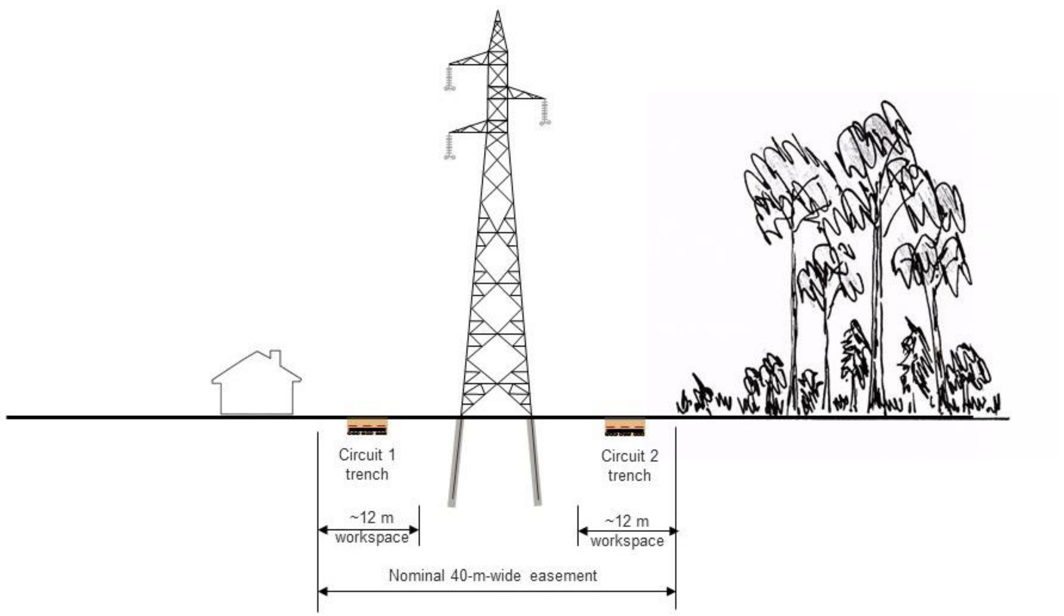


Source: Google Maps (Street view) Image capture 2021 © 2021 Google

HVDC full underground route (Ballarat-Horsham 220kV)



