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Electric Power Transmission 101

November 2021

Community Consultation Group

10 November 2021

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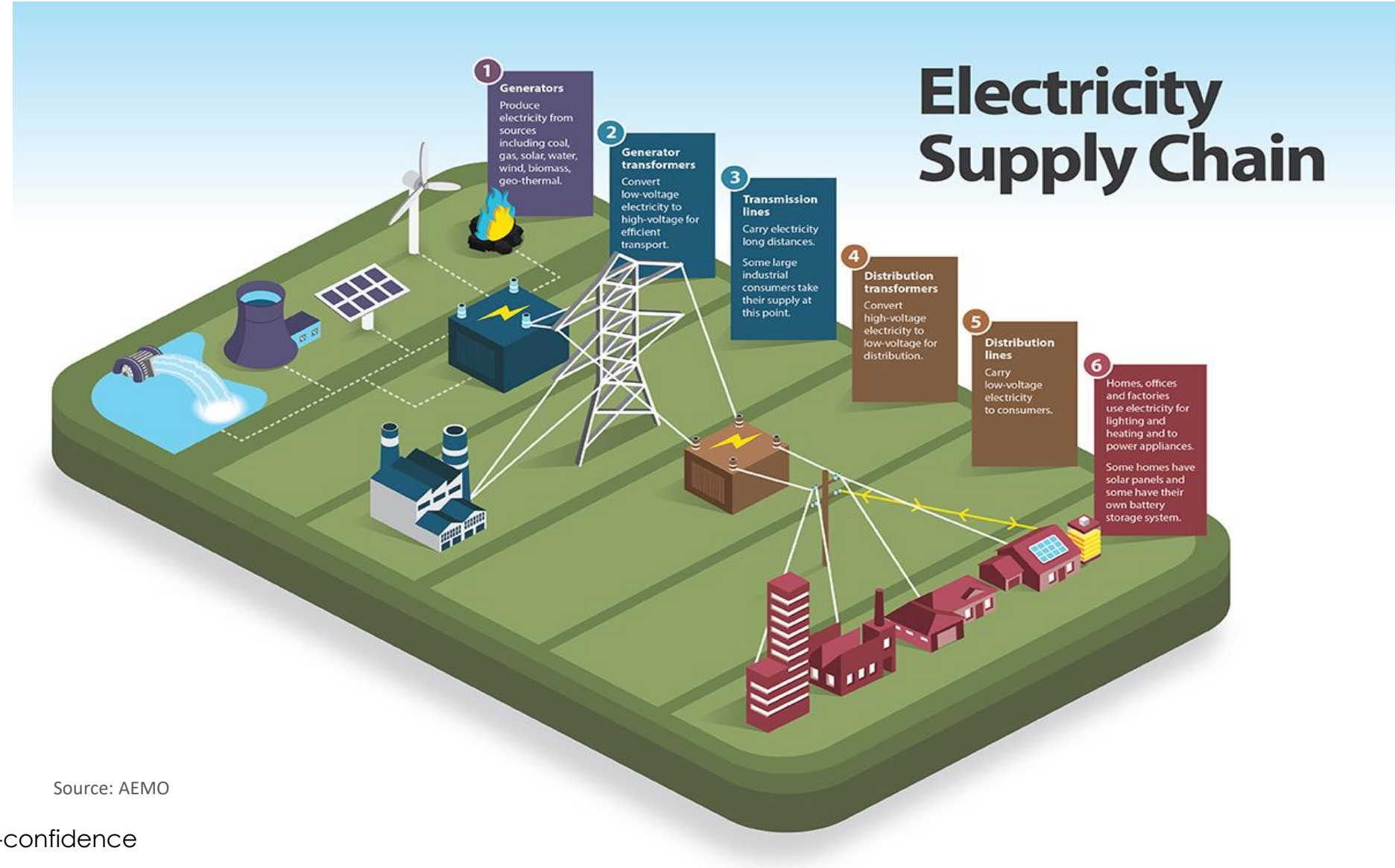
Electricity Supply Chain
1 Generators
Produce electricity from sources including coal, gas, solar, water, wind, biomass, geo-thermal.
2 Generator transformers
Convert low-voltage electricity to high-voltage for efficient transport.
3 Transmission lines
Carry electricity long distances.
Some large industrial consumers take their supply at this point.
4 Distribution transformers
Convert high-voltage electricity to low-voltage for distribution.
5 Distribution lines
Carry low-voltage electricity to consumers.
6
Homes, offices and factories use electricity for lighting and heating and to power appliances.
Some homes have solar panels and some have their own battery storage system.

