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Visual Descriptions, Metadata, and Connectivity Relationships

Electrical Distribution Network Equipment Guide

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Summary

This document describes the main equipment found in an overhead medium- and low-voltage electrical distribution network. It first presents the typical structure of a utility pole, including medium-voltage, low-voltage, and telecommunication lines.

The various types of equipment are then detailed: fuse cutouts, disconnecting switches, transformers, capacitor banks, voltage regulators, overhead-underground transitions, and automatic circuit reclosers. For each, the document explains their function, visual characteristics, and relevant metadata for automatic annotation (phases, rated power, status, control, configuration, etc.). Several diagrams, examples, and counterexamples are provided to enhance visual identification in field-acquired data.

The document concludes with an explanation of a data structure that enables the representation of the network in an electrical simulation, linking equipment from the source to the consumers.

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Introduction

This document presents the main equipment of a medium- and low-voltage electrical distribution network that is visible from field surveys, such as LiDAR data or high-resolution imagery. It was prepared by the Renewable Energy Integration team at CanmetENERGY in Varennes and aims to provide a clear baseline reference for the systematic identification of this equipment within the context of image recognition and automated analysis.

The objective is twofold:

1. Describe each type of equipment with its distinctive visual characteristics (shape, position, connections, typical behaviour on a utility pole or on the ground).

2. Provide useful properties for network characterization in order to facilitate the development of electrical topologies and the automated classification of assets on images or point clouds.

The following elements are presented in this document:

- Devices for opening/closing circuits (fuse cutouts, disconnecting switches)
- Transformation or regulation equipment (transformers, voltage regulators, capacitor banks)
- Interfaces between overhead and underground networks (overhead-underground transitions)
- Protection devices, such as automatic circuit reclosers

For each equipment category, the document provides the following:

- A concise functional description
- Visual identification criteria
- Useful metadata for annotation
- Real-world examples
- Counterexamples to prevent confusion

Scope and Limitations

This document provides a simplified, primarily visual representation of the electric distribution network. The descriptions and metadata presented are based on typical scenarios and do not cover all possible configurations. The electric distribution network is described using examples commonly found in Quebec. As a result, there may be minor differences compared with other regions of Canada.

Certain assumptions have been adopted for consistency and may not accurately reflect actual electrical behaviour, particularly in situations involving bidirectional flows, network reconfigurations, or equipment that is not visible.

Terminology and Definitions

The following terms are used throughout this document to provide consistent descriptions of the states and properties of electric distribution network equipment.

TERM	DEFINITION
Open a disconnecting switch or fuse cutout	The circuit is interrupted: the equipment is visibly in an unaligned or disengaged state, and no current flows.
Close a disconnecting switch or fuse cutout	The circuit is continuous: the equipment is aligned in the connected position, allowing current to flow.
Phase	The number of lines associated with an alternating-current circuit. There is a maximum of three phases. One-phase and three-phase lines are the most common. This information can be determined visually from the number of medium-voltage lines connected to the equipment, upstream and/or downstream. More than one three-phase circuit may be installed on the same pole. For example, if six phase conductors are present, there are two three-phase circuits.
Width	The number of elements in the equipment being described, equal to or greater than the number of phases of the equipment. If the number of elements exceeds the number

TERM	DEFINITION
	of phases, at least two of the equipment elements are connected to the same phase.
Ground/neutral	For the purposes of this document, a ground wire is also referred to as the neutral conductor. It is a conductor that is electrically connected to the ground. When present, the neutral conductor is not included in the width. Note that a ground wire is conceptually different from a neutral conductor in other contexts.

The terminology used in this document follows the vocabulary used by the Institute of Electrical and Electronics Engineers (IEEE) [1]. Please note that artificial intelligence was used to help improve the clarity and conciseness of this document.

General Overview

The electric distribution network generally consists of three groups of lines stacked on the same utility pole. Their position and appearance provide important visual cues for automatic identification of equipment. These lines include the following:

- Medium-voltage (MV) lines: located at the top of the poles and typically consisting of bare wires.
- Low-voltage (LV) lines: located in the middle of the poles, consisting of sheathed wires and supported by the ground wire. The ground wire is typically bare and is always present, but it is not always accompanied by LV lines. There are generally two or three conductors in LV lines, in addition to the ground wire.
- Telecommunications lines: installed at the bottom of the poles and consisting of telephone, Internet, and fibre-optic cables.

In addition to these conductors, one or more of the following types of equipment may be present:

- Insulator (*isolateur*): provides mechanical support and insulation between lines and between the lines and the pole.
- Guy wire (*hauban*): provides structural support to the pole and has no electrical function. Guy wires are typically located where lines curve or at the end of a line.
- Guy anchor (*ancrage*): the point at which a guy wire is secured to the ground.
- Disconnecting switch (*sectionneur*)
- Transformer (*transformateur*)
- Capacitor bank (*batterie de condensateurs*)
- Voltage regulator (*régulateur de tension*)
- Fuse cutout (*coupe-circuit à fusible*)
- Overhead-underground transition (*liaison aérosouterraine*)
- Automatic circuit recloser (*disjoncteur réenclencheur*)

To ensure consistent interpretation of the diagrams, a common legend is used throughout this document. This legend provides the graphical basis for the figures illustrating the various types of equipment.

Medium-voltage line	Telecommunications line
Currentless medium-voltage line	Insulator
Low-voltage line	Fuse cutout
Neutral conductor (ground)	Guy wire

The following figures present comprehensive views combining several types of network equipment. They illustrate how groups of lines, devices, and structural components are arranged together in real-world environments. These examples serve as visual references for the interpretation and annotation of images taken in the field.

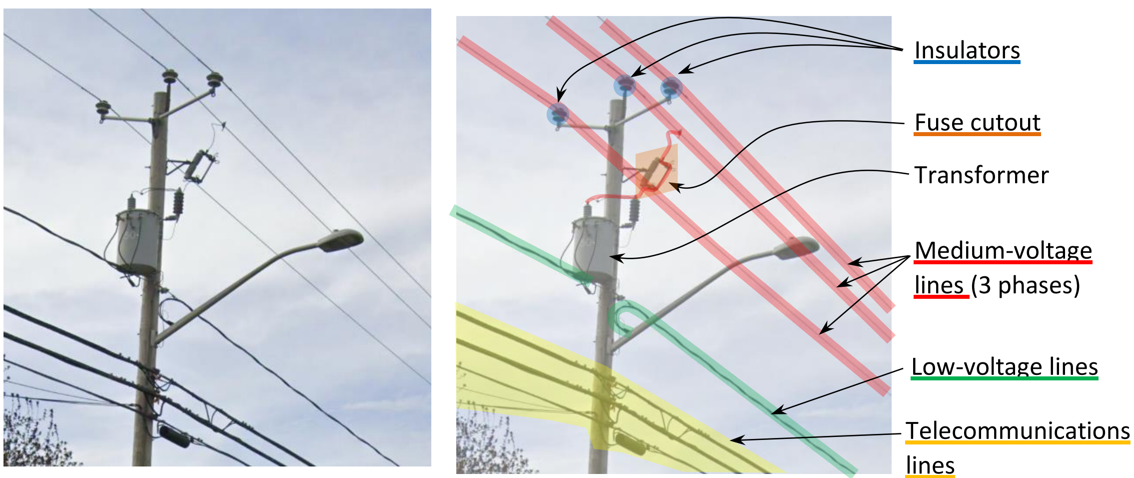


Figure 1 – General Example No. 1 ([Google Street View link])

Figure 2 – General Example No. 2 (Google Street View link)

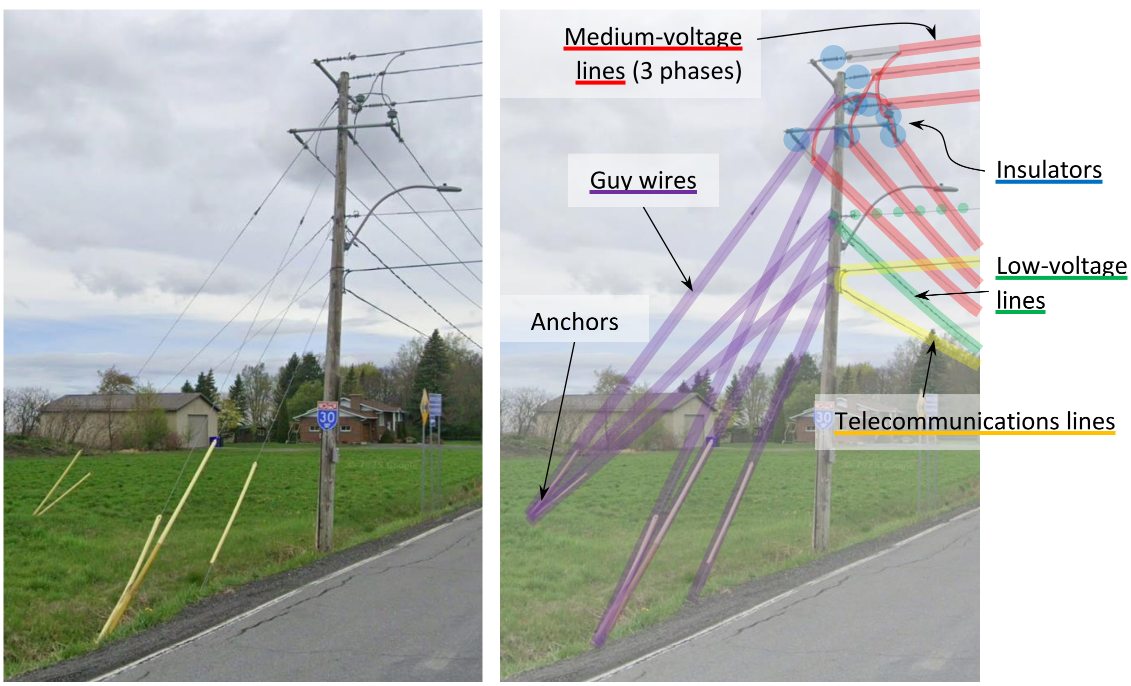


Figure 3 – General Example No. 3 (Google Street View link)

Equipment of Interest

This section presents the electrical distribution network equipment that is relevant for automated analysis based on images or point clouds. Table 1 summarizes the metadata useful for the classification, annotation, and interpretation of equipment of interest. Each equipment type can be characterized by a set of metadata that are visually observable in field survey data.

Table 1 – Equipment of Interest Metadata

	→ Equipment → / ↓ Metadata ↓	Line	Fuse Cutout	Disconnecting Switch	Transformer	Capacitor Bank	Voltage Regulator	Overhead-Underground Transition	Automatic Circuit Recloser
Geometry	Path	✓							
	Position		✓	✓	✓	✓	✓	✓	✓
	Length	✓							
	Elevation	✓							
Attributes	Rated value				✓	✓	✓		
	Asset number				✓	✓	✓		✓
	State		✓	✓					
	Mounting				✓				
	Controlled remotely			✓		✓			
	Number of phases	✓	✓	✓	✓	✓	✓	✓	✓
	Width	✓	✓	✓		✓	✓	✓	✓
Connectivity	Phase identification	✓							
	Upstream node identification	✓	✓	✓	✓	✓	✓	✓	✓
	Connection to upstream node	✓	✓	✓	✓	✓	✓	✓	✓
	Downstream node identification	✓	✓	✓	✓		✓		✓
	Connection to downstream node	✓	✓	✓	✓		✓		✓

Note that this section focuses on the metadata specific to each equipment type (geometry and attributes). Connectivity metadata, namely node identification and upstream and downstream node connections, are addressed in the "Data Structure" section.

In addition to the line, most utility poles include only one other type of equipment, with the exception of fuse cutouts, which are almost always used to protect and isolate other equipment.

Line

Lines are conductors that carry electricity. They are generally either overhead or underground. Line is a generic term encompassing high-, medium-, and low-voltage lines.

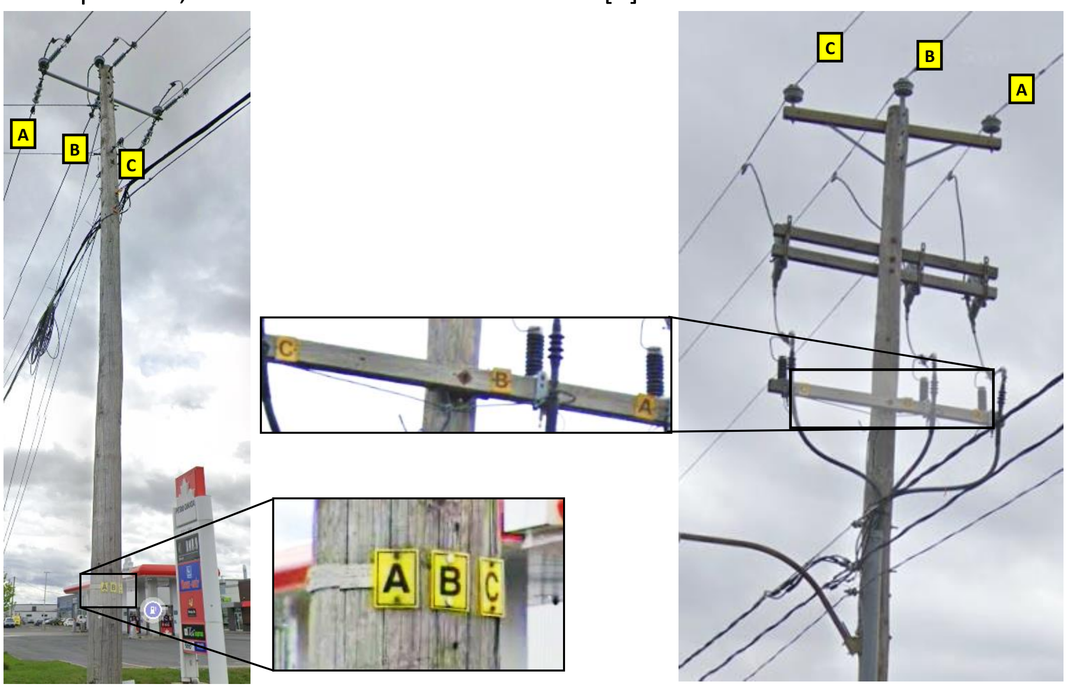
Medium-Voltage (MV) Lines

Overhead medium-voltage lines are generally located near the top of poles. The phases are designated A, B, and C. In practice, they are often arranged in sequence, either A-B-C or C-B-A. Small identification tags may be used to indicate the phases on the network, as illustrated in Figure 4.

- The different phases are never directly connected to one another. Consequently, all conductors connected to phase A, for example, can be assumed to belong to phase A.
- The lines on either side of voltage regulators, automatic circuit reclosers, fuse cutouts, and disconnecting switches generally have the same phases in the same order.
- A set of three single-phase lines, comprising phases A, B, and C, forms a three-phase line.
- Conductors may be mounted on a pole in various configurations (e.g., vertically along the pole or horizontally on one or more crossarms). The physical arrangement of the conductors on the pole is not relevant for modelling the distribution network.
- In rare cases, four conductors may be observed at the top of a pole, consisting of a three-phase line and a neutral conductor (for example, in

Prince Edward Island and Manitoba). In the vast majority of cases, however, the neutral conductor is located at the same level as the LV lines.

- Because most MV lines have a bare wire, ceramic insulators are used to securely attach the MV lines to the pole while preventing current from flowing.
- Where lines are colour-coded, the Canadian convention for three-phase lines is red, black, and blue for phases A, B, and C, respectively. Where present, the neutral conductor is white. [2]



[Google Street View link – Varennes] [Google Street View link – Longueuil]

Figure 4 – Identification of MV Line Phases

Low-Voltage (LV) Lines

At the low-voltage level, there are two line configurations:

- Three-phase (3 conductors [L1, L2, L3] + optional neutral conductor)
- Single-phase (2 conductors [L1, L2] + neutral conductor)

When both configurations are present, they are usually separated from one another. They may share the same neutral conductor. They may be either twisted around the neutral conductor or installed parallel to it.

It should be noted that it is difficult to distinguish between lines L1, L2, and L3, especially when they are twisted around the neutral conductor. The way they are arranged is not relevant for modelling the distribution network.

