Voltage Conversion from 4.16kV to 27.6kV

[redacted] Overhead Subdivision

[redacted] Ontario

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Declaration of Sole Authorship

I, [redacted], confirm that this work submitted for assessment is my own and is expressed in my own words. Any uses made within it of the works of any other author, in any form (ideas, equations, figures, text, tables, programs), are properly acknowledged at their point of use. A list of the references used is included.

____________________________ ____________________________

Signature Date

Proposal

Introduction:

[redacted] is the Local Distribution Company (LDC) which services the customers of [redacted], Ontario with all of their electrical distribution requirements. Local Distribution Companies across Ontario convert higher voltages such as 27.6kV to lower more common voltages such as 120/240V which can be used by residential customers.

In Ontario, Local Distribution Companies are required to follow certain *Standards and guidelines provided by regulatory and control bodies such as,* , the *Electrical Safety Authority*, *Canadian Standards Association* and the Ontario Energy Board. In addition, there are relevant procedures and requirements that are unique to the distribution company and the municipality that the LDC serves.

The Regulation 22/04 sets out objective-based electrical safety requirements for distribution companies to get *Approval of Electrical Equipment*, *Approval of Plans*, *Drawings*, and *Specifications for Installation Work*, and *Inspection and Approval of Construction* before crews are able to put systems into service.

In addition to the *Regulation 22/04*, there are also *CSA Standards such as the CAN3-C235-83 (Preferred Voltage levels for AC Systems, 0 to 50,000V)* that applies directly to the distribution system, which affects residential, commercial and industrial customers as well as the CSA 22.3 No.1 which provides the Standards for the design for Overhead Systems.

The voltage level at the point of service must be between certain maximum and minimum values as set by the *Canadian Standards Association (CAN3-C235-83)* and the LDC is to ensure there are no fluctuations in voltages outside of those specified ranges.

Problem Statement:

The 4.16kV infrastructure is gradually being phased out, due to its limited capacity, inability to serve load growth, and high system losses associated with it; as well as inadequate ability to switch customers over to another feeder in the event of an outage.

As a part of [redacted] on-going 4.16kV conversion program, designers are faced with (now considered) sub-standard designs and the challenges to meet current standards and best utility practices. Some of the areas of focus are: Placement of structures such as transformers below secondary bus on the pole, rear-yard primary conductors on deteriorated poles, open wire secondary bus, undersized transformation, voltage drop problems at the service entrance, linear design of supporting structures considering weather conditions and a standards valid about 50 - 60 years ago and other design criteria.

Designers within the Electrical Distribution Utilities have multiple criteria and strategies to specify and design the upgraded system. The semi-custom approaches demand the need of a standardized procedure that provides a guideline for designers to maintain a consistent approach for electrical distribution rebuilds.

This report will compile, define and structure the fundamental considerations when designing an electrical distribution system upgrade. In specific, the current practices and standards considered for voltage conversion and rebuild of electrical overhead distribution circuits within [redacted] service territory.

Methodology:

The techniques used in this Report will outline existing internal design procedures as laid out by [redacted]. with regards to the redesigning of an existing overhead electrical distribution circuit for the purpose of a primary voltage conversion project. The following procedures will be followed:

- **Pole Health Index**
  - [redacted] conducts yearly pole testing on various parts of the system to ensure that these assets have a remaining strength of more than 60%. As per *CSA C22.3 1 Overhead Systems 8.3.1.3*. Wood poles with a remaining strength of 60% or less shall be replaced. Areas supporting legacy voltages tend to have more structures nearing their end of life cycle and require replacement prior to being deemed unsatisfactory.

- **Transformer Load Reports**
  - Smart metering data allows utilities to record interval consumption data (typically hourly for residential customers). Through the use of our Customer Information System paired with smart meter data, transformer load report data can be collected and analyzed to properly size new assets according to current and expected demand, i.e penetration of electric vehicles.

- **Secondary Voltage Drop Calculations**
  - Replacement of legacy secondary bus systems such as open secondary bus, enables the secondary system to lower power losses. This is achieved by upgrading the secondary buses to newer conductors with better impedance and conducting properties. This results in the reduction of the voltage drop. In addition, pole spacing is maximized by the use of spun bus conductors while contributing to the

overall aesthetics of the residential and commercial areas. Moreover, the use of better conducting secondaries, enables the design of systems where the number of transformers can be reduced to achieve the same power consumption requirements. Reducing the amount of transformers establishes more of an emphasis on secondary voltage drop calculations to ensure these voltage levels meet the requirement of *CSA Standard CAN3-C235-83 - Table 3*.

- **Field Data Collection**
    - Data collection includes, locations of poles, anchors, down-guys, conductor sizes and attachment heights on poles, as well as various communication companies (joint-use) in which are attached to the poles.
    - Data also includes observations of the surroundings including but not limited to; sidewalks, driveways, trees, gardens, etc.

- **Non-linear Structural Analysis**
    - Poles affected directly by voltage conversion projects are structures that, in the case of the project explored in this report, were installed over 50-60 years ago. Therefore, the overhead system design at the time considered linear analysis for the design of supporting structures including; guying, stub poles and pole load. The current design approach considers the non-linear behavior of the overhead system under weather condition loads as well as the displacement of the structures due to the inherent modulus of elasticity of poles and their fiber strength. The non-linear design of overhead structures was standardized by the *CSA Standard C22.3 No. 1 and it has remained the only accepted design approach for overhead distribution structures* until the time this report has been written.

- **Fuse Coordination**
  - Upon performing primary voltage conversions projects, primary and secondary conductors are replaced along with installation of transformers with higher capacity. These changes also impact fault levels within the system. Therefore, fuse coordination is necessary to avoid nuisance momentary or sustained outages while protecting the equipment and sectionalizing the system to improve reliability and system resiliency.

Hypothesis:

While electrical distribution designers base their design on current regulations and standards, the lack of consistency among designs creates challenges to coordinate: design methodologies, protection coordination, structural designs and system reliability. My Hypothesis is that a structured definition of all the aspects to be considered during the design of a distribution voltage conversion and system rebuild, will result in a reliable and resilient electrical distribution system.

Proposal Approval Email

TR Proposal Results   Inbox x

[redacted]

Jun 1, 2022, 10:17 AM   *   <-,

[redacted]

Your Technology Report is due by [redacted]

Please follow the Technology Report Guidelines. https-//www oacett ors/MembersbiQLCeai1vLIB

PleiltQ tQnd your TR Report electronicolly *os* ii PDF attachment.

Thank you,

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Executive Summary

[redacted] is a forward-thinking utility that specializes in using the most up-to-date equipment to create a safe, reliable power grid that supplies electrical needs to its customers. Designing and maintaining a reliable system involves replacing and/or upgrading assets that are deteriorated or nearing end of useful life along with standardizing to higher primary voltages throughout the system to allow for a more reliable and efficient distribution system.

This report describes the aspects to be considered when designing an electrical distribution system upgrade such as: Pole Health Index, Transformer Load Reports, Secondary Voltage Drop Calculations, Field Data Collection, Non-linear Structural Analysis & Fuse Coordination; while adhering to the *Reg.22/04*, *CSA Standard CAN3-C235-83*, *CSA C22.3 No.1-20 (Clause 8.1.3) and other applicable standards to the electrical distribution system.*

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List of Illustrations

1.0 Introduction

[redacted] is known as a Local Distribution Company (LDC). In Ontario, there are currently 60 LDCs that are responsible for the distribution of power from transmission lines to homes and businesses. LDCs help deliver electricity to more than five million residential, business, industrial and industrial customers across the province. They are responsible for the installation and maintenance of power lines and poles. The Ontario Energy Board (OEB) regulates these Local Distribution Companies through their activities and defines performance standards which must be met.

