

Guidelines for the Design, Installation, Operation & Maintenance of Street Lighting Assets

Electrical Safety Authority

Guidelines for the Design, Installation, Operation &

Maintenance of Street Lighting Assets

Contents:

1.0 Introduction
- 1.1 Scope
- 1.2 Summary of Incidents
  - 1.2.1 Background
  - 1.2.2 Sources of Contact Voltage

2.0 Design and Installation:
- 2.1 Components
  - 2.1.1 Conductor / Cable
  - 2.1.2 Connectors
  - 2.1.3 Poles
  - 2.1.4 Brackets
  - 2.1.5 Luminaires
  - 2.1.6 Receptacles – For Seasonal Lighting
  - 2.1.7 Protection and Control
    - 2.1.7.1 Control
    - 2.1.7.2 Protection
  - 2.1.8 Underground Ducting
  - 2.1.9 Handwells
    - 2.1.9.1 Best Practices
    - 2.1.9.2 Recommendations
- 2.2 Seasonal Lighting
  - 2.2.1 Background
- 2.3 Grounding and Bonding
  - 2.3.1 Introduction
  - 2.3.2 Definitions
  - 2.3.3 The general Function of Grounding and Bonding in Power Distribution
  - 2.3.4 The Role of Grounding and Bonding in Street Lighting
  - 2.3.5 How to Achieve Effective Grounding and Bonding for Municipal Street Lighting
    - 2.3.5.1 Which components require Grounding and Bonding?
    - 2.3.5.2 Which Grounding and Bonding materials should be used?
    - 2.3.5.3 Which methods of Grounding are acceptable?
    - 2.3.5.4 What (if any) resistance standard should be determined for grounding?
    - 2.3.5.5 What, how & when do we test the system?
    - 2.3.5.6 How can a ground Systems' resistance be lowered if targets are not obtained?
    - 2.3.5.7 How shall Street Lighting equipment be bonded?
  - 2.3.6 The Impact of Grounding practices on equipment Function
  - 2.3.7 Summary of Essential Minimum Requirements
- 2.4 Voltage Drop
- 2.5 Demarcation Points and Service Entrances
- 2.6 Inspection and Verification
- 2.7 Third Party Attachments and Regulation 22/04
  - 2.7.1 Design
  - 2.7.2 Construction
  - 2.7.3 Third Party Attachments to Street Lighting Plant

3.0 Operation and Maintenance:
- 3.1 Minimum Maintenance Guidelines
  - 3.1.1 General
  - 3.1.2 The Ontario Electrical Safety Code (OESC)
  - 3.1.3 Canadian Standards Association (CSA)

3.1.4 Non-Routine Maintenance
3.1.5 Routine Maintenance
3.1.6 Electrical Power Supply for other Facilities
3.1.7 Routine Maintenance and Inspection Reports
3.1.8 Non-Routine Maintenance and Inspection Reports
3.1.9 Emergency Locates
3.1.10 Outcome Targets
3.2 Typical Lights-out Procedures - Troubleshooting
3.3 Detection and Testing Contact Voltage
3.3.1 Detection of Contact Voltage on Street Lighting Infrastructure
3.3.2 Detection Equipment
3.3.3 Verification and Measurement
3.3.3.1 Identify Suitable ground references
3.3.3.2 Eliminate capacitive coupling and obtain accurate, repeatable measurement
3.3.4 Characterize Contact Voltage Source
3.3.5 Mitigation Steps
3.4 Safe Limits of Approach
3.5 Developing a Contact Voltage Detection Program
3.5.1 Should we develop a contact voltage detection (CVD) program?
3.5.2 What is the most effective way to combat contact voltage Hazards?
3.5.3 How often and extensively should we conduct CVD?
3.5.4 What elements should be developed in a CVD program?
3.5.5 Who will develop and manage the program?
3.5.6 Who should perform contact voltage testing?
3.5.7 What happens when we discover contact voltage?
3.5.8 Summary of Contact Voltage Mitigation Strategies
3.5.9 Conclusion
4.0 Management:
4.1 Pole Testing and Replacement
4.2 Condition Surveys
4.3 Expected Service Life of Roadway Lighting Assets
5.0 Appendices
5.1 Definitions
5.2 References
5.3 Other Documents for Information Purposes

1.0 INTRODUCTION

The Guidelines for the Electrical Design, Installation, Operation, and Maintenance of Street Lighting Assets were created in response to electrical contact incidents experienced throughout Ontario. The ESA invited stakeholders to participate in writing street light asset guidelines. The stakeholders represent street light asset owners, contractors and consultants. The primary purpose of the guideline is to document best practice information from professional practitioners for the safe electrical design, installation, operation and maintenance of roadway lighting systems in Ontario to mitigate electrical hazards to the public and comply within the requirements of the Ontario Electrical Safety Code (OESC).

1.1 SCOPE

The scope of the guideline is inclusive of all roadway illumination equipment on public Rights of Way, including lighting on traffic signal poles. The equipment consists of poles, luminaires, brackets, photocells, lamps, relays, conductors, ducts, handwells, vaults, and associated hardware.

Non roadway illumination on or off Public Rights of Way, and all other illumination equipment not on Public Rights of Way, is not included in this guideline. To further clarify, traffic signals, flashing beacons, lighted pedestrian crossovers, park walkway lighting, parking lot lighting, sports lighting, area lighting and bus shelters are not included in the guideline. Note that the out of scope installations listed in this paragraph may also have contact voltage issues.

1.2 SUMMARY OF INCIDENTS

1.2.1 BACKGROUND

In recent years there has been an increased amount of attention paid to the condition of low voltage electrical distribution systems, including those supplying street lights. This can be attributed to a number of high-profile incidents where members of the public have reported receiving an electric shock after coming in contact with publicly accessible infrastructure. The consequences of these incidents range from pedestrians reporting a “tingling” sensation to cases which have resulted in fatality. Animals are particularly susceptible to such occurrences and there have been numerous cases where pet dogs have been injured or killed after contact with inadvertently energized structures in the public right-of-way. These issues can occur at any time of year, but appear to be more common in the winter months, which can likely be explained by the presence of melting snow and road salt. The media has reported extensively on these incidents resulting in increased awareness by the public, asset owners, utilities and regulators.

1.2.2 Sources of Contact Voltage

Ostensibly, these incidents are caused by contact between a person or animal and an inadvertently energized structure. Such electrical shock occurrences are the direct result of a failure of an electrical insulation system. The root cause of this failure can be attributed to one or more of a list of causes, including:

a) *Aged infrastructure*

As an installation ages, electrical insulation on cables and connectors tends to become brittle and may begin to crack, exposing energized components. This effect is accelerated by the presence of moisture and other contaminants (road salt, for example) and by exposure to freeze/thaw cycles.

b) *Inadequate design*

Improperly sized cables, connectors or ducts, lack of circuit protection and inadequate grounding and bonding could cause electrical failure. Components installed in below grade enclosures that can fill with water or ice should be rated accordingly.

c) *Improper installation*

Poor workmanship can directly result in a hazard to the public. Specific examples of this include sub-standard insulation taping and connectors or other components not being installed in accordance with the manufacturer's instructions. Such components are tested and qualified based on the assumption that they are installed properly; meaning that if they are not the product is not guaranteed to perform as designed.

d) *Accidental damage*

Third parties may dig-in to a cable without knowing it, or compromise the integrity of a structure when working nearby (for example, a number of below grade handwells have been found to be filled with concrete after adjacent sidewalk work has been completed).

e) *Rodent Damage*

Rodents such as squirrels, mice and raccoons have been known to chew through wire or connector insulation.

f) *Vandalism/ Theft or Power*

Unauthorized connections to supply circuits may be made using unapproved components or work practices. Vandals may remove ground conductors or damage access covers, resulting in exposed wires.

g) *Insulation Destruction Testing*

To determine presence of voltage in an underground supply cable, crews have been "stripping" the insulation off the cable exposing the bare conductor and re-taping. One incident root cause was found to have the insulation stripped and left bare in the handwell.

Often times, the compromised integrity of the conductor insulation results in a high-impedance fault which goes unnoticed by the party responsible for maintaining the asset until reported by a member of the public or identified through a mobile or manual voltage scanning program. Experience has shown that any conductive structure in the vicinity of a cable fault has the potential to become energized and pose a hazard to the public.

Table 1 describes street light system components and possible failure modes which could result in a contact voltage occurrence. It should be noted that in addition to those components listed in *Table 1*, a failure in the street light electrical distribution system could result in the energizing of other structures as well, such as bus shelters, signs, traffic poles and fences.

Table 1
Potential Sources of Contact Voltage in Street Light Systems

Component	Possible Cause of Energization
Pole	Direct contact with a pinched wire or degraded connector insulation between the pole (if conductive) and/or any conductive attachments (such as cable guards). Note that some normally non-conductive materials (such as concrete) will conduct electricity when wet.
Pole foundation or sidewalk bay	Exposed conductors (due to insulation degradation, inadvertent damage such as a dig-in, etc.) will cause a potentially dangerous voltage gradient when water and salt are present.
Pull-box or handwell	Below grade conductors and splices are exposed to harsh conditions which can result in accelerated degradation. Also, stripping of the insulation and not repairing the insulation in an approved manner or not repairing at all can contact the metal lid. If the pull-box is conductive, contact voltage will result if there is direct contact or if water and salt are present.
Distribution Panels	Pinched or exposed wires can contact the panel enclosure and cause it to become energized.
Luminaires	Luminaires mounted above a certain height are not required to be grounded, and as a results may become energized.
Rodent Damage	If wires are accessible to wildlife, they may damage the electrical insulation resulting in an exposed conductor.
Vandalism/ Theft of Power	Unauthorized manipulation of supply circuits and/or related infrastructure can lead to substandard installations due to unapproved materials and improper work practices.

Additionally, voltage detected on surfaces which are bonded to the system neutral may not be a result of contact voltage but the return current and the impedance of the return path may be the result of an elevated neutral voltage. If concerned, the asset owner should contact the local electricity distribution utility to determine the exact cause and follow-up actions necessary to resolve the issue. In the meantime, the circuit should be made safe until the root cause is determined.

2.0 Design and Installation

2.1 Components

2.1.1 Conductor / Cable

There are two categories of streetlight cable, one cable that runs between streetlight poles (bus) and the other that supplies power to the luminaires (service drop). Cables shall be CSA certified, meet the requirements of the OESC and shall have designation suitable for their applications. Example, RWU90 can be used for direct buried installations while RW90 cannot be used for this type of installation. In order to reduce mechanical damage to the cable insulation and reduce the likelihood of contact voltage, an outer cable jacket should be used and/or higher cable insulation value.

Types - The cable types that are typically used for streetlight installations are:

Streetlight bus – RW90, RWU90, TWN75/T90, USEI75, USEI90

Streetlight service – RW90, RWU90, NMWU90

The voltage rating for the streetlight cable shall be 300V, 600V or 1000V.

Conductor Material: The conductor material used for cable conductor is a matter of code requirements and economics. However, the two most commonly used streetlight cable conductor materials are copper and aluminum. A quick comparison of a copper and aluminum conductor with equivalent size reveals the following: Copper has higher conductivity than aluminum (aluminum has only about 60 percent of the conductivity of copper) and it is more ductile (i.e. can be drawn out easier). Copper has relatively high tensile strength (the greatest stress a substance can bear along its length without breaking apart). However, copper is more expensive and heavier than aluminum conductor for the same conductivity. The lightness of aluminum conductor makes it more favorable for overhead spans.

Size: Once the conductor material is selected, the size of the conductor is governed by the required circuit ampacity and voltage drop. However, because streetlight circuits tend to be relatively lightly loaded but long in length, voltage drop typically dictates the conductor size. The conductor shall be sized according to the OESC and such that the voltage drop in the circuit from the service entrance point to the last Street Light on the circuit will not exceed the accepted voltage regulation of the ballast (for example, 10%-13% of nominal for constant wattage ballast). See section 2.4 on Voltage Drop.

2.1.2 Connectors

There are a number of different street lighting connectors currently available. The connector should be designed for the environment in which it is to be installed and be compatible with the conductors it is joining. When joining similar metals it is always desirable to use a connector fabricated from the same material. When joining dissimilar metals (copper to aluminum), an aluminum connector should be used. The connector insulation should be appropriate for the environment, with below grade connectors designed and certified for submersibility. Other considerations include the number of connectors to be joined, the size of those connectors, the tools available to the installers and the amount of working space.

Some common connectors include:

- Block
- Split-bolt (not recommended)
- Wedge
- Wing nut
- Compression sleeve

Some common insulation types include:

- Tape (self-amalgamating, PVC)
- Heat shrink sleeve
- Cold shrink sleeve
- Pre-molded
- Gel-based cover
- EPDM Rubber cover

*Note: Tape Insulation on split bolts is not recommended for phase connections as they have been a root cause of contact voltage incidents.

2.1.3 POLES

General

There are generally four types of poles (based on material) used to support streetlight luminaires and associated hardware, namely; wood, reinforced concrete, metal and fibre-reinforced polymer (FRP). When selecting a pole for streetlight application, the pole must be able to withstand the mechanical loading of the attached components (luminaire and bracket) and the weather loading as specified by the applicable design code. CSA standard C22.3 No. 1 "Overhead Systems" can be consulted for typical weather loading and overload factors that can be used in selecting the appropriate pole. If flags, banners or any items that can add excessive wind or mechanical load to the pole will be attached to the pole in the future, then the selected pole must have sufficient strength to restrict the loading of these appurtenances.

1. Wood Poles

Wood poles shall be manufactured and tested in accordance with CSA standard O15.1 " Wood Utility Poles and Reinforcing Stubs" . Wood poles can either be butt treated or full length treated for protection against rot, fungi and insects in accordance with CSA standards O80 " Wood preservation" . Full-length treated poles offer the advantage of allowing for future adjustment in burial depth due to grade change without the need to worry about embedding untreated portions of the pole in the ground. There are different species of wood poles which have different strength characteristics, such as, western red cedar, Jack pine, Douglas fir, etc. However, CSA has defined classes for wood poles to indicate the strength of the pole by specifying minimum tip and butt dimensions and an ultimate load that the pole must be able to support when applied 0.6m (2ft) from the tip. Pole class designation for wood poles are based on numbers with higher numbers having lower strength (example a class 6 pole has breaking strength of 1500 lbs (6700 N) while a class 4 pole has breaking strength of 2400 lbs (10700 N).

The setting depth for wood poles depends on the pole length and soil condition; refer to CSA std. O15 for nominal setting depths.

2. Reinforced Concrete Poles

Reinforced concrete poles shall be manufactured and tested in accordance with CSA standard A14 "Concrete Poles". When used in corrosive environment, these poles can be treated with special coating to inhibit corrosion. Re-enforced concrete poles can be manufactured in different shapes and lengths and can be specified to include pre-drilled holes to ease installation.

The setting depth for concrete poles depends on the pole length and soil condition; refer to the manufacturer for nominal setting depths.

3. Metal Poles

Metal poles are available in aluminum or steel either for anchor-base mounting or direct burial. Special "breakaway" or "frangible" base poles are also available for certain road and traffic conditions. The setting depth for direct buried metal poles depend on the pole length and soil condition, refer to the manufacturer for nominal setting depths.

All metal poles must be bonded to the streetlight circuit bonding conductor. In addition, OESC section 10 & 75 permits steel poles to be used as the grounding electrode for equipment mounted on the pole and where the pole is directly embedded in soil and the portion of the pole in contact with the soil is not coated with any non-metallic coating or covering. The use of the metal pole as a grounding electrode must also be approved by the manufacturer of the steel pole.

Steel poles shall comply with all applicable requirements in the latest issues of the following standards:

- CSA G40.20/ CSA G40.21 " General Requirements for Rolled or Welded Structural Quality Steel/Structural Quality Steel"
- CSA G164 "Hot Dip Galvanizing of Irregularly Shaped Articles"
- CSA W59-03 "Welded Steel Construction (Metal Arc Welding)"
- OPSS 2423 “Material Specification for Steel Poles, Base Mounted”

- Aluminum poles shall comply with all applicable requirements in the latest issues of the following standards:
- ASTM B221 "Standard Specification for Aluminum and Aluminum-Alloy Extruded Bars, Rods, Wire, Profiles, and Tubes"
- ASTM B26 "Standard Specification for Aluminum Alloy Sand Castings"
- ASTM B108 "Standard Specification for Aluminum-Alloy Permanent Mold Castings
- OPSS 2451 “Material Specification for Aluminum Poles, with cast aluminum Frangible Couplings, Direct Burial”
- OPSS 2452 “Material Specification for Aluminum Poles. Base Mounting”

4. Fiber-Reinforced Polymer (FRP) or Fiberglass Poles

There is currently no CSA design standard for FRP poles. However, ANSI C136.20 " American National Standard for Roadway and Area Lighting Equipment - Fiber-Reinforced Composite (FRC) Lighting Poles" and ASCE manual 104 " Recommended Practice for Fiber-Reinforced Polymer Products for Overhead Utility Line Structures" can be used as the design guide for these poles. FRP poles have been gaining more widespread acceptance as an alternative to wood, concrete and metal poles due to their light-weight, high strength-weight ratio, high resistance to corrosion and non-conductivity.

The setting depth for FRP poles depend on the pole length and soil condition, refer to the manufacturer for nominal setting depths.

2.1.4 Brackets

There are many types of street lighting brackets available on the market today, and care should be taken in selecting the right type for the right application. The bracket most commonly used in streetlight applications with cobra head luminaries is a one-piece tapered elliptical aluminum (TEA) bracket as shown *Figure 1.*

Some points to consider when selecting a bracket:

1. Pole location with respect to curb or roadway (length of bracket).
2. Bracket strength - the bracket must have sufficient strength to support the weight of luminaire and wind loading on the luminaires effective projected area.
3. Type of pole - Wood or metal pole plate required.
4. Bracket rise – beware of maintaining proper clearances on distribution poles. See section 3.4 for Safe Limits of Approach.
5. Bracket length – this impacts the reach required to position the luminaire.

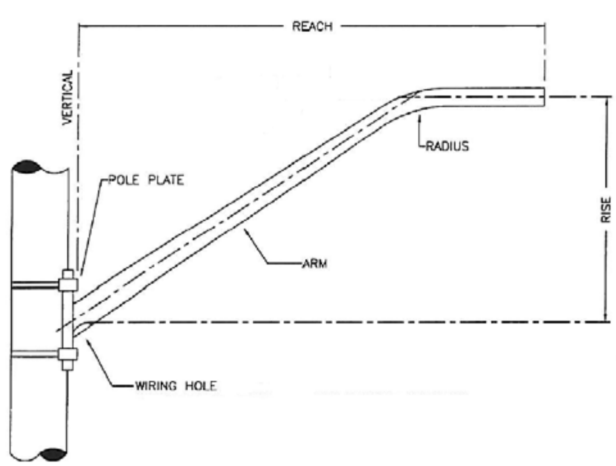


Figure 1 Tapered Elliptical Bracket on Streetlight Pole

2.1.5 LUMINAIRES

Luminaires for street lighting generally consist of one or more of the following components:

a) Light source and socket
b) Ballast assembly (including starting aid for H.P.S. lamps)
c) Reflecting elements or element
d) Refracting glassware or plastic enclosure
e) Housing or body complete with bird stop and optical filter where necessary.

For Street lighting luminaire classification refer to ANSI/IES RP-8.

Installation Standards and Specifications for Poles & Luminaires

The Ontario Provincial Standards (OPS) provide a comprehensive set of standard specifications and drawings in the administration of road building in Ontario. In general, OPS Section 6 is for electrical works. Specifically, OPSS 615 and 617 provide the specifications for the installation of poles and luminaires

OPSS 615 CONSTRUCTION SPECIFICATION FOR ERECTION OF POLES
OPSS 617 CONSTRUCTION SPECIFICATIONS FOR INSTALLATION OF ROADWAY LUMINAIRES

BALLASTS

General

Most High Intensity Discharge (HID) lamps (such as HPS, MH, MV) require a ballast to start and operate within the limits set out by the lamp manufacturer. These operating limits are developed and published by lamp type and wattage by the American National Standards Institute (ANSI). To operate a lamp properly, both ballast and lamp must be electrically compatible and must conform to the same standard (e.g. "S50" for a 250W HPS lamp per ANSI). A typical ballast assembly consists of a transformer (core and coil) - current limiting device, an optional capacitor for power factor correction and an igniter (starter) for HPS and some low wattage MH lamps.