Source: AEMO

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Power Generation

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Source: Loy Yang

Source Newport Power Station

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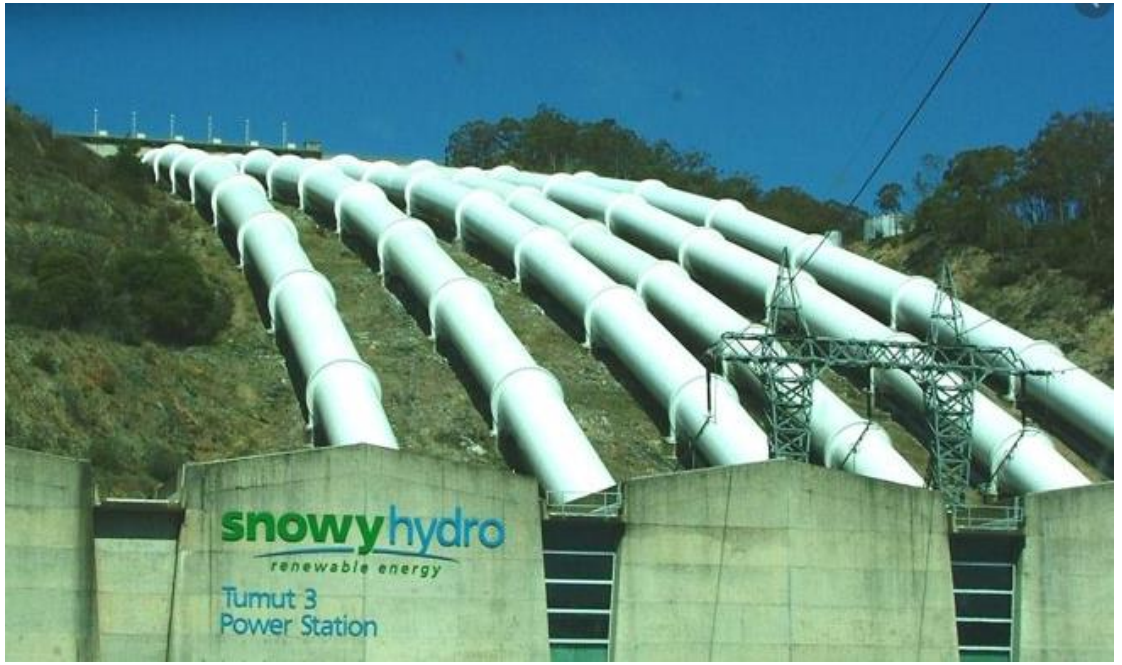
Source: AGL Mortlake Power Station



Source Snowy Hydro Tumut 3

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Power Generation

Source: NEOEN Numurkah Solar Farm

Source: AGL Macarthur Wind Farm

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What is Electric Power Transmission?

the movement of electrical energy from generating stations to distribution substations using the interconnected network

Source: AusNet Services

What is Electric Power Distribution

the process of distributing electrical energy from electrical transmission system to final individual end users

