DISTRIBUTION SYSTEM OPTIMIZATION STUDY

WESTARIO POWER Inc.

METSCO Project # P-20-190

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This report is based on existing equipment and loading data obtained from the Client for their power distribution circuits. Any future modifications to the assumptions and study input data could affect the DSO study results and the study may need to be redone at the expense of the Client.

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1. INTRODUCTION

1.1. Project Background

The electrical supply for the town of Kincardine is provided by Westario Power Inc. (Westario). The distribution system consists of four substations servicing approximately 4000 residential and commercial customers. Each station comprises a 7.5 MVA transformer (44kV/4.16 kV) and four feeders with G&W "Viper" reclosers. Stations MS1, MS2 and MS3 have been upgraded to include SCADA monitoring capabilities and upgraded feeder egress cables. MS4 has not yet been upgraded. Feeder insulation and all major switching devices are rated for 15kV but are operating at 4.16kV.

There are operational constraints caused by phase unbalances, load constraints, voltage drop, and insufficient feeder backups during system maintenance activities. The system is projected for 3% annual growth and in addition, a major development is projected along the eastern corridor.

This study is required because of the following key concerns:

- **Load Growth:** The primary driver for this study is a need to accommodate load growth expectations over the next 10 years.
- **System Reliability:** When stations are taken out of service, the system in unable to supply existing loads resulting in breaker trips and undervoltage events.
- **Safety risks:** Crews are unable to safely and reliably de-energize/isolate large or small portions of the distribution system including stations without complex switching operations.
- **Costs:** In the absence of a 10-year plan, ongoing remedial measures such as line extensions and customer transformation may not be optimized.
- **Future Capacity:** Some areas within Westario's distribution system do have areas of vacant land slated for future development. These areas may not have lines built or lines that require additional capacity.

1.2. Scope of Work

The scope of work of the project as taken from the RFP documentation, includes the following specific tasks:

- Develop a single line distribution plan to adequately solve capacity constraints on Westario's distribution lines, referring to streets and taking into consideration existing distribution lines.
    - The distribution plan shall consider as a minimum, additional distribution line construction, additional/relocated open points, additional stations, and voltage conversions or a combination of all the above.
    - The distribution plan shall include new distribution lines, recommended wire sizes, new tie points to be created, or relocated open points between stations and feeders as required to ensure adequate system operations.

- To recommend other cost-effective solutions ensuring continued system capacity and reliability.
- To provide overall system plan to ensure continued system reliability for future load growth and to allow for system maintenance/repairs more easily. For example, Westario wants to ensure that should one of our stations need to be isolated for planned/unplanned maintenance/repair work, there is sufficient switching options/capacity on the switched lines.
- To consider all high-level costs with projected scenarios and offer the most economical solution to Westario including benefits/downsides of other options.
- To provide full study documentation that includes all the tables, values, design drawings, equipment recommendation, location maps, software files (as applicable), and all necessary data for Westario to conduct this project.
- To include full network system for the town of Kincardine.

1.3. Model Delivered

The deliverables of this project include the load flow models which were developed in CYME. These models have been provided electronically and presume the following caveats:

- Models were prepared manually from PDF drawings of the town and are not geo-spatially referenced. Linear measures such as conductor lengths were scaled from drawings and entered manually. As a result, spatial references within the graphics of the model cannot be used and new line sections must have lengths entered manually as data.
- Models are only useful if they are kept up to date. Westario Power Inc. will need to adopt a process to update models or accept that they will slowly become inaccurate.

2. TECHNICAL DATA

Table 2-1 shows the technical limitations of the 15kV feeder egress cables and overhead feeder conductors, while Table 2-2 shows the technical limitations of the Station Transformers.

Table 2-1: Ampacities of Cables and Overhead Conductors.

Type	Environment	Station	Voltage (kV)	Emergency Limit (A)
350 MCM Cu XLPE	In duct	MS1-MS3	15	440
336 MCM ACSR	Aerial	MS1-MS3	15	481
250 MCM Cu XLPE	In duct	MS4	15	385
266 MCM ACSR	Aerial	MS4	15	416
4/0 AWG ACSR	Aerial	MS1-MS4	15	328

Table 2-2: Station Data.

Type	Transformers	Breakers	SCADA
MS1	7.5MVA @4.16kV	4x15kV	Y
MS2	7.5MVA @4.16kV	4x15kV	Y
MS3	7.5MVA @4.16kV	4x15kV	Y
MS4	7.5MVA @4.16kV	4x15kV	N

3. LOAD FORECAST

Westario provided historical loading, past load forecasts and a list of large new loads for the purposes of this project. Load forecasting is out of scope however the forecast is critical to the System Plan as the needs of the planning area are heavily driven by project load growth.

3.1. Actuals and Past Load Forecast

In 2015, a load forecast was prepared based on 3% growth/year from the 2015 system peak of 18,886kVA. This forecast has been the basis of regional planning meetings. Over the period of 2010 to 2016 there were two sharp spikes of 10-20%, suggesting that unusual situations occurred that are not reliable for forecasting purposes, but should be considered in the planning criteria. Loads in the period of 2017 to 2020 were almost 25% lower than projected however, another noticeable spike occurred in 2017 (see Figure 3-1).

Table 3-1: Historical Loading to 2020 and Forecasts

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Actuals Loads (kVA, .97PF)	17,888	22,504	16,668	16,791	18,030	18,866	21,683	15,437	16,373	18,130	15,018
2015 Forecast @ 3%							19,432	20,015	20,615	21,234	21,871

3.2. Current Load Forecast

In 2020, a new load forecast was created by Westario based on 3% load growth on the 2020 peak load of 15,018kVA and the peak experienced in 2021 is slightly above (3.3%) those projections. For the purposes of this study, the load forecast will be the 2021 measured loads, with a 3%/year growth rate.

Table 3-2: Current Loading and Forecast

	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
Actual 02/21	15,800										
2015 Forecast	22,527	23,203	23,899	24,616	25,354	26,115	26,898	27,705	28,536	29,392	30,274
2020 Forecast	15,469	15,933	16,411	16,903	17,410	17,932	18,470	19,024	19,595	20,183	20,788
2021 Forecast	16,000	16,480	16,974	17,483	18,007	18,547	19,103	19,676	20,266	20,874	21,500

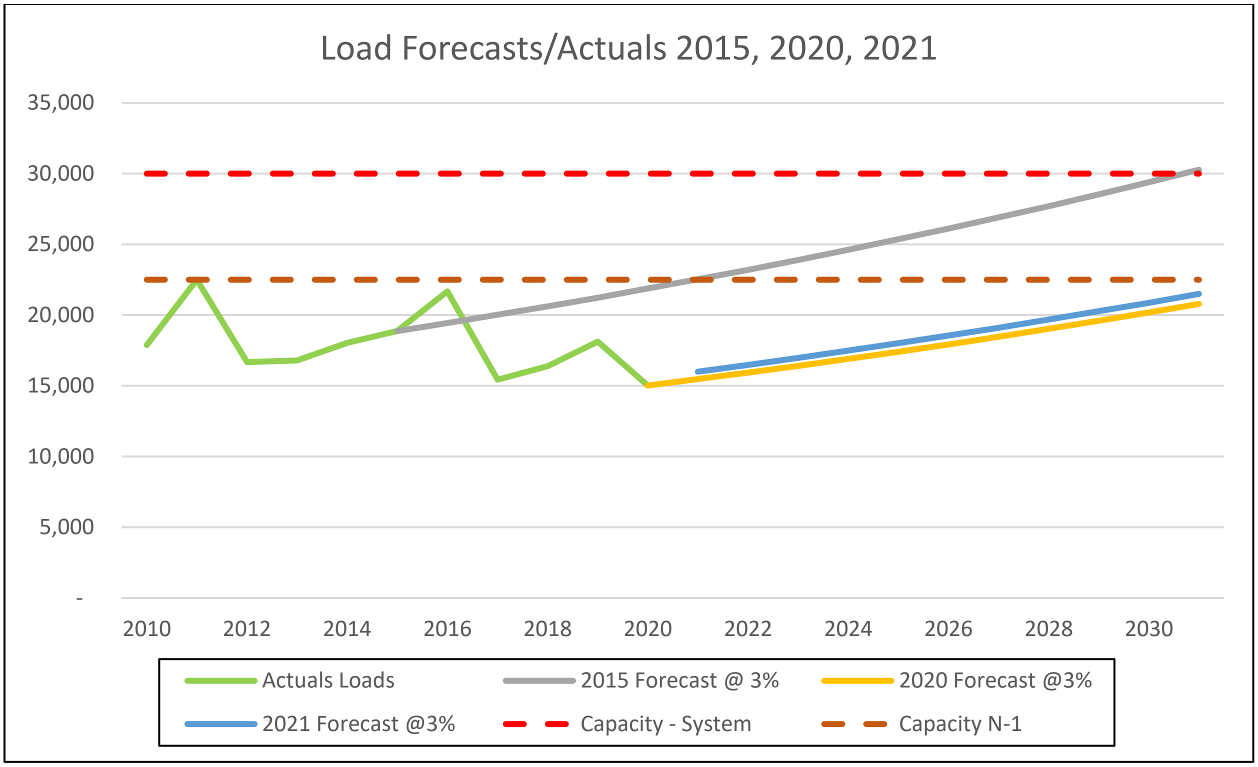

Figure 3-1: Historical Loads and Load Forecasts.

3.3. Data Source for 2021 Actuals

In a modelling exercise, there is a need to establish the distribution of loads across stations, feeders, and phases at a point in time, which can then be scaled for projected peak loads in the same proportions as the measured time. The resulting load distribution is an estimation but is sufficiently accurate for the purposes of modelling.

Westario provided load data based on actual measurements over the month of February 2021. Loads provided for MS1, MS2 and MS3 were collected three times in February on the Westario SCADA System and for MS1 and MS2 were also captured by recorded data between Feb 2020 and Feb 2021. The SCADA system reported the system peak had occurred on Feb 2, 2021 between 6:00pm and 7:00pm.

The loads for MS4 were collected via portable load monitors for the period of Feb 10 to Feb 17, 2021, which did not directly overlap the system peak time, however a comparison of the charts revealed a second peak on Feb 12, 2021 which is close to the same magnitude. Considering variation in load diversity, phase balance, and peak duration, the distribution of loads on Feb 12th is used. Very short load spikes are ignored as they are likely the result of an in-rush current or transient.

Table 3-3: Measurements of Station Peak Loads

Station	Peak Load (MW)	Measured
MS1	2.96	Feb 7, 6:11pm
MS2	4.64	Feb 7, 6:34
MS3	3.81	Feb 7, 6:20pm
MS4	3.87	Feb 12, "evening"
Total Load	15.28MW~15.8 MVA @.97%PF	

3.4. Load Growth Characteristics and Exceptions

Westario is projecting a background load growth of 3% over the next 10 years. Included in this total are small developments, in-fill projects, and new customers. However, Kincardine also has property that could be developed, which would contribute to load growth more than background growth.

For the purposes of this study the following loads are projected, except for the Pumping station which is assumed to be included in background load growth. The Pumping station is placed as a point load in future-looking models.

- 3 Story Condo project of (~500kVA) on MS2 in the North End.
- 100-Lot Subdivision (~400kVA) on MS4 in the South End
- A Pump Station in the downtown beach area, on the waterfront (Phase 1, 500kVA, Phase 2 -additional 500kVA)

In addition, the following load is NOT included in the load forecast and is treated as a unique requirement.

- Major CI development along Hwy 21 9MVA total.

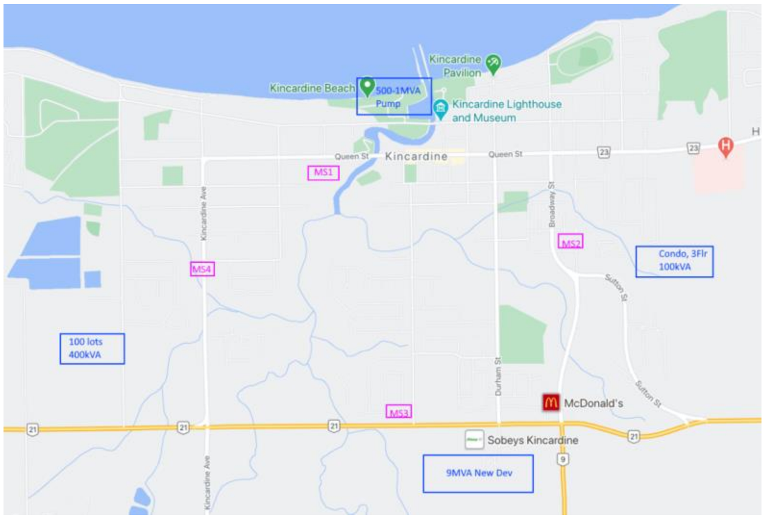

Figure 3-2: New Loads and Existing Stations

3.5. Other Factors

Electrical distribution systems are in the process of change. Customer demands are evolving, and new technologies are having unpredictable impacts. The following changes to the system have been considered in the development of this planning report.

DERs

The Impact of Distributed Energy Resources (DERs) has not been included in the Load Forecast. DERs in the Town of Kincardine are most likely to be small residential units such as rooftop solar, and residential energy storage or small wind turbines. Wind and storage are unknown factors at this time but would not be considered reliable enough to shift loads at peak, and solar might achieve a level of penetration that impacts total energy consumption but would not be useful during the evening peak experienced by Westario. Any major DER facilities will be connected directly to the 44kV system and not be an impact on the distribution network.

EVs

Another disruptive technology is the emergence of electric vehicles (EVs). Penetration of EVs has not reached predicted levels over the last 10 years but could accelerate quickly under certain economic conditions. EVs can be a significant load and each EV can exceed the entire load of a household, however predictions are that either with control technology or price signalling, the EVs will not contribute greatly to system peak. Should such an impact occur, it will be visible in the actual loads versus forecast loads and will accelerate the system reinforcement projects.

Load Growth Trends

There is also the potential that load growth is reduced or reversed, due to a variety of economic and technical factors such as the closing of a significant employment centre or the introduction of energy efficient appliances and LED lights. This project makes no attempt to estimate these impacts, and any changes would also be visible in a comparison of actual loads versus the load forecast and will delay system reinforcement projects. The impact of such disruptions will be visible in the forecast versus actual loads over time.

4. PLANNING FACTORS

4.1. Capacity Planning

For the purposes of this project, the following load forecast is assumed.

Table 4-1: Load Forecast for System Planning

	2021	2026	2031
Based on 2021 + 3%/yr.	16	18.5	21.5
New CI Development	-	+5.0	+4.0 (9 total)

For the purposes of Capacity Planning there are two key trigger points. Generally speaking, a Local Distribution Company (LDC) will begin to plan for new capacity when utilization of the existing assets reaches 80%. Such planning may include starting the design process and acquiring land or major assets. In addition, if the LDC is relying on the interconnected system for transformer backup as is the case in Kincardine, the available capacity is considered to be the total capacity minus the single largest transformer. This is known as the N-1 capacity.

Table 4-2: Capacity and Contingency Without New Development

Spare Capacity (Shortfall) without Development	2021 (16MVA)	2026 (18.5MVA)	2031 (21.5MVA)
Total Capacity (30MVA)	+14.0	+11.5	+8.5
80% Capacity (24MVA)	+8.0	+5.5	+2.5
N-1 (22.5MVA)	+6.5	+4.0	+1.0

Table 4-2 above illustrates that the entire system will be within 1MVA of overload if a transformer is out of service during system peak. While this is technically feasible, it is unlikely that system loads can be balanced within that tolerance and this is an undesirable condition.

The new development along Hwy 21 is projected as a 9MVA load. This load is likely to come online in phases, and have a long ramp up time, followed by two or more bursts of construction. The load required at the site is almost the equivalent of an entire station when it is completed.

Table 4-3: Capacity and Contingency with New Development

Spare Capacity (Shortfall) without Development	2021 (16MVA)	2026 (23.5MVA)	2031 (30.5MVA)
Total Capacity (30MVA)	+14.0	+6.5	(0.5)
80% Capacity (24MVA)	+8.0	+0.5	(5.5)
N-1 (22.5MVA)	+6.5	(1.0)	(8.0)

4.2. Other factors

In addition to load, there are several other factors to consider when planning for station transformers. These factors include:

- Availability of mobile power transformers
- Condition of existing stations.
- Station Egress and Line Conductor sizing

Mobile Transformer

Westario has a mobile power transformer (44kV/4.16kV) which can be deployed if a station transformer is projected to be out of service for an extended period. There is significant effort involved to deploy a mobile power transformer and estimates of connection time generally range between 1 and 3 days. This time can be reduced if the station facility is set up to accommodate the mobile transformer from both a land use and physical connection standpoint.

Condition of MS4

The station known as MS4 is due for an upgrade similar to what occurred at the other 3 stations. The reclosers have been converted to 15kV G&W "Viper" reclosers but the egress cables are still the older 250MCM Cu which have less current carrying capacity than the 350MCM Cu at the other stations. Recent test reports have indicated higher than baseline 'Gas in Oil' test results at a level that should be monitored. Transformer replacement is not yet indicated but regular testing is warranted. Due to the proximity of the site to a water course, it is likely that any significant station project will also have to include oil containment features. Some of the feeders supplied from MS4 include sections of 266ACSR which is smaller than the standard 336ASCR used throughout the system.

Stations MS1, MS2, and MS3

Stations MS1, MS2 and MS3 have been upgraded to the 15kV G&W "Viper" reclosers and have had the feeder egress cables upgraded to 350MCM Cu. These stations are in "good" condition. Stations MS1 and MS3 would seem to have enough land for an additional transformer if needed.

5. DSO STUDY RESULTS AND OPTIONS

Exception Criteria

For the purposes of modelling, the following exception criteria has been established:

- Feeders and station operating voltage: 94% to 106%
- Feeder cables and conductor's emergency loading limit: 100 %
- Equipment emergency loading limit (Switches, Reclosers, Transformers, etc.): 100 %

Modelling Methodology

A model was created manually by digitizing the client provided single line drawings of stations and feeders down to the level of the distribution transformer. Loads are allocated across the distribution transformer population by taking the total system load divided by the total system transformation to establish an average utilization factor. This factor was applied to each transformer in the system.

For future loads, the average utilization factor was adjusted by the ratio of the future to current peak and results in a "scaling up" of loads at the distribution transformer level. This assumption is known to be imprecise, however the result is a reasonable estimation of load distribution. Where point loads are known they can be modelled and, in this case, a 500kVA load was modelled for the water pumping facility downtown in models that reflect the ultimate loading.

The point of general modelling at the planning stage is to determine the range of viable solutions and cannot be used to calculate loads on individual line segments. For that level of detail, the first step would be to establish a stable system design and populate all known loading information.

The following modelling "cases" were developed and assessed, and contingency switching plans were created. Where sections of 1/0 conductor were encountered, they were avoided.

Table 5-1: Description of Options in Load Flow Study

Study	Configuration Notes	Scenarios
Base Case Feb 2021 Loads:	Current System Configuration	Normal Contingency
Base Case Ultimate Loads	Includes Point Load for 500kVA Pump station at Waterfront. includes Minor Upgrades (Phase Balancing and Station Egress)	Normal – Initial Normal – Upgraded Contingency – Upgraded
Transformer Upgrade	All 4 Stations upgraded to 10MVA @4.16kV	Normal Contingency
Voltage Conversion 1	All 4 Stations Upgrade to 10MVA @13.8kV	Normal Contingency
Voltage Conversion 2	Stations and feeders reconfigured to 2 x 20MVA sites	Normal Contingency

5.1. Base-Case 2021 Loads (4 stations at 7.5MVA @ 4.16kV)

This section presents the load flow study results as modelled with the loads as forecast for Feb 2021 and based on the initial system configuration.

5.1.1. Normal

Below are the results of modelling the initial system configuration with the measured Feb 2021 loads in the normal condition.

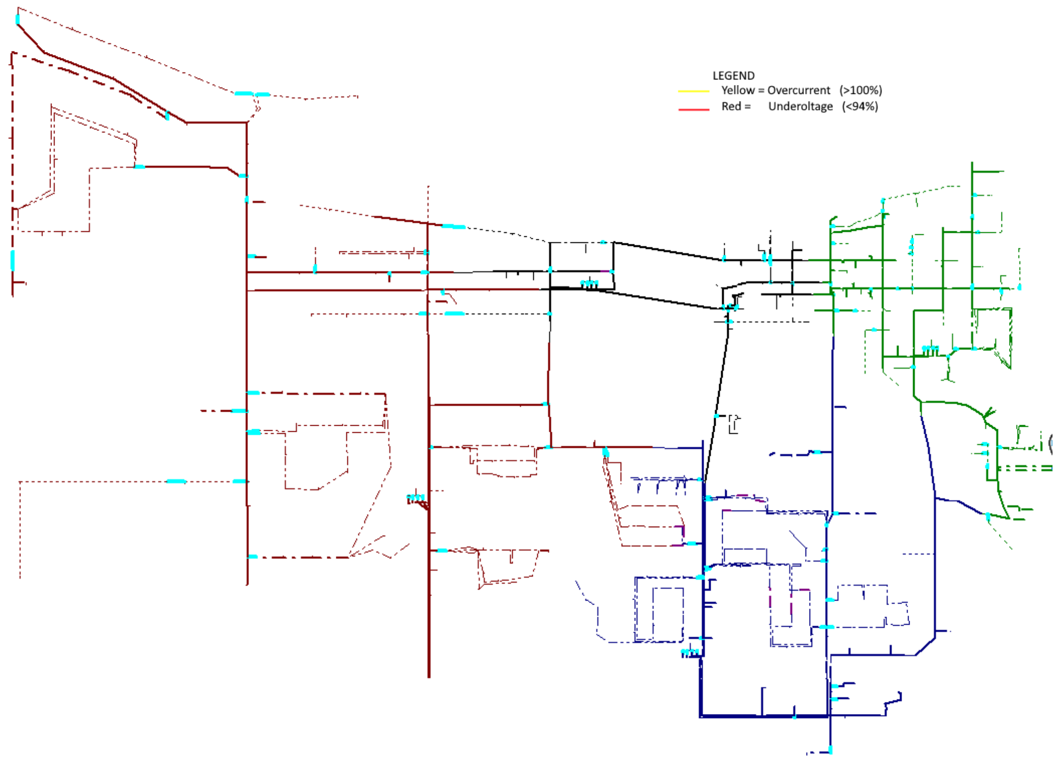

Figure 5-1: Load Flow Results - Base Case 2021 (Normal)

For detailed table of results see: Table D-1: Station and Feeder Loads - Base Case 2021 (Normal).

