WEBINAR

Installations 102

March 29, 2022

By: Wissam Geahchan, Applications Engineer

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ATTENTION

AUDIENCE PARTICIPATION

- Questions can be asked at any time using the chat function on the webinar screen
- Any unanswered questions will be followed up through email
- This presentation, a recording of the webinar and a brief survey will be emailed to all registrants

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ABOUT ME

Wissam Geahchan

Applications Engineer, Nexans Canada

- Active member on CSA and UL standards committees
- Experience applying the Canadian Electrical Code in a variety of applications
- LEED Green Associate
- Soccer coach

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Installations 102: 2-Part Series

- Industry standards & guides
- Installation Types & Considerations
  - Underground
  - Overhead
  - Underwater
  - Vertical
- Field Testing Cables
  - Installation Testing
    - Very Low Frequency
    - Tan Delta
    - Partial Discharge

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DISCLAIMER

"Cable" Installations 102

This presentation is not meant to be a comprehensive “How-To” presentation.

Only qualified personnel who are familiar with the processes and associated safety precautions shall install cable and perform field testing.

Tailored to the North American market (even more so towards Canada)

Industry Standards and Guides

1. **CSA C22.1 Canadian Electrical Code, Part 1 (CEC)**
2. **CSA C22.3 No.1 -Overhead Systems**
3. **CSA C22.3 No. - Underground Systems**
4. **NFPA 70, National Electrical Code (NEC)**
5. **Provincial Electrical Safety Codes**
    1. Ontario Electrical Safety Code - OESC
    2. BC Safety Standards Act
    3. ….
6. **Municipal Electrical Safety Codes**
7. **Local Authorities Having Jurisdiction (AHJ)**
    1. Electrical Safety Authority - ESA (Ontario)
    2. Technical Safety BC
    3. ….
8. **National, Provincial, Municipal Building Codes**
    1. National Building Code (NBC)
    2. Ontario Building Code (OBC)

11. **NEMA TCB 2-2017 – Guidelines for the Selection and Installation of Underground Non-metallic Raceways**
12. **IEEE 400 - Guide for Field Testing and Evaluation of the Insulation of Shielded Power Cable Systems Rated 5kV and above**
13. **IEEE 400.2 – Guide for Field Testing of Shielded Power Cable Systems Using VLF**
14. **IEEE 400.3 – IEEE Guide for Partial Discharge Testing of Shielded Power Cable Systems in a Field Environment**
15. **IEEE 524 – Guide for the Installation of Overhead Transmission Line Conductors**
16. **IEEE 525 – Guide for the Design & Installation of Cable Systems in Substations**
17. **IEEE 576 - Recommended Practice for Installation, Termination, and Testing of Insulated Power Cable as Used in Industrial and Commercial Applications**
18. **IEEE 835 – Power Cable Ampacity Tables**
19. **IEEE 1185 – Recommended Practice for Cable Installation in Generating Stations and Industrial Facilities**
20. **IEC 60364 Series – Low voltage electrical installations**
21. **IEC 60287 Series – Electric cables**
22. **IEC 60502 Series – Power cables with extruded insulation and their accessories for rated voltages from 1 kV to 30 kV**

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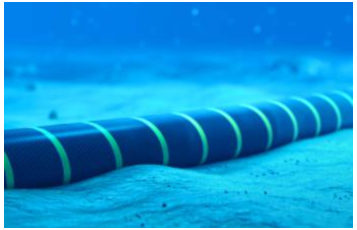
Installation Types

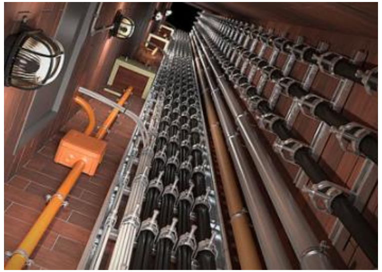
Underground/ Buried

Aboveground/ Overhead

Underwater/ Submarine



Vertical



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Underground Installations

Underground cables can be:

(1) Direct-buried in soil

(2) Buried in a raceway

a. Direct-buried duct, or
b. Concrete-encased duct bank

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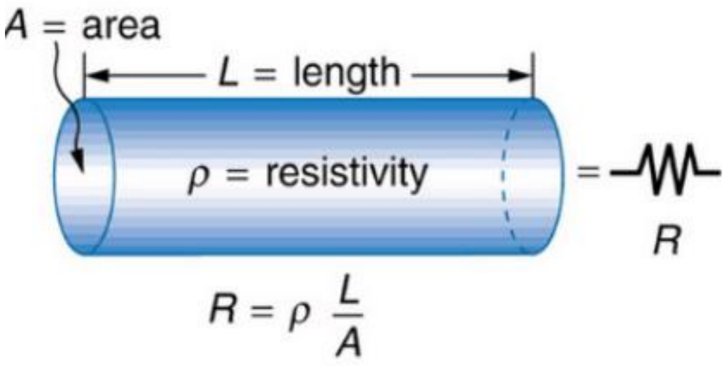
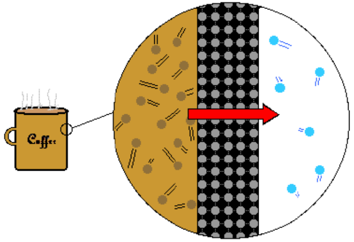
Underground Installations - General

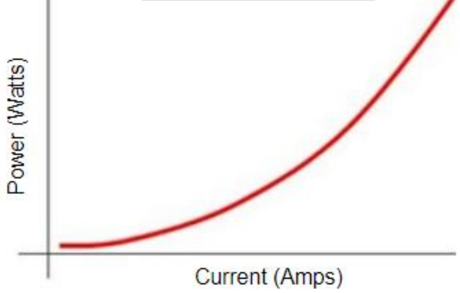
Conductor heat dissipation increases with an increase in current.

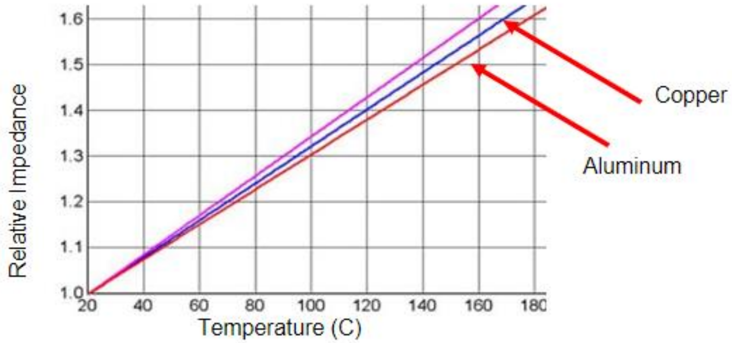
Conductor impedance increases with the conductor's operating temperature.