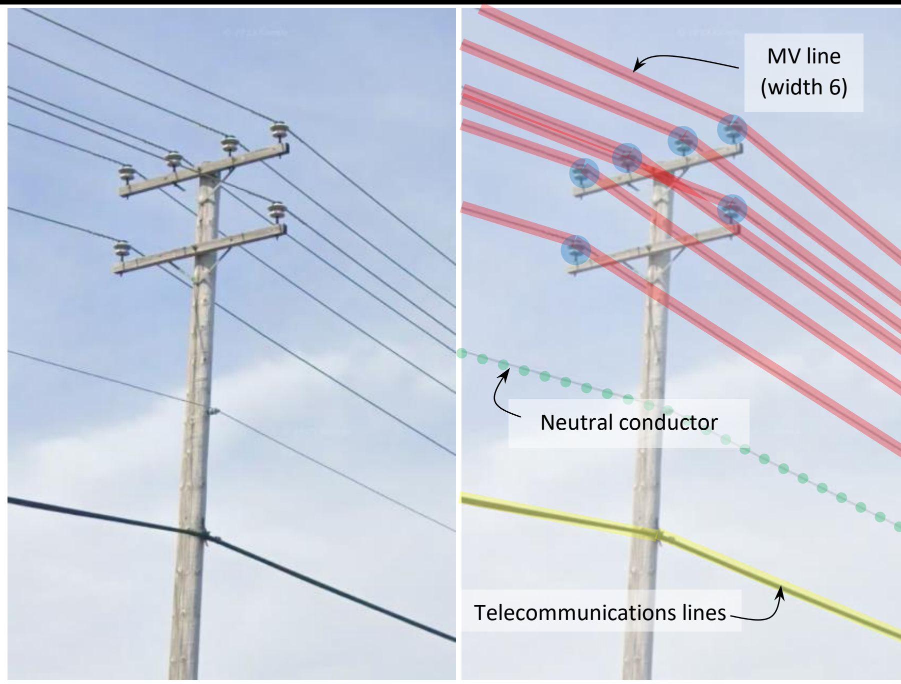
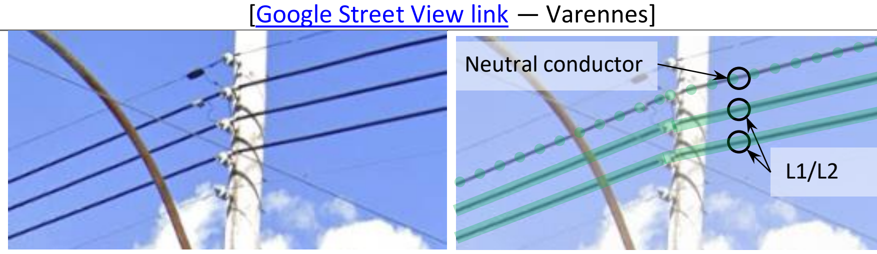
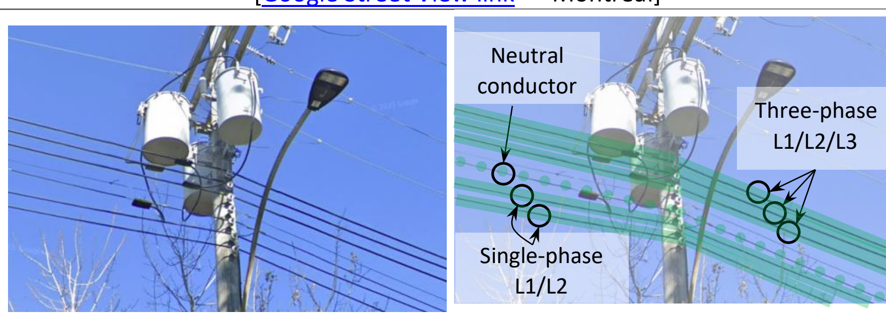
As a general rule, LV lines are sheathed and do not have insulators attaching them to utility poles.

Metadata

- Path: Sequence of coordinates following the route of the line between the upstream node and the downstream node.
- Length (m): Length of the path.
- Elevation (m): Average elevation of the line above sea level.
- Phases: Integer value ranging from 1 to 3.
- Phase identification: When known, for MV lines, sequence of letters A, B, and/or C identifying each conductor (the number of components must be equal to the Width).
- Width: Number of conductors (integer value greater than or equal to the number of phases, excluding the neutral conductor).
- Upstream node identification
- Connection to upstream node
- Downstream node identification
- Connection to downstream node

Examples

Note: The metadata omitted from each of these examples cannot be determined from the field survey data.

Metadata	Images
2 three-phase MV lines – Width = 6 – Phases = 3	 [Google Street View link — Varennes]
Single-phase LV line: – Width = 2	 [Google Street View link — Montréal]
Three-phase LV line: – Width = 3 Single-phase LV line: – Width = 2	 [Google Street View link — Montréal]

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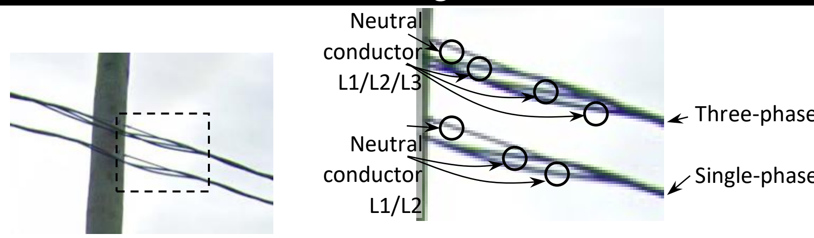
– Width = 3

Single-phase LV line:
– Width = 2</td><td>

[Google Street View link — Varennes]</td></tr>
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Fuse Cutout

Fuse cutouts are protective devices designed to automatically open a circuit when the current exceeds a specified threshold. They are also used to isolate a section of the distribution network or a piece of equipment, similar to a disconnecting switch in certain practical applications. A fuse cutout is much more commonly found in the closed state than in the open state.

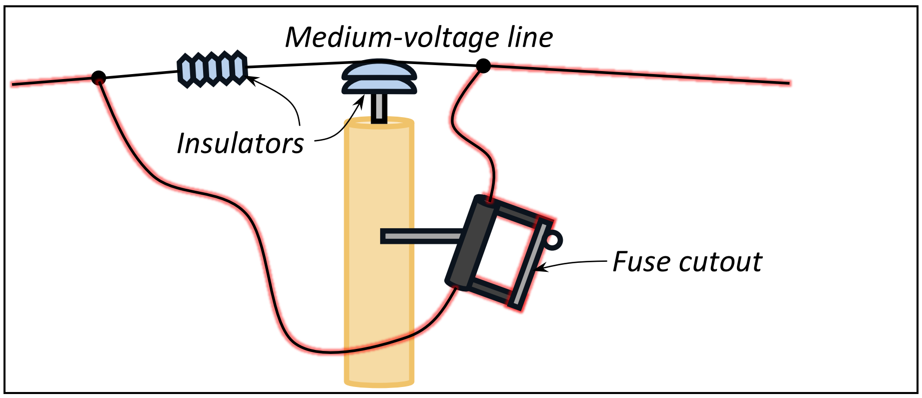

Figure 5 – Diagram of a Fuse Cutout

A fuse cutout is characterized by the following features:

- A long fuse tube
- Supported by insulators
- Direct connection to the medium-voltage lines
- A ring that allows it to be operated from the ground using a hot stick
- A pivotal point that allows it to be opened or closed manually

A fuse cutout may be observed in one of two distinct visual states. The open state is generally easy to identify in images because the fuse tube hangs downward or is disengaged from the fuse (see Figure 6):

- Closed: The tube is aligned with and inserted into its support, and the circuit is continuous.
- Open: The tube is pivoted downward or disengaged from its support, and the circuit is interrupted.

Unlike a disconnecting switch, whose elements are all in the same state, each fuse cutout has its own operating state, which may differ from that of the others.

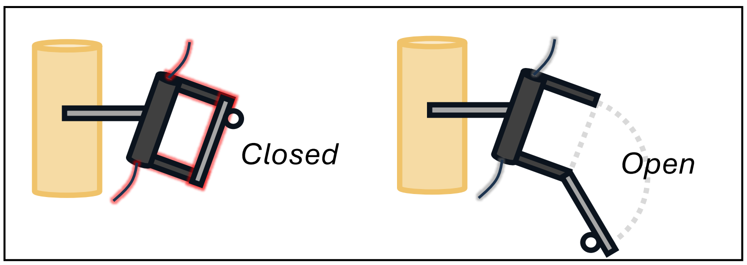

Figure 6 – Diagram of a Fuse Cutout in a Closed State and in an Open State

The following equipment is commonly installed with fuse cutouts:

- Transformers
- Capacitor banks
- Voltage regulators
- Overhead-underground transitions

Some less common fuse cutouts are referred to as “in-line” cutouts, meaning they are installed as an integral part of the line and do not have a separate mounting support on the pole.

Metadata

- Position: Equipment coordinates
- Phases: Integer value ranging from 1 to 3

- Width: Number of fuse cutouts, integer value greater than or equal to the number of phases
- State of each fuse cutout: open or closed
- Upstream node identification
- Connection to upstream node
- Downstream node identification
- Connection to downstream node

Examples

Note: The metadata omitted from each of these examples cannot be determined from the field survey data.

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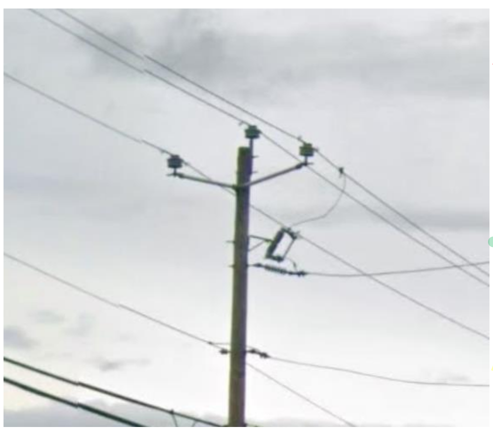
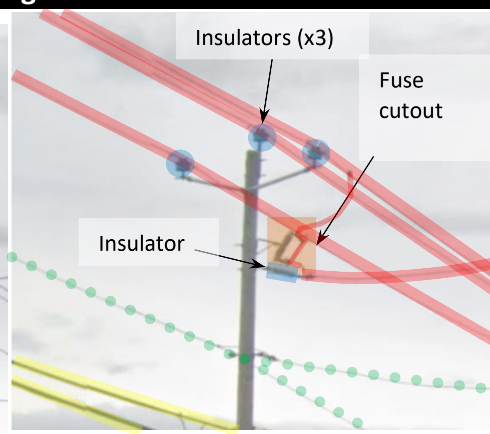

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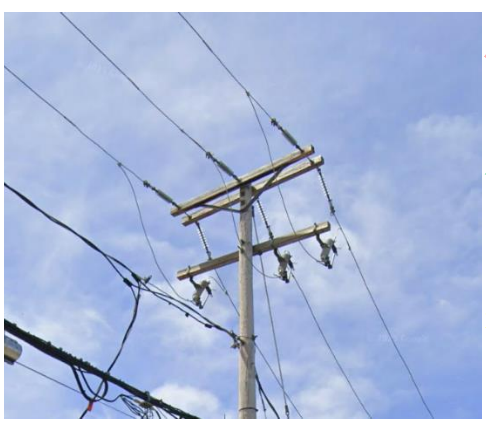
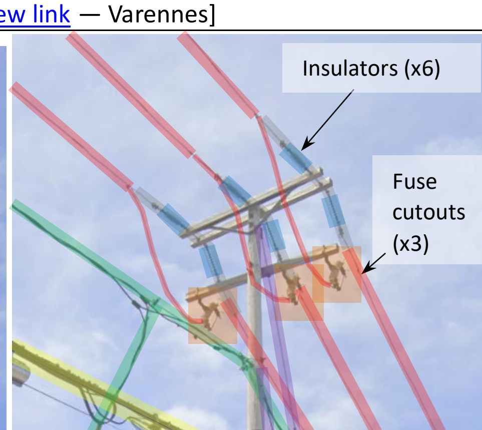

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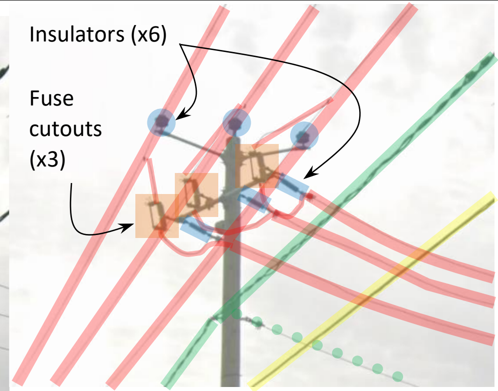

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- Phases = 3
- Width = 3

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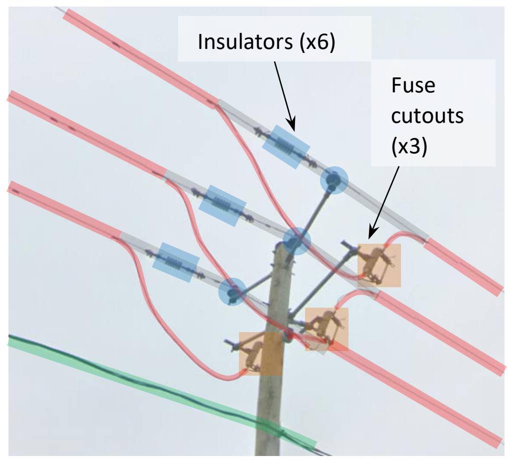

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- Width = 1

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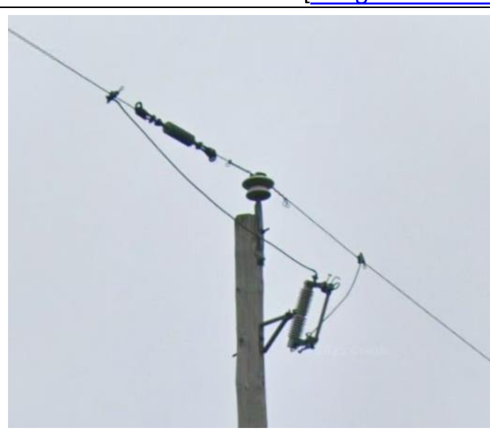
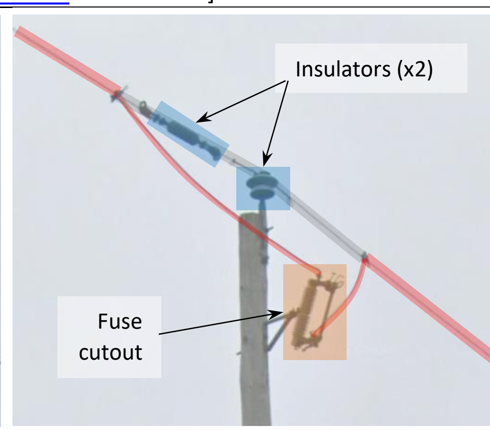

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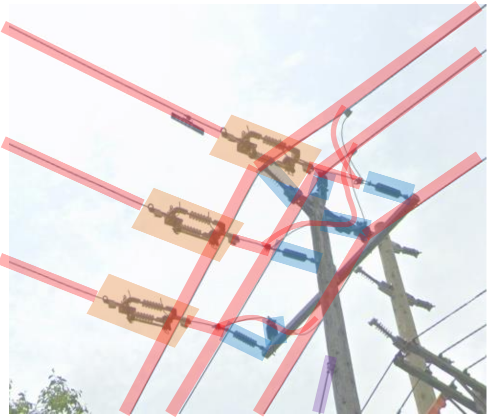
– State = [closed, closed, closed] – Phases = 3 – Width = 3 PS: This is an “in-line” mounting	  [Google Street View link — Toronto]

Disconnecting Switch

Disconnecting switches are devices used to isolate sections of medium-voltage lines. They are installed directly on MV lines, typically at the top of utility poles.

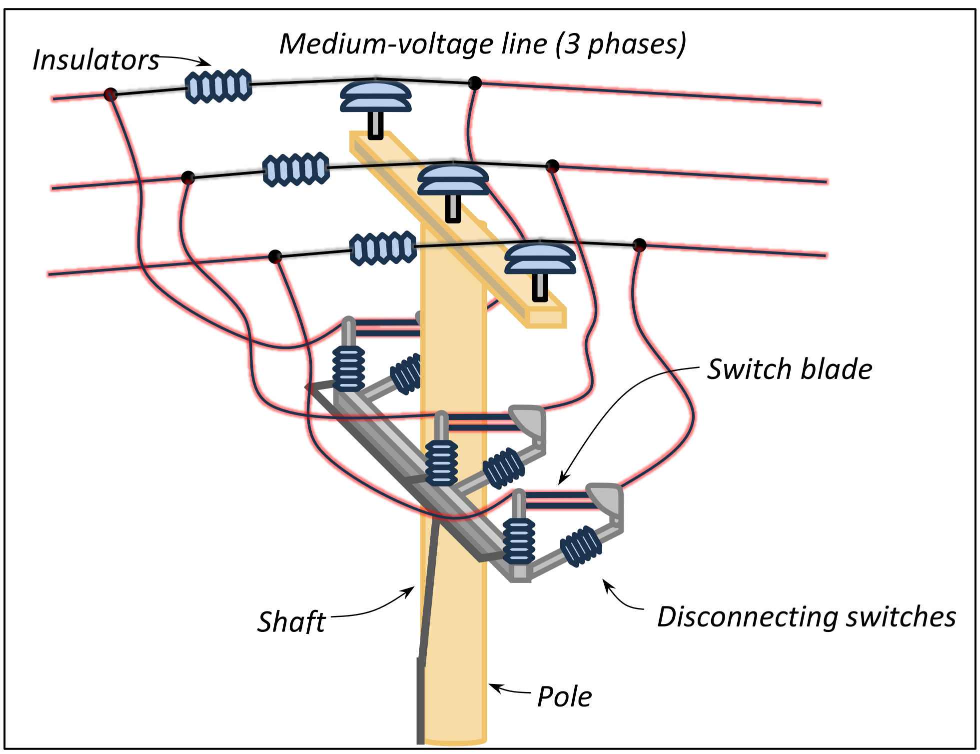


Figure 7 – Diagram of a Three-Phase Disconnecting Switch in Closed Position

Visually, a disconnecting switch consists of three main pieces of equipment:

- Insulators supporting each phase
- One or more switch blades, which are aligned when closed and misaligned or separated when open
- An operating lever mounted on the pole, allowing the device to be operated manually or by motor

A disconnecting switch typically includes one switch blade per phase, resulting in one to three visually identifiable blades in the images.