Abnormal Conditions:

- None

5.1.2. Contingency

Below are the results of modelling the initial system configuration with the measured Feb 2021 loads in the contingency condition.

MS1 O/S

Switching plan for transferring loads from MS1 to MS2-MS4:

- 1F1 to 4F2 Queen and Kincardine Ave. (Close 1F1-4F2B B, 4F2-1F1A, 1F1-4F2C and Open 1F1-1)
- 1F2 to 2F2A Huron Terrace and Lambton (Close MS1F2-MS2F2-TIE-A, MS1F2-MS2F2-TIE-B and Open 1F2-1)
- 1F3 to 3F4 on Russell St. (Close 1F3-3F4 and Open 1F3-1)
- 1F4 no customers.

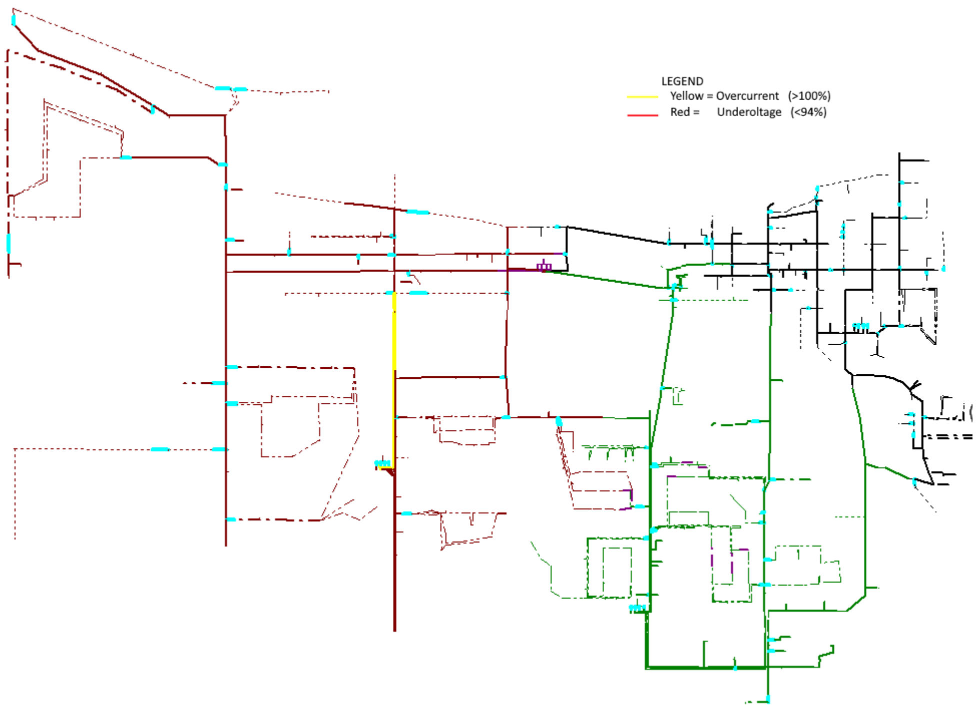

Figure 5-2: Load Flow Results - Base Case 2021 (MS1 O/S)

For detailed table of results see: Table D-2: Station and Feeder Loads - Base Case 2021 (MS1 O/S).

Abnormal Conditions:

- Overloading on MS4 F2: Phase A current increases to 111% .

MS2 O/S

Switching Plan for transferring loads from MS2 to MS1 and MS3:

- 2F1B to 3F2 North and Sutton St. (Close 2F1-3F2 A and Open 2F1-1)
- 2F2A to 1F2 on Huron Terrace (Close MS1F2-MS2F2-TIE-A, MS1F2-MS2F2-TIE-B and Open 2F2-1)
- 2F4 to 2F3 Queen and Nelson (Close 2F3-2F4 A, 2F3-2F4 B and Open 2F3-1)
- 2F3 to 3F1 Durham and Park (Close 2F3-3F1 and Open 2F4-1)

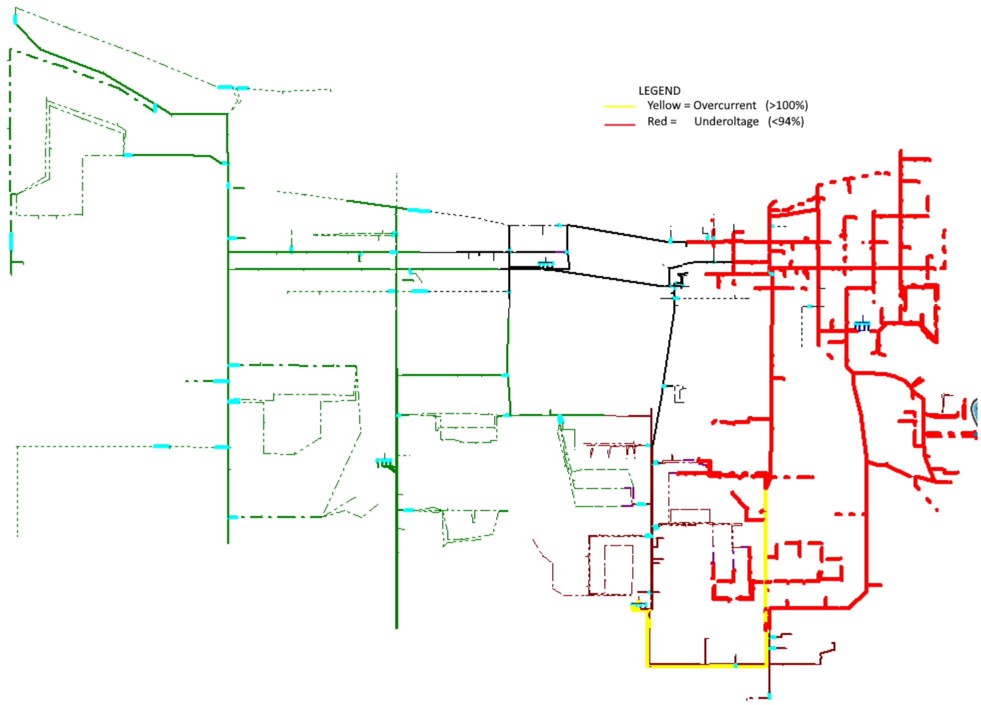

Figure 5-3: Load Flow Results - Base Case 2021 (MS2 O/S)

For detailed table of results see: Table D-3: Station and Feeder Loads - Base Case 2021 (MS2 O/S).

Abnormal Conditions:

- Undervoltage on MS1 F2: Phase C voltage drops to 92%.
- Overloading on MS3 F1: Phase A current increases to 136% .
- Undervoltage on MS3 F1: Phase A, B, and C voltages drop to 80, 87 and 87%,
- Overloading on MS3 F2: Phase C current increases to 106% .
- Overloading on MS3 TX: Transformer power increases to 112%

MS3 O/S

Switching Plan for transferring loads from MS3 to MS1, MS2 and MS4:

- 3F1 to 2F3 (Close 2F3-3F1 and Open 3F1-1)
- 3F2 to 2F1B (Close 2F1-3F2 A and Open 3F2-1)
- 3F3 to 4F1 (Close 4F1-3F3 and Open 3F3-1)
- 3F4 to 1F3 (Close 1F3-3F4 and Open 3F4-1)

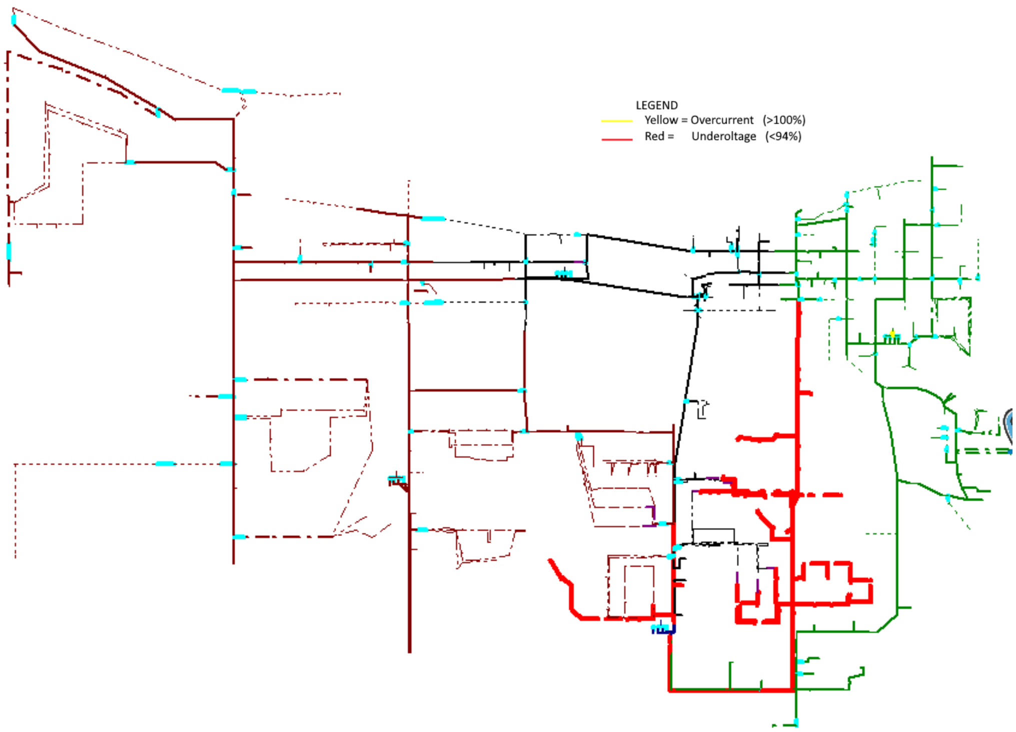

Figure 5-4: Load Flow Results - Base Case 2021 (MS3 O/S)

For detailed table of results see: Table D-4: Station and Feeder Loads - Base Case 2021 (MS3 O/S).

Abnormal Conditions:

- Undervoltage on MS2 F3: Phase A, B, and C voltages drop to 91, 92 and 93%,
- Overloading on MS2 TX: Transformer power increases to 106%

MS4 O/S

Switching Plan for transferring loads from MS4 to MS1:

- 4F4 to 4F1 (Close 4F1-4F4 and Open 4F4-1)
- 4F1 to 1F1 (Close 1F1-4F1 and Open 4F1-1)
- 4F3 to 4F2 (Close 4F2-4F3 and Open 4F3-1)
- 4F2 to 1F4 (Close 4F2-1F4 and Open 4F2-1)

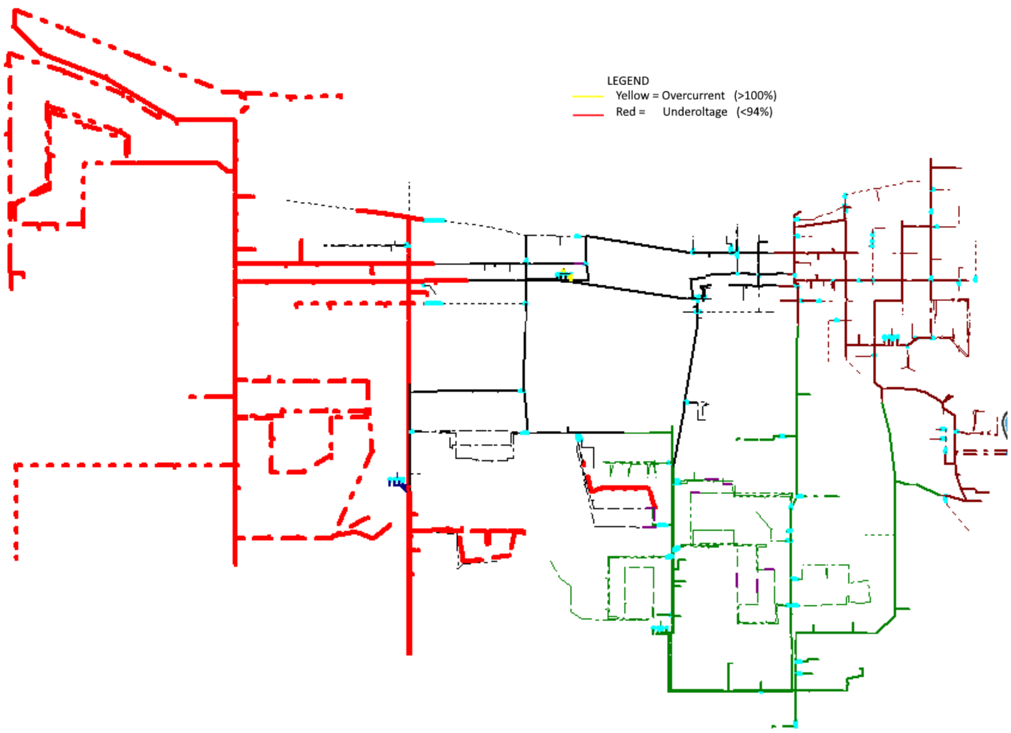

Figure 5-5: Load Flow Results - Base Case 2021 (MS4 O/S)

For detailed table of results see: Table D-5: Station and Feeder Loads - Base Case 2021 (MS4 O/S).

Abnormal Conditions:

- Undervoltage on MS1 F4: Phase A, B, and C voltages drop to 91, 93 and 93%,

5.2. Base-Case Ultimate Loads

This section presents the load flow study results as modelled with the loads as forecast for Feb 2031 and based on the initial system configuration in the normal condition.

5.2.1. Initial Configuration – Normal

The initial configuration is the Base Case System with Ultimate (2031) loads and no modifications.

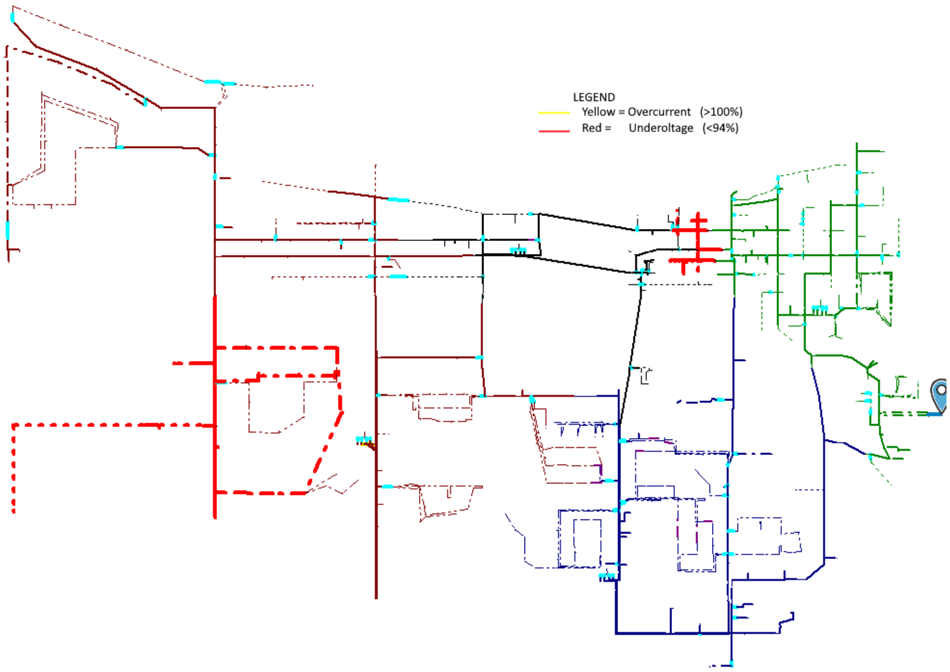

Figure 5-6: Load Flow Results - Initial (Normal)

For detailed table of results see: Table D-6: Station and Feeder Loads - Initial (Normal).

Abnormal Conditions:

- Undervoltage on MS1 F2: Phase A, and C voltages drop to 93%
- Undervoltage on MS4 F2: Phase B voltage drops to 93%
- Overloading on MS4 F2: Phase B current increases to 104% of its emergency limits

5.2.2. Minor Upgrades

The violations in the "Initial Configuration" can be remediated with the planned upgrade of the feeder egress at MS4 to 350MCM Cu and the balancing of phase current. For all remaining "Ultimate Load" models, it is assumed that these steps have been taken. Model changes for phase balancing include:

- Phase balance MS1-F2;
  - Step 1: Transfer Load T05415 25W (23.22 kVA) from phase C to B
  - Step 2: Transfer Load T05058 W (23.22 kVA) from phase C to B
  - Step 3: Transfer Load T05054 R (23.22 kVA) from phase A to B
  - Step 4: Transfer Load T05088 R (23.22 kVA) from phase A to B
  - Step 5: Transfer Load T05086 100R (23.22 kVA) from phase A to B
  - Step 6: Connect Fuse 1F2-8 R from phase B to A
  - Step 7: Transfer Load T05073 100R (23.22 kVA) from phase A to B
  - Step 8: Transfer Load T05425 50R (23.22 kVA) from phase A to B
- Phase balance MS4-F2;
  - Step 1: Transfer Load T05542 75B (23.88 kVA) from phase B to A
  - Step 2: Transfer Load T05554 75B (23.88 kVA) from phase B to A
  - Step 3: Transfer Load T05136 50R (23.88 kVA) from phase B to A

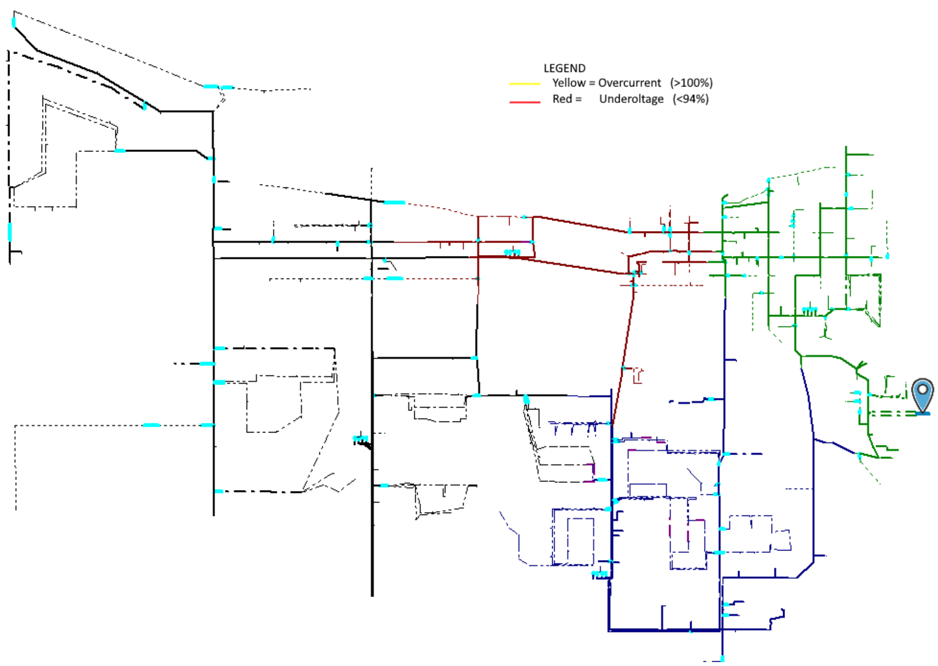

Figure 5-7: Load Flow Results - Minor Upgrades (Normal)

For detailed table of results see: Table D-7: Station and Feeder Loads - Minor Upgrades (Normal).

Abnormal Conditions:

- None

5.2.3. Contingency

Below are the results of modelling the "Minor Upgrades" system configuration with the loads as forecast for Feb 2031, in the contingency condition.

<u>MS1 O/S</u>

The following switching plan was modelled for transferring loads from MS1 to MS2-MS4:

- 1F1 to 4F2 Queen and Kincardine Ave. (Close 1F1-4F2B B, 4F2-1F1A, 1F1-4F2C and Open 1F1-1)
- 1F2 to 2F2A Huron Terrace and Lambton (Close MS1F2-MS2F2-TIE-A, MS1F2-MS2F2-TIE-B and Open 1F2-1)
- 1F3 to 3F4 on Russell St. (Close 1F3-3F4 and Open 1F3-1)

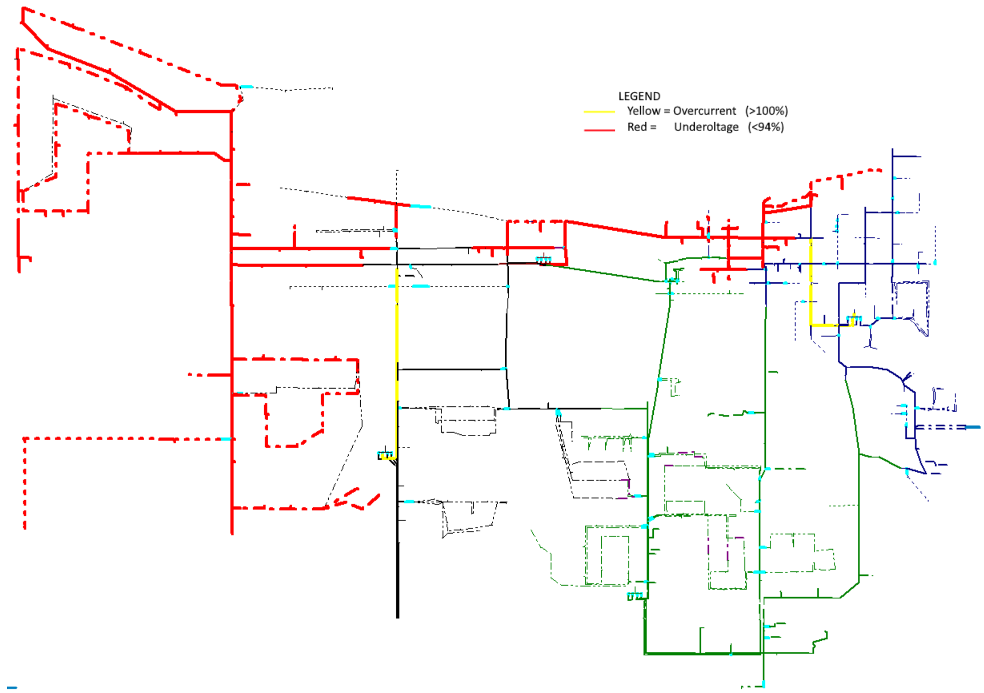

Figure 5-8: Load Flow Results - Minor Upgrades (MS1 O/S)

For detailed table of results see: <u>Table D-8: Station and Feeder Loads - Minor Upgrades (MS1 O/S)</u>.