The function of a ballast is to provide sufficient voltage to start the lamp and/or to limit the current to the operating value of the lamp. All ballasts have wattage losses which must be included in the circuit load. Some ballast types have a high starting current which becomes an important factor in sizing of the supply circuit components (fuses, breakers, relays and wires).

List of Available Ballast Designs

Low Power Factor Reactor Ballast *(See Figure 2)*

Used where line voltage exceeds lamp voltage, used only to limit the lamp current. Economical, small, has a low p.f. about 50%. Not recommended where line fluctuations exceed ± 5%, producing lamp wattage variations ± 10%. Starting current about 150% of operating current.

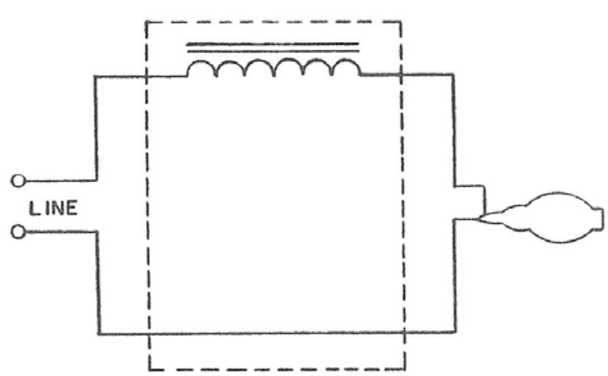


FIGURE 2 – LOW POWER FACTOR REACTOR BALLAST

High Power Factor Reactor Ballast *(See Figure 3)*
The power factor (p.f.) is improved to nearly 90% through the addition of a capacitor across the line. This reduces the total line current by approximately 50%, thus permitting doubling the maximum number of lights that can be supplied from a given wire size.

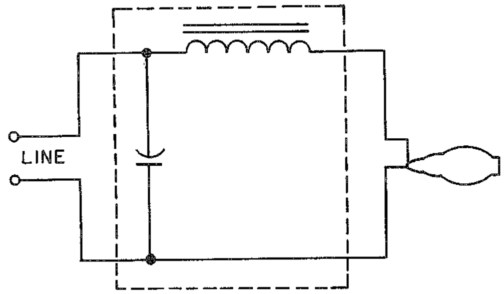


FIGURE 3 – HIGH POWER FACTOR REACTOR BALLAST

Low Power Factor Autotransformer Ballast *(See Figure 4)*
In addition to the same characteristics and function of low power factor reactor ballast, this ballast raises the line voltage to the value required to start the lamp.

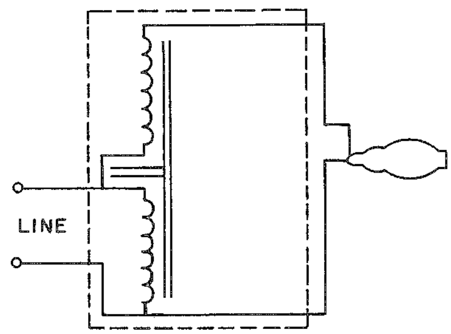


FIGURE 4 – LOW POWER FACTOR AUTOTRANSFORMER BALLAST

High Power Factor Autotransformer Ballast *(See Figure 5)*
Same as low power factor autotransformer ballast above; however, through the addition of a capacitor in the primary circuit the power factor is increased to approximately 90%, resulting in the same advantages of high power factor reactor ballast above.

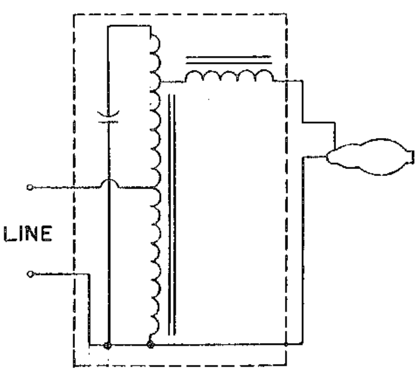


FIGURE 5 – HIGH POWER FACTOR AUTOTRANSFORMER BALLAST

Constant Wattage (Regulator) Autotransformer Ballast *(See Figure 6)* – (CWA)
With the capacitor in series, the light output becomes more stable. With line voltage variations of ± 10% the lamp wattage varies only ± 5%. In addition to have a leading 90% p.f., this ballast draws a line starting current that is lower than operating current.

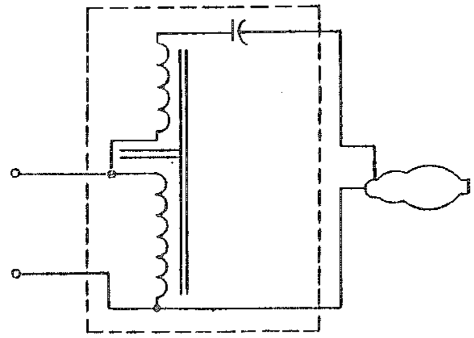


FIGURE 6– CONSTANT WATTAGE AUTOTRANSFORMER BALLAST

Premium Constant Wattage Ballast *(See Figure 7)* – (CWI)
Same as constant wattage (regulator) autotransformer ballast above except the ballast has two separate windings offering the advantages of an isolating transformer. A voltage variation of ± 13% causes the lamp wattage to vary by ± 25%.

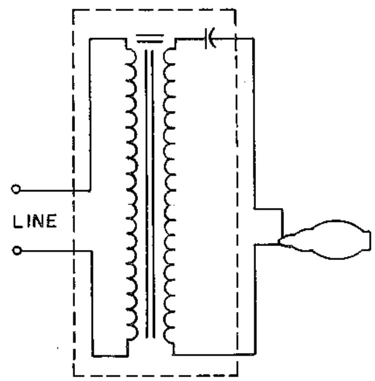


FIGURE 7 – PREMIUM CONSTANT WATTAGE BALLAST

High Pressure Sodium Ballast Assemblies
High pressure sodium ballasts have a starting aid in the form of an electronic solid state circuit which provides superimposed pulses of 2500 or 4000 V ± during starting *(see Figure 8).* This is in addition to the normal magnetic circuit that controls the open circuit voltage and limits the lamp current. A full range of lead or lag ballasts are available, giving a high power factor of 90% plus or a low power factor of 50%. Because of the relatively high voltage starting characteristics of these ballasts, the life span may be reduced when they are left connected to a defective or burnt out lamp over an extended period of time. It is also extremely dangerous to attempt to change lamps while the electrical circuit and ballast are alive. This results from the fact that a regular starter will continually supply high voltage pulses to a burned out lamp, broken lamp, or an empty socket. A "protected starter" can be used to eliminate voltage being supplied to a burned out lamp, broken lamp, or an empty socket.

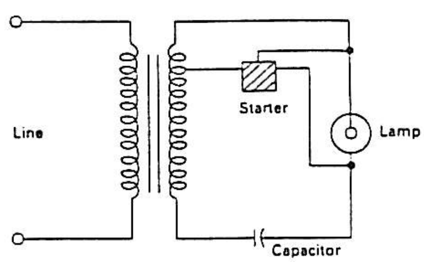


FIGURE 8 - CWI BALLAST WITH STARTER

Low Pressure Sodium Ballast Assemblies
Low pressure sodium ballasts are the 'Reactor Autotransformer' type that show good stability under varying input conditions. A 10% ± variation in the supply voltage will create less than a 4% variation in lamp watts with a corresponding lamp lumen variation of less than 2%.
NOTE In both cases of sodium ballasts the supply voltage will affect the colour output of the lamp if it is not held within the recommended tolerance, i.e. H.P.S. will appear rather pink and the L.P.S. will appear too orange.

LED driver (current regulator) LED drivers effectively provide the same function as ballasts in traditional lighting products. Drivers regulate power to the LED, thereby controlling the brightness or intensity of the LED. The driver system converts the supply voltage to a DC voltage and provides a DC output current to the LED. It holds the current at a constant level/output over variable supply voltage ranges.

2.1.6 Receptacles – for seasonal lighting

Receptacles used on streetlight poles for seasonal lighting shall be of the ground fault circuit interrupter (GFCI) type. These receptacles shall be provided with weatherproof covering as per OESC for use in outdoor wet locations. However, experience has shown that while these weatherproof covers work well when the receptacle is not in use, they do not provide sufficient weatherproofing while in use and have resulted in numerous site visits to reset the GFCI. In order to reduce the nuisance trips and the ingress of water/moisture into the receptacle, "while-in-use" weather covers are recommended. These "in-use" weatherproof covers allow the receptacle to be protected from weather elements even when a power cord is plugged in. See *Figure 9*

Figure 9 - In Use Weatherproof Receptacle Cover

The size of the receptacles used shall be 15 amps or as specified by OESC.

The "while-in-use" weatherproof covers should be constructed from high-impact, UV-resistant Non-metallic material or sturdy, corrosion-resistant metallic material and shall be CSA certified.

2.1.7 Control and Protection

2.1.7.1 Control

The control of streetlight and/or streetlight circuits is typically accomplished with the use of photo-electric controllers (photo-cell) arranged in one of the following manner:

- Individually-controlled streetlights
- Group-controlled streetlights

Individually-controlled streetlights (*see Figure 10*) consist of various secondary voltage systems with each light directly connected to the secondary distribution bus at different locations and individually controlled by a photo-cell mounted on top of the luminaire.

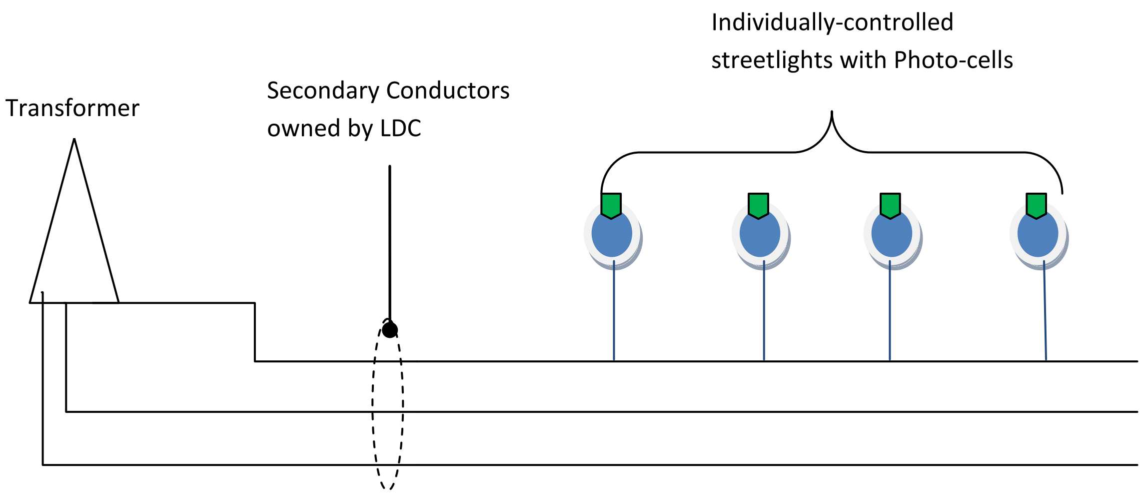


Figure 10 - Individually-controlled Streetlight Circuit

Group-controlled streetlight circuits *(see Figure 11)* consist of an additional streetlight conductor that supplies power to all the streetlights, which is owned by the streetlight asset owner (Municipality). The additional streetlight conductor is connected to the secondary distribution circuit via a service entrance switch and/or relay. The relay (or contactor) is centrally controlled using either a photo-cell controller or a cascade. The cascade is essentially a voltage signal from an existing streetlight circuit that is initially controlled by a photo-controller. The cascade system consist of one group of streetlights controlling the next group which can then control the next group and in theory can continue indefinitely. See *Figure 12* for streetlight schematic using cascade control. Having too many groups of streetlight on a cascade system increases the risk of complete "lights out" if the initial control fails. In each group of streetlights, there are typically 10 to 14 streetlights served by one switch, one relay (or contactor) and one photo-cell (or cascade) depending on circuit loading and voltage drop.

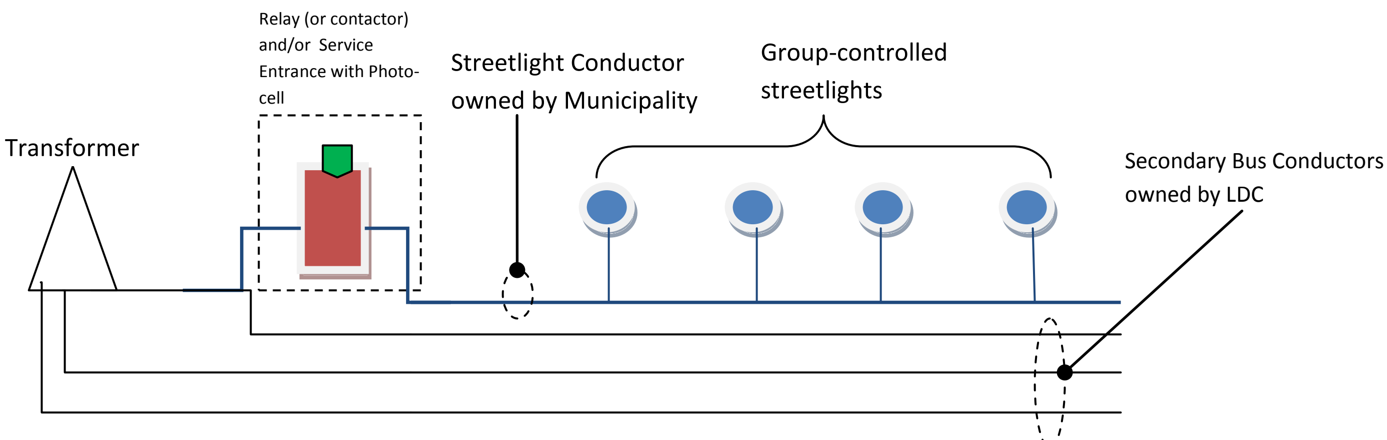


Figure 11 - Group-controlled Streetlight Circuit

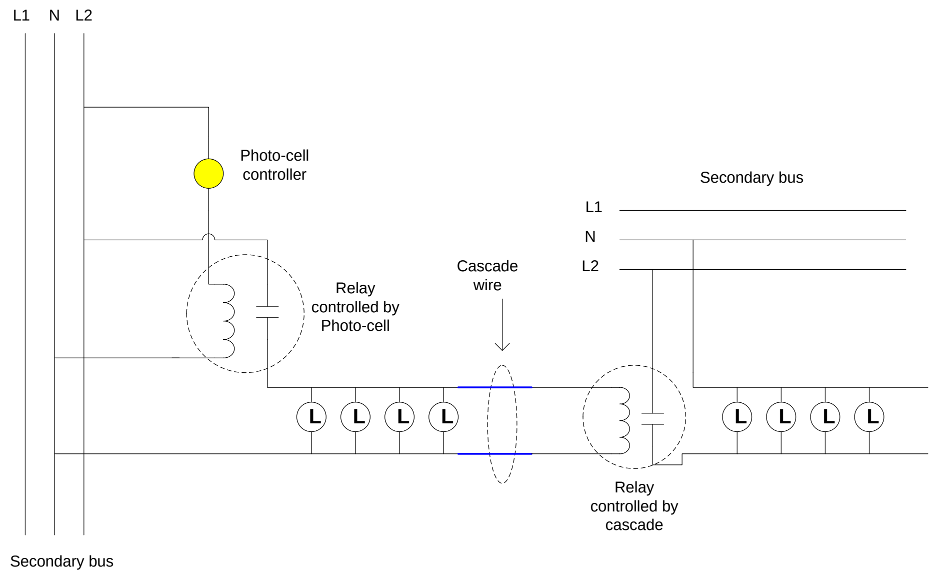


Figure 12 - Streetlight Circuits being initially controlled by Photo-cell and intermediate controlled by cascade (not shown - service entrance switch and ground conductor)

Photo-Electric Controls
All photoelectric controls shall meet the design and testing requirements of the latest applicable ANSI and UL standards:

- ANSI C136.10 " American National Standard for Roadway and Area Lighting Equipment—Locking-Type Photocontrol Devices and Mating Receptacles—Physical and Electrical Interchangeability and Testing"
- UL 773 " Plug-in Locking Type Photocontrols for Use with Area Lighting"

The photoelectric control shall provide reliable switching of high-pressure mercury vapour and high-pressure sodium vapour lamps under the following environmental conditions:

- Ambient temperature range: -40 ^{0}C to 65 ^{0}C
- Moisture level: 96% relative humidity at 50 ^{0}C

Photocontrols used in street lighting applications are generally the normally closed (NC) type made to be "fail safe". That is, should there be a component failure other than in the photocontrol relay itself, the relay closes, energizing the streetlight circuits.

2.1.7.2 PROTECTION

Streetlight Bus – protection for overload and line faults
Protection furnished for street lights shall be capable of handling the operating voltage of the circuit involved and shall have the following characteristics:

- Service entrance disconnect switch (complete with fuse or circuit breaker) to be used with dedicated streetlight circuits for protection. Service entrance shall be sized according to the OESC. If luminaires are fed from a common secondary distribution bus that supplies other load, the service entrance switch is not required but each luminaire (or service wire to a group of luminaires) must be protected.
- Luminaire – fault protection for the luminaire and service wire is typically provided by a inline, water-tight, electrical quick disconnect (load-breaking) fuse. This fuse should be sized to prevent the service wire from being burnt down under fault condition. Example: a #14 cu service wire will require a maximum fuse size of 15A. When sizing the fuse for the luminaire(s), the lamp/ballast starting current and momentary high inrush current should be taken into consideration to avoid nuisance operation of the fuse.
- Human and Animals – in order to protect human and animals from electric shock in case of a faulted circuit to conductive equipment, all non-current carrying conductive components must be bonded together with a conductor of sufficient size. The impedance of the complete ground-fault circuit (phase conductor and bonding conductor) should be low enough to ensure sufficient flow of ground-fault current for fast operation of the proper circuit protective devices, and to minimize the potential for stray ground currents on solidly grounded systems - ref: IEEE std 141-1993

2.1.8 UNDERGROUND DUCTING

In past and current practice of installing underground ducting for streetlighting, the ducts terminate just short of the pole and the cables are then inserted through the pole's wiring aperture leaving bare cables (without duct) between the end of the duct and the pole.

Ducting should be a continuous system where the duct should end inside the poles below grade aperture or pole footing and above the entrance point for direct buried poles. The current shape and size of the pole's wiring aperture may not allow for ducting to be terminated into the pole. Pole manufacturers should be advised to change the shape and size of the wiring aperture to accept 50mm PVC duct used for streetlighting. The ducting should then pass through this aperture and continue up to the pole's hand hole. This will eliminate dirt and debris collecting inside the duct thus allowing for easier replacement of old or deteriorated cables.

Conduits

Conduits are typically used to provide mechanical protection for cables and ease of future replacement. When conduits are used they shall conform to the following requirements:
Material – conduits should be constructed from non-metallic materials such as PVC, HDPE, etc.
The conduits and fittings shall be designed, manufactured and tested in accordance with the applicable CSA or NEMA standards listed below.
The minimum installation depth of the conduit shall be in accordance with the OESC
Size - the conduit shall be sized in accordance with the OESC.
Standards - C22.2 No. 211.1, C22.2 No. 211.2, NEMA TC 7

2.1.9 HANDWELLS

Handwells/junction boxes are a common component of streetlighting systems and are typically used as follows:

- As a pull point where distances exceed the desired maximum for supply conductors,
- As an access point for changes in direction of underground ducts; this avoids pulling the cables through a bend in the duct,
- As an access point where ducts are required to cross a roadway or enter a bridge structure,
- As a branch location where multiple circuits in a single conduit continue in separate directions
- Embedded in bridge structures, i.e barrier walls, sidewalks, abutments, etc., for connection to bridge mounted lighting poles or underpass lighting.