Source: AusNet Services

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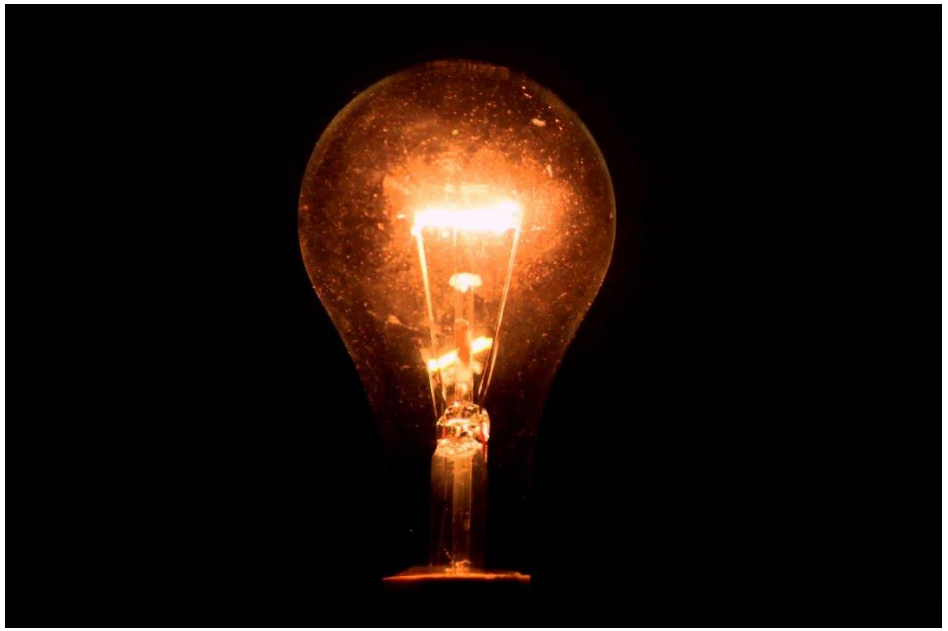
What is electrical current ?

Stream of charged electrons/ particle moving through a conductor or space

Source: iStock



Source: iStock

What is voltage ?

Voltage is the electric potential difference or electric pressure between two points

Source: iStock

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What is power?

Power is the amount of electricity required to make the world run and is the relationship between voltage and current

$$P = V * I$$

P – Power
V – Voltage
C – Current

To increase power either voltage or current needs to increase

$$\uparrow P \ by \ either \ \uparrow V \ or \ \uparrow I$$

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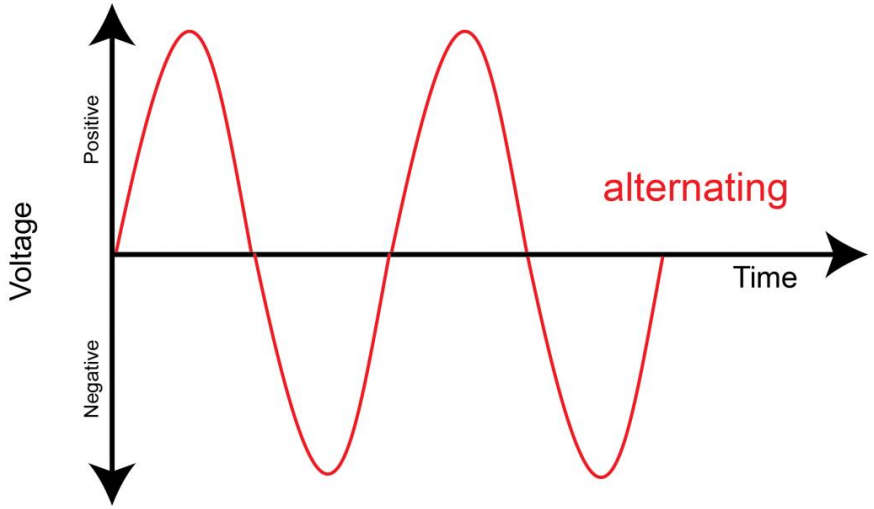
What is Alternating current (AC) ?