Source: MapshareVic @ May 2025

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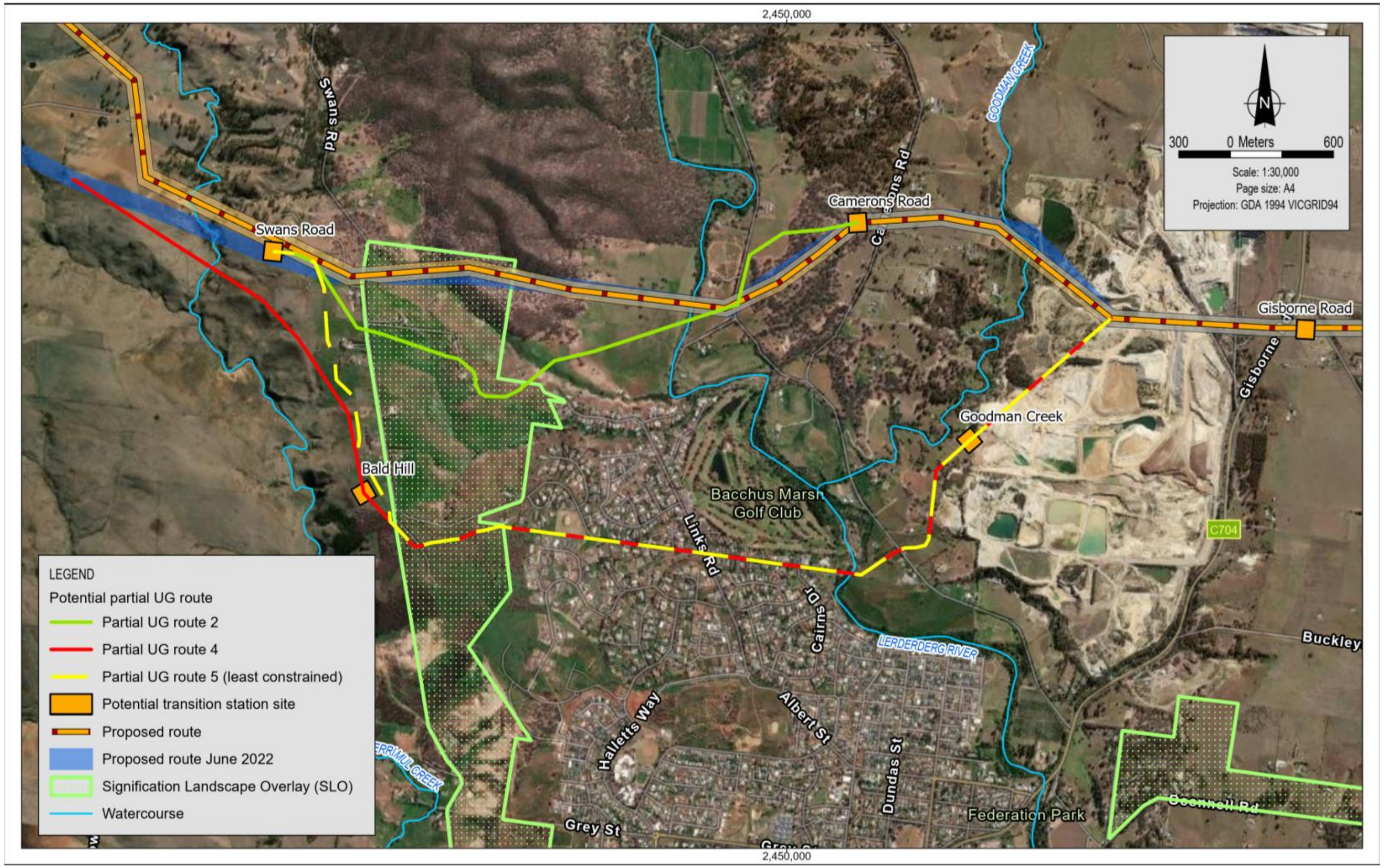
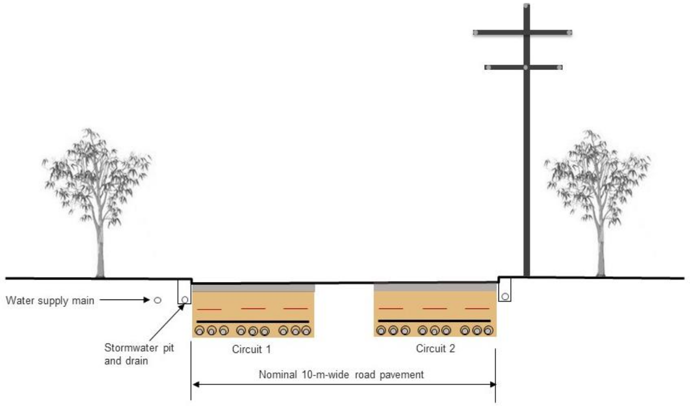
Partial underground

HVAC partial underground routes (Darley)