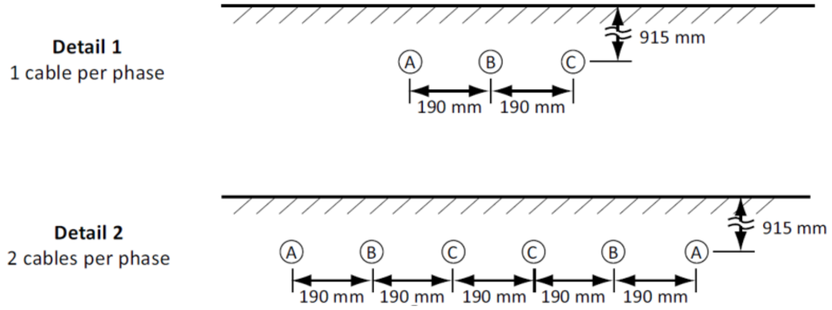


$$P = I^2R$$



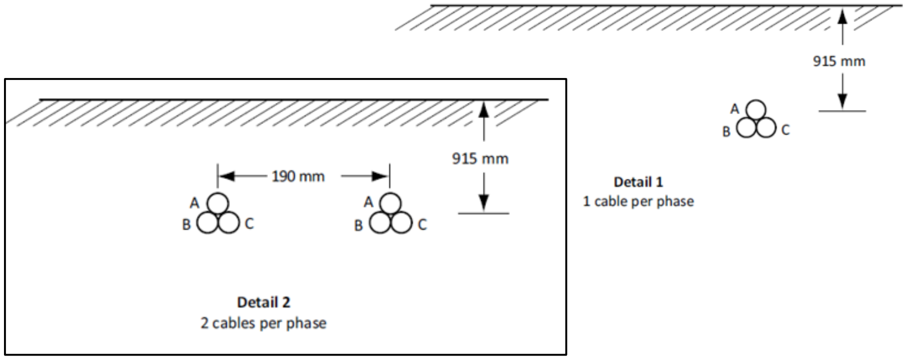


Underground – Direct Buried



Allowable insulated copper conductor ampacities < 5000 V

Size, AWG or kcmil	1/Phase Detail 1	2/Phase Detail 2
1/0	315	269
2/0	357	304



Allowable insulated copper conductor ampacities < 5000 V

Size, AWG or kcmil	1/Phase Detail 1	2/Phase Detail 2
1/0	262	221
2/0	298	250

*source CSA C22.1 Canadian Electrical Code, Part 1

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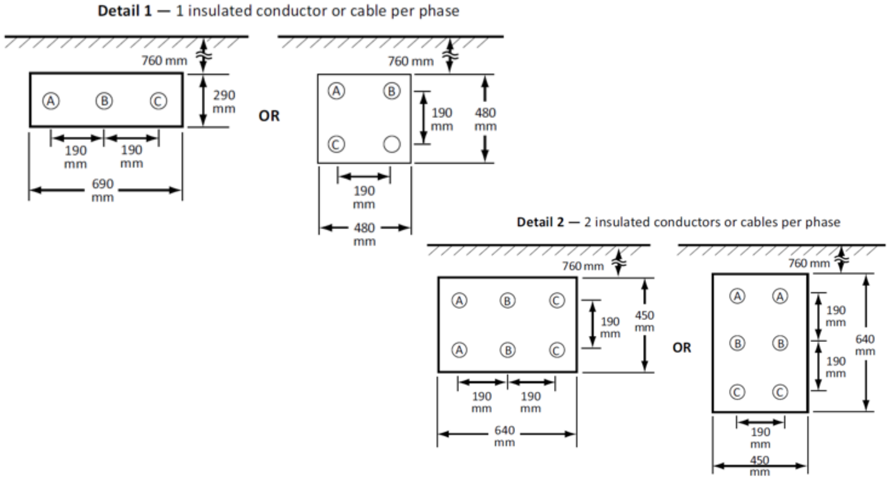
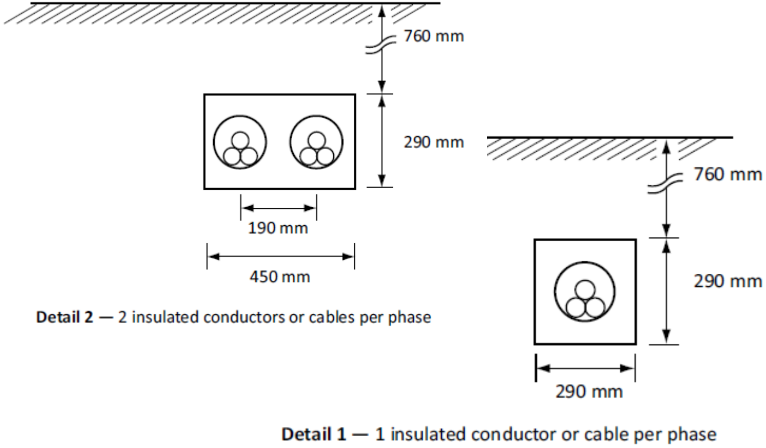
Underground – Concrete Duct Bank



Allowable insulated copper conductor ampacities < 5000 V

Size, AWG or kcmil	1/Phase Detail 1	2/Phase Detail 2
1/0	258	221
2/0	293	250
3/0	333	283

*source CSA C22.1 Canadian Electrical Code, Part 1



Allowable insulated aluminum conductor ampacities < 5000 V

Size, AWG or kcmil	1/Phase Detail 1	2/Phase Detail 2
1/0	199	171
2/0	226	194
3/0	257	219

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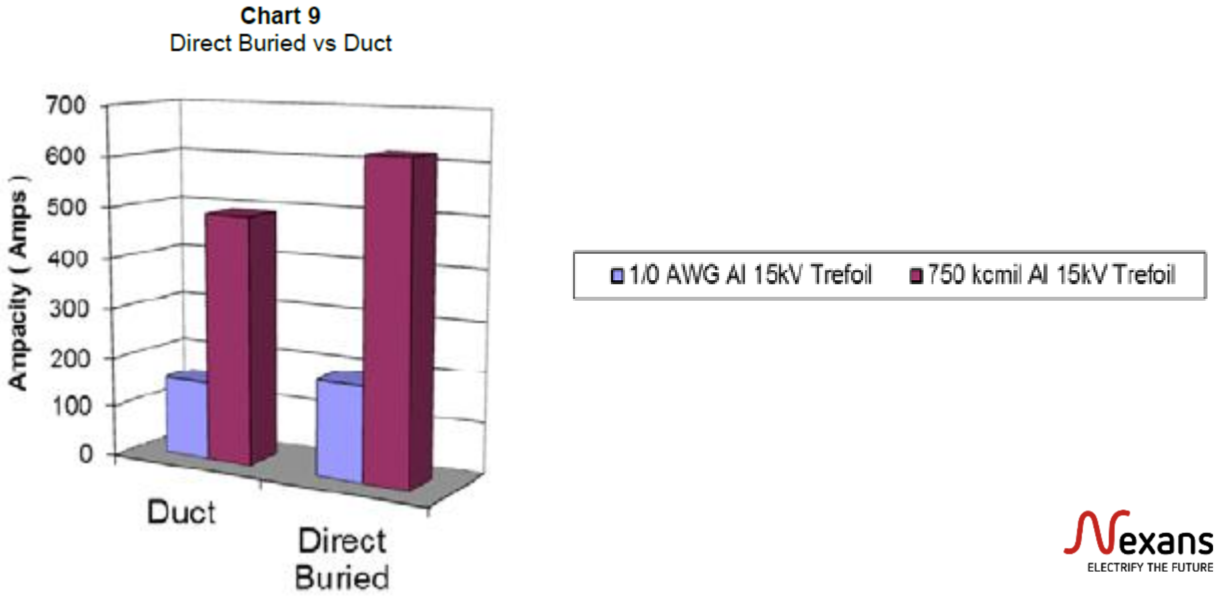
Underground – Compare

