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Barkley Technologies Inc.

Report to:

Ottawa River Power Corporation

Municipal Substation Planning Report

August 16, 2016

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Introduction

The purpose of this report is to provide Ottawa River Power Corporation with a Municipal substation development plan for Almonte in the Town of Mississippi Mills. The plan has been developed to address the following challenges.

1. Maintenance
2. Asset management
3. Reliability
4. Load growth

Almonte has evolved and developed over the years resulting in the growth of three substations. Each substation has feeder ties with at least one other station for the planned redundancy in the event of a failure or the periodic requirement to take line sections out of service with the ability to feed from another direction or station. The ties also provide capacity and options for substation maintenance or failures.

As the result of load growth over many years, the three substations in Almonte are approaching capacity limits making it difficult to move load between them for maintenance or emergency situations. This report is the result of studying the load characteristics, urban development and the relationship between stations to determine the most efficient and economical way to expand the system to meet the needs of Almonte now and in the future.

Methodology

The study process was split into three categories:

1. Power Flow
2. Load Forecasting
3. Asset Management

1. Power Flow

The most effective way to forecast and analyze substations is to use power flow software to model the distribution system and simulate various load growth and loss of service scenarios. Since Ottawa River Hydro uses Essex Energy's DESS power flow software, we have developed the model in DESS as well to maintain continuity and models will become a part of the deliverable.

The main inputs for the development of the DESS model are:

1. Network data – GIS information i.e. Conductor, transformers, switches etc.
2. Loading information – SCADA, AMI, metering service providers.

The DESS geometric network was developed by comparing the existing GIS data to a previously developed DESS model and revising/updating as required. Open points for Almonte were verified and updated by Ottawa River Power.
The loading for this study was provided by Utilismart's on-line service Settlement Manager. Ottawa River Power Corporation provided the useful assistance as to how to separate the load data into MS1, MS2 and MS3 datasets for winter and summer peak loading. As with many of Ontario's LDC's, the Almonte system's highest coincidental peak occurs in the winter season which is the focus of this study. Monthly station inspection records were used to allocate the metered load in the proper proportion on each phase of each feeder.

2. Load Forecasting

Once the DESS model was updated and calibrated to match the most current substation peaks, the Municipality of Mississippi Mills was contacted to discuss what known areas of growth are present and forecasted for Almonte. Stephen Stirling – Town Planner responded by providing a map (see below) that outlines where the town will likely experience development as well as possible town boundary expansions.

Development forecasts are not carved in stone and anything that depends on the economy as the driver is subject to change, however Municipal Planners have a very good idea of what is realistic and what is not when it comes to local development. The drawing prepared by the Planner suggests that the majority of the new development will be north of the existing town limits. This gives us important direction because we at least know what to prepare for and the task of how to integrate added infrastructure using a planned approach.

3. Asset Management

When studying a system to determine where investment should be considered and what equipment needs to upgraded or remain, it is important to know how the substations are and have been performing and the best way to do that is review maintenance records and discuss any concerns with the Maintenance people. Two reports were given to Barkley Technologies by Ottawa River Power as follows.

- OP 5_3 Almonte Stations Data.doc (Major equipment inventory of MS1, MS2 and MS3)
- ORPC_Report.pdf (MS2- MS3 inspection and maintenance report January 2015)

Phase Balance

For this project, phase balancing was performed for two reasons:

1. Phase balancing decreases system losses and reduces the possibility of overloaded conductor and equipment on a distributions system
2. When simulating, moving load and open points from one feeder to another most definitely effects the phase balance and sometimes adversely. However it is good practice to at least start out with a balance of plus minus 10% of the feeder average

The following recommended phase changes for transformer and lateral taps on the 4kV system in Almonte are the results form DESS phase balancing.

Winter Peak

MS1

	F1 (Amps)			F2 (Amps)			F3 (Amps)		
	R	W	B	R	W	B	R	W	B
Existing	72	100	160	100	233	74	293	191	220
Balanced	93	107	134	99	199	105	258	214	232

MS2

	F1 (Amps)			F2 (Amps)			F3 (Amps)		
	R	W	B	R	W	B	R	W	B
Existing	167	152	227	148	163	192	137	166	151
Balanced	188	178	187	169	163	172	145	147	149

MS3

	F1 (Amps)			F2 (Amps)		
	R	W	B	R	W	B
Existing	156	151	102	202	204	257
Balanced	140	133	136	220	224	219

Phase Balance Report

Feeder	ChangeNum	NodeID	*Node Name*	NewPhaseR	NewPhaseW	NewPhaseB
1F1	1	3928	*Dunn Tap*			R
1F1	2	3981	*Hope Tap*			R
1F1	3	3884	*T2118*	W		
1F2	1	3707	*Wellington Tap*		B	
1F2	2	3707	*Wellington Tap*		B	
1F3	1	3849	*T2254*	W		
1F3	2	3881	*T2185*	W		
1F3	3	3604	*T72*	W		
1F3	4	3857	*T2505*	B		
1F3	5	3837	*T2164*		R	
1F3	6	3859	*Dip to Pad TX (Mill St)*			W
2F1	1	3544	*T1*			W
2F1	2	3900	*T1189*			R
2F1	3	3537	*T4*			R
2F1	4	3958	*T1497*			W
2F1	5	3637	*T1270R*	W		
2F1	6	3564	*T6*		R	
2F1	7	3530	*T1271R*			R
2F1	8	3638	*T5*	B		
2F1	9	3520	*T15*	W		
2F2	1	3656	*T79*			R
2F2	2	3667	*ADHS Tap*			R
2F2	3	3635	*T38*			R
2F2	4	3977	*Victoria Tap*	B		
2F2	5	3663	*Princess St.*		B	
2F3	1	3588	*Dip to Clay*		R	
2F3	2	3552	*T62*		B	
2F3	3	3565	*T2024*			R
2F3	4	3548	*Tatra Tap*			W
3F1	1	3801	*Shipman Tap*		B	
3F1	2	3971	*SW3*	B		
3F1	3	3888	*T2122*	B		
3F2	1	3740	*William St. Tap*			R
3F2	2	3732	*T0221*	W		
3F2	3	3776	*T2163*			R
3F2	4	3767	*T2206*		R	

3F2	5	3737	*T2202*	W		
3F2	6	3752	*T0222*	W		
3F2	7	3765	*T2203*		R	
3F2	8	3751	*T2217*			W
3F2	9	3728	*T2190*	B		

Note:

DESS performs a phase balance based on tracing from the end of line back to the source. It does not have any consideration for issues such as pole framings or clearances etc. so it is possible that some of the phase change recommendations are not practical if they require significant work beyond just transferring a tap from one phase to another.
However if the majority of changes are completed, the balance will be improved and switching for load transfers will have a better chance of matching the simulations.

Power Flow Simulations

The main objectives of the power flow simulations are:

- Existing System:
  Determine the maximum load the existing substations and feeders can support while each station is removed from service and what the most efficient configurations are.

- Enhanced System:
  What system changes are necessary to allow removal from service each substation and picking the load up from the other two during peak conditions.

- Future System:
  Add forecasted development load and determine if a new station is required, where it will be located and how to back-feed it if removed from service.

Existing Configuration:

Using the Utilismart high voltage meter readings from the Settlement Manager website, the following station winter peaks were used for the study exercises.

MS#1 February 2016 = 3018 KW's

MS#2 February 2016 = 3110 KW's

MS#3 February 2016 = 2198 KW's

Total 8326 KW's

Voltage Reference: For use with load flows to determine voltage thresholds.