Local Distribution Companies must adhere to specific Regulations, the *Electrical Safety Authority (ESA)*, *Canadian Standards Association (CSA)*, and any relevant procedures that are unique to the distribution company and the municipality.

The Electrical Distribution Safety Regulation, *Ontario Regulations 22/04*, sets out objective-based safety requirements for distribution systems. These cover the design, construction and maintenance of electrical distribution systems owned by distribution companies licensed by the Ontario Energy Board. The Regulation requires distribution companies to get approval of equipment, plans, specifications and inspection of construction before putting systems into service. The *Electrical Safety Authority* audits to ensure compliance to safety standards and undertakes inspections to confirm compliance with the Regulation.

Aside from *Regulation 22/04*, there is also *CSA Standard CAN3-C235-83 (Preferred Voltage levels for AC Systems, 0 to 50,000V) along with the CSA 22.3 No.1 and CSA 22.3 No. 7* that applies directly to the LDC's design and maintenance of the distribution system.

These requirements must be met if not surpassed during the design stage for acceptance.

While all the regulations and standards are met, this report compiles and structures the different aspects to be considered as a means to have consistent designs among different designers within the same organization.

2.0 Problem Statement

[redacted] is gradually phasing out its 4.16kV infrastructure due to its limited capacity, inability to serve load growth, and high system losses associated with it.

There are various issues being covered under this Technology Report such as: challenges involved when redesigning an existing overhead electrical distribution system which is now outdated in regard to legacy standards, placements of structures such as transformers below secondary bus, rear-yard primary conductor, open secondary bus, etc.

This report will outline the steps involved [redacted] is required to follow by *ESA*, *CSA*, *Reg. 22/04* and various internal procedures that are unique to [redacted] when doing primary voltage conversion projects.

3.0 Methodology

3.1 Pole Health Index

[redacted] has about 30,000 poles in its system, of which over 97% of them are wood poles. [redacted] conducts yearly pole testing on various parts of its system to ensure that the wood poles have a remaining strength of more than 60%, as per *CSA C22.3 1 Overhead Systems 8.3.1.3*.

The parts of the system that are tested are determined by a particular yearly testing cycle. [redacted] utilizes a 1 to 5 year testing cycle on its hydro pole infrastructure after it has been in service for 20 years. That is, if a pole is installed today, it will be tested in 20 years from now. Then, after the first test, the pole will be tested in 1 to 5 years maximum depending on its remaining strength. All this information is recorded in the GIS databases. These databases are queried on a regular basis to determine pole replacements, areas with a higher density of aging poles, and it is overlaid on the capital project schedules so they can be replaced before their end of life.

In addition to pole testing, [redacted] uses a deterioration curve for wood poles based on historical data, previous pole testing results, and reliability data. This allows [redacted] to replace problematic areas that would not be assessed within the pole testing cycle. Deterioration of wood poles can also be the result of foreign interference, i.e, minor unreported vehicle accidents and any other external factors. Therefore, [redacted] also performs yearly inspections by grid areas of all the assets including wood poles. Every area is patrolled and assessed at least once every three years.

The combination of pole testing, calculated health index and regular inspections, enhances the maintenance of the system and minimizes the risk of missing any deteriorated wood pole before failure.

Areas supporting legacy voltages tend to have more structures nearing their end of life cycle and require replacement prior to being deemed unsatisfactory. Under primary voltage conversions such as the one covered in this Technology Report, hydro poles in these areas were nearing the end of their useful life (50-55 years old) or are close to replacement (nearing 60% remaining strength). Through field verifications and the data submitted to [redacted] by its pole testing contractor, the Engineering Technologist with their experience and the experience of qualified and competent linemen can decide if a structure is requiring replacement immediately or it can last through to its next testing cycle as described above.

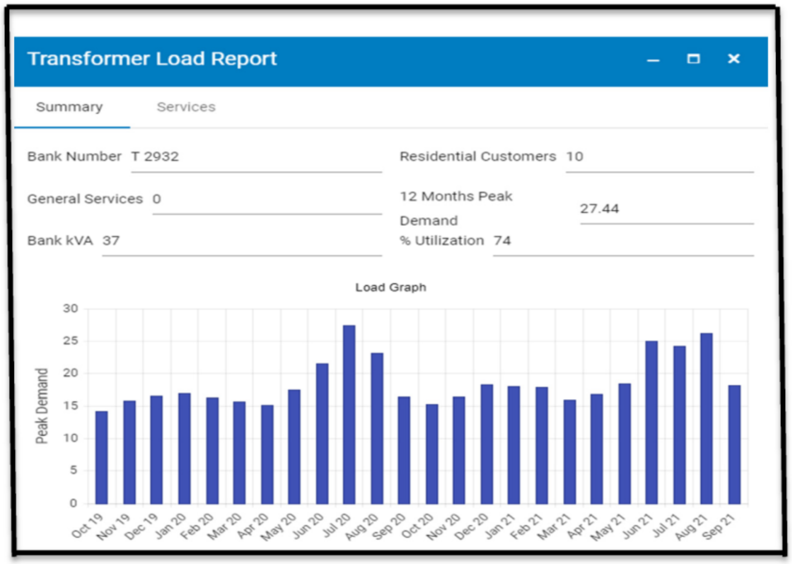
3.2 Transformer Load Reports

Transformer Load Reports are a crucial part to the design process, especially when a primary voltage conversion is being undertaken. A transformer that is underloaded will create more losses than a transformer that is loaded to its ideal operating condition (100%) through $P_{loss} = I^2R$. Alternatively, a transformer that is overloaded (<100%) can cause issues with safety and reliability. The assets performance will decrease overtime. The hydro utility has various transformer sizes at its disposal and range from sizes of 10KVA, all the way up to 100 KVA.

Through the use of the Customer Information System (CIS), transformer load report data can be collected and analysed to properly size new assets according to demand.

Under this project, rear-yard primary is to be removed to alleviate safety concerns related to high voltage in backyards, tree trimming near primary lines, access, etc. Eliminating the rear-yard transformer means that a new unit is to be installed on the roadway, more accessible to line trucks and the line crew. Re-evaluating where this transformer is to be placed allowed for a transformer consolidation under this project. A transformer consolidation occurs when more than one transformer is combined to help maximize its load according to demand. Transformer load reports are analyzed to see if this is a possibility and then calculations are undergone to ensure accuracy.