Handwells are available in several material types and a variety of sizes. They are typically round or square/rectangular in shape with either an open or closed bottom. The more common material types include precast concrete (with cast metal frames and covers), polymer-concrete, polyethylene, and PVC.

2.1.9.1 BEST PRACTICES

Handwell Problems

In order to address best practices, it is first necessary to identify some of the shortcomings or problems associated with the use of handwells.

The metal components require bonding to ground. These connections are typically a weak link.

Most handwells are not suitable for deliberate vehicular traffic and are subject to collapse of the cover and/or walls when travelled over.

The limited wall space makes it difficult to have more than one or two ducts enter the same wall and any attempts to do so can result in affecting the integrity of the wall. This is more of an issue with round concrete handwells.

There is little room for coiling of cables and therefore a good possibility exists for cables to come in contact with the frame and cover.

Handwells are not water tight and can fill with water leading to deterioration of cable insulation as previously noted.

2.1.9.2 Recommendations

To reduce the possibility of contact voltage it is recommended to use non-metallic handwells. Where metallic handwells are used, all metal components must be bonded to the system ground.

The location of handwells is important; most are capable of supporting an occasional non-deliberate vehicle load. If however, they will be subject to regular vehicular loading, a handwell rated for such loads must be used. ANSI/SCTE 77 “Specification for Underground Enclosure Integrity” provides guidance for selecting the right enclosure based on the site conditions. In addition to the loading factor, handwells located in areas that may be subject to “scraping” by a snow plough blade should be slightly recessed to prevent being “clipped’ by the blade.

Where multiple ducts are required to enter a handwell, careful design practice should be followed to ensure that orientation of the ducts does not affect the integrity of the handwell. Open bottom handwells can help resolve such conflicts by having some ducts enter through the bottom and others through the side. Refer to the OESC for maximum number of conductors in a box.

If the decision is made to make use of a larger chamber such as a maintenance hole, it should be noted that the larger chambers are subject to confined space requirements of the Occupational Health and Safety Act; this will impact maintenance procedures.

It is an OESC requirement that all non current carrying metal parts be bonded to the system ground. Provision should be available to facilitate this requirement.

In order to mitigate the collection of water within the handwells, crushed stone is recommended as a drainage pocket below each installation. In clay soils, it may be necessary to provide a more effective drain for larger chambers, such as, a connection to a drainage ditch or storm sewer.

2.2 Seasonal Lighting connected to Street Light Circuits

2.2.1 Background

Unlike electrical equipment that is required to operate 365 days per year, Seasonal Lighting presents a unique challenge and risk. Typically, seasonal lighting operates for a limited period during the Christmas season. Outside of this time period, electrical supply equipment may lie dormant and unused for up to 10 months per year. Mechanical and weather related forces continue to act on this equipment year round, however damage may not be identified for extended periods. In many cases, seasonal outlets continue to be energized and as such, continue to pose the same risk of electrical shock as during times of use.

To ensure this equipment continues to perform in an electrically safe manner, the following points should be observed:

- **An annual equipment inspection routine and record should be maintained by the owner of the asset. This should include periodic inspection of all seasonal equipment that is live throughout the year.**
- **Seasonally energized equipment should be inspected prior to energizing and use.**
- When attached to LDC assets, equipment should meet local supply authority connection requirements as determined by OESC rules and ESA Regulation 22-04.

All equipment and devices should meet CSA approval and be designed for the application. As an example, weatherproof covers should protect the outlet at all times and be designed to allow for protection of the male plug adapter. It is recommended to use “Weatherproof when in Use” receptacle cover *(See Figure 9)*. It is also recommended that the receptacle and loads be attached to the plant, a minimum 3m above grade to discourage unauthorized connections. Street Light Asset Owners (SLAO’s) must ensure that third parties receive authorization from the Street Light Asset Owner to use this receptacle and the SLAO must ensure that the devices being plugged in are being used as intended.

Electrical installation should be completed by a Licensed Electrical Contractor under Ontario Regulation 570/05 made under Part VIII of the Electricity Act, 1998

Asset owners should consider public safety awareness campaigns, directing the public and Business Improvement groups to contact the electrical supply authority or ESA should they notice damaged or questionable equipment.

2.3 Grounding and Bonding For Municipal Street Lighting

2.3.1 Introduction

A thorough consideration of grounding and bonding theory and practice is foundational to the design of any electrical system. The grounding and bonding standards chosen by the designer will affect system performance, equipment reliability and safety factors for both humans and animals. Of central importance is the fact that grounding and bonding methods play a major role in the mitigation of 'contact' voltage hazards. This section will summarize the basics of electrical grounding and bonding and attempt to guide the reader through the major issues as they relate to municipal street lighting design.

Before designing a system, designers are cautioned to establish a design philosophy. The designer must decide whether to simply comply with minimum code requirements or perhaps to ''raise the bar' where it is warranted. The OESC serves its function properly by establishing a minimum across-the-board safety standard. It then becomes an engineering responsibility to define design objectives which address functionality, reliability and risk analysis. Engineers and designers must understand and address electrical safety issues and design safety into the system proactively.

The following recommendations attempt to incorporate information provided in the Ontario Electrical Safety Code, IEEE standards 142 and 1100, MEA, MTO, and OPS publications and a survey of articles from popular trade journals and engineering handbooks. Other recommended references are BS 7671, IEC 60364, NFPA 70 and the NESC.

2.3.2 Definitions

The term '**grounding'** refers to making an intentional, permanent, electrical connection between an electrical system and the earth. The term '**bonding'** refers to joining the non-current carrying metallic components of an electrical system to each other to form a permanent, electrically conductive path. Ultimately the bonding conductors connect to the grounding system at the service entrance panel.

Bonding conductors are often loosely referred to as **'ground wires'** even by electrical professionals. A 'grounding' conductor actually connects the system to an earth electrode whereas 'bonding conductors' interconnect equipment components. Grounding and bonding conductors typically are either bare or are covered with green insulation.

Grounding and bonding conductors must have sufficient ampacity to carry any fault current that is likely to be present and have sufficiently low impedance to operate protective devices and limit voltage rise.

Impedance is the total opposition to current flow presented by a conductor. It is the sum of the resistance, capacitive reactance and inductive reactance presented by the circuit element in question. Its unit is the Ohm and its symbol is the omega. It is an important design factor since it has an impact on breaker trip time, transient energy dissipation, lighting dissipation, arc flash and other electrical characteristics of the system.

Ampacity is the current carrying capacity of a conductor expressed in amperes.

2.3.3 The General Function of Grounding and Bonding in Power Distribution

Grounding can serve many varied functions in electrical systems and it is of great importance that the designer bear in mind 'why' grounding is done before jumping to the 'how' stage. To this end it may be useful to briefly look at the general reasons for grounding electrical equipment before delving into street lighting in specific.

To list some of its more common functions, grounding is specified where it is required to:

- establish a common voltage reference point
- control and stabilize system voltages
- promote effective RF transmission from antennae
- limit step and touch potentials
- provide cathodic protection
- provide a return path for clearing faults on high voltage power transmission and distribution systems
- provide a sink for transient energy, electrical noise, electrostatic discharge and lightning.

As we shall see, only a few of these have any significance to street lighting system designers.

In contrast to grounding, bonding facilitates the operation of fuses, breakers and other protective devices by providing a return path for fault current back to the source. An equally important role for bonding is to reduce or eliminate any difference in potential energy (voltage) between metal surfaces, structures or components. This is crucial because shock and arc hazards begin with a difference in voltage between two points.

Finally, it should be noted that while grounding and bonding play a key role in electrical safety, the designer must not ignore other effective means of protection such as isolation, clearance, insulation, guarding, relaying, alarming and the use of warning labels; topics which are outside the scope of this section.

2.3.4 The Role of Grounding & Bonding in Street Lighting

Effective 'system grounding' at the power distribution panel is an absolute must for basic compliance with the OESC, however for street lighting purposes there is really very little to be gained by providing 'supplemental grounding' of equipment at the poles.

To provide poles with effective protection from lightning damage would require air terminals and large ampacity 'down conductors' connected to the earth. To provide a substantial reduction of step and touch potentials would require a significant investment in grounding by constructing a ground mat around each and every pole which is not practical.

Finally, the earth cannot be relied upon as a return path for fault current or for the proper operation of protective devices such as fuses and breakers because the impedance of the earth is variable and is generally far too high to be effective on Low Voltage distribution systems such as streetlighting.

In some cases, the inappropriate placement of ground rods has actually aggravated existing problems, making matters worse by increasing the level of stray current or by creating ground loops.

The key design consideration for protecting street lighting equipment from the hazards of contact voltage is to provide for effective bonding and not to rely upon supplementary grounding. A continuous, low impedance bonding system of sufficient ampacity can provide a fault current return path that will operate breakers and fuses quickly and thereby remove contact voltage from metal surfaces.

It is essential and worth emphasizing that bonding is more important than grounding in the role of clearing faults and removing dangerous voltages at street lighting poles. Much literature has been written on the subject.

2.3.5 HOW TO ACHIEVE EFFECTIVE GROUNDING AND BONDING FOR MUNICIPAL STREET LIGHTING

2.3.5.1 WHICH COMPONENTS REQUIRE GROUNDING AND BONDING?

a) System Grounding and Bonding

The 'system' must be solidly grounded at the service entrance by connecting the neutral terminal (aka the 'identified conductor') to the earth.

The term 'solidly grounded' refers to making a direct connection to earth, in contrast to other methods of grounding where resistors, inductors and special transformers are used to connect the electrical system to earth. Street lighting systems must be solidly grounded and the grounding conductor must provide a continuous path to earth with no intermediate devices.

Multiple bonding of ground and neutral at other points downstream from the service panel contributes to the creation of 'objectionable currents' which can then create shock and arcing hazards and as such represents a violation of the OESC. Be careful to bond neutral and ground together, but only at the power distribution panel.

For system grounding purposes, the ESA will generally accept either two driven ground rods or a grounding plate. Unfortunately the allowance of grounding plates by the code has inadvertently promoted the seriously erroneous notion that one ground plate is as effective as two rods. In fact quite the opposite is true. Plates were originally intended only for situations where ground rods cannot be driven. The British code BS7430 makes a point of clarifying the difference between rods and plates and the designer is cautioned to research the subject further if this point is not well understood.

Street lighting power distribution systems should be solidly grounded. Depending upon local soil conditions this will generally require two driven ground rods or multiple plates. Additional electrodes may be necessary to satisfy this requirement. Performing an earth resistivity study prior to specifying or installing equipment may be required.

b) Equipment Grounding and Bonding;

All conductive surfaces in a street lighting system must be bonded to each other and to the earth. Conductive surfaces and components include metal power distribution panels, metal hand wells, hand well covers, metal and concrete poles, metal junction boxes, junction box covers, relay and control panels, mast arms and luminaires.

This system of bonding conductors provides a continuous electrical path which permits fault current to return from the equipment back to its source (the utility transformer). Bonding conductors also provide an 'equipment ground', because they are connected to the system earth electrode back at the service panel.

Providing additional supplementary ground electrodes at individual poles or at intervals distributed between the poles would exceed OESC requirements. Traditionally each municipality has developed their own standard practice in this regard. At this point the designer is cautioned to ask why additional equipment grounding should be installed, what purpose it really serves and should be able to justify the number of grounding electrodes specified. Recommended guidelines are provided below.

2.3.5.2 WHICH GROUNDING AND BONDING MATERIALS SHOULD BE USED?

Grounding and bonding materials used for street lighting applications should all conform to CSA C22.2 No. 41-07 “Grounding and Bonding Equipment” as a starting point. The designer may also refer to OPS 609 and UL467 standards when specifying grounding and bonding materials.

The following items should be specified in all municipal street lighting contracts:

a) Ground rods shall be 3.0 m x 19 mm (10 foot x 3/4 inch dia.) copper-clad steel rods.
b) Ground plates shall be 254mm x 400mm x 6mm (10" x 16" x 1/4") galvanized steel with a minimum surface area of 0.2 square meters.
c) Grounding Electrode Connectors shall be of the compression type and be rated for direct burial. Exothermic welding is an acceptable alternative. Mechanical connectors

are unacceptable for direct burial applications unless specifically approved for the application.

d) Bonding conductors will typically be a stranded copper wire. Refer to the OESC for proper sizing. A #6 AWG wire is typical. Splicing is permitted where the connections are accessible.

e) Ground electrode conductors will typically be a hard drawn stranded copper wire. Refer to the OESC for sizing and installation instructions. Splicing is generally forbidden unless an approved method is used. Soldering alone is not an acceptable connection method.

f) Grounding grid conductors where used to interconnect grounding electrodes, shall be large enough to ensure a degree of mechanical integrity. A #2 AWG bare, solid copper wire is typical.

g) Ground enhancement compounds will reduce resistivity to earth and is readily available from a number of suppliers.

h) Anti-corrosion compounds shall be applied to all mechanical lugs.

i) Hand wells where used should have sufficient strength for the application and shall be fitted with a bolt-on, removable cover. Non-metallic types are preferred, otherwise the cover and frame should be bonded to the system.

j) Street lighting equipment should provide 'ground' lugs' or 'pigtails' for bonding purposes. This includes panels, poles, hand wells and luminaires. Equipment which does not provide for electrical bonding should incorporate guarding or insulation as an alternative means of protection from contact voltage. Compliance with relevant CSA standards is a must. Mast arms may rely upon clearances and insulation (rubber grommets) for protection from contact voltage since most mast arm manufacturers do not provide a bonding lug.

k) Miscellaneous specifications may be required to cover utility locates, tamping, surface restoration and site cleanup.

l) ***Clean surfaces;*** *non-conductive protective coating such as paint or enamel are used on the equipment, conduit, couplings or fittings. Such coating shall be removed from threads and other contact surfaces in order to ensure a good electrical connection.*

2.3.5.3 WHICH METHODS OF GROUNDING ARE ACCEPTABLE?

This section discusses 'how' grounding should be accomplished and does not address the issue of 'how much' grounding is required; 2.3.7 provides that information.

Municipal street lighting systems and equipment shall be solidly grounded using either manufactured or "made" grounding electrodes as defined by the OESC. In-situ grounding involves bonding to existing infrastructure such as building frames, rebar and water pipes and is not recommended for street lighting applications.

"Made" electrodes consist of a bare copper conductor buried either directly in the earth or in concrete and is a method accepted by the OESC. However, where the designer is attempting to establish a solid earth connection for equipment grounding purposes, this method should be augmented by incorporating additional electrodes of the manufactured variety which are buried below the frost line in native soil. Street lighting system designers may take advantage of this by using a bare bonding conductor buried directly in the earth to provide supplemental equipment grounding.

Common manufactured electrodes include rods, plates and copper strips. Each has their purpose and proper application, but where street lighting is concerned, designers should be seriously looking at specifying a good quality ground rod. Of the three, a rod has far superior "grounding characteristics". Unlike a plate, it is able to distribute electrical charges over a much larger volume of earth. Furthermore, when properly driven to its full length it will penetrate into native soil and below the frost line whereas plates are generally buried in much more shallow layers of earth where temperature, humidity and resistivity are less stable and do not promote good conductivity.

Grounding specifications should require that rods be driven to their full length in a manner which does not damage the rod. The OESC permits ground rods to be driven on an angle if necessary.

Ground rods should be copper-clad for corrosion resistance and steel for strength.

Grounding electrodes must be properly spaced if they are to be effective. The optimum spacing for a ground rod is twice its length which would typically be 6 meters and the minimum spacing is the length itself which is typically 3 meters.

Spacing for ground plates is typically 2 meters and burial to a depth of 600 mm is required.

A typical ground rod. **A typical ground plate.**

2.3.5.4 WHAT (IF ANY) RESISTANCE STANDARD SHOULD BE DETERMINED FOR GROUNDING?

Establishing a maximum resistance standard for a grounding system is a valuable method of ensuring that the intended electrical characteristics are being accomplished by the design, that specifications are being followed by contractors when installing the equipment and to facilitate the performance of annual maintenance checks.

Determining a specific resistance standard is however not a simple matter since it must take into consideration system design objectives, economics, earth resistivity, existing underground structures and other factors. Average earth resistivity may be 10,000 ohm-cm, low earth resistivity is defined as < 5,000 ohm-cm and > 20,000 ohm-cm is considered high. High resistivity soils may necessitate the installation of additional electrodes or the use of special methods to achieve your design objectives. Rock and gravel are particularly problematic.

The NEC requires that a service be grounded with a maximum resistance of 25 ohms to earth. This is approximately the value that one properly installed ground rod will yield in soil of 'average' resistivity. The OESC does not specify a particular value, having removed the old 10 ohm requirement back in the 1980's. Ten ohms is however, the approximate value two properly installed ground rods will yield in soil of average resistivity and ten ohms is a commonly specified value in many standards (see US Army TM 5-690, MIL-STD-188-124A, FAA-STD-019d etc).

For this reason, street lighting designers should require that system grounding (at the power distribution panel) yield a maximum value of 10 (ten) ohms to earth.

Supplementary grounding at street lighting poles however, is a separate issue.

Bonding is really the key to protecting human beings from contact voltage by means of supporting effective fault clearance; we cannot rely upon the earth as a path for clearing faults; we are not trying to construct a lightning protection system and placing a single ground rod at each and every pole will not substantially lower step and touch potentials.

For this reason, street lighting designers should not rely upon or invest a significant effort or expense in grounding poles. Where grounding at poles is deemed necessary, the quality of the ground should however be verified. A ground rod placed at a pole should not exceed 25 ohms of resistance to earth. This is a reasonable and attainable value that will not generally require special materials or methods. Lower values are only justifiable for generating stations, central offices, telecommunications towers etc.

The real issue then becomes one of, how many rods do we install at the poles? To answer this question we must once again review our design objectives and ask ourselves what it is exactly that we are trying to achieve. In consideration of both safety and economy it would be best not to make an arbitrary decision. Unfortunately, no definitive quantitative criteria exists upon which to set this value since no particular design objective is served.

Old standards recommend grounding every fifth pole and the last pole in the system, but since pole spacing standards vary greatly, this practice will yield varying results. As a result the recommendation which follows is based on traditional power utility practice instead.

In order to provide a nominal level of supplementary equipment grounding for step and touch potentials, lightning, accidental contact with high voltage wires and a measure of redundancy for the bonding conductor the street lighting design may require the installation of one ground rod a maximum of every 300 meters.

It may be of interest to note that contact voltage and stray current hazards only exist in the first place because we reference our electrical power transmission and distribution systems to earth at the transformers. In most of North America we use a TN-C-S system.

This means that neutral and ground are combined up to the service and separate afterwards. European designers may be familiar with a different system.

Furthermore, it is crucial that designers dismiss the erroneous notion that 'electricity always exclusively follows the path of least resistance'. Nothing could be further from the truth. In fact, electricity follows all available paths in inverse proportion to the relative impedances of those paths, back to the source (the distribution transformer).

This is known as Kirchhoff's current law and it is because of this law that a faulted hot conductor making contact with a pole will pass current through a human or animal body to the earth and take this or any other path available back to its source. The problem is that the low level of current (milliamps) that it takes to kill or seriously injure a human being is far too small to operate a standard fuse or breaker.

Once again it is the bonding conductor that protects us. It provides a direct low impedance path back to the source so that sufficient fault current will flow (as dictated by Ohms law) which then operates the breaker or fuse and removes the source of power until such time that trouble shooting and repairs can take place.

2.3.5.5 What, how & when do we test the system?

a) Earth resistivity studies shall be conducted using the standard 4 point, Wenner, fall-of-potential method with a properly calibrated instrument prior to designing the system.

b) Resistance to earth of a grounding system should be measured using a 3 point test with a properly calibrated instrument. This test must be conducted prior to connection and prior to energizing the system. Do not use a clamp-on instrument for verifying the resistance of a newly constructed grounding system. Clamp-on instruments can be useful for monitoring changes in existing systems once a base line is established and can be used without disconnecting the ground electrode conductor or de-energizing the system.

   Resistance values obtained will vary with rainfall and temperature.

c) Many companies manufacture the required instrumentation.