CSA Standard CAN3-C235-83

10 CSA Standard CAN3-C235-83

Table 2

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

Nominal System Voltages	**Voltage Variation Limits Applicable at Utilization Points**			
	Extreme Operating Conditions			
		Normal Operating Conditions		
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				
120/208Y	108/187	110/190	125/216	127/220
240/416Y	216/374	220/380	250/432	254/440
277/480Y	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

Exercise 1 – MS#1 Out of Service

1a – Peak Load

Using existing normal open points transfer all load from MS#1 to MS#2 and MS#3 as follows:

- 1F1
  - Open station switches at MS#1 – F1
  - Close LS12
  - Open F7
  - Close LS16

- 1F2
  - Open station switches at MS#1-F2
  - Close LS45

- 1F3
  - Open station switches at MS#1-F3
  - Close LS9

Results:

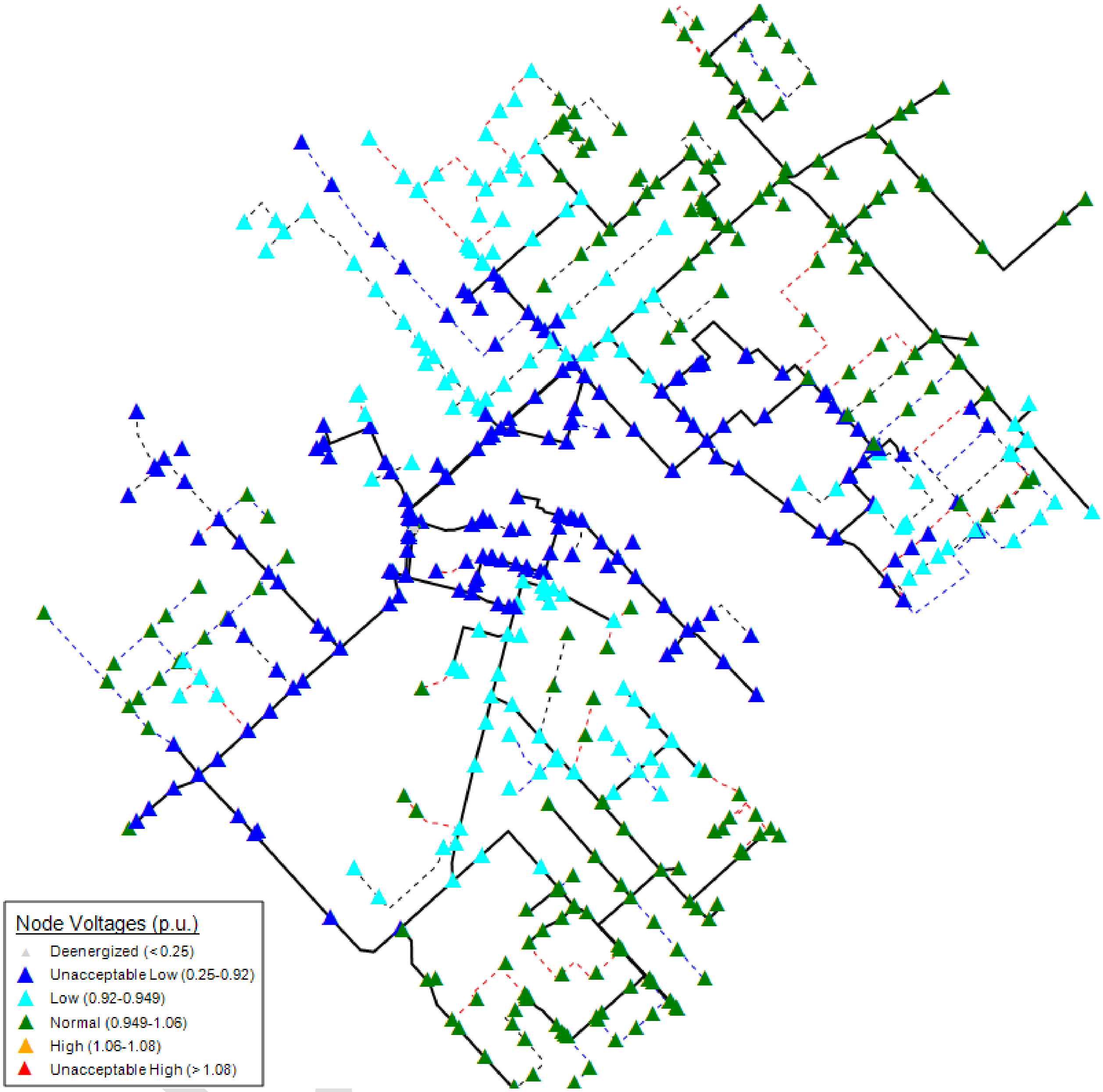
MS#2 February 2016 = 5036 KW's (100.72%)

MS#3 February 2016 = 2984 KW's (99.47%)

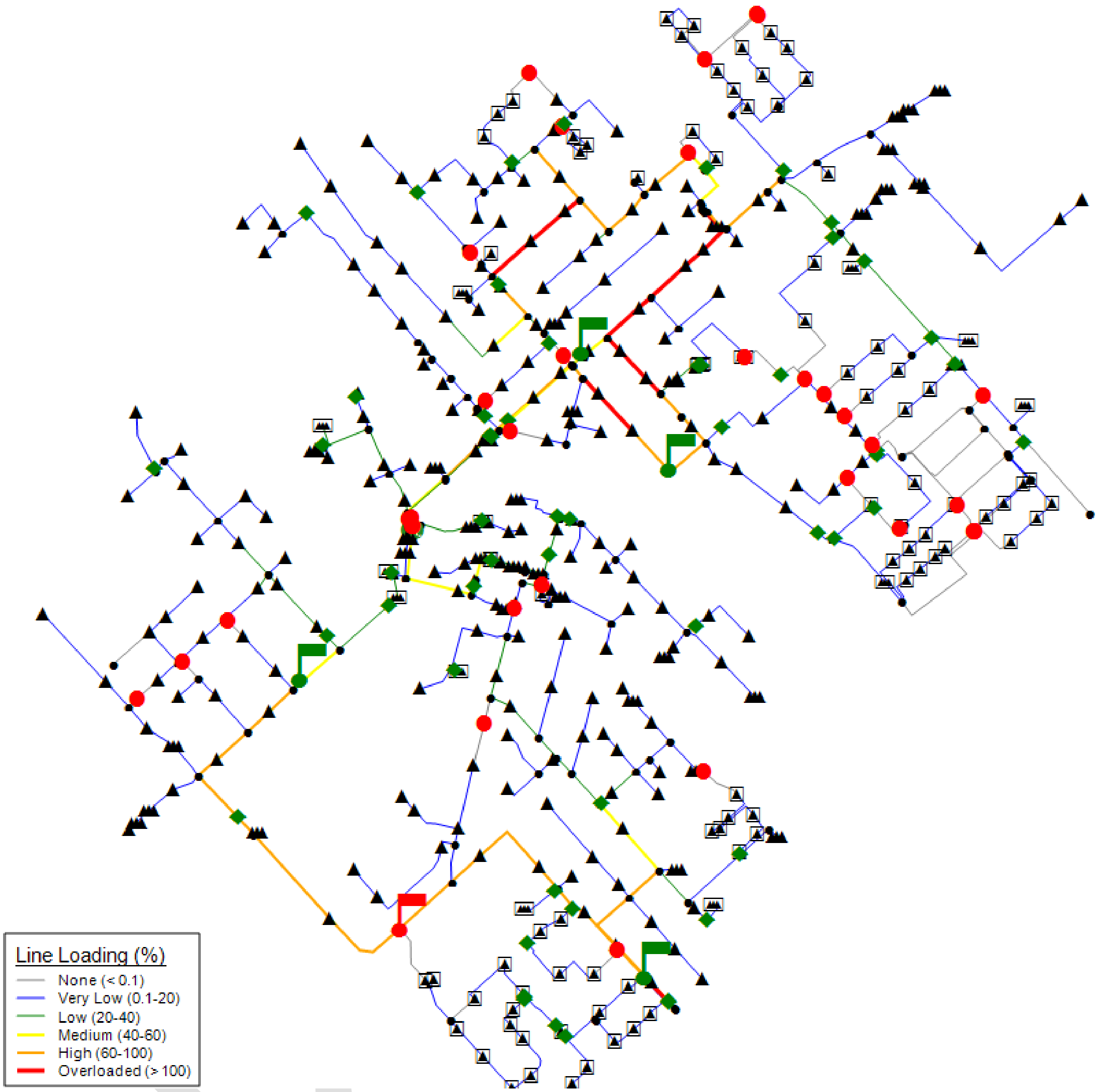
Voltage – Widespread low voltage (see report)

Conductor Loading

- 2F3 (3/0 ACSR) 3ph loaded at 138.8% (see report)
- 2F2 (#4 ACSR) 3ph loaded at 115.6% (see report)