Illustration 1



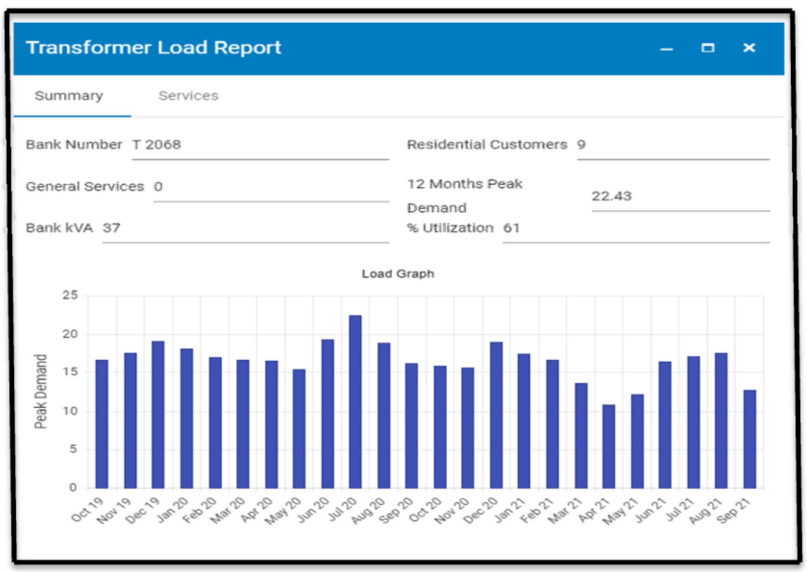
T 2068 - Measured Transformer Efficiency (22.43 KVA)

$$Efficiency_{\ (\%)} = Output_{\ (Watts)}/Input_{\ (Watts)}$$

$$Efficiency_{\ (\%)} = 2243_{(Watts)}/3700_{(Watts)}$$

$$Efficiency_{\ (\%)} = 0.60 \times 100$$

$$Efficiency_{\ (\%)} = 60$$



T 2068 - Measured Transformer Efficiency (27.44 KVA)

$$Efficiency_{\ (\%)} = Output_{\ (Watts)}/Input_{\ (Watts)}$$

$$Efficiency_{\ (\%)} = 2744_{(Watts)}/3700_{(Watts)}$$

$$Efficiency_{\ (\%)} = 0.74 \times 100$$

$$Efficiency_{\ (\%)} = 74$$

Appendix 6 shows a part of the area in question where a transformer consolidation is considered. Shown are T 2932 & T 2068 being removed and being replaced with a larger 50 KVA unit, T 12126 in the road allowance.

Adding together both *T 2932 (27.44KVA)* & *T 2068 (23.43KVA)*, shows what size transformer is required (49.87KVA) and the anticipated efficiency of said transformer.

Illustration 2

Re-sized Transformer Efficiency (50 KVA)

$$Efficiency_{(\%)} = Output_{(Watts)}/Input_{(Watts)}$$
$$Efficiency_{(\%)} = 4987_{(Watts)}/5000_{(Watts)}$$
$$Efficiency_{(\%)} = 0.99 \times 100$$
$$Efficiency_{(\%)} = 99$$

When evaluating transformer load reports, it's important to note that each customer may peak at different times during the year. Assuming all customers will peak at the same time to allow for proper transformer sizing is appropriate and a good practice. All customers sharing the same peak at the same time is rare but not unrealistic.

Coincidence factor is the sum of peak loads of all the components in a system divided by peak of the entire system. It tells how likely the individual components are peaking at the same time. The highest possible coincidence factor is 1, when all of the individual components are peaking at the same time.

Illustration 3

$$Coincidence\ Factor = Coincidence\ Peak\ (kW)/Sum\ of\ individual\ Peaks\ (kW)$$

$$Coincidence\ Factor = 49.87\ (kW)/58.06\ (kW)$$

$$Coincidence\ Factor = 0.85$$

Taking into consideration the *coincidence factor* of 0.85 and each individual customer's peak, we were able to better determine a more accurate scenario for this transformer's peak demand according to past load report data. Summing up the coincidence factor from both table 1 & table 2 the value is 30.29 kW. [redacted] does not stock 30 KVA units so the next available unit is 50 KVA as shown in illustration 5.

Illustration 4

TABLE 1
T 2932

Service Address	Peak (kW)	Last Reading (kW)	Coincidence Factor (kW)
405 Oak Park Dr.	1.99	0.75	0.63
409 Oak Park Dr.	3.31	1.05	0.89
411 Oak Park Dr.	3.42	2.85	2.42
415 Oak Park Dr.	2.23	0.65	0.55
419 Oak Park Dr.	3.03	2.48	2.1
425 Oak Park Dr.	2.9	1.58	1.34
437 Oak Park Dr.	7.14	2.85	2.42
441 Oak Park Dr.	2.41	1.47	1.24
445 Oak Park Dr.	2.51	1.44	1.22
449 Oak Park Dr.	2.42	1.49	1.26

TABLE 2
T 2068

Service Address	Peak (kW)	Last Reading (kW)	Coincidence Factor (kW)
400 Oak Park Dr.	1.57	1.05	0.89
412 Pinetree Dr.	3.25	2.78	2.36
408 Oak Park Dr.	1.57	1.05	0.89
412 Oak Park Dr.	3.74	1.03	0.87
416 Oak Park Dr.	2.63	1.32	1.12
420 Oak Park Dr.	2.17	1.19	1.01
426 Oak Park Dr.	1.83	0.82	0.69
432 Oak Park Dr.	8.08	8.08	6.86
438 Oak Park Dr.	1.86	1.81	1.53

3.3 Secondary Voltage Drop Calculations

In the event of a primary voltage conversion where an existing piece of equipment such as an overhead transformer is installed in the backyard of a customer's home; it is in the utilities best interest and a utility best practice to remove the primary conductor and transformer from the rear yard as a part of this voltage conversion.

Once the primary conductor is removed from the backyard, a new larger secondary bus can be installed in its place to feed the existing customers. The secondary bus size will need to be determined through voltage drop calculations from individual customer load report data.

In this circumstance, 4/0 AL. Triplex was deemed the correct size due to the backyard configuration. This rear yard has a few sizeable corners that would not allow for [redacted] standard 250kcmil to be installed due to guying requirements on the 180 grade steel messenger. The 4/0 AL. Triplex guying requirements are much less and more suitable for this location.

Appendix 6 depicts the voltage drop calculations that were conducted before any installation of a new secondary bus was placed in the field to ensure customers are within the limits set out by *CAN3-C235-83.*

3.4 Field Data Collection

After determining the scope of work required under a primary voltage conversion at the office through the use of the Geographic Information System (GIS), it is important to visit these job sites prior to do Field Data Collection of infrastructure that is already installed in the field and do verifications of infrastructure that may have not been captured through the GIS.

