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Introduction to Power Distribution

21 September 2023 | Technical Topic Webinar

Mr. Jagdeep Singh Suran (Jag Suran)
Team Leader (Energy) at Arcadis Australia & EIT Lecturer

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About the Presenter

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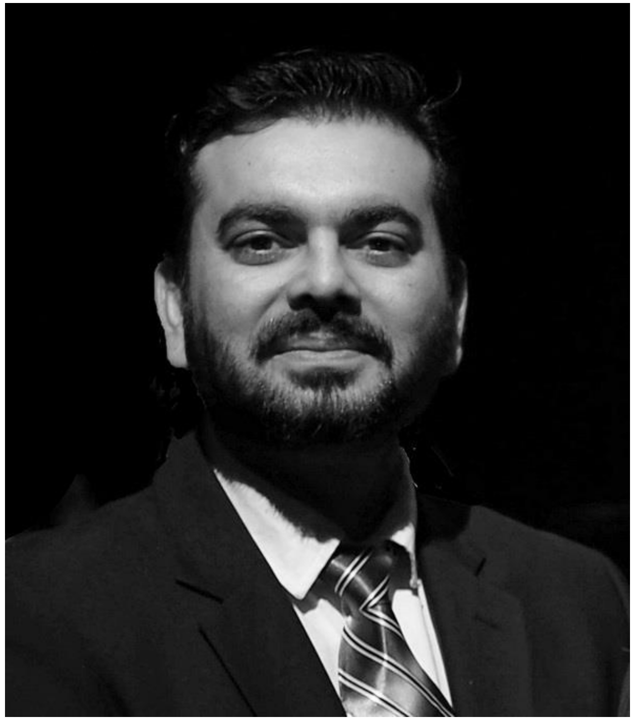
Mr. Jagdeep Suran
Team Leader (Energy) at Arcadis Australia & EIT Lecturer



Jagdeep, originally from India, completed his bachelor's and master's degrees in Electrical and Power Engineering (Honours) at Guru Nanak Dev Engineering College in Ludhiana, Punjab, India.

In India, he served as an engineering lecturer in the Vocation Education and Training (VET) sector. His role focused on developing the skills of rural students and preparing them for careers as tradespersons in technical schools. He provided practical teaching on the job, equipping students with the necessary expertise.

In 2008, Jagdeep relocated to Australia and continued his engineering journey as an electrical engineer. Over the years, he has held various senior and design management positions. He has played a pivotal role as the lead designer on numerous major and complex power distribution projects. His expertise extends to overhead, underground, and substation designs, power relocations, as well as large-scale industrial and commercial supply projects.

Currently, Jagdeep works for a global consultancy as a Technical Leader, overseeing significant and intricate projects. Alongside his technical responsibilities, he remains committed to sharing his industry knowledge with new graduate engineers and junior engineers, much like his previous work in India.

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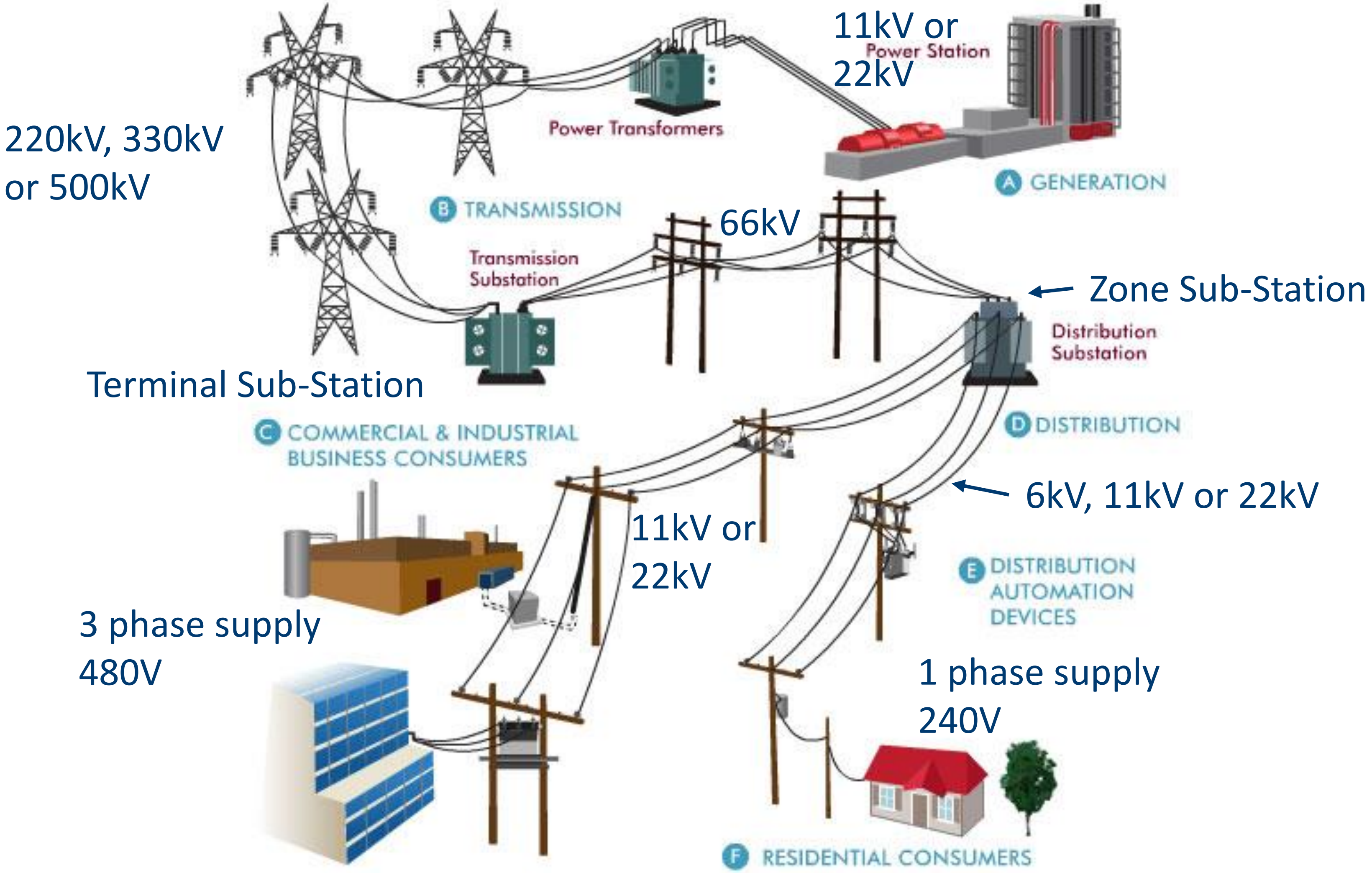
PART 1 – About Power Distribution

- Power System Supply Model
- Types of Power Distribution

Power System Supply Model



Types of Power Distribution

Power Distribution Systems are classified based on:

- **Nature of Supply**
  - AC Distribution
  - DC Distribution
- **Type of Connection System**
  - Radial HV System
  - Ring Feed System
  - IFT (Inter Feeder Tie / Interconnected) System
- **Type of Distribution Construction**
  - Overhead Construction
  - Underground Construction
  - Hybrid Construction
- **Distribution Systems based on distance to zone substation**
  - Urban System
  - Rural System
  - Single Wire Earth Return (S.W.E.R.) System
- **Common Electrical Utility Distribution Systems**
  - Overhead Distribution (Most common)
  - Underground Distribution
  - Hybrid Distribution

Key Plant & Equipment

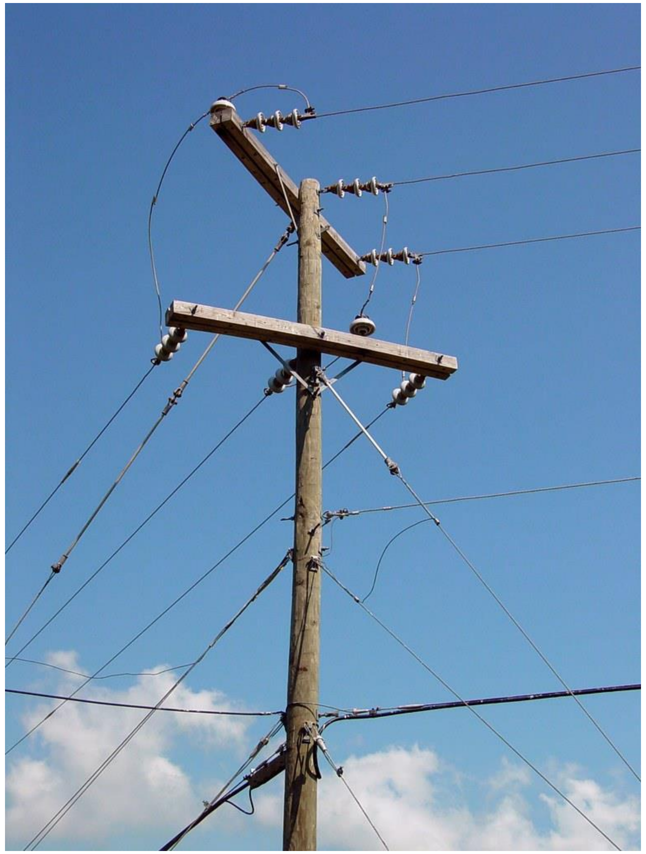
OVERHEAD POWER DISTRIBUTION

Key Equipment – Power Distribution

OVERHEAD POWER DISTRIBUTION – KEY PLANT & EQUIPMENT

› Poles
› Insulators
› Conductors (Bare & Bundled conductors)
› Cross-Arms & Brackets
› Pole mounted HV Equipment
› Other Pole Top Assemblies - Armour Rods/Vibration Dampers, Stays & Antennas, other assets
› **Latest Development** – Pole mounted Battery Storage Boxes

Poles – Wood



Creosote Treated Wood Pole
(Brown in colour on site)

CCA Treated Wood Pole
(Green in colour on site)

Size & Strength of Wood Poles
(Metres/ kN)

Poles – Concrete

Concrete Pole
(Grey in colour & Smooth Finish)