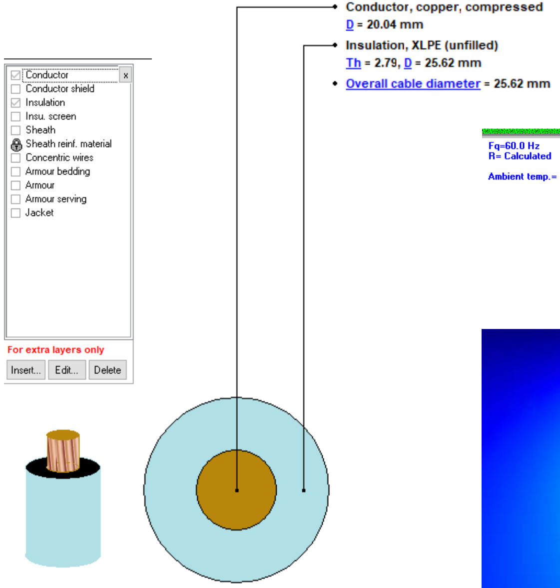
The addition of duct material and air spacing between the cable and the duct add to the thermal resistance of the ampacity calculations thereby decreasing the ampacity of cable in duct compared to direct buried cable.

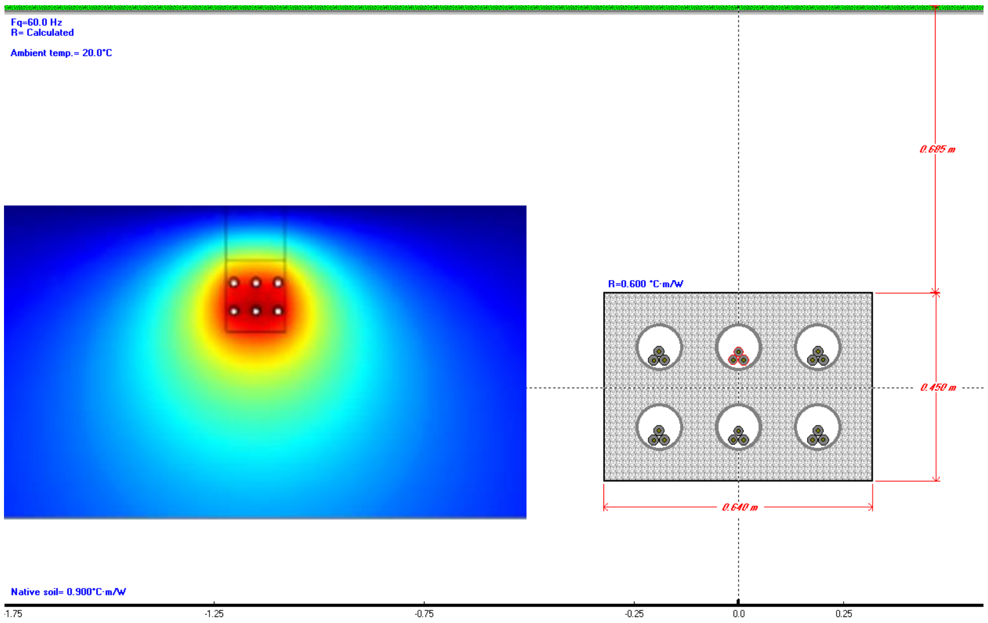


*Source – ICEA P-117-734

Underground – Ampacities

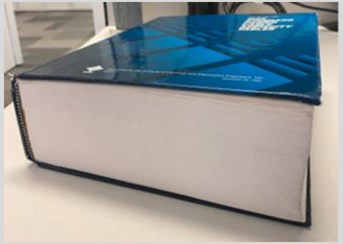
Neher-McGrath methodology and IEC 287 and IEC 853





*source CYME – CYMCAP Software

Another useful way to determine the ampacities for power cables is to use one of the 3000+ ampacity tables in IEEE 835 - Power Cable Ampacity Tables



Underground – Factors

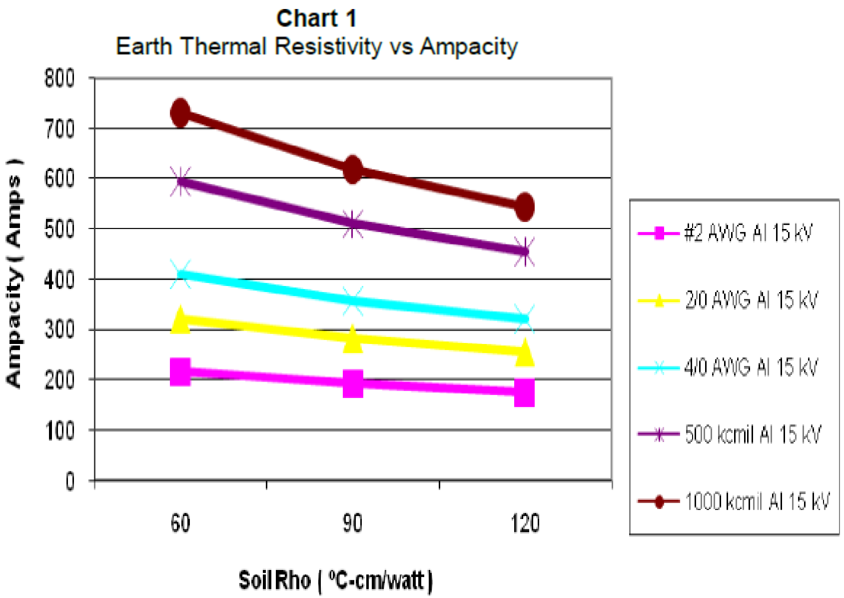
These factors and typical values need to be accounted for when doing any ampacity studies, calculations or simulations for underground installation:

Load factor	100%
Earth (backfill) thermal resistivity	90Ccm/W
Concrete thermal resistivity	60Ccm/W
Ambient earth temperature	20C
Ambient air temperature	40C
Maximum conductor temperature	75C or 90C
Conductor insulation level	100% or 133%
Ground and bonding (cable grounded/bonded on both ends?)	Y/N
Separation from any other adjacent installation	3m
Number of circuits, conductors per phase, and number of phases	varies
Armour material	Aluminum or Steel
Bedding material for direct buried cables	Sand
Height above sea level	300m
Latitude	45-490
Conduit material and size	DB PVC
Burial depth	varies