<u>Abnormal Conditions:</u>

- Overloading on MS2 — F2: Phase C current increases to 130%
- Undervoltage on MS2 — F2: Phase A, B, and C voltages drop to 93%
- Overloading on MS2 — TX: Transformer power increases to 120%
- Overloading on MS4 — F2: Phase A current increases to 142%
- Undervoltage on MS4 — F2: Phase A, B, and C voltages drop to 92, 93 and 92%

MS2 O/S

Follow this switching plan for transferring loads from MS2 to MS1 and MS3:

- 2F1B to 3F2 North and Sutton St. (Close 2F1-3F2 A and Open 2F1-1)
- 2F2A to 1F2 on Huron Terrace (Close MS1F2-MS2F2-TIE-A, MS1F2-MS2F2-TIE-B and Open 2F2-1)
- 2F4 to 2F3 Queen and Nelson (Close 2F3-2F4 A, 2F3-2F4 B and Open 2F3-1)
- 2F3 to 3F1 Durham and Park (Close 2F3-3F1 and Open 2F4-1)

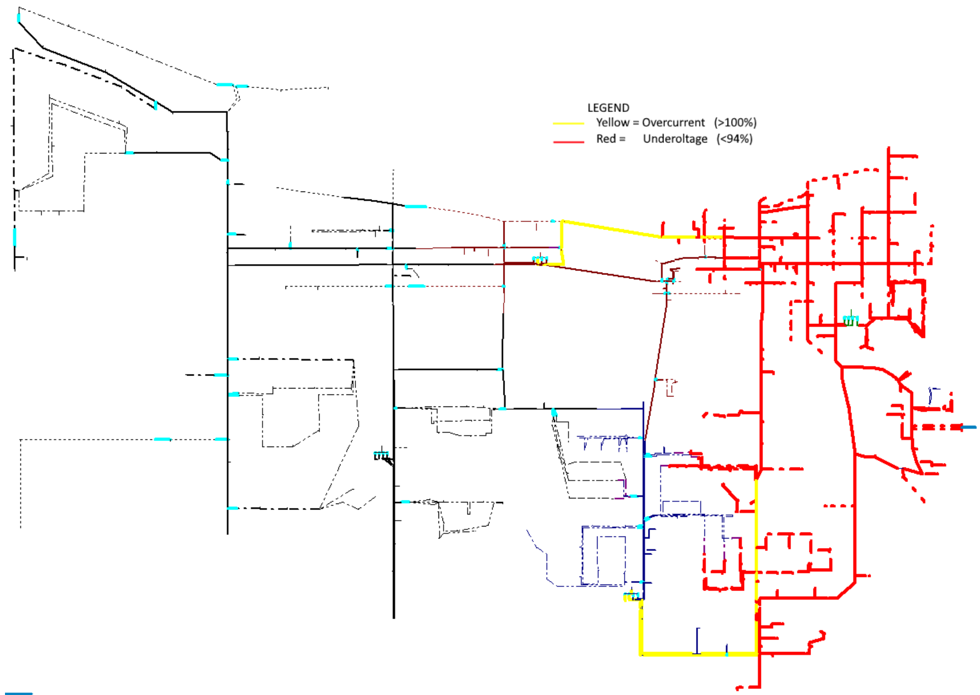

Figure 5-9: Load Flow Results - Minor Upgrades (MS2 O/S)

For detailed table of results see: Table D-9: Station and Feeder Loads - Minor Upgrades (MS2 O/S).

Abnormal Conditions:

- Overloading on MS1 — F2: Phase C current increases to 140%
- Undervoltage on MS1 — F2: Phase A. B, C voltages drop to 90, 92, and 86%
- Overloading on MS3 — F1: Phase B current increases to 133%
- Undervoltage on MS3 — F1: Phase A, B, and C voltages drop to 83, 86 and 85%
- Overloading on MS3 — F2: Phase C current increases to 133%
- Undervoltage on MS3 — F2: Phase A, B, and C voltages drop to 90, 94 and 86%
- Overloading on MS3 — TX: Transformer power increases to 131%

MS3 O/S

Switching Plan for transferring loads from MS3 to MS1, MS2 and MS4:

- 3F1 to 2F3 (Close 2F3-3F1 and Open 3F1-1)
- 3F2 to 2F1B (Close 2F1-3F2 A and Open 3F2-1)
- 3F3 to 4F1 (Close 4F1-3F3 and Open 3F3-1)
- 3F4 to 1F3 (Close 1F3-3F4 and Open 3F4-1)

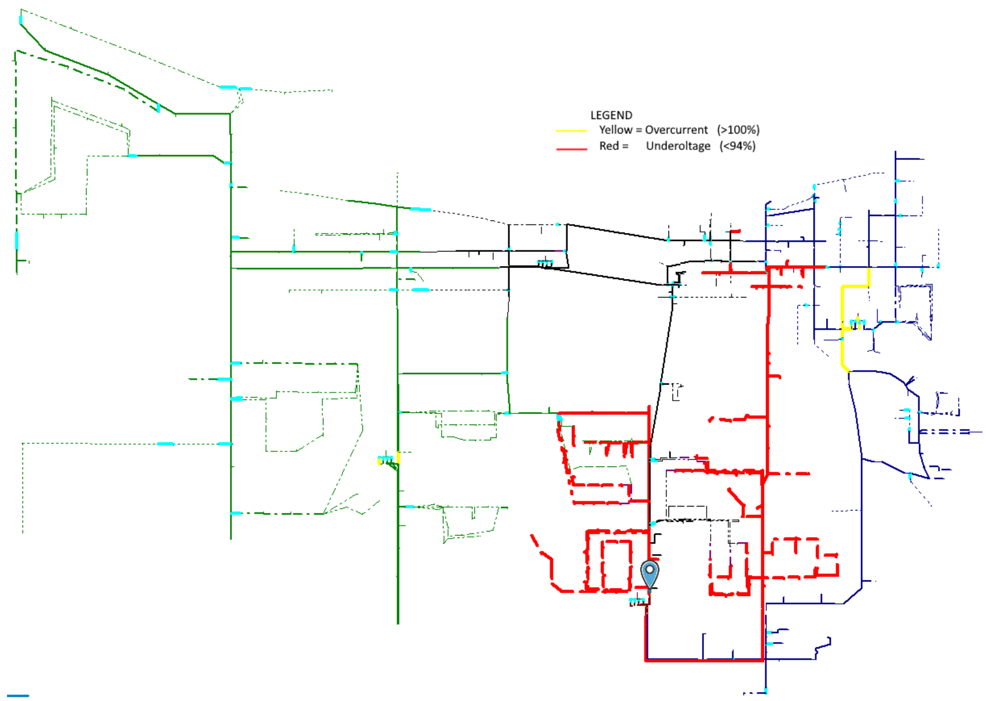

Figure 5-10: Load Flow Results - Minor Upgrades (MS3 O/S)

For detailed table of results see: Table D-10: Station and Feeder Loads - Minor Upgrades (MS3 O/S).

Abnormal Conditions:

- Overloading on MS2 F1: Phase C current increases to 134%
- Overloading on MS2 F3: Phase A current increases to 119%
- Undervoltage on MS2 F3: Phase A, B, and C voltages drop to 87, 89 and 90%
- Overloading on MS2 TX: Transformer power increases to 145%
- Overloading on MS4 F1: Phase C current increases to 105%
- Undervoltage on MS4 F1: Phase A, B, and C voltages drop to 93, 93 and 90%

MS4 O/S

Switching Plan for transferring loads from MS4 to MS1:

- 4F4 to 4F1 (Close 4F1-4F4 and Open 4F4-1)
- 4F1 to 1F1 (Close 1F1-4F1 and Open 4F1-1)
- 4F3 to 4F2 (Close 4F2-4F3 and Open 4F3-1)
- 4F2 to 1F4 (Close 4F2-1F4 and Open 4F2-1)

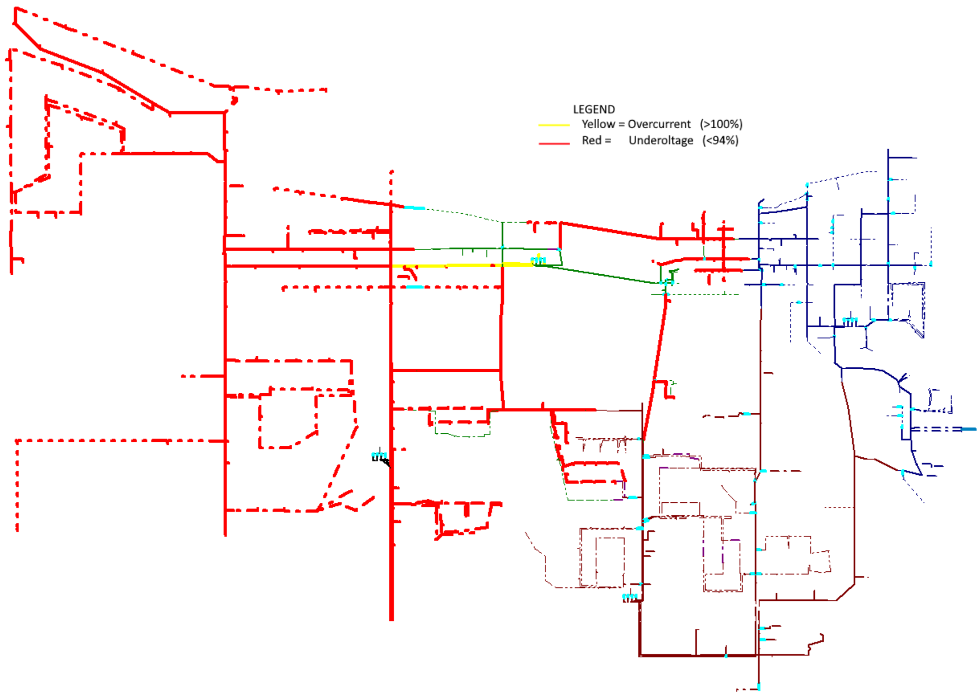

Figure 5-11: Load Flow Results - Minor Upgrades (MS4 O/S)

For detailed table of results see: Table D-11: Station and Feeder Loads - Minor Upgrades (MS4 O/S).

Abnormal Conditions:

- Overloading on MS1 F1: Phase A current increases to 127%
- Undervoltage on MS1 F1: Phase A, B, and C voltages drop to 90, 94 and 93%
- Undervoltage on MS1 F3: Phase A, B, and C voltages drop to 91, 93 and 92%
- Overloading on MS1 F4: Phase A current increases to 123%
- Undervoltage on MS1 F4: Phase A, B, and C voltages drop to 87, 90 and 90%
- Overloading on MS1 TX: Transformer power increases to 144%

5.3. Transformer Upgrade (4x10MVA @ 4.16kV)

This section presents the load flow study results as modelled with the loads as forecast for Feb 2031 with the modification that the transformers at MS1, MS2, MS3 and MS4 are converted to 10MVA transformers with a distribution voltage of 4.16kV.

This upgrade rectifies the transformer overload condition however the feeder results are the same as in Section 5.2.

5.3.1. Normal

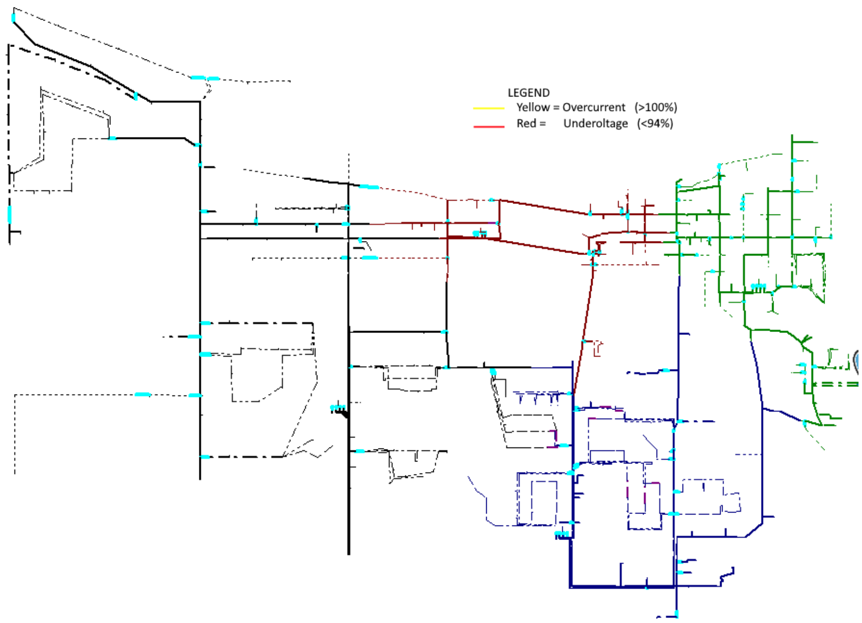

Figure 5-12: Load Flow Results - Transformer Upgrade (Normal)

For detailed table of results see: Table D-12: Station and Feeder Loads - Transformer Upgrade (Normal).

Abnormal Conditions:

- None

5.3.2. Contingency 2031 Loads

MS1 O/S

Switching plan for transferring loads from MS1 to MS2-MS4:

- 1F1 to 4F2 Queen and Kincardine Ave. (Close 1F1-4F2B B, 4F2-1F1A, 1F1-4F2C and Open 1F1-1)
- 1F2 to 2F2A Huron Terrace and Lambton (Close MS1F2-MS2F2-TIE-A, MS1F2-MS2F2-TIE-B and Open 1F2-1)
- 1F3 to 3F4 on Russell St. (Close 1F3-3F4 and Open 1F3-1)
- 1F4 no customers.

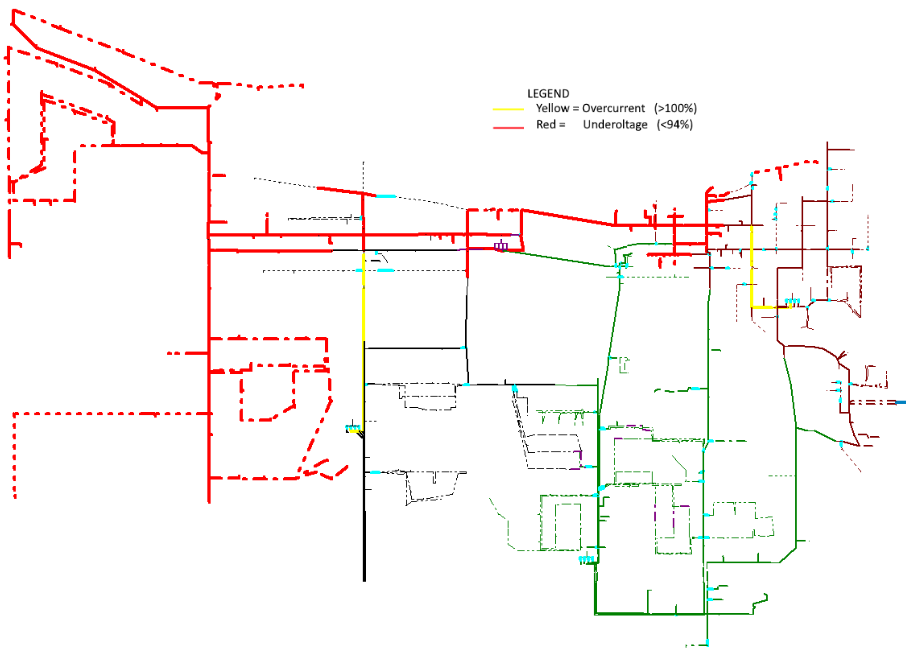

Figure 5-13: Load Flow Results - Transformer Upgrade (MS1 O/S)

For table of results see: Table D-13: Station and Feeder Loads - Transformer Upgrade (MS1 O/S).

Abnormal Conditions:

- Overloading on MS2 F2: Phase C current increases to 130%
- Undervoltage on MS2 F2: Phase A, B, and C voltages drop to 93%
- Overloading on MS4 F2: Phase A current increases to 142%
- Undervoltage on MS4 F2: Phase A, B, and C voltages drop to 92, 93 and 92%

MS2 O/S

Switching Plan for transferring loads from MS2 to MS1 and MS3:

- 2F1B to 3F2 North and Sutton St. (Close 2F1-3F2 A and Open 2F1-1)
- 2F2A to 1F2 on Huron Terrace (Close MS1F2-MS2F2-TIE-A, MS1F2-MS2F2-TIE-B and Open 2F2-1)
- 2F4 to 2F3 Queen and Nelson (Close 2F3-2F4 A, 2F3-2F4 B and Open 2F3-1)
- 2F3 to 3F1 Durham and Park (Close 2F3-3F1 and Open 2F4-1)

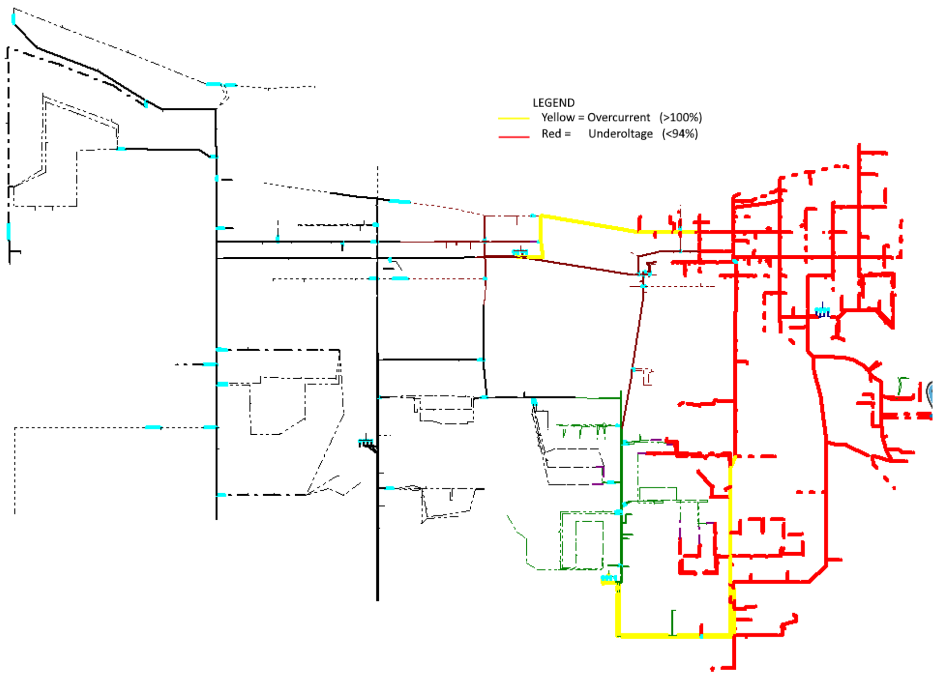

Figure 5-14: Load Flow Results - Transformer Upgrade (MS2 O/S)

For detailed table of results see: Table D-14: Station and Feeder Loads - Transformer Upgrade (MS2 O/S).

Abnormal Conditions:

- Overloading on MS1 F2: Phase C current increases to 140%
- Undervoltage on MS1 F2: Phase A. B, C voltages drop to 90, 92, and 86%
- Overloading on MS3 F1: Phase B current increases to 133%
- Undervoltage on MS3 F1: Phase A, B, and C voltages drop to 83, 86 and 85%
- Overloading on MS3 F2: Phase C current increases to 133%
- Undervoltage on MS3 F2: Phase A, B, and C voltages drop to 90, 94 and 86%

MS3 O/S

Switching Plan for transferring loads from MS3 to MS1, MS2 and MS4:

- 3F1 to 2F3 (Close 2F3-3F1 and Open 3F1-1)
- 3F2 to 2F1B (Close 2F1-3F2 A and Open 3F2-1)
- 3F3 to 4F1 (Close 4F1-3F3 and Open 3F3-1)
- 3F4 to 1F3 (Close 1F3-3F4 and Open 3F4-1)

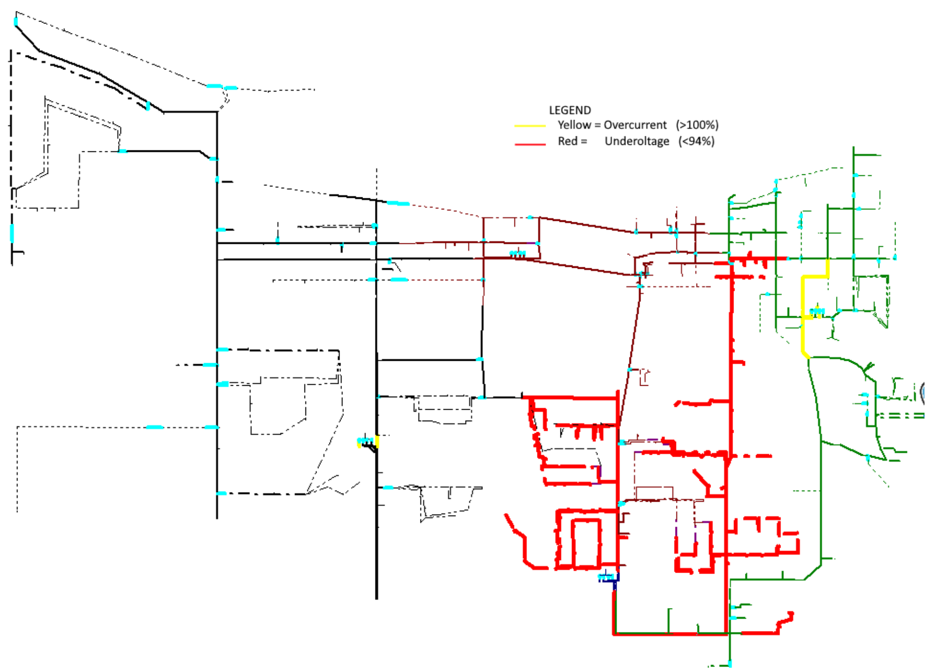

Figure 5-15: Load Flow Results - Transformer Upgrade (MS3 O/S)

For detailed table of results see: Table D-15: Station and Feeder Loads - Transformer Upgrade (MS3 O/S).