Used for complex structures

Street light poles

Source: https://www.utilitystructures.com/

Poles – Steel & Composite

Steel Pole for EHV

Steel Pole for Street Lighting

Composite Fibre Poles

Composite Pole base

Source: https://paylesspowerpoles.com.au/

Insulators

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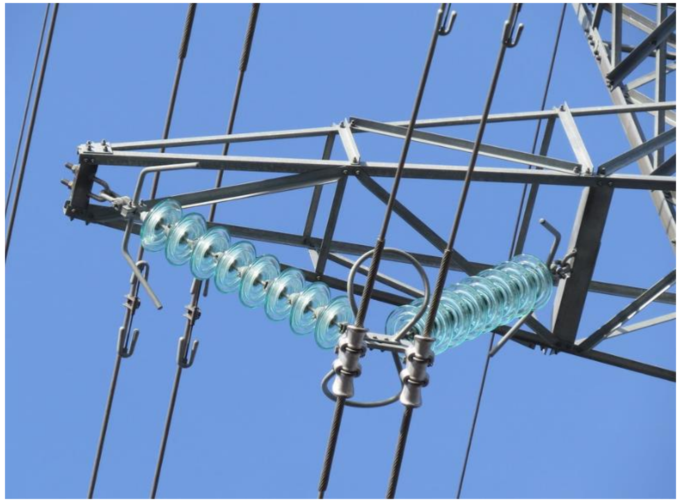
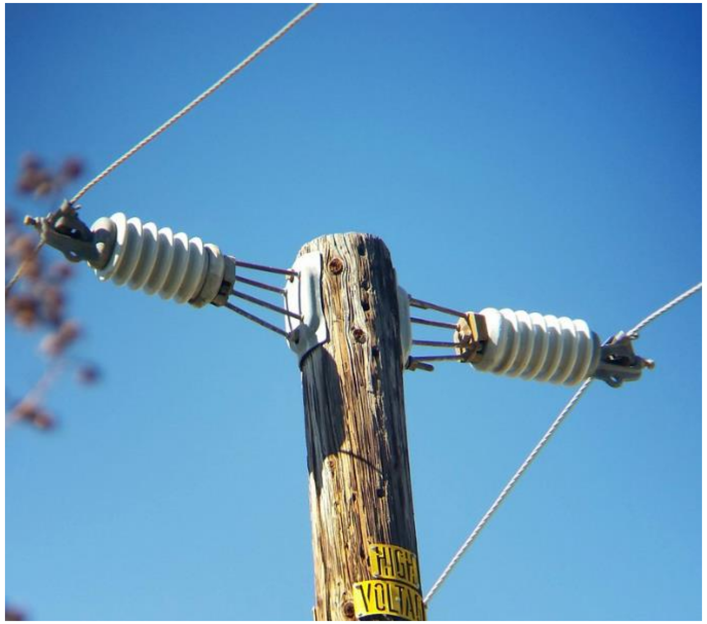


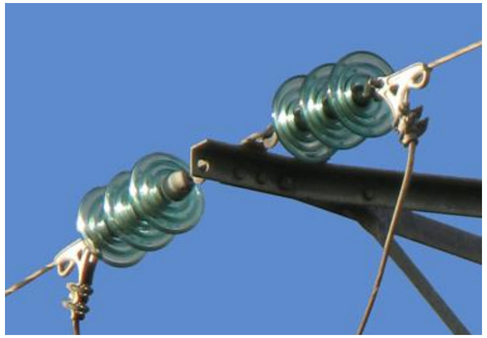
EHV Glass Insulators

66kV Porcelain Insulator

Tie-Top Type



Clamp-Top Type



66kV Glass Insulators

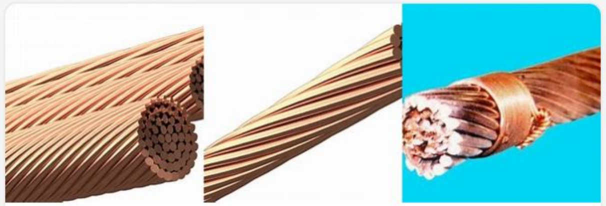
22kV Polymer Insulator

Shackle Insulators

Source: https://flickr.com

Conductors

Copper Conductors (Cad Cu)



Hard Drawn

Soft Annealed

Flexible

Aluminium Conductors

Alloy

AAC

Steel Reinforced

ACSR

Covered Conductors

Steel Conductors (SC/GZ)

Bundled Conductors (HV & LV ABC)

Source: https://www.coveredconductor.com/

Cross-Arms

Types

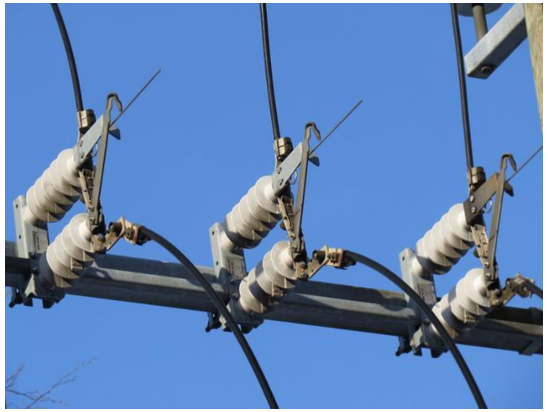
- 66kV Lines: Steel X-arms
- 22kV Lines: Mainly Steel X-arms, sometimes Wood X-arms
- LV Lines (Bare): Wood X-arms

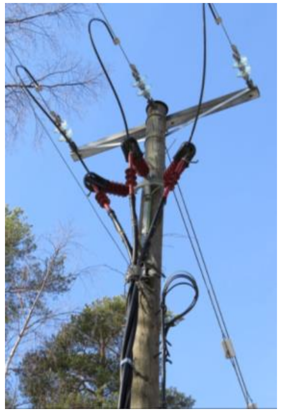
	Steel	Wood
Approx. Cost Relationship	2-6	1
Approx. Mass Relationship	0.5-1.5	1
Durability	Excellent	Fair
Fire Resistance	Excellent	Poor
Lighting Resistance	Poor	Fair
50Hz Resistance	Poor	Fair
Fitting of Attachments	Pre-drilled holes	Pre-drilled holes
Appearance	Good	Fair
Availability	Unrestricted	Unrestricted

HV Switchgear

Typical HV Switchgear on Poles

- Capacitor Banks
- Air Break Switch / Load Break Switches
- Reclosers / Remote Control Gas Switch (RCGS)
- HV MGS (Manual Gas Switches)
- Transformers
- Cable Heads

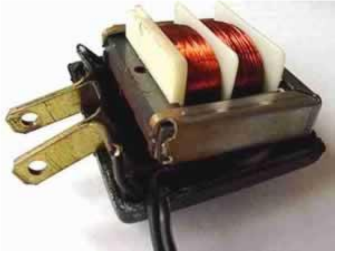


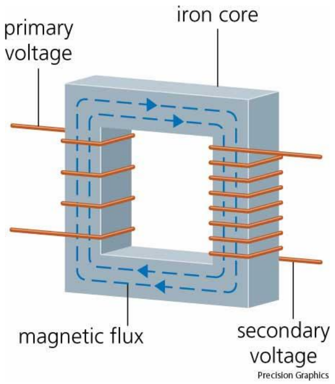

Source: https://electrical-engineering-portal.com/
https://www.cniguard.com/
https://insulect.com/

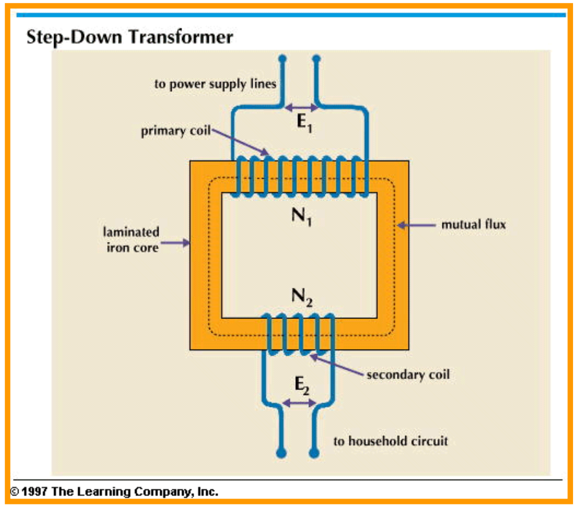
Transformers

Transformers

- Basic construction
- Small Transformers
- Distribution pole mounted Transformers
- Power Transformers







Source: https://electrical-engineering-portal.com/
https://tmurphy.physics.ucsd.edu/

Other Pole Top Assemblies

Typical HV Switchgear on Poles

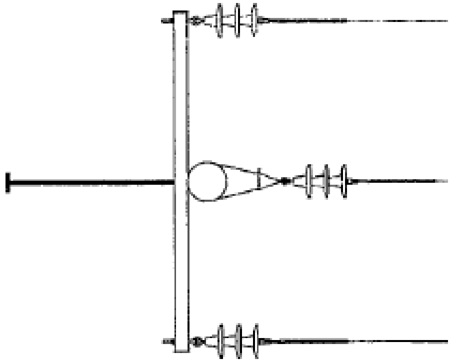
- Armour Rods/ Vibration Dampers
- Stays
- Antennas & other assets

Source: https://www.artisanmake.com/
https://www.transnet.co.nz/
http://emfsafetynetwork.org/smart-meter-infrastructure/