Underground – Soil Thermal Resistivity

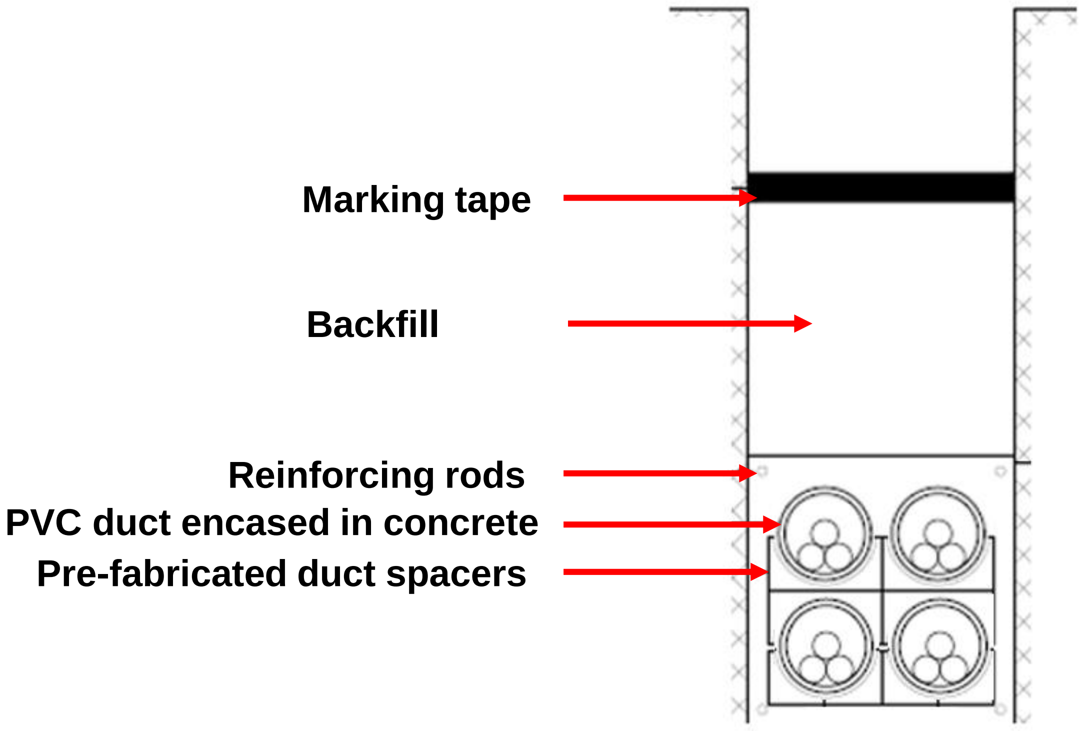
Ampacity ratings for cables are significantly influenced by the soil thermal resistivity.

The following chart* shows this relationship.



*Source – ICEA P-117-734

Underground – Cross-section

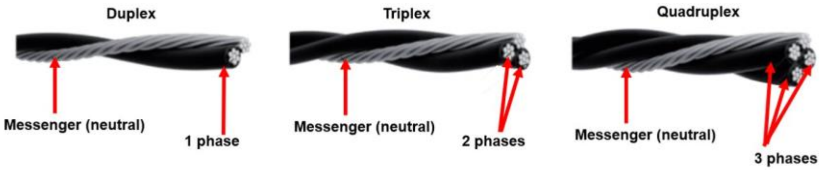


Typically, polypropylene rope is provided in all ducts to aid in pulling cables into ducts.

Overhead Installations - Conductors

Covered wire (Line wire)

- Used for short spans in applications where space is constricted (i.e. along alleys or on poles carrying multiple circuits)
- Most common constructions of factory assembled, or twisted conductors include duplex, triple and quadruplex cable with a bare neutral messenger or **NS75/NS90 (neutral-supported)**.



Open wire

- Used for long spans for their reduced cost and weight
- AAC/ASC, AAAC/AASC or ACSR

ACSR – *Aluminum Conductor Steel Reinforced* – Most predominant conductor of choice for transmission applications over long distances because of their high “strength to weight” ratio and good current carrying capacity.

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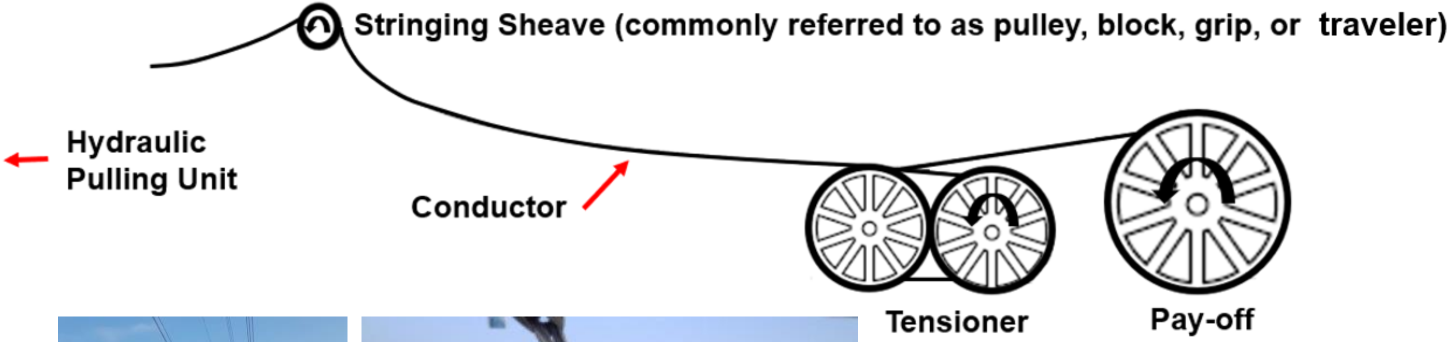
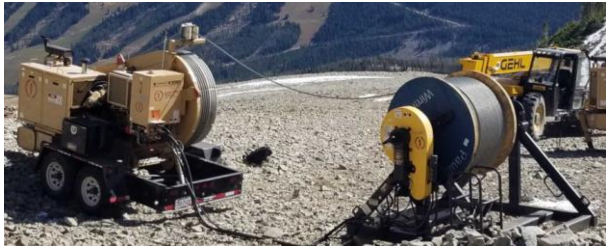
Overhead Installations - Stringing

Conductor stringing methods involve pulling the conductor into position under tension using a tensioner, stringing sheave(s), and a pulling device.