- A type of current in which the direction of flow of electrons changes at regular intervals or cycles
- Generation technologies such as coal / gas fired power stations, hydro electric power stations and wind turbines generate at AC

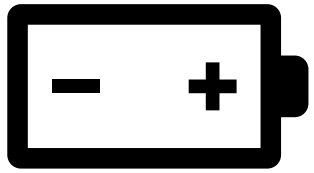
Source: Siemens

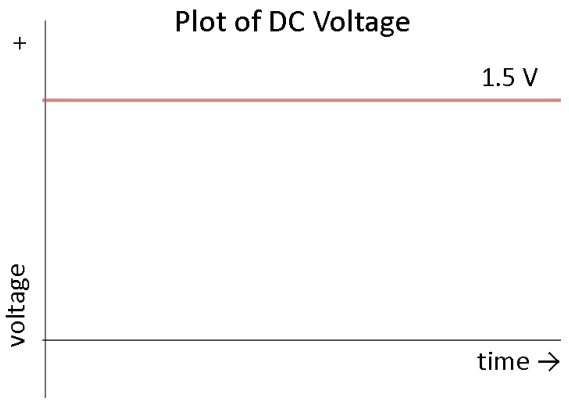


Source: iStock

What is Direct Current (DC) ?

- **Electrical current which flows constantly in one direction**
- **Energy sources such as solar PV and batteries generate/utilise DC**





HVAC and HVDC electrical Power transmission

Vast majority of power plants and most power distribution systems uses HVAC current

HVAC tends to be the cheapest and most flexible system to support Transmission & Distribution under normal circumstances.

For HVDC transmission AC /DC conversion is required at transmitting and receiving end

HVDC can be a better solution over long distances where no intermediate connections (tap offs) are required because every connection requires a complex system to convert back to AC.

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Types Power Transmission

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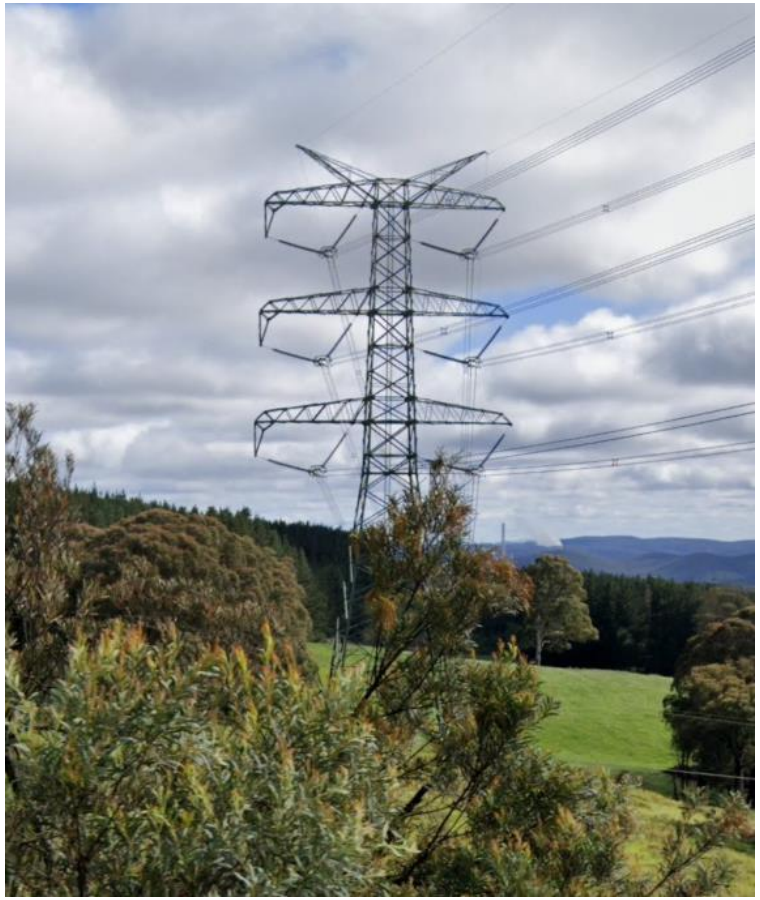
Overhead Power Transmission Line