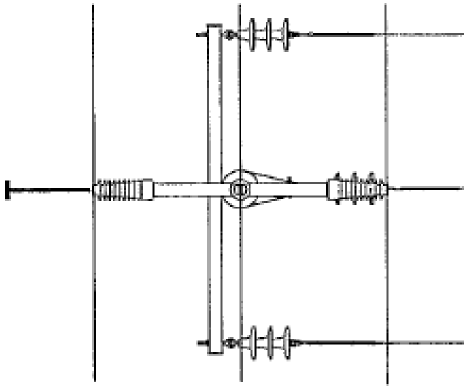
Stays - Identification

Stay Types

- In-Line Stays
- Bisect Stays
- Side-Walk or
  Footpath Stay

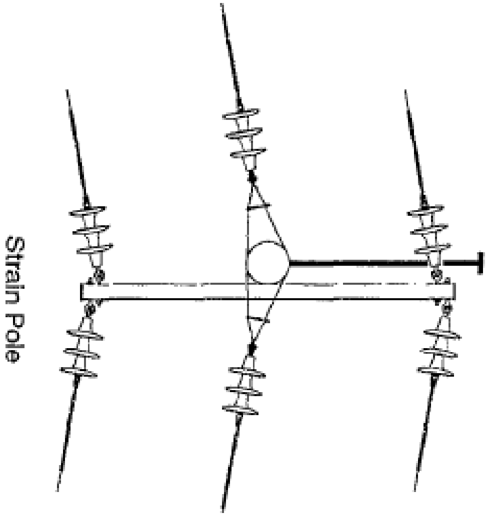


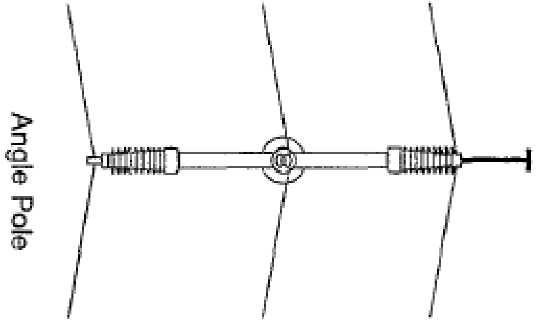
Termination Pole



Tee-off Pole

In-Line Stays

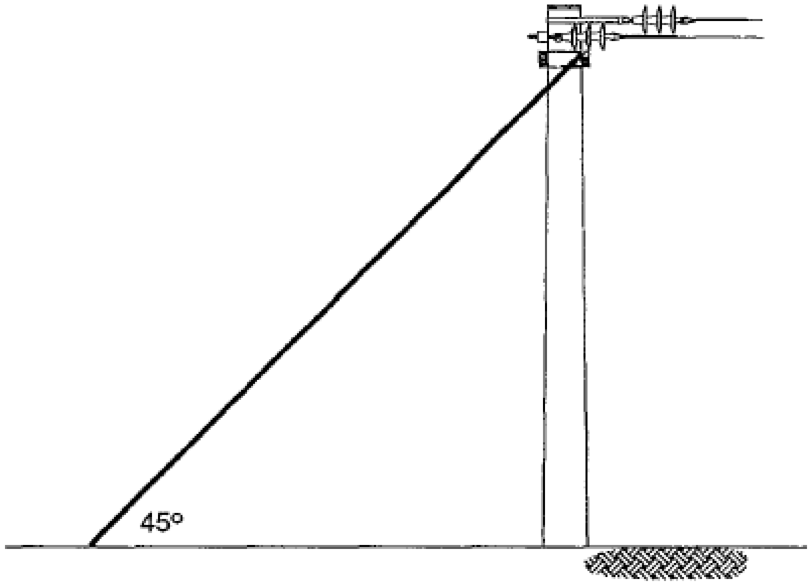




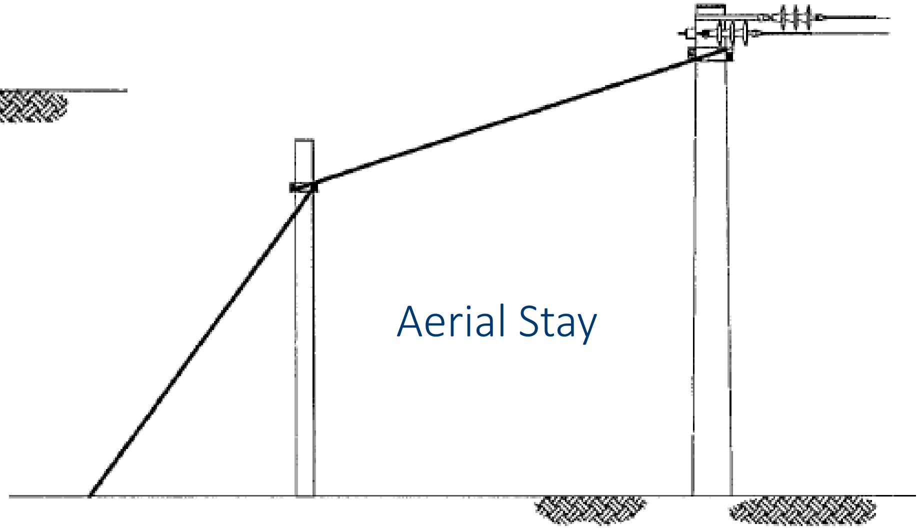
Bisect Stays

Side-Walk Stays
(Footpath Stays)

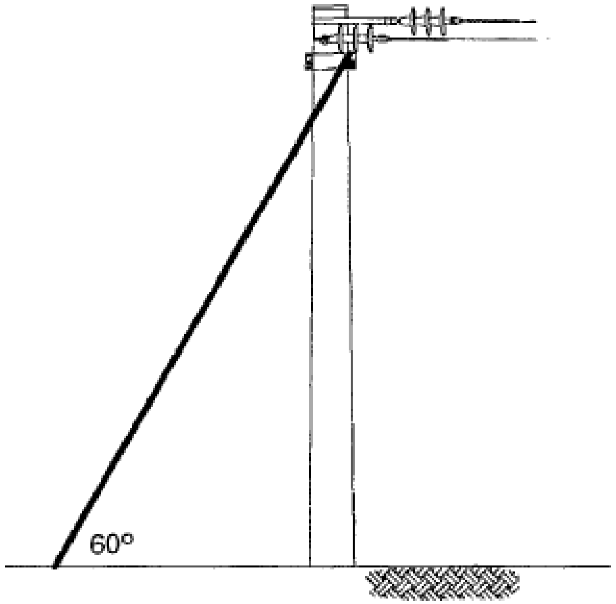
Stays - Angles



45 Degree Stay



Aerial Stay



60 Degree Stay

Latest – Pole mounted BESS

Pole-mounted Battery Energy Storage Systems (BESS)

Varied sizes up to 70kVA and 85kWh

Source: https://paylesspowerpoles.com.au/

Key Plant & Equipment

UNDERGROUND POWER DISTRIBUTION

Key Equipment – Power Distribution

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UNDERGROUND POWER DISTRIBUTION – KEY PLANT & EQUIPMENT

- Extra High Voltage (EHV) & High Voltage (HV) Cables
- Low Voltage (LV) Cables
- LV Service Cables
- Types of Insulation – Underground Cables
- Conduits
- Cable Joints and Joint Bays
- Cabinets, Pits and Pillars
- Substations

Power Cables

HV Cables

Single-Core Three-Core

LV Cables

4c-240mm2 LV XLPE Al Cable

4c-16mm2 LV XLPE Cu Cable

Cable Components

Source: https://lonheo.en.made-in-china.com/
https://www.indiamart.com/
https://fr.vwcable.com/

Conduits

Metallic Conduits

Mainly used for outer mechanical protection

Electrical PVC Conduits

Heavy Duty
Medium Duty
Light Duty

Conduit Bends

90 Degree

45 Degree

22.5 Degree

Corrugated Conduits

Flexible

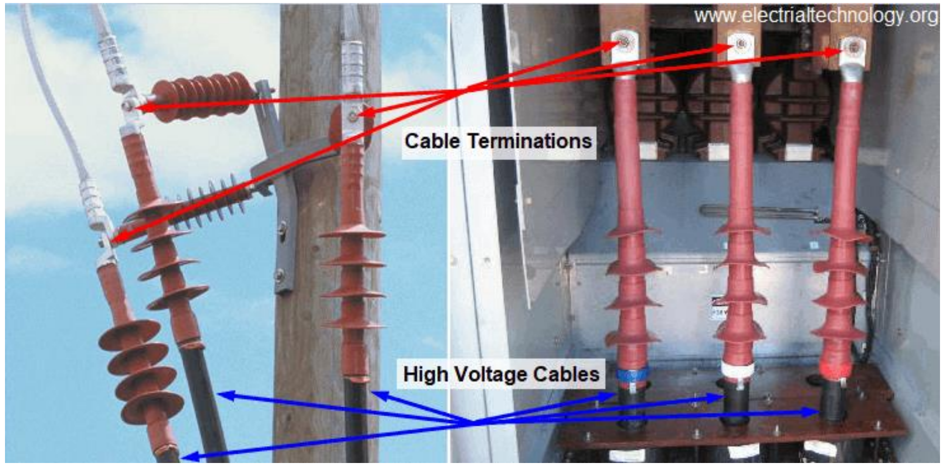
Source https://www.vinidex.com.au/
https://www.ezitown.com/
https://camotesislands-homebuilders.com/
http://www.skylarkconstructionkenya.com/
https://www.ctube-gr.com/
https://awm.mmem.com.au/

Joints, Joint Bays & Terminations

Cable Joints

Joints

Cable Terminations



Joint Bays

Precast Joint bay lowered to site

with Cable joints

Source https://www.protopservices.com/
https://www.mascoteng.com.au/
https://www.transnet.co.nz/
https://www.cableservices.co.uk/
https://www.electricaltechnology.org/

Other U/G Equipment

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Cabinets

Pillars

LV termination mains pillar

2-way open/switching point link pillar

Pits

Round pits - Most common

Square Conc. Pits

Pad Mount Substations

Source https://www.giantelectrical.com.au/
https://convicaustralia.com.au/
https://ars.com.au/
https://www.jaybro.com.au/

Part 2 – Power Distribution Design

- Why we need Design – Key Considerations
- Overview of Overhead Line Design
- Overview of Underground Cable Design
- Think Safe – Safety in Design

Power Distribution Design

NEED OF POWER DISTRIBUTION DESIGN

Power distribution design is crucial for efficiently and safely supplying electricity to homes, businesses, industries, and other facilities. It involves planning and implementing the infrastructure necessary to transmit electrical energy from power generation sources (such as power plants) to end-users (consumers).