Abnormal Conditions:

- Overloading on MS2 F1: Phase C current increases to 134%
- Overloading on MS2 F3: Phase A current increases to 119%
- Undervoltage on MS2 F3: Phase A, B, and C voltages drop to 87, 89 and 90%
- Overloading on MS2 TX: Transformer power increases to 109%
- Overloading on MS4 F1: Phase C current increases to 105%
- Undervoltage on MS4 F1: Phase A, B, and C voltages drop to 93, 93 and 90%

MS4 O/S

Switching Plan for transferring loads from MS4 to MS1:

- 4F4 to 4F1 (Close 4F1-4F4 and Open 4F4-1)
- 4F1 to 1F1 (Close 1F1-4F1 and Open 4F1-1)
- 4F3 to 4F2 (Close 4F2-4F3 and Open 4F3-1)
- 4F2 to 1F4 (Close 4F2-1F4 and Open 4F2-1)

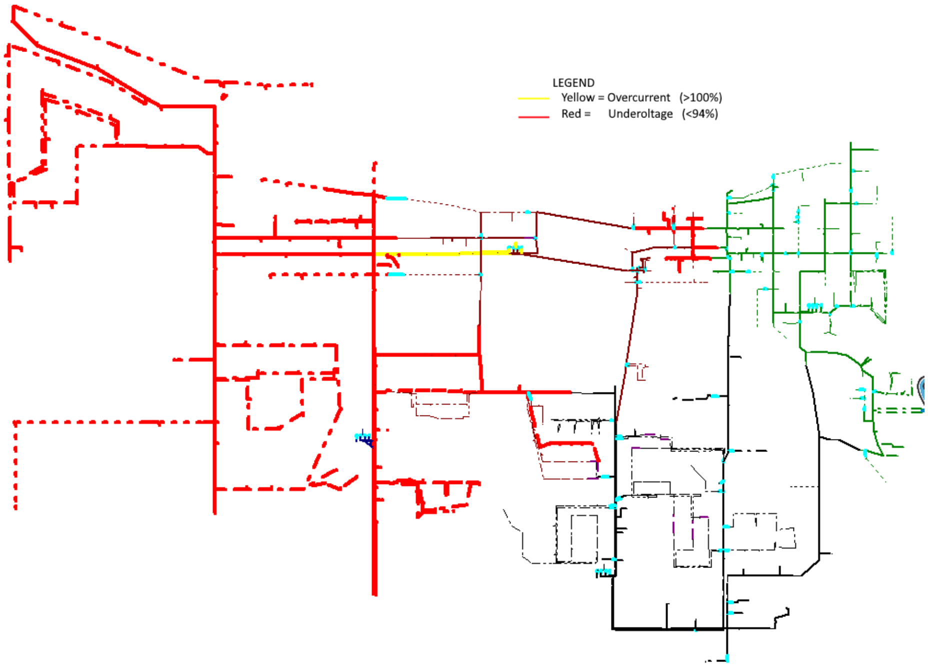

Figure 5-16: Load Flow Results - Transformer Upgrade MS4 O/S)

For detailed table of results see: Table D-16: Station and Feeder Loads - Transformer Upgrade (MS4 O/S).

Abnormal Conditions:

- Overloading on MS1 — F1: Phase A current increases to 127%
- Undervoltage on MS1 — F1: Phase A, B, and C voltages drop to 90, 94 and 93%
- Undervoltage on MS1 — F3: Phase A, B, and C voltages drop to 91, 93 and 92%
- Overloading on MS1 — F4: Phase A current increases to 123%
- Undervoltage on MS1 — F4: Phase A, B, and C voltages drop to 87, 90 and 90%
- Overloading on MS1 — TX: Transformer power increases to 108%

5.4. Voltage Conversion 1 (4 x 10MVA @ 13.8kV)

This section presents the load flow study results as modelled with the loads as forecast for Feb 2031 and based on the initial system configuration with the modification that the transformers at MS1, MS2, MS3 and MS4 are converted to 10MVA transformers with a distribution voltage of 13.8kV.

5.4.1. Normal

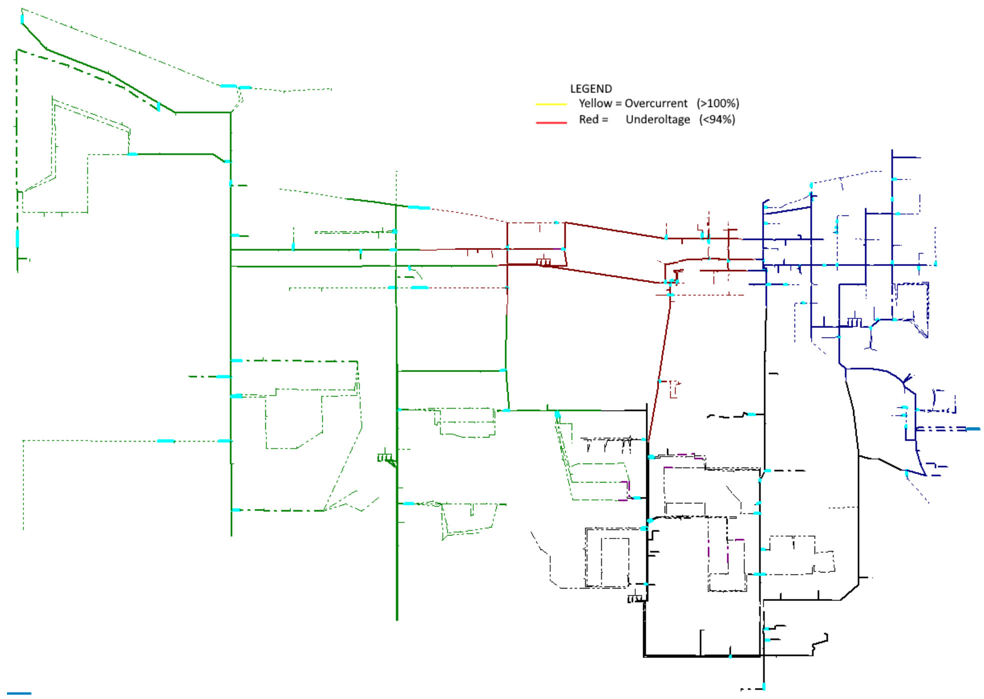

Figure 5-17: Load Flow Results - Voltage Conversion 1 (Normal)

<u>Abnormal Conditions:</u>

- None

5.4.2. Contingency

MS1 O/S

Switching plan for transferring loads from MS1 to MS2-MS4:

- 1F1 to 4F2 Queen and Kincardine Ave. (Close 1F1-4F2B B, 4F2-1F1A, 1F1-4F2C and Open 1F1-1)
- 1F2 to 2F2A Huron Terrace and Lambton (Close MS1F2-MS2F2-TIE-A, MS1F2-MS2F2-TIE-B and Open 1F2-1)
- 1F3 to 3F4 on Russell St. (Close 1F3-3F4 and Open 1F3-1)
- 1F4 no customers.

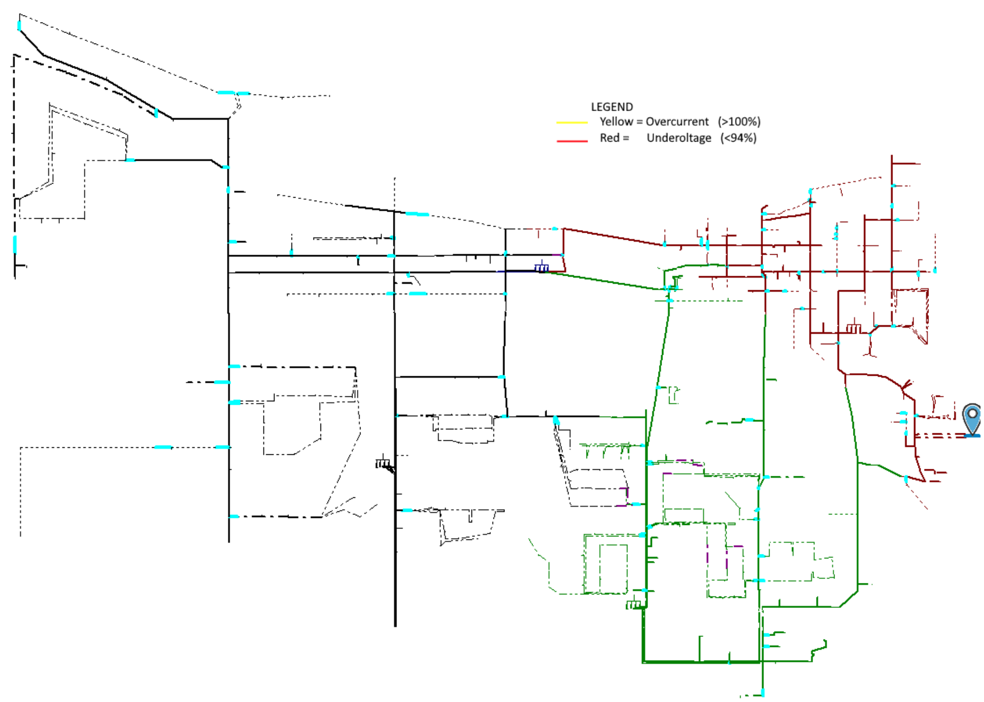

Figure 5-18: Load Flow Results - Voltage Conversion 1 (MS1 O/S).

Abnormal Conditions:

- None

MS2 O/S

Switching Plan for transferring loads from MS2 to MS1 and MS3:

- 2F1B to 3F2 North and Sutton St. (Close 2F1-3F2 A and Open 2F1-1)
- 2F2A to 1F2 on Huron Terrace (Close MS1F2-MS2F2-TIE-A, MS1F2-MS2F2-TIE-B and Open 2F2-1)
- 2F4 to 2F3 Queen and Nelson (Close 2F3-2F4 A, 2F3-2F4 B and Open 2F3-1)
- 2F3 to 3F1 Durham and Park(Close 2F3-3F1 and Open 2F4-1)

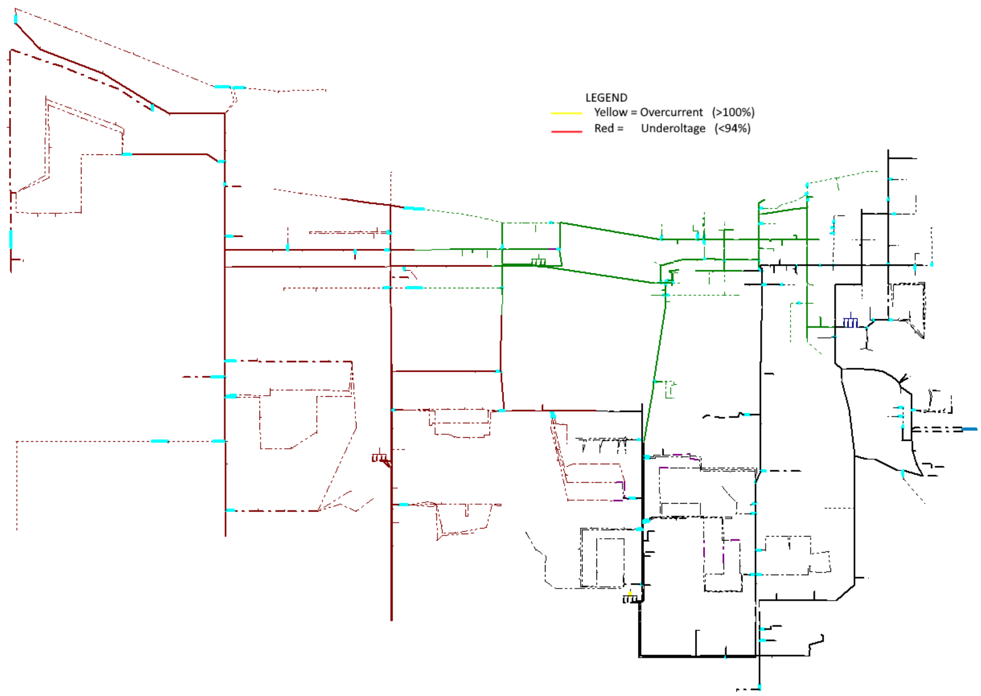

Figure 5-19: Load Flow Results - Voltage Conversion 1 (MS2 O/S).

Abnormal Conditions:

- None

MS3 O/S

Switching Plan for transferring loads from MS3 to MS1, MS2 and MS4:

- 3F1 to 2F3 (Close 2F3-3F1 and Open 3F1-1)
- 3F2 to 2F1B (Close 2F1-3F2 A and Open 3F2-1)
- 3F3 to 4F1 (Close 4F1-3F3 and Open 3F3-1)
- 3F4 to 1F3 (Close 1F3-3F4 and Open 3F4-1)

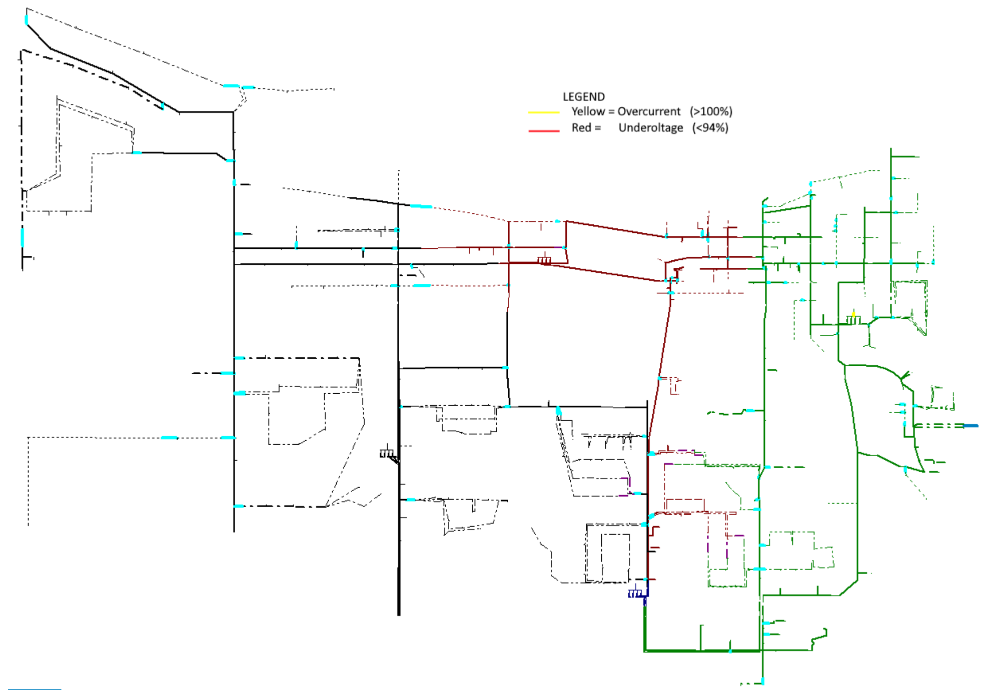

Figure 5-20: Load Flow Results - Voltage Conversion 1 (MS3 O/S).

Abnormal Conditions:

- None

MS4 O/S

Switching Plan for transferring loads from MS4 to MS1:

- 4F4 to 4F1 (Close 4F1-4F4 and Open 4F4-1)
- 4F1 to 1F1 (Close 1F1-4F1 and Open 4F1-1)
- 4F3 to 4F2 (Close 4F2-4F3 and Open 4F3-1)
- 4F2 to 1F4 (Close 4F2-1F4 and Open 4F2-1)

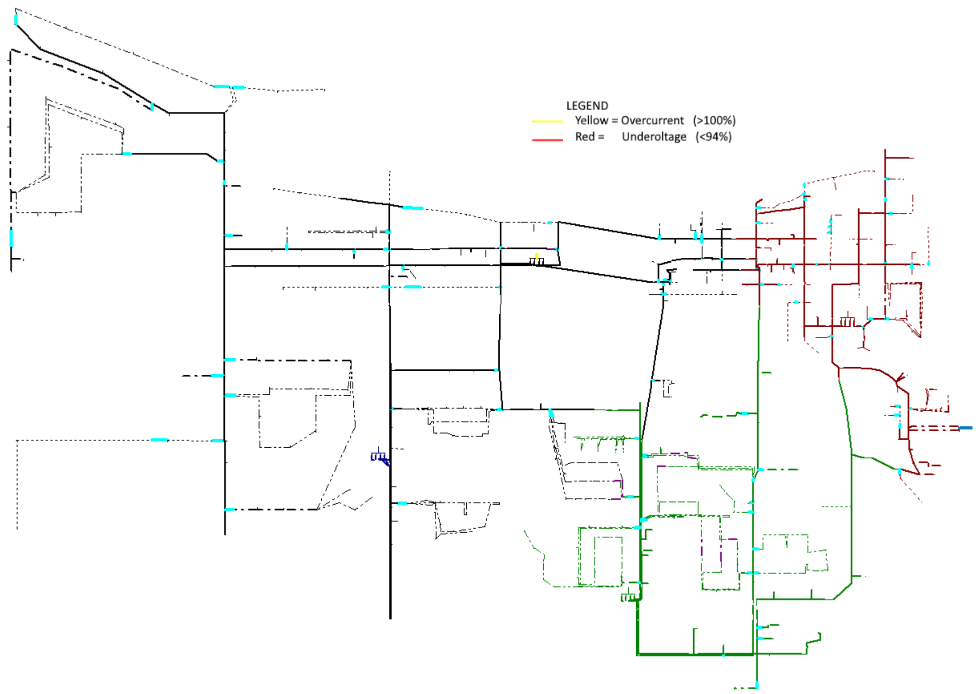

Figure 5-21: Load Flow Results - Voltage Conversion 1 (MS4 O/S).

Abnormal Conditions:

- None

5.5. Voltage Conversion 2 (2 x 20MVA @ 13.8kV)

This section presents the load flow study results as modelled with the loads as forecast for Feb 2031 and based on the modification that the transformers at MS1, MS2, MS3 and MS4 are converted to two locations at MS1 and MS2 each with 2 x 10MVA transformers with a distribution voltage of 13.8kV.

The system has a final loading of approximately 22.5MVA. With a 2-station design, there are options for load splitting between stations. For the purposes of this modelling, it is assumed that station MS1 carries approximately 12MVA of load and station MS3 carries approximately 10MVA. The contingency scenario for the loss of at Transformer at MS3 does not require external switching however the loss of a Transformer at MS1 would require at least 2MVA to be transferred to MS3 on peak.

5.5.1. Normal

In the 2-station design, the feeder layout would be reconfigured from the current 4-station design. For the purposes of modelling, the following switching actions were executed to reconfigure the feeders and to transfer loads from MS2 and MS4 to MS1 and MS3:

- 2F4 to 2F3 Queen and Nelson (Close 2F3-2F4 A, 2F3-2F4 B and Open 2F3-1)
- 4F3 to 4F2 (Close 4F2-4F3 and Open 4F3-1)
- 4F4 to 4F1 (Close 4F1-4F4 and Open 4F4-1)
- 4F2 to 1F4 (Close 4F2-1F4 and Open 4F2-1)
- 2F2A to 1F2 on Huron Terrace (Close MS1F2-MS2F2-TIE-A, MS1F2-MS2F2-TIE-B and Open 2F2-1)
- 2F3 to 3F1 Durham and Park (Close 2F3-3F1 and Open 2F4-1)
- 2F1B to 3F2 North and Sutton St. (Close 2F1-3F2 A and Open 2F1-1)
- 4F1 to 1F1 (Close 1F1-4F1 and Open 4F1-1)

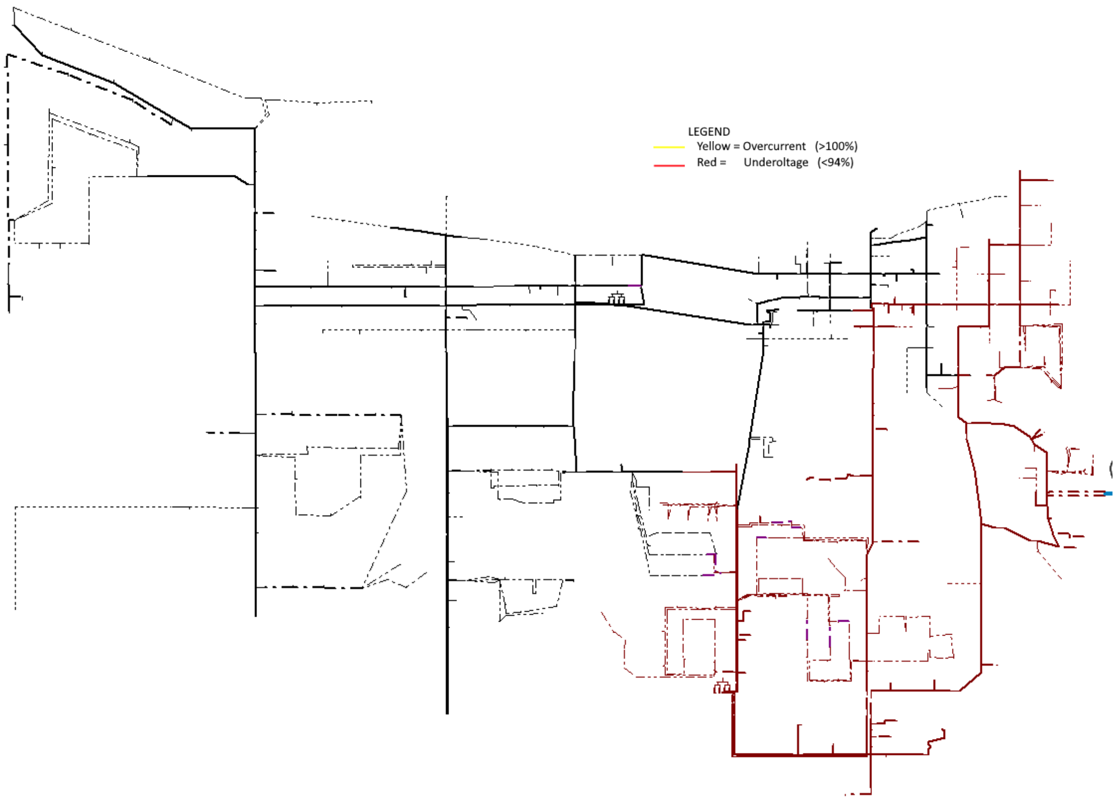

Figure 5-22: Load Flow Results - Voltage Conversion 2 (Normal).