Choose an instrument which filters out common circulating earth currents and provides a low resistance range for testing bond resistances. Calibrate it on an annual basis.

d) Leakage current to ground may be a useful measurement to make once the system is commissioned.

2.3.5.6 HOW CAN A GROUND SYSTEMS' RESISTANCE BE LOWERED IF TARGETS ARE NOT OBTAINED?

The resistance to earth of a grounding system can be lowered by the following methods:

a) increasing the number of grounding electrodes.
b) increasing the length (depth) and surface area of electrodes.
c) the use of horizontal grounding grid wires.
d) the use of ground enhancement materials such as conductive concrete.
e) the use of a more effective grid pattern (for example using a triad vs. linear row)
f) the use of exothermic welding or compression fittings rated for direct burial.
g) installing the rod in undisturbed soil away from the base is preferred

Ground electrode and bonding conductor impedances can be lowered by not coiling excess wire in hand wells and by eliminating sharp right hand bends wherever possible.

Chemically enhanced ground rods are premium products available to install for street lighting applications and may require special safety and environmental issues.

2.3.5.7 HOW SHALL STREET LIGHTING EQUIPMENT BE BONDED?

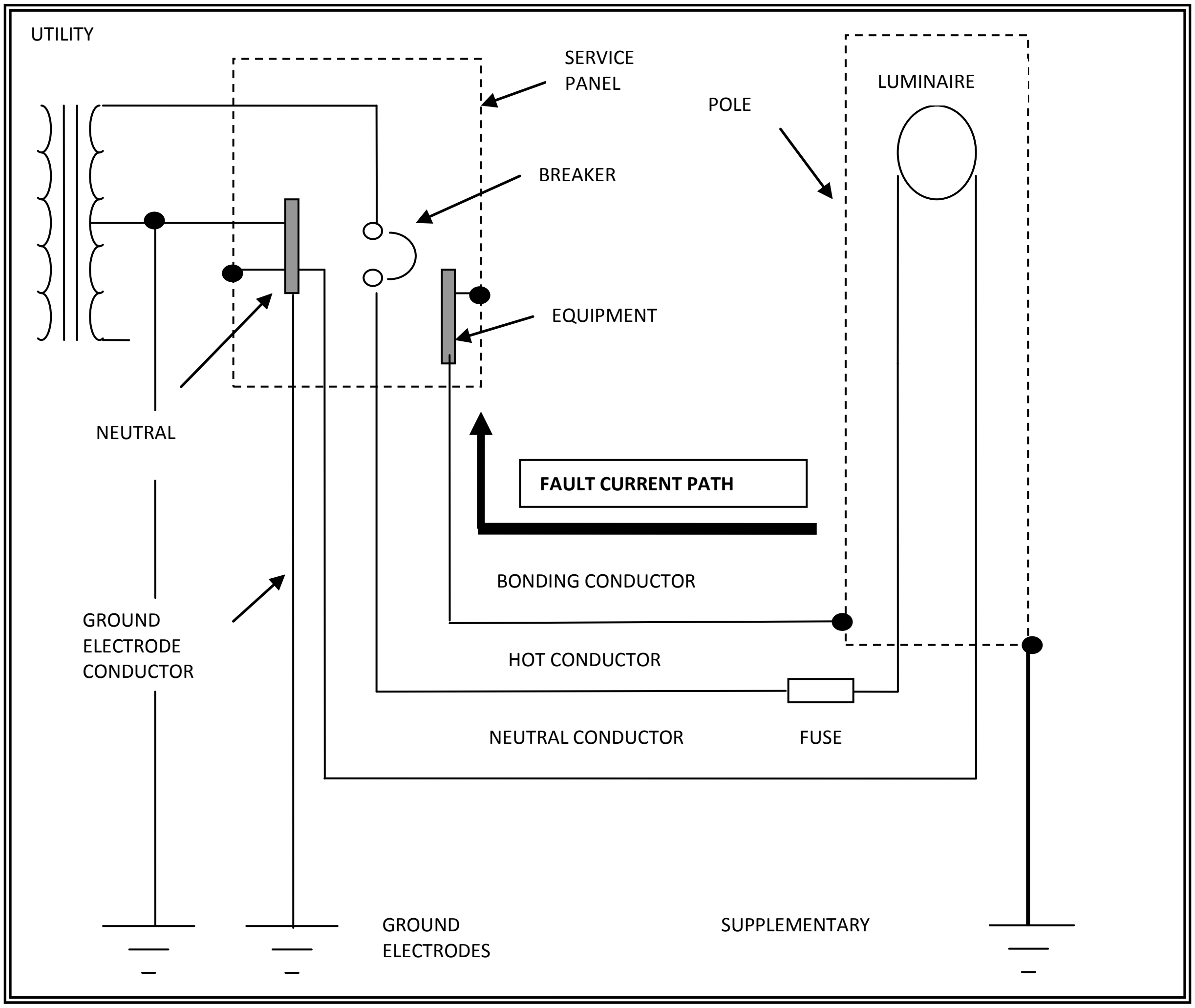
Bonding shall be specified in such a manner to provide a continuous electrical path of sufficient ampacity and low impedance to support the effective operation of protective devices.

Bonding of neutral to ground in the service panel is usually achieved by a jumper or brass screw located between the neutral bus bar and the equipment frame or equipment grounding bus bar. Because this jumper is removable, it is important to verify the presence and integrity of this main bonding connection at the time of installation.

Bonding to poles and luminaires is accomplished at designated 'ground' lugs or with pigtail wires supplied by the equipment manufacturer. Concrete poles must provide for a continuous bond between internal rebar (in the pole) and the ground lug provided.

Pole hand hole covers on non metallic poles should be of a non-metallic material. Where a metal cover is used, consideration should be given to positively bonding the cover with a bonding jumper rather than relying on the mounting screws for a solid bond. The mounting screw shall be tamper proof.

Electrically bonding the poles to each other and to metal hand hole frames shall be accomplished using stranded copper wire. This bonding conductor shall run continuously from the equipment grounding bar in the service panel to the last pole in the system.



Power Distribution Schematic Diagram

2.3.6 The Impact of Grounding Practices on Equipment Function

In addition to the previous recommendations, grounding and bonding specifications must take into consideration equipment manufacturer's requirements. New technologies are emerging and the street lighting designer must remain cognizant of new developments because they may have implications for grounding and bonding.

Should the designer decide to specify Ground fault protection or detection equipment at the power distribution panel, the requirements, limitations and characteristics of the grounding and bonding system must be fully understood in order to achieve the design objectives Grounding also has implications for harmonics and power quality issues that may require consideration.

Finally, and for future consideration, where electronic ballasts, LED's and adaptive lighting methods are employed, it may be necessary to provide a superior standard of grounding to support the function of Surge Protection Devices (TVSS), devices that are incorporated into many modern electronic products.

Solar powered, LED Street light.

Electronic Ballast.

2.3.7 Summary of Essential Minimum Requirements

- Bond all non-current carrying metallic components to the service ground bar.
- Size all conductors, including the bonding conductor, to meet ampacity and impedance requirements.
- Connect the service panel neutral bar to earth using at least 2 ground rods.
- perform inspection of the bonding system when installed
- Meet or exceed all OESC and manufacturer requirements.

2.4 Voltage Drop

All electrical equipment has a specified operating voltage range for normal operation. In order to meet this voltage range, the voltage drop associated with the electrical circuit delivering power to the equipment must be minimized. Streetlight luminaires are typically powered by ballast or a driver circuit (in the case of LED luminaires) which has the capability of regulating the voltage output to the lamp.

The maximum permissible voltage drop from the point of power supply to the point of equipment utilization shall not exceed the maximum percentage specified for each luminaire. Example, luminaires supplied with CWI ballast can typically withstand a maximum voltage drop of 10% of the rated line voltage. Therefore, for a 120V supply voltage these luminaries will operate effectively (minimal reduction in light output) with a voltage drop of 12V. However, when streetlight circuits are to be installed on sections of the distribution system where the primary voltage is lower than nominal, the voltage drop allowable on the streetlight circuit should be adjusted to reflect the lower primary voltage. Also, in order to allow for a margin of safety in the design, the manufacturer suggested maximum voltage drop should be reduced. Hence, as a good design practice, the maximum voltage drop on circuits utilizing these ballast (CWI) should be in the range of 9 – 10V. The maximum voltage drop may also be limited by the fault current required to operate the protective device at the service entrance. That is, the circuit length must be restricted to ensure that the impedance of the circuit is low enough to generate sufficient fault current at the furthest luminaire to trip the upstream protective device in a timely manner.

In order to calculate the voltage drop along a streetlight circuit, the following information should be known;

- conductor type and size (determines the Impedance per unit length), Z
- segment length (length between each luminaire), L
- load drawn by each luminaire (i.e. lamp wattage plus ballast load), I

The conductors (wire) carrying current to the luminaires in the street lighting system have a small amount of impedance (resistance and reactance). The impedance of the wire depends on the size of the wire, the material of the wire, the length of the wire and the temperature of the wire. When current flows through the wires on its way to the luminaires, a voltage drop proportional to the impedance and the current is developed along the length of the wire. This voltage subtracts from the voltage at the source of power (voltage drop) and results in a lower voltage at the luminaires. If the impedance of the wire is too high for the amount of current flowing through it, the voltage dropped along the wire will be too high to allow sufficient voltage at the luminaires. High resistance can also result in conductor overheating. The square of the current (I^2) flowing through the wire multiplied by the resistance of the wire (R) yields the power dissipated in the wire as heat (I^2R). Therefore, the higher the resistance of the wire, the higher the voltage dropped along the wire, and the more power is used up by the wiring system. The OESC suggests a value of 5% of the system voltage as the maximum allowable voltage drop in a lighting branch circuit. However, for Roadway Lighting Systems (such as streetlight circuits), OESC 2009 Bulletin 75-6-* permits the voltage drop to exceed 5%, provided that the voltage drop does not result in a voltage at the luminaire that is outside the rated operating voltage limitations of the luminaire. This is applicable on dedicated streetlight circuits only.

The voltage drop calculation determines the size (gauge) of wire of a specified material that is necessary to carry the required current the required distance without creating too large of a loss in the wire.

The voltage drop along each segment can be found by using the following approximation:

V_d=I* $R\cos\phi + IX\sin\phi$

Where:

V_d	is the voltage drop along a segment of wire
I	is the current through the same length of wire
R	is the resistance for the segment of wire
X	is the reactance for the segment of wire
ϕ	is the load angle
Cosϕ	is the load power factor
Sinϕ	is the load reactive factor

It should be noted that the above equation is an approximation but gives very accurate results for typical streetlight circuits

The values for R and X can be obtained from manufacturer or via published data such as tables in IEEE std 141 "IEEE Recommended Practice For Electric Power Distribution for Industrial Plants" and the NEC (National Electric Code).

The current, I, for any segment of wire is calculated by adding the currents for each luminaire the particular segment of wire feeds (i.e. all the luminaires downstream on that wire). The Resistance, R, and Reactance, X, for a particular segment of wire is calculated by multiplying the length of the wire in that segment by the impedance per unit length (e.g. ohms/km) of wire for that particular size and material of wire. The total voltage drop to the farthest luminaire is calculated by adding the voltage drops for each segment of wire from the service entrance (or supply point) to that luminaire.

When calculating the voltage drop for a circuit, the voltage drop must be calculated for the phase wire (hot wire) and for the neutral wire. This is especially true for a two-wire circuit in which the current that travels out in the phase wire must return in the neutral, and so the current in the neutral wire is the same as the current in the phase wire. The total voltage drop in the two-wire circuit, then, can be calculated by determining the voltage drop in just the phase wire and multiplying that number by 2 (assuming that both wires are the same size and type). Alternatively, the impedance per unit length can be doubled (multiplied by 2) and proceed with the normal voltage drop calculation.

On three-wire systems (two phase wires and one neutral), the neutral current represents the sum of the two phase currents. However, the phase currents are opposite each other and if the phase currents are equal, then the total neutral current will be zero. That is, the current returning in the neutral wire from one of the phase wires will cancel out the current returning in the neutral wire from the other phase wire. Therefore, if the loads on the two phase wires are balanced, there will be no current in the neutral wire, hence, no voltage drop in the neutral wire. In this case, the total voltage drop to the farthest luminaire is simply the total voltage drop in the phase wires, and the neutral wire can be disregarded.

VOLTAGE DROP EXAMPLE

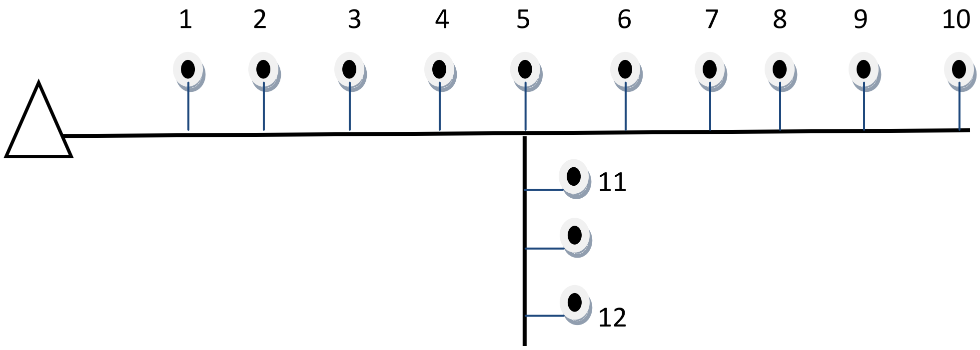
Supply voltage: 120V

Streetlight bus: 2-#4 Cu USEI75 Cable (characteristic phase impedance = 1.956 ohms/km)

Luminaires: 150W HPS (1.67A total lamp load) spaced at 30m apart

Service entrance/Source located 20m away from first luminaire.

Assume that maximum voltage drop will be at luminaire #10



Street Lighting Voltage Drop Calculation — November 23, 2010

Project: ESA Streetlight Working Group - Example — File:

Load Power Factor (cosϕ) 0.9 — Load angle, ϕ 0.451 rads

Luminaire No. & Size	Span To Next Luminaire, L (m)	Resistance To Next Luminaire, R_L (ohms/km)	Reactance To Next Luminaire, X_L (ohms/km)	Impedance To Next Luminaire, Z_L (ohms/km)	Load Current At Luminaire: From Luminaire (A)	Load Current At Luminaire: From Branches (A)	Load Current At Luminaire: From Last Luminaire (A)	Total Load, I (A)	Voltage Drop Accurate: To Next Luminaire (V)	Voltage Drop Accurate: Total at Luminaire (V)
0 Transformer	0	0	0	0	0		23.37	23.37	0.000	0
0 Relay	20	0	0	0	0		23.37	23.37	0.000	0
1 150W HPS	30	1.71	0.487	1.778	1.08		22.29	23.37	1.228	1.228
2 150W HPS	30	1.71	0.487	1.778	1.08		21.21	22.29	1.171	2.399
3 150W HPS	30	1.71	0.487	1.778	1.08		20.13	21.21	1.114	3.513
4 150W HPS	30	1.71	0.487	1.778	1.08		19.05	20.13	1.058	4.571
5 150W HPS	30	1.71	0.487	1.778	1.08		17.97	19.05	1.001	5.572
6 150W HPS	30	1.71	0.487	1.778	1.08	5.0	11.88	17.97	0.944	6.516
7 150W HPS	30	1.71	0.487	1.778	1.08		10.80	11.88	0.624	7.140
8 150W HPS	30	1.71	0.487	1.778	1.08		9.72	10.80	0.567	7.707
9 150W HPS	30	1.71	0.487	1.778	1.08		8.64	9.72	0.511	8.218
10 150W HPS	30	1.71	0.487	1.778	1.08		7.56	8.64	0.454	8.672
11 150W HPS	0	0	0	0.000	1.08		6.48	7.56	0.000	8.672
12 150W HPS	0	0	0	0.000	1.08		5.40	6.48	0.000	8.672
13 150W HPS	0	0	0	0.000	1.08		4.32	5.40	0.000	8.672
14 150W HPS	0	0	0	0.000	1.08		3.24	4.32	0.000	8.672
15 150W HPS	0	0	0	0.000	1.08		2.16	3.24	0.000	8.672
16 150W HPS	0	0	0	0.000	1.08		1.08	2.16	0.000	8.672
17 150W HPS	0	0	0	0.000	1.08		0.00	1.08	0.000	8.672
18 150W HPS	0	0	0	0.000	0.00		0.00	0.00	0.000	8.672
19 150W HPS	0	0	0	0.000	0.00		0.00	0.00	0.000	8.672
20 150W HPS	0	0	0	0.000	0.00		0.00	0.00	0.000	8.672

Max. volatge drop **8.7**

Characteristic Impedances of Standard Street Lighting Conductors - KWHydro (Phase + Neutral)

	R	X	Z	
1-4/0 Al & 1-2/0 ACSR overhead quadruplex	0.687	0.412	0.80	ohms/km @ 25 °C
1-#2 Al & 1-2/0 ACSR overhead duplex	1.278	0.436	1.35	ohms/km @ 25 °C
1-#4 Al & 1-4 ACSR overhead S/L cable	2.765	0.504	2.81	ohms/km @ 25 °C
2-#4 Cu underground S/L cable	1.710	0.487	1.78	ohms/km @ 25 °C
2-#1 Cu underground S/L cable	0.845	0.459	0.96	ohms/km @ 25 °C

Typical Lamp Loads

70W HPS	0.83 A
100W HPS	1.08 A
150W HPS	1.67 A
200W HPS	2.08 A
100W MH	1.13 A
175W MH	1.75 A
250W MH	2.33 A

HPS - High Pressure Sodium

MH - Metal Halide

Terminology: Source <---------------[]-----------------------------[]------------------------------[]----------------------------[]

Next Luminaire — Luminaire — Last Luminaire

Calculated voltage drop = 8.7 V

% Voltage Drop = 8.7/120 = 7.25%

2.5 Demarcation Points and Service Entrances

Demarcation points play a role in determining which party owns existing electrical infrastructure in the field. Demarcation points play a larger role at present than they did in the past.

For most Ontario municipalities, the implementation, growth, operation and maintenance of street lighting systems were originally handled entirely by the LDC. By consequence the street lighting systems grew up together with the hydro distribution systems with little difference made between the two (components & wiring practice).

As of January 1, 2003, most Ontario municipalities have been assuming ownership of the street lighting systems which exist within their region. They also have been assuming the management responsibilities which the LDC previously undertook. This has resulted in the present day scenario in which municipalities and their LDC must work to differentiate between the municipal street lighting system and the hydro distribution system.

To complicate this matter further, there is no consistent standard across Ontario detailing which party owns which electrical infrastructure in any given application; it differs from municipality to municipality.

In some instances this matter has proven to be highly contentious, as the demarcation points on existing infrastructure may be undefined. This has resulted in, and may continue to result in:
1. Both the LDC and SLAO failing to locate a buried cable under the assumption that the cable belongs to the other party,
2. Both the LDC and SLAO failing to maintain degrading electrical wiring under the assumption that the wiring belongs to the other party. This may result in potential shock hazards.

As such, greater emphasis must be placed to establish a solid demarcation point on all existing infrastructure. It is recommended that each SLAO and LDC define and document which assets each party owns and is operationally responsible, especially as it pertains to electrical shock hazard mitigation and keeping the general public safe. This is particularly important for underground cable locates.

The following illustrations are examples of the multiple demarcation point scenarios possible within existing conditions and exemplify the need for clearly defined demarcation points such that both the Asset owner and the LDC are aware of what infrastructure they own and maintain.