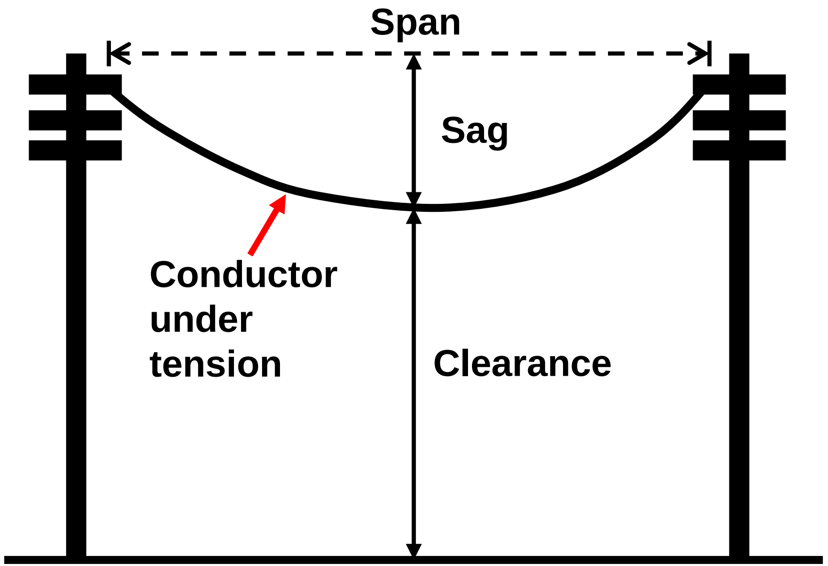
Examples:



Overhead Installations - Considerations

Sag and Tension

- When the cable/conductor is hung between two supports, it forms an arc.
- Gravitational force (or weight) acting on the cable causes **tension**.
- The **sag** is the vertical distance in level between the points of support and the lowest point of the conductor.



Sag and tension are inversely proportional.

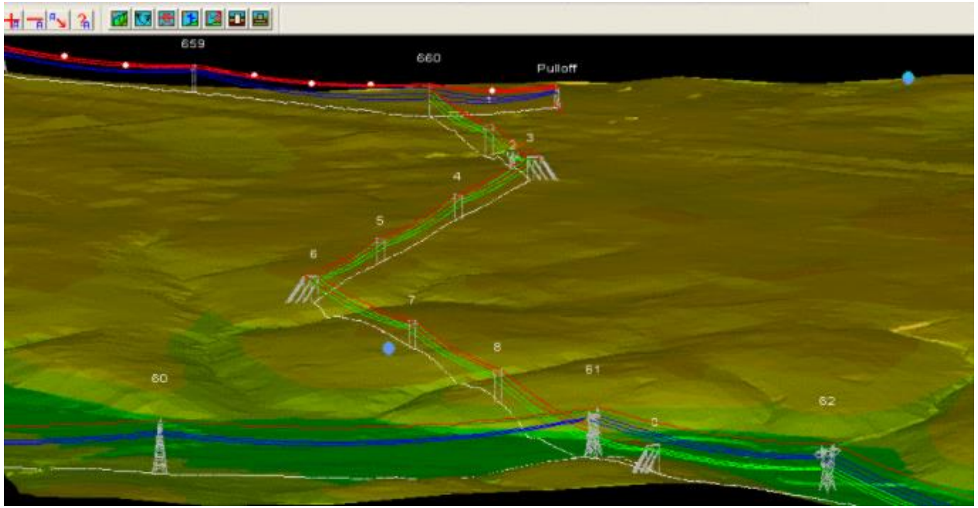
Sag is affected by several factors including:

1. Conductor weight – heavier conductor = more sag
2. Span – longer span = more sag
3. Tension – high tension = less sag
4. Wind – high wind = more sag
5. Temperature – low temperature = less sag
6. Ice loading – lines covered in ice + wind pressure = increased weight

Overhead Installations - Considerations

Modelling

Modelling of an overhead cable system using PLS-CADD or other software is critical to ensure that the cable system will adequately handle all types of weather conditions and temperature extremes including the most severe situation under which wind and ice loading occurs.



POWER LINE SYSTEMS

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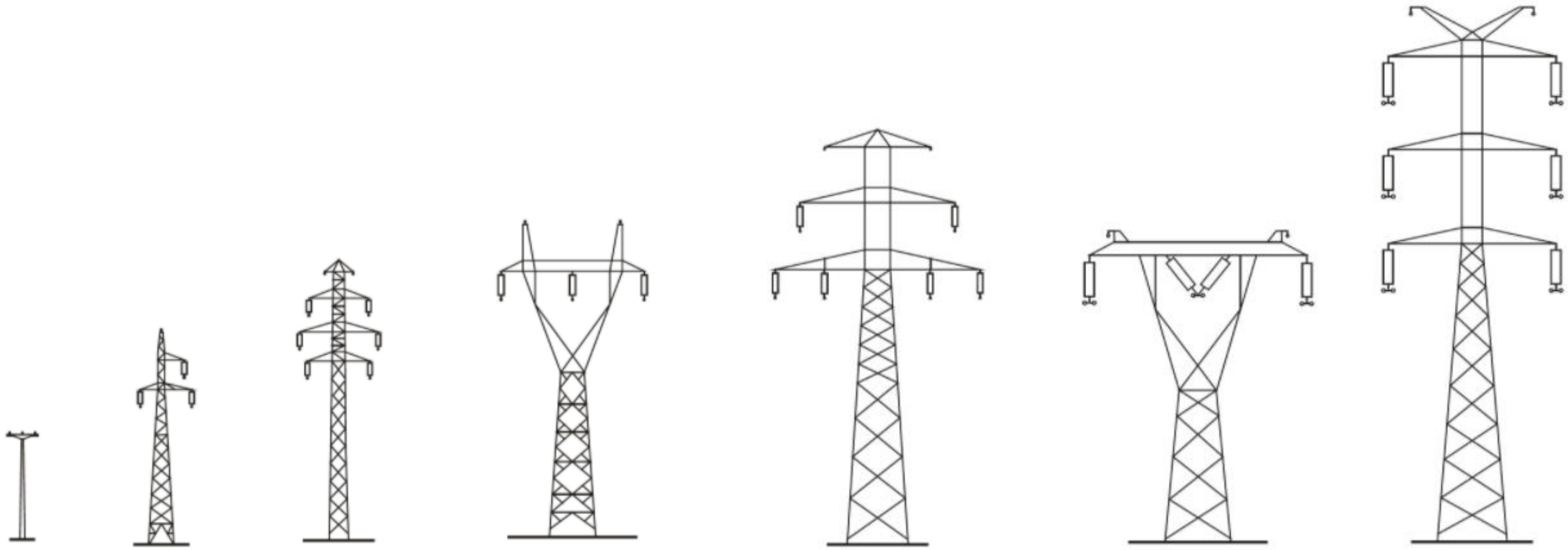
Overhead Installations - Considerations

Transmission Tower Types

Different types can be used depending on the voltage class, number of circuits, and required/desired accessories.