There are two control configurations:

- Not controlled remotely (manually operated):
    - A lever accessible to operators located near the base of the pole (no control enclosure)
    - The lever is mechanically connected to the switch blades by a shaft.
    - No remote operation is possible; an operator must manually operate the lever.

- Remote-controlled (power-operated):
    - A control enclosure is located near the base of the pole. This enclosure is the most reliable visual indicator for identifying a remote-controlled disconnecting switch.
    - The enclosure is mechanically connected to the switch blades by a shaft.
    - The disconnecting switch can be controlled remotely from a control system.

When multiple disconnecting switches are installed at the same location, they are typically operated by the same control and are generally in the same state. Disconnecting switches can be observed in two distinct visual states, as shown in Figure 8:

- Closed: The current flows, the blades are aligned, and there is mechanical and electrical continuity.

- Open: The current flow is interrupted, the blades are misaligned or separated, and there is no mechanical or electrical continuity.

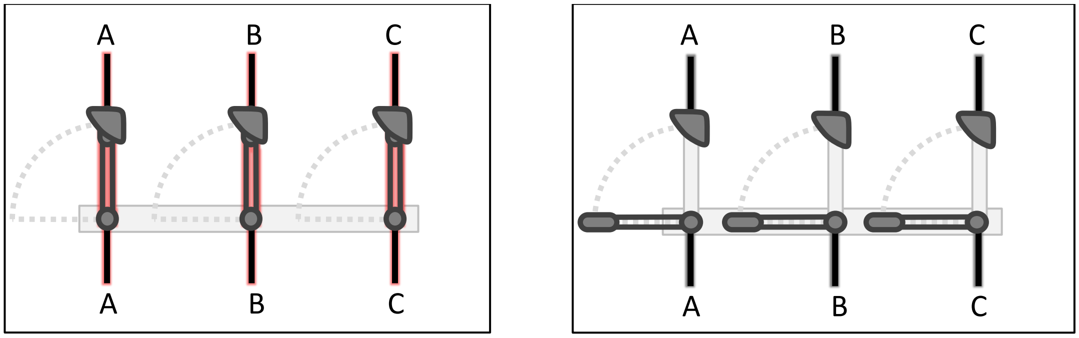


Figure 8 – Top-View Diagram of a Three-Phase Disconnecting Switch in the Closed (Left) and Open (Right) Positions

Metadata

- Position: Equipment coordinates
- Phases: Integer value ranging from 1 to 3
- Width: Number of blades in the disconnecting switch, integer value greater than or equal to the number of phases
- State: open or closed
- Remote-controlled: if control devices are present and enable the equipment to be operated remotely
- Upstream node identification
- Connection to upstream node
- Downstream node identification
- Connection to downstream node

Examples

Note: The metadata omitted from each of these examples cannot be determined from the field survey data.

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- Remote-controlled = Yes
- State = closed

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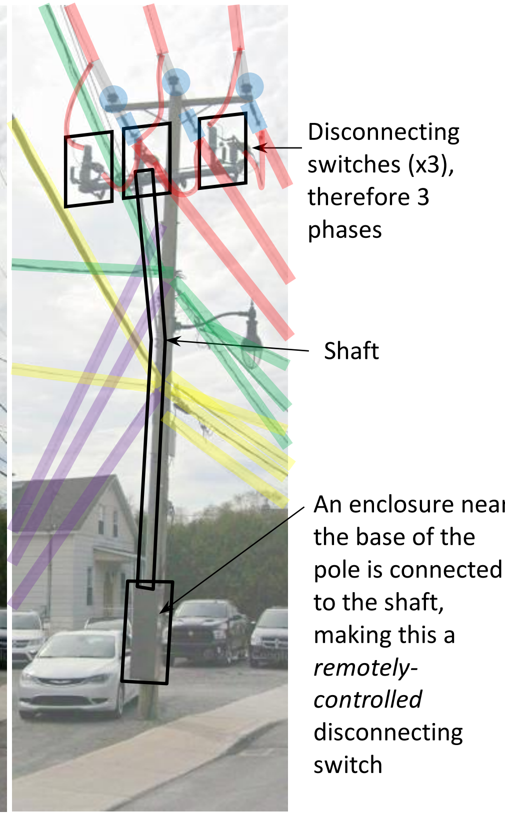

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- Remote-controlled = No
- State = open

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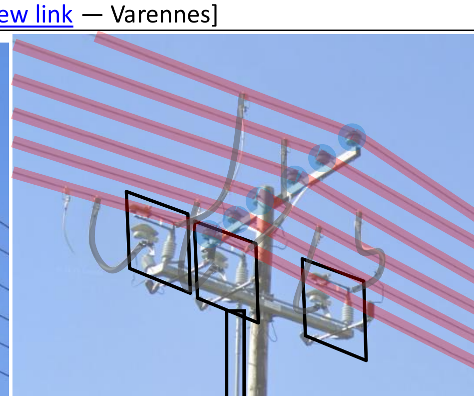

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- State = closed

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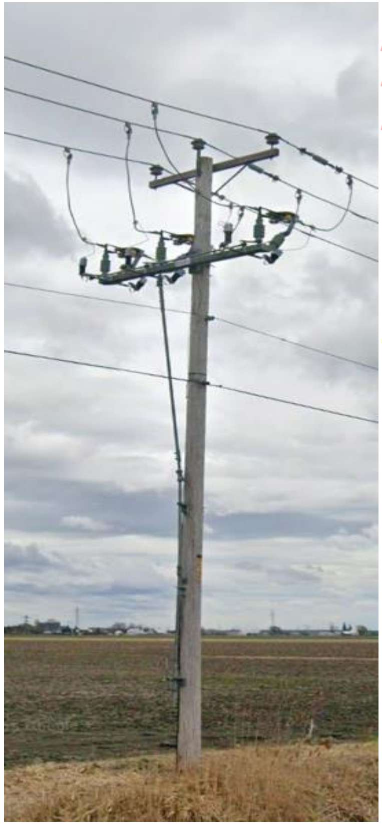
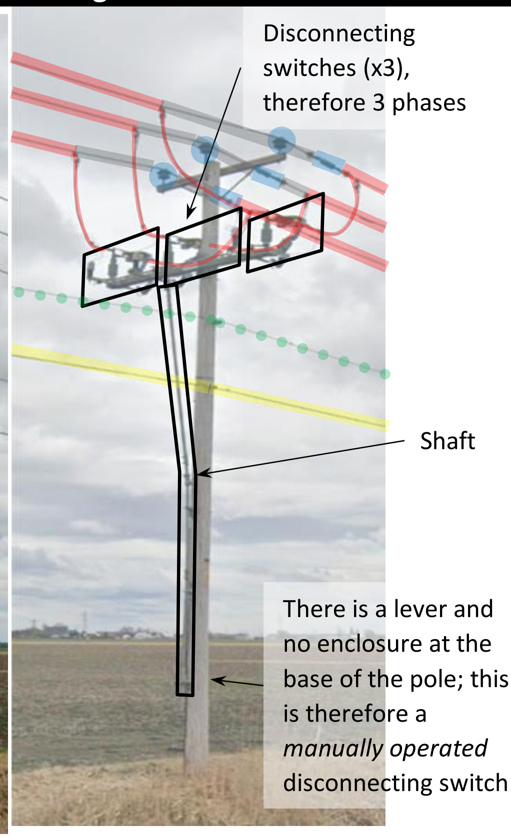

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- State = open

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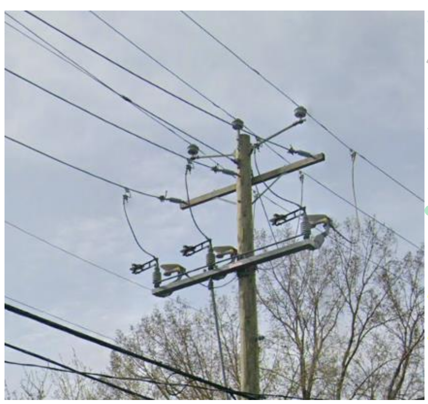
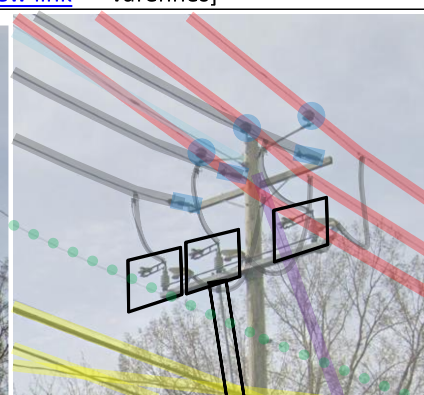



[Google Street View link — Varennes]

</td></tr>
</table>

Transformer

Transformers convert electrical power from a medium-voltage line to a low-voltage line. They are among the most common pieces of equipment found in the distribution network.

Three common mounting configurations are used:

- Pole-mounted (elevated):
    - Typically cylindrical in shape, although some units are rectangular
    - Installed between the MV and LV lines
    - Always accompanied by a fuse cutout installed upstream, above the transformer
    - Typically light gray, but may also be green or black and, in the case of older units, there may be signs of rust
    - The most common mounting configuration
- Pad-mounted (at ground level):
    - Typically rectangular in shape
    - Installed on a concrete slab
    - Displays the electricity distributor's logo
    - Typically green
    - They are found in areas where the distribution network is underground.
- Mounted in an underground vault [3]:
    - The transformer is located beneath a rectangular metal plate at ground level.
    - Typically found in densely populated urban areas served by underground distribution systems
    - Identifiable by the word "Transformer" marked directly on the plate.

In overhead distribution networks, different types of transformers can be distinguished:

- Single-phase transformer:
    - One enclosure, one phase
    - MV side: connected to one phase (or, less commonly, two phases)
    - LV side: single-phase output (120 V) with three conductors (L1, L2, and neutral)

- Primarily used in residential areas
- Three-phase transformer:
    - One enclosure, three phases
    - MV side: connected to three phases
    - LV side: three-phase output (600 V) with three conductors (L1, L2, and L3) — called a delta configuration — or four conductors (L1, L2, L3, and neutral) – called a wye configuration
    - Primarily used in commercial and industrial areas
- Assembly of three single-phase transformers providing three-phase service:
    - Three enclosures, three phases: three single-phase transformers mounted on the same utility pole, considered to be three separate single-phase transformers
    - MV side: Each transformer is connected to one phase (or, less commonly, two phases), while supplied as a whole by all three phases.
    - LV side: three-phase output (600 V) with three conductors (L1, L2, and L3) — called a delta configuration — or four conductors (L1, L2, L3, and neutral) — called a wye configuration. Each transformer is connected to two conductors on the LV side. See Figure 9.
    - One way to determine whether the LV-side assembly is connected in a wye or delta configuration is by examining the connectivity between the transformers on the LV side.
        - If a single conductor connects all three transformers, it is the neutral conductor, indicating a wye configuration.
        - If the transformers are connected together in pairs and no neutral conductor is used, the assembly is configured in delta.
    - Primarily used in commercial and industrial areas

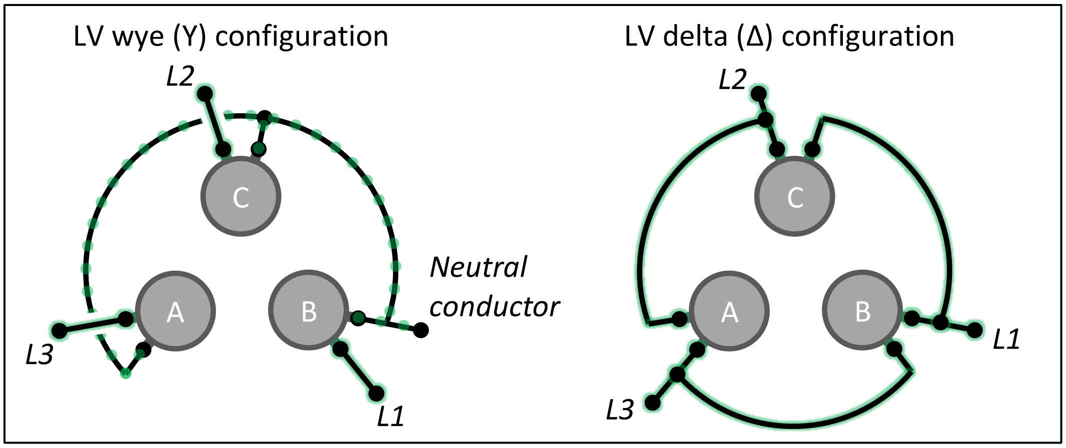


Figure 9 – Diagram of Three-Phase LV Wye and Delta Configurations

In this context, because the MV lines in underground distribution networks are not visible from the surface, it is not possible to determine whether a pad-mounted transformer or one that is mounted in an underground vault is single-phase or three-phase, or whether the configuration is wye or delta.

In the metadata, note that the LV configuration (wye or delta) is not documented directly ; rather, it is reflected in the connection to the LV node (downstream).

The transformer's rated power is generally printed on its enclosure. The typical rated capacities listed in Table 2 [4], based on an IEEE international standard, are expressed in kilovolt-amperes (kVA) and vary depending on whether the transformer is single-phase or three-phase. Although transformer rated capacities can be as high as 100,000 kVA, only those below 2,000 kVA are included, as these are the most common in medium-voltage distribution networks.

Table 2 – Preferred Transformer Rated Capacities in Kilovolt-Amperes [4]

Single-Phase Transformer	Three-Phase Transformer
5	15
10	30
15	45
25	75
37.5	112.5
50	150
75	225
100	300

Single-Phase Transformer	Three-Phase Transformer
167	500
250	750
333	1,000
500	1,500
–	2,000

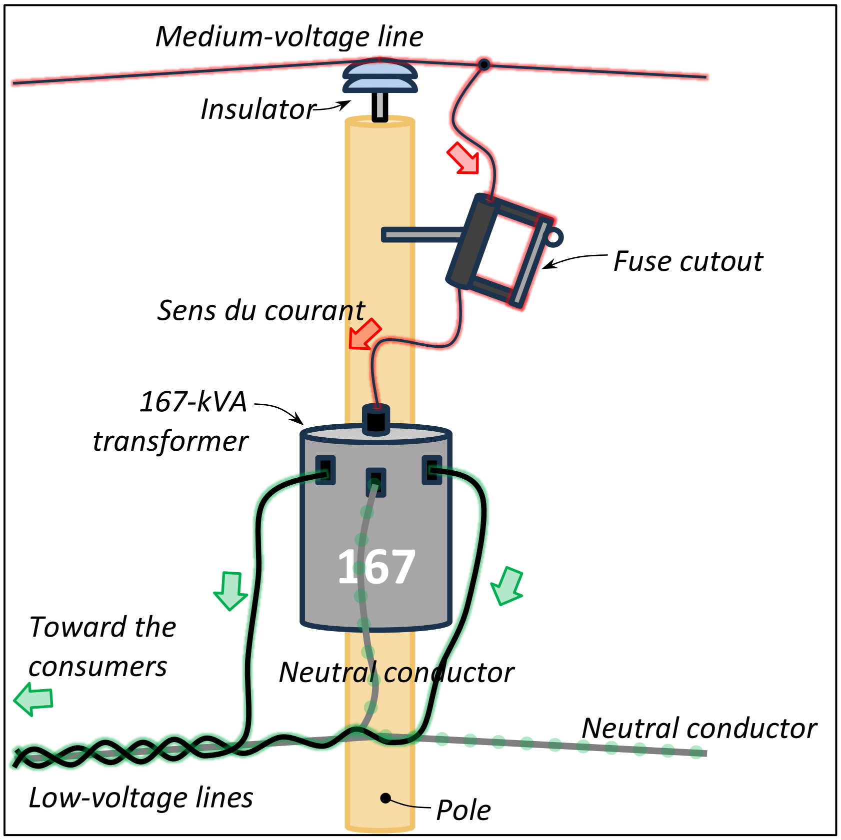


Figure 10 – Diagram of a Pole-Mounted Single-Phase Transformer

⚠ Note that equipment similar to pole-mounted transformers, such as telecommunications enclosures, may be mistaken for transformers. Transformers can be identified by their position, as they are located between the medium-voltage and low-voltage lines. Telecommunications enclosures are generally located below the low-voltage lines.