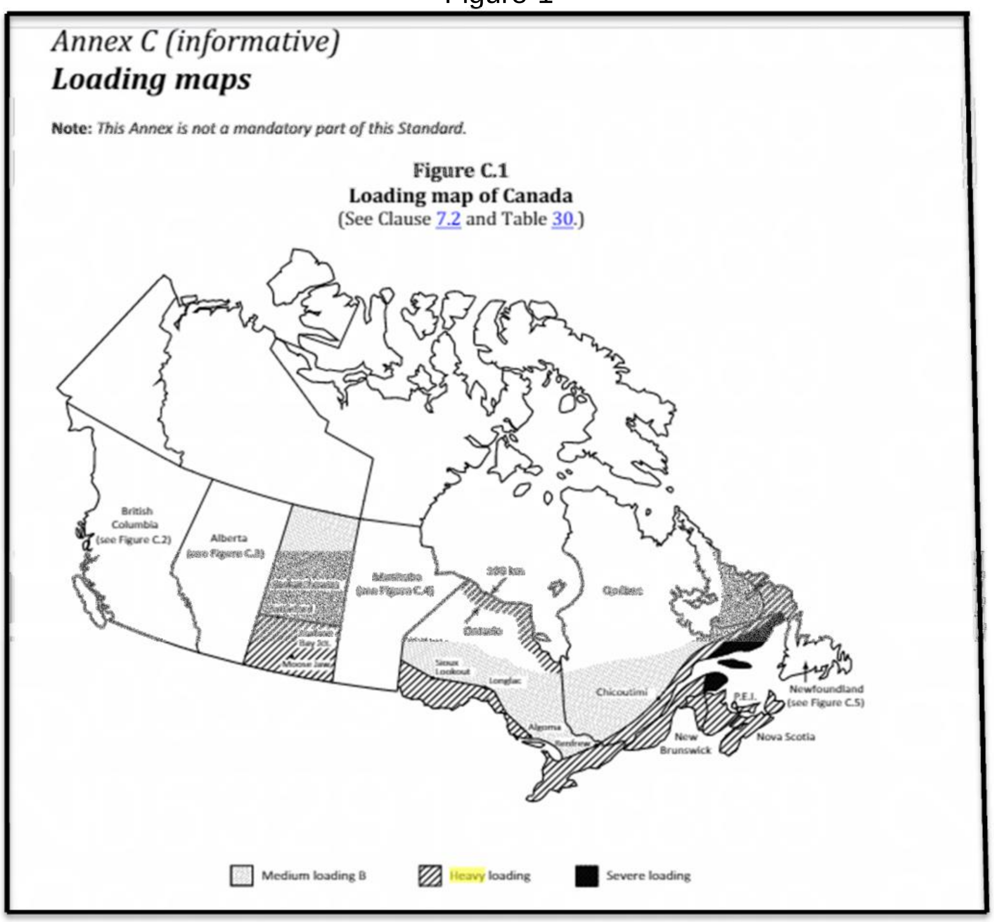
Data collection includes items such as: size, class and location of existing poles, circuit configuration, primary and secondary conductor sizes, transformer locations and sizes, secondary attachment points to customers, guying attachment points to anchor locations, anchor lead lengths from the utility pole and joint-use attachments (i.e communication companies that have fiber optic, coaxial cable, etc. attachments that are below the electrical distribution system).

Appendix 9 shows examples of the attributes captured during field inspections and the data collected by querying geographical systems.

3.5 Non-linear Structural Analysis

Designing new or redesigning existing electrical distribution systems, it is paramount to put an emphasis on the structural system due to the fact these structures support high-voltage conductors and a large amount of forces that can dictate the systems resilience to its surroundings and the weather. This is captured using geometric non-linear structural analysis software such as "SpidaCalc". Non-linear analysis refers to considering factors such as, modulus of elasticity of wood poles, cantilever forces, displacement of the structures and strength of the materials. These attributes are also put under additional stress factors such as wind speed, temperature and ice accumulation (Figure 1.). The latter factors ensure that the ultimate design can withstand heavy weather conditions as defined by the CSA 22.3 No. 1.

Figure 1



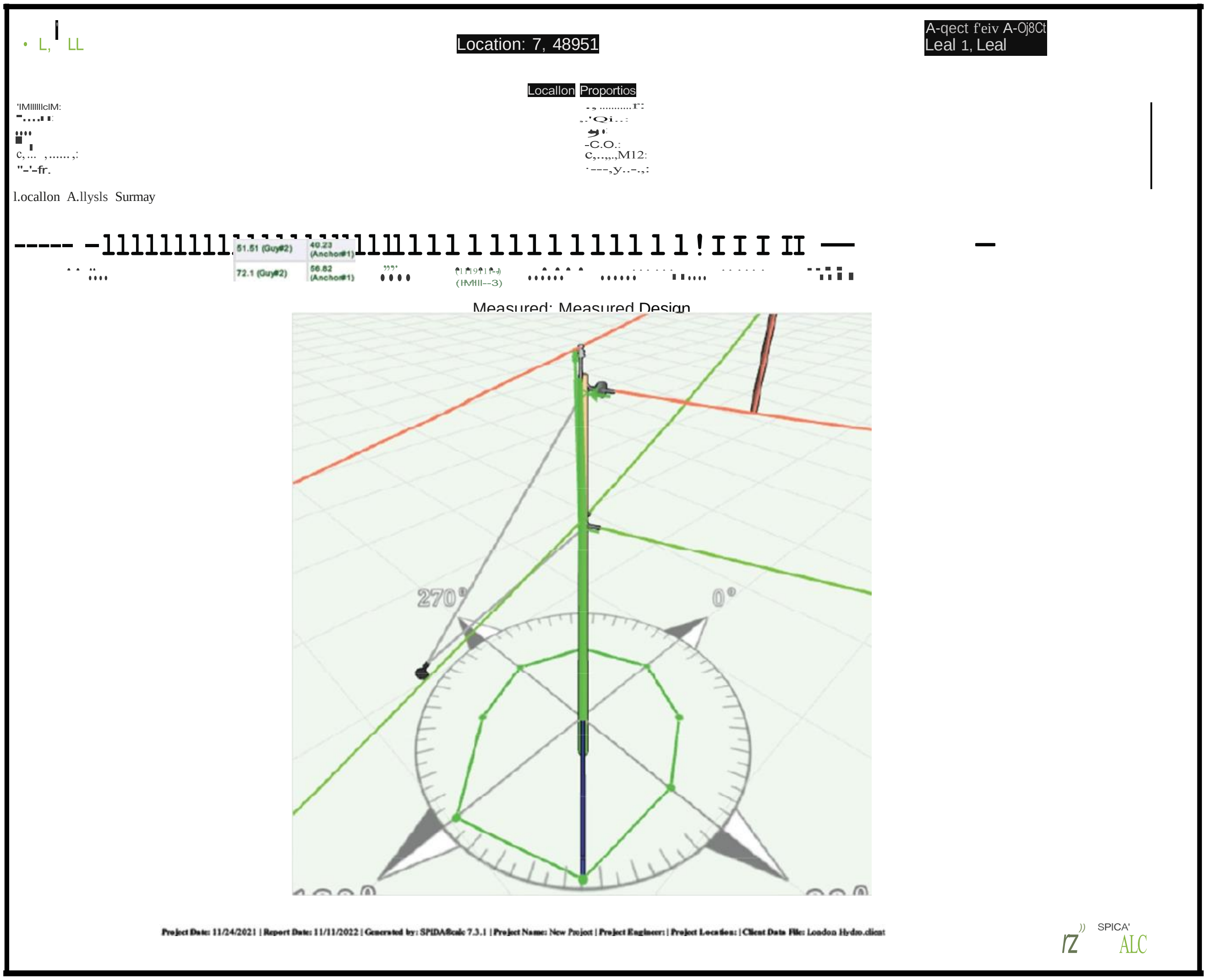
During the early design stages it's beneficial to use this software for key locations that structural integrity is key. Crucial areas to consider are Grade One constructions such as rail crossings/waterway crossings, large primary conductor corners and where sensitive-expensive equipment will be installed.

To utilize this software properly, the height and class of pole needs to be determined, the conductor size's both primary and secondary, attachments and attachment heights, etc. Most if not all of this information can be obtained from the utility's GIS software and if not, any outstanding information can be verified through the Field Data Collection portion of the project.