***1st Scenario:* LDC Secondary Feeding both SL and all other customers along bus**

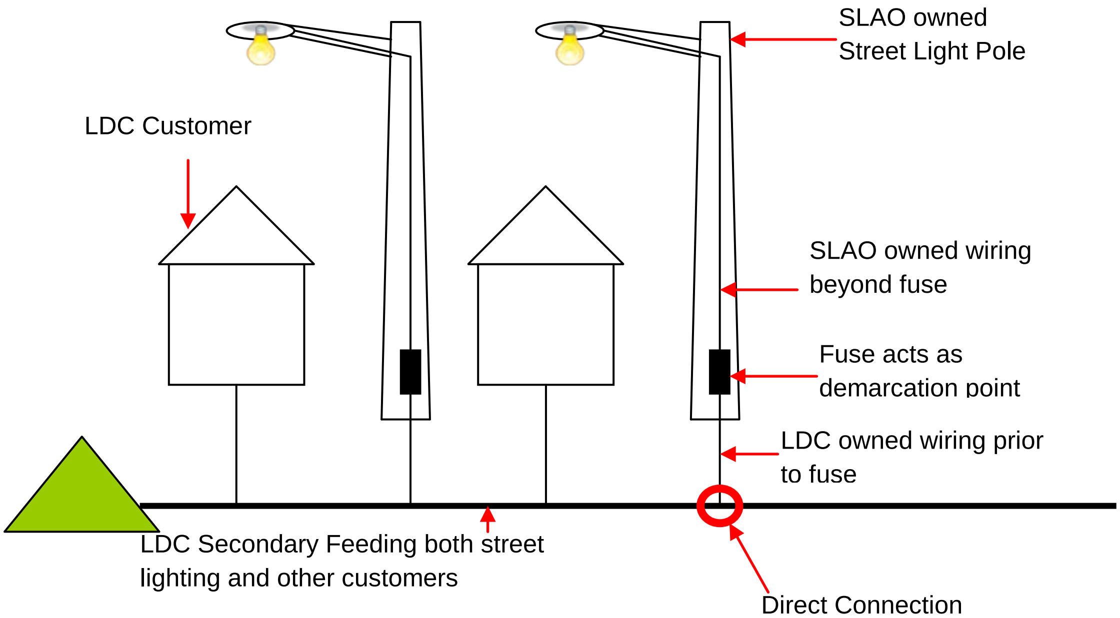


Illustration 1-1 *(above)* – LDC Bus feeding both Street Lights and customers. Street Light Poles are SLAO owned with fusing located in the hand hole.

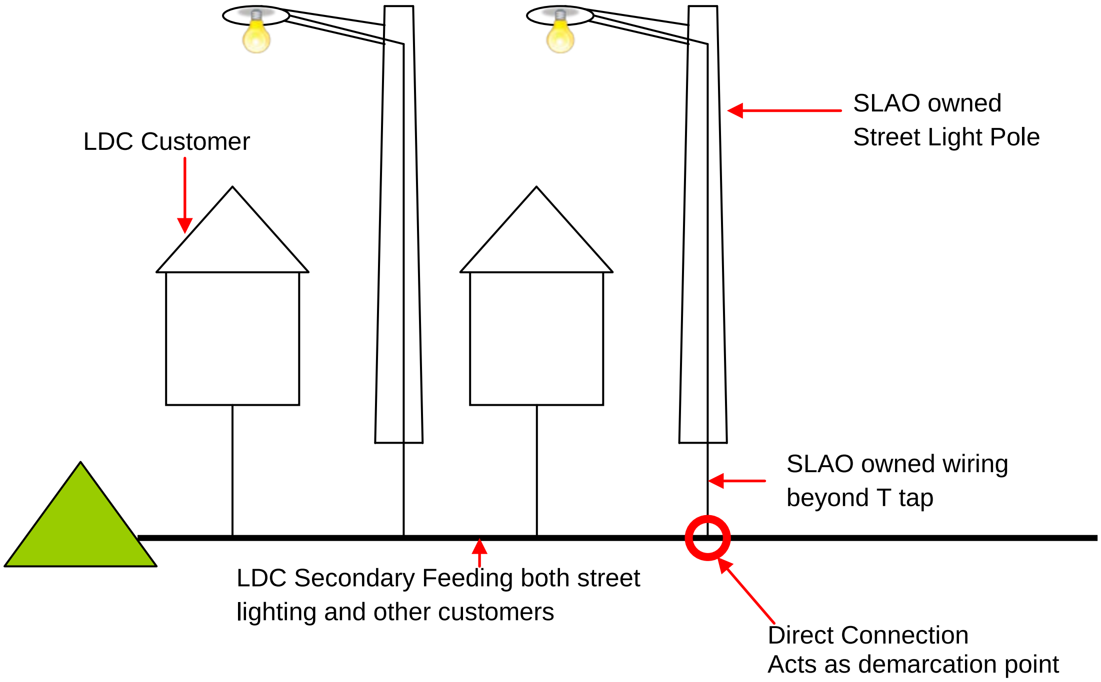


Illustration 1-2 *(above)* – LDC Bus feeding both Street Light and customers. Street Light Poles are SLAO owned and un-fused.

__2nd Scenario: 3 Examples of how wiring ownership can be defined in a single scenario.__
LDC feeding dedicated street lighting bus. Street light poles are SLAO owned with fusing located in the handhold.

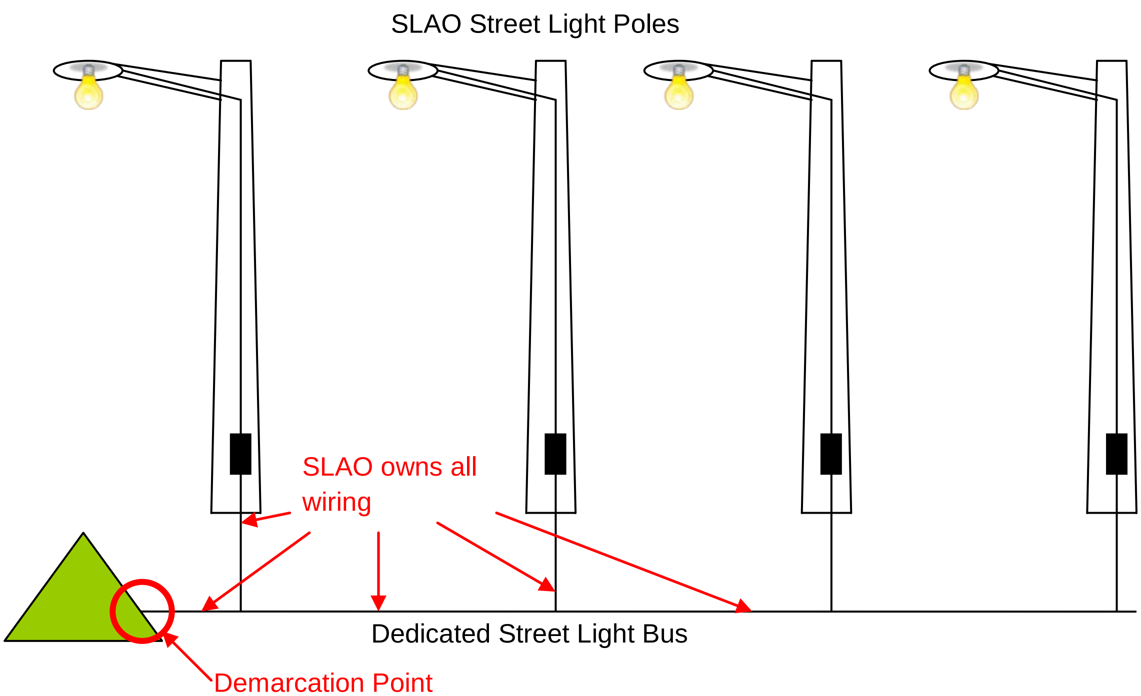


Illustration 2 – 1 *(above)* - The SLAO owns all wiring infrastructure directly out of transformer including the street light bus.

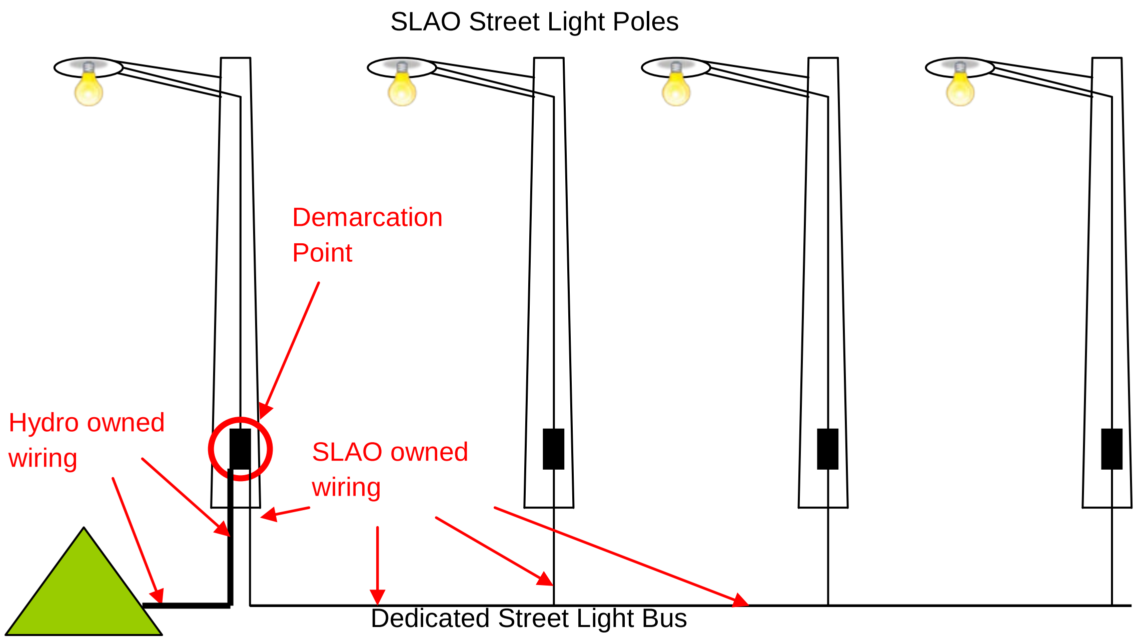


Illustration 2-2 *(above)* - The SLAO owns all wiring after the fuse located in the first pole

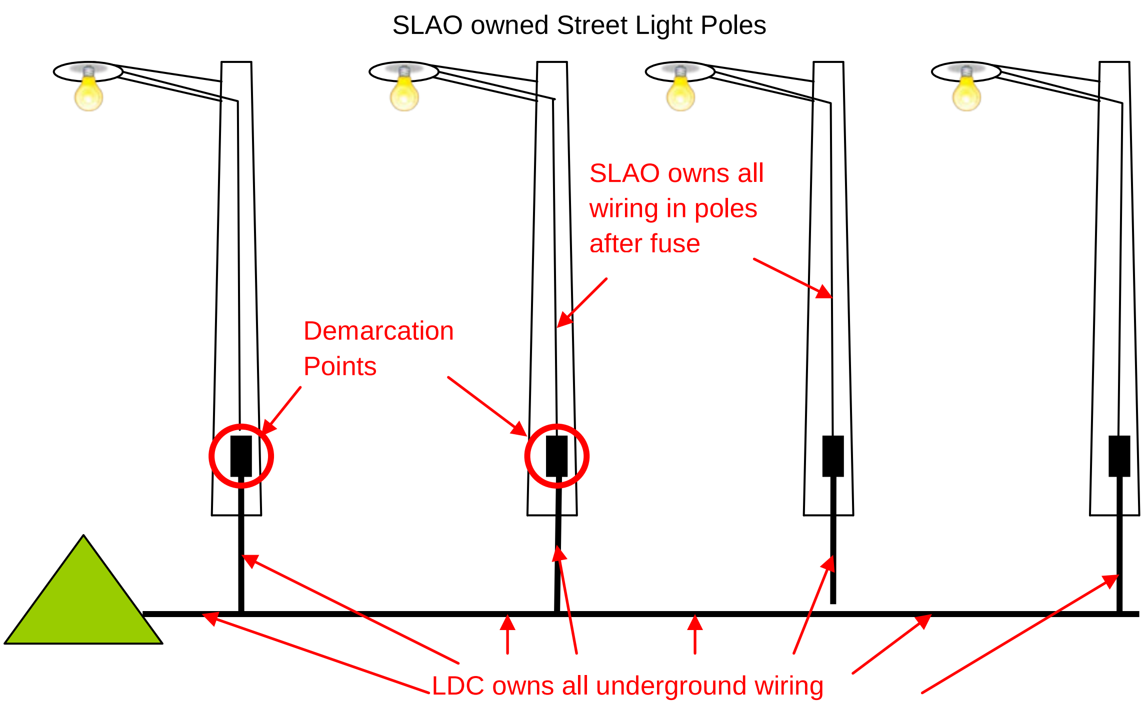


Illustration 2-3 *(above)* - The SLAO owns the wiring in the pole only, between the fuse and the street light. In this case the LDC owns all underground wiring.

In new street lighting installations, it is recommended that the point of demarcation be defined as the service entrance for the street lighting systems or the street lighting pedestal. The street lighting pedestal itself is generally owned by the SLAO (*See Illustration 3 below)*.

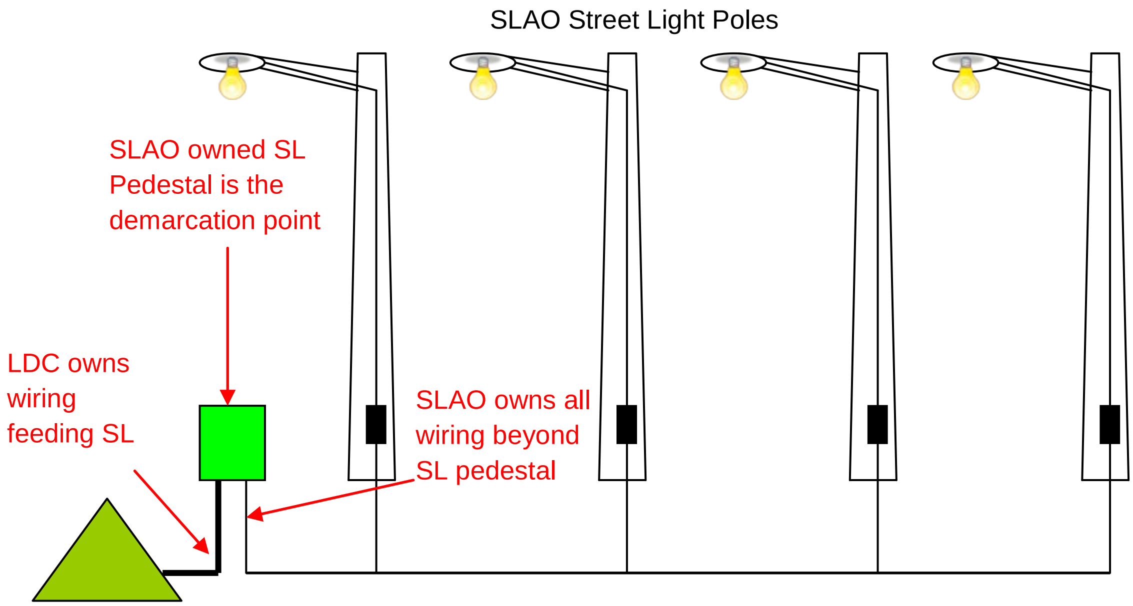


Illustration 3 *(above)* – Demarcation point practice for new street lighting installations.

It is suggested the street lighting pedestal be physically located in an area where accidents causing physical damage to the pedestal are least likely to occur. An example of this is to place the pedestal away from any intersections.

In new street lighting installations in which there is only one street light being added to the existing hydro grid, then the in-line fuse will act as the demarcation point. Typical examples of this is when the SLAO wishes to add a single street light to an existing hydro pole with existing hydro secondary already in place.

For Overhead installations, refer to OESC Bulletin 75-6-*

2.6 Inspection and Verification

The Ontario Electrical Safety Code requires a contractor to file with the inspection department of the Electrical Safety Authority (ESA), a completed application for inspection of any work on an electrical installation before, or within 48 hours after, commencement of the work.

Contact number for taking out an application for inspection is:
1 877 ESA SAFE (1 877 372 7233)

The site or location is required to be made accessible to the ESA inspector. Wiring shall not be concealed until it has been inspected

Once ESA has determined the installation is in full compliance with the Ontario Electrical Safety Code, a Connection Authorization will be issued to the LDC allowing the energization of the equipment. A certificate of inspection will be issued to the contractor.

The asset owner may require an inspection of the installation prior to energization to ensure municipal standards have been met, separate from the ESA inspection.

2.7 THIRD PARTY ATTACHMENTS AND REGULATION 22/04

Licensed Distribution Companies (LDC's) are required under Ontario Regulation 22/04 to design, construct and maintain electrical distribution systems they own up to 50kV to the customer's demarcation point. The regulation is objective based and relies on Engineer approved standards meeting the minimum requirements of CSA.

2.7.1 DESIGN

Third party attachments such as telecommunication equipment, street lighting, decorations, signs etc. are not part of the distribution system. However, to the extent these attachments may affect the safety of the distribution system, they may be indirectly subject to the Regulation. Hence, prior to authorizing third party attachments, the distributor is to ensure that attachments to its distribution systems meet the safety requirements of the Regulation.

Authorizing the third party attachments may be as simple as confirming that the equipment installations that are being proposed by a third party are consistent with the distributor's Standard Designs. Alternately, the authorization may require detailed evaluation, by the distributor or the third party, to determine whether the attachments meet the safety requirements. In granting approval for attachments, the distributor is to note limitations and requirements that are relevant to its applicable Standard Designs or to the plan submitted.

2.7.2 CONSTRUCTION

For third party construction, the distributor should ensure that the construction is in compliance to its Standard Designs or to an approved plan. The distributor could inspect the site using a qualified person or require assurance of construction compliance to Standard Designs or to approved plan from the third party. Any variation from Standard Designs or plan should be noted for resolution by the owner in the record of inspection.

Once the inspection record has been prepared and all non-compliances have been rectified the distributor can prepare and issue a Certificate (*). The purpose of the Certificate is to ensure that there is no negative impact on the distribution system by the third party installation and does not require the approval of the third party's equipment by the distributor. In these installations, it is likely that the construction will be placed into service by the third party prior to a Certificate being issued.

When a distributor determines during the course of its operation that a third party attachment does not comply to its Standard Designs or approved plan, the distributor should advise the third party of the non-compliances and could pursue additional remedial solutions through its attachment agreements. Where the third party does not rectify the non-compliance within a reasonable time, the distributor may notify ESA, who in turn may carry out its own investigation.

(*) Note: The issuance of a Certificate by the distributor is subject to the cooperation afforded by the third party.

2.7.3 THIRD PARTY ATTACHMENTS TO STREET LIGHTING PLANT

Street lighting asset owners will often find third party attachments on their plant without any prior notification. Street lighting infrastructure is often used to support temporary communication system repairs. The party attaching to street lighting assets is required to obtain permission from asset owners prior to installing any plant. The street light asset owner must ensure that their asset will support the proposed third party attachment. The installation of banners on street light poles is especially critical to ensure that the forces created by wind loading are supported by the street light pole. Asset owners are encouraged to investigate the use of third party attachment agreements so that all parties understand the liabilities and responsibilities

3.0 OPERATION AND MAINTENANCE

3.1 MINIMUM MAINTENANCE GUIDELINES

3.1.1 GENERAL

The Roadway Lighting System should be maintained according to this guideline. Defects in the Roadway Lighting System should be identified, documented, and corrected by appropriate action, whether by Routine Maintenance or Non-Routine Maintenance.

3.1.2 THE ONTARIO ELECTRICAL SAFETY CODE (OESC)

The Ontario Electrical Safety Code identifies that work performed on Roadway Lighting Systems must be inspected by the Electrical Safety Authority (ESA). Inspections and permits may be requested individually, or an annual inspection agreement may be entered into with the ESA by completing the "Contractor Application for the Inspection of Electrical Maintenance Work Performed on Roadway Electrical Systems". This application and additional information can be found on the Electrical Safety Authority's website at www.esasafe.com. Copies of all ESA inspection reports should be kept on file.

3.1.3 CANADIAN STANDARDS ASSOCIATION (CSA)

When required for the purposes of the electrical work, all electrical components shall be according to CSA requirements. Provincial, Federal and local laws and by-laws pertaining to the electrical work, as well as, by the latest issue of CSA Standards pertinent to the electrical work, shall govern all electrical work. In the event of conflict of regulations, the strictest regulation shall apply.