⚠ Note that equipment similar to pad-mounted transformers, such as telecommunications enclosures or donation boxes, may be mistaken for transformers. The presence of the electricity distributor's logo may be an indicator that the equipment is a transformer.

⚠ Note that equipment similar to underground-vault transformers, such as manhole covers, tactile pedestrian plates, or tree pits, may be mistaken for transformers. Transformers can be identified by the rectangular shape of their plate and the inscription "Transformer."

ℹ Typically, when three transformers are installed on the same utility pole, they have the same rated power.

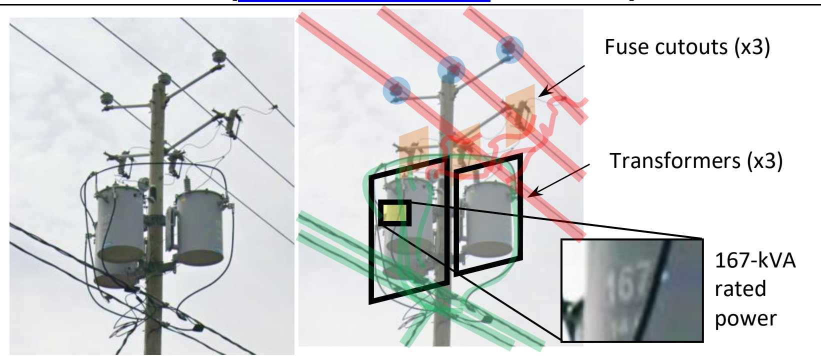
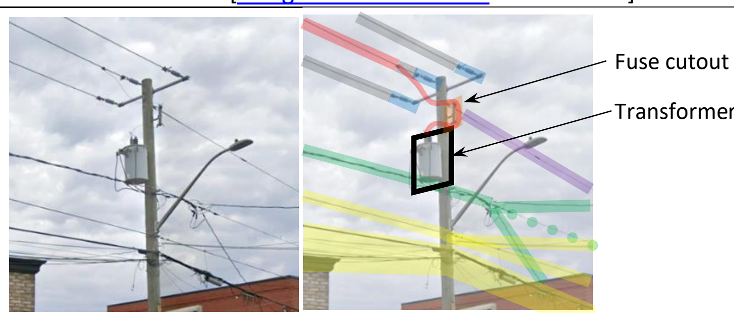
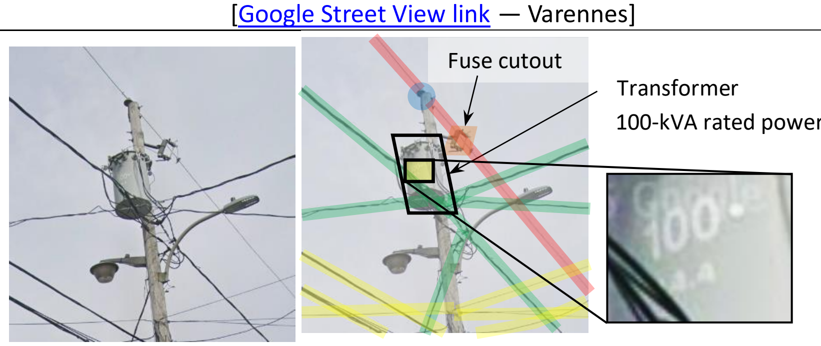
Metadata

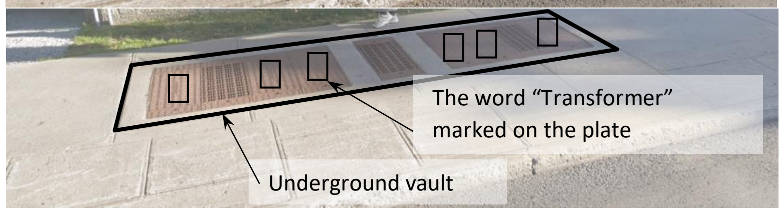
- Position: Equipment coordinates
- Phases: Integer value ranging from 1 to 3
- Rated power (kVA)
- Asset number
- Mounting: Pad, pole, or underground vault
- Upstream node identification (MV side)
- Connection to upstream node (MV side)
- Downstream node identification (LV side)
- Connection to downstream node (LV side)

Note: The width is not an important parameter for the transformer, as it can be derived from the other metadata.

Examples

Note: The metadata omitted from each of these examples cannot be determined from the field survey data.

Metadata	Images
– Asset number = TSS6926 – Mounting = pad	 [Google Street View link — Varennes]
– Three single-phase transformers – LV configuration = wye – Rated power = 167 kVA – Mounting = pole	 [Google Street View link — Varennes]
– Mounting = pole	 [Google Street View link — Varennes]
– Rated power = 100 kVA – Mounting = pole	 [Google Street View link — Varennes]

Metadata	Images
− Mounting = underground vault	  [Google Street View link — Montréal]
− Phases = 3 − Mounting = pole	 [Google Street View link — Ottawa]

Counterexamples

Images	Explanatory Notes
	This is most likely a pad-mounted telecommunications enclosure. There is no electricity distributor’s logo, and its depth is relatively shallow for a pad-mounted transformer. [Google Street View link — Varennes]

Images	Explanatory Notes
	This is most likely a pole-mounted telecommunications enclosure. Wires can be seen connecting the enclosure to the telecommunications lines, and it is located below the height of the telecommunications lines. [Google Street View link — Varennes]
	This is most likely a pole-mounted telecommunications enclosure. Wires can be seen connecting the enclosure to the telecommunications lines, and it is located below the height of the telecommunications lines. [Google Street View link — Varennes]
	These are manhole covers, not underground vaults. Underground vaults are generally larger than manhole covers. [Google Street View link — Montréal]

Capacitor Bank

Capacitor banks are used to regulate the power factor on medium-voltage lines. They are generally installed in rural areas, along long distribution lines. They can often be identified by the capacitors' rectangular shape.

A capacitor bank can be identified by the following characteristics:

- A generally rectangular shape
- Installation typically at the top of a pole, between the MV and LV lines
- A fused cutout associated with each phase, located immediately above

- A single connection to the MV line per phase (an essential visual criterion for distinguishing capacitor banks from regulators)

Capacitor banks can be three-phase or single-phase. On three-phase networks, capacitors can be connected in a delta (Δ) or wye (Y) configuration. As with transformers, the type of configuration is not documented directly but is apparent from the connection to the upstream node.

Each capacitor bank has a rated power expressed in kilovolt-amperes reactive (kVAr), generally ranging from 50 to 600 kVAr [5], and may have one of the values listed in Table 2. The rated power is usually printed on the capacitor bank.

A remotely controlled version is also available, in which the capacitors are accompanied by a small cylindrical transformer and a control enclosure. These devices allow the rated power of the capacitor bank to be adjusted to achieve the desired power factor. Without these devices, the rated power of the capacitor bank is fixed.

Each capacitor bank is generally equipped with cutouts (one per phase) located on the medium-voltage (MV) conductors immediately upstream of the equipment. Remotely controlled capacitor banks have a fourth cutout that supplies power to the small cylindrical transformer.

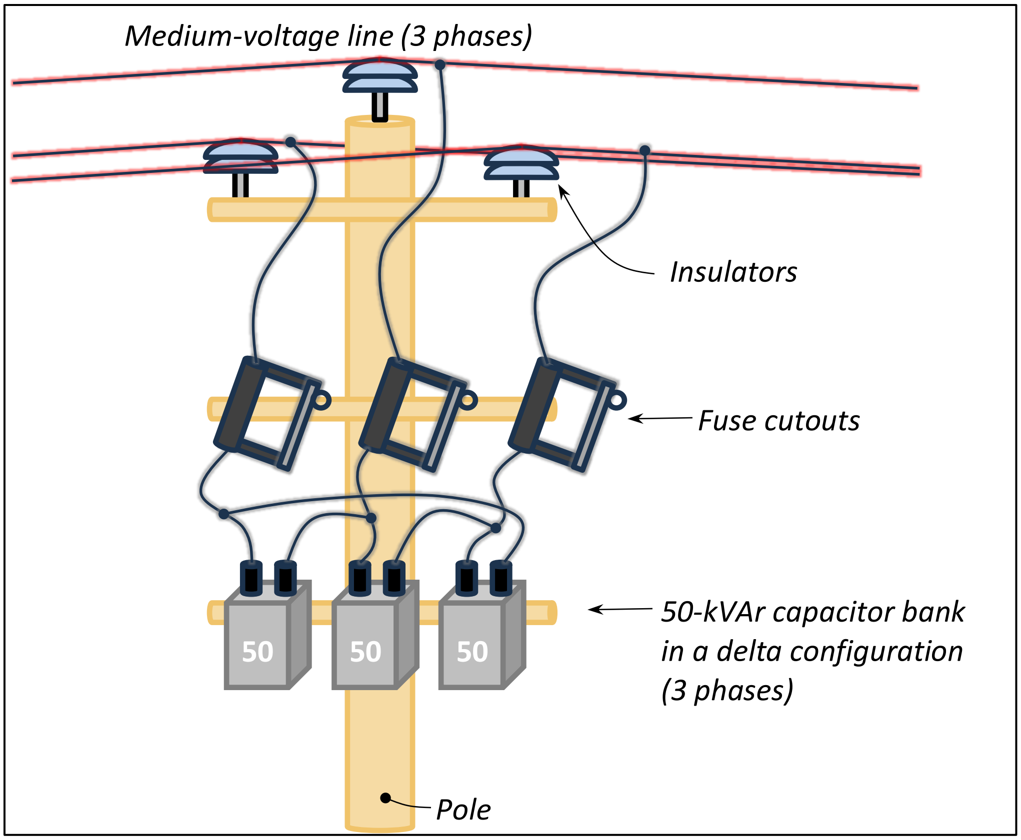


Figure 11 – Diagram of a Capacitor Bank in a Delta Configuration

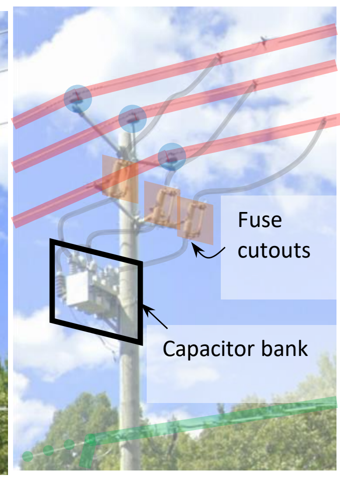
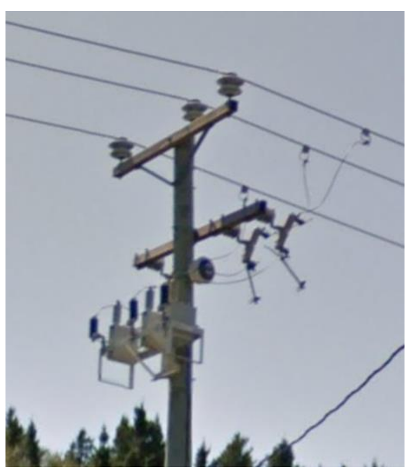
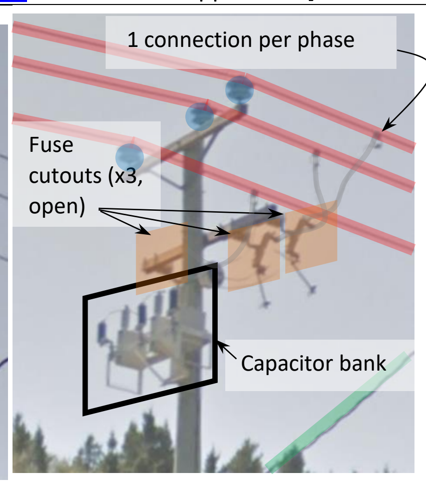
Metadata

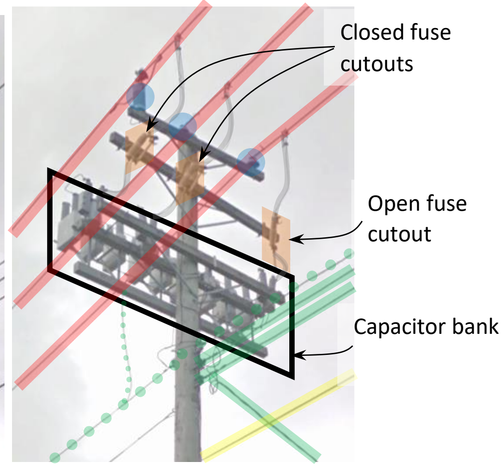
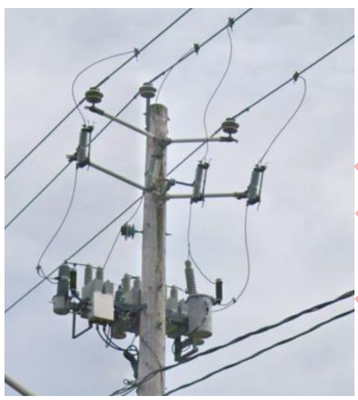
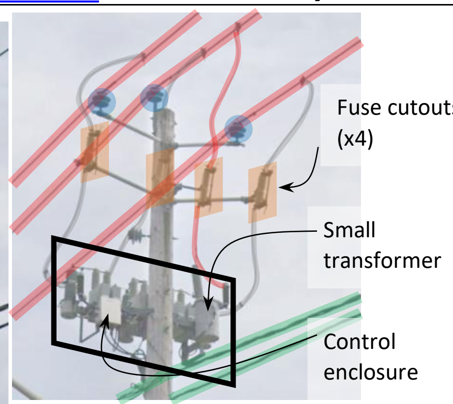
- Position: Equipment coordinates
- Phases: Integer value ranging from 1 to 3
- Width: Number of capacitor banks (integer value greater than or equal to the number of phases)
- Rated power (kVAr)
- Asset number
- Remote-controlled: if control devices are present and enable the equipment to be operated remotely
- Identification of the upstream connected node
- Connection to the upstream connected node

Note that the fourth connection for a remotely controlled capacitor bank is disregarded when connecting to the node.

Examples

Note: The metadata omitted from each of these examples cannot be determined from the field survey data.

Metadata	Images
− Phases = 3 − Width = 3 − With fuse cutouts (closed) − Remote-controlled = No	  [Google Street View link — Chaudière-Appalaches]
− Phases = 3 − Width = 3 − With fuse cutouts (open) − Remote-controlled = No	  [Google Street View link — Gaspésie]

Metadata	Images
– Phases = 3 – Width = 3 – With fuse cutouts (closed, closed, open) – Remote-controlled = No	  [Google Street View link — British Columbia]
– Phases = 3 – Width = 4 – With 4 fuse cutouts (closed), with the third one from the left supplying the transformer – Remote-controlled = Yes	  [Google Street View link — Varennes]
Other examples (all remote-controlled)	[Google Street View link — Montréal] [Google Street View link — Laurentian Mountains] [Google Street View link — Montréal] [Google Street View link — Montréal] [Google Street View link — Montréal]

Voltage Regulator

Voltage regulators are used to maintain the network's voltage within an appropriate range, particularly in rural areas where lines are long and subject to significant voltage variations.

A voltage regulator can be identified by the following features:

- a large enclosure, generally cylindrical
- a position typically between two sections of medium-voltage lines

- a large number of insulators, often more than on a capacitor bank
- two connection points to the medium-voltage line, one upstream and one downstream, separated by an insulator (this double connection point is a key feature)
- fuse cutouts, typically three per phase, at least one of which is open

Voltage regulators are generally found in groups of three single-phase regulators. Each voltage regulator has a rated current in amperes (A), corresponding to one of the standard values listed in Table 3 [6]. The rated current is generally printed on the voltage regulator. Standard values vary depending on the line voltage, so it is often possible to narrow down the list of possible values by considering only the voltages that can be found in the area. There are standard values in kilovolt-amperes (kVA) for three-phase regulators, but they are less common.