Source: AusNet Services

Source: AusNet Services

Source: AusNet Services

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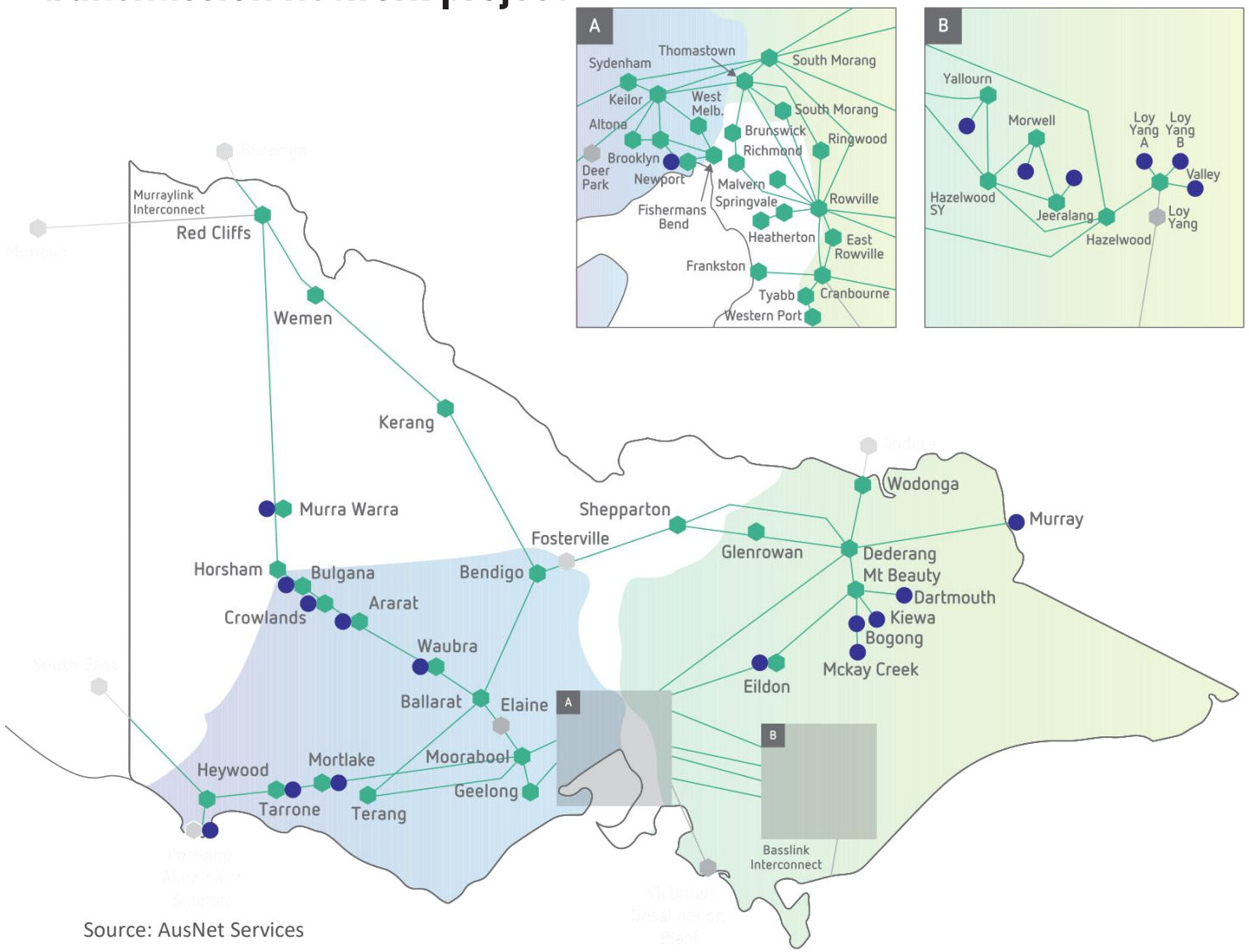
Transmission Network