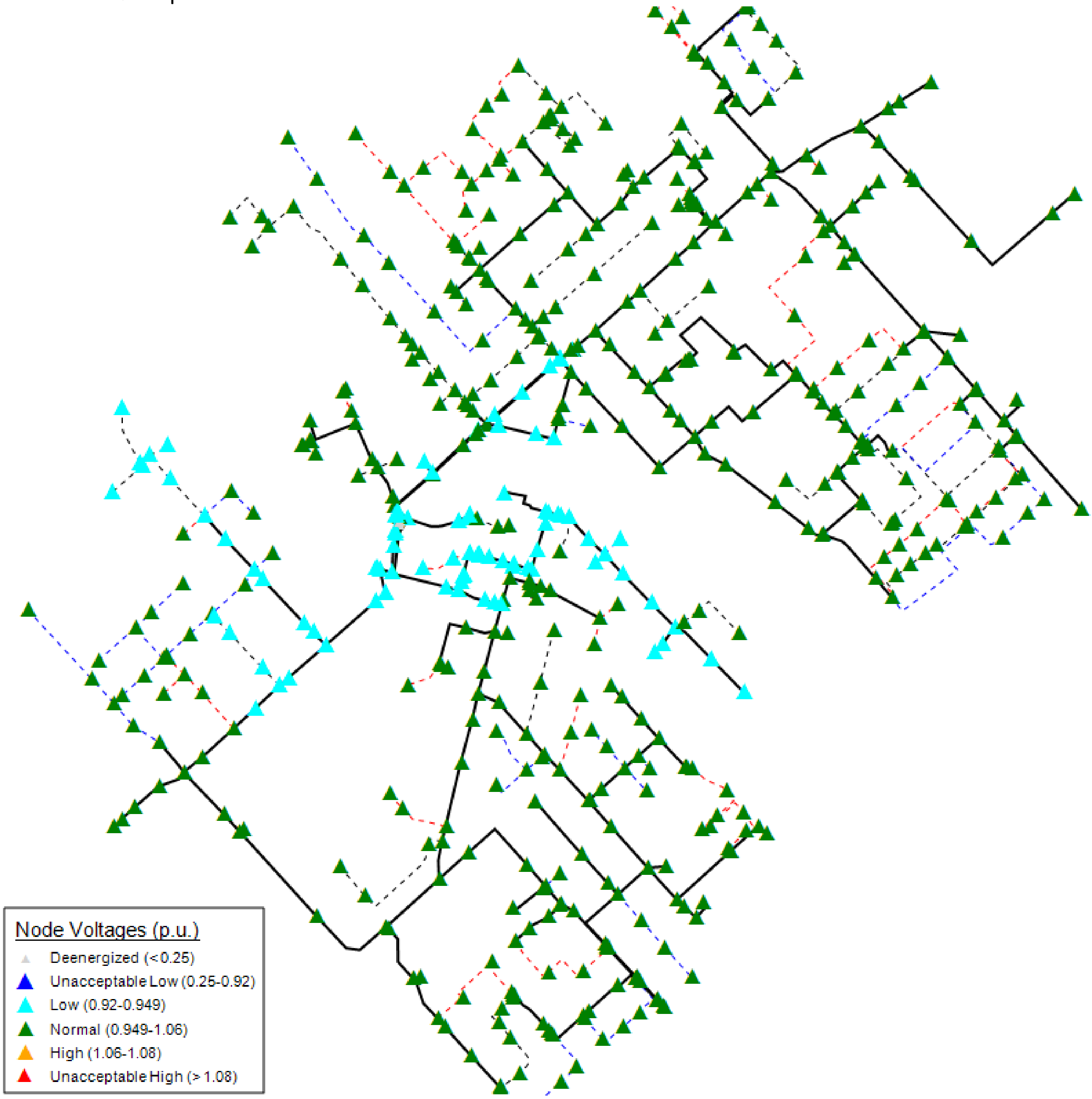
Voltage Report at Peak Load with MS#1 out of service



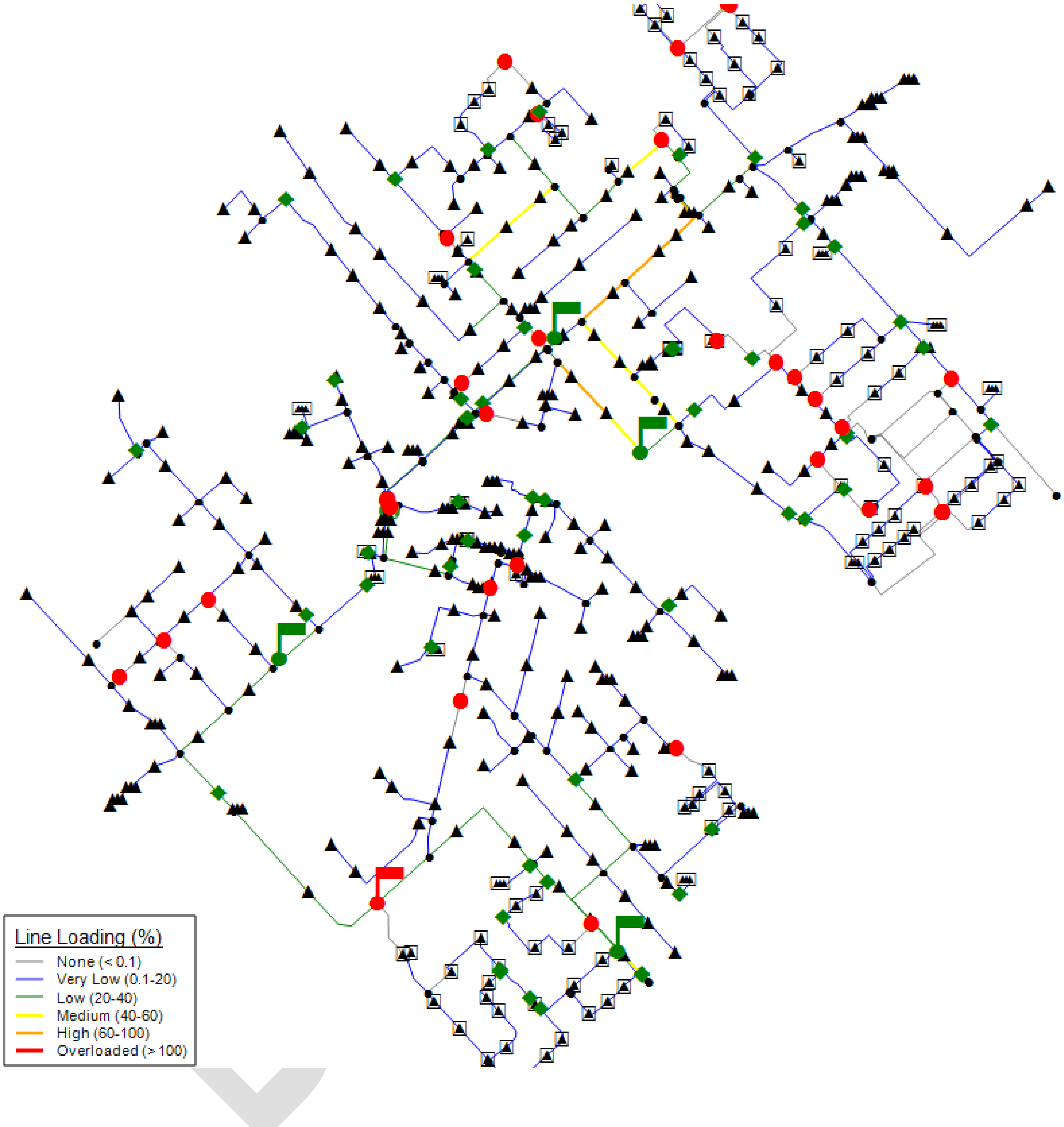
Conductor Loading Report at Peak Load

1b – Reduce Load until voltage holds at satisfactory level. (off peak interruption required)