Some Key Factors:

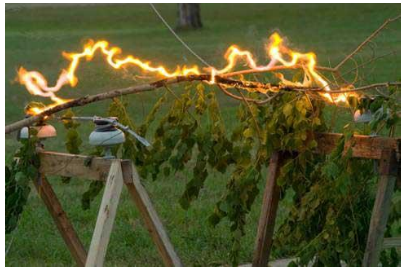
- Efficiency – Reduce and minimize Energy Losses
- Safety – Minimising the risks and meeting Reliability
- Voltage Regulation
- Environment Impact
- Capacity Planning – To cope with future growth
- Financial Benefits to Distribution Companies – By reducing maintenance costs and risks.

Power Distribution Design

Key Considerations in Power Distribution Design

- Load Analysis
- Voltage Level
- Circuit Design
- Protection and Switchgear
- Earthing and Bonding
- Environmental Conditions
- Regulatory Compliance
- Regulatory Compliance
- Cost Consideration

By carefully considering these factors, power distribution design aims to create a system that is safe, efficient, reliable, and capable of meeting both current and future electricity needs



Overhead Line Design

Brief Overview of Overhead Power Distribution

Overhead Line Design concepts

Various Stages & Considerations

- Route Selection
- Survey – Land & O/H Line
- Detail Design
- Detailed costing of Design
- Design Drawings
- Construction
- Audits
- Energisation / in service

Detail O/H Line Design Steps

- Select Structure types
- Select Conductor size/ type
- Select Stringing Charts
- Select Pole types/ Length & Strength
- Select cross-arm size & type
- Select Insulators
- Select Stay types & strength as required
- Select load details/ Transformer size details
- Select customer connection types

Definitions

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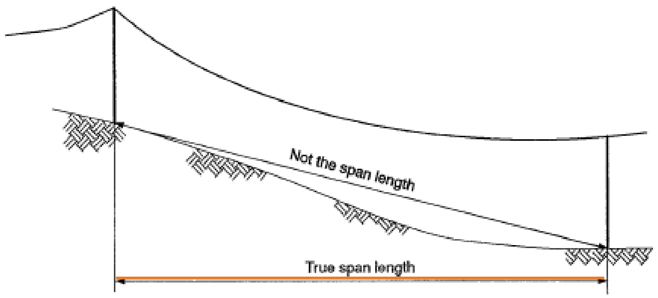
Span Length

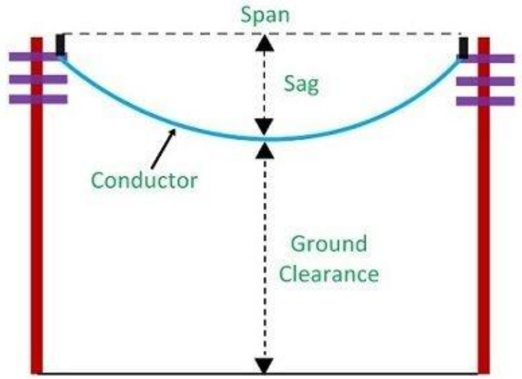


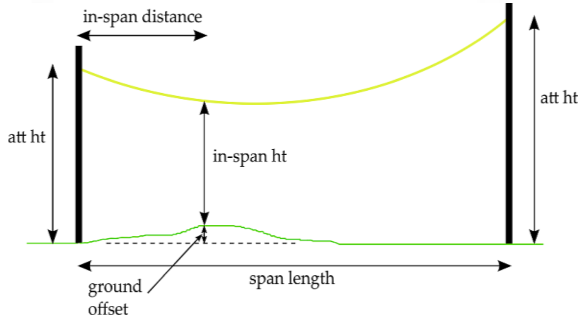
The distance in meters of conductor between poles measured horizontally.

Shorter spans – generally slacker stringing

Longer spans - tighter conductor stringing and stays.

Sag

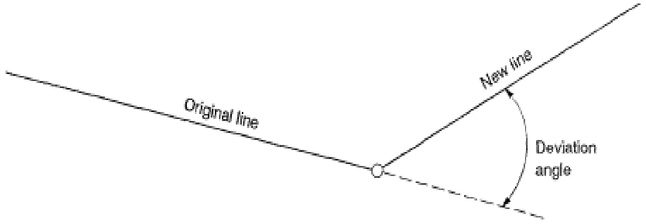




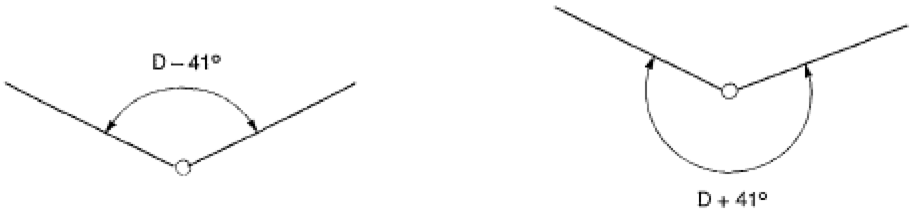
The amount that the conductor hangs below a straight line between two points of attachment assuming a parabolic shape.

Sag = Avg. conductor height - Ground clearance

Line Deviation



Line Deviation is the angle between two pole lines if the first one was to continue past the pole



Deviation angle can determine the type of structure that is allowed at the pole.

i.e. choosing Anchor instead of Strain

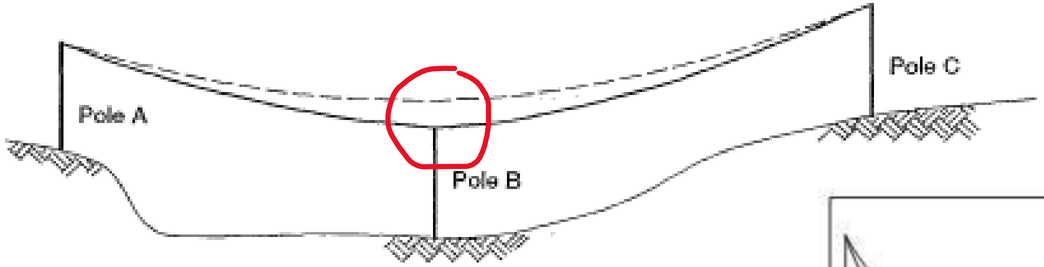
Definitions

Mean Equivalent Span (MES) / Ruling Span

$$S_R = \sqrt{\frac{\sum S^3}{\sum S}} = \sqrt{\frac{S_1^3 + S_2^3 + \dots S_n^3}{S_1 + S_2 + \dots S_n}}$$

MES is a kind of average span length used for obtain accurate sag & tension for stringing charts.

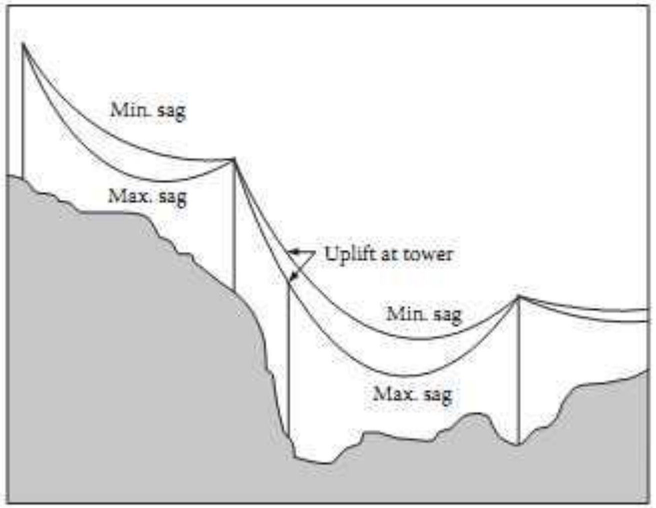
Uplift



Uplift occurs when the weight span of a structure is negative. On steeply inclined spans, the low point of sag may fall beyond the lower support. This is typically check at -5 degree, No wind.

How to fix:

- Use slack stringing – decrease conductor tension
- Increase adjacent span length
- Increase elevation of point B
- Decrease elevation at Point A & C



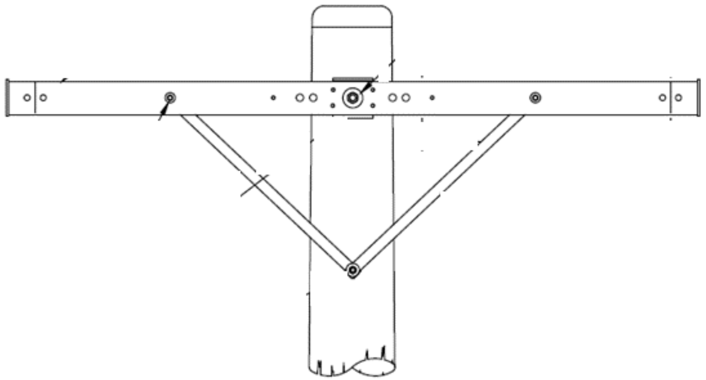
Source https://polesnwires.com/
https://industrial-electronics.com/

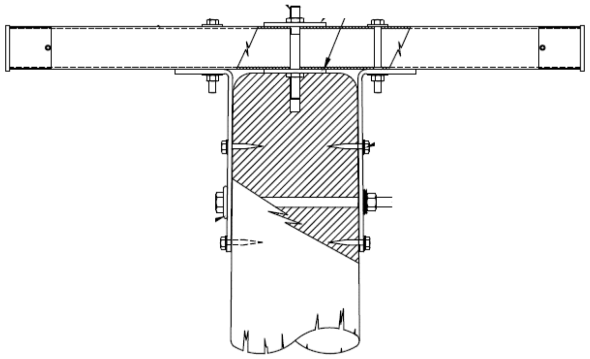
Cross-Arms

Steel X-Arms: For HV Lines (66kV & 22kV)