LEGEND

- AusNet Services' electricity distribution network
- AusNet Services' gas distribution network
- AusNet Services' terminal/switching stations
- Non-AusNet Services terminal/switching stations
- Power stations (non-AusNet Services)
- AusNet Services' regulated transmission lines
- Non-AusNet Services transmission lines

Source: AusNet Services

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Types Power Transmission

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Underground Power Transmission Cable Construction

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Over to Barton

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Construction methods

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Topics

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Difference between above ground and underground transmission

Difference between HVAC and HVDC underground

Underground construction 101

Overhead vs underground

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Aspect	Overhead construction	Underground construction
Connection	Terminal stations (new or existing)	• Terminal stations (new or existing) if HVAC • Terminal stations and converter stations if HVDC
Ancillary infrastructure	None	Reactive compensation substations every 30 km if HVAC
Structures and spacing	Transmission towers every 450 to 550 m	Cable joint pits every 550 to 1100 m
Structure footprint	Approximately 21 m by 21 m for double circuit 500 kV transmission tower	Approximately 10 m by 2.3 m by 2.3 m One pit per circuit (minimum two pits)
Construction workspace	Approximately 50 m by 80 m for each tower	▪ Up to 35 m wide for entire route except where trenchless construction methods (e.g., HDD) used ▪ HDD drill and exit pads up to 60 m by 100 m
Access	Access tracks required to each tower site (along construction right of way where appropriate)	Access tracks required to cable joint pits and along construction right of way
Easement	• 40 to 60 m for 220 kV • 80 to 100 m for 500 kV	▪ 30 m for HVAC 500 kV cables ▪ 15 to 20 m for HVDC cables (depending on number of circuits)
Land use restrictions on easement	▪ Buildings and structures ▪ Over height machinery ▪ Gun irrigators ▪ Earthworks that reduces minimum ground clearance ▪ Vegetation over 3 m unless allowed for in design	▪ Buildings and structures ▪ Heavy machinery ▪ Stockpiling materials and silage bails ▪ Earthworks that reduces minimum ground cover ▪ Deep rooted crops and vegetation
Operation and maintenance	▪ Annual and periodic inspection ▪ Faults repaired in hours to days	▪ Annual and periodic inspection ▪ Faults repaired in weeks to months
Electric and magnetic fields	▪ Within ARPANZA reference limit ▪ Lower than underground cables at equivalent height	▪ Within ARPANZA reference limit ▪ Higher than overhead transmission lines at equivalent height

Difference between HVAC and HVDC underground construction

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Number of cables

HVAC requires up to 9 cables per circuit / transmission line

HVDC requires up to 3 cables per circuit / transmission line

Typically, one circuit / transmission line per trench

Width of trenches

~1.5 m deep by 4 m wide for HVAC transmission line with 9 cables

~1.5 m deep by 1.5 m wide for HVDC transmission line with 3 cables

Construction workspace similar depending on number of trenches

Space for topsoil and subsoil stockpiling

Space for haul road (heavy vehicle access for thermal backfill)

Space for joining cables

Difference between HVAC and HVDC underground construction

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Required infrastructure

Underground HVAC transmission lines require reactive compensation substations every 30 km	Underground HVDC transmission lines require converter stations (AC <> DC) at each end
	