3.1.4 NON-ROUTINE MAINTENANCE

Non-Routine Maintenance is required whenever there is a Critical Failure of any system component of the Roadway Lighting System or whenever vehicular accidents, weather or other factors have caused damage to System Components. Critical Failures of the Roadway Lighting System are identified in *Table 2* below.

After detecting or being made aware of the Critical Failure, Non-Routine Maintenance should be initiated in a timely manner.

Table 2
Critical Failures in the Roadway Lighting System

Critical Failure
Aerial Span Wire Down
Pole Knocked Down or Hit
Power Supply Knocked Down
Power Supply Failure
Ground Fault
Presence of Voltage on Non-Current Carrying System Components
Energization of Surfaces Accessible by the Public
Overhead equipment unfastened or hanging over roadway
Damage that exposes the public to energized electrical equipment (e.g. vandalism)
Faulty Photo Control Circuits for Group Control of Lighting
Unbalanced, unlatched or partially unlatched high mast lighting ring
Failure of a Pole, Arm, or other Structural Element

3.1.5 ROUTINE MAINTENANCE

Routine Maintenance activities should be completed on all Roadway Lighting Systems and should include:

- Inspecting, checking, elementary testing, cleaning, lubricating and performing minor repairs on all Roadway Lighting System Components including luminaires, lighting brackets, wiring, poles, frangible and safety bases, pads and footings, lowering and raising devices, sub-stations, distribution assemblies, cabinets and power supplies on a regular basis.
- Visual inspection and repair of all grounding and bonding connections and terminations once every 4 to 5 years as part of the relamping cycle. Check that all connections and terminations are tight; and that wires are not corroded, frayed, or broken.
- Testing, repair and replacement of faulty components on all Roadway Lighting System Components including luminaires, lighting brackets, wiring, grounding, poles, pole bases, frangible and safety bases, pads and footings, lowering and raising devices, sub-stations, distribution assemblies, cabinets and power supplies a minimum of once every 4 years..

Luminaires that are replaced should be replaced with luminaires of similar photometric performance, or as directed by the asset owner.

- Perform ground resistance testing at each power supply ground electrode a minimum of once every 4 years.
- Perform ground resistance testing at each ground grid and ground electrode a minimum of once every 8 years.
- Group replacement of light sources (lamps) in Roadway Lighting Systems on a fixed cycle according to Table 2.

In addition to the aforementioned Routine Maintenance activities, the following activities should be completed for all High Mast Lighting Systems:

- Top-latching raising and lowering systems should be inspected, operationally tested, and maintained at least once every 2 years.
- Non-latching raising and lowering systems should be inspected, operationally tested, and maintained at least once every 6 months.

Table 3
Recommended Group Replacement Cycle for Light Sources in Roadway Lighting Systems

Light Source	Group Replacement Cycle (years)
High Pressure Sodium	4-5
Metal Halide	3 - 4
Low Pressure Sodium	3 - 4
Induction	Replacement according to the manufacturer's recommendations and the owner's experience
Light Emitting Diode	Replacement according to the manufacturer's recommendations and the owner's experience

3.1.6 Electrical Power Supply for other Facilities

Some non-LDC power supplies provide power to both Roadway Lighting Systems and other systems. Where safe and practical to do so, maintenance on the Roadway Lighting Systems should be performed without de-energizing the other systems.

3.1.7 Routine Maintenance and Inspection Reports

Routine Maintenance and Inspection Reports should be completed for all routine maintenance activities and should contain the following information:

- Date, time and origin of report
- Location of deficiency
- Date and time of arrival at the site
- Weather conditions at the site
- Defects as observed
- Steps taken to rectify the defects and description of repair work completed
- Inspection reports shall include status of the following functions:
    - operational status
    - Status of all protection equipment – surge protectors, breakers, lightning arrestors, etc.
    - Conditions and status of all hardware, poles, luminaires, etc.
- Status of all grounding and bonding equipment
- Any additional or follow-up work that may be required and the relative urgency of the follow-up work required and temporary repairs made.
- All reports must contain full details of work performed.
- Date and time repairs were completed

3.1.8 Non-Routine Maintenance and Inspection Reports

Non-Routine Maintenance and Inspection Reports should be completed for all non-routine maintenance activities and should contain the following information:

- Date, time and origin of report
- Location of deficiency
- Date and time of arrival at the site
- Weather conditions at the site
- Defects as observed
- Steps taken to rectify the defects and description of repair work completed
- Inspection reports shall include status of the following functions:
  - operational status
  - Status of all protection equipment – surge protectors, breakers, lightning arrestors, etc.
  - Conditions and status of all hardware, poles, luminaires, etc.
- Status of all grounding and bonding equipment
- Any additional or follow-up work that may be required and the relative urgency of the follow-up work required and temporary repairs made.
- Note of any police officer's name and badge number and complete damage report detailing material and repairs required.
- Record Incident or Motor Vehicle Collision Number if available
- All reports must contain full details of work performed.
- Date and time repairs were completed

3.1.9 Emergency Locates

Emergency locates may be required in order to proceed with emergency repairs to protect public and worker safety and to repair roadway infrastructure or other infrastructure within the roadway right-of-way (e.g. utilities). Therefore emergency locates should be performed in a timely manner and with the same dispatch as Non-Routine Maintenance on Critical Failures of the Roadway Lighting System.

3.1.10 Outcome Targets

The Roadway Lighting Systems should be maintained such that the following outcome targets are met or exceeded:

Feature	Outcome Targets
Roadway Lighting System	✓ Response to all Critical Failures in a timely manner from the time of detection or being made aware of the Critical Failure. ✓ Permanent or temporary repairs completed or made safe before leaving the site ✓ Permanent repairs completed in a timely manner. ✓ For continuous lighting, the percentage or number of luminaires not functioning, and the duration of the non-functioning, does not exceed the limits in the "Minimum Maintenance Standards for Municipal Highways" (Ontario Regulation 239/02). ✓ For partial lighting, no more than 30% of the luminaires connected to a power supply not functioning, and no single luminaire not functioning for more than 14 days from the date of being made aware of, or upon detection of, the failure. ✓ Bonding and grounding System Components perform their intended function and comply with the Ontario Electrical Safety Code in place on the date of installation.

Feature	Outcome Targets
High Mast Lighting System	✓ Response to all Critical Failures in a timely manner from the time of detection or being made aware of the Critical Failure. ✓ Permanent or temporary repairs completed or made safe before leaving the site ✓ Permanent repairs completed in a timely manner. ✓ No more than 25% of the luminaires per high mast lighting pole not functioning. ✓ Bonding and grounding System Components perform their intended function and comply with the Ontario Electrical Safety Code in place on the date of installation.

3.2 Typical Lights-Out Procedures – Troubleshooting

- Disconnect inline fuses for the streetlight luminaire
- Test incoming voltage at fuses
- Test fuses
- Repair luminaire as necessary
- Reconnect fuses
- Test incoming voltage at luminaire
- Secure all ground connections to the pole hand hole, handwell and any other ground connections at the pole
- Visually establish the integrity of the ground wires, crimps, etc.

For detailed lights out procedures refer to IES DG-4: Design Guide for Roadway Lighting Maintenance

Temporary Repair (Response Maintenance)

1. Response Maintenance is defined as the response to a reported or discovered malfunction of street light. Prioritize all calls and actions to maintain public safety and convenience. The priorities should consider all situations such as:
   a) Public and personal safety
   b) Impact on traffic flow/pattern
   c) Location of problem
   d) Time of day
   e) Scope of remediation (repairs, modification, replacement, etc.)
2. Request help (e.g. journeyman, lineman, policeman) if possible and use the safest method for all existing conditions.
3. After the work site is secured, the repairperson shall then correct the malfunction of minor nature. This corrective action shall include, but not be limited to, the activities as follows:
   a) Check for contact voltage
   b) Check for power and line source
   c) Replacement of blown fuses or resetting of circuit breakers
   d) Repair or replacement of electrical cabinet
   e) Replacement of the malfunctioning photo cell
   f) Replacement of the malfunctioning ballast
   g) Replacement of the street light fixture
   h) Perform load check (as per Section 3.3.4)
   i) Check again for contact voltage
   j) Ensure site is left safe, with no undue harm potential to the public as per Local and Provincial Standards
4. For knockdowns (poles, cabinet, etc.), remove facilities if possible to reduce potential damage. Refer to Emergency Repair Procedure. Coordinate with on-duty police officer at site. Replace unsafe component or cabinet.
5. If a power outage occurs, the appropriate LDC shall be informed to restore power source.
6. If the damage affects public safety, the repairperson should contact and coordinate with the police to ensure site safety prior to leaving the site.

   The repair person shall record all completed work activities on a work order or similar documentation

Emergency Repair

METHOD AND PROCEDURE:

1. Secure the location according to provincial Work Zone Traffic Control Plan. Coordinate with on-duty police officer at site. When a police officer is not at site, request the assistance of a police officer if needed.
2. The repairperson shall inspect the type of emergency, damage, knock down and road condition. Attachments to knock down pole, e.g. traffic sign, light fixture, mast arm, etc., shall be noted.
3. Prior to the start of any repair work, request appropriate journeyman, lineman, specialist or other help if needed and use the safest method for all existing conditions.
4. If the damaged pole is a streetlight only pole, perform emergency repair as appropriate; otherwise, notify the corresponding pole owners. Traffic signal and traffic sign support poles are maintained by municipal traffic operations department.
5. If the damaged facility carries electrical cables and priority repair is required, inspect the electrical system. When deficiencies are found, they shall be repaired immediately or make safe for next working day repair. Make safe any exposed wires and connectors.
6. Remove facilities if possible to reduce potential damage. Clear pole, obstruction and debris from roadway.

The Repairperson shall record all completed work activities on a work order with Incident or Motor Vehicle Collision Number if available.

3.3 Detection and Testing of Contact Voltage

Contact voltage can occur on most types of streetlight installations and can result in the exposure of pedestrians or their pets to shock, injury or death. Contact voltage is caused by faults in electrical systems from overheating, corrosion, improper wiring, construction damage, or damage to third party lines such as LDC lines or seasonal lighting. Workmanship problems may contribute to the underlying failure. Contact voltage may be present on metal poles, handwells, and access panels as well. Non-metallic poles can also conduct electricity when wet and an internal fault can deliver a shock through concrete or rebar. Similarly, sidewalks can become energized by an underground fault in cables or connections.

The actual voltage detected or measured is not related to the severity or risk of shock posed by the underlying fault. Published data from New York utility Consolidated Edison demonstrates that voltage recorded by the utility during investigation of reported, confirmed shocks range from 1-120V and higher, with many voltages below 5V. These measurements are taken by workers arriving at the scene hours later or even the following day. This suggests that voltages from high impedance faults do not remain constant over time, but are functions of environmental conditions, such as temperature and moisture levels in the soil. Detection of contact voltage is possible using existing technology. Investigation of findings 1V or greater is recommended to ensure public safety and system reliability. It should be kept in mind that an effective detection program will typically yield many findings in the 1-10V range. Many of these findings will be traceable to an electrical fault.

3.3.1 Detection of Contact Voltage on Street Lighting Infrastructure

Contact voltages are detected in three ways.

- Direct detection – A managed program of testing streetlights for contact voltage.
- Incidental detection – Energized streetlights may be discovered during maintenance work or through abnormalities noticed during visual inspections.
- Reported shock – Streetlight involved in a shock incident reported by the public.

3.3.1 a) Direct Detection

An asset owner or electric utility may positively impact public safety by periodically testing streetlights for contact voltage. The goal of such a program is to detect energized streetlights (or other objects) which could indicate electrical faults internally or underground. Once detected, further steps can be taken to evaluate whether a potential hazard exists and make a decision to effect a repair. It is advisable to use the most sensitive means available to detect possible faults and then use a more rigorous measurement process to rule out conditions which do not come from a fault and therefore are not likely to be hazardous. A very sensitive detection process accomplishes the goal of proactively finding and repairing faults, preventing contact voltage incidents, and improving the safety and reliability of the system.

3.3.1b) Incidental detection

Detection of an energized streetlight can also occur during regularly scheduled repair and maintenance work. The addition of pre and post-work tests for contact voltage is recommended for both public and worker safety. These checks are ideally performed with a voltmeter against a grounded reference point.

3.3.1c) Reported shock

First responders investigating a reported shock site should assume a fault condition exists and treat surfaces as energized until proven otherwise using actual voltage measurements against verified ground references.

Figure 13 - SVD 2000 mobile detection system

3.3.2 DETECTION EQUIPMENT

This guideline is not intended to suggest a requirement to use a specific technology, but adoption of contact voltage methods should consider the public safety ramifications resulting from the limitations of the method chosen. The most sensitive detection tools on the market, and the only ones with any significant field use are the SVD2000, *Figure 13* (Power Survey Company) and the LV-S-5, *Figure 14* (HD Electric.) Voltmeters are used to verify indications from both of these, and can also be used to check for voltage before and after regular streetlight maintenance activities.

Figure 14 - HD Electric LV-S-5 Low Voltage Detector

3.3.2. a) Mobile Electric Field Detection

The SVD2000 is a Mobile Electric Field Detector and Comparator (MEDAC). MEDAC detection relies on a capacitive sensor which detects small changes in the ambient electric field caused by the presence of an object energized by AC voltage (typically 60Hz). The sensor operates on a mobile platform, and deviations from background field levels are readily apparent to a trained technician as the sensor moves with relation to energized objects. The SVD2000 has been tested by an accredited independent laboratory for reliable detection of contact voltage in field operating environments. In operation the system routinely produces detections of street lights energized to as little as 1 volt. It can test an area quickly, and provides both positive indication of an energized surface, and evidence that streetlights not giving rise to an electric field indication were *not* energized at the time of testing. It simultaneously detects handwell covers and sidewalks energized by failed underground cables. As of this writing it is used in several cities in the US and Canada and has detected tens of thousands of streetlights energized by contact voltage. It is the most sensitive detection method currently available.

MEDAC systems have limitations with respect to streetlight contact voltage detection. Underground distribution and mixed OH/UG distribution are generally testable, though field levels from directly overbuilt high voltage lines can mask contact voltage signals in some areas.

3.3.2. b) HD Electric LV-S-5 Low Voltage Detector and "pen testers"

Handheld capacitive or "pen" testers have been used to detect contact voltage. They detect a potential difference exceeding a pre-set threshold between the sensor tip and the user's body, which is assumed to be capacitive coupled to ground. The HD Electric LV-S-5 is the most sensitive pen tester available. Independent lab tests have documented detection of 5V in a lab environment, though its sensitivity to contact voltage in the field environment outside the laboratory has never been independently tested. As of this writing, all other marketed pen detectors are less sensitive than the LV-S-5 and are not recommended for use in contact voltage detection. Along with direct voltmeter measurements, the LV-S-5 is one of two methods for detecting contact voltage directly under primary distribution lines.

Pen testers have limitations as general contact voltage detection tools. The asset list-based process misses faults in conduit or underground, which may energize sidewalks or other surfaces that do not appear on an asset list. Also, the threshold filters out findings without allowing the user to determine whether a potential hazard exists. The ground reference (the user) is always in proximity and sometimes in physical contact with the presumed energized surface, making the test subject to false negatives. Point measurements provide no evidence that a tested streetlight (or other surface) can be said to have *not* been energized at the time of test. Variations from user to user also affect the reliability of testing with a pen tester and usage practices must be trained and reinforced for all personnel:

I. Make solid metal-to-metal contact with each surface tested. Paint can mask energized surfaces from detection with a contact device.
II. Test each part of the lamp separately. Metal surfaces in physical contact are not necessarily in electrical contact, especially if painted or corroded *(see Fig 15.)*
III. Grip the detector firmly with a full bare hand, no gloves.
IV. Hold the detector at arms' length and test from several angles to reduce the chance of standing on energized ground.
V. Test the battery frequently, especially in cold weather.
VI. Use common sense – do not disturb visibly damaged wiring or streetlights with evidence of burning, smoke, or other signs of an active electrical fault.

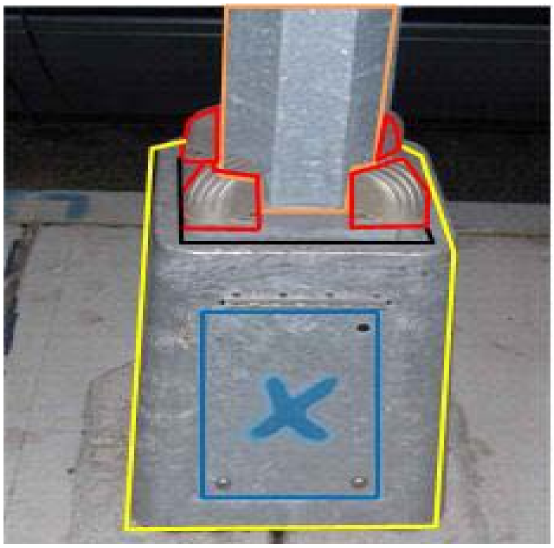


Figure 15 - Physical contact is not electrical contact. "Pen tester" must test each part of a lamp separately, e.g. pole, base, access door, bolt covers, mounting flange

Figure 16 - Digital Voltmeter with low impedance voltage measurement option built in.

3.3.2 c) Digital Voltmeter (DVM) with Low Impedance Feature (Figure 16)

Digital Voltmeters can be used to detect contact voltage directly. A DVM is always used as a means of verifying the voltage once it has been detected by whatever means. DVMs are impractical for large scale contact voltage surveys of streetlighting infrastructure. Each measurement with a DVM requires three steps:

- a reliable earth-ground reference point must be established
- test probes must make solid physical contact with the electrified surface (each part)
- DVM's are impractical for detecting underground faults

DVM's are therefore only of use in contact voltage detection where testing is done as part of routine maintenance or where municipal assets are few in number. This does not diminish the fact that DVM's are a must for verification of a fault which has been detected by a wide area scanning technology. Always select a DVM with low impedance (LoZ) voltage setting so as to be able to distinguish real hazards from capacitive coupled voltages. Various manufacturers including Fluke, Greenlee and Agilent offer DVM's with this feature. Analog voltmeters are also capable of loading down a circuit sufficiently to eliminate ghost or phantom voltages. For convenience, it may be preferable to use a meter with a built in feature versus an add-on shunt resistor.

Figure 17 - Examples of a handheld electric field detectors which can be used to check ground references for voltage

3.3.3 Verification and Measurement

Detection of a voltage is the first step, followed by an investigation to accomplish the following:

1. Identify a ground reference point to use for a field measurement
2. Eliminate false positive detections due to capacitive coupling
3. Accurately measure the voltage
4. Characterize the source of the voltage

3.3.3.1 Identify suitable ground references

A suitable ground reference must not be energized (by the same fault being tested) and must have low impedance to ground. Ground references available at street level include but are not limited to fire hydrants, fence or sign posts driven into earth, grounded street furniture, and temporary grounds driven for the purpose of testing.

General Do's and Don'ts for selecting ground references:

- **Do** Carry long ground leads, 15m (50ft) minimum, to easily reach a suitable ground in the immediate area. Ground leads should have strong spring clamps.
- **Do** spend extra time making a clean, bare metal contact for your measurement.
- **Do** verify that ground references are not energized
- **Do** a proper utility check for underground infrastructure prior to driving a test ground rod.
- **Don't** use ground electrode inside or directly adjacent to the light being tested. If lamp has voltage, the ground electrode will also have some elevated potential to local ground
- **Don't** connect to an auxiliary part of a ground reference, such as an operating handle or knob. The main body is more likely to be solidly grounded.

A handheld electric field detector like the ones pictured in *Figure 17* are ideal tools for verifying a reference is not energized, indicating zero e-field. Otherwise, a voltage test can be repeated using two or more references. The voltage reading should be the same among them. If they differ, a reference could be at elevated potential. Pen testers cannot indicate the absence of a voltage, and are not suitable for verifying ground references.

Re-verifying all voltage measurements against multiple field grounds using the shunt resistor provides a useful assurance that ground references have low impedance and do not contribute very large errors to measurement.