Results – 43% of peak



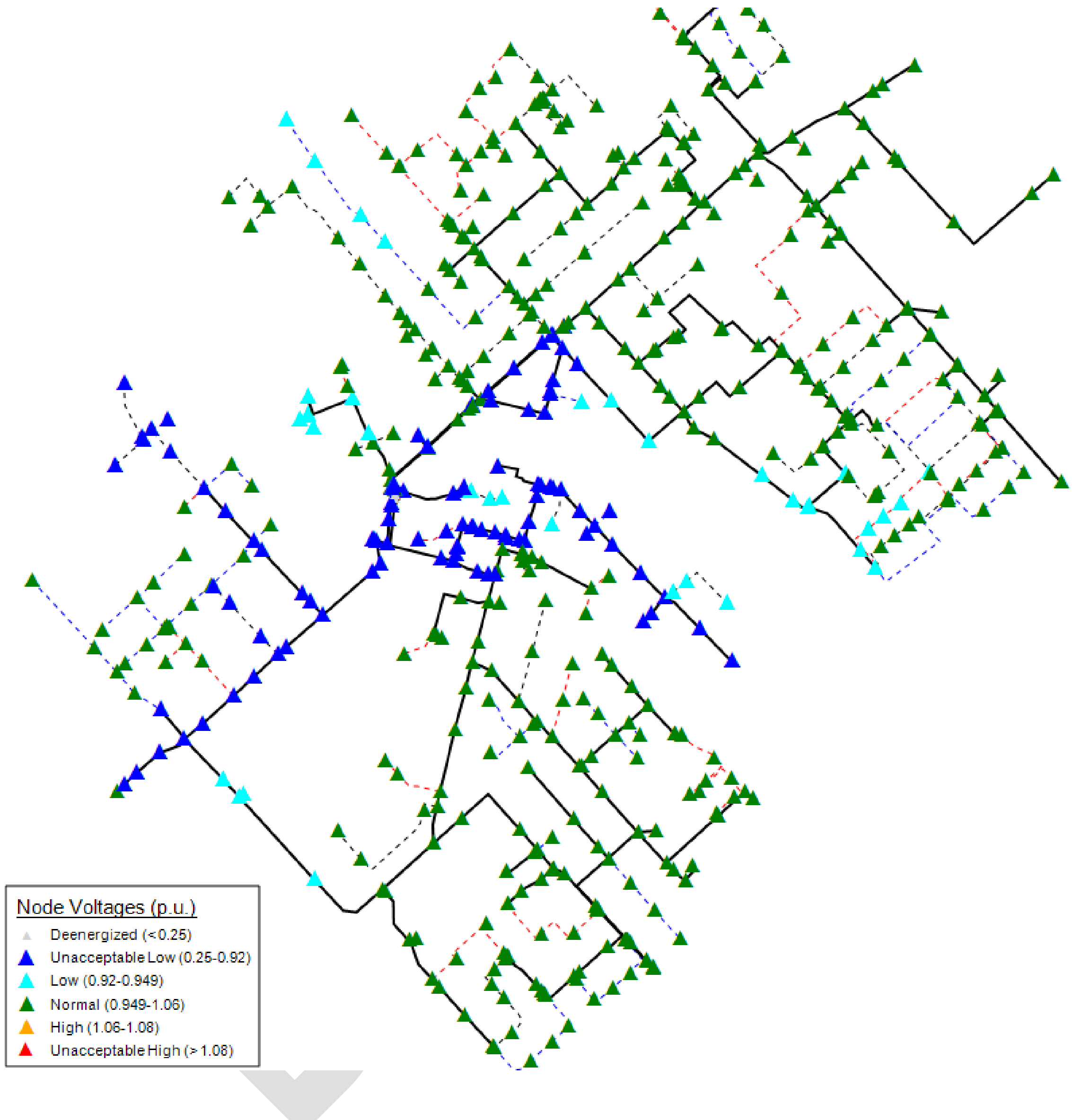
Voltage Report MS#1 out of service at 43% Peak Load



Conductor Loading Report at 43% Peak Load

1c – Peak load conditions. Decrease off- load taps on HV side of station transformers to increase secondary voltage at MS#2 and MS#3.

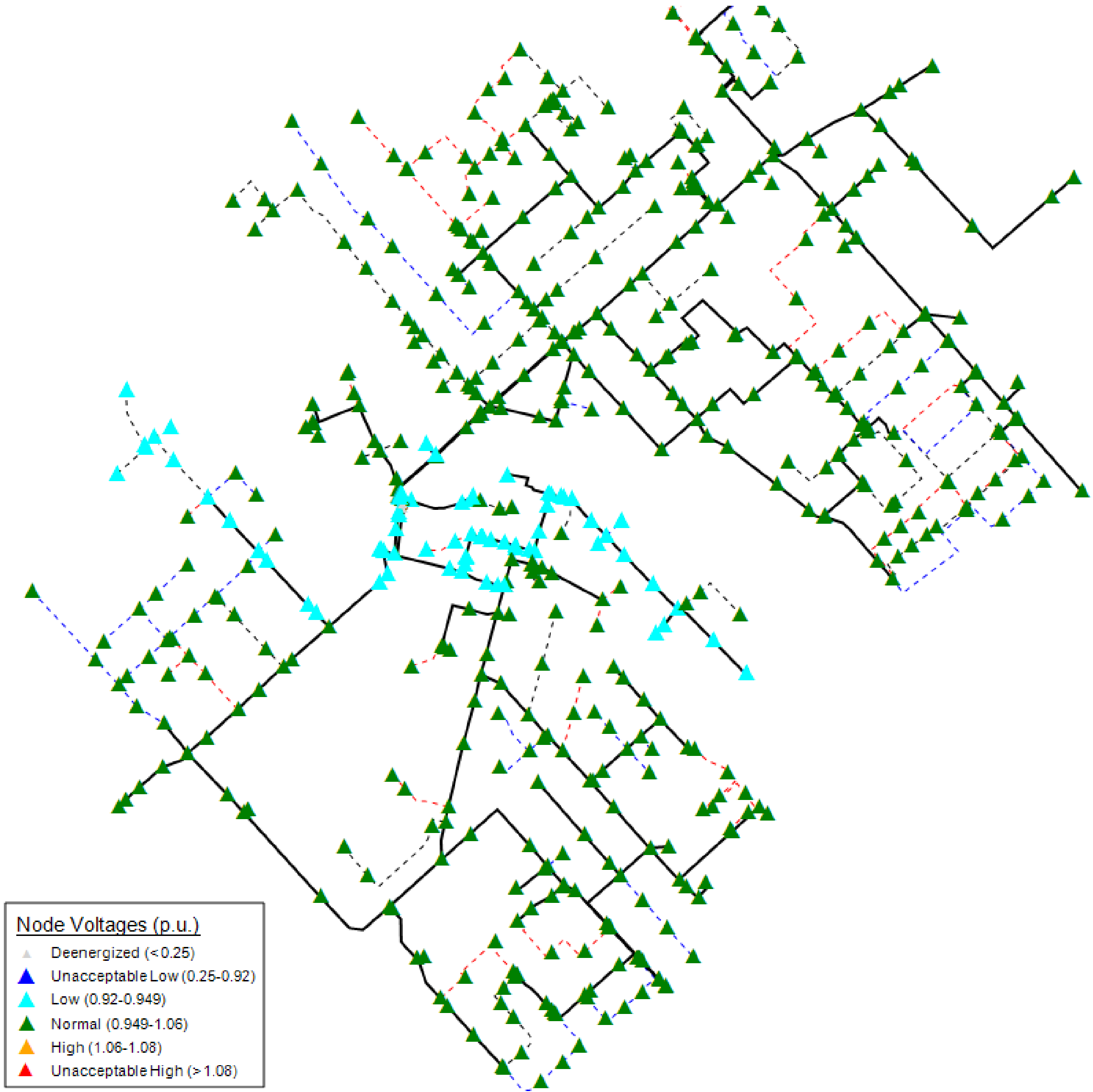
Results – Low voltage



Voltage Report at Peak Load with MS#2 and MS#3 Tapped at (maximum)

1d – Reduce Load until voltage holds at satisfactory level with MS#2 and MS#3 tapped