Table 3 – Preferred Rated Values in Amperes for Single-Phase Voltage Regulators [6]

	Phase-to-Ground Rated Voltage						
Rated Current (A)	2.5 kV	5.0 kV	7.62 kV	13.8 kV	14.4 kV	19.92 kV	34.5 kV
50			✓	✓	✓	✓	✓
75			✓				
100		✓	✓	✓	✓	✓	✓
150		✓	✓	✓			✓
167						✓	
200	✓	✓		✓	✓		✓
201						✓	
219			✓				
231					✓		
250		✓					
300	✓			✓	✓		
328			✓				
334		✓				✓	
400	✓			✓	✓		
418						✓	
438			✓				

	Phase-to-Ground Rated Voltage						
Rated Current (A)	2.5 kV	5.0 kV	7.62 kV	13.8 kV	14.4 kV	19.92 kV	34.5 kV
463					✓		
483				✓			
500	✓	✓					
502						✓	
546			✓				
578					✓		
604				✓			
656			✓				
668	✓	✓					
694					✓		
725				✓			
833		✓					
875			✓				
1,000	✓						
1,093			✓				
1,312			✓				
1,332	✓						
1,665	✓						

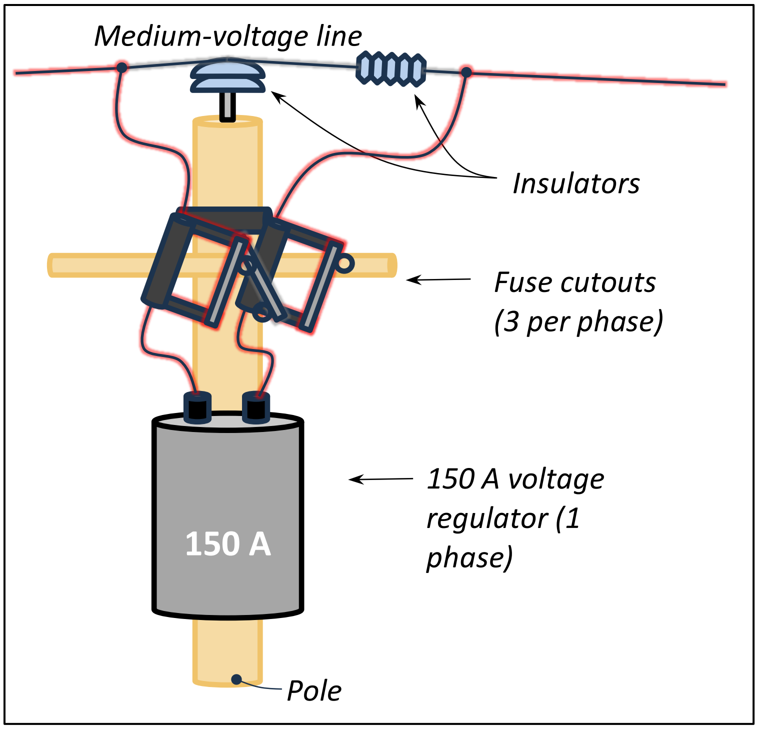


Figure 12 – Diagram of a Single-Phase Voltage Regulator

Fuse cutouts can have two possible configurations: normal and bypass.

- Normal: Two cutouts, upstream and downstream, are closed and supply power to the voltage regulator. The bypass cutout is open, as shown in Figure 13. This is the most common configuration.
- Bypass: The state of the cutouts is reversed compared with the normal configuration. The voltage regulator is not energized, and current flows directly from one line to the other without regulation, as shown in Figure 14. This configuration is relatively uncommon and is used when voltage regulators are faulty or undergoing maintenance.

It is important to note that, in Figure 13 and Figure 14, the designations upstream line and downstream line are arbitrary.

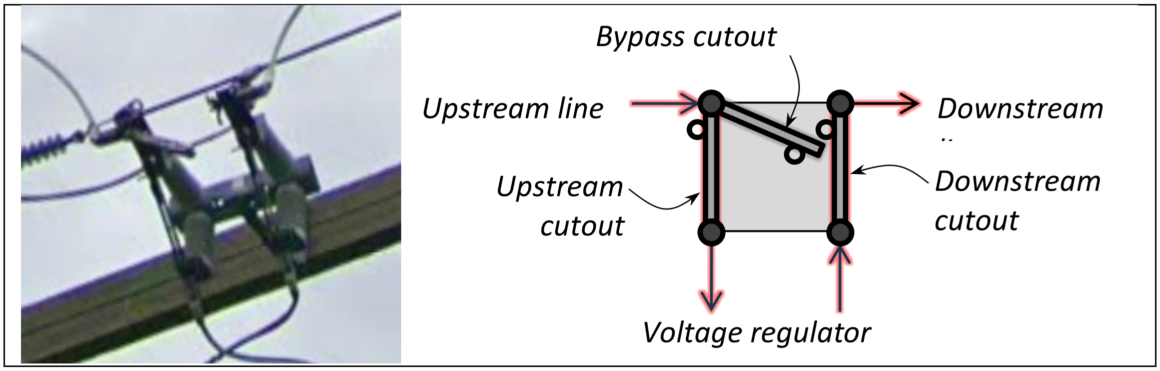


Figure 13 – Normal Cutout Configuration

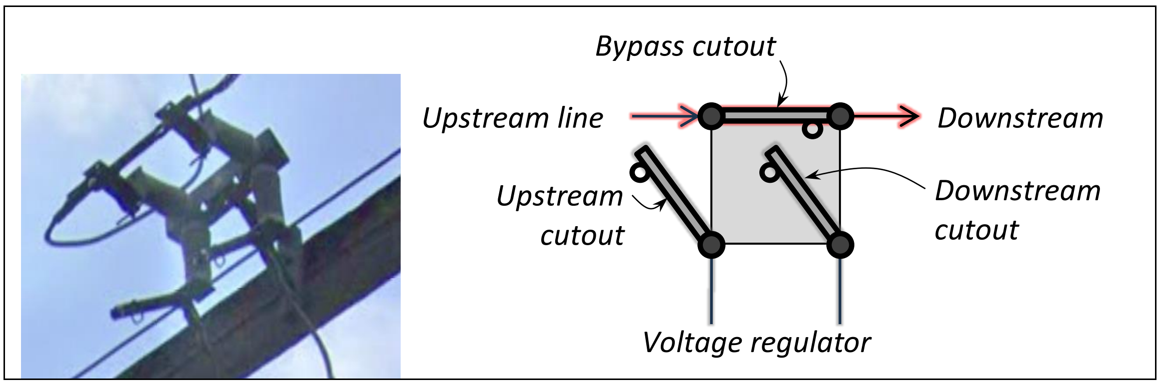


Figure 14 – Bypass Cutout Configuration

It is possible to find voltage regulators that are not equipped with fuse cutouts identical to those shown in Figure 13 and Figure 14. Instead, the cutouts may be positioned remotely on upstream and downstream poles. Bypass cutouts are therefore absent in this configuration. Example in Lanaudière

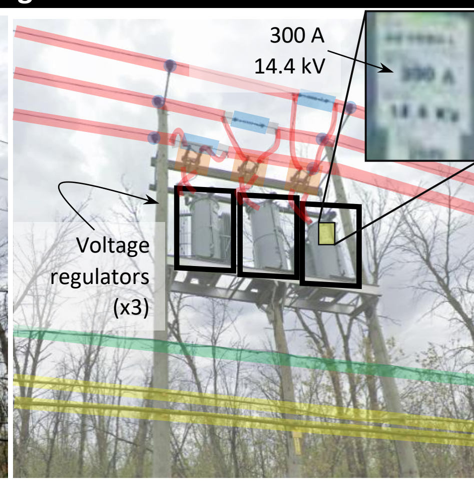
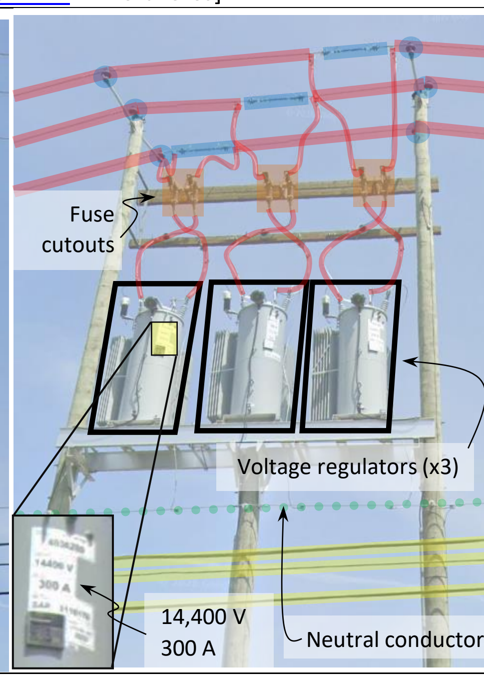
Metadata

- Position: Equipment coordinates
- Phases: Integer value ranging from 1 to 3
- Width: Integer value greater than or equal to the number of phases
- Rated value (A)
- Asset number
- Identification of upstream node

- Connection to upstream node
- Identification of downstream node
- Connection to downstream node

Examples

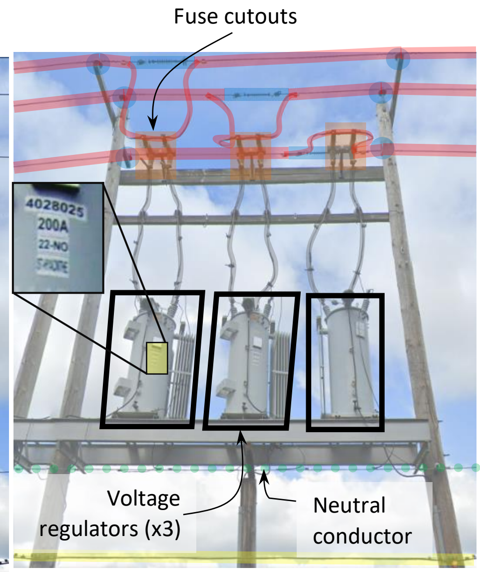
Note: The metadata omitted from each of these examples cannot be determined from the field survey data.

Metadata	Images	
– Phases = 3 – Width = 3 – Rated current = 300 A – With fuse cutouts, normal config.		
	[Google Street View link — Verchères]	
– Phases = 3 – Width = 3 – Rated current = 300 A – With fuse cutouts, normal config.		

<table>
<tr><th>Metadata</th><th>Images</th></tr>
<tr><td colspan="2">[Google Street View link — Montérégie]</td></tr>
<tr><td>

Phases = 3
Width = 3
With fuse cutouts, bypass config.
Rated current = 200 A
Asset number = [4026025, 4028026, unknown]

</td><td>

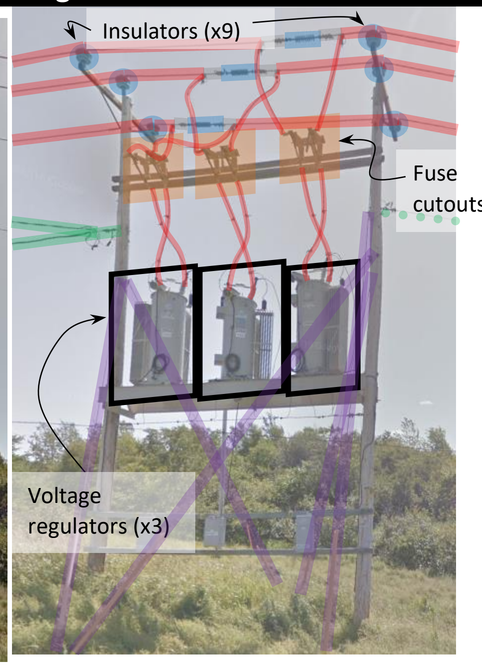
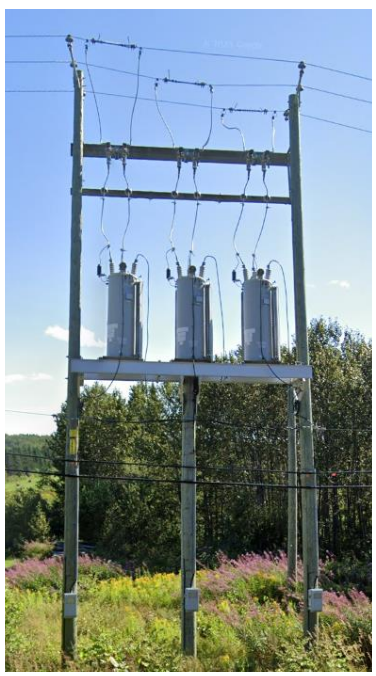
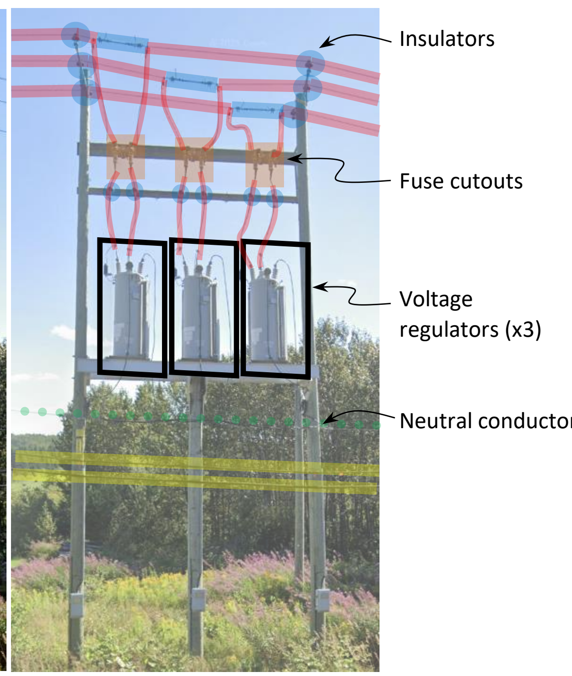


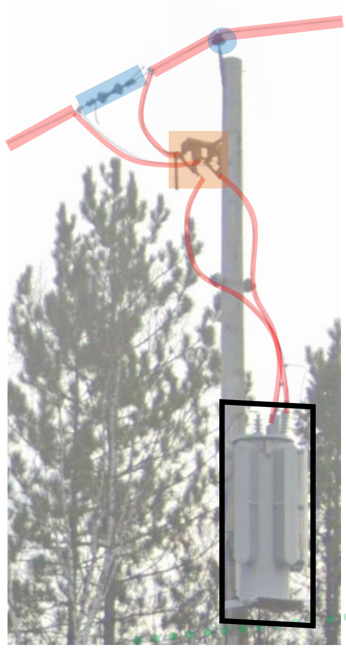
[Google Street View link — Montérégie]
</td></tr>
<tr><td>

Phases = 3
Width = 3
With fuse cutouts, normal config.

</td><td>

[Google Street View link — Laurentian Mountains]
</td></tr>
</table>

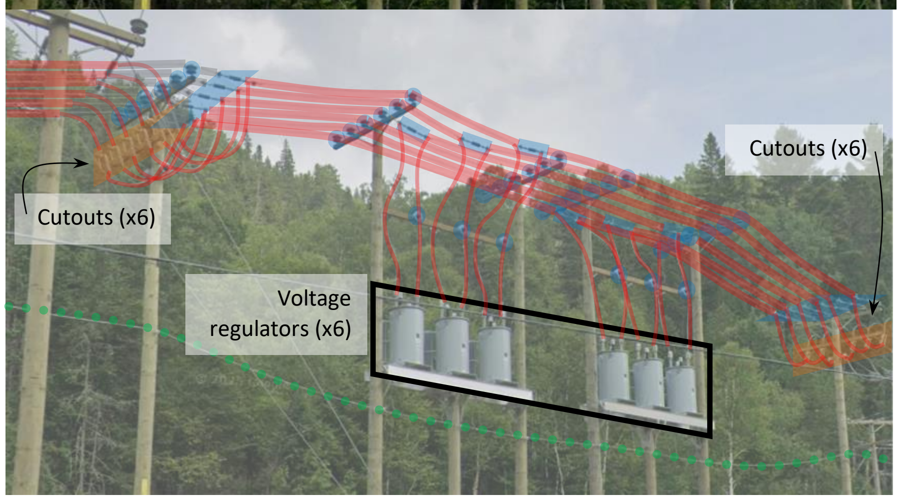
Metadata	Images
- Phases = 3 - Width = 3 - With fuse cutouts, normal config.	  [Google Street View link — Gaspésie]
- Phases = 3 - Width = 3 - With fuse cutouts, normal config.	  [Google Street View link — Gaspésie]

Metadata	Images
− Phases = 1 − Width = 1 − With fuse cutouts, normal config.	  [Google Street View link — Outaouais]

<table>
<tr><th>Metadata</th><th>Images</th></tr>
<tr><td>

- Phases = 3
- Width = 6
- With fuse cutouts (remote)

</td><td>



[Google Street View link — Lanaudière]

</td></tr>
<tr><td>Other examples</td><td>[Google Street View link — Lanaudière]
[Google Street View link — Lanaudière]
[Google Street View link — Lanaudière]
[Google Street View link — Saguenay]</td></tr>
</table>

Overhead-Underground Transition

An overhead-underground transition is the location where medium-voltage lines enter or emerge from the ground, generally near a pole equipped with a concrete base.