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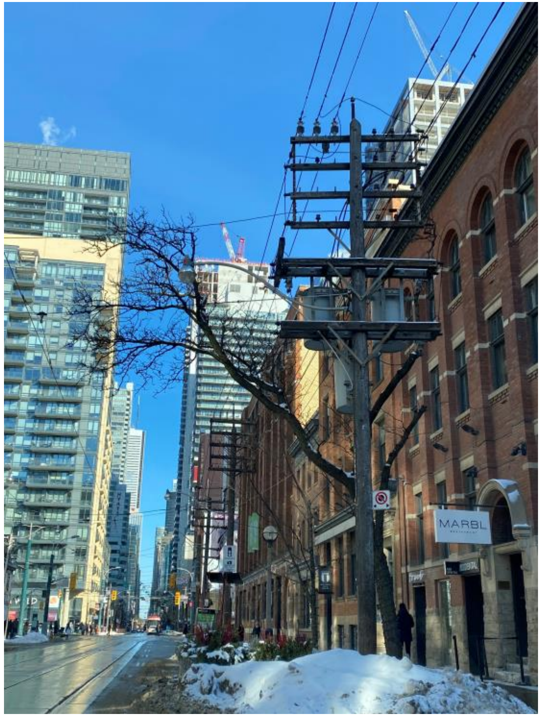
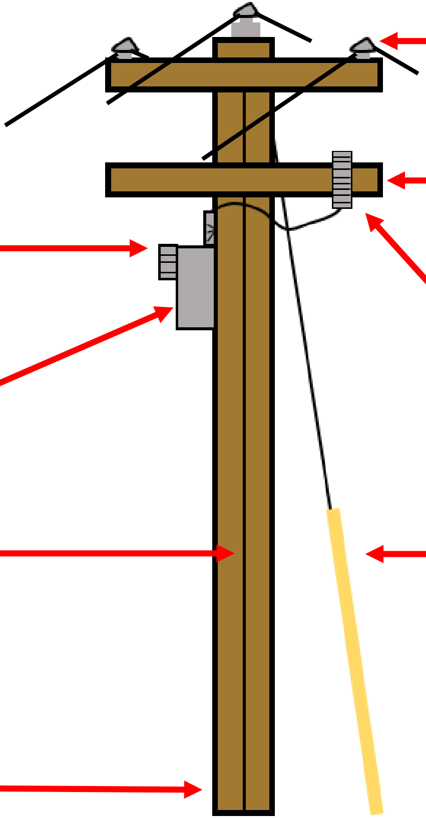
Overhead Installations - Considerations

Common Transmission Pole Components





Conductor

Lightning Arrestor
Protects the pole and equipment from lightning strikes

Transformer
Converts voltage

Ground wire
Runs the entire length of the pole and directs electricity safely to earth

Power Pole

Insulator
Prevents energized wires from coming into contact with each other or the pole

Crossarm
Holds the wires on the pole

Fuse Cutout
Opens when there is a problem with the line

Guy wire –
To stabilize the pole

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Overhead – Factors

These factors and their typical values need to be accounted for when doing any ampacity studies, calculations or simulations for underground installation:

Conductor Conductivity…………………………………………………………………………...1350-61.2%, 6201-52.5%, 5005-53.5%
Thermal resistivity…………………………………………………………………...………..375Ccm/W for both PE and XLPE
Conductor temperature…………………..…………………………………………………..……………..…………...75C or 90C
Ambient air temperature…………………..………………………………………………………...…………25C or 40C
Wind Velocity………………………………………………………………………………………………...……..2 ft/s
Solar absorption………………………………………………………………………......bare 0.5, covered or insulated 0.91
Sun altitude at 12:00 noon…………………………………………………………..……………………………....83°
Azimuth of line……………………………………………………………………………..…………………..…..270°
East-west line…………………………………………………………………………………........……..at latitude 30°N
Elevation……………………………..…………………………………………………………..……………………sea level
Azimuth of sun…………………………..…………………………………………………..………………………..180°
Emissivity…………………………...……………………………………………………….. Bare 0.5, covered or insulated 0.91

Underwater Installations

Installing a submarine (or sub-sea) transmission cable is both costly and challenging.

Specialized vessels are required to lay down the transmission cable on the sea floor with an on-board take-up and special equipment that can handle > 3000 tons of cable.

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Underwater Installations

The following are actions required for this type of installation:

1. Select and survey path
2. Obtain permits
3. Select appropriate cable system
4. Lay and/or bury the cable in the seabed
    a. Trench is excavated and then cable is laid, or
    b. Cable is laid, then buried under sediment/rocks as a second operation
5. Inspect the installation
6. Notify the appropriate stakeholders of cable position

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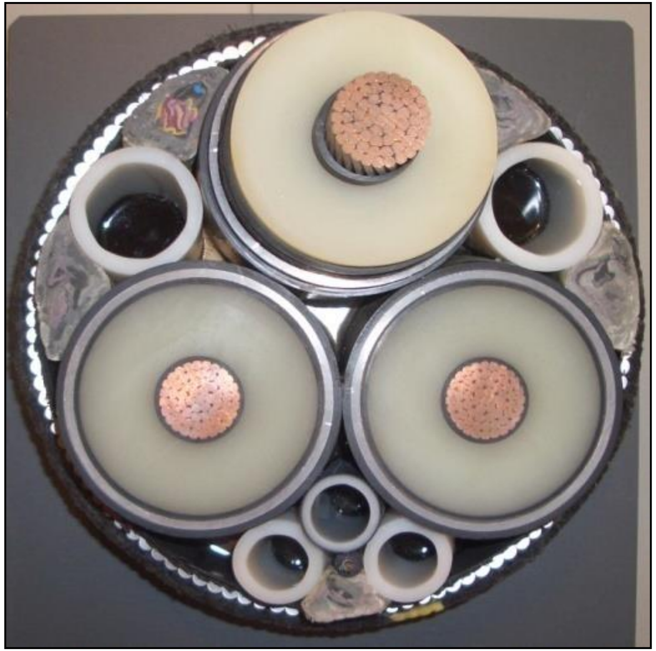
Underwater Installations

Nexans Aurora Vessel

CAPJET – A trenching system

Underwater Installations - Project



Wolfe Island Canada (2008) – the first 245 kV 3-core XLPE submarine cable system in the world

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Vertical Installations

For vertical installations, the use of a messenger may be necessary to support the cable during installation.

See Rule 12-120, as well as Table 21 of the Canadian Electrical Code for more information.

Table 21 *
Supporting of insulated conductors in vertical runs of raceways
(See Rule 12-120.)

Conductor sizes, AWG or kcmil	Maximum distance, m	
	Copper	Aluminum
14 to 8	30	30
6 to 0	30	60
00 to 0000	24	55
250 to 350	18	40
Over 350 to 500	15	35
Over 500 to 750	12	30
Over 750	10	25

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* Table 21 from CSA C22.1 Canadian Electrical Code, Part 1

Field Testing Cables

- **Installation Test** will be discussed
- Field tests should be made as soon as possible after installation
- Only qualified persons should perform field testing
- Before applying test voltages, the cable being tested must be disconnected completely from all other equipment