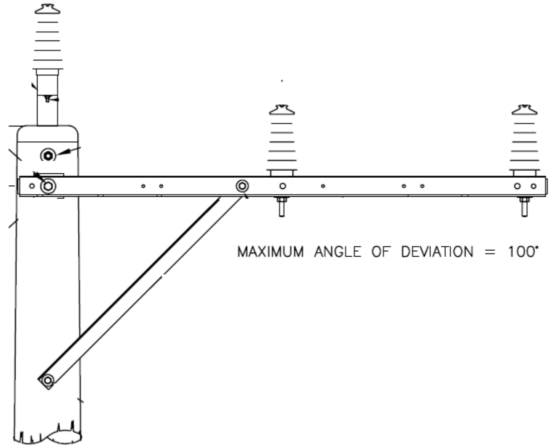
Wood X-Arms: For LV Lines

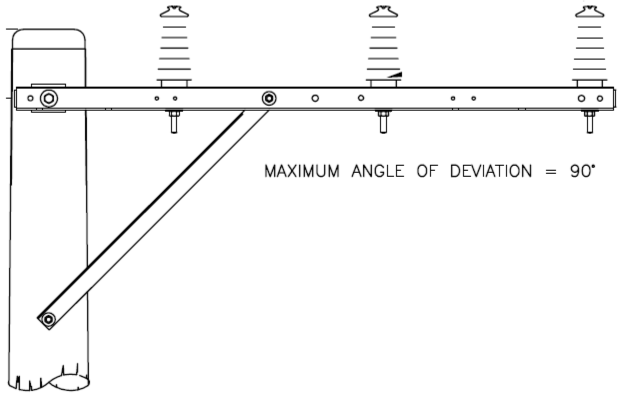
Pole Top Construction





Offset & Extreme Offset Construction





Overhead Structures

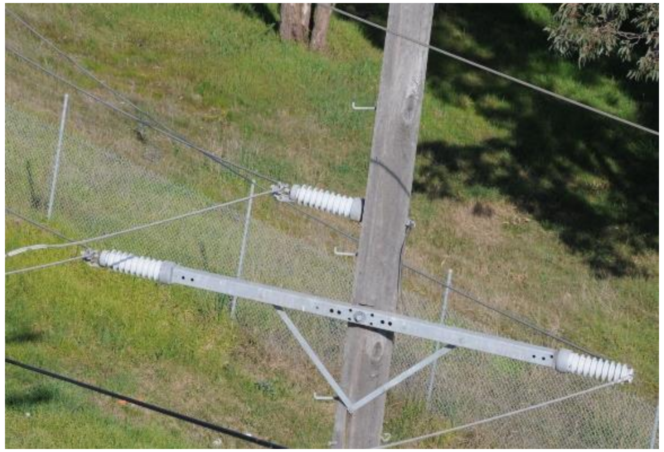
Intermediate (INT)

For Single & Double Circuits

For conductor deviations up to 3°

Tie top insulators

Intermediate Angle Types



Used when angle of deviation is > 3°

Clamp top insulators for pull-off side

For Greater deviation, Angle Type 2 structure is used.

Subsidiary Structures

For Bottom

Circuits

Note: These structure types are also used for HV ABC & LV ABC, however without the cross-arms. ABC conductors attached to the pole using various brackets.

Overhead Structures

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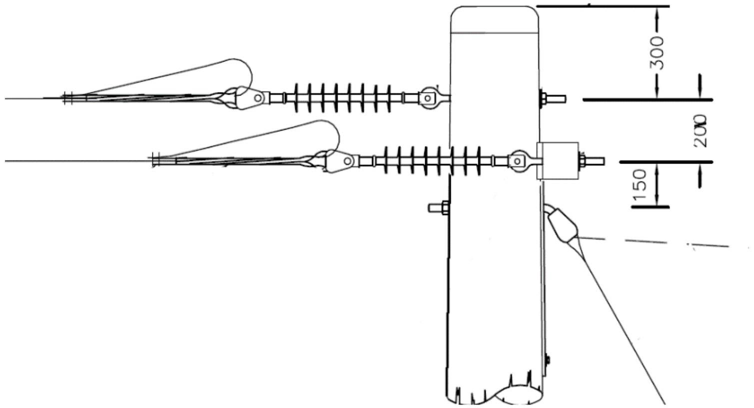
Strain (ST) Structures

Types: Strain, Subsidiary Stain & Slack Strain

Mainly used for:

- Change in conductor type
- Change in conductor tension
- Switching

Termination Structures



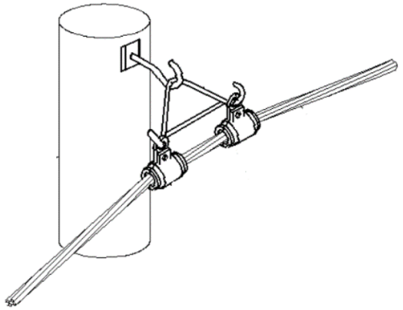
Used when conductors need to be terminated.

Anchor Structures

Used when there is change in conductor height or the permissible limits of a strain construction exceeds

Overhead Structures

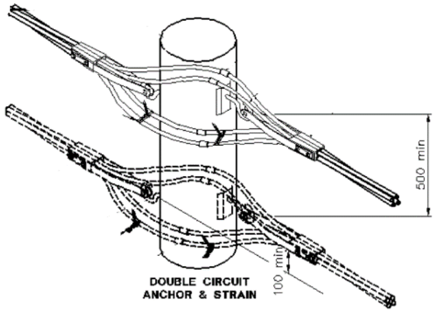
LV ABC INT



LV ABC INT or Angle type 1:
Angle of deviation up to 25°.

LV ABC Angle type 2:
Angle of deviation up to 50°.

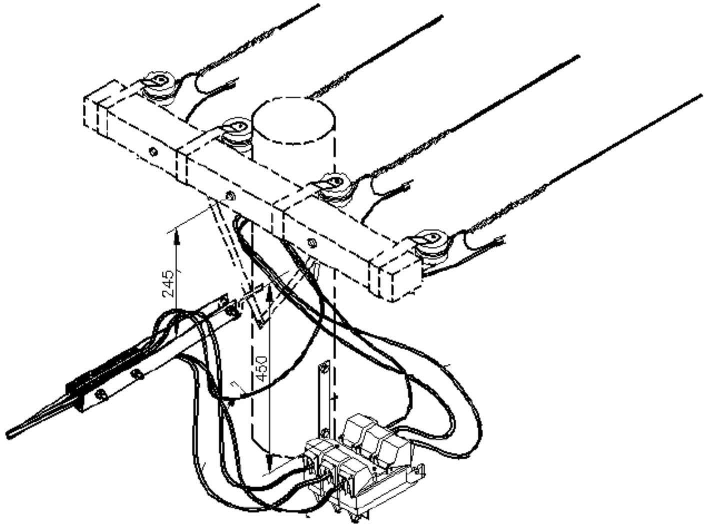
LVABC Strain



Preference shall be given to running the Strain without any connectors.

In case of in-line strain, the connectors should not touch the pole.

Bare Wires – LV ABC Interface



Mainly 2 types of bare wire interfaces; via Switched FSD & Direct

Switch FSD is mainly to create an LV open point.

Underground Cable Design

Brief Overview of Underground Power Distribution

Underground Power Distribution

Reasons for Underground:

- Aesthetical purposes
- Undergrounding of Overhead Lines
- New residential development (URD)
- New Industrial/ Commercial Estates
- Project requirements

Underground Stages and Process:

- Customer Load
- Cable Selection
- Calculations – Volt drops, cable calcs
- Detail Design
- Substation size and placement
- Lighting requirements (For estate designs)
- Connections and terminations
- Labelling of U/G Assets
- Detailed costing of Design
- Design Drawings
- Construction
- Audits
- Energisation / in service

Cable Selection

Voltage selection

- 66kV - Single core EHV cables
- 22kV – three core HV cables
- LV – three phase or single phase LV cables

Insulation & Protection

- XLPE - Crosslinked Polyethylene
- PVC - Polyvinyl chloride
- Screens and armours

Earthing & Bonding

Terminations and Joints

Current Rating calcs

- Steady State (Continuous) rating
- Cyclic rating
- Emergency rating

a) For buried cables:

$AR = BR \times F_{gt} \times F_d \times F_g \times F_{gr}$

Where:

AR = Actual Current Rating

BR = Basic Current Rating

F_{gt} = Rating Factor for ground temperature

F_d = Rating Factor for cable depth

F_g = Rating Factor for soil thermal resistivity

F_{gr} = Rating Factor for grouping of cables

b) For cables in air:

$AR = BR \times F_{at}$

Where:

AR = Actual Current Rating

BR = Basic Current Rating

F_{at} = Rating Factor for air temperature

Source https://www.topcable.com/

Master planning – Estate Designs

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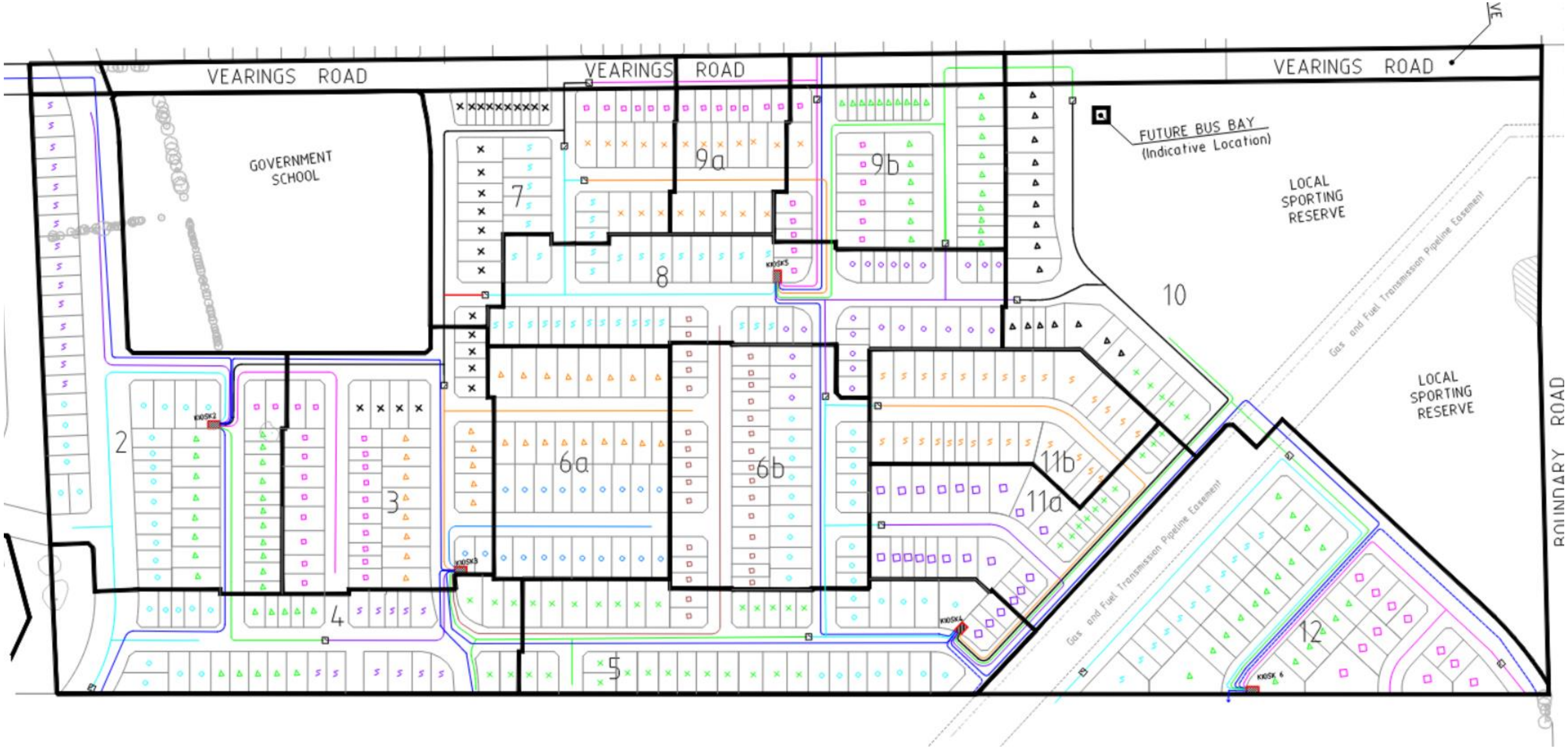
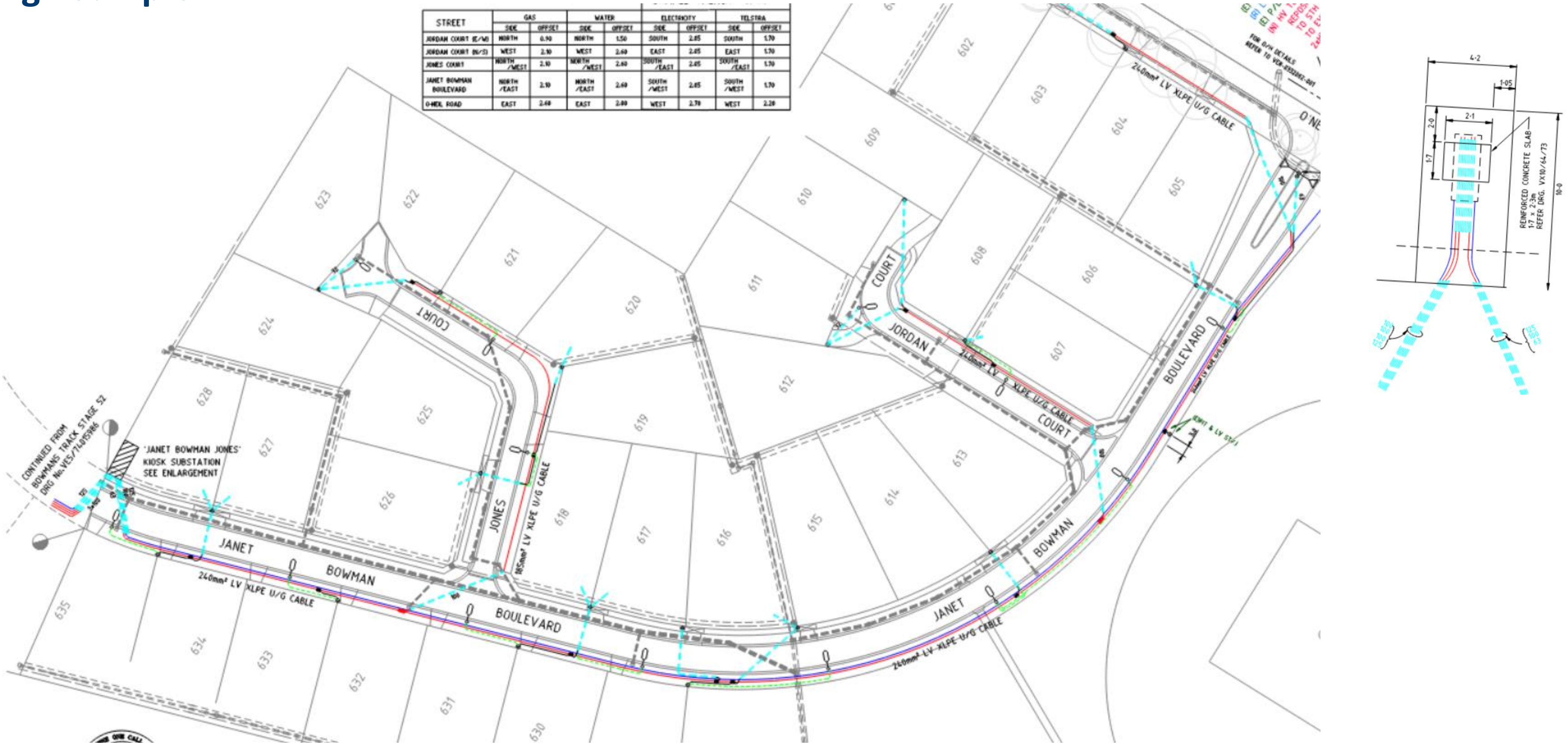
Master planning - Sample



Master planning – Estate Designs

Design Drawing - Sample



STREET	GAS		WATER		ELECTRICITY		TELSTRA	
	SIDE	OFFSET	SIDE	OFFSET	SIDE	OFFSET	SIDE	OFFSET
JORDAN COURT (E/W)	NORTH	0.90	NORTH	1.50	SOUTH	2.85	SOUTH	1.70
JORDAN COURT (N/S)	WEST	2.10	WEST	2.60	EAST	2.85	EAST	1.70
JONES COURT	NORTH /WEST	2.10	NORTH /WEST	2.60	SOUTH /EAST	2.85	SOUTH /EAST	1.70
JANET BOWMAN BOULEVARD	NORTH /EAST	2.10	NORTH /EAST	2.60	SOUTH /WEST	2.85	SOUTH /WEST	1.70
O-NEIL ROAD	EAST	2.40	EAST	2.80	WEST	2.70	WEST	2.20

Think Safe

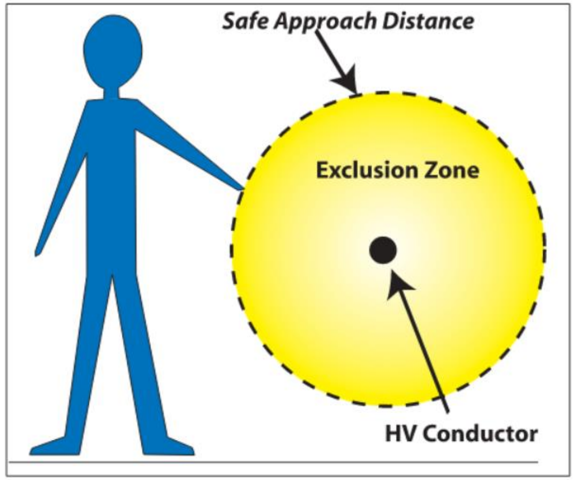
Importance of Safety in Design

Safety Considerations – O/H Design

Regulatory References

- The Blue Book – Code of Practice on electrical safety for work on OR near HV apparatus
- The Green Book – Electrical Safety rules for Electrical Distribution Networks
- SIR

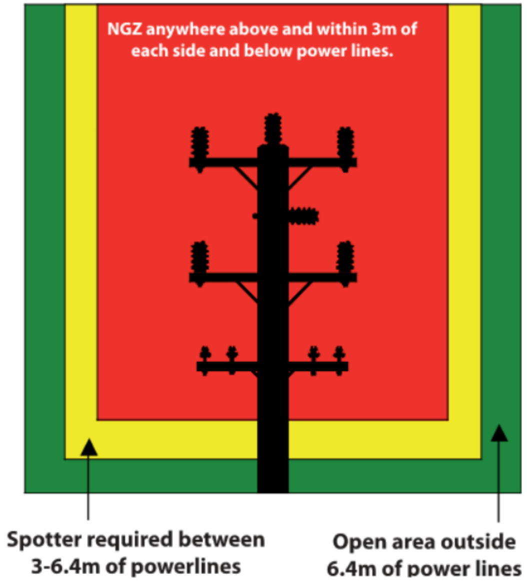
- Safe approach Distance



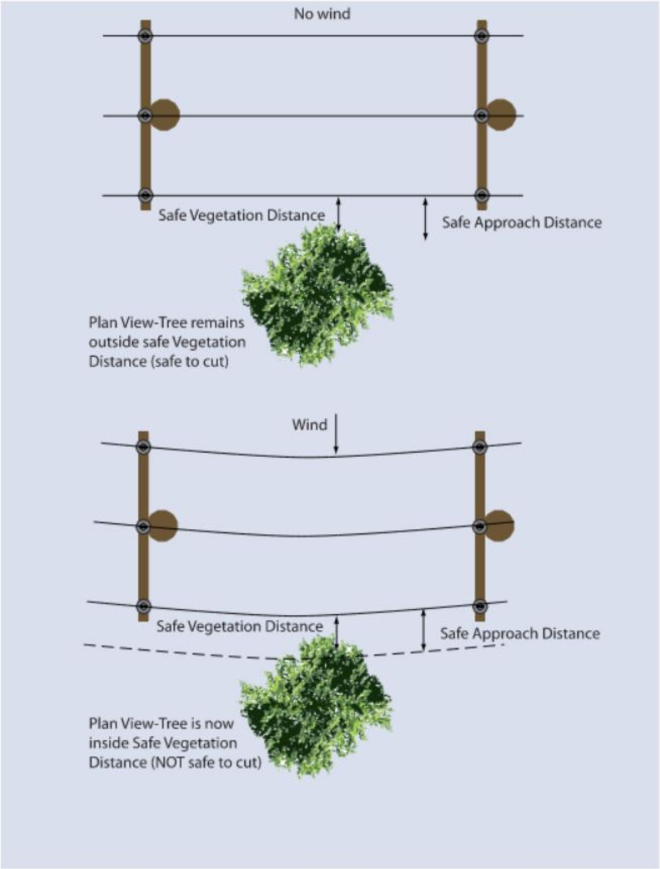
- No Go Zone

RED ZONE	No Go Zone. Written permission from the Network Operator required to undertake works. (Refer to VESI NGZ Guidelines).
YELLOW ZONE	Trained and registered spotter, (Safety Observer) required.
GREEN ZONE	Open area. Normal safe work practices and precautions apply.