<u>Abnormal Conditions:</u>

- None

5.5.2. Contingency

MS1-TX1 O/S

The majority of MS1 loads are transferred within the station or at the first device. Switching Plan for transferring the residual 2MVA loads from MS1 to MS3:

- 1F1 to 3F3 (Open 1F1-4F1 and Close 4F1-3F3)

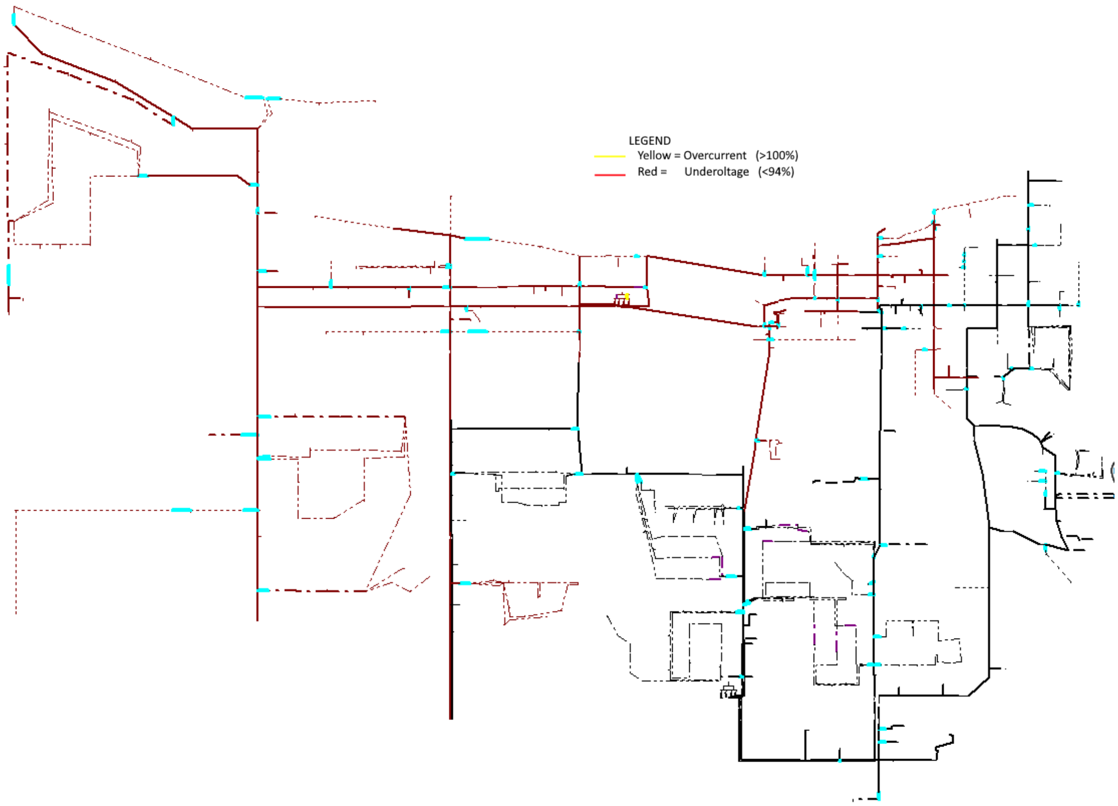

Figure 5-23: Load Flow Results - Voltage Conversion 2 (MS1-TX1 O/S).

Abnormal Conditions:

- None

MS3-TX1 O/S

No Switching Plan required. MS3 loads are transferred within the station or at the first device.

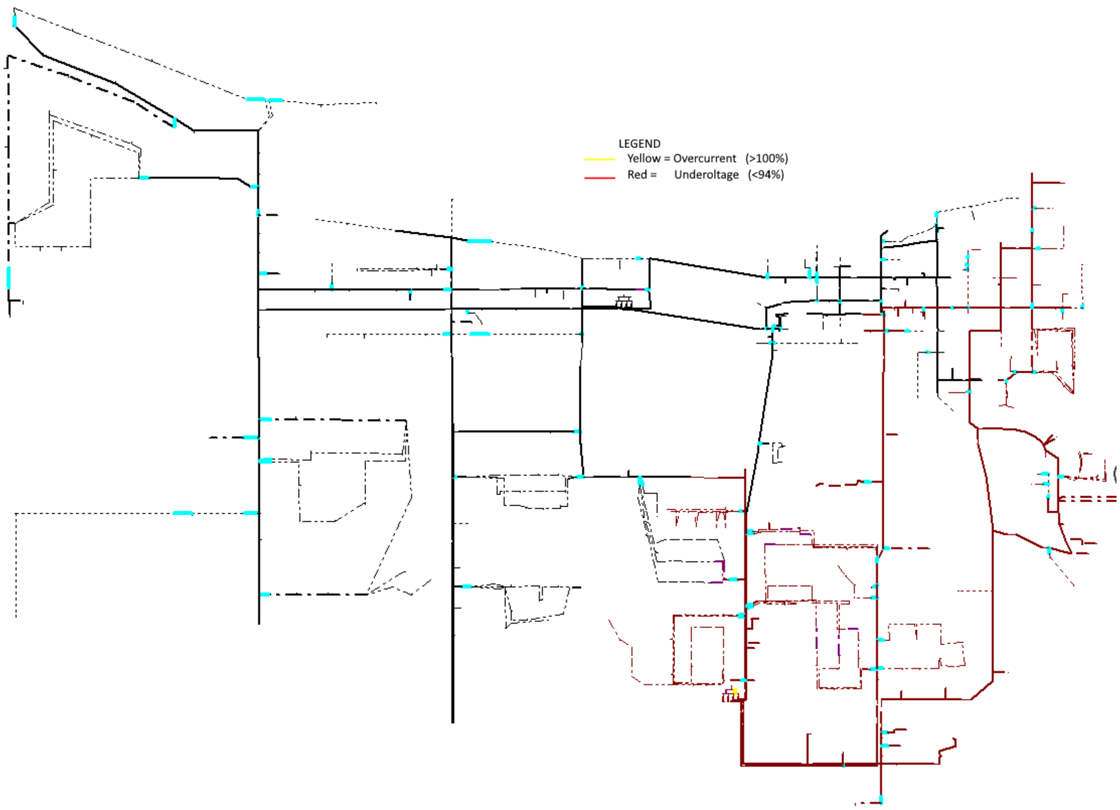

Figure 5-24: Load Flow Results - Voltage Conversion 2 (MS3-TX1 O/S).

Abnormal Conditions:

- None

5.6. Study Conclusions

The feeder and breaker requirements for a 13.8kV system are approximately one-quarter of those of a 4.16kV system. As a result, the final 13.8kV feeder layouts are well under loaded compared to the usage of a new system, and the feeder load allocation in the models are arbitrary and subject to change due to realignment of the system as it is developed.

For this reason, the feeder and station loading tables for the Voltage Conversion scenarios are not presented with the same level of detail as was provided for the load allocation. However, the transformer and feeder capacity can be seen as adequate based on the averages as shown below.

Table 5-2: Normal Scenario Average Results – Voltage Conversion 1

	Load Forecast	Capacity (@13.8kV)	Utilization Factor
Transformers (4)	~22.5MVA	4 x 10MVA =40MVA	56%
Feeders (16 x 440A)	22.5MVA/16= 1.4MVA/feeder	440A x 13.8kV x1.73 = 10.5MVA	13%

Table 5-3: Normal Scenario Average Results – Voltage Conversion 2

	Load Forecast	Capacity (@13.8kV)	Utilization Factor
Transformers (4)	~22.5MVA	2 x 20MVA =40MVA	56%
Feeders (8 x 440A)	22.5MVA/8= 2.8MVA/feeder	440 x 13.8kV x1.73 = 10.5MVA	27%

Table 5-4: Contingency Scenario Average Results – Voltage Conversion 1

	Load Forecast	Capacity (@13.8kV)	Utilization Factor
Transformers (3)	~22.5MVA	3 x 10MVA =30MVA	75%
Feeders (12 x 440A)	22.5MVA/12= 1.9MVA/feeder	440A x 13.8kV x1.73 = 10.5MVA	18%

Table 5-5: Contingency Scenario Average Results – Voltage Conversion 2

	Load Forecast	Capacity (@13.8kV)	Utilization Factor
Transformers (3)	~22.5MVA	1 x 20MVA +1 x 10MVA = 30MVA	75%
Feeders (6 x 440A)	22.5MVA/6= 3.75MVA/feeder	440A x 13.8kV x1.73 = 10.5MVA	36%

Table 5-6: Summary of Load Flow Study Results

Study	System Capacity	Feeder – Abnormal Conditions
1. Base Case Initial Loads (2021) (16.08MVA)	Normal (54%)	None
	Contingency (71%)	For Each Scenario, phase imbalance results in O/L in spot locations and localized Voltage Drop violations
	Additional Remediation Needed: Execute Phase Balancing Exercise	
2. Existing System Ultimate Loads (22.8MVA)	Normal (75%)	1F2 undervoltage in area of new Pumping station 4F2 Phase B Voltage Drop, and O/L on station egress
	Normal W Phase Balancing	1F2 Phase Balance results in No Violations 4F2 Phase Balance results in No Violations (egress update optional)
	Contingency (100%)	Load imbalance results in Transformer O/L Voltage Drop and Feeder O/L in all scenarios
	Additional Remediation Needed: System Reinforcement is required, Feeder and Station Transformers	
3. Transformer Upgrade 4x10MVA @4.16kV (22.8MVA)	Normal (56%)	No Violations under "Phase Balancing" scenario
	Contingency (75%)	Resolves Station Loading Constraint Feeder O/L and Voltage Drop unchanged from Study 2
	Additional Remediation Needed: Feeder Support is needed to reduce Voltage Drop and O/L	
4. Voltage Conversion 1 (4x10MVA @13.8kV) (22.8MVA)	Normal (56%)	No Violations
	Contingency (75%)	No Violations
	No Additional Remediation Needed:	
5. Voltage Conversion 2 (2x20MVA @13.8kV) (22.8MVA)	Normal (56%)	No Violations
	Contingency (75%)	No Violations
	No Additional Remediation Needed:	

6. SYSTEM TOPOLOGY, CHALLENGES, AND OPPORTUNITIES

6.1. Geography

The Town of Kincardine is bisected by a river/greenspace system that limits the ability to move power from south to north. In the area near the waterfront there are only two connecting roads, each serving high density commercial areas, and as such it would be challenging to accommodate new feeders. In addition, the area to the northwest and nearest the water is not considered to be a viable site for a new transformer station to be built.

The city is bounded on the east by a corridor on both sides of Highway 27 and a significant Municipal facility to the south. The north section contains a corridor that has been proposed for development as a large Commercial Area with a projected load of 9MVA and an approximate 10-year build program. Such development processes can vary a great deal from initial plans and are more likely to be delayed than accelerated, however under favourable conditions development can proceed over just a few years. In addition to the known developments, the south end of the Highway 27 corridor is adjacent to large tracks of farmland that could be developed in the future.

6.2. Options for Capacity Planning

The ultimate load requirements for the Town of Kincardine are approximately 22.5MVA plus an additional 9MVA for the Commercial Area for a 10-year planning total of 31.5MVA. Under N-1 capacity planning criteria, this would require five (5) x 10MVA transformers, however the fifth transformer would be only needed in the final years of the study.

From a high-level perspective there are eight opportunities for creation of new station transformer locations. These locations include the existing four locations, expansions to double the transformer design at MS1 and MS3, one potential new location in the new Commercial Area development, and one potential location adjacent to the Municipal Lands in the south area of town.

Factors that may affect choice of transformer locations include:

- Ability to obtain land in Commercial development area
- Ability to obtain land in Municipal Services region
- Technical constraints on placing additional transformer at MS1 or MS3
- Costs to upgrade MS4 site vs costs to reconfigure MS4 feeders for alternate site
- Resale value/liability of existing MS4 and MS2 properties
- Reconfiguration costs of 44kV supply feeders (assume to be negligible)

6.3. Feeder Planning

The need for feeder reinforcement is a function of system voltage decisions. The existing 4.16kV supply voltage results in feeders that are fully loaded to deliver full transformer load. Switching to achieve this optimized loading is improbable in a real-world system. When the system voltage is increased to 13.8kV, the system's current requirements to supply the same amount of load are reduced by a factor of four (4). The impact on voltage drop is exponentially affected by current, and further impacted by the increased voltage base when calculated as a percentage. These combined impacts eliminate the need for feeder upgrade for load carrying effects.

The distribution system in the Town of Kincardine exhibits persistent phase imbalance problems. These would also be reduced if the voltage were to be converted to 13.8kV, however in the interim, some switching flexibility could be gained with reduced phase imbalance. Westario can review work practises to determine the causes of phase imbalances, however, historically problems have been found to include a habit of connecting single phase loads to the phase most accessible from the bucket truck.

In the short term, feeder loads can approach 100% in contingency scenarios. Feeder reclosers are currently set for 400A, although modelling criteria suggests 440A to be a viable setting. After phase balancing is completed, there may be benefit in setting reclosers to the full 440A to permit operational flexibility.

6.4. Other benefits/impacts

System Losses

The conversion of a distribution system from 4.16kV to 13.8kV will result in an improvement in losses. Loss calculations have not been presented in detail, as losses are sensitive to system configuration. However, the model output gives the following loss results which are representative indicators.

Table 6-1: Representative Losses

System Model	Total Losses on Peak
2021 Load - 4.16kV	969 kVA
2031 Load - 4.16kV	1,930 kVA
2031 Load – 13.8kV (4 Stations)	820 kVA
2031 Load – 13.8kV (2 Stations)	1,120 kVA

Reliability

The conversion of a distribution system from many short feeders to less longer feeders will have a negative effect on system reliability indices such as SAIDI and SAIFI. For each feeder level event, more customers are impacted, and more customer-outage and customer hours are recorded. This impact will mean the “4-station” options are somewhat preferrable to the “2-station” options.

However, considering the other benefits of voltage conversion, this reliability impact is often offset with the application of Distribution Automation (DA) which is now less expensive to implement on the longer feeders.

6.5. Cost Estimates

Cost estimates provided in this review are provided at the “Feasibility” or “Class 4” level and have an expected accuracy range of -30%->+50%. The following costs are used for comparison purposes:

- New Transformer on Existing Pad - $1.2M
- New Transformer on New Pad: - $1.5M
- Overhead Feeders - $750k/km (Double Circuit or Single Circuit Congested Area)

6.6. Options Analysis.

The result of the system review is to focus on four options for the 10-year plan. For each option, the costs are similar, and the technical results are also viable, however there are some operational differences. Each of these options are impacted by the new Commercial Development requirements for a new station. However, relative to the existing system, the options include:

- Option 0 “Do Nothing”
- Option 1 “Upgrade Existing System ”
- Option 2 “Voltage Conversion, 4 Stations of 10MVA @ 13.8kV”
- Option 3 “Voltage Conversion to 2 stations @ 13.8kV”

Table 6-2: Option 0 – “Do Nothing”

Actions	Phase Balancing (move load from Phase A and C to Phase B), Raise recloser setting to 440A Remediate MS4 (egress oil containment) as necessary (not include in estimate)
Remediation	The costs of Option 0 are the nominal costs of field work to balance loads and is not considered in this assessment.
Results	Results, the system will operate at 2021 loads, however as loads are added (particularly the Pumping station at the waterfront), Overload and Voltage Drop will be experienced in Contingency Scenarios.
Impact of New Dev	Place 7.5MVA-10MVA station at New Development Area. Monitor Loads as N-1 Contingency limit will still be 30MVA and total load will approach 31.5MVA
Planning Costs	$0 +MS4 Rehab

Table 6-3: Option 1 "Upgrade Existing System "

Actions	Phase Balancing (move load from Phase A and C to Phase B), Raise recloser setting to 440A Remediate MS4 (egress oil containment) as necessary (not included in estimate) Replace Station Tx's with 4 x 10MVA @ 4.16kV New Feeder to NW (3.0km) New Feeder MS4 to MS 3 (2.5km)
Remediation	4 x $1.2M for 4.16kV transformers 5.5 km feeder x $750k/km (3km MS4 along Queen St, 2.5km along Hwy 21)
Results	Feeder Extension along Queen St.is not straightforward Emergency Condition, Voltage Drop and O/L
Impact of New Dev	Place 10MVA station at New Development Area. Timing of new station may provide relief while other stations are being converted.
Planning Costs	$9.0M +MS4 Rehab

Table 6-4: Option 2 "Voltage Conversion, 4 Stations of 10MVA @ 13.8kV"

Actions	Replace all Tx's with 10MVA at (@13.8kV?)
Remediation	4 x $1.2M for 13.8kV transformers Distribution Tx Conversion. (650 Tx's x $5,000 = $3.25M)
Results	Normal and Contingency - No Violations.
Impact of New Dev	Place 10MVA station at New Development Area. Timing of new station may provide relief while other stations are being converted.
Planning Costs	$8.15M +MS4 Rehab

Table 6-5: Option 3 "Voltage Conversion, 2 Stations of 20MVA @ 13.8kV"

Actions	2 x 10MVA at MS 1 and MS 3. Remove Stations 2 and 4, Tie feeders together at MS2 and 4.
Remediation	4 x $1.2M for 13.8kV transformers Distribution Tx Conversion. (650 Tx's x $5,000 = $3.25M) $500k Station Reconfiguration costs
Results	Normal and Contingency - No Violations.
Impact of New Dev	Place 10MVA station at New Development Area. Timing of new station may provide relief while other stations are being converted.
Planning Costs	$8.65M (MS4 Rehab not required)

7. RECOMMENDATIONS

7.1. Hybrid Option

There is a strong technical preference for voltage conversion. This is driven by the need for voltage support and load capacity in the NW of the city where new transformation sites are not viable and where new feeders cannot be provided. However, within the voltage conversion options, there is no strong preference for the "4-station" or "2-station" configuration as both would be considered overbuilt in a "green-field" setting.

With an ultimate loading of 31.5MVA, there will be a need for sites for five (5) x 10MVA transformers in the planning period. The most likely final solution, based on land availability and development timing, will be a "Hybrid" combination of the two concepts. Possibly with two transformers at MS1 or MS3, (or both) and a single unit at MS2 or MS4, or one located in the new development properties.

There is a future potential for development along the south end of the Hwy 21 corridor, which may result in the need for a sixth transformer, or a feeder connection between what is now MS4 and MS3.

7.2. Immediate Remedial Work

There are existing overload and undervoltage violations under contingency scenarios and 2021 loads. These are most directly addressed through phase balancing, and by adjusting recloser settings to 440A. These activities will allow time for further design and planning activities to take place.

7.3. Decision Tree

As the system develops, certain decision points will drive the selection of planning options. This will include:

- Real estate options: Westario should consider the availability of land within the new development property, and within the Municipal Services property. If there are no opportunities in these areas, then the denser "2-station" options will be preferred.
- Existing properties: Westario should confirm if oil containment would be required at MS4 if the transformer ever needed replacement. Also of interest would be the potential clean-up costs versus the land value of the existing MS4 and MS2 properties.
- Existing station layout: Westario should undertake a preliminary design review to confirm if there is space at MS1, and MS3 for an additional transformer, and presuming so, would it be a permanent installation, or a temporary one during voltage conversion.
- New Development on Hwy 21: The timing of the development will impact conversion discussions. If the development is to proceed slowly, then conversion may start in the downtown core, however if it were to accelerate, it may be more reasonable to start conversion in that area. Loads introduced at the new subdivision and condo development are not likely to be impactive. Dual voltage transformers may be preferred.

7.4. Voltage Conversion Plan

There are many factors to consider when implementing the voltage conversion program. The main concern at the start is the reliance on a single 13.8kV transformer, meaning that the loss of that unit will cause significant outage concerns. New transformers have been recorded to experience infant failures in some instances.

While a voltage conversion is in progress, there is an issue with supplying existing loads. One option is to convert a feeder "one street at a time" with the coordinated use of back-to-back line transformers often called a "rabbit". Using this method, each customer will experience an outage for the duration that it takes to convert all the transformers on a street (4 to 8 hours) but is generally completed in one step. The alternative is to replace the existing distribution transformers with a dual wound unit well in advance of the conversion, and then when the primary is converted to the new voltage, many transformers can be switched over reasonably quickly in a second outage at a later time.

Voltage conversion should take advantage of low load times of the year when individual station transformers can be taken out of service without compromising the system integrity. Once the conversion begins, a logical path will help ensure that pockets of customers are not left without backup supply.

A plan to convert/install five (5) x 10MVA transformers may be as follows:

- Systematic replacement of 600 distribution transformers with dual voltage transformers over approximately 3 years. (200 units per year @$5,000/unit = $1Million/year).
- In parallel, investigate real estate and operational constraints on station locations.
- Monitor the new development site for load growth. When needed, install a 10MVA-13.8kV transformer to supply new loads. This may be located at the MS3 site, or the new development site. It would be preferrable to avoid voltage conversion at this site and therefore efforts should be made to supply this site at 13.8kV. (Year 4 @$1.5M)
- MS3 or MS1: either convert the existing transformer or place the new transformer as a second unit. (Year 5 @$1.2M)
- MS1 or MS3: either convert the existing transformer or place the new transformer as a second unit. Convert those feeders that connect to MS2. (Year 6-7 @$1.2M)
- MS2 or as 2nd New Tx at MS1 and decommission MS2. (Year 7-8 @$1.2M)
- MS4 or 2nd at MS3 (Year 8-9 @$1.2M) (needed as load exceeds 30MVA, might include rehab of MS4.
- Consider new mobile sub at 13.8kV, when loads approach N-2 (30MVA) capacity.