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Field Testing Cables

1. Very Low Frequency (VLF)
2. Partial Discharge (PD)
3. Tan delta

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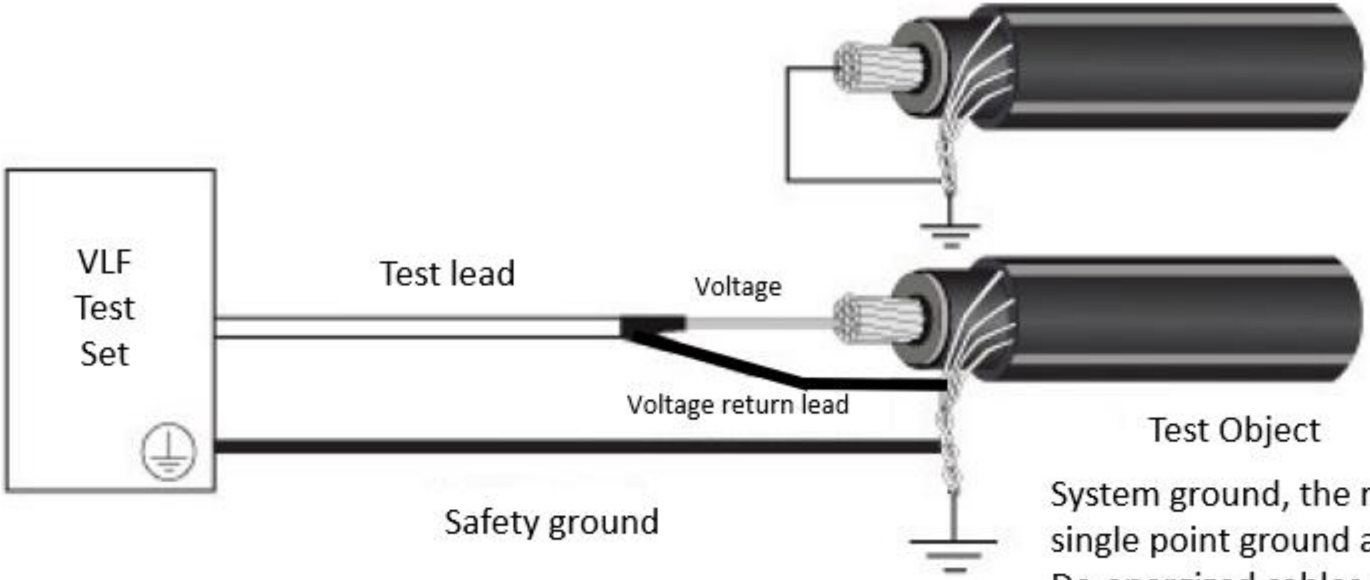
Very Low Frequency (VLF) Test

- A method for verifying the integrity of the cable insulation
- Carried out at a frequency of between 0.01 – 1 Hz.
- The cable being tested must withstand an AC voltage for the specified testing time without flashover.
- For XLPE insulated cables. this type of testing is sometimes preferred over DC Hipot test because it can offer more diagnostic information and typically the voltages used in the test are much lower so there is less risk to field aged cables

IEEE 400.2 - *Guide for Field Testing of Shielded Power Cable Systems Using Very Low Frequency (VLF) (less than 1 Hz)* describes VLF withstand tests and measurements that are performed in the field on service-aged shielded medium

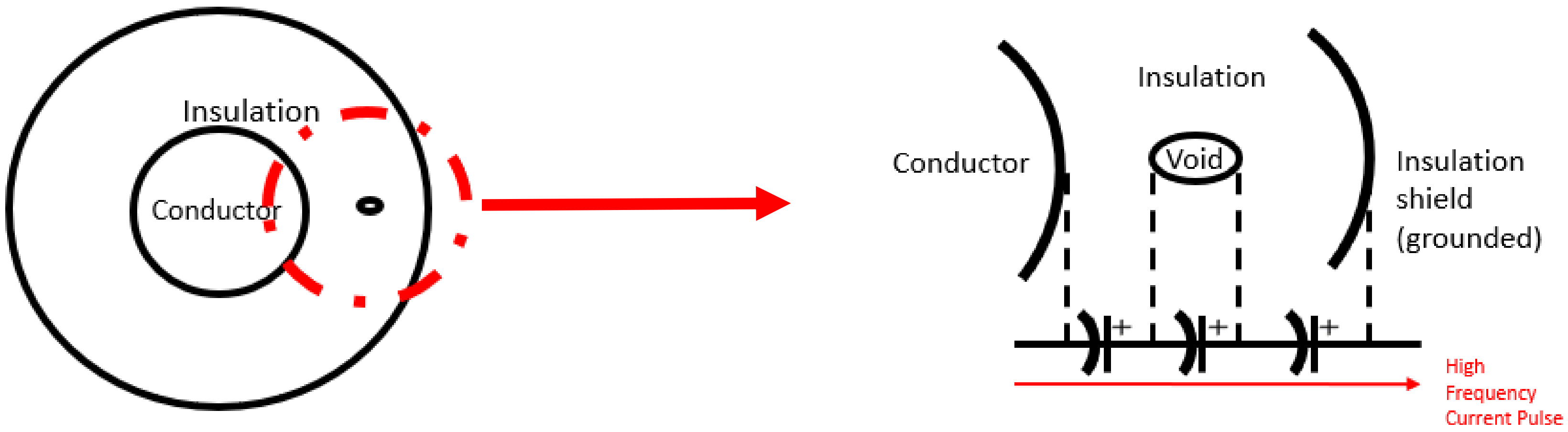
VLF Test – Typical Set-up



System ground, the recommended single point ground at the test site.
De-energized cables <u>not under test</u> should be grounded.

Partial Discharge Test

Partial discharge cable testing involves applying a voltage conductive to partial discharge and then measuring the discharge current pulses.



IEEE 400.3 - *Guide for Partial Discharge Testing of Shielded Power Cable Systems in a Field Environment* provides more information on this type of testing.

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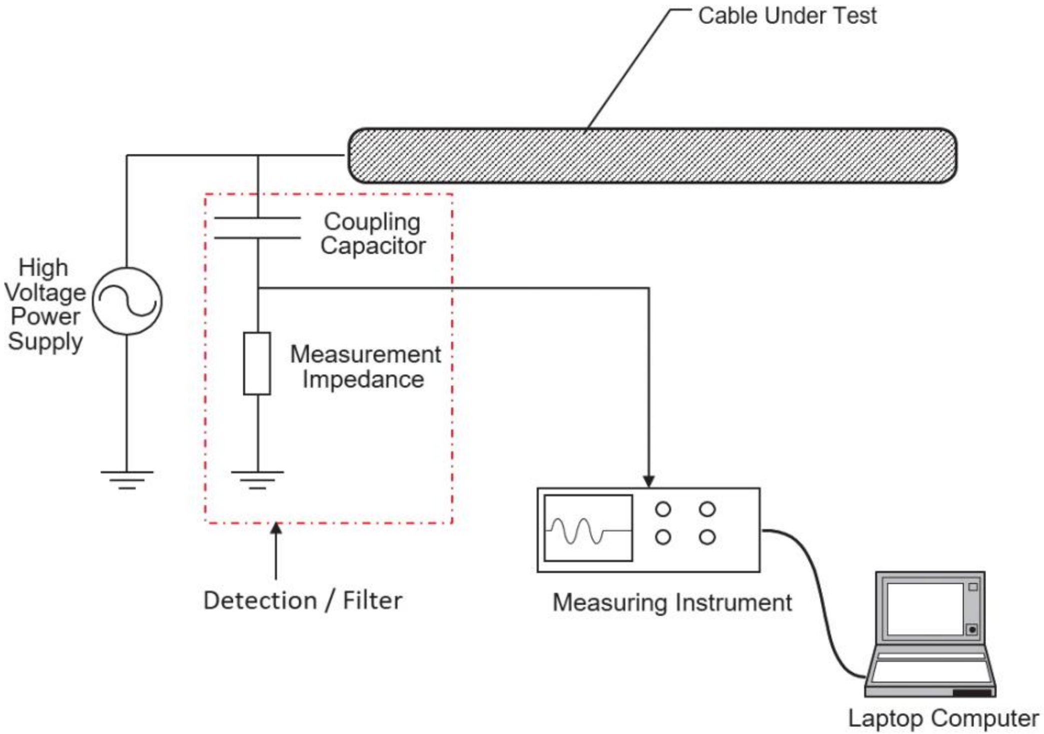
PD Test – Typical Set-up