Source: AusNet Services	Source: WWW NSEnergy courtesy Transnet BW

Difference between HVAC and HVDC workspace and easement requirements

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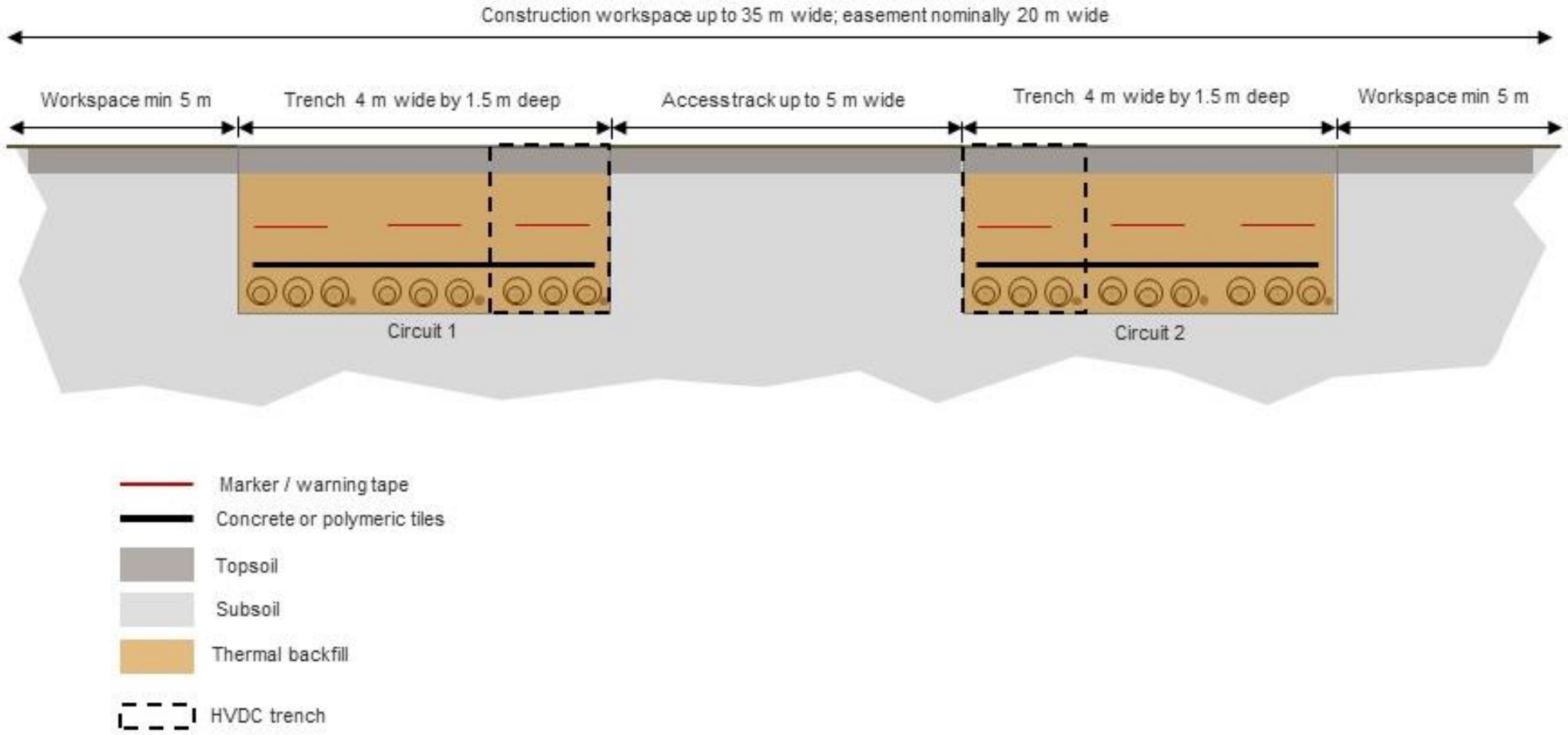

Difference between HVAC and HVDC underground construction

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HVAC trench and direct laid cables

Source: WWW EMC Global Sas Al Nakheel to Mussaffah Project

Typical HVAC cable joint pit

Source: WWW

HVDC trench and direct laid cables

Source: WWW TenneT Suedlink

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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

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

Separation from third party assets

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Overhead construction sequence

Construct access tracks

Clear vegetation to 3 m; ground level at tower sites

Construct tower hardstands; stockpile topsoil and subsoil

Excavate and pour tower foundations

Erect tower steelwork (fabricated onsite)