No Go Zone for Distribution & Sub-Transmission lines



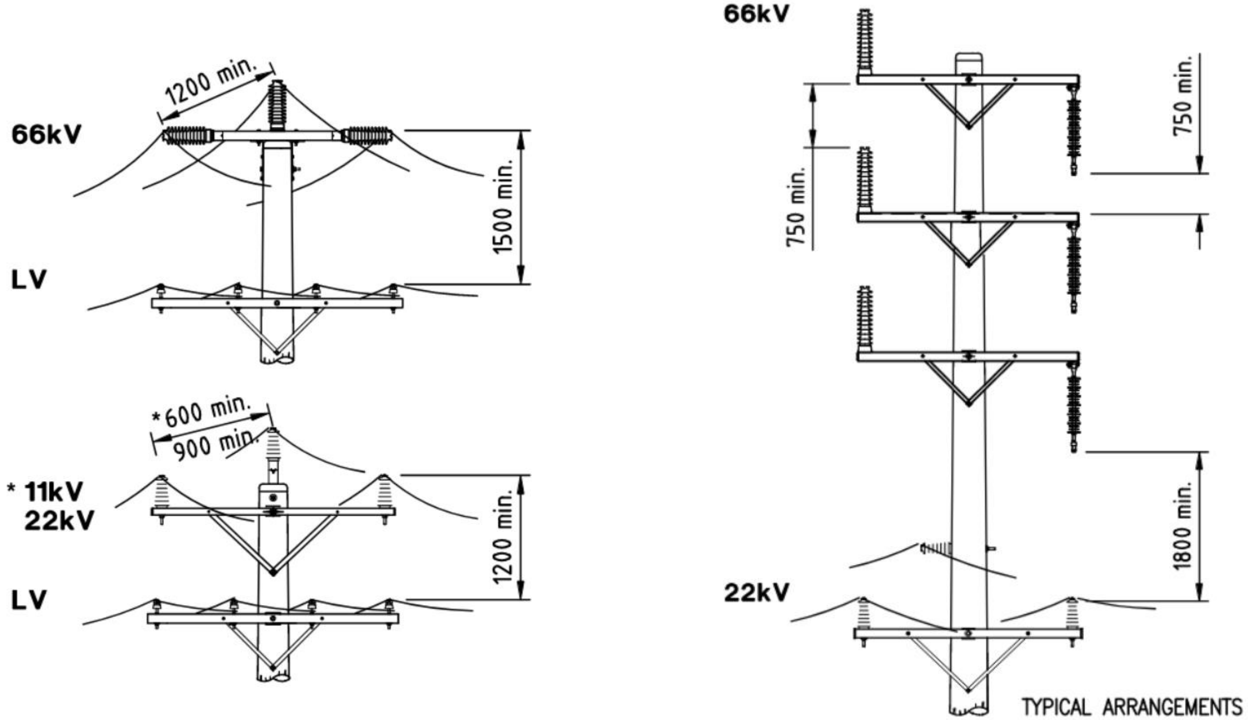
- Conductor Sag & Sway



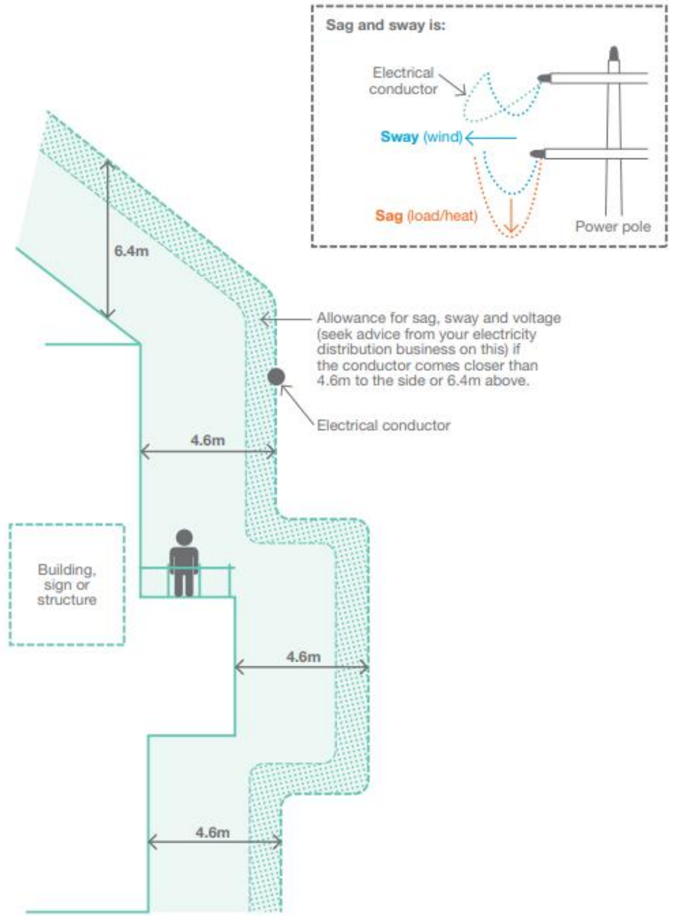
Safety Considerations – O/H Design

Maintaining clearances to other assets

- Refer to local utility standards and regulatory requirements



Designing near Buildings and Structures

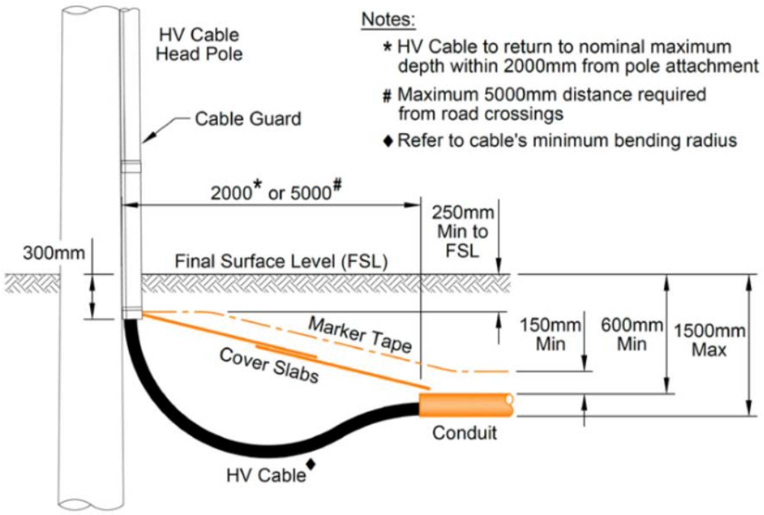


Safety Considerations – U/G Design

Design considerations

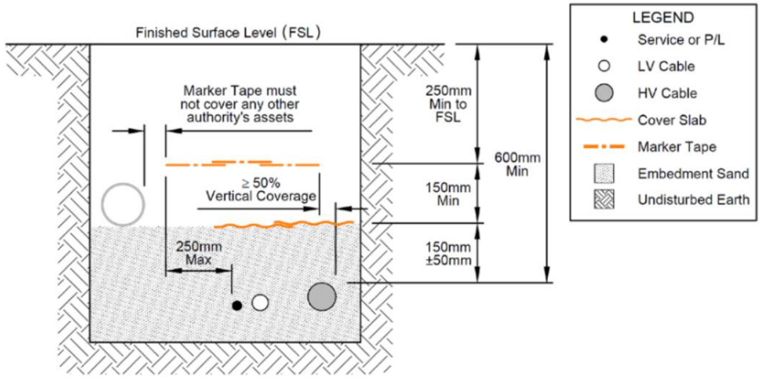
› Min. depth requirements of U/G cables

Application	Directly Buried with Cover Slab	Buried Enclosed in HDPVC Conduit	Bored installations enclosed conduit*
LV - multi-core	600mm	600mm	750mm
11kV - 22kV	600mm	600mm	750mm
66kV	750mm	750mm	1000mm