These installations are typically found in areas where MV lines transition to underground lines, such as commercial or historic areas, or in locations where overhead wires are not permitted or desired.

The number of phases generally corresponds to the number of wires entering or emerging from the ground. A fuse cutout is typically installed with each overhead-underground transition.

The following components are almost always installed with overhead-underground transitions:

- Cutouts (often 1 per phase, sometimes 2)
- Insulators on the overhead section of the line
- Metal or sheathed conduits extending to the ground
- A visible transition structure at the base of the pole

⚠ Note that only overhead-underground transitionsassociated with medium-voltage lines are of interest for electrical distribution network modelling, not overhead-underground transitions associated with low-voltage lines.

ℹ Sometimes, the number of overhead-underground transitions (i.e., the number of conductors) differs from the number of fuse cutouts, or even from the number of phases.

ℹ Sometimes, there is a disconnecting switch instead of fuse cutouts. Example in Montréal

ℹ Sometimes, the cutouts are located on a different pole from the one where the overhead-underground transition is located. Example in Montréal

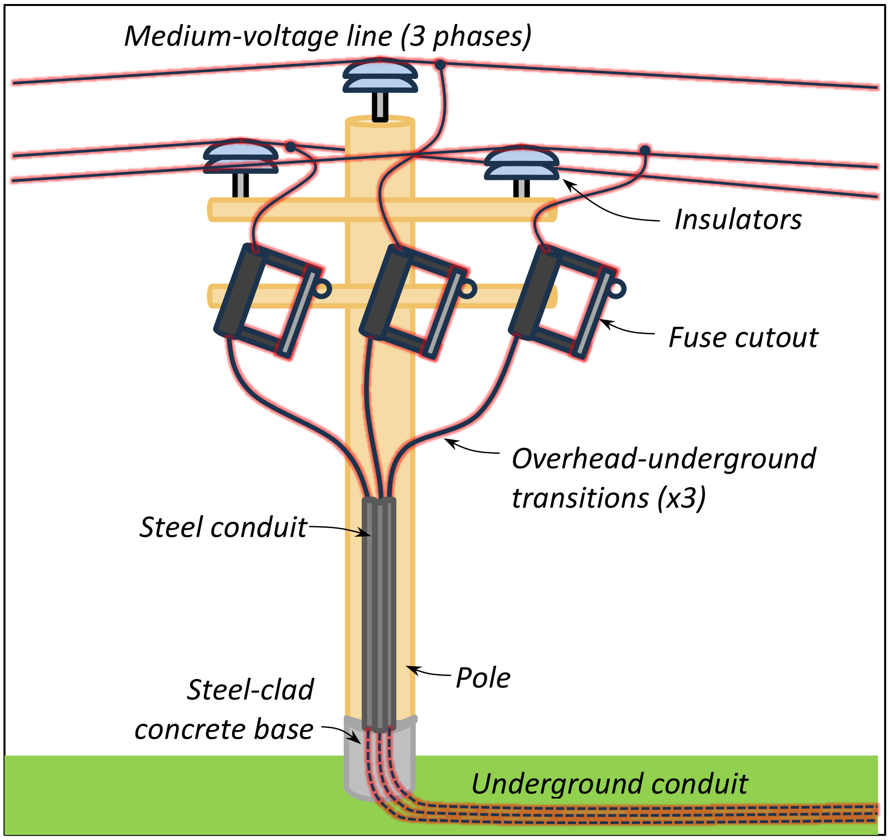


Figure 15 – Diagram of a Three-Phase Overhead-Underground Transition

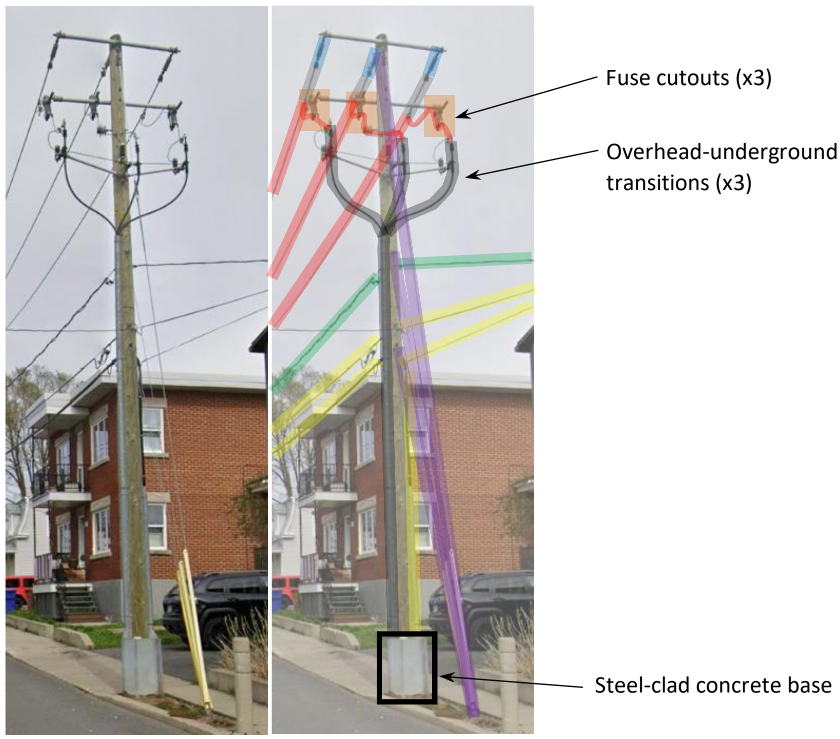
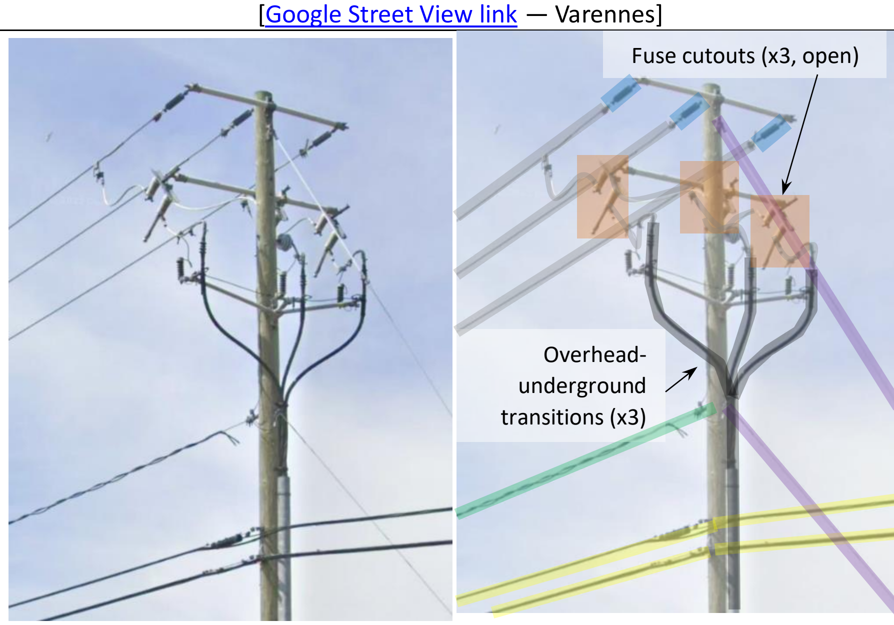
Metadata

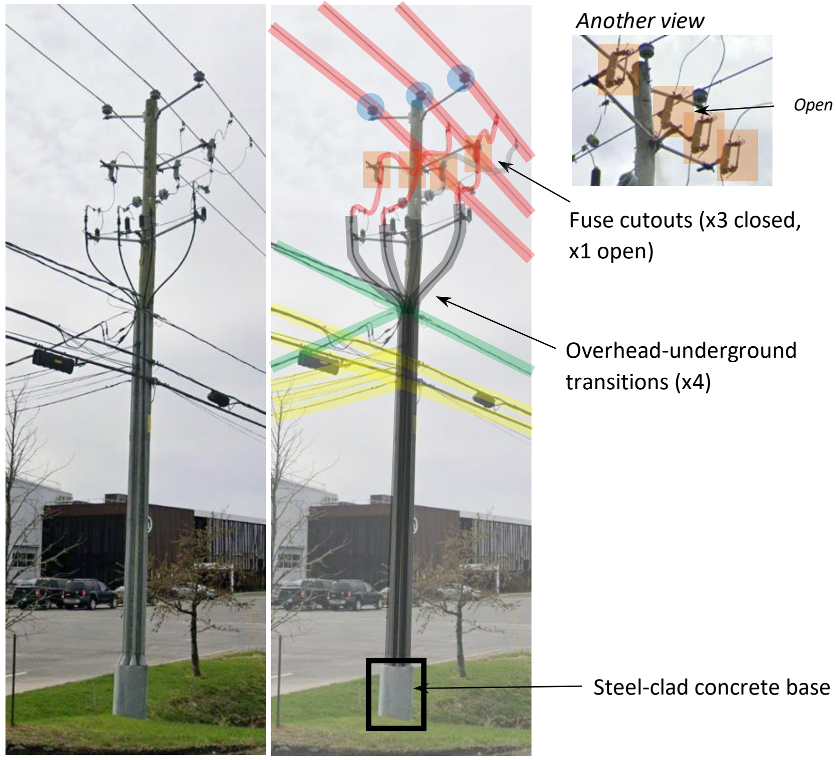
- Position: Equipment coordinates
- Phases: Integer value ranging from 1 to 3
- Width: Number of the conductors entering the ground, integer value greater than or equal to the number of phases
- Identification of the upstream node
- Connection to the upstream node

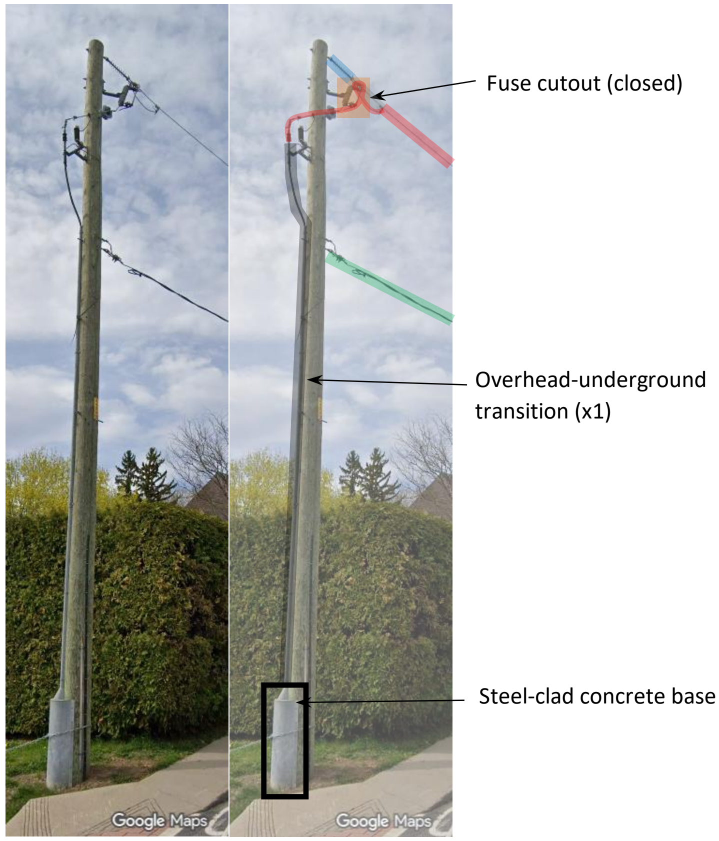
Note: Even if a downstream node of the overhead-underground transition actually exists, it is omitted from this document because it is underground and does not appear in surface surveys.

Examples

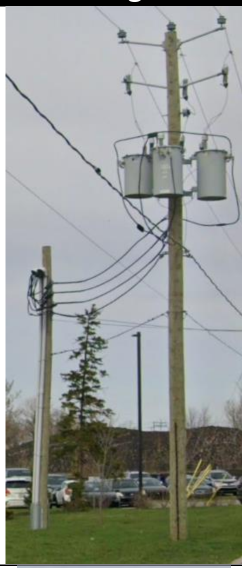
Note: The metadata omitted from each of these examples cannot be determined from the field data survey.

Metadata	Images
– Phases = 3 – Width = 3 – With fuse cutouts (closed)	 [Google Street View link — Varennes]
– Phases = 3 – Width = 3 – With fuse cutouts (open)	 [Google Street View link — Varennes]

Metadata	Images
– Phases = 3 – Width = 4 – With fuse cutouts (3 closed, 1 open)	 [Google Street View link — Varennes]
– Phases = 3 – Width = 4 – With fuse cutouts (closed)	 [Google Street View link — Varennes]

Metadata	Images
– Phase = 1 – Width = 1 – With a fuse cutout (closed)	 [Google Street View link — Varennes]

Counterexamples

Images	Explanatory Notes
	The overhead-underground transition on the pole on the left is connected to the low-voltage lines (i.e., *downstream* of the transformers). Although this is technically an overhead-underground transition, it is not relevant to electrical distribution network modelling. [Google Street View link — Varennes]
	The conduits on the pole are connected to the telecommunications lines and a telecommunications enclosure. This is an overhead-underground transition used by a telecommunications provider and is not relevant to electric distribution network modelling. [Google Street View link — Varennes]

Automatic Circuit Recloser

Automatic circuit reclosers are protective devices used to open the circuit in the event of a fault on a medium-voltage line and then automatically reclose the circuit after a short delay. Their purpose is to restore power more quickly when a fault is temporary.

Automatic circuit reclosers:

- are typically installed on the pole at the MV line level;
- appear as cylindrical or rectangular modules, often grouped together (one module per phase); and
- are accompanied by fuse cutouts, three per phase.

The fuse cutouts are configured in the same manner as those for the voltage regulator.

Metadata

- Position: Equipment coordinates
- Phases: Integer value ranging from 1 to 3
- Width: Number of reclosers (integer value greater than or equal to the number of phases)
- Asset number
- Identification of upstream node
- Connection to upstream node
- Identification of downstream node
- Connection to downstream node

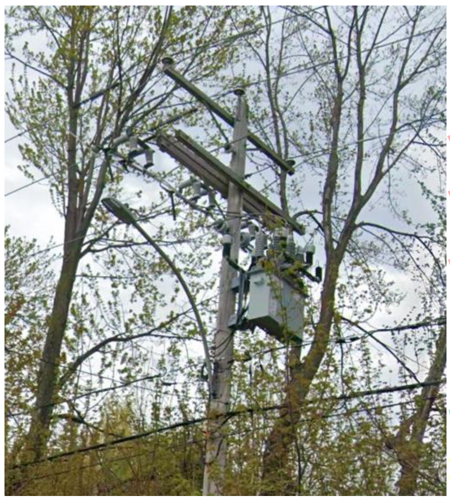
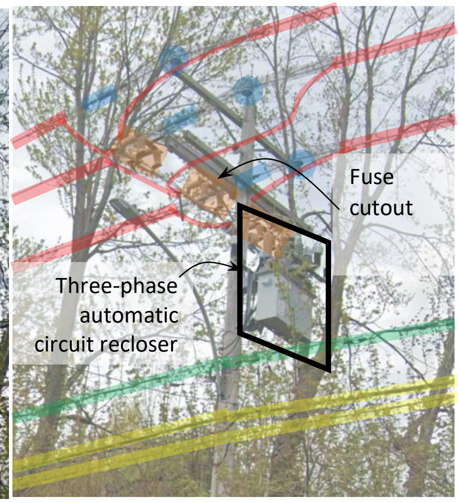
Examples

Note: The metadata omitted from each of these examples cannot be determined from the field survey data.

<table>
<tr><th>Metadata</th><th>Images</th></tr>
<tr><td>

- Phases = 3
- Width = 3
- With fuse cutouts, normal config.

</td><td>

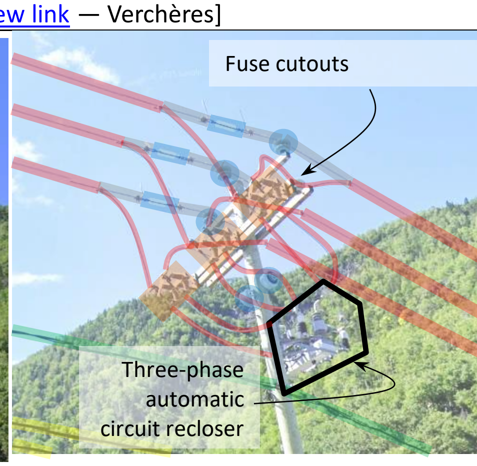



[Google Street View link — Verchères]

</td></tr>
<tr><td>

- Phases = 3
- Width = 3
- With fuse cutouts, normal config.