3.3.3.2 ELIMINATE CAPACITIVE COUPLING AND OBTAIN ACCURATE, REPEATABLE MEASUREMENT

Field measurements, especially if the voltage is low, are subject to large errors. Though surface voltage measurements do not directly correlate with the severity or risk of shock posed by an underlying electrical problem, it is important to obtain accurate, trustworthy data about energized surfaces whether they are reported as shock sources or detected as part of a proactive testing effort. This small extra effort reduces confusion from technician to technician and among various parties involved with testing, troubleshooting, repair and general oversight of streetlight testing efforts. It also ensures that field efforts are not wasted by either pursuing false positive indications or failing to recognize a problem.

Voltage measurement with a shunt resistor eliminates instances of capacitive coupling (sometimes called "phantom voltage" by electrical tradesmen) from detection results. While the terms 'ghost' or 'phantom' voltage may not be found in the official IEEE dictionary, they are nevertheless ubiquitous in the electrical industry. Many articles and papers are available on the subject. Experienced electricians and technicians learn to recognize and distinguish ghost voltages from real contact or stray voltage situations. Voltage appears on metal surfaces due to capacitive coupling and as such generally does not represent a shock hazard. It is therefore important that professionals who may be conducting a search for legitimate contact voltages be aware of this phenomenon and be properly equipped with discriminating instrumentation such as a shunt resistor, digital voltmeter with a low impedance (Lo-Z) voltage setting or an analogue meter. Once the source is adequately loaded by the instrumentation, capacitive coupling will drop significantly in magnitude.

Measure the voltage using Lo-Z setting or fitted with a shunt resistor in parallel with the test leads, as shown in *Figure 18*. 3000Ω shunt resistors can be constructed from easily available parts or can be purchased from the voltmeter manufacturer. The voltage measurement will change slightly when the shunt resistor is placed into the circuit, because a small amount of current is allowed to flow from the energized source to ground. If the voltage is sourced only from capacitive coupling, no current will flow and the measured voltage will collapse to zero.

After eliminating findings of capacitive coupled voltage, a few additional measurements will ensure accurate, repeatable data. Field measurements are dynamic, changing with the precise measurement point and the pressure applied by the technician. By observing and minimizing the small change in voltage with the shunt engaged, the technician can minimize contact and ground impedances and get accurate readings that are repeatable from person to person. This activity calls for a "pushbutton shunt" *(Figure 19)* or a resistor that can be quickly engaged and disengaged without disconnecting or moving the test leads.

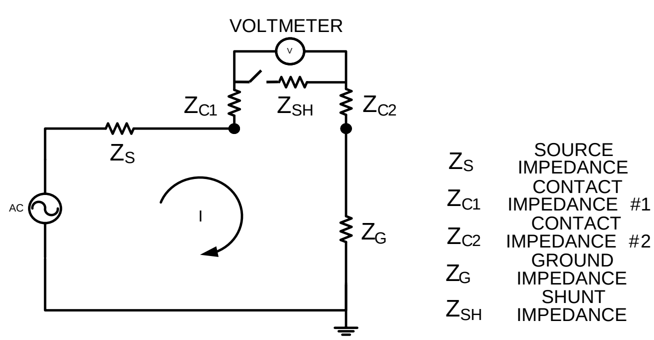


Figure 18 - Measurement circuit of energized object with shunt resistor in parallel. Switch represents the pushbutton capability, which is most helpful for repeated measurements.

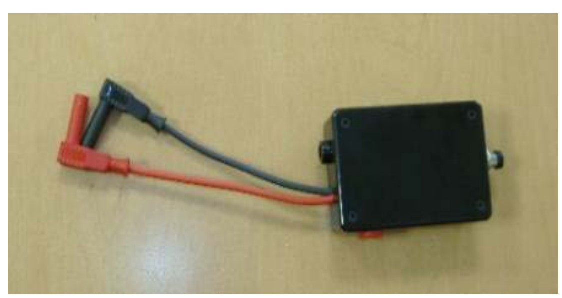


Figure 19 - Pushbutton shunt resistor puts shunt resistance in parallel with test leads only while button is engaged, allowing quick measurements with and without shunt without the need to move test leads.

3.3.4 Characterize Contact Voltage Source

Voltage measurement alone cannot distinguish a fault condition from Neutral to Earth Voltage (NEV), but the voltage source can be characterized to determine the appropriate actions. AC voltage sources can be one of three types:

a) Phase (or supply) conductor fault- faults in internal wiring, service cable, or 3rd party owned conductors
b) Neutral fault – if neutral is faulty, return current is forced through the grounding of the streetlight, energizing the pole to a voltage proportional to Z_G.
c) Neutral to Earth voltage (NEV) - neutral voltage rise due to return current flowing through the impedance of the neutral

Phase conductor faults are sourced at line voltage, nominally 120V. Whatever the voltage at the time of a test, these may become hazardous as the fault deteriorates or environmental conditions change. Neutral faults, similarly, pose risk of shock if a person or animal becomes a parallel path to ground for return current. NEV is generally stable, low voltage and presents little to no risk of shock. Of these three, only NEV is a normally occurring condition which does not accompany some material fault in cable or connections.

Harmonic analysis can help determine the likely source behind a detected voltage. Equipment is available from several manufacturers to do this analysis. Non-linear loads, including lighting ballasts, impose third harmonic (3HD) voltage distortion on neutral return current. Measurements of >10% 3HD indicate either a neutral fault or NEV. A load test can distinguish a faulty neutral from NEV because only the faulty neutral will cause a greater than normal voltage drop under load. A line source is pure 60Hz with <5% 3HD. Consequently, measurements of <5% 3HD characterize faults in distribution or supply conductors, ahead of the load. When 3HD is between 5% and 10%, the source is less clear and should not be characterized from harmonic analysis alone. Further hands-on troubleshooting steps will be needed to locate the source, as described in the next section. *Figure 20* shows harmonic analysis output with 2.8% 3HD, indicating the voltage is sourced by a phase conductor.

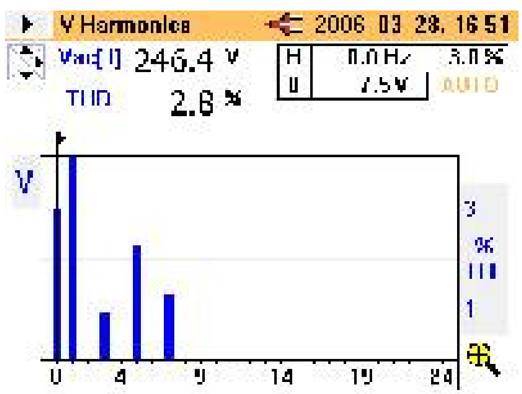


Figure 20 - Output screen showing 2.8% harmonic voltage distortion from a Fluke model 345, one of many tools available for harmonic spectrum analysis.

3.3.5 Mitigation Steps

If harmonic analysis is inconclusive (between 5-10% 3HD,) perform all steps.

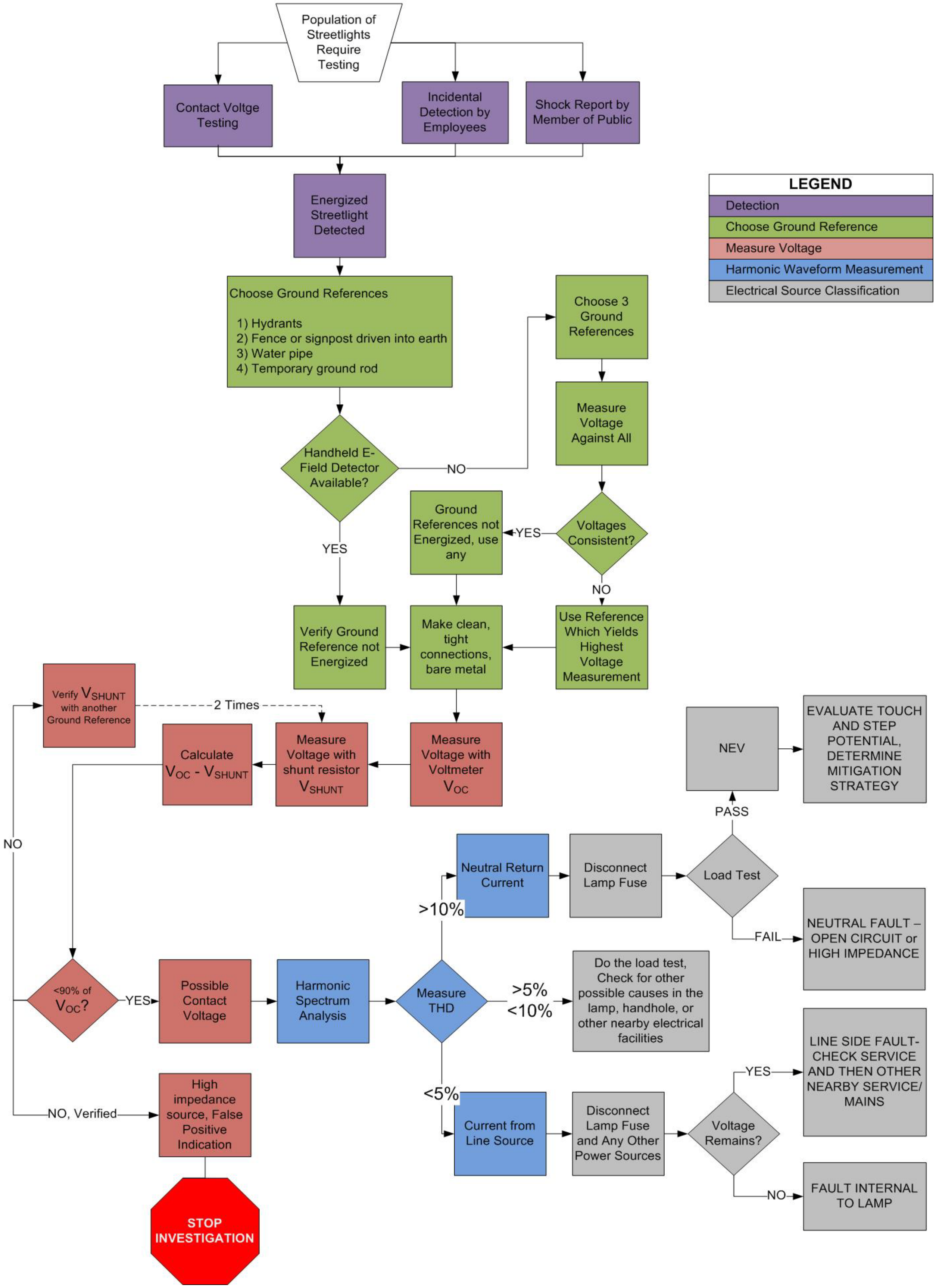
<5% Harmonic

1. Test the "hot" and neutral wires for reversed polarity.
2. Unplug or unmake the fuse connection to disconnect lamp feed source. If the elevated voltage condition goes away, the fault is downstream of the fuse. Check connections and accessible parts of the streetlight for damage if the source is a phase fault.
3. Check to see if additional sources are connected via overhead cables. If so, de-energize those one at a time to see if they are the cause of the energized streetlight.
4. If the elevated voltage condition remains on the streetlight pole with the fuse and any other sources disconnected, the fault is in the underground service conductor or main feeder. Check for voltage on the service conduit, handwell, sidewalk, or roadway. Disconnect the service at the feed structure. If voltage remains, there may be a faulty service to a nearby kiosk, building, etc or faulty secondary running past/under the site. This is a hazardous condition and should not be left unattended

>10% harmonic

1. Check for neutral faults by performing a load test with dummy load, typically 1000W or more. If voltage drop is >5%, check neutral connections or cable for possible repair or replacement. Start at the feed structure and work back towards the supply transformer.
2. If the load test passes and voltage is low, <10V, the source is most likely NEV. Reducing NEV is best achieved by checking and remaking neutral splices upstream of the energized lamp starting from the feed structure and working towards the source transformer to reduce the neutral path impedance. On a long circuit, longer term projects may be required such as increasing the size of the neutral. An engineering analysis will be required to determine if mitigation is necessary.

STREETLIGHT CONTACT VOLTAGE DETECTION AND MEASUREMENT WORK FLOW



3.4 SAFE LIMITS OF APPROACH

Maximum clearances are given in the chart below with reference to the Ontario Health & Safety Act (OH&SA) requirements for both personnel and equipment in respect of utilization voltages. Further information is provided by the Infrastructure Health and Safety Association – IHSA (formerly Electrical & Utility Safety Association (E&USA)) and by the OH&SA. The worker should consult these relevant guidelines if not familiar with their content. Also, refer to the requirements as provided in Authority/Utility standard specifications and/or standard drawings.

Both OH&SA and IHSA provide guidance to assist workers in working safely in close proximity to electrical wires and equipment and to assist in applying appropriate emergency response measures in the event of electrical contact. It is the responsibility of the Owner and Contractor to ensure that maintenance is carried out in a safe manner. Legislation requires that all related hazards are identified ahead of time and that only competent workers are allowed to work without direct supervision. A competent worker is defined as a worker who is qualified because of knowledge, training and experience to perform the work, a worker who is familiar with the OH&SA and with the provisions of the Regulations that apply to the work and a worker who has knowledge of all potential or actual danger to health or safety in the work being carried out.

Prior to carrying out any work, a determination on whether hazards exist must be made. This should include verifying the operating voltage of the overhead and exposed lines. Workers should always consider the system as being live, having the potential to cause serious injury or death. Contact must be avoided at all costs. A safe work plan must be developed ahead of time to address all related matters. Whether or not the worker is a licensed power line worker, the safe limits of approach must be adhered to and proper PPE and precautions must be taken.

The worker must also consider the age of the system in-so-far-as it may not have been designed with the clearances below in mind. A worker must be aware of these situations which must be addressed in the safe work plan.

<table>
<tr><th colspan="7">SAFE LIMITS OF APPROACH
Maintain Maximum Clearances and Install Barriers Where Practical</th></tr>
<tr><th rowspan="2"></th><th colspan="3" rowspan="2">Personnel Zones *</th><th colspan="3">Mobile Work Equipment *</th></tr>
<tr><th rowspan="2">O.H.S.A.</th><th rowspan="2">Non-Isolated Booms</th><th rowspan="2">Certified Insulated A.D.</th></tr>
<tr><th>Voltages</th><th>O.H.S.A. Minimum</th><th>Authorized Worker</th><th>Restricted Zone</th></tr>
<tr><td>750V to 15kV</td><td rowspan="4">> 3.0m</td><td rowspan="2">> 0.9m</td><td>0.9m to 0.3m</td><td rowspan="4">> 3.0m</td><td rowspan="2">> 0.9m</td><td>> 0.3m</td></tr>
<tr><td>> 15kV to 35kV</td><td>0.9m to 0.45m</td><td rowspan="2">> 0.45m</td></tr>
<tr><td>> 35kV to 50kV</td><td>> 1.2m</td><td>1.2m to 0.6m</td><td>> 1.2m</td></tr>
<tr><td>> 50kV to 150kV</td><td>> 1.5m</td><td>1.5m to 0.9m</td><td>> 2.4m</td><td>> 0.9m</td></tr>
<tr><td>> 150kV to 250kV</td><td>> 4.5m</td><td>> 2.1m</td><td>2.1m to 1.2m</td><td>> 4.5m</td><td>> 3.0m</td><td>> 1.2m</td></tr>
<tr><td>> 250kV to 550kV</td><td>> 6.0m</td><td>> 3.7m</td><td>3.7m to 2.75m</td><td>> 6.0m</td><td>> 4.6m</td><td>> 2.75m</td></tr>
<tr><td colspan="4">* For detailed information relating to Limits of Approach Conditions and Restrictions, refer to Electrical Utility Safety Rule # 129 and trade specific documentation.</td><td>Cranes
Power Shovels
Back Hoes
Mechanical
Brush Cutter</td><td>RBD, Aerial Ladder, Work Platform, Uncertified Aerial Device</td><td>Certified and Tested by Certified Laboratory</td></tr>
</table>

3.5 Developing a Contact Voltage Detection Program

This section addresses the typical questions faced by asset managers when developing a contact voltage detection program. It attempts to look at the subject of contact voltage detection more from a project management perspective and is presented in a question and answer format. Recommended practices are written in italics and highlighted.

3.5.1 Should we develop a contact voltage detection (CVD) Program?

Contact voltage is a condition that won't go away by simply ignoring it and one which will only become more prominent as infrastructure ages. It is a serious public safety concern that warrants serious consideration.

Despite the best preventative efforts being made during design and construction, contact voltage detection is a valuable part of maintaining a street lighting system.

Due to the nature of a high impedance fault or a failing system neutral, a dangerous voltage can be present and can remain on a conductive surface which is otherwise properly grounded and bonded.

In this circumstance, the protective device may not operate to remove the hazard if the fault current is below the trip threshold. This is analogous to the dangerous condition that exists when the earth is relied upon to act as a fault current return path.

The occurrence of system faults leading to contact voltage is common, therefore a program of regularly scheduled CVD is recommended.

While the use of modern ground fault monitoring instrumentation and/or double (Class II) insulation might reduce the risk, it cannot be eliminated.

Recommendation: each SL Asset owner in Ontario creates a written CVD policy to deal with the hazard in a proactive manner.

3.5.2 What is the most effective way to combat contact voltage hazards?

The best way to deal with any hazard is to try to prevent it in the first place. In order to reduce the probability of a future contact voltage incident, asset managers should adopt appropriately considered guidelines as presented throughout this document.

A comprehensive review should include:

- grounding and bonding practices
- conductor clearances and burial depths
- guarding and mechanical protection
- conductor insulation grades
- connection and splicing methods
- component specifications (poles, luminaires, enclosures etc)
- protective devices (fuses, breakers, GFCI's etc)
- fault monitoring and communications systems

Recommendation: each SL owner in Ontario review its street lighting design and construction standards with contact voltage prevention in mind.

3.5.3 How often and extensively should we conduct CVD?

Policy on CVD varies greatly across North America. Some asset owners in the USA are required to test their electrical assets twelve times per year, others test voluntarily, while others do no testing whatsoever and have no policy in place.

The spectrum of options for CVD is wide and includes:

- Test new installations upon commission.
- One-time audit of existing infrastructure.
- Test only areas of high exposure or high risk.
- Spot checks at trouble-call times.
- Routine tests at re-lamp intervals.
- Testing before and after maintenance work is performed
- Regular testing independent of other maintenance cycles. (Typically done on a monthly, semi-annual or annual basis).
- performing multiple-asset, wide area mobile patrols (As opposed to manual, asset specific, foot patrols).
- Any combination of the above

To determine the appropriate approach, standard risk assessment techniques may apply and start with a comprehensive review of all the relevant data including:

- engineering standards (past and present)
- asset condition assessments
- maintenance intervals and practices
- maintenance records (faults and failures)
- public contact voltage incident reports
- performing an initial detection audit of a portion, if not all of its asset

A few of the key Risk Factors are as follows:
a) Streetlights and other loads supplied from underground infrastructure are more likely to have buried or concealed faults than overhead systems, where conductors are mostly visible and out of reach of the public.
b) High Pedestrian/ pet traffic increases exposure to faults, if they are present
c) Conductive raceways/ equipment provide more paths for fault energy to objects or surfaces not intended to be energized, in the public right of way.
d) Age, environmental conditions, high vehicular traffic, vandalism, and rodents may make some areas more prone to wear or damage.

Once all the relevant information has been collected and analyzed, some indication of the areas of greatest concern may begin to emerge. CVD frequency and extent should be reviewed based on initial and subsequent findings.

Recommendation: Each SL owner in Ontario review their assets and establish their own standards for CVD on new and existing installations based on the list above.

<u>Note: Incidence of reported shock should not be the sole consideration when evaluating risk for the purpose of developing a CVD program. Many cases are never reported.</u>

3.5.4 What elements should be developed in a CVD program?

Where it has been determined that a formal, comprehensive CVD program should be implemented by SL Asset owners, the following program elements may need to be incorporated:

- a management team or committee
- a policy or mission statement
- a risk management assessment of assets
- written test procedures (for CVD)
- pre-determined acceptance standards (pass/fail criteria)
- test record and data collection forms
- a testing schedule (frequency, areas etc.)