After all the information has been compiled and entered into the program for analysis, a better understanding of the overall system can be understood. The program will help dictate any outstanding items that need to be addressed prior to construction such as increased guy lengths, higher class poles, attachment heights, etc.

The analysis results are shown in the software program as strength percentage for each individual item. The higher the percentage the more forces are being applied to that item. For example; if any pole, anchor or guy wire fails (exceeds 100%) a re-design of that item will need to be addressed. This can include a higher class pole, different attachment heights or additional guy wires being installed (Figure 2.).

Figure 2


Location: 7, 48951
Leal 1, Leal
Locallon Proportios
Locallon A.llysls Surmay
51.51 (Guy#2)
40.23 (Anchor#1)
72.1 (Guy#2)
58.82 (Anchor#1)
Measured: Measured Design
270°
0°
Project Date: 11/24/2021 | Report Date: 11/11/2022 | Generated by: SPIDAcalc 7.3.1 | Project Name: New Project | Project Engineer: | Project Location: | Client Data File: London Hydro.client

3.6 Fuse Coordination

A fault on a wire or cable will result in a momentary outage (or sustained) to all customers supplied by the same primary circuit and a momentary voltage dip to all customers supplied by the same municipal substation or transformer station bus. The voltage dip will last for as many cycles as it takes for the fuse to clear.

There are two classes of fuses used for protection on [redacted] overhead distribution system: Current Limiting Fuses and Expulsion Fuses.

A Current Limiting Fuse is a ribbon or wire made of tin or silver, which is surrounded by quartz sand. When this fuse experiences a fault, the silver ribbon or wire melts, which then may cause an arc. The heat of the arc gets absorbed by the quartz sand. If the fault is large enough, the heat from the arc may transform the sand into a crystalline structure known as fulgrate. Fulgurate has a high impedance and will extinguish the arc current and allow the fuse to drop out. This fuse can enforce a current zero, which means that it can clear in less than 0.01 seconds.

An Expulsion Fuse releases gasses caused by the arc inside the cartridge heating a fibrous material surrounding the fuse element. The gas deionizes the surrounding air to stifle the arc caused after the melting of the fuse element.

A Time Current Curve (TCC) Program (CYMTCC) was used to plot the Inrush of the transformer size. Using the point value of the Inrush was sufficient in this case however Inrush curves can also be calculated using Full Load Current (FLC) of the transformer.

ILLUSTRATION 4

$$FLC_{(l<p)} = KVA \times 1000 / V_{LN}$$

$$FLC_{(l<p)} = 200\ KVA \times 1000 / 16,000V_{LN}$$

$$FLC_{(l<p)} = 12.\ SA$$

The total transformation downstream of this fuse is tallied up (200 KVA) and applied to the above calculation. The Full Load Current in the event of a fault at this location will see 12.5A. [redacted] does not stock 12.5A fuses so the next highest fuse available is rated for 15K and will suffice as protection for the downstream devices.

The coordination between downstream devices such as transformers and fuse ***04151 15K*** are shown below on *Appendix 7*, through the use of the TTC Program.

3.7 Conclusion

This report shows the amount of work and understanding of the electrical distribution system when it comes to designing or redesigning a portion of overhead infrastructure that is required to follow *Regulation 22/04*, *CSA Standards* and various unique specific utility procedures. As shown in the report, the location of equipment needs to be considered when eliminating rear-yard primary transformers and conductors. This leads to conducting secondary voltage drop calculations to each customer's home and this needs to comply with *CSA CAN3-C235-83.* The proposed transformers location requires the proper spacing for back-guying of this new secondary bus as described in the Non-linear Structural Analysis part of the report. Once the transformer locations have been chosen and the secondary voltage drops are within allowable tolerances, a radial fuse will need to coordinate with all the devices downstream of it to provide additional protection in the event of a fault. This fuse will protect the feeder upstream of it and will not allow the fault to ripple throughout the system.

List of References

1. Ontario Regulation 22/04. https://www.ontario.ca/laws/regulation/040022/v9
2. CSA Standard C22.3 No.1-20 (Overhead Systems)
3. CSA Standard CAN3-C235-83 Table 3
4. SpidaCalc https://www.spidasoftware.com/spidacalc/
5. Electrical Safety Authority https://esasafe.com/role/edsr/

Appendix 1
Minimum Grades of Construction

6 Minimum grades of construction

6.1 General

For the purposes of strength requirements for communication and supply lines less than or equal to 69 kV nominal voltage (see Clause 8), lines shall be classified under the grades specified in this Clause on the basis of relative hazards. Grades of construction apply to structures, guys, crossarms, conductors (including cables and suspension strands), messengers, insulators, pins, or posts and fastenings.

Where two or more conditions affect the grade of construction, the grade used shall be the strongest required under any of the conditions.

For supply lines at nominal voltages greater than or equal to 70 kV with no communication circuits in their proximity, the strength requirements of Clause 8 or of CSA C22.3 No. 60826 may be applied.

6.2 Order of grades

Grades of construction for supply and communication lines range from 1 through 3, with Grade 1 being the strongest.

6.3 Minimum grades of construction

6.3.1 General

Tables 27, 28, and 29 specify the minimum grades of construction for crossings, lines in proximity, and joint-use, respectively.

6.3.2 Crossings

6.3.2.1

Table 27 specifies the minimum grades of construction for in-span crossings of supply and communication lines across highways and roads, private and public property, pipelines, waterways, railways, aerial tramways, and other communication and supply lines.

6.3.2.2

Common-structure crossings are classified as joint-use. Span guys that form a crossing shall have the same grade and strength requirements as would the wire or cable attachments they support, if such attachments were to form the crossing themselves.

6.3.3 Proximities

Table 28 specifies the minimum grades of construction where structures or conductors of communication and supply lines are in proximity to any of the following: railways, highways and roads, pipelines, navigable waterways not classified as minor waterways, aerial tramways, other communication or supply circuits or lines, and other private or public property.

6.3.4 Joint-use

Table 29 specifies the minimum grades of construction for joint-use.

Appendix 2
Strength of Supporting Systems According to Deterministic Design

7.9.2

For all load cases involving wind, assumed loads on the structure shall be calculated using the wind directions that create the maximum stress on the supporting structure.

8 Strength of supporting systems according to deterministic design methods

8.1 General

8.1.1

Clause 8 specifies the strength requirements for supply and communication lines designed to withstand the loads specified in Clause 7. The strength requirements in Clause 8 shall apply to all grades of construction unless otherwise specified.

8.1.2

The longitudinal strength requirements specified in Clause 8 generally apply only to the structure immediately adjacent to a crossing, or at the ends of a proximity or joint-use section. The requirements specified in Clause 8 for transverse strength and strength at angles generally apply to each of the structures within the crossing, proximity, or joint-use section.

8.1.3

The method of analysis for structures shall be the non-linear method including stability (buckling) check.

Note: *See Clause A.8.1.3 for information regarding non-linear design.*

The methods and assumptions used for analysis of a joint-use structure are to be determined by the structure owner(s).

Deformation, deflection, or displacement of parts of the structure and adjacent structures can sometimes change the effects of the assumed loads. When changes in the effects of assumed loads can be estimated due to deformation, deflection, or displacement of parts of the structure, and adjacent structures, they may be included in the non-linear analysis.

8.1.4

The deflection of the structures should be considered in regard to deformation and strength reduction of the structures.