</td><td>

[Google Street View link — Gaspésie]

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- Phases = 3
- Width = 3
- With fuse cutouts, normal config.

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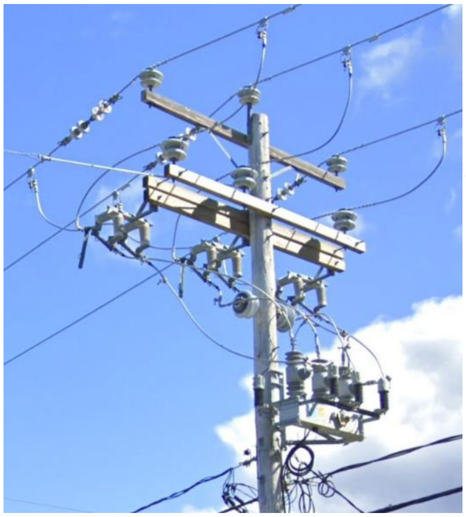
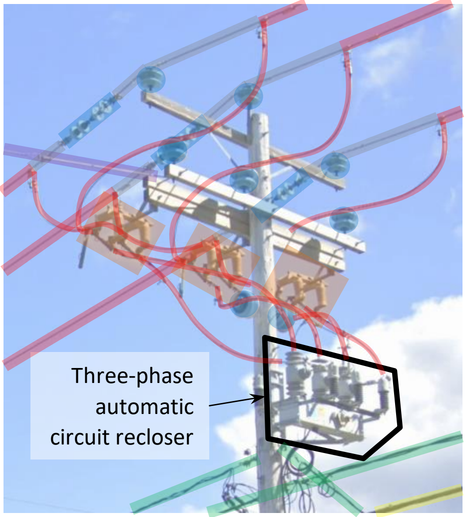

[Google Street View link — Gaspésie]
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[Google Street View link — Chaudière-Appalaches]
</td></tr>
</table>

Diagram of the Distribution Network

In the context of impact studies or the automatic reconstruction of the network from images, it is essential to have a simple and consistent representation of the distribution network and how its equipment is interconnected. Figure 16 illustrates how the pieces of equipment are connected to one another, following the path of the current from the source to the consumers. The network can be represented as an ordered sequence of components, each of which plays a role in protecting, transforming, or distributing power.

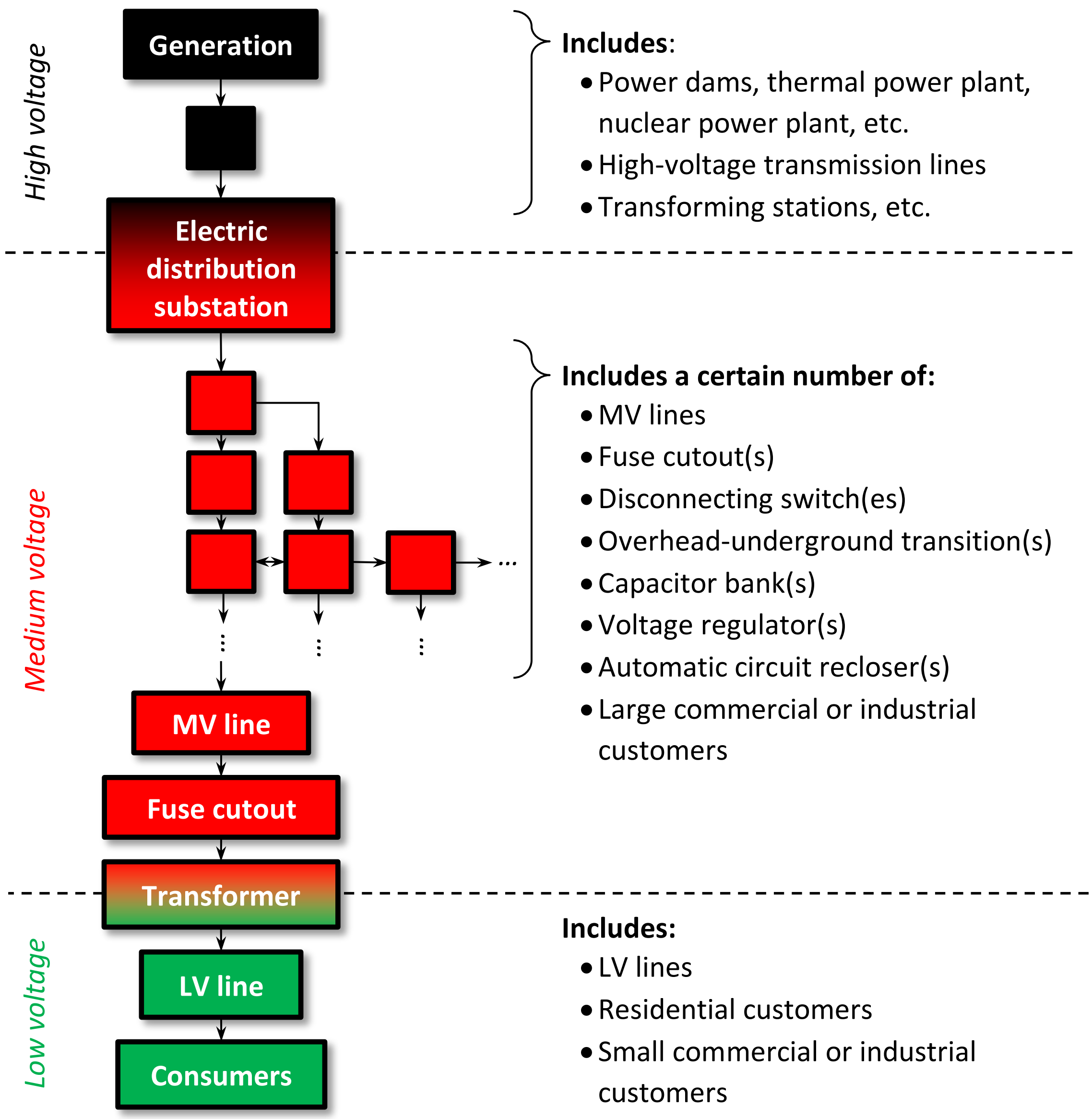


Figure 16 – Simplified Diagram of an Electrical Network

Data Structure

The equipment in the distribution network must be recorded in a database. There are four types of data:

1. Nodes: represent connection points. The electrical term “bus” may also be used.

2. Equipment connecting two nodes: overhead lines, disconnecting switches, fuse cutouts, voltage regulators, pole-mounted transformers, automatic circuit reclosers.

3. Equipment connected to a single node: capacitor banks, overhead-underground transitions.

4. Equipment not connected to any nodes: pad-mounted transformers, underground vault transformers.

Each type of equipment (lines, disconnecting switches, capacitor banks, etc.) has its own table, some of which are illustrated in Figure 17. The node identifier is referenced in the other tables to represent the relationships between the equipment.

⚠ Note that overhead-underground transitions are connected to two nodes: one overhead node and one underground node. However, since the underground portion is not visible in the survey data, overhead-underground transitions are considered to be connected to only one node (overhead).

⚠ Since pad-mounted transformers and underground vault transformers are connected to two underground nodes that are not visible in the survey data, they are considered not to be connected to any nodes.

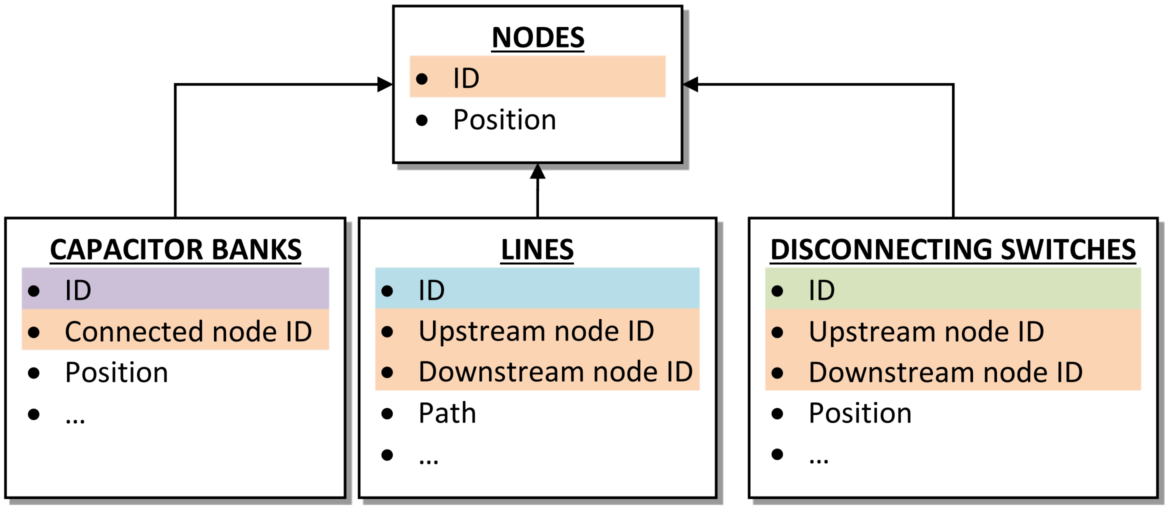


Figure 17 – Examples of Relationships Between Equipment

Node Table

Nodes correspond to the connection points between the equipment. All subsequent equipment is connected to these nodes. Since several of these equipment types are point features, multiple nodes may have the same geographic location.

Table 4 – Fields in the Node Table

FIELD	TYPE	DESCRIPTION
ID	Incremental integer	Unique node identifier
Position	Coordinate	Node coordinates (latitude and longitude)

Tables for Equipment Connecting Two Nodes

For each type of equipment connecting two nodes, reference is made to the upstream and downstream nodes. By convention, electrical power flows from the upstream node (source) to the downstream node (load). There is one table for each type of equipment (i.e., one table for disconnecting switches, one table for lines, etc.).

Table 5 – Fields Common to Tables for Equipment Connecting Two Nodes

FIELD	TYPE	DESCRIPTION
ID	Incremental integer	Unique equipment identifier
Position	Coordinate	Equipment coordinates (latitude and longitude)

Field	Type	Description
Width	Integer	Number of elements (e.g., number of conductors, number of cutouts, etc.)
Upstream node ID	Integer	Reference to the identifier of the node connected upstream of the equipment
Connection to upstream node	Integer array	Configuration of the connection to the upstream node. For example, for a three-phase line, [4,6,5] means that: – the 1st conductor of the line is connected to the 4th element of the upstream node; – the 2nd conductor of the line is connected to the 6th element of the upstream node; – the 3rd conductor of the line is connected to the 5th element of the upstream node.
Downstream ID node	Integer	Reference to the identifier of the node connected downstream of the equipment
Connection to downstream node	Integer array	Configuration of the connection to the downstream node. For example, for a three-phase disconnecting switch, [3,1,2] means that: – the 1st disconnecting switch is connected to the 3rd element of the downstream node; – the 2nd disconnecting switch is connected to the 1st element of the downstream node; – the 3rd disconnecting switch is connected to the 2nd element of the downstream node.
Other equipment-specific metadata	…	See Table 1

There is no single prescribed way to record the configurations in the “Connection” fields, provided that all elements connected to the same node are consistent.

The number of elements in the upstream and downstream connections must correspond to the “Width” field.

The upstream and downstream nodes may be one and the same in certain situations (see disconnecting switch example below). In this situation, the “Connection” fields must not contain duplicate elements.

The presence of an insulator on a line means that the segment on one side is not electrically continuous with the segment on the other side. Therefore, a distinct node is located on each side of the insulator.

In low-voltage systems, the neutral conductor is implicit and does not need to be considered in the connection.

In the case of low-voltage lines where the conductors are twisted, it becomes very difficult to identify them. It is therefore assumed that all conductors are present in the standard order (i.e., [1,2,3] for three-phase and [1,2] for single phase).

An item of equipment may be present but not connected to any node. This may be due to a temporary situation pending work, or to equipment that will soon be removed.

Example of a disconnecting switch in Montérégie

Tables for Equipment Connected to a Single Node

For each piece of equipment connected to a single node, reference is made to the connected node. There is one table for each type of equipment (i.e., one table for overhead-underground transitions and one table for capacitor banks).

Table 6 – Fields Common to Tables for Equipment Connected to a Single Node

FIELD	TYPE	DESCRIPTION
ID	Incremental integer	Unique equipment identifier
Position	Coordinates	Equipment coordinates (latitude and longitude)
Width	Integer	Number of elements (e.g., number of capacitors, number of entries, etc.)
Connected node ID	Integer	Reference to the identifier of the node connected to the equipment
Connection to node	Integer array	Configuration of the connection to the node. For example, for an overhead-underground transition, [1,3,2] means that: – the 1st entry is connected to the 1st element of the node;

FIELD	TYPE	DESCRIPTION
		– the 2nd entry is connected to the 3rd element of the node; – the 3rd entry is connected to the 2nd element of the node.
Other equipment-specific metadata	…	See Table 1

The number of elements in “Connection to node” must correspond to the “Width” field.

Tables for Equipment Not Connected to Any Nodes

These tables are intended for equipment for which it is not possible to determine the nodes to which it is connected. There is one table for each type of equipment. Only pad-mounted and underground-vault transformers are described in this document and may be included in the same table.

Table 7 – Fields Common to Tables for Equipment Not Connected to Any Nodes

FIELD	TYPE	DESCRIPTION
ID	Incremental integer	Unique equipment identifier
Position	Coordinates	Equipment coordinates (latitude and longitude)
Other equipment-specific metadata	…	See Table 1

Examples

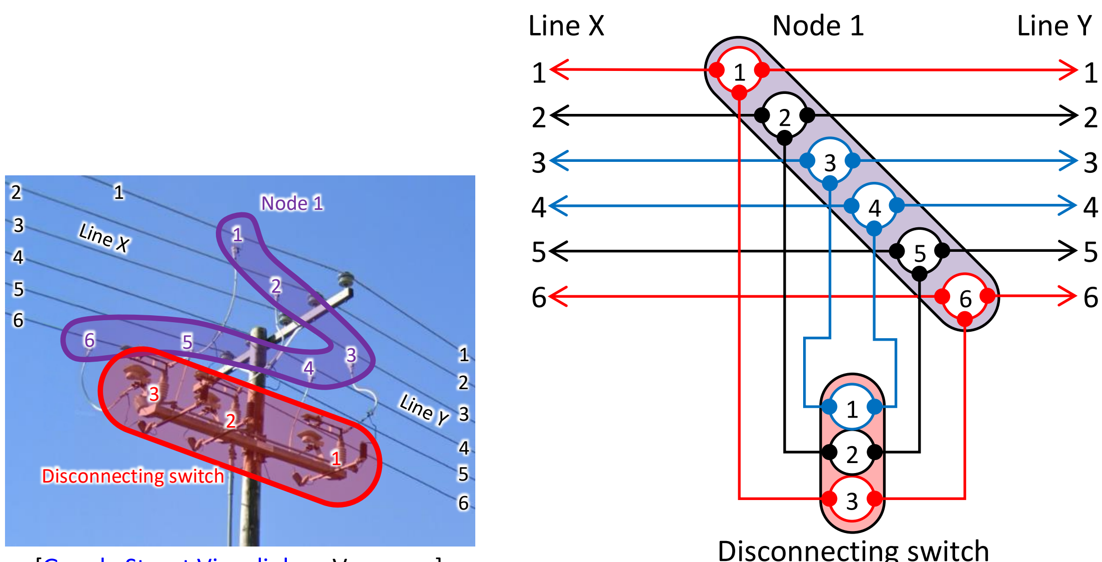
Examples illustrating certain cases are described in this section. Each example includes:

1. an annotated image of the equipment, including connection numbering;
2. a graph representing the connections between the various pieces of equipment; and
3. a table providing the upstream and downstream node information for each piece of equipment.

In these tables, "N.A." (not available) indicates that the upstream or downstream node is not shown in the image and is located somewhat farther away, whereas "N/A" (not applicable) indicates that the node in question does not exist.

Disconnecting Switch

The case described in this example involves a single node. The upstream and downstream nodes of the switch are one and the same.