- a test & repair protocol (who does what)
- an incidence reporting form and protocol
- tool and test instrument specifications
- test instrument calibration and inspection records
- procedures for barricading hazardous areas (if CV is found)
- personal protective equipment requirements
- a CV oriented review of engineering practices
- updates to existing asset inspection checklists
- changes to existing electrical work safety practices
- staffing requirements
- a budget

3.5.5 Who will develop and manage the program?

Each SLAO should consider forming a team of qualified persons for the purpose of developing a CVD policy and a project charter. The team may consider coordinating with the owners of other electrical assets, such as park lighting and traffic signals.

3.5.6 Who should perform contact voltage testing?

Persons trained in performing CVD may assist in troubleshooting but must report incidents immediately and defer repair work to qualified persons.

This policy must apply whether the work is performed by the asset owners staff, by the street lighting maintenance contractor or by a specialist brought in for the specific purpose of CVD.

Street lighting equipment should be checked both before regular maintenance work is performed, for worker safety, and after work is performed, for public safety. This will protect against the possibility of worker induced faults.

Anyone involved in performing CVD or electrical maintenance must be protected from electrical hazards by a comprehensive program of workplace electrical safety training. CSA Z462 is an excellent resource for developing such a program.

Should any serious electrical accident occur it must be reported, investigated, corrected, and documented as per the OESC and related OESC bulletins.

3.5.7 What happens when we discover contact voltage?

Aside from the standard procedures for securing and evaluating the electrified structure, the decision to repair or not-to-repair, may appear to present a contentious issue. This is often connected with the issue of setting an 'acceptable voltage threshold' for energized surfaces.

The best historical data collected to date would indicate the following concepts are valid;

a) The voltage found on an energized surface cannot serve as an indicator of Mean-Time-Between-Failure, for the equipment.

   Any unintentionally energized surface of a street lighting pole or associated electrical enclosure indicates a possible fault condition. It should be investigated regardless of the voltage measurement based on section 3.5.3. The root cause may be hazardous or benign, but voltage measurement alone is insufficient to make that determination.

b) Unintended voltages measured on a surface are not constant over time.

   The only reliable conclusion that can be made from the presence of contact voltage (once NEV and capacitive coupling “aka, phantom voltages” have been eliminated as a cause), is that on some level, an electrical fault does exist. Many variables contribute to the voltage that may be discovered at any given time on the surface of faulted equipment.

Appendix 2 contains a more detailed analysis of these variables. Voltage from an active high impedance fault may rise up to line voltage at any time.

Since contact voltage is not constant, using just a voltage threshold as a guide for determining the degree of hazard is inadequate. The correct methodology is to find energized streetlight conditions where they exist, then use the data gathered from measurement and diagnostics to make decisions about safety and repair activity. Safe voltage thresholds are used in NEV mitigation or worker protection standards which do not deal with faulted systems exposed to the general public. Those threshold values are unsuitable for the issue of CVD.

Recommendation: When a legitimate electrical fault is found to exist, repairs ought to be effected in a timely manner before the situation deteriorates further, causes harm or results in the failure of equipment.

3.5.8 Summary of Contact Voltage Mitigation Strategies

No.	Lifecycle Phase	Strategy	Notes
1	Systems Design	Prevention	The specification of equipment, protective devices, insulation, bonding conductors and system design is the optimal starting point where CV hazard mitigation should begin.
2	Equipment Manufacturing	Prevention	Manage the purchasing process to ensure that suppliers conform to CSA, ISO and other applicable standards.
3	Equipment Installation	Prevention	Managing construction methods and workmanship provides an opportunity to avoid creating hazards through training, supervision and the use of proper tools and materials.
4	Commissioning	Detection	Includes testing and inspecting the new asset. A key opportunity to detect and correct latent hazards.
5	Operation & Maintenance	Detection	Effectiveness depends on frequency and technical methodology. CV testing intervals should coincide with commissioning, re-lamping and trouble calls. Periodic, independent wide area auditing is strongly recommended where warranted by risk analysis.
6	Equipment Retrofit	Protection/ Fault Detection	Street lighting poles and power distribution centers could be retrofitted with various instruments to provide early warning of possible system faults. Be aware of their limitations and operational characteristics.
7	Replacement	Predictive Corrective Action	Schedule replacement of aged infrastructure before problems occur. May include poles, arms, luminaires and power distribution panels and wiring. Prevention may be more cost effective in the long run than detection. Both strategies are recommended.
8	Public Awareness Campaign	Proactive	Prepare a public information bulletin. Coordinate with your media personnel.

3.5.9 Conclusion

Contact voltage hazard mitigation is best accomplished by means of a balanced approach which includes system design, quality control, inspection, testing, risk analysis, life cycle analysis and infrastructure replacement.

Three essential conclusions can be made:

a) SLAO's should proactively test street lighting assets for contact voltage.
b) Any CVD program must be scaled and tailored to the needs of the community it serves. Various technologies and detection strategies may be employed and the asset manager must understand the limitations and risks of each approach.
c) Elevated voltage conditions found should be remedied in a timely fashion and proper records maintained.

In the future, collaboration between agencies will hopefully provide more useful data on the phenomenon of contact voltage which may lead to more accurate modeling of failure modes, risk assessment methods and decision making protocols to assist asset managers in developing more effective programs.

4.0 Management

4.1 Pole Testing

Pole testing is used by some asset managers to assess the remaining life of a wooden pole. If necessary, further pole decay can be slowed or prevented through the application of treatment. Experience has shown that an inspection/treatment frequency of 10 years can reduce pole replacements by as much as 6%. This guideline does not cover testing on poles other than wood.

Adding new loads or apparatus to existing poles requires analysis and permission as per the pole owners requirements. Loading should follow manufacturer's guidelines.

4.2 Condition Surveys

Condition surveys can be used to collect detailed information about the as-built status and condition of the street light system. This information is useful for developing or updating a geographic information system or asset registry, optimizing maintenance programs or proactively rebuilding aging sections of the system. Whether or not to complete a condition survey (and at what frequency) should be determined by the party responsible for the system. A condition survey may also be necessary when ownership of street light assets is transferred from one party to another.

The method of surveying (i.e. visual from ground, visual from bucket-truck, etc.) will determine the level of detail that can be attained. Prior to undertaking such a survey, it is recommended that surveyors be trained to make and record observations that are as objective as possible to ensure consistency of data. Where subjective judgments are necessary, they should be accompanied by a standardized description of what constitutes good condition and poor condition. If a condition survey is to be undertaken, some or all of the factors and components that follow should be considered:

1) Pole
   (a) Structural condition
      - *Have there been any grade changes or washouts?*
      - *Is the pole bent in any way?*
      - *Are there any cracks?*
      - *Is the pole leaning, and if so to what degree?*
      - *Is any rebar exposed (concrete poles)?*
      - *Are there any signs of corrosion including chipped or peeling paint (metal or concrete poles)?*
      - *Are there any signs of excessive surface wear?*
      - *Is pole footing compromised – nuts/bolts tight*
   (b) Are there any obstructions preventing access, or potentially damaging encroachments to the pole that should be cleared (i.e. vegetation, third party structures or signs, etc)?

(c) Hand hole and internal wiring (if applicable)
  - *Are all access point covers present and properly secured?*
  - *Is the insulation on any wiring and/or connections in acceptable shape and rated and approved for the application?*
  - *Are there any missing grounding or bonding connections?*
  - *Are there any obvious signs of electrical faults on the back of the cover plate (ie. Pitting)?*
  - *Is there fusing present?*

(d) Are there any unauthorized third party attachments?
(e) Are there any signs of vandalism, graffiti or pest infestation?
(f) Is contact voltage present?
(g) Collect Pole Label Information – Class, Manufacturer, Age, Number

2) Luminaire support bracket
(a) Is there any loose or missing hardware?
(b) Are clearances being maintained?
(c) Is there any visible damage or corrosion?

3) Luminaire
(a) Is there any loose or missing hardware?
(b) Is the photocell operating correctly (if applicable)?
(c) Is there any dirt or grime which is impacting the effectiveness of the luminaire?
(d) Is there any visible damage or corrosion or sign of pest infestation?
(e) What is the type , wattage, manufacturer, etc? (photo?)

4) Pull-box, handwell or Service Entrance (if applicable)
(a) Structural condition
  - *Are there any cracks on the cover or frame?*
  - *Is any hardware missing?*
  - *Is there any foreign debris inside the pull-box that could damage the electrical insulation?*
  - *Are metal parts bonded or grounded (if applicable)?*
  - *Is there any water or ice present?*
  - *Is the Service Entrance secured/ locked?*

(b) Electrical components
  - *Is the cable insulation cracked or brittle?*
  - *Are there any exposed energized connections?*
  - *Is there any* evidence of wear or abrasion on the connector or conductor insulation?

5) Tree trimming
(a) Are any tree branches or other vegetation blocking the path of the light or encroaching on electrical clearances?

Ultimately, the value gained from condition surveys will depend on the size of the street light system and the practices of the party responsible for its operation and maintenance. The decision whether or not to complete a survey and at what frequency should only be made after a thorough review of the costs and benefits and after a clear understanding of the scope of work is established.

4.3 EXPECTED SERVICE LIFE OF ROADWAY LIGHTING ASSETS

The table below summarizes the expected service life of some typical roadway light elements.

The expected service life numbers are intended to be used for capital planning and asset management purposes. These numbers are NOT intended to be an estimate of the elements design life or their mean time between failure.

Electrical Asset Group	**Electrical Asset**	**Expected Service Life**
Power Supplies		
	Supply Control Cabinet and Equipment	20 years
	Distribution Assembly Cabinet and Equipment	20 years
Grounding		
	Grounding Components	25 years
Conventional Lighting		
	Luminaires	20 years
	HPS Lamps	4 years (relamping interval)
	Conventional Poles and Footings	30 years (not accounting for pole knockdowns)
	Arms and Brackets	30 years
	Underground Plant (e.g. ducts, electrical chambers, cables)	30 years
Highmast Lighting		
	Luminaires	20 years
	HPS Lamps	4 years (relamping interval)
	Raising and Lowering Equipment (top-latching system)	30 years
	Raising and Lowering Equipment (non-latching/bottom-latching system)	20-25 years
	Highmast poles and footings	40 years
	Underground Plant	30 years

5.0 APPENDICES

APPENDIX 1

<u>IEEE Paper Review: "Grounding of Distributed Low-Voltage Loads: the Street Lighting Systems"</u>

The recent paper entitled "Grounding of Distributed Low-Voltage Loads: the Street Lighting Systems" published by the Institute of Electrical and Electronics Engineers is highly insightful and relevant to the topics covered in this set of 'guidelines' and as such is recommended reading.

The paper is co-authored by Parise, Martirano, Mitolo, Baldwin and Panetta. Appearing in a 2010 journal it summarizes the both the difficulties presented to the street lighting electrical designer by the challenge of protecting the public from shock hazards, along with many traditional and forward thinking solutions.

In this paper the authors provide a context for the discussion by explaining the differences in grounding and bonding systems and standards, as found variously around the world. The relative advantages and disadvantages of these systems are compared.

The limitations of grounding, bonding and traditional overcurrent and ground fault protection schemes are presented in consideration of the physical nature of typical electrical faults that can occur in street lighting. This leads the reader to the logical conclusion that ongoing monitoring and maintenance is critical to protecting the public from contact voltage hazards.

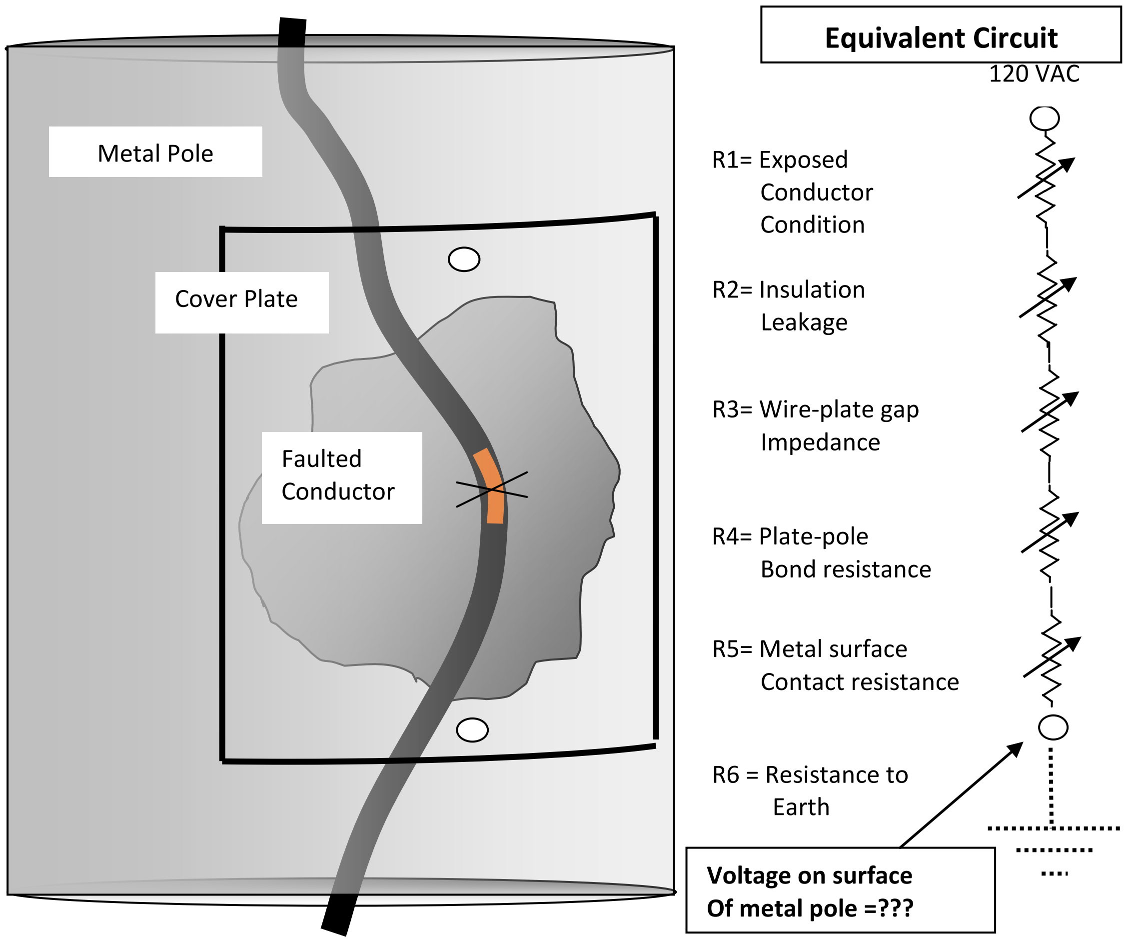
While maintenance and periodic testing are part of the contact voltage mitigation puzzle, the paper also emphasizes the importance of 'designing' the hazard out of the system from the onset by incorporating:

- effective grounding and bonding strategies
- double insulation (class II)
- proper construction specifications
- isolation transformers
- testing facilities at the power distribution panel
- the use of ground fault detection with surge protection
- the use of fault monitoring and communications equipment

This paper appears in the <u>Industrial and Commercial Power Systems Technical Conference (I&CPS), 2010 IEEE</u>. It is available @ http://ieeexplore.ieee.org/xpl/freeabs_all.jsp?arnumber=5489893 ISBN 978-1-4244-5600-0.

APPENDIX 2

A Hypothetical Contact Voltage Scenario



In this example, a partial list of the variables that might affect the voltage impressed upon the surface of a metal pole where a damaged or leaky conductor is touching the hand hole cover plate is considered:

1) The resistance of leaky insulation as affected by temperature, voids, imbedded metal particles, absorbed moisture, wear, and damage sustained during installation or damage from pests.
2) The condition of the exposed conductor, which may be oxidized, nicked or open.
3) The contact surface area and pressure between the wire and the pole, or
4) The arc gap distance (if it is an arcing fault)
5) Any moisture or chemicals present on the inside surface of the pole
6) The bond between the cover plate and the pole
7) Outside surface conditions may be affected by oxidation, paint, dirt etc.
8) Daily load cycling: may influence the evolution of the fault characteristics.

The contact area and pressure between the wire and the pole may be affected by original installation practices, wind loading, road vibration and thermal expansion and contraction. Where arcing or current flow contributes to further insulation or conductor deterioration the fault may blow open and clear or evolve into a more solid state. The voltage present at any given time on the surface will be sporadic and as variable and unpredictable as the interface impedances listed. This would imply that fault current protection schemes which depend upon minimum code required grounding and bonding methods may not be entirely effective for high resistance faults and that a program of regular contact voltage auditing is warranted. Furthermore, contact voltage auditing cannot and will not detect all faulted structures and so emphasis must be placed upon prevention during engineering and construction phases.

5.1 Definitions

Contact voltage – Streetlight energized due to faults in internal wiring or underground service cable

Critical Failure means any failure related to the System Components, which causes the improper operation of, or the failure System Components such that they are operating under substantial Degraded Performance; or the failure of any System Component that adversely affects the Roadway Lighting System or impacts on the public safety.

Degraded Performance means the operation of any Roadway Lighting System with less than 100% performance of the operational System Components.

Electrical Work means any work associated with the installation, maintenance, modification or removal of electrical equipment including work required for all auxiliary concrete, mechanical, metallic or associated non-electrical components or equipment.

ESA is an acronym for Electrical Safety Authority, Ontario's enforcement agency for the OESC.

Ground Reference – Intentionally or unintentionally grounded object not bonded or physically contacting the streetlight which is used in the field as a ground for the purpose of voltage measurements.

High Mast Lighting System means a Roadway Lighting System where there are three or more luminaires per pole and the height of the pole exceeds 20 metres.

Neutral-to-Earth Voltage [NEV] – A potential difference between the grounded neutral conductor of the utility distribution system with respect to earth potential at a specific location. NEV is a small, normally occurring potential rise resulting from return current flowing through the impedance of the neutral path.

Non-Routine Maintenance means activity required to repair unexpected failure of equipment components. It requires immediate action and takes precedence over routine maintenance activities for the duration of the required action.

OESC is an acronym for the Ontario Electrical Safety Code.

Routine Maintenance means preventative maintenance carried out on equipment at specified intervals and includes, but is not limited to checking, testing, cleaning, tightening, lubricating, etc. of equipment as well as minor repairs (generally with hand tools and with materials at hand). The purpose of Routine Maintenance is to ensure that problems are solved before failures occur. Minor maintenance problems that cannot be corrected "on the spot" shall be logged and scheduled for further follow-up.

Roadway Lighting System means a system of luminaires, poles, sign luminaires, underpass illumination, cables, power supply equipment, control system and all associated materials required to provide illumination on a roadway, highway, street, or associated appurtenances on a Municipal or Provincial right of way.

Shunt resistor – any small load, placed in parallel with the leads of a high impedance digital voltmeter, used to assess the relative magnitude of the source impedance of an energized streetlight.

System Components means all hardware and software components, devices, parts and materials included in the Roadway Lighting System.

5.2 Additional References

Ontario Electrical Safety Code including all appending bulletins issued by the Electrical Safety Authority of Ontario.

Ontario Regulation 22/04-Electrical Distribution Safety Regulation

Ontario Regulation 22/04-Technical Guideline for Section 7: Approval of plans, drawings and specifications for installation work

Ontario Regulation 22/04-Technical Guideline for Section 8: Inspection and Approval of Construction

Guideline for Third Party Attachments

CSA Standards pertinent to the Electrical Work.

CSA C22.3 No.7-10

Guide to Municipal Standard Construction MEA Part 6 Street Lighting

IEEE std 142

Kitchener-Wilmot Hydro Streetlight Bus Voltage Drop Calculation

Section 5.4 of Minnesota Streetlight Design manual

Ontario Traffic Manual

Street Lighting Design Manual City of Oshawa

Lighting Reference Guide, Natural Resource Canada.

5.3 OTHER DOCUMENTS FOR INFORMATION PURPOSES

Ontario Regulation 239/02 Minimum Maintenance Standards for Municipal Highways

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