APPENDIX A: OVERVIEW MAP OF TOWN OF KINCARDINE FEEDERS

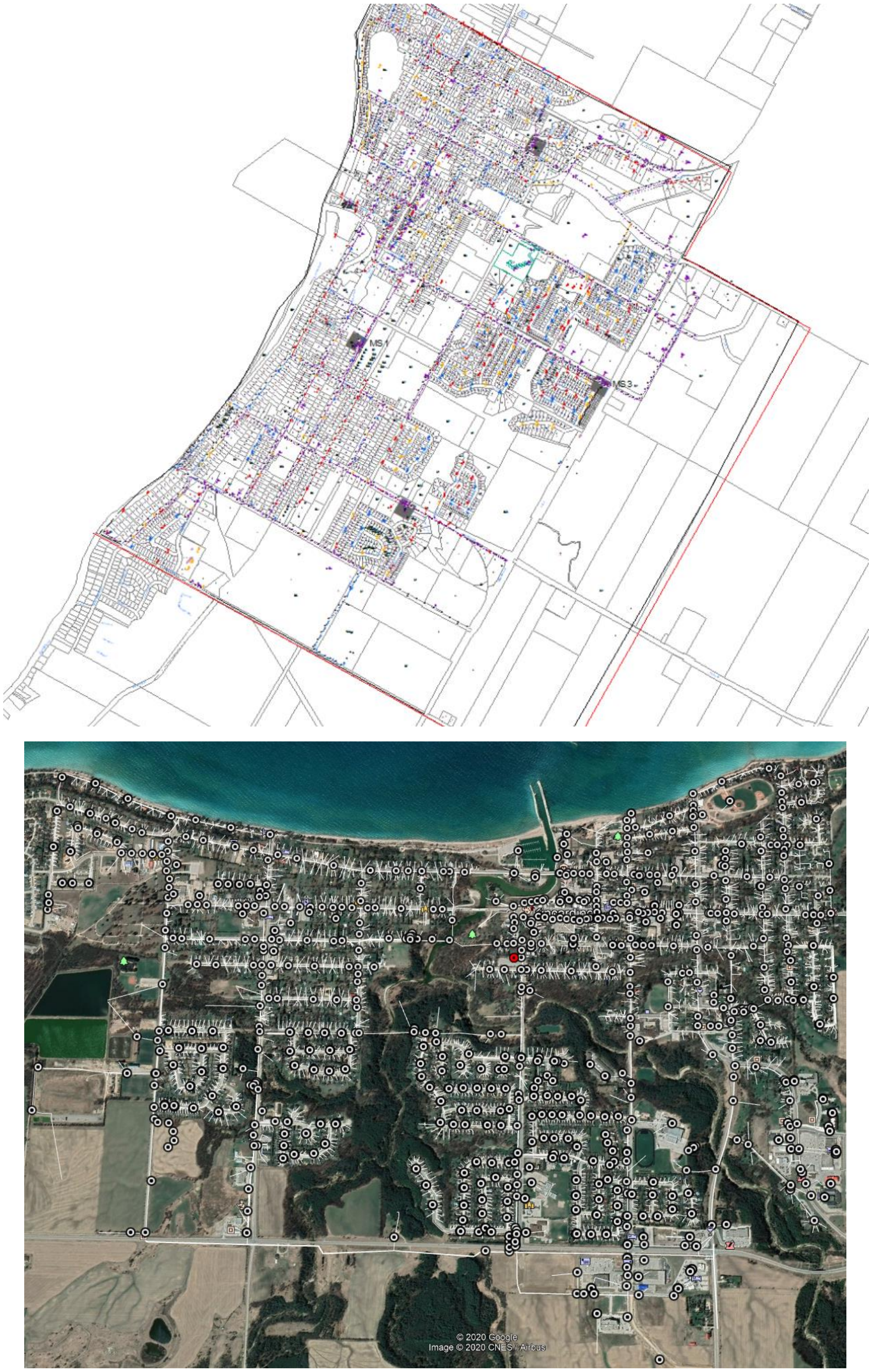

Figure A-1: The Overview Map of Town of Kincardine Feeders.

APPENDIX B: SINGLE LINE DIAGRAM OF TOWN OF KINCARDINE FEEDERS

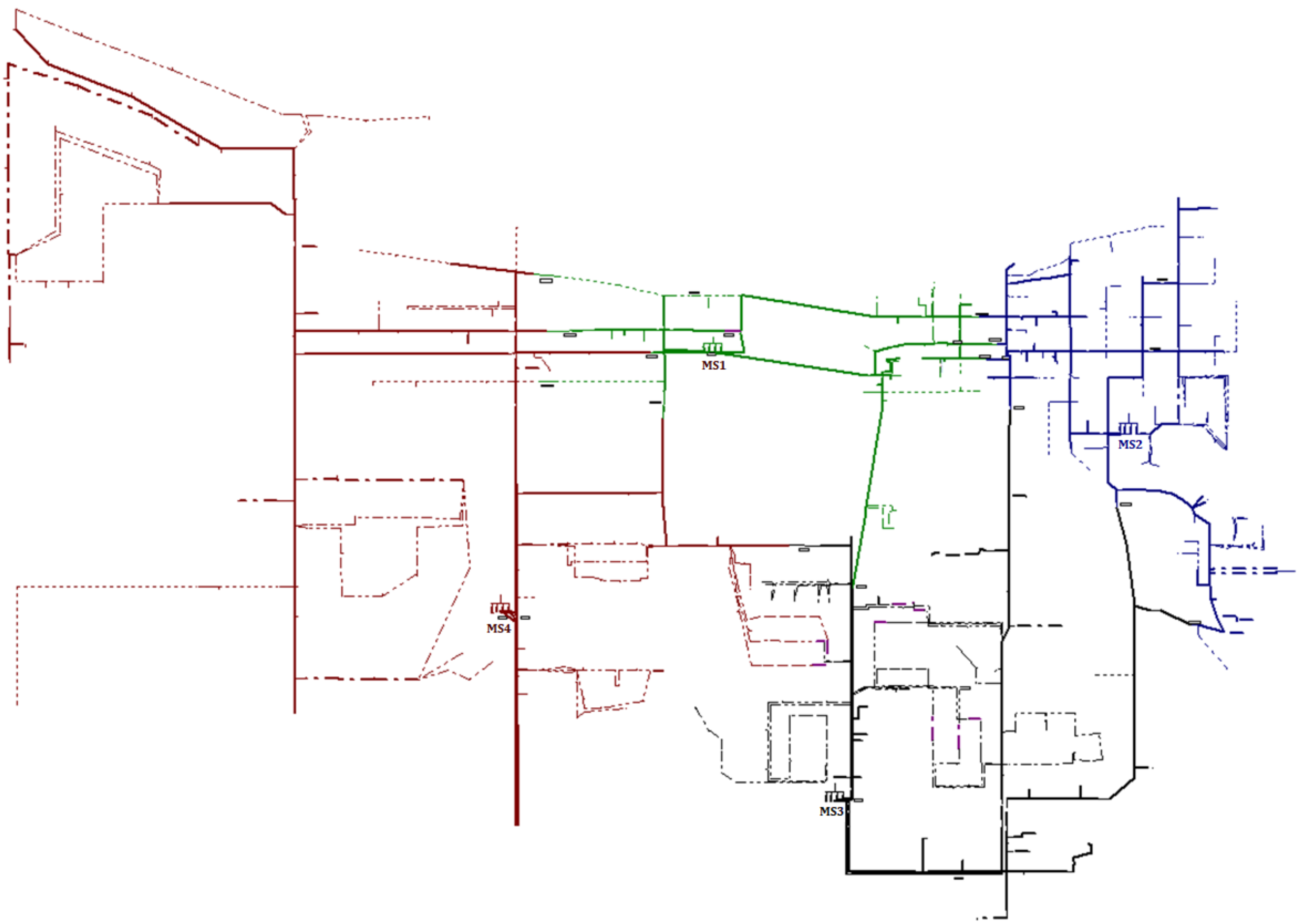

Figure B-1: The Single Line Diagram of Town of Kincardine Feeders.

APPENDIX C: SINGLE LINE DIAGRAMS OF TOWN OF KINCARDINE SUBSTATIONS

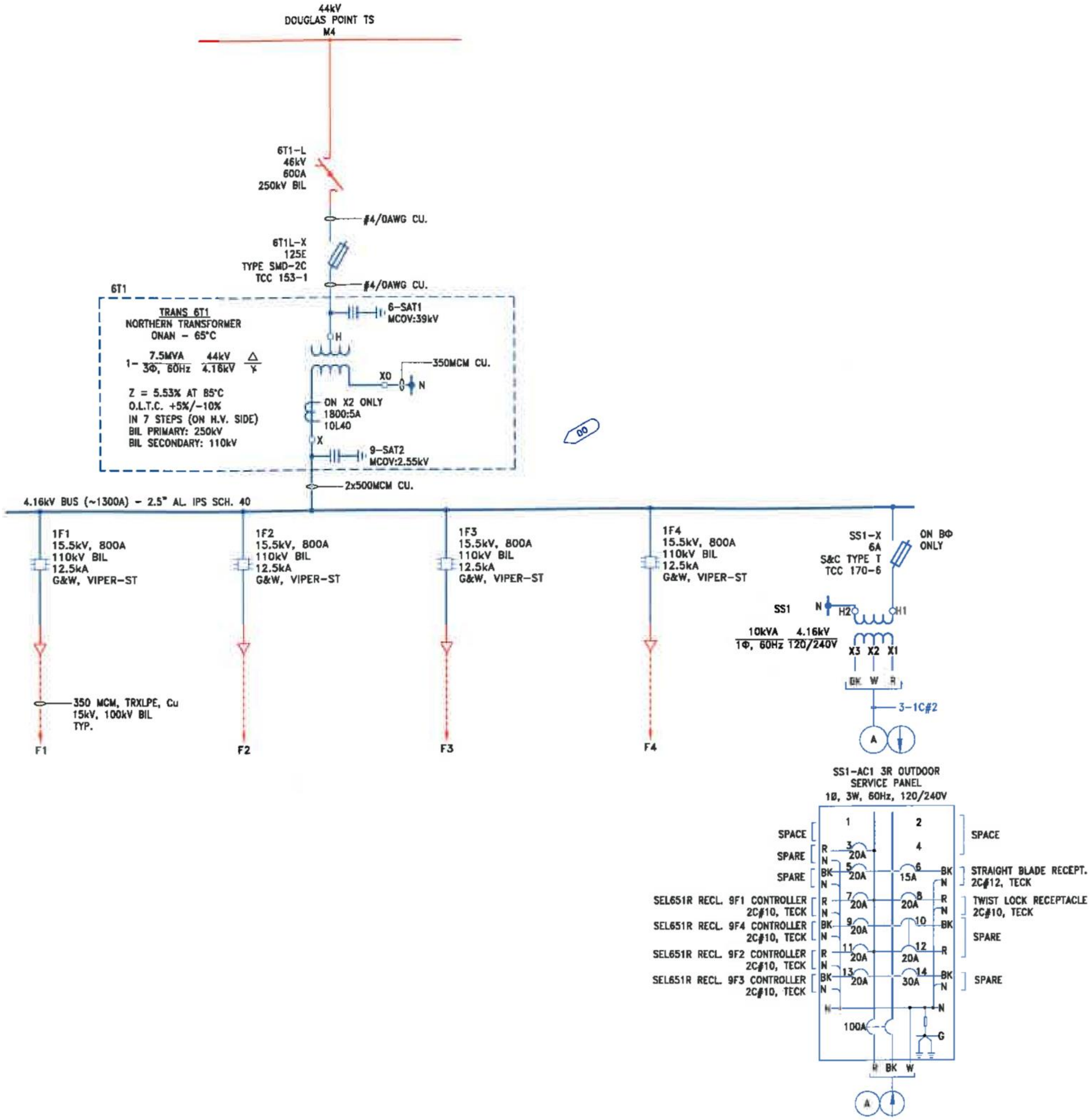

Figure C-1: The Single Line Diagram of Substation MS1 of Town of Kincardine.

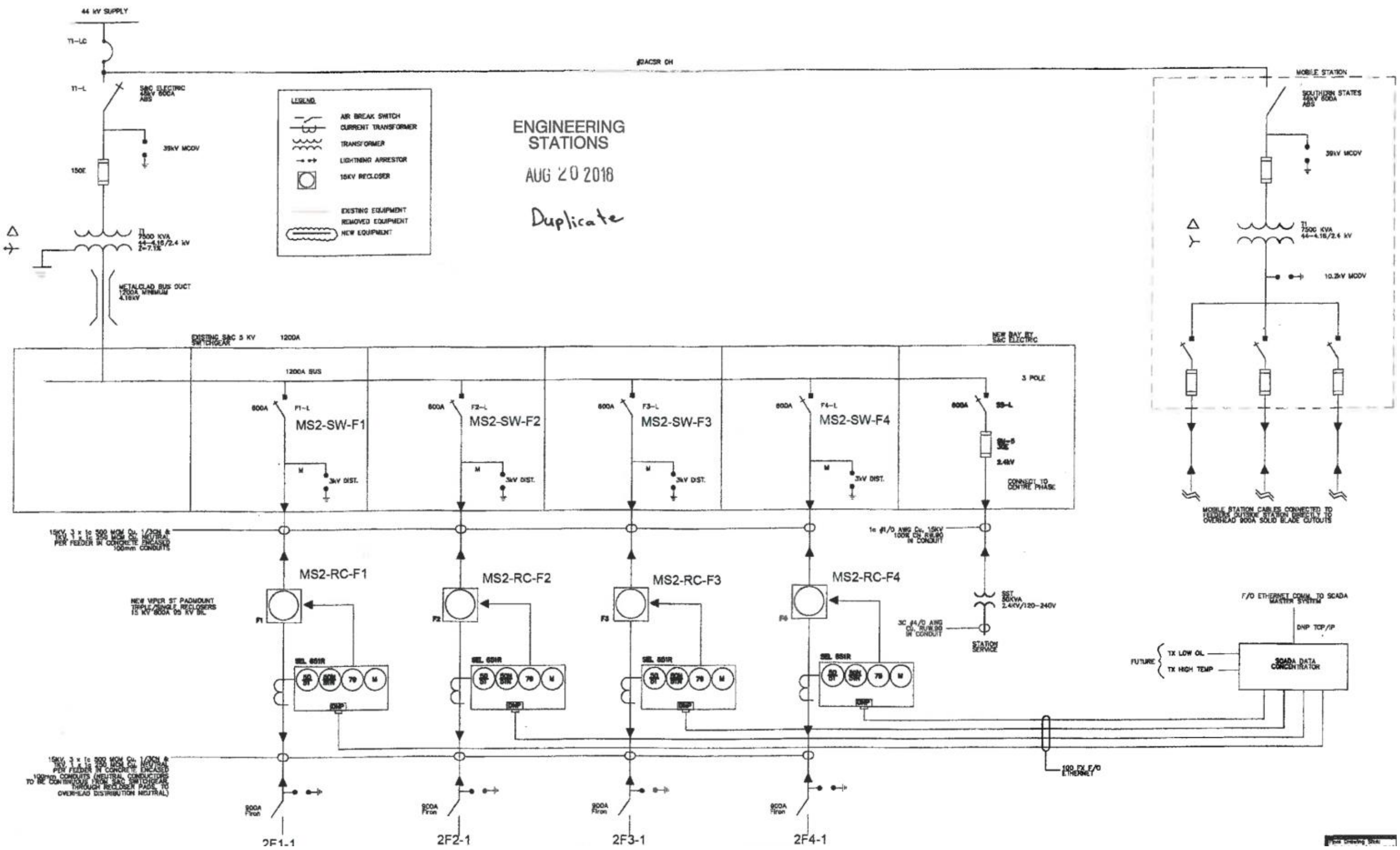

Figure C-2: The Single Line Diagram of Substation MS2 of Town of Kincardine.

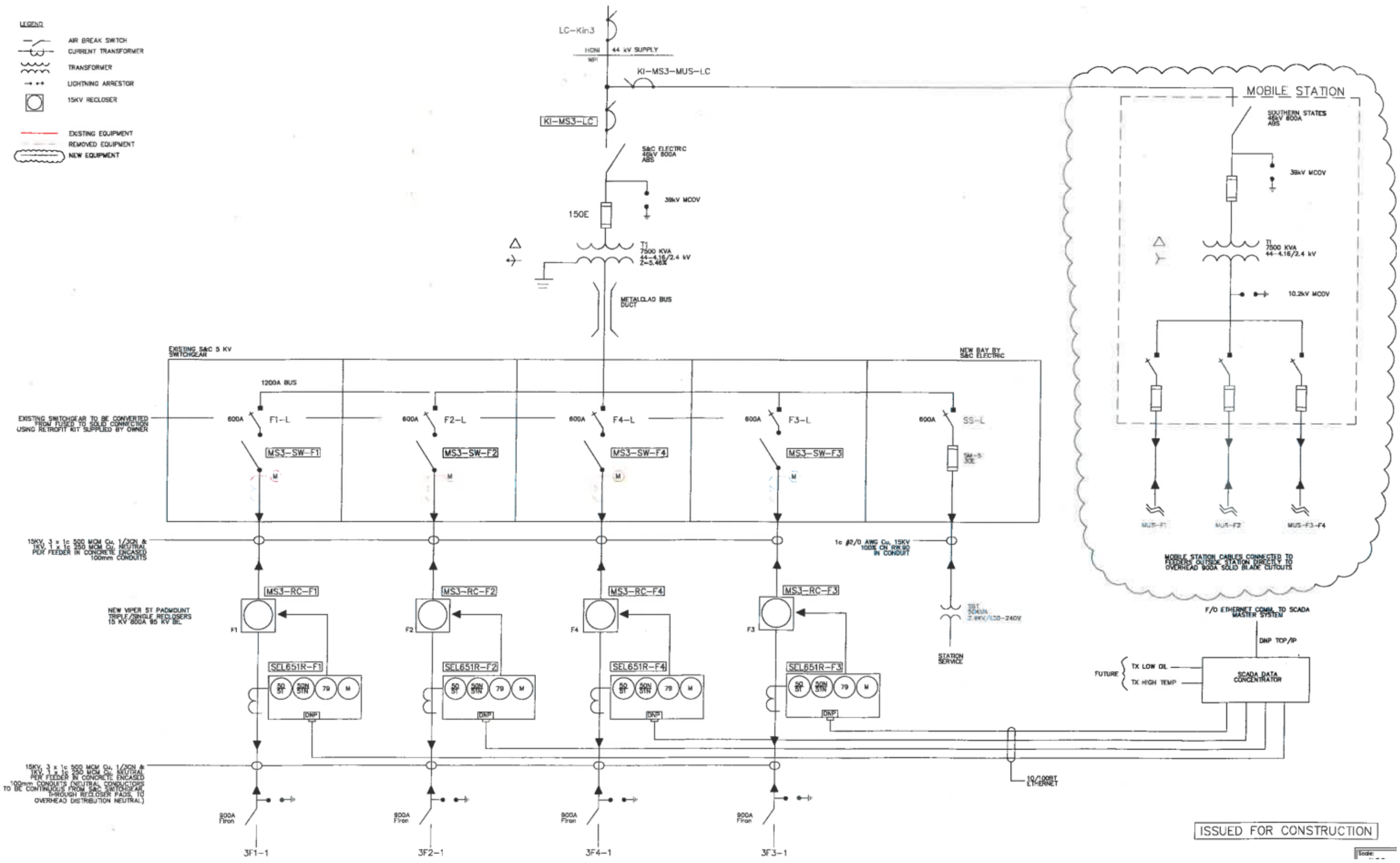

Figure C-3: The Single Line Diagram of Substation MS3 of Town of Kincardine.