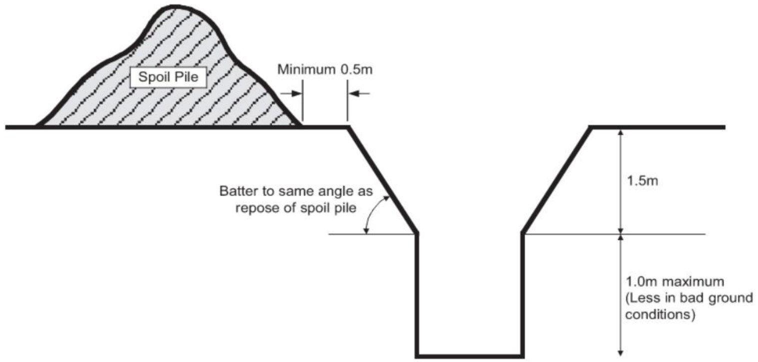


Trench Depth – Do not design too deep

› Standard Trench



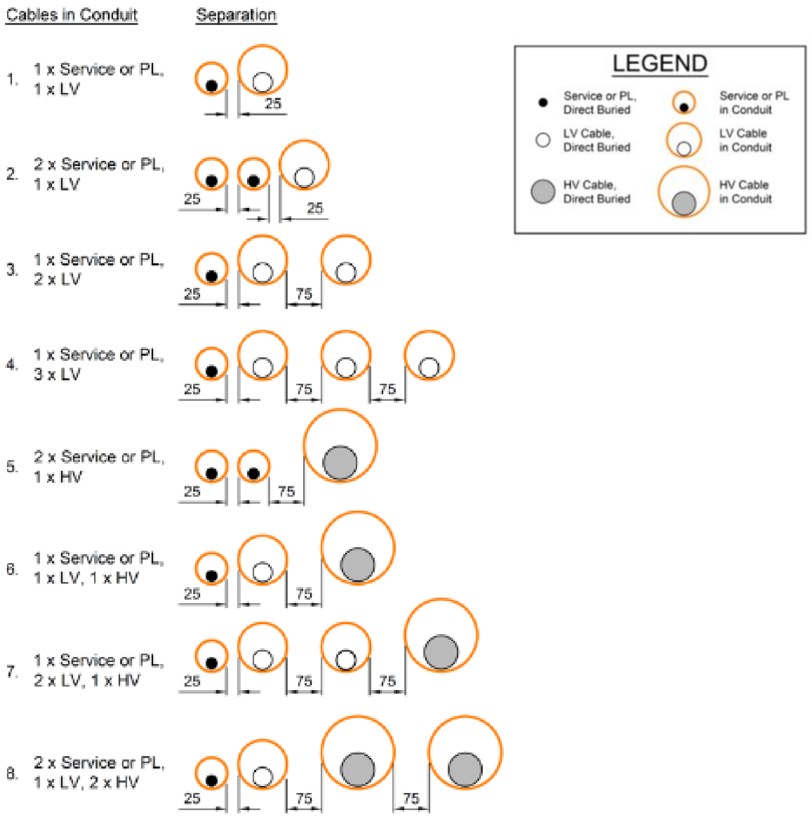
› Special case – Deep trench scenario



Safety Considerations – U/G Design

U/G Clearances

- Refer to local utility standards / Regulations



Clearances to other utility U/G assets

Clearance of Electrical Cables and Conduits (Up to 22 kV) to Other Utility Assets and Structures - Generic Table for Auditing Purposes

Minimum Horizontal or Parallel Clearance (Offset) to Cable or Conduit			Minimum Vertical & Crossing Clearance[3]
Water	≤ 200 Water Main: 500mm - Separate Trench	> 200 to ≤ 375mm Water Main 1000mm - Separate Trench	225mm
Sewer	≤ 300DIN Sewer Main: 500mm - Separate Trench	> 300DIN Sewer main 1000mm - Separate Trench	225mm (≤ 300 DIN) 300 (>300 DIN)
Gas - reticulation	OD ≤ 50mm Gas Pipe: 300mm	OD > 50mm Gas Pipe 500mm	150mm
Gas - Transmission	500mm		300mm (Trench ≤ 1.5m wide) 500mm (Trench > 1.5m wide)
Communications[5]	100mm to LV Cable/Conduit, 300mm to HV Cable/Conduit 50mm to LV cover slab, 250mm to HV cover slab		100mm LV 300mm HV
Lighting & Distribution Poles	300mm to all other assets (including concrete footpaths and building line) 1000mm to driveway crossings and pedestrian/pram crossing (Refer to section 4.11)		N/A
Storm Water Pipe	300mm to all other assets		100mm LV, 300mm HV[6]
Other Assets/ Structures[7]	100mm LV, 300mm HV		100mm LV, 300mm HV

Part 3 – Modern Challenges to Legacy Distribution Model

- Emerging Technologies & Renewables – Green Energy
- Electric Vehicle – EV Charging Stations
- Embedded Networks

Modern Challenges

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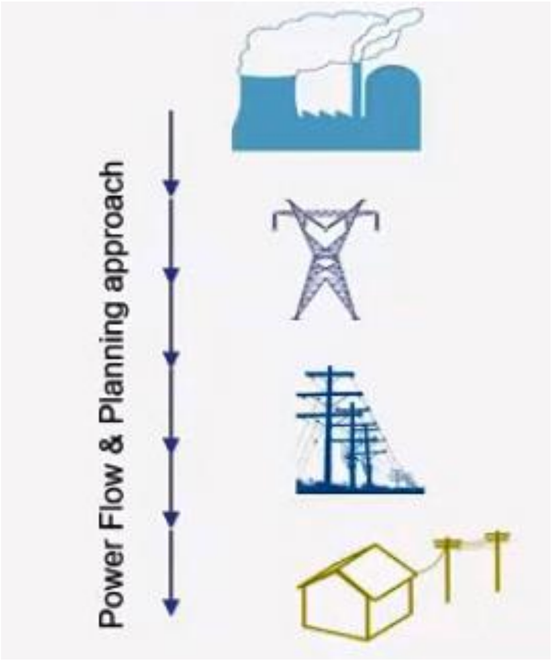
Emerging Technologies & Renewables – Green Energy

- The introduction of Solar & Battery storage systems & Green energy has significantly impacted the operating models of utilities, posing challenges to their financial targets. As rooftop solar panels generate more kilowatt-hours, there is a direct correlation with a decrease in kilowatt-hours sold by utilities.
- Consequently, utilities are shifting their investment focus towards the green energy sector to align with the changing dynamics of the energy market.

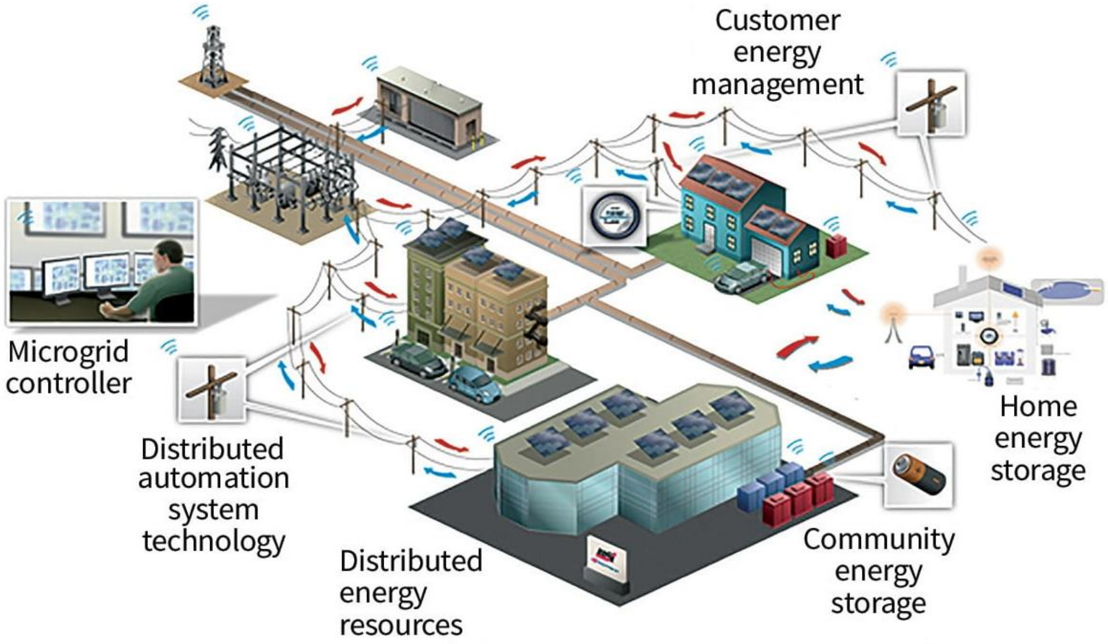
Modern Challenges

Traditional vs New DER (Distributed Energy Resources)

› Traditional Network



› DER Network

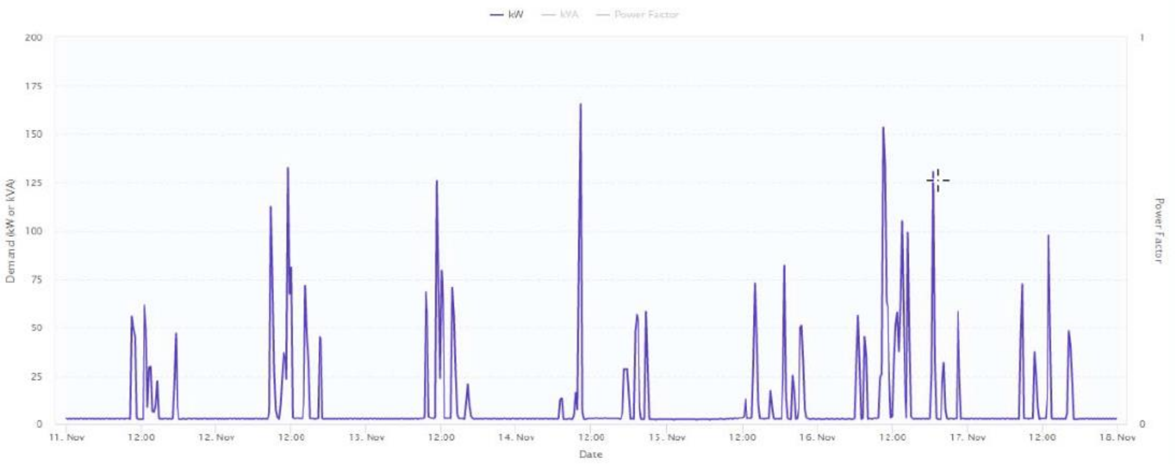


Source https://revel-energy.com/distributed-energy-resources/

Modern Challenges

EV (Electrical Vehicle) charging stations

- The uninterrupted network reliability is essential for ultrafast charging stations. However, the current Utility Delivery Timeframes have left EV companies dissatisfied. Consequently, they are actively exploring alternative solutions for their supply needs to ensure efficient and timely charging services



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Professional Certificate of Competency in Earthing and Lightning Protection	6 November 2023
Professional Certificate of Competency in Power Distribution	6 November 2023
Professional Certificate of Competency in Electrical Power System Fundamentals for Non-Electrical Engineers	13 November 2023
Graduate Diploma of Engineering (Electrical Systems)	2 January 2024
Online – Master of Engineering (Electrical Systems)	2 January 2024
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Q&A

Engineering Institute of Technology.

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Website
www.eit.edu.au

Head Office
1031 Wellington Street West Perth
Perth, WA 6005

Phone
Inside Australia: 1300 138 522
Outside Australia: +61 8 9321 1702

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