Install hurdles at roads, rail lines and fences etc

String conductors (approximately 5 km sections)

Install insulator strings and tie off conductors

Reinstate and rehabilitate temporary worksites

Underground construction sequence

Construct access tracks and haul road along route

Clear and grade easement (remove all vegetation)

Stockpile topsoil and subsoil

Excavate trenches and cable joint pits

Horizontally directional drill crossings (roads, rail lines and major watercourses)

Install conduits and thermal backfill

Construct cable joint pits

Pull cables through ducts

Join cables at each cable joint pit

Reinstate and rehabilitate construction right of way (remove excess subsoil)

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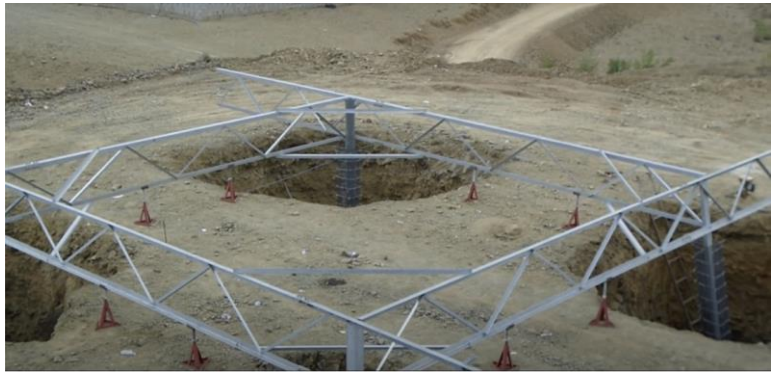
Source: AusNet Services

Typical 500 kV transmission tower hardstand and foundation



Source: AusNet Services

Source: AusNet Services

Erecting 500 kV transmission tower

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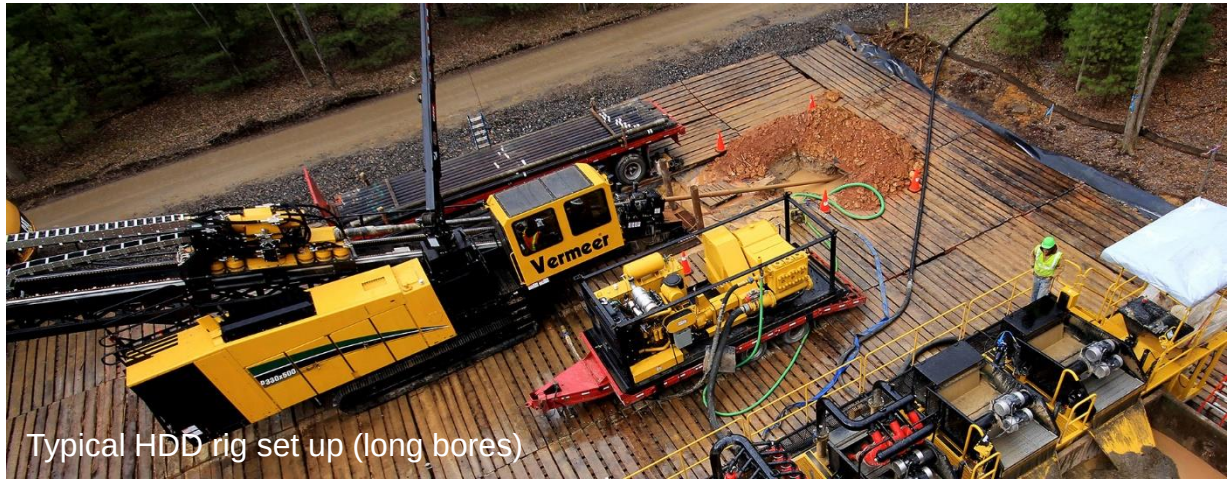

Typical HDD rig set up (long bores)

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

Questions