[Google Street View link — Varennes]

Figure 18 – Example of the Connectivity Around a Disconnecting Switch

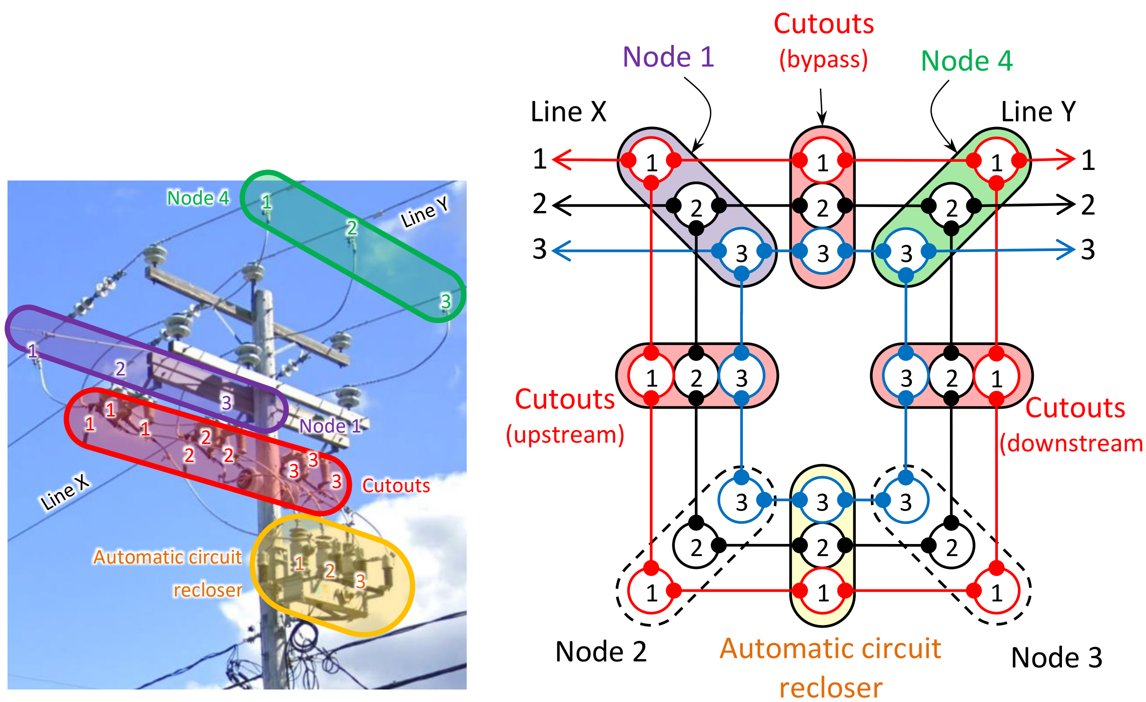
Table 8 – Example of the Data Structure for a Disconnecting Switch

	Line X	Line Y	Disconnecting Switch
Width	6	6	3
Upstream node ID	N.A.	1	1
Connection to upstream node	N.A.	[1, 2, 3, 4, 5, 6]	[3, 2, 1]
Downstream node ID	1	N.A.	1
Connection to downstream node	[1, 2, 3, 4, 5, 6]	N.A.	[4, 5, 6]

Automatic Circuit Reclosers and Voltage Regulators

In this example, nodes 2 and 3 have been added for the connectivity between the fuse cutouts and the automatic circuit recloser, even though they are not explicitly visible in the image.

It should also be noted that the group of nine fuse cutouts has been divided into three groups: three downstream, three upstream, and 3 three on a bypass connected to the automatic circuit recloser. This separation will also be shown for a voltage regulator.



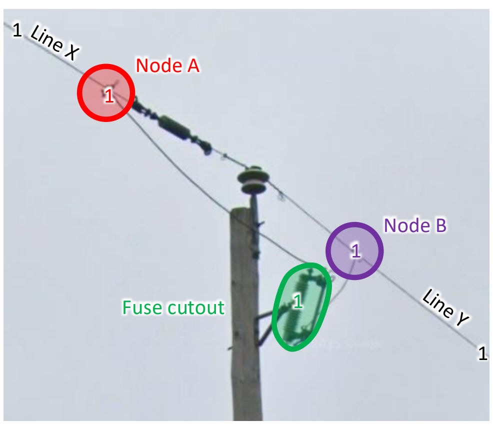
[Google Street View link — Gaspésie]

Figure 19 – Example of the Connectivity Around an Automatic Circuit Recloser

Table 9 – Example of the Data Structure for an Automatic Circuit Recloser

	LINE X	FUSE CUTOUT (UPSTREAM)	AUTOMATIC CIRCUIT RECLOSER	FUSE CUTOUT (DOWNSTREAM)	FUSE CUTOUT (BYPASS)	LINE Y
Width	3	3	3	3	3	3
Upstream node ID	1	1	3	4	1	N.A.
Connection to upstream node	[1, 2, 3]	[1, 2, 3]	[1, 2, 3]	[1, 2, 3]	[1, 2, 3]	N.A.
Downstream node ID	N.A.	2	2	3	4	4
Connection to downstream node	N.A.	[1, 2, 3]	[1, 2, 3]	[1, 2, 3]	[1, 2, 3]	[1, 2, 3]
State (closed, open)	N/A	[C, C, C]	N/A	[C, C, C]	[O, O, O]	N/A

Fuse Cutout



[Google Street View link — Varennes]

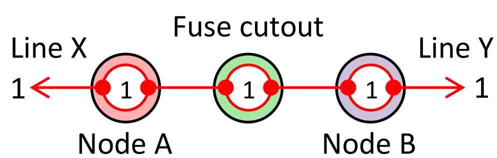


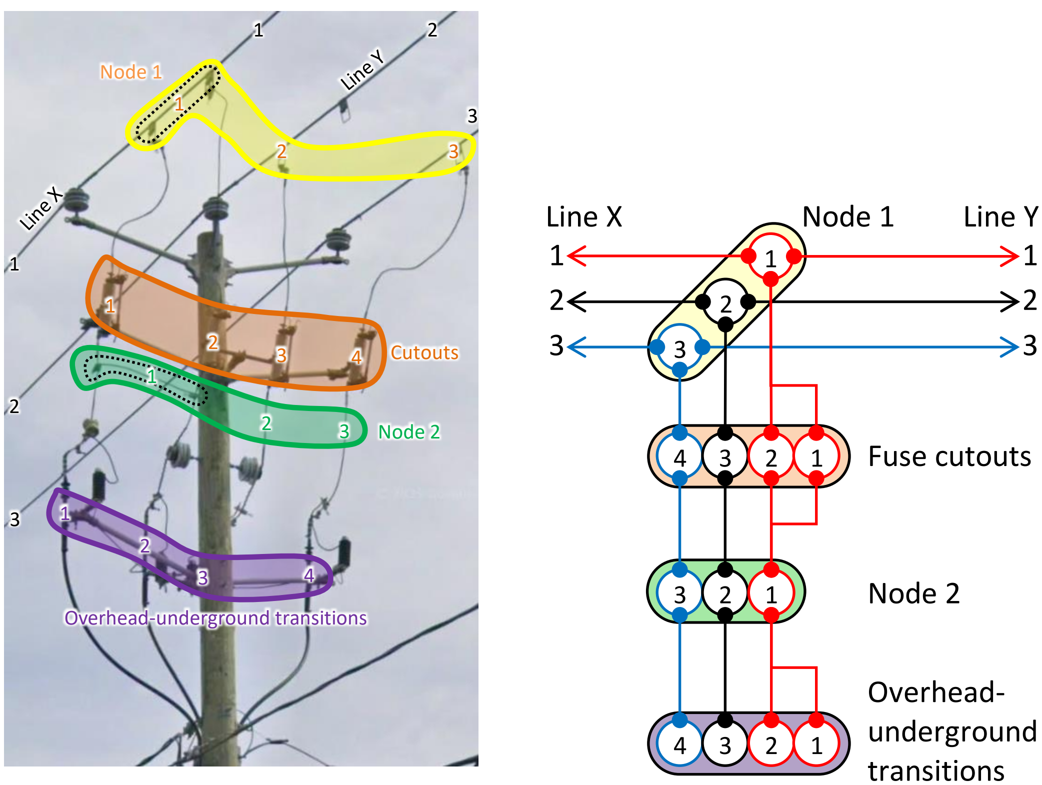
Figure 20 – Example of the Connectivity Around a Fuse Cutout

Table 10 – Example of the Data Structure for a Fuse Cutout

	LINE X	FUSE CUTOUT	LINE Y
Width	1	1	1
Upstream node ID	A	A	N.A.
Connection to upstream node	[1]	[1]	N.A.
Downstream node ID	N.A.	B	B
Connection to downstream node	N.A.	[1]	[1]

Overhead-Underground Transition

This situation is particular because it contains four cutouts and four overhead-underground transitions, with the first two connected to the same conductor upstream of the cutouts, as well as downstream.



[Google Street View link — Varennes]

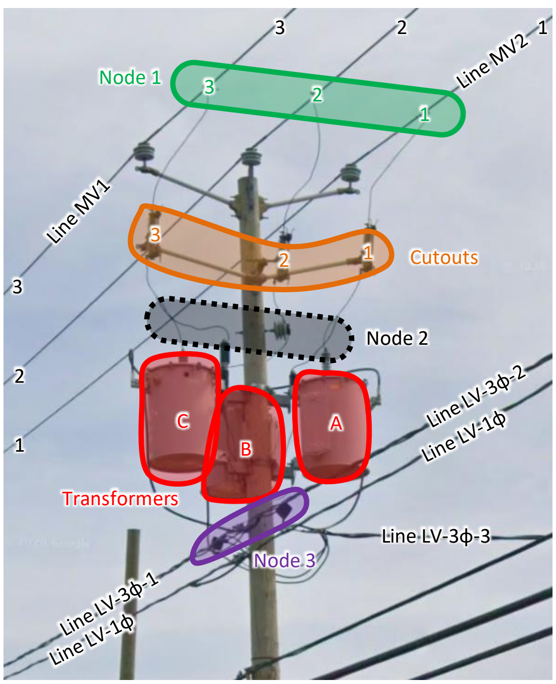
Figure 21 – Example of the Connectivity Around an Overhead-Underground Transition

Table 11 – Example of the Data Structure for an Overhead-Underground Transition

	LINE X	FUSE CUTOUT	OVERHEAD-UNDERGROUND TRANSITION	LINE Y
Width	3	4	4	3
Upstream node ID	1	1	2	N.A.
Connection to upstream node	[1, 2, 3]	[1, 1, 2, 3]	[1, 1, 2, 3]	N.A.
Downstream node ID	N.A.	2	N/A	1
Connection to downstream node	N.A.	[1, 1, 2, 3]	N/A	[1, 2, 3]

Transformers

In this example, there are three single-phase transformers (three-phase mounting) connected in a wye configuration on the LV side, since they are all connected by a common conductor (the neutral conductor). Furthermore, each transformer is connected to a single phase of the MV line. This example combines three-phase (3ϕ) and single-phase (1ϕ) LV lines.



[Google Street View link — Varennes]

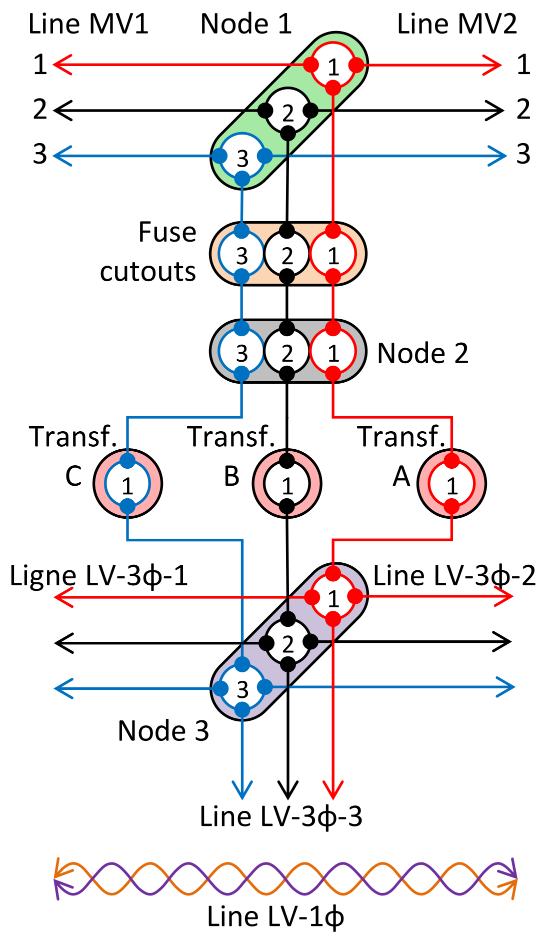


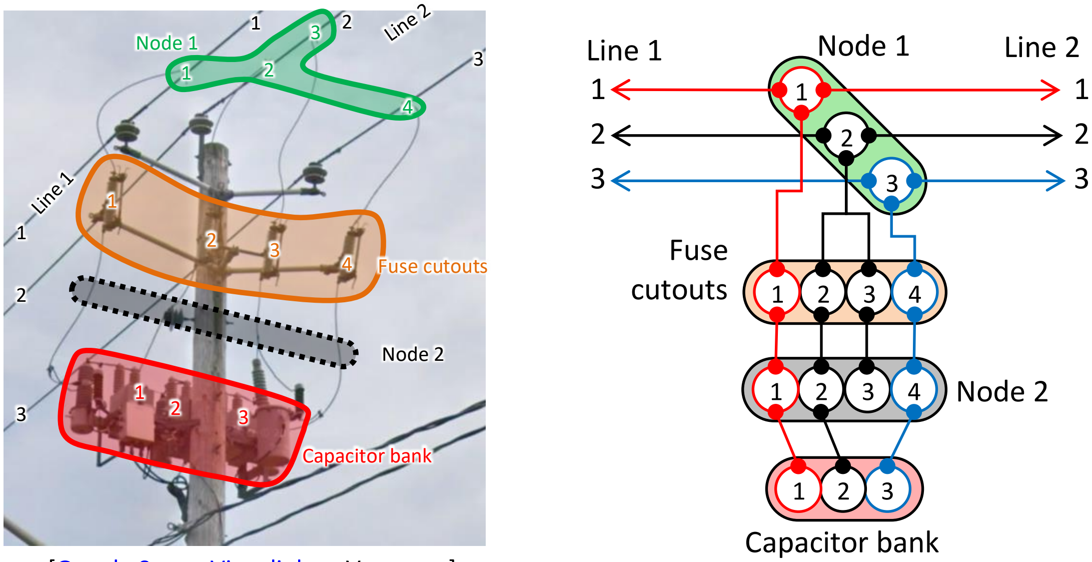
Figure 22 – Example of the Connectivity Around Transformers

Table 12 – Example of the Data Structure for Transformers

	LINE MV1	LINE MV2	FUSE CUTOUT	TRANSFORMER A	TRANSFORMER B	TRANSFORMER C	LINE LV-3Φ-1	LINE LV-3Φ-2	LINE LV-3Φ-3	LINE LV-1Φ
Width	3	3	3	1	1	1	3	3	3	2
Upstream node ID	1	N.A.	1	2	2	2	3	3	3	N.A.
Connection to upstream node	[1,2,3]	N.A.	[1,2,3]	[1]	[2]	[3]	[1,2,3]	[1,2,3]	[1,2,3]	N.A.
Downstream node ID	N.A.	1	2	3	3	3	N.A.	N.A.	N.A.	N.A.
Connection to downstream node	N.A.	[1,2,3]	[1,2,3]	[1]	[2]	[3]	N.A.	N.A.	N.A.	N.A.

Capacitor Bank

The example below describes the connectivity of a remotely controlled capacitor bank. In particular, it can be observed that there are four fuse cutouts, and therefore their width is equal to 4. The bank consists of three capacitors, so its width is equal to 3. The cutout that does not supply any of the capacitors can be identified by its position between the small cylindrical transformer and the medium-voltage (MV) line that has two connections (the middle one in this example).



[Google Street View link — Varennes]

Figure 23 – Example of the Connectivity Around a Remotely Controlled Capacitor Bank

Table 13 – Example of the Data Structure for a Remotely Controlled Capacitor Bank

	LINE 1	LINE 2	FUSE CUTOUT	CAPACITOR BA
Width	3	3	4	3
Upstream node ID	1	N.A.	1	2
Connection to upstream node	[1, 2, 3]	N.A.	[1, 2, 2, 3]	[1, 2, 4]
Downstream node ID	N.A.	1	2	N/A
Connection to downstream node	N.A.	[1, 2, 3]	[1, 2, 3, 4]	N/A

Conclusion

This document provides a structured basis for identifying, characterizing, and modelling electrical distribution network equipment from visual surveys by combining descriptions, metadata, and connectivity relationships. It is intended to support applications such as automated recognition, the development of geospatial databases, and electrical network simulation, in a context that can be adapted to different partners and use cases.

The approach presented emphasizes data consistency and progressive integration. Even when the complete set of metadata cannot be extracted, identifying and locating equipment already provides valuable information. The presence of equipment, even when only partially characterized, makes it possible to progressively enrich the inventory, target field validation activities, and support spatial and topological analyses.

This document aims to improve the accuracy of electrical distribution network models, thereby enhancing their representativeness and enabling the modelling of real-world networks.

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