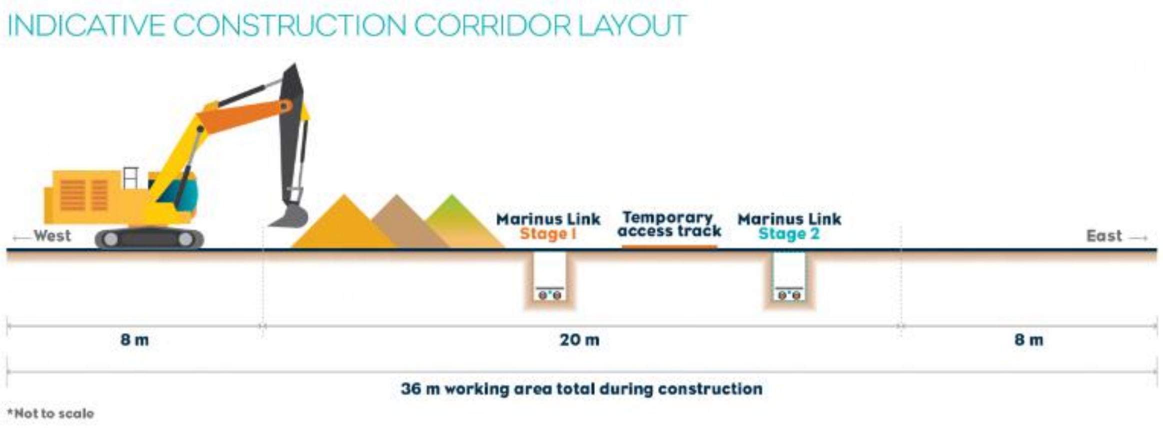


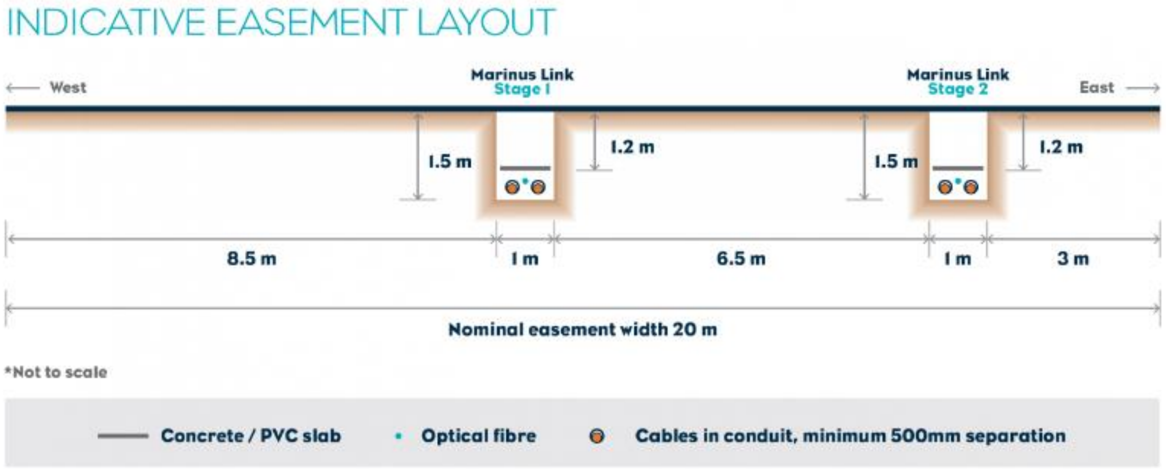
HVAC partial underground route (Darley)

- Partial UG route 5 (Swans Road/Robertsons Road) is the least constrained route as it:
  - Minimises native vegetation loss
  - Avoids Darley military camp
  - Removes structures from greater horizontal field of view
- Partial underground requires:
  - 500kV AC underground cables (18 cables in total)
  - Cable joint pits every 500 to 700m
  - Transition stations near Goodman Creek and Swans Road

08 Marinus Link

Marinus Link





- Second Tasmania-Victoria interconnector
- Cable trenches 1m wide by 1.5m deep
- Cable trenches 6.5m apart
- Cables installed in conduits
- Cable joint pits every 700m to 1,100m
- Thermal backfill
- Heavy haul access tracks
- HDD under some watercourses and roads

Comparison to WRL

Parameter	Marinus Link	WRL	
Purpose	Network interconnection	Network augmentation	
Connections	No, point-to-point interconnector	Yes, renewable energy generators	No, point-to-point interconnector
Capacity	1500MW in two stages; initially 750MW	4500MW	3000MW
Voltage	±320kV	500kV	±525kV
Technology	HVDC (voltage source converters)	HVAC	HVDC
Configuration	Two symmetrical monopoles	Double circuit	Two bipole systems
Length	~345km (255km subsea, 90km land)	~190km	~190km
Construction method	Underground	Overhead	Underground
Construction corridor width	36m	80-100m	~35m
Easement width	20m	80-100m	25-35m

09

Cost

Underground and overhead costs

- Underground costs more than overhead
- HVDC underground is less costly than HVAC underground as less cables are required
- Significant cost in HVDC underground or overhead is the converter stations
- Significant cost in HVAC underground is the cables and reactive compensation stations
- Significant cost in HVAC partial underground is the cables and transition stations

Cost estimate	Incremental cost compared to overhead construction
Amplitude (2021)[1]	4 to 6 times for HVDC solution
Transgrid (2022)	3.5 times for HVDC solution; 10 times for HVAC solution
AusNet (2023)	6 to 8 times for HVDC solution; at least 10 times for HVAC solution
NSW Parliament (2024)	3 to 6 times for HVDC solution; up to 10 times for HVAC solution
VicGrid (2024)	3 to 4 times for HVDC solution

1 Amplitude costs based on original WRL configuration; optimised WRL configuration not costed by Amplitude

Western Renewables Link

Thank You

Western Renewables Link
PO Box 638
Ballarat
VIC 3353

T 1300 360 795
E info@westernrenewableslink.com.au
W westernrenewableslink.com.au

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AusNet