8.2 Materials

8.2.1

Materials, including those used in foundations and settings, shall be able to withstand and maintain safely the loads specified in Clause 7.

8.2.2

Tie wires and fastenings shall have no sharp edges at points of contact with conductors and shall be applied such that they do not damage line conductors. Tie wires shall be made of a material that does not cause corrosion. The side pull of the conductor due to a change in the direction of the conductors shall be against the insulator rather than the tie wire.

Appendix 3
Clause 8.1.3 Non-linear Analysis

A.8.1.3

Clause 8.1.3 mandates that geometric non-linear analysis is the structural analysis method required by this Standard. It also enables the use (non-mandatory) of load non-linearities which might exist as the structure deflects. If load non-linearity is considered, care should be taken in choosing assumptions on how other inter-connected structures are modelled in order to ensure loads are not underestimated. Interconnected structures could be assumed fixed, assumed infinitely flexible, their flexibility approximated, or the structure completely modelled. It should be completely understood how each assumption affects the assumed load and its effects on the structure.

Previous editions of this Standard that allowed linear analysis as a structural analysis method frequently used the term buckling, which is a term commonly associated with the requirements of linear analysis. This includes vertical buckling calculations, such as Euler's buckling equations, and only considers a simplistic model of the structure. In contrast, non-linear analysis incorporates these calculations in a more comprehensive manner, and frequently uses the term stability checks, taking the entire structure and its attachments into account utilizing finite element analysis.

Geometric non-linearity and changes in the stiffness of the structure can occur in a few ways. Individual members that make up the structure can begin to behave in a manner that is non-linear, such as localized buckling or stress failure, or they fail to provide the stiffness initially assumed for other reasons (e.g., cable or wire goes slack). Stiffness can also change strictly due to structure deflections. For instance, the direction of a member could change, which could change the stiffness this member provides to the overall structure. Stiffness can also change due to the current state of the structure (stress load) or from the applied loads through an effect often called stress stiffening or geometric stiffening. This effect can cause structural elements to increase or decrease in stiffness depending on the tensile or compressive loads. In a non-linear analysis, all significant changes to a structure's stiffness should be included as part of the structure's geometric non-linearity. Since structure support mechanisms such as guy wires and pole braces offer stiffness to the structure that must be considered as additional support members in the structure's analysis, any change to their stiffness as the structure deflects must be accounted for as well. If the structure's stiffness changes to resist the assumed loads, several iterations of the re-estimation might be required to determine the final structural response.

Another way a structure's response to loads can change is due to a change in where the loads are applied, since the attachment points on the structure have moved during its deflection. This effect is called the P-Delta effect. As a structure deflects in response to the loads applied to it, the fact that the loads are essentially moved to a different absolute location will change how the loads affect the structure. This is said to "soften" the stiffness of the structure and reduce its ability to support the assumed loads. If the P-Delta effect is significant, the structure will collapse. If the effect is moderate, the structure will deflect more than initially expected, but not severe enough to cause complete failure. Estimating the structure's deflection as accurately as possible is important in order to have the best prediction of actual structure and member stresses.

If the assumed forces (loads) that are applied to the structure in the analysis can change in magnitude or direction due to movement or deflection of the structure, this can be an important secondary effect. The primary source of load non-linearity comes from attachments that are connected between structures (e.g., wires, cables). If one or both of the structures deflect, the distance between the structures and the associated attachment's angle could change. The change in angle changes the direction of the loads being applied to the structure. The change in distance between the structures will change the magnitude of the loads through either slackening or tightening of the span attachments. Assumptions made as to the flexibility/modelling of the adjacent structures to the structure being analyzed can have an effect on how drastically the magnitudes of the loads change.

Appendix 4
Nominal System Voltages

Ptalerrvd Vollage Levels for AC Systems.010 SO 000 V 9

Table 1

Nominal System Voltages

	Standard lor Present and Future	Recognized Existing Standard - Nol Preferred tor Future	
Single-Pila.		480 600	Noto: llmltoo appllodon fID&Cilll circuits l'ilJOll U street fighting andweldcr loads.
Three-Phase Up to 1000 V (Chiefly for UUllzatlon Circuits)	120/208Y 2t0/416Y 347/600Y 600	240 480 277/480Y	
Above 1000 V (Chiefly lor Distribution and Subtransmission)	2 400/4 160Y 7 200/12 470Y 8 000/13 SOOY 14 400/24 940Y 000134600:Y 000	2 400 4 800/8 320Y 13 800 22 000 21 ·£100 MOOO	

Notas:

(1} On single-phas6 system$:
Single number.J (eg, N) indfr:ate 2-conductor circuit:;;
Double numbers (eg, 120/240) Indicate 3-conductor circuits.

(2) On three-phase systems:
Sln,gle numbers (eg. 240) indicate 3-conductor circuits;
.l'U»&,1'!(1111, 1 attm»/1:.tt!lDW} te• ,t lt/tlffllU!JUll,.'ly -M?a IB!d tml lfft,Jkc, ro,(ffllt.lJ Ot drf:lJJ$?J.

(3) The 4-conductor system of 20 000/34 5(}()Y, although no1 an e1<lsting standard in current Canadian usage, has been Included to encourage a single standard at the neill step above current power distribution practice.

(4J The level ol 46 kV has been Included as a nominal system voltage. However, actual usage at oresent Includes both 44 kV and 49 kV (nominal) levels.