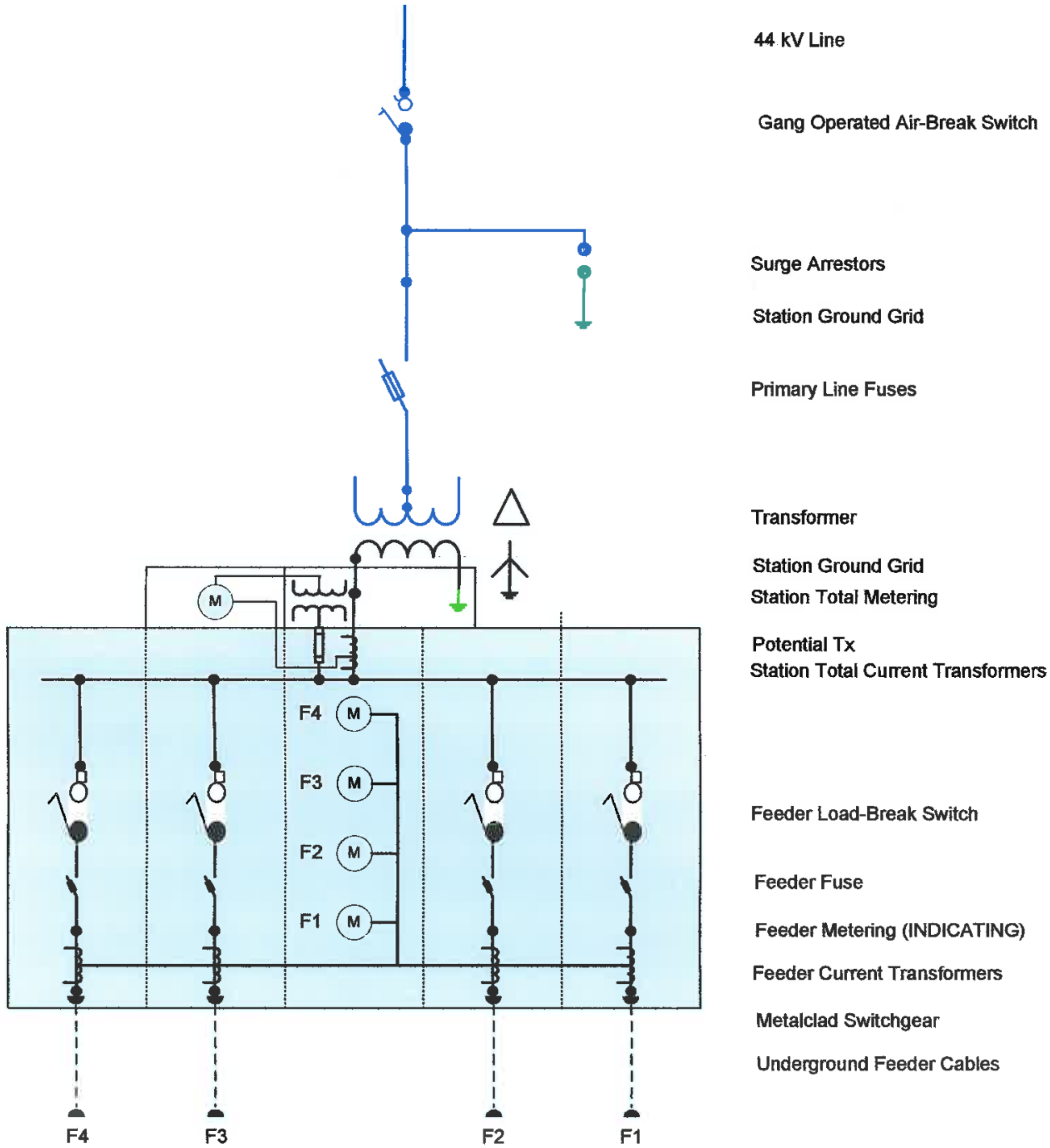

Figure C-4: The Single Line Diagram of Substation MS4 of Town of Kincardine.

APPENDIX D: DETAILED DSO STUDY RESULTS

Table D-1: Station and Feeder Loads - Base Case 2021 (Normal)

Station	Feeder	Amps (A)	Amps (B)	Amps (C)	Amps (Max)	Amps (Avg)	kVA	kW	kVAR	PF (Avg)	Emer Limit (A)	Emer Limit (kVA)	Loading %
MS1	1F1	149	88.9	104.2	149	114	815	801	153	0.983	440	3170.25	34%
	1F2	163.1	109.1	118.5	163.1	130.2	931	911	191	0.979	440	3170.25	37%
	1F3	188.3	161.8	142.4	188.3	164.2	1174	1152	227	0.981	440	3170.25	43%
	1F4	0	0	0	0	0	0	0	0	0	440	3170.25	0%
	Total	500.4	359.8	365.1	500.4	408.4	2952	2883	636	0.977	1041	7500	39%
MS2	2F1	245.7	156.2	229.8	245.7	210.6	1515	1498	226	0.989	440	3170.25	56%
	2F2	159.9	160.7	201.6	201.6	174.1	1253	1239	182	0.989	440	3170.25	46%
	2F3	165.5	156.9	149.4	165.5	157.3	1132	1119	168	0.989	440	3170.25	38%
	2F4	144.1	142.9	110.2	144.1	132.4	953	945	122	0.992	440	3170.25	33%
	Total	715.2	616.7	691	715.2	674.3	4929	4843	920	0.983	1041	7500	66%
MS3	3F1	201.1	200.8	202.6	202.6	201.5	1454	1406	370	0.967	440	3170.25	46%
	3F2	175.2	176	201.9	201.9	184.4	1331	1292	318	0.971	440	3170.25	46%
	3F3	125.8	83.6	104.9	125.8	104.8	756	739	162	0.978	440	3170.25	29%
	3F4	53.9	74.2	53.9	74.2	60.7	438	428	93	0.977	440	3170.25	17%
	Total	556	534.6	563.3	563.3	551.3	4032	3891	1056	0.965	1041	7500	54%
MS4	F1	188.6	190	188.8	190	189.1	1364	1322	337	0.969	385	2773.97	49%
	F2	269.6	294.6	277.6	294.6	280.6	2024	1950	544	0.963	385	2773.97	77%
	F3	89.6	44.6	51.6	89.6	61.9	447	435	103	0.973	385	2773.97	23%
	F4	53	0	0	53	17.7	127	124	30	0.976	385	2773.97	14%
	Total	600.8	529.2	518	600.8	549.3	4017	3856	1127	0.96	1041	7500	54%
Total	Total	2372	2040	2137	2372	2183	15918	15472	3740	0.972	4164	30000	53%

Table D-2: Station and Feeder Loads - Base Case 2021 (MS1 O/S)

Station	Feeder	Amps (A)	Amps (B)	Amps (C)	Amps (Max)	Amps (Avg)	kVA	kW	kVAR	PF (Avg)	Emer Limit (A)	Emer Limit (kVA)	Loading %
MS1	1F1	0	0	0	0	0	0	0	0	0	440	3170.25	0%
	1F2	0	0	0	0	0	0	0	0	0	440	3170.25	0%
	1F3	0	0	0	0	0	0	0	0	0	440	3170.25	0%
	1F4	0	0	0	0	0	0	0	0	0	440	3170.25	0%
	Total	0	0	0	0	0	0	0	0	0	1041	7500	0%
MS2	2F1	245.3	155.7	229.1	245.3	210	1515	1498	226	0.989	440	3170.25	56%
	2F2	325.7	268.3	323.5	325.7	305.8	2206	2161	444	0.98	440	3170.25	74%
	2F3	165.5	156.5	149	165.5	157	1132	1119	167	0.989	440	3170.25	38%
	2F4	143.9	142.4	109.8	143.9	132	953	945	122	0.992	440	3170.25	33%
	Total	880.4	722.9	811.4	880.4	804.9	5916	5777	1276	0.977	1041	7500	79%
MS3	3F1	201.9	201.4	203.2	203.2	202.2	1454	1407	370	0.968	440	3170.25	46%
	3F2	175.9	176.5	202.5	202.5	185	1331	1292	318	0.971	440	3170.25	46%
	3F3	126.3	83.9	105.2	126.3	105.1	756	739	162	0.978	440	3170.25	29%
	3F4	245	240.8	198	245	227.9	1640	1604	340	0.978	440	3170.25	56%
	Total	749.1	702.6	708.9	749.1	720.2	5264	5078	1385	0.965	1041	7500	70%
MS4	F1	189.3	190.5	189.3	190.5	189.7	1364	1322	337	0.969	385	2773.97	49%
	F2	**428**	**389.5**	**389.9**	**428**	**402.5**	**2895**	**2788**	**777**	**0.963**	**385**	**2773.97**	**111%**
	F3	90	44.7	51.7	90	62.1	447	435	103	0.973	385	2773.97	23%
	F4	53.2	0	0	53.2	17.7	127	124	30	0.976	385	2773.97	14%
	Total	760.5	624.7	630.9	760.5	672	4913	4703	1419	0.957	1041	7500	66%
Total	Total	2390	2050	2151	2390	2197	16084	15558	4079	0.967	4164	30000	54%

Table D-3: Station and Feeder Loads - Base Case 2021 (MS2 O/S)

Station	Feeder	Amps (A)	Amps (B)	Amps (C)	Amps (Max)	Amps (Avg)	kVA	kW	kVAR	PF (Avg)	Emer Limit (A)	Emer Limit (kVA)	Loading %
MS1	1F1	149.6	89.2	104.7	149.6	114.5	815	801	153	0.983	440	3170.25	34%
	1F2	332.2	225.4	337.5	337.5	298.4	2126	2078	448	0.977	440	3170.25	77%
	1F3	189.3	212.9	142.5	212.9	181.6	1294	1266	266	0.978	440	3170.25	48%
	1F4	0	0	0	0	0	0	0	0	0	440	3170.25	0%
	Total	671.1	527.5	584.7	671.1	594.4	4292	4174	1002	0.973	1041	7500	57%
MS2	2F1	0	0	0	0	0	0	0	0	0	440	3170.25	0%
	2F2	0	0	0	0	0	0	0	0	0	440	3170.25	0%
	2F3	0	0	0	0	0	0	0	0	0	440	3170.25	0%
	2F4	0	0	0	0	0	0	0	0	0	440	3170.25	0%
	Total	0	0	0	0	0	0	0	0	0	1041	7500	0%
MS3	**3F1**	**598.3**	**548.1**	**507**	**598.3**	**551.1**	**3966**	**3733**	**1339**	**0.941**	**440**	**3170.25**	**136%**
	3F2	**441.8**	**339.1**	**467.6**	**467.6**	**416.2**	**2994**	**2888**	**792**	**0.965**	**440**	**3170.25**	**106%**
	3F3	126.6	83.6	105.1	126.6	105.1	756	739	162	0.978	440	3170.25	29%
	3F4	54.2	74.2	53.9	74.2	60.8	438	428	93	0.977	440	3170.25	17%
	Total	**1220.9**	**1045**	**1133.6**	**1220.9**	**1133.2**	**8371**	**7865**	**2867**	**0.94**	**1041**	**7500**	**112%**
MS4	F1	188.6	190	188.8	190	189.1	1364	1322	337	0.969	385	2773.97	49%
	F2	269.6	294.6	277.6	294.6	280.6	2024	1950	544	0.963	385	2773.97	77%
	F3	89.6	44.6	51.6	89.6	61.9	447	435	103	0.973	385	2773.97	23%
	F4	53	0	0	53	17.7	127	124	30	0.976	385	2773.97	14%
	Total	600.8	529.2	518	600.8	549.3	4017	3856	1127	0.96	1041	7500	54%
Total	Total	2493	2102	2236	2493	2277	16680	15895	4996	0.953	4164	30000	56%

Table D-4: Station and Feeder Loads - Base Case 2021 (MS3 O/S)

Station	Feeder	Amps (A)	Amps (B)	Amps (C)	Amps (Max)	Amps (Avg)	kVA	kW	kVAR	PF (Avg)	Emer Limit (A)	Emer Limit (kVA)	Loading %
MS1	1F1	149.2	89.1	104.3	149.2	114.2	815	801	153	0.983	440	3170.25	34%
	1F2	163.4	123.2	282.4	282.4	189.7	964	943	201	0.978	440	3170.25	64%
	1F3	245.5	225.4	198.2	245.5	223	1593	1557	336	0.977	440	3170.25	56%
	1F4	0	0	0	0	0	0	0	0	0	440	3170.25	0%
	Total	558.1	437.7	584.9	584.9	526.9	3412	3323	776	0.974	1041	7500	45%
MS2	2F1	427.7	335.9	437.5	437.5	400.4	2879	2814	610	0.977	440	3170.25	99%
	2F2	160	160.7	201.8	201.8	174.2	1253	1239	182	0.989	440	3170.25	46%
	2F3	383.2	372.6	362.6	383.2	372.8	2681	2587	706	0.965	440	3170.25	87%
	2F4	144.2	142.9	110.3	144.2	132.5	953	945	122	0.992	440	3170.25	33%
	Total	**1115.1**	**1012.1**	**1112.2**	**1115.1**	**1079.8**	**7979**	**7673**	**2188**	**0.962**	**1041**	**7500**	**106%**
MS3	3F1	0	0	0	0	0	0	0	0	0	440	3170.25	0%
	3F2	0	0	0	0	0	0	0	0	0	440	3170.25	0%
	3F3	0	0	0	0	0	0	0	0	0	440	3170.25	0%
	3F4	0	0	0	0	0	0	0	0	0	440	3170.25	0%
	Total	0	0	0	0	0	0	0	0	0	1041	7500	0%
MS4	F1	323.3	280.9	304.5	323.3	302.9	2179	2099	584	0.963	385	2773.97	84%
	F2	270.5	295.3	278.5	295.3	281.4	2024	1950	544	0.963	385	2773.97	77%
	F3	89.6	44.7	51.7	89.6	62	447	435	103	0.973	385	2773.97	23%
	F4	53.2	0	0	53.2	17.7	127	124	30	0.976	385	2773.97	14%
	Total	736.6	620.9	634.7	736.6	664.1	4856	4641	1429	0.956	1041	7500	65%
Total	Total	2410	2071	2332	2410	2271	16247	15637	4393	0.962	4164	30000	54%

Table D-5: Station and Feeder Loads - Base Case 2021 (MS4 O/S)

Station	Feeder	Amps (A)	Amps (B)	Amps (C)	Amps (Max)	Amps (Avg)	kVA	kW	kVAR	PF (Avg)	Emer Limit (A)	Emer Limit (kVA)	Loading %
MS1	1F1	407	283.1	301.1	407	330.4	2330	2261	562	0.97	440	3170.25	93%
	1F2	165.8	110.5	120.1	165.8	132.1	932	912	192	0.979	440	3170.25	38%
	1F3	191.4	164	144.2	191.4	166.5	1174	1152	228	0.981	440	3170.25	44%
	1F4	380.4	349	341.8	380.4	357.1	2518	2411	729	0.958	440	3170.25	86%
	Total	1144.6	906.6	907.2	1144.6	986.1	7109	6797	2083	0.956	1041	7500	95%
MS2	2F1	245.7	156.2	229.8	245.7	210.6	1515	1498	226	0.989	440	3170.25	56%
	2F2	159.9	160.7	201.6	201.6	174.1	1253	1239	182	0.989	440	3170.25	46%
	2F3	165.5	156.9	149.4	165.5	157.3	1132	1119	168	0.989	440	3170.25	38%
	2F4	144.1	142.9	110.2	144.1	132.4	953	945	122	0.992	440	3170.25	33%
	Total	715.2	616.7	691	715.2	674.3	4929	4843	920	0.983	1041	7500	66%
MS3	3F1	201.1	200.8	202.6	202.6	201.5	1454	1406	370	0.967	440	3170.25	46%
	3F2	175.2	176	201.9	201.9	184.4	1331	1292	318	0.971	440	3170.25	46%
	3F3	125.8	83.6	104.9	125.8	104.8	756	739	162	0.978	440	3170.25	29%
	3F4	53.9	74.2	53.9	74.2	60.7	438	428	93	0.977	440	3170.25	17%
	Total	556	534.6	563.3	563.3	551.3	4032	3891	1056	0.965	1041	7500	54%
MS4	F1	0	0	0	0	0	0	0	0	0	385	2773.97	0%
	F2	0	0	0	0	0	0	0	0	0	385	2773.97	0%
	F3	0	0	0	0	0	0	0	0	0	385	2773.97	0%
	F4	0	0	0	0	0	0	0	0	0	385	2773.97	0%
	Total	0	0	0	0	0	0	0	0	0	1041	7500	0%
Total	Total	2416	2058	2162	2416	2212	16070	15531	4059	0.966	4164	30000	54%

Table D-6: Station and Feeder Loads - Initial (Normal)

Station	Feeder	Amps (A)	Amps (B)	Amps (C)	Amps (Max)	Amps (Avg)	kVA	kW	kVAR	PF (Avg)	Emer Limit (A)	Emer Limit (kVA)	Loading %
MS1	1F1	201.6	120	140.9	201.6	154.2	1095	1078	194	0.984	440	3170.25	46%
	1F2	374.1	245.6	314.2	374.1	311.3	2212	2140	557	0.967	440	3170.25	85%
	1F3	256.1	266.8	192	266.8	238.3	1693	1662	327	0.982	440	3170.25	61%
	1F4	0	0	0	0	0	0	0	0	0	440	3170.25	0%
	Total	831.8	632.4	647.1	831.8	703.8	5077	4916	1268	0.968	1041	7500	68%
MS2	2F1	330.2	208.6	308.2	330.2	282.3	2036	2017	276	0.991	440	3170.25	75%
	2F2	214	215.3	270.4	270.4	233.2	1682	1668	218	0.992	440	3170.25	61%
	2F3	222	210.1	200.3	222	210.8	1521	1507	203	0.991	440	3170.25	50%
	2F4	193.1	190.8	147.3	193.1	177.1	1277	1270	140	0.995	440	3170.25	44%
	Total	959.3	824.8	926.2	959.3	903.4	6643	6527	1236	0.983	1041	7500	89%
MS3	3F1	272.1	271.5	275	275	272.9	1962	1899	494	0.968	440	3170.25	63%
	3F2	235.7	237.1	272.5	272.5	248.4	1786	1739	407	0.974	440	3170.25	62%
	3F3	168.9	112.2	140.9	168.9	140.7	1011	991	201	0.98	440	3170.25	38%
	3F4	72.4	99.6	72.3	99.6	81.4	586	574	115	0.98	440	3170.25	23%
	Total	749.1	720.4	760.7	760.7	743.4	5432	5243	1424	0.965	1041	7500	72%
MS4	F1	253.3	256.1	253.8	256.1	254.4	1828	1777	428	0.972	385	2773.97	67%
	F2	**364.6**	**399.7**	**375.6**	**399.7**	**380**	**2730**	**2633**	**722**	**0.964**	**385**	**2773.97**	**104%**
	F3	120.1	59.7	69	120.1	82.9	596	582	126	0.977	385	2773.97	31%
	F4	70.9	0	0	70.9	23.6	170	166	36	0.976	385	2773.97	18%
	Total	808.9	715.5	698.4	808.9	740.9	5415	5197	1520	0.96	1041	7500	72%
Total	Total	3349	2893	3032	3349	3092	22567	21883	5448	0.97	4164	30000	75%

Table D-7: Station and Feeder Loads - Minor Upgrades (Normal)

Station	Feeder	Amps (A)	Amps (B)	Amps (C)	Amps (Max)	Amps (Avg)	kVA	kW	kVAR	PF (Avg)	Emer Limit (A)	Emer Limit (kVA)	Loading %
MS1	1F1	201.3	120.2	140.8	201.3	154.1	1095	1078	194	0.984	440	3170.25	46%
	1F2	320.3	277.7	289.4	320.3	295.8	2102	2040	507	0.971	440	3170.25	73%
	1F3	255.9	311.1	191.3	311.1	252.8	1796	1758	367	0.979	440	3170.25	71%
	1F4	0	0	0	0	0	0	0	0	0	440	3170.25	0%
	Total	777.5	709	621.5	777.5	702.7	5070	4912	1256	0.969	1041	7500	68%
MS2	2F1	330.2	208.6	308.2	330.2	282.3	2036	2017	276	0.991	440	3170.25	75%
	2F2	214	215.3	270.4	270.4	233.2	1682	1668	218	0.992	440	3170.25	61%
	2F3	222	210.1	200.3	222	210.8	1521	1507	203	0.991	440	3170.25	50%
	2F4	193.1	190.8	147.3	193.1	177.1	1277	1270	140	0.995	440	3170.25	44%
	Total	959.3	824.8	926.2	959.3	903.4	6643	6527	1236	0.983	1041	7500	89%
MS3	3F1	272.1	271.5	275	275	272.9	1962	1899	494	0.968	440	3170.25	63%
	3F2	235.7	237.1	272.5	272.5	248.4	1786	1739	407	0.974	440	3170.25	62%
	3F3	168.9	112.2	140.9	168.9	140.7	1011	991	201	0.98	440	3170.25	38%
	3F4	72.4	99.6	72.3	99.6	81.4	586	574	115	0.98	440	3170.25	23%
	Total	749.1	720.4	760.7	760.7	743.4	5432	5243	1424	0.965	1041	7500	72%
MS4	F1	253.1	255.7	253.6	255.7	254.1	1828	1775	427	0.971	416	2997.33	61%
	F2	375.9	386.7	376.4	386.7	379.7	2728	2632	720	0.965	416	2997.33	93%
	F3	120.1	59.6	69	120.1	82.9	596	582	126	0.977	416	2997.33	29%
	F4	71	0	0	71	23.7	170	166	36	0.976	416	2997.33	17%
	Total	820.1	702	699	820.1	740.4	5415	5197	1520	0.96	1041	7500	72%
Total	Total	3306	2956	3007	3306	3090	22560	21879	5436	0.97	4164	30000	75%

Table D-8: Station and Feeder Loads - Minor Upgrades (MS1 O/S)

Station	Feeder	Amps (A)	Amps (B)	Amps (C)	Amps (Max)	Amps (Avg)	kVA	kW	kVAR	PF (Avg)	Emer Limit (A)	Emer Limit (kVA)	Loading %
MS1	1F1	0	0	0	0	0	0	0	0	0	440	3170.25	0%
	1F2	0	0	0	0	0	0	0	0	0	440	3170.25	0%
	1F3	0	0	0	0	0	0	0	0	0	440	3170.25	0%
	1F4	0	0	0	0	0	0	0	0	0	440	3170.25	0%
	Total	0	0	0	0	0	0	0	0	0	1041	7500	0%
MS2	2F1	332	209.4	309.6	332	283.7	2036	2017	277	0.991	440	3170.25	75%
	2F2	**544.3**	**520.3**	**573.5**	**573.5**	**546**	**3921**	**3808**	**938**	**0.971**	**440**	**3170.25**	**130%**
	2F3	223.1	211	201.1	223.1	211.7	1521	1507	203	0.991	440	3170.25	51%
	2F4	194.1	191.6	147.9	194.1	177.9	1277	1270	140	0.995	440	3170.25	44%
	Total	**1293.5**	**1132.3**	**1232.1**	**1293.5**	**1219.3**	**9006**	**8712**	**2281**	**0.967**	**1041**	**7500**	**120%**
MS3	3F1	271.8	271.7	274.1	274.1	272.5	1962	1899	493	0.968	440	3170.25	62%
	3F2	235.4	237.1	271.7	271.7	248.1	1786	1739	407	0.974	440	3170.25	62%
	3F3	168.7	112.2	140.6	168.7	140.5	1011	991	201	0.98	440	3170.25	38%
	3F4	332.3	400.7	263.5	400.7	332.2	2391	2332	528	0.975	440	3170.25	91%
	Total	1008.2	1021.7	949.9	1021.7	993.3	7302	7023	1998	0.962	1041	7500	97%
MS4	F1	252.8	254.8	252.8	254.8	253.5	1828	1775	427	0.971	416	2997.33	61%
	F2	**592.1**	**513.7**	**529.1**	**592.1**	**545**	**3925**	**3779**	**1062**	**0.963**	**416**	**2997.33**	**142%**
	F3	120	59.4	68.8	120	82.7	596	582	126	0.977	416	2997.33	29%
	F4	70.9	0	0	70.9	23.6	170	166	36	0.976	416	2997.33	17%
	Total	1035.8	827.9	850.7	1035.8	904.8	6552	6355	1964	0.97	1041	7500	87%
Total	Total	3338	2982	3033	3338	3117	22860	22090	6243	0.966	4164	30000	76%