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Tan Delta Test

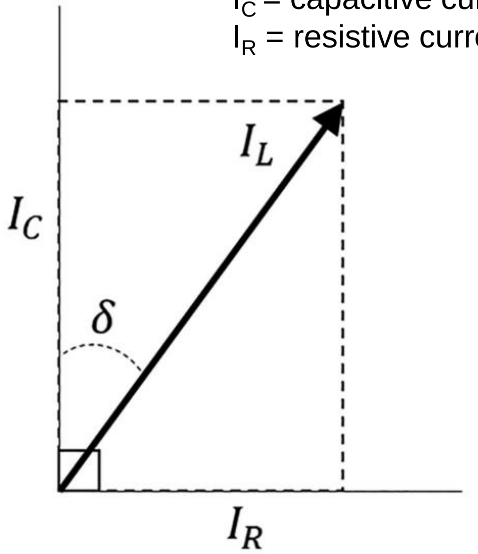
An ideal cable insulation system will be entirely capacitive in nature. But in the real world, there is also a resistive current that results from impurities (increased by aging effects like water trees).

The ratio of the resistive current to the capacitive current (I_R/I_C) is the **tangent δ or “tan delta”.**

For a given frequency and voltage, tan delta increases as the resistive current increases (or as the resistance in the insulation decreases).

This provides a measurable way to see how aging and impurities have affected a given cable.

I_L = leakage current
I_C = capacitive current
I_R = resistive current



$$I_C = V/(2 * \pi * f * C)$$

$$I_R = V/R$$

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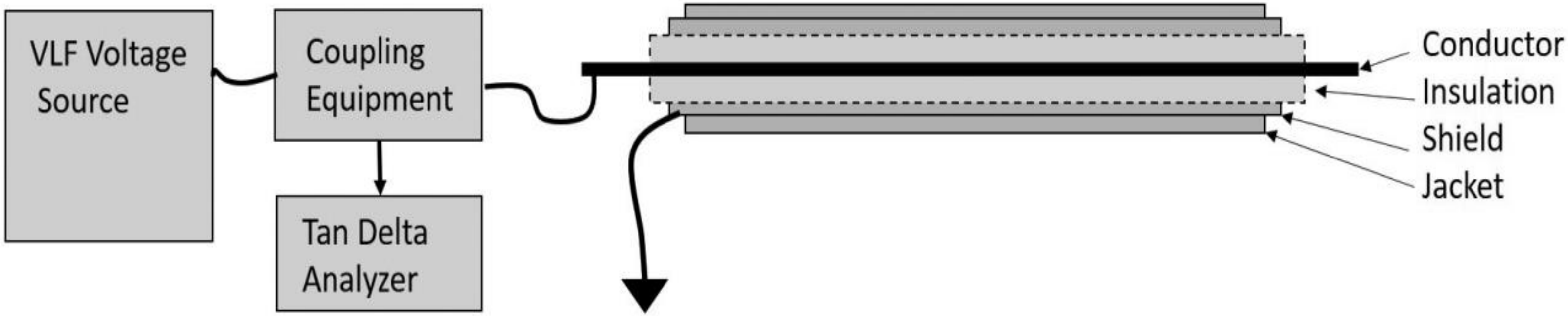
Tan Delta Test – Typical Set-up



Field Testing

There continues to be much debate in the industry on what test methods and equipment are the best.

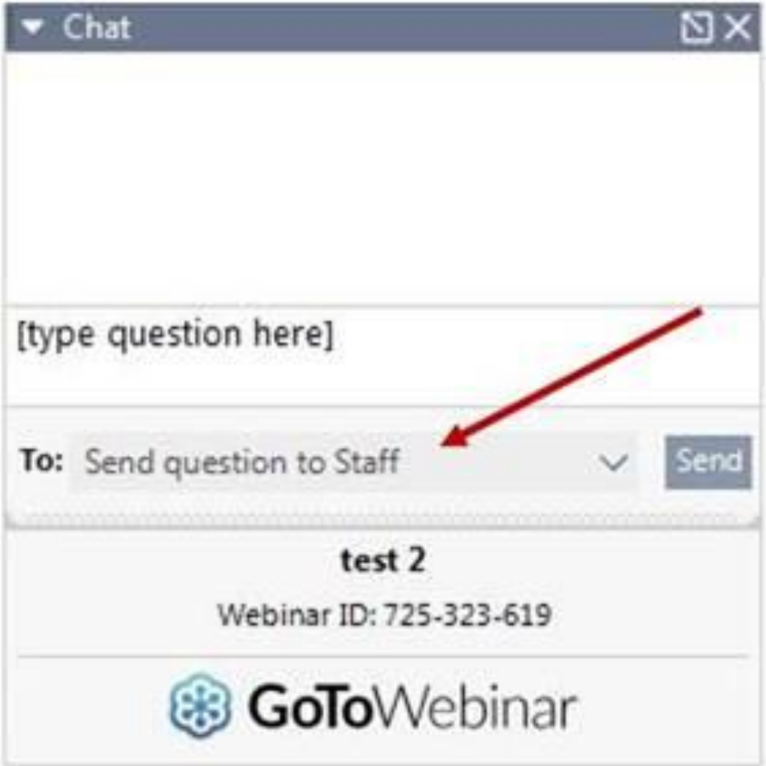
Ultimately, it comes down to:

- what cable types are being tested
- what the voltage level is
- what information you are trying to obtain.

Key Takeaways

1. Reviewed more standards and industry guides that govern the installation of cable.
2. Discussed 4 more types of cable installation methods
    a. Underground
    b. Overhead
    c. Underwater
    d. Vertical
3. Learned about the factors that need to be considered to make these installations safe, efficient, and compliant.
4. Discussed 3 more types of field installation testing
    a. Very Low Frequency (VLF)
    b. Partial Discharge (PD)
    c. Tan delta

Q & A



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Contact:

Wissam Geahchan
Applications Engineer, Nexans Canada
wissam.geahchan@nexans.com

www.nexans.ca

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