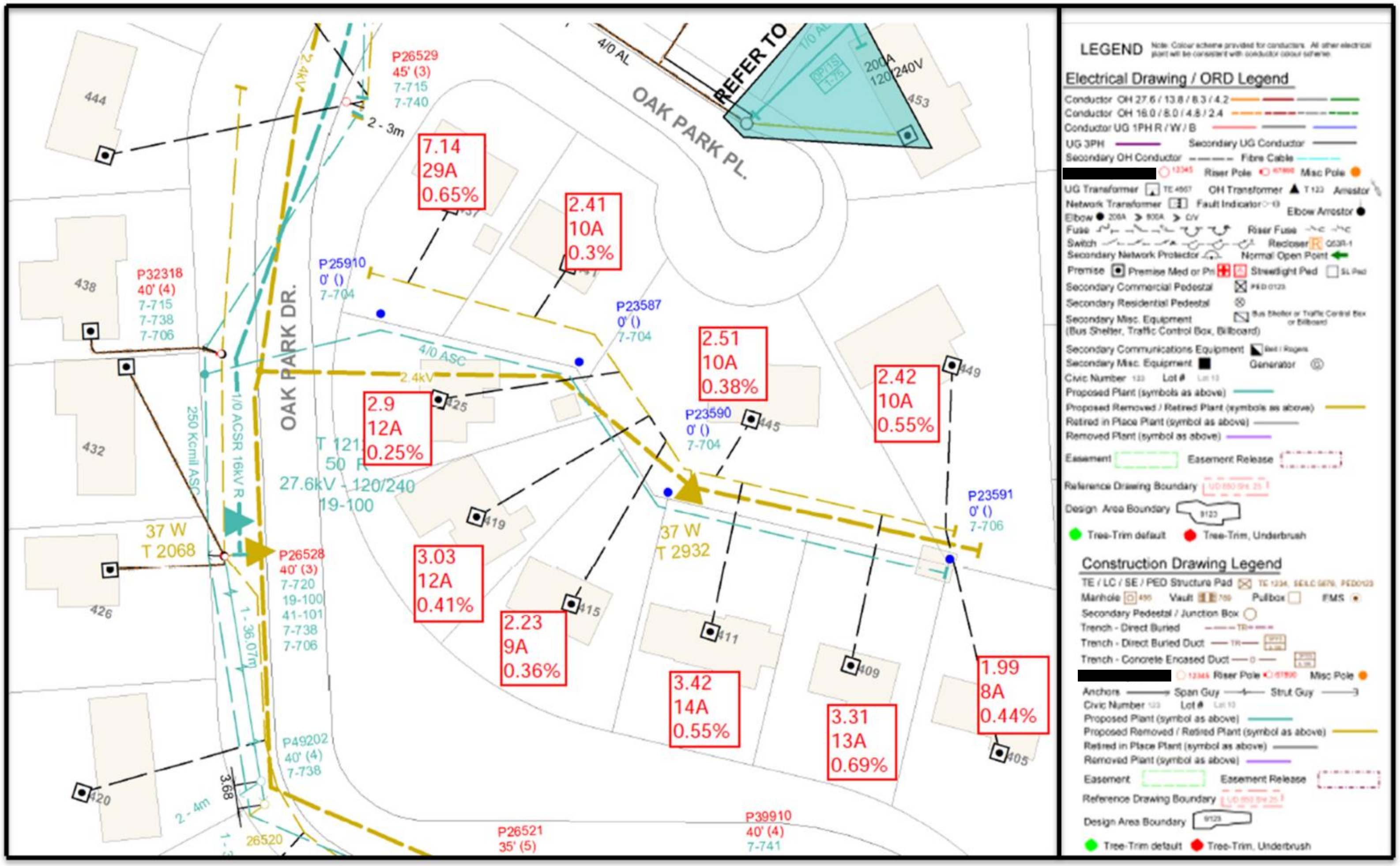
Appendix 5
Recommended Voltage Variation Limits for Circuit up to 1000V, at Utilization

Table2

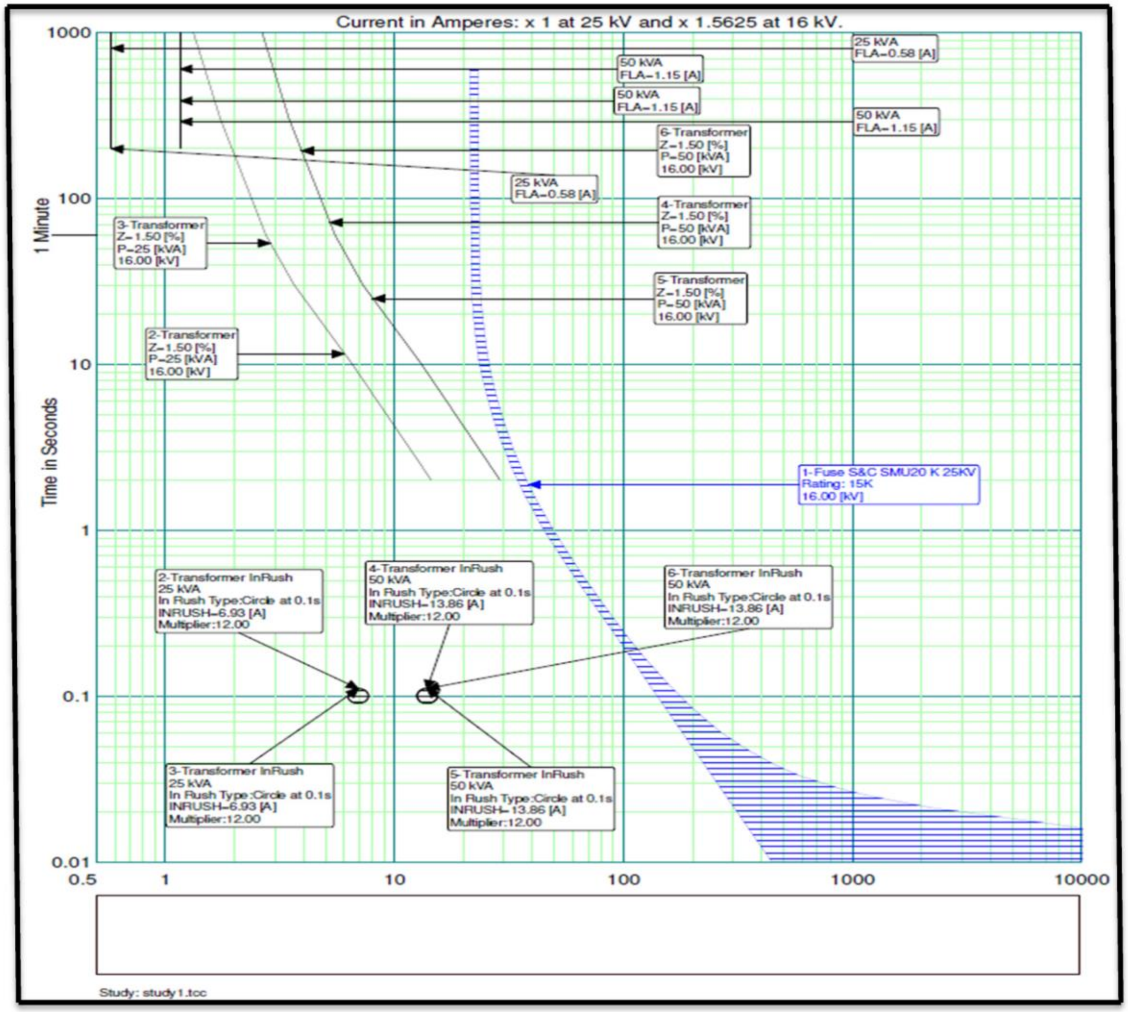
Recommended Voltage Variation Limits for Circuits
up to 1000 V, at Utilization Points

Nom.lrtJ1 $:ittem 'Vo1tagH	Voltage Variation Limits Applicable at Utilization Points			
	&tr Opaieilt!!J('; nt!lll4nll			
		N'Q:i:mu ,o,:2ating OQn:llition:s		
Single-Phase				
120/240	104/208	108/216	125/250	127/254
240	208	216	250	254
480	416	432	500	508
600	520	540	625	635
Three-Phase 4-Conductor				
I20/208Y	108/187	110/190	125/216	127/220
240/416Y	216/374	220/380	250/432	254/440
2TT/480Y	240/416	250/432	288/500	293/508
347/600Y	300/520	312/540	360/625	367/635
Three-Phase 3-Conductor				
240	208	216	250	254
480	416	432	500	508
600	520	540	625	635