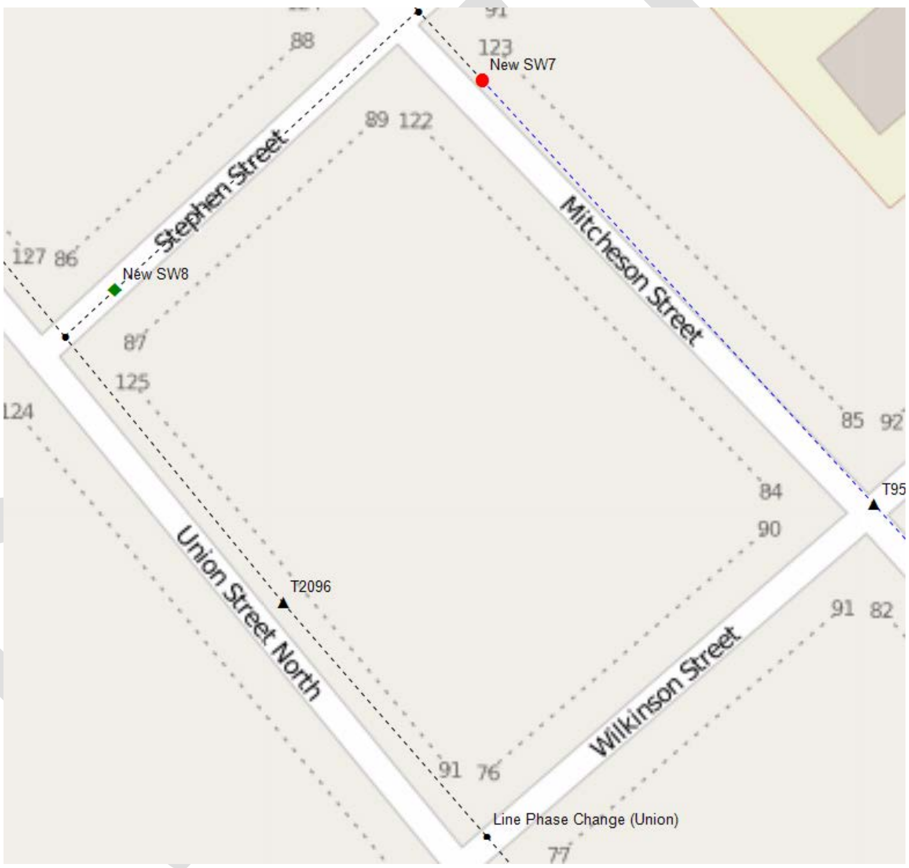
Results – 65% of peak



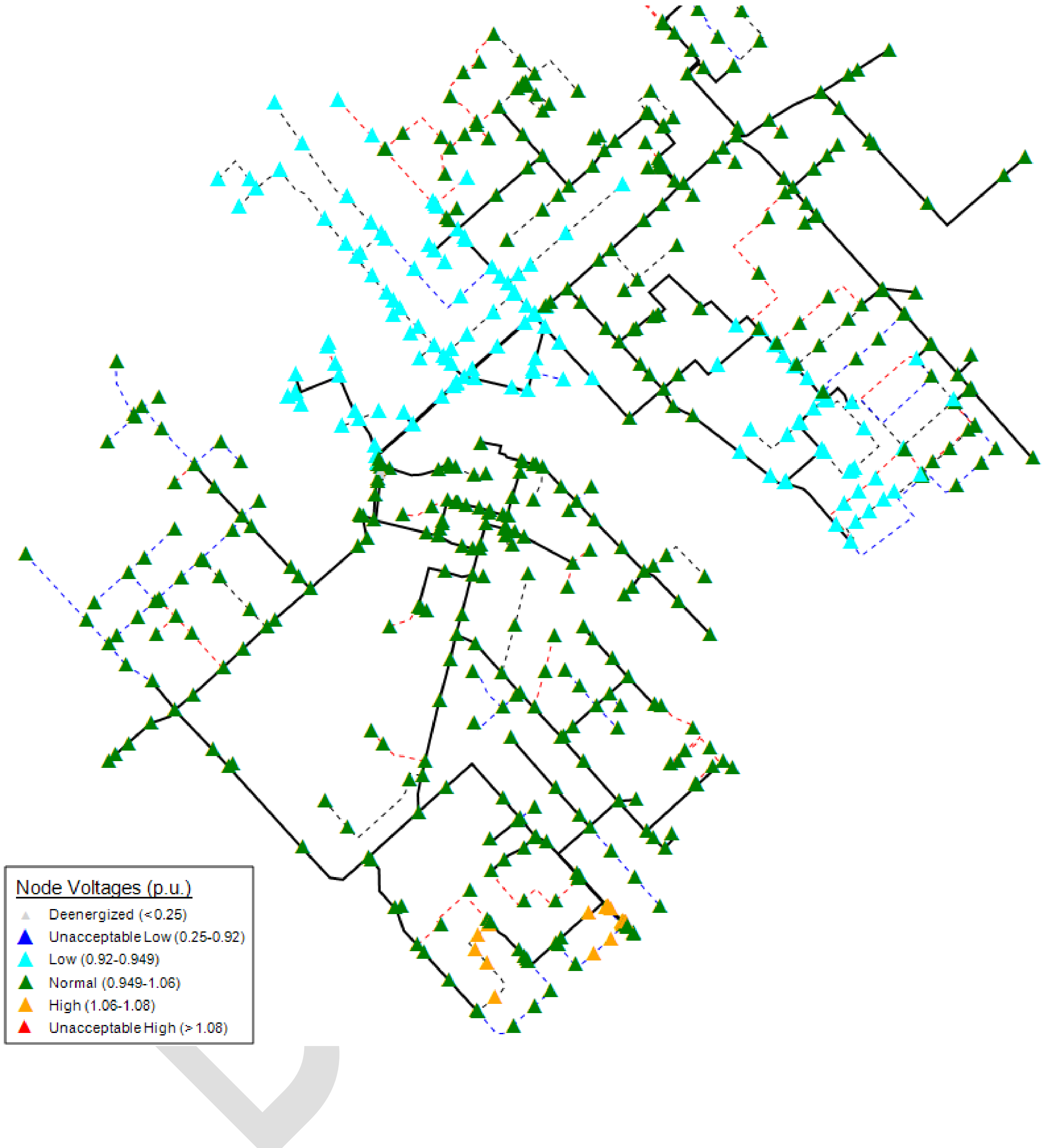
Voltage Report at 65% with MS#2 and MS#3 Tapped at maximum

1e – Voltage Regulators:

1. Perform switching as per Exercise 1a
2. Install voltage regulators on 3F1 and 3F2 feeders. +10% boost and -10% buck 32 steps at .625%. Six single phase regulators.
3. Station taps reset to existing settings. Load is at peak.
4. Install New SW6 (Open) on 1F3 north of tap to Farm St. Tap
5. Close LS28
6. Mitcheson St.
    a. Install New SW7 (Open) on single phase on Mitcheson St. south of Stephen St.
    b. Install 88m of single phase 1/0 ACSR on Stephen St. from Union St. Nth. to Mitcheson St.
    c. Add New SW8 (closed) on single phase on Stephen St. , east of Union St. Nth



7. Open S9 (Check)
8. Close LS43 (Check)
9. I phase tap that feeds transformer T0110 change to red phase



Voltage Report at peak load with regulators installed at MS#3

Exercise 2 – MS#2 Out of Service

2a – Peak Load

Using existing Normal Open Points, transfer load from MS#2 to MS#1 as follows:

- 2F1
    - Open station switches at MS#2 – F1
    - Close LS9
    - Open SW37
    - Close New SW1 (St Paul's Tap)

- 2F2
    - Open station switches at MS#2 – F2
    - Tie 2F2 to 2F3

- 2F3
    - Open station switches at MS#2-F3
    - Close LS45
    - Close SW58

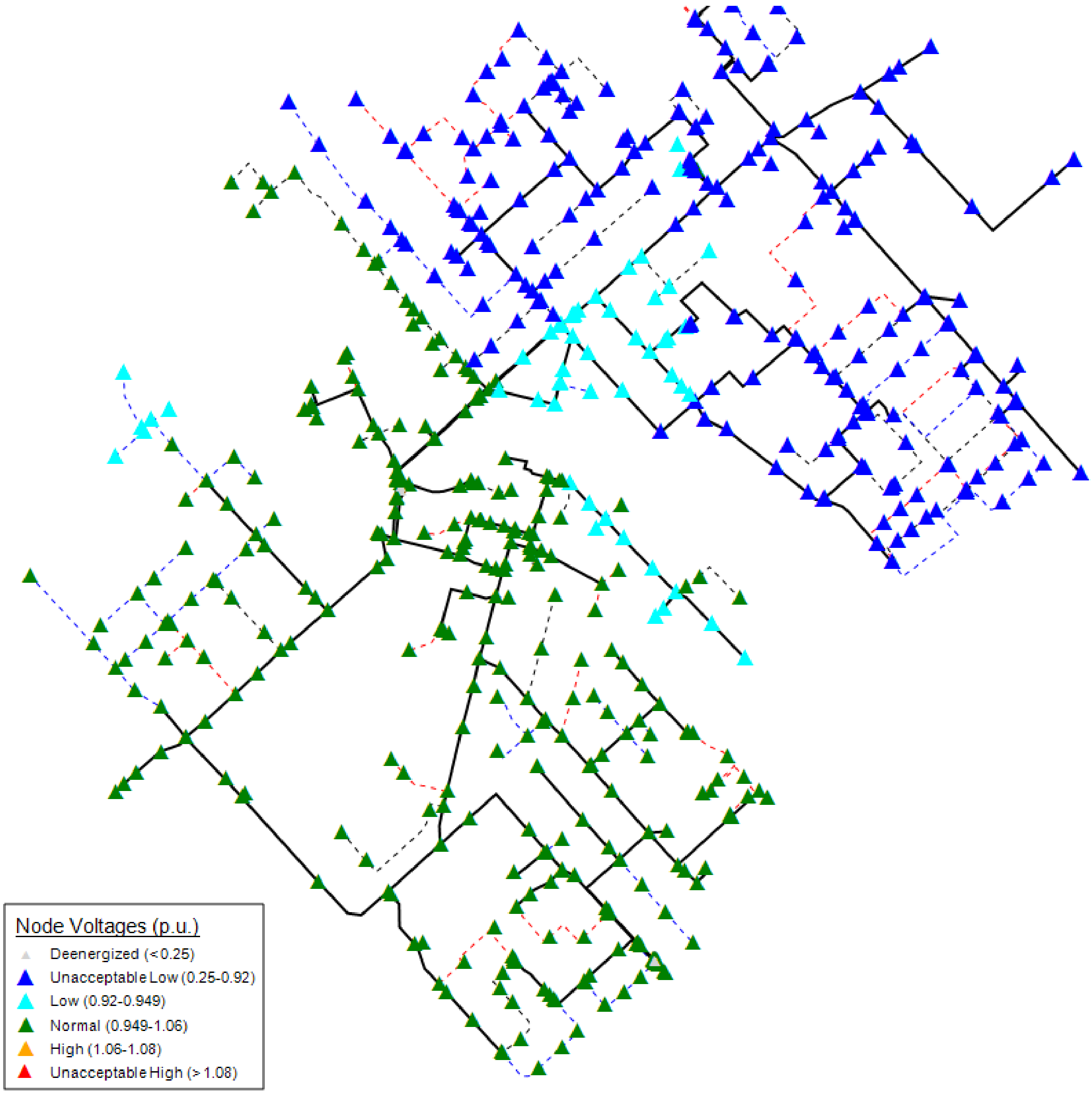
Results:

MS#1 February 2016 = 5844 KW's (116.9%)

MS#3 February 2016 = 2285 KW's (76.18%)

Voltage – Widespread low voltage (see report)

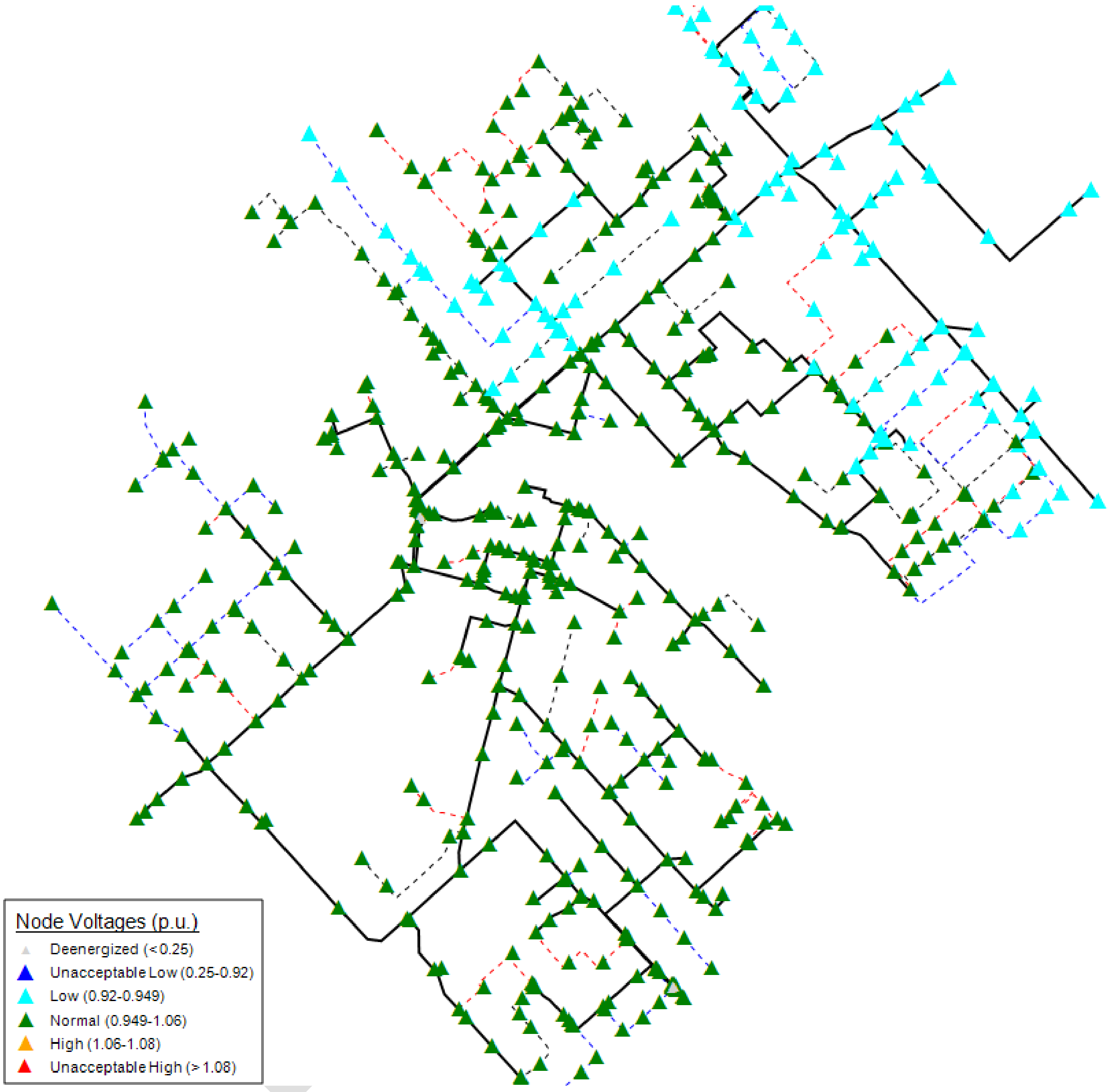
Adjustment - 850 MW's of load was switched from MS#1 to MS#3 to provide relief on MS#1 and increase voltage. Voltage still remains widespread low.



Voltage Report at Peak Load with MS#2 out of service

2b – Reduce Load until voltage holds at satisfactory level. (off peak interruption required)

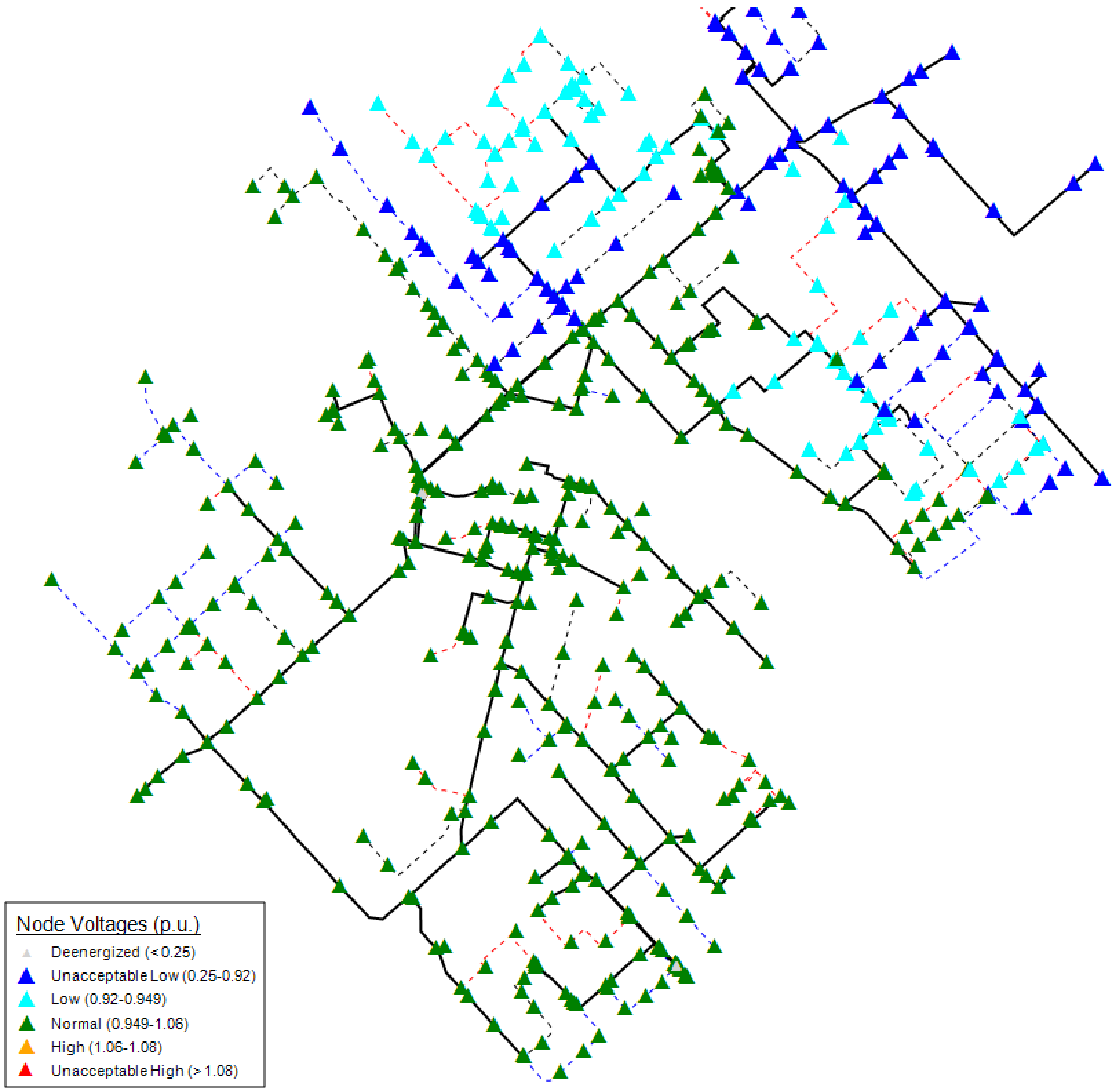
Results – 47% of peak



Voltage Report MS#2 out of service at 47% Peak Load

2c – Peak load conditions. Decrease off- load taps on HV side of station transformers to increase secondary voltage at MS#1.