Table D-9: Station and Feeder Loads - Minor Upgrades (MS2 O/S)

Station	Feeder	Amps (A)	Amps (B)	Amps (C)	Amps (Max)	Amps (Avg)	kVA	kW	kVAR	PF (Avg)	Emer Limit (A)	Emer Limit (kVA)	Loading %
MS1	1F1	202.6	120.9	142	202.6	155.2	1095	1078	194	0.984	440	3170.25	46%
	1F2	**561.3**	**447.1**	**615.2**	**615.2**	**541.2**	**3817**	**3682**	**1007**	**0.965**	**440**	**3170.25**	**140%**
	1F3	258.1	383.4	192	383.4	277.8	1960	1912	432	0.976	440	3170.25	87%
	1F4	0	0	0	0	0	0	0	0	0	440	3170.25	0%
	Total	1022	951.4	949.2	1022	974.2	7021	6732	1992	0.959	1041	7500	94%
MS2	2F1	0	0	0	0	0	0	0	0	0	440	3170.25	0%
	2F2	0	0	0	0	0	0	0	0	0	440	3170.25	0%
	2F3	0	0	0	0	0	0	0	0	0	440	3170.25	0%
	2F4	0	0	0	0	0	0	0	0	0	440	3170.25	0%
	Total	0	0	0	0	0	0	0	0	0	1041	7500	0%
MS3	**3F1**	**582.7**	**586.8**	**569.1**	**586.8**	**579.5**	**4185**	**3963**	**1343**	**0.947**	**440**	**3170.25**	**133%**
	3F2	**538.2**	**439.5**	**585.3**	**585.3**	**521**	**3759**	**3625**	**995**	**0.964**	**440**	**3170.25**	**133%**
	3F3	168.5	11.4	140.5	168.5	106.8	1011	991	201	0.98	440	3170.25	38%
	3F4	72.2	99	72	99	81.1	586	574	115	0.98	440	3170.25	23%
	Total	**1361.6**	**1136.7**	**1366.9**	**1366.9**	**1288.4**	**9828**	**9254**	**3309**	**0.942**	**1041**	**7500**	**131%**
MS4	F1	253.1	255.7	253.6	255.7	254.1	1828	1775	427	0.971	416	2997.33	61%
	F2	375.9	386.7	376.4	386.7	379.7	2728	2632	720	0.965	416	2997.33	93%
	F3	120.1	59.6	69	120.1	82.9	596	582	126	0.977	416	2997.33	29%
	F4	71	0	0	71	23.7	170	166	36	0.976	416	2997.33	17%
	Total	820.1	702	699	820.1	740.4	5411	5194	1518	0.96	1041	7500	72%
Total	Total	3204	2790	3015	3204	3003	22260	21180	6819	0.951	4164	30000	74%

Table D-10: Station and Feeder Loads - Minor Upgrades (MS3 O/S)

Station	Feeder	Amps (A)	Amps (B)	Amps (C)	Amps (Max)	Amps (Avg)	kVA	kW	kVAR	PF (Avg)	Emer Limit (A)	Emer Limit (kVA)	Loading %
MS1	1F1	201.7	120.5	141	201.7	154.4	1095	1078	194	0.984	440	3170.25	46%
	1F2	321.3	298.4	289.2	321.3	303	2149	2084	523	0.97	440	3170.25	73%
	1F3	334.6	399.6	266.6	399.6	333.6	2365	2308	519	0.976	440	3170.25	91%
	1F4	0	0	0	0	0	0	0	0	0	440	3170.25	0%
	Total	857.6	818.5	696.8	857.6	791	5706	5513	1474	0.966	1041	7500	76%
MS2	**2F1**	**576.6**	**450.3**	**588.8**	**588.8**	**538.6**	**3884**	**3800**	**804**	**0.978**	**440**	**3170.25**	**134%**
	2F2	214.1	215.2	270.5	270.5	233.3	1682	1668	218	0.992	440	3170.25	61%
	2F3	**524.3**	**507.8**	**492.5**	**524.3**	**508.2**	**3665**	**3522**	**1016**	**0.961**	**440**	**3170.25**	**119%**
	2F4	193.2	190.7	147.4	193.2	177.1	1277	1270	140	0.995	440	3170.25	44%
	Total	**1508.2**	**1364**	**1499.2**	**1508.2**	**1457.1**	**10895**	**10412**	**3210**	**0.956**	**1041**	**7500**	**145%**
MS3	3F1	0	0	0	0	0	0	0	0	0	440	3170.25	0%
	3F2	0	0	0	0	0	0	0	0	0	440	3170.25	0%
	3F3	0	0	0	0	0	0	0	0	0	440	3170.25	0%
	3F4	0	0	0	0	0	0	0	0	0	440	3170.25	0%
	Total	0	0	0	0	0	0	0	0	0	1041	7500	0%
MS4	**F1**	**435**	**378.5**	**411.8**	**435**	**408.4**	**2942**	**2836**	**784**	**0.964**	**416**	**2997.33**	**105%**
	F2	375.2	385.2	375.5	385.2	378.6	2727	2631	719	0.965	416	2997.33	93%
	F3	119.1	59.4	68.8	119.1	82.4	596	582	126	0.977	416	2997.33	29%
	F4	70.8	0	0	70.8	23.6	170	166	36	0.976	416	2997.33	17%
	Total	1000.1	823.1	856.1	1000.1	893.1	6569	6267	1969	0.954	1041	7500	88%
Total	Total	3366	3006	3052	3366	3141	23170	22192	6653	0.958	4164	30000	77%

Table D-11: Station and Feeder Loads - Minor Upgrades (MS4 O/S)

Station	Feeder	Amps (A)	Amps (B)	Amps (C)	Amps (Max)	Amps (Avg)	kVA	kW	kVAR	PF (Avg)	Emer Limit (A)	Emer Limit (kVA)	Loading %
MS1	**1F1**	**557.1**	**384.4**	**409.6**	**557.1**	**450.4**	**3135**	**3047**	**737**	**0.972**	**440**	**3170.25**	**127%**
	1F2	329	283	295.1	329	302.4	2106	2042	514	0.97	440	3170.25	75%
	1F3	262.5	317.2	194.8	317.2	258.2	1798	1760	369	0.979	440	3170.25	72%
	1F4	**539.4**	**465**	**469.6**	**539.4**	**491.3**	**3421**	**3269**	**101**	**0.956**	**440**	**3170.25**	**123%**
	Total	**1688**	**1449.6**	**1369.1**	**1688**	**1502.2**	**10826**	**10247**	**3492**	**0.947**	**1041**	**7500**	**144%**
MS2	2F1	330.2	208.6	308.2	330.2	282.3	2036	2017	276	0.991	440	3170.25	75%
	2F2	214	215.3	270.4	270.4	233.2	1682	1668	218	0.992	440	3170.25	61%
	2F3	222	210.1	200.3	222	210.8	1521	1507	203	0.991	440	3170.25	50%
	2F4	193.1	190.8	147.3	193.1	177.1	1277	1270	140	0.995	440	3170.25	44%
	Total	959.3	824.8	926.2	959.3	903.4	6643	6527	1236	0.983	1041	7500	89%
MS3	3F1	272.1	271.5	275	275	272.9	1962	1899	494	0.968	440	3170.25	63%
	3F2	235.7	237.1	272.5	272.5	248.4	1786	1739	407	0.974	440	3170.25	62%
	3F3	168.9	112.2	140.9	168.9	140.7	1011	991	201	0.98	440	3170.25	38%
	3F4	72.4	99.6	72.3	99.6	81.4	586	574	115	0.98	440	3170.25	23%
	Total	749.1	720.4	760.7	760.7	743.4	5432	5243	1424	0.965	1041	7500	72%
MS4	F1	0	0	0	0	0	0	0	0	0	416	2997.33	0%
	F2	0	0	0	0	0	0	0	0	0	416	2997.33	0%
	F3	0	0	0	0	0	0	0	0	0	416	2997.33	0%
	F4	0	0	0	0	0	0	0	0	0	416	2997.33	0%
	Total	0	0	0	0	0	0	0	0	0	1041	7500	0%
Total	Total	3396	2995	3056	3396	3149	22901	22017	6152	0.961	4164	30000	76%

Table D-12: Station and Feeder Loads - Transformer Upgrade (Normal)

Station	Feeder	Amps (A)	Amps (B)	Amps (C)	Amps (Max)	Amps (Avg)	kVA	kW	kVAR	PF (Avg)	Emer Limit (A)	Emer Limit (kVA)	Loading %
MS1	1F1	201.3	120.2	140.8	201.3	154.1	1095	1078	194	0.984	440	3170.25	46%
	1F2	320.3	277.7	289.4	320.3	295.8	2102	2040	507	0.971	440	3170.25	73%
	1F3	255.9	311.1	191.3	311.1	252.8	1796	1758	367	0.979	440	3170.25	71%
	1F4	0	0	0	0	0	0	0	0	0	440	3170.25	0%
	Total	777.5	709	621.5	777.5	702.7	5070	4912	1256	0.969	1388	10000	51%
MS2	2F1	330.2	208.6	308.2	330.2	282.3	2036	2017	276	0.991	440	3170.25	75%
	2F2	214	215.3	270.4	270.4	233.2	1682	1668	218	0.992	440	3170.25	61%
	2F3	222	210.1	200.3	222	210.8	1521	1507	203	0.991	440	3170.25	50%
	2F4	193.1	190.8	147.3	193.1	177.1	1277	1270	140	0.995	440	3170.25	44%
	Total	959.3	824.8	926.2	959.3	903.4	6643	6527	1236	0.983	1388	10000	66%
MS3	3F1	272.1	271.5	275	275	272.9	1962	1899	494	0.968	440	3170.25	63%
	3F2	235.7	237.1	272.5	272.5	248.4	1786	1739	407	0.974	440	3170.25	62%
	3F3	168.9	112.2	140.9	168.9	140.7	1011	991	201	0.98	440	3170.25	38%
	3F4	72.4	99.6	72.3	99.6	81.4	586	574	115	0.98	440	3170.25	23%
	Total	749.1	720.4	760.7	760.7	743.4	5432	5243	1424	0.965	1388	10000	54%
MS4	F1	253.1	255.7	253.6	255.7	254.1	1828	1775	427	0.971	416	2997.33	61%
	F2	375.9	386.7	376.4	386.7	379.7	2728	2632	720	0.965	416	2997.33	93%
	F3	120.1	59.6	69	120.1	82.9	596	582	126	0.977	416	2997.33	29%
	F4	71	0	0	71	23.7	170	166	36	0.976	416	2997.33	17%
	Total	820.1	702	699	820.1	740.4	5415	5197	1520	0.96	1388	10000	54%
Total	Total	3306	2956	3007	3306	3090	22560	21879	5436	0.97	5552	40000	56%

Table D-13: Station and Feeder Loads - Transformer Upgrade (MS1 O/S)

Station	Feeder	Amps (A)	Amps (B)	Amps (C)	Amps (Max)	Amps (Avg)	kVA	kW	kVAR	PF (Avg)	Emer Limit (A)	Emer Limit (kVA)	Loading %
MS1	1F1	0	0	0	0	0	0	0	0	0	440	3170.25	0%
	1F2	0	0	0	0	0	0	0	0	0	440	3170.25	0%
	1F3	0	0	0	0	0	0	0	0	0	440	3170.25	0%
	1F4	0	0	0	0	0	0	0	0	0	440	3170.25	0%
	Total	0	0	0	0	0	0	0	0	0	1388	10000	0%
MS2	2F1	332	209.4	309.6	332	283.7	2036	2017	277	0.991	440	3170.25	75%
	2F2	**544.3**	**520.3**	**573.5**	**573.5**	**546**	**3921**	**3808**	**938**	**0.971**	**440**	**3170.25**	**130%**
	2F3	223.1	211	201.1	223.1	211.7	1521	1507	203	0.991	440	3170.25	51%
	2F4	194.1	191.6	147.9	194.1	177.9	1277	1270	140	0.995	440	3170.25	44%
	Total	1293.5	1132.3	1232.1	1293.5	1219.3	9006	8712	2281	0.967	1388	10000	90%
MS3	3F1	271.8	271.7	274.1	274.1	272.5	1962	1899	493	0.968	440	3170.25	62%
	3F2	235.4	237.1	271.7	271.7	248.1	1786	1739	407	0.974	440	3170.25	62%
	3F3	168.7	112.2	140.6	168.7	140.5	1011	991	201	0.98	440	3170.25	38%
	3F4	332.3	400.7	263.5	400.7	332.2	2391	2332	528	0.975	440	3170.25	91%
	Total	1008.2	1021.7	949.9	1021.7	993.3	7302	7023	1998	0.962	1388	10000	73%
MS4	F1	252.8	254.8	252.8	254.8	253.5	1828	1775	427	0.971	416	2997.33	61%
	F2	**592.1**	**513.7**	**529.1**	**592.1**	**545**	**3925**	**3779**	**1062**	**0.963**	**416**	**2997.33**	**142%**
	F3	120	59.4	68.8	120	82.7	596	582	126	0.977	416	2997.33	29%
	F4	70.9	0	0	70.9	23.6	170	166	36	0.976	416	2997.33	17%
	Total	1035.8	827.9	850.7	1035.8	904.8	6552	6355	1964	0.97	1388	10000	66%
Total	Total	3338	2982	3033	3338	3117	22860	22090	6243	0.966	5552	40000	57%

Table D-14: Station and Feeder Loads - Transformer Upgrade (MS2 O/S)

Station	Feeder	Amps (A)	Amps (B)	Amps (C)	Amps (Max)	Amps (Avg)	kVA	kW	kVAR	PF (Avg)	Emer Limit (A)	Emer Limit (kVA)	Loading %
MS1	1F1	202.6	120.9	142	202.6	155.2	1095	1078	194	0.984	440	3170.25	46%
	1F2	**561.3**	**447.1**	**615.2**	**615.2**	**541.2**	**3817**	**3682**	**1007**	**0.965**	**440**	**3170.25**	**140%**
	1F3	258.1	383.4	192	383.4	277.8	1960	1912	432	0.976	440	3170.25	87%
	1F4	0	0	0	0	0	0	0	0	0	440	3170.25	0%
	Total	1022	951.4	949.2	1022	974.2	7021	6732	1992	0.959	1388	10000	70%
MS2	2F1	0	0	0	0	0	0	0	0	0	440	3170.25	0%
	2F2	0	0	0	0	0	0	0	0	0	440	3170.25	0%
	2F3	0	0	0	0	0	0	0	0	0	440	3170.25	0%
	2F4	0	0	0	0	0	0	0	0	0	440	3170.25	0%
	Total	0	0	0	0	0	0	0	0	0	1388	10000	0%
MS3	**3F1**	**582.7**	**586.8**	**569.1**	**586.8**	**579.5**	**4185**	**3963**	**1343**	**0.947**	**440**	**3170.25**	**133%**
	3F2	**538.2**	**439.5**	**585.3**	**585.3**	**521**	**3759**	**3625**	**995**	**0.964**	**440**	**3170.25**	**133%**
	3F3	168.5	11.4	140.5	168.5	106.8	1011	991	201	0.98	440	3170.25	38%
	3F4	72.2	99	72	99	81.1	586	574	115	0.98	440	3170.25	23%
	Total	1361.6	1136.7	1366.9	1366.9	1288.4	9828	9254	3309	0.942	1388	10000	98%
MS4	F1	253.1	255.7	253.6	255.7	254.1	1828	1775	427	0.971	416	2997.33	61%
	F2	375.9	386.7	376.4	386.7	379.7	2728	2632	720	0.965	416	2997.33	93%
	F3	120.1	59.6	69	120.1	82.9	596	582	126	0.977	416	2997.33	29%
	F4	71	0	0	71	23.7	170	166	36	0.976	416	2997.33	17%
	Total	820.1	702	699	820.1	740.4	5411	5194	1518	0.96	1388	10000	54%
Total	Total	3204	2790	3015	3204	3003	22260	21180	6819	0.951	5552	40000	56%

Table D-15: Station and Feeder Loads - Transformer Upgrade (MS3 O/S)

Station	Feeder	Amps (A)	Amps (B)	Amps (C)	Amps (Max)	Amps (Avg)	kVA	kW	kVAR	PF (Avg)	Emer Limit (A)	Emer Limit (kVA)	Loading %
MS1	1F1	201.7	120.5	141	201.7	154.4	1095	1078	194	0.984	440	3170.25	46%
	1F2	321.3	298.4	289.2	321.3	303	2149	2084	523	0.97	440	3170.25	73%
	1F3	334.6	399.6	266.6	399.6	333.6	2365	2308	519	0.976	440	3170.25	91%
	1F4	0	0	0	0	0	0	0	0	0	440	3170.25	0%
	Total	857.6	818.5	696.8	857.6	791	5706	5513	1474	0.966	1388	10000	57%
MS2	**2F1**	**576.6**	**450.3**	**588.8**	**588.8**	**538.6**	**3884**	**3800**	**804**	**0.978**	**440**	**3170.25**	**134%**
	2F2	214.1	215.2	270.5	270.5	233.3	1682	1668	218	0.992	440	3170.25	61%
	2F3	**524.3**	**507.8**	**492.5**	**524.3**	**508.2**	**3665**	**3522**	**1016**	**0.961**	**440**	**3170.25**	**119%**
	2F4	193.2	190.7	147.4	193.2	177.1	1277	1270	140	0.995	440	3170.25	44%
	Total	**1508.2**	**1364**	**1499.2**	**1508.2**	**1457.1**	**10895**	**10412**	**3210**	**0.956**	**1388**	**10000**	**109%**
MS3	3F1	0	0	0	0	0	0	0	0	0	440	3170.25	0%
	3F2	0	0	0	0	0	0	0	0	0	440	3170.25	0%
	3F3	0	0	0	0	0	0	0	0	0	440	3170.25	0%
	3F4	0	0	0	0	0	0	0	0	0	440	3170.25	0%
	Total	0	0	0	0	0	0	0	0	0	1388	10000	0%
MS4	**F1**	**435**	**378.5**	**411.8**	**435**	**408.4**	**2942**	**2836**	**784**	**0.964**	**416**	**2997.33**	**105%**
	F2	375.2	385.2	375.5	385.2	378.6	2727	2631	719	0.965	416	2997.33	93%
	F3	119.1	59.4	68.8	119.1	82.4	596	582	126	0.977	416	2997.33	29%
	F4	70.8	0	0	70.8	23.6	170	166	36	0.976	416	2997.33	17%
	Total	1000.1	823.1	856.1	1000.1	893.1	6569	6267	1969	0.954	1388	10000	66%
Total	Total	3366	3006	3052	3366	3141	23170	22192	6653	0.958	5552	40000	58%

Table D-16: Station and Feeder Loads - Transformer Upgrade (MS4 O/S)

Station	Feeder	Amps (A)	Amps (B)	Amps (C)	Amps (Max)	Amps (Avg)	kVA	kW	kVAR	PF (Avg)	Emer Limit (A)	Emer Limit (kVA)	Loading %
MS1	**1F1**	**557.1**	**384.4**	**409.6**	**557.1**	**450.4**	**3135**	**3047**	**737**	**0.972**	**440**	**3170.25**	**127%**
	1F2	329	283	295.1	329	302.4	2106	2042	514	0.97	440	3170.25	75%
	1F3	262.5	317.2	194.8	317.2	258.2	1798	1760	369	0.979	440	3170.25	72%
	1F4	**539.4**	**465**	**469.6**	**539.4**	**491.3**	**3421**	**3269**	**101**	**0.956**	**440**	**3170.25**	**123%**
	Total	**1688**	**1449.6**	**1369.1**	**1688**	**1502.2**	**10826**	**10247**	**3492**	**0.947**	**1388**	**10000**	**108%**
MS2	2F1	330.2	208.6	308.2	330.2	282.3	2036	2017	276	0.991	440	3170.25	75%
	2F2	214	215.3	270.4	270.4	233.2	1682	1668	218	0.992	440	3170.25	61%
	2F3	222	210.1	200.3	222	210.8	1521	1507	203	0.991	440	3170.25	50%
	2F4	193.1	190.8	147.3	193.1	177.1	1277	1270	140	0.995	440	3170.25	44%
	Total	959.3	824.8	926.2	959.3	903.4	6643	6527	1236	0.983	1388	10000	66%
MS3	3F1	272.1	271.5	275	275	272.9	1962	1899	494	0.968	440	3170.25	63%
	3F2	235.7	237.1	272.5	272.5	248.4	1786	1739	407	0.974	440	3170.25	62%
	3F3	168.9	112.2	140.9	168.9	140.7	1011	991	201	0.98	440	3170.25	38%
	3F4	72.4	99.6	72.3	99.6	81.4	586	574	115	0.98	440	3170.25	23%
	Total	749.1	720.4	760.7	760.7	743.4	5432	5243	1424	0.965	1388	10000	54%
MS4	F1	0	0	0	0	0	0	0	0	0	416	2997.33	0%
	F2	0	0	0	0	0	0	0	0	0	416	2997.33	0%
	F3	0	0	0	0	0	0	0	0	0	416	2997.33	0%
	F4	0	0	0	0	0	0	0	0	0	416	2997.33	0%
	Total	0	0	0	0	0	0	0	0	0	1388	10000	0%
Total	Total	3396	2995	3056	3396	3149	22901	22017	6152	0.961	5552	40000	57%