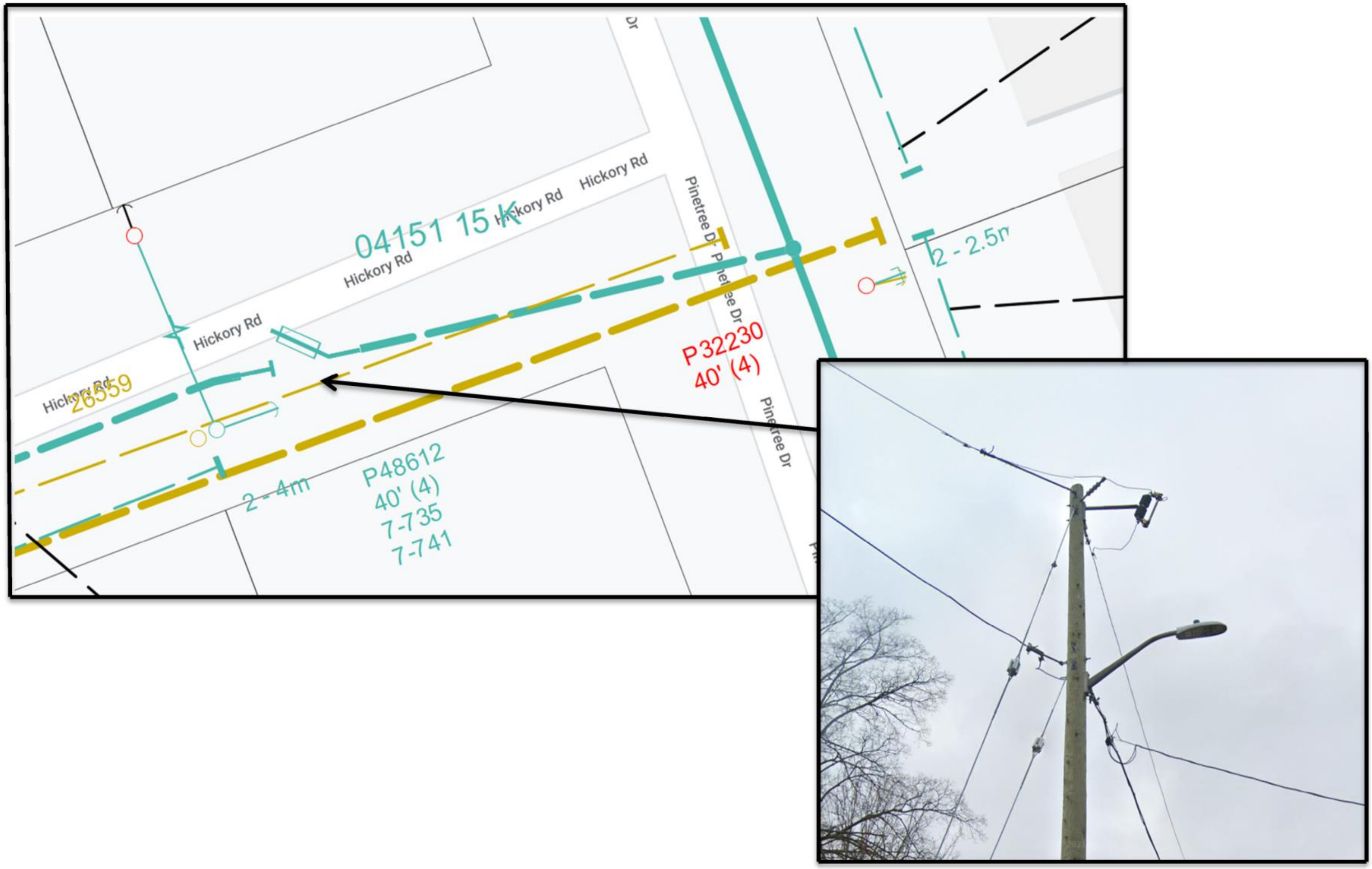
Appendix 6
Transformer Relocation & Secondary Voltage Drop Calculations



Appendix 7
CYMTCC Fuse Coordination



Appendix 8
Fuse Location



Appendix 9
Data Collected by Querying Geographical Systems

Conductor Data

G3E_FNO	G3E_CNO	G3E_FID	G3E_CID	G3E_ID	STATE	GRID_ID	INSTALL_DATE	EQUIP_OWNER	ORIENTATION	LENGTH	NODE1_ID	NODE2_ID	STATION1_ID	NORMAL_STATUS	CIRCUIT_CLASSIFICATION	CONNECTED_VOLTAGE	SYSTEM_VOLTAGE	CIRCUIT1	PHASE
306	30602	35345827	1	26326	In Service	P-55		[redacted]	UG	2	501593	501592		CLOSED	DISTRIBUTION	4.16kV	4.16kV	44F1	RWB
306	30602	35490471	1	60912	In Service	P-55		[redacted]	UG	7	1566337	1561816		CLOSED	DISTRIBUTION	2.4kV	4.16kV	44F1	W
306	30602	35490486	1	60913	In Service	P-55	11/29/2011 8:17	[redacted]	UG	232	1561596	1603613		CLOSED	DISTRIBUTION	2.4kV	4.16kV	44F1	W
306	30602	35490541	1	60919	In Service	P-55	8/20/2012 14:36	[redacted]	UG	8	1566337	1576475		CLOSED	DISTRIBUTION	2.4kV	4.16kV	44F1	B
306	30602	35490581	1	60924	In Service	Q-55	11/29/2011 8:06	[redacted]	UG	163	1603651	1561654		CLOSED	DISTRIBUTION	2.4kV	4.16kV	44F1	B

Pole Test Data

G3E_FID	POLE_NUMBER	POLE_OWNER_TYPE	MATERIAL	STATE	INSP_YEAR	REINSP_N	RETEST_YEAR	GIS_ASSET_YEAR	INSP_YEAR_INSTALLED
36727730	36055	HYDRO POLE	WOOD	In Service	2020	1	2021	1960	1960
19078471	13802	HYDRO POLE	WOOD	In Service	2016	5	2021	1956	1956
10825230	1054	HYDRO POLE	WOOD	In Service	2016	5	2021	1957	1957
11469648	29575	HYDRO POLE	WOOD	In Service	2018	3	2021	1970	1970
14268192	6151	HYDRO POLE	WOOD	In Service	2014	5	2019	1994	1994
14883786	7958	HYDRO POLE	WOOD	In Service	2016	5	2021	1975	1975
13032546	13766	HYDRO POLE	WOOD	In Service	2016	5	2021	1989	1989
16391102	12643	HYDRO POLE	WOOD	In Service	2016	5	2021	1966	1966
13688850	4268	HYDRO POLE	WOOD	In Service	2018	3	2021	1993	1993

Transformer Data

G3E_ID	STATE	GRID_ID	INSTALL_DATE	EQUIP_OWNER	XFMR_TYPE	SECONDARY_VOLTAGE	LOCATION_NUMBER	BANK_KVA_RATING	XFMR_KVA_RATING	NO_UNITS
11087	In Service	Q-56			3-PH. POLEMOUNT	120/208Y	T 1291	111	37	3
5538	In Service	Q-56			1-PH. POLEMOUNT	120/240	T 4626	37	37	1
5539	In Service	Q-56			3-PH. POLEMOUNT	120/208Y	T 1216	112	112	1
5540	In Service	Q-56			1-PH. POLEMOUNT	120/240	T 1902	75	75	1
5541	In Service	Q-56			3-PH. POLEMOUNT	120/208Y	T 5036	300	100	3
26734	In Service	Q-55		[redacted]	DEAD FRONT, LOOP FEED W/ UNDER-OIL LOADBREAK	240/120	TE 126	50	50	1
5542	In Service	Q-56			1-PH. POLEMOUNT	120/240	T 685	50	50	1
5544	In Service	Q-56			DEAD FRONT, W/ UNDER-OIL LOADBREAK	208Y/120	TE 1649	150	150	1