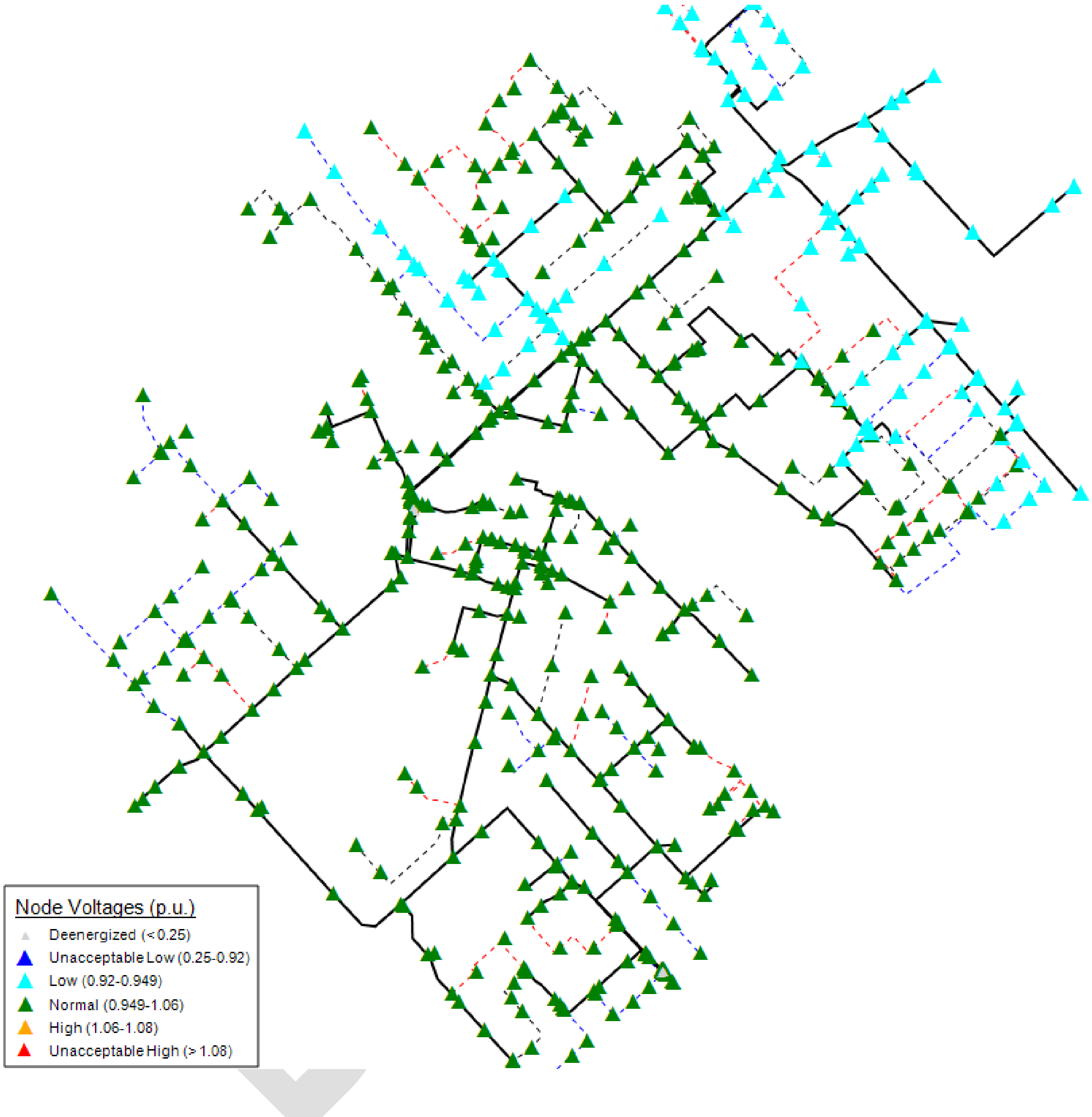
Results – Low voltage



Voltage Report at Peak Load with MS#1 Tapped at (maximum)

2d– Decrease off- load taps on HV side of MS#1 station transformers to increase secondary voltage at MS#1. Decrease load until voltage holds at satisfactory level at MS#1

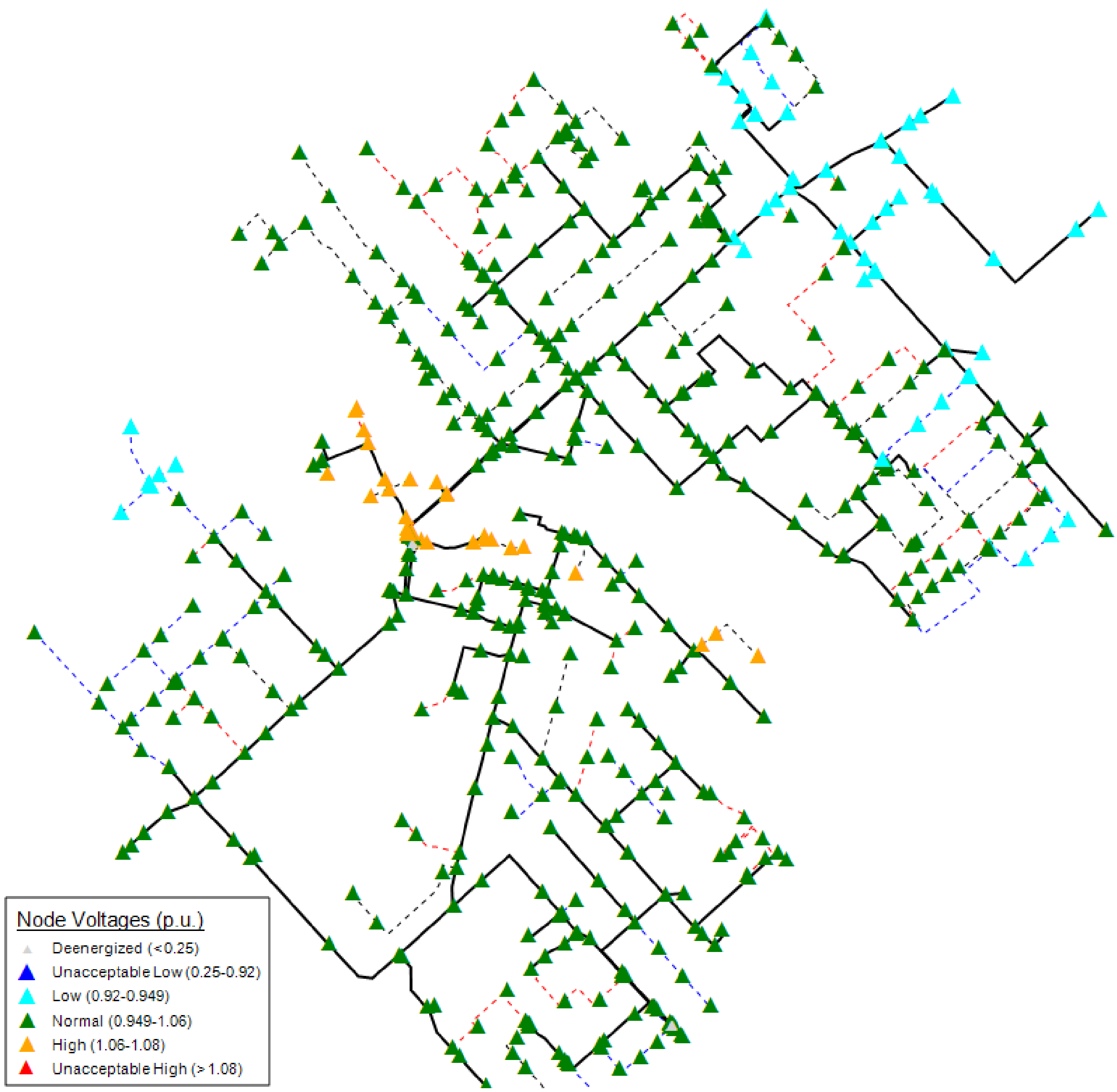
Results – 59% of peak



Voltage Report with Load at 59% with MS#1 Tapped at maximum

2e – Voltage Regulators:

1. Perform switching as per Exercise 2a
2. Install voltage regulators on 1F2 and 1F3 feeders. +10% boost and -10% buck 32 steps at .625%. Six single phase regulators.
3. Open New SW7
4. Close New SW8



Voltage Report at peak load with regulators installed at MS#1

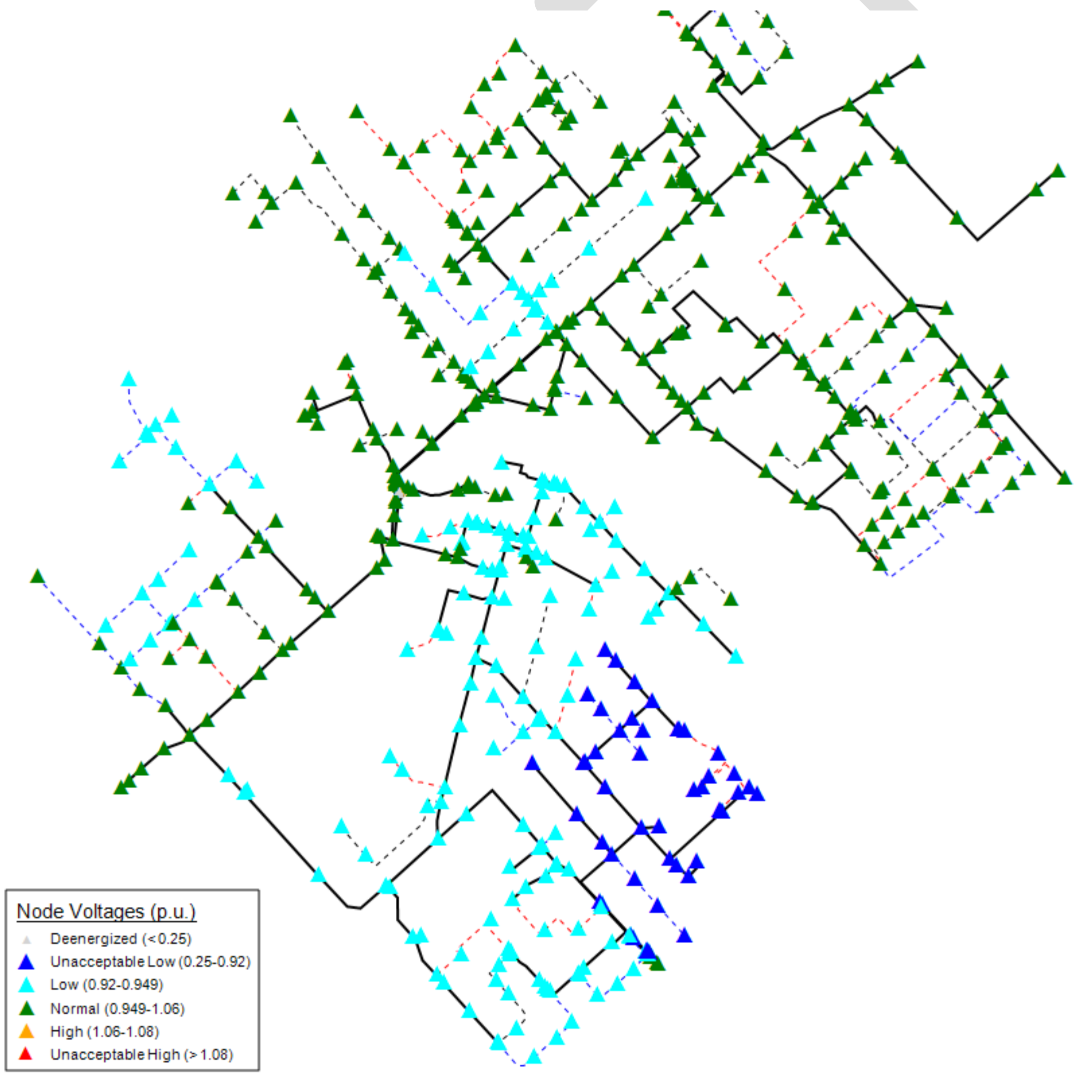
Exercise 3 – MS#3 Out of Service

3a – Peak Load

Using existing Normal Open Points, transfer load from MS#2 to MS#1 as follows:

- 3F1
  - Open station switches at MS#3 – F1 (SW58)
  - Close LS12
  - Close LS54

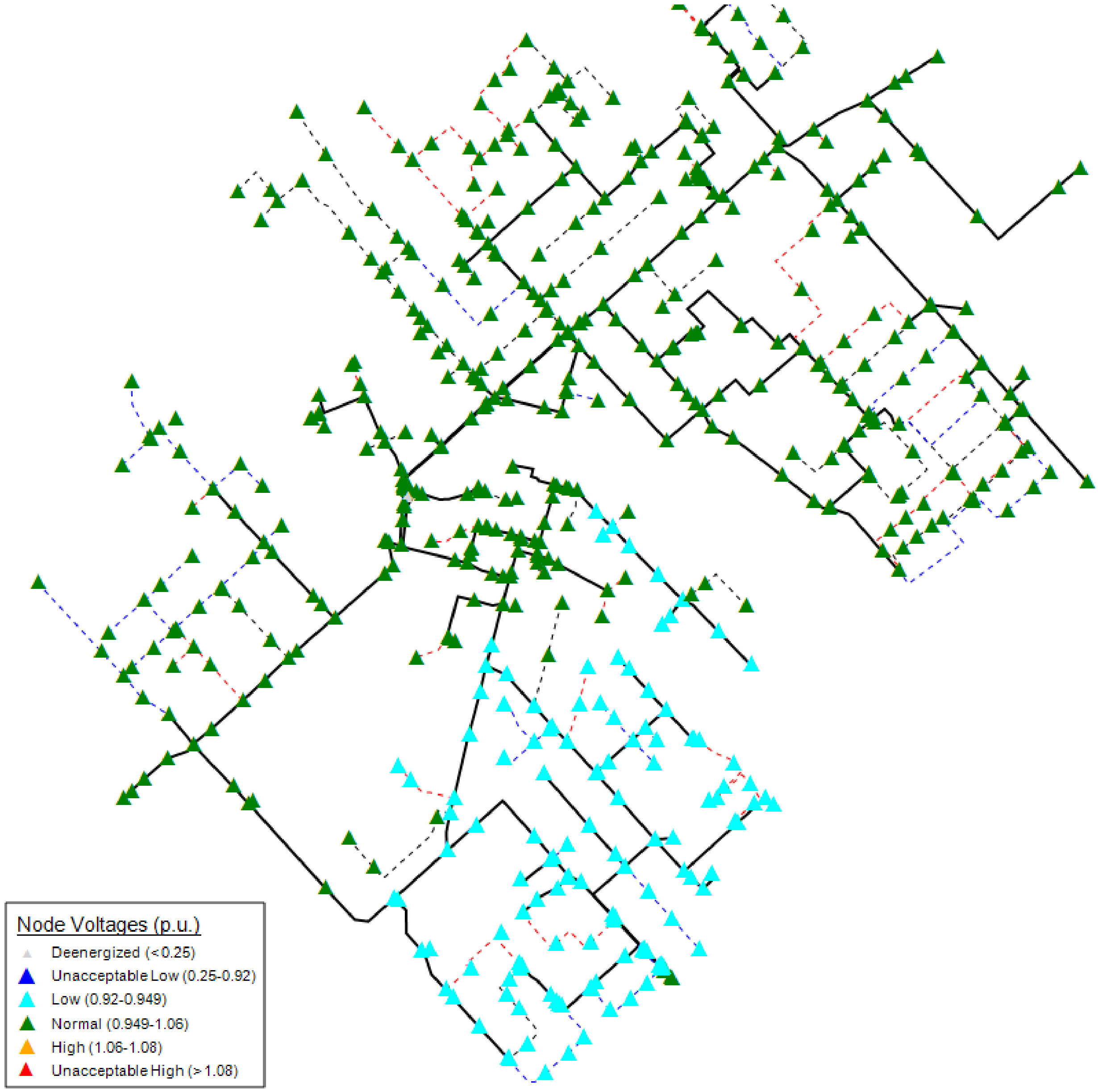
- 3F2
  - Open station switches at MS#3 – F2 (SW61)
  - Close LS4
  - Close LS28



Voltage Report at Peak Load with MS#3 out of service

3b – Reduce Load until voltage holds at satisfactory level. (off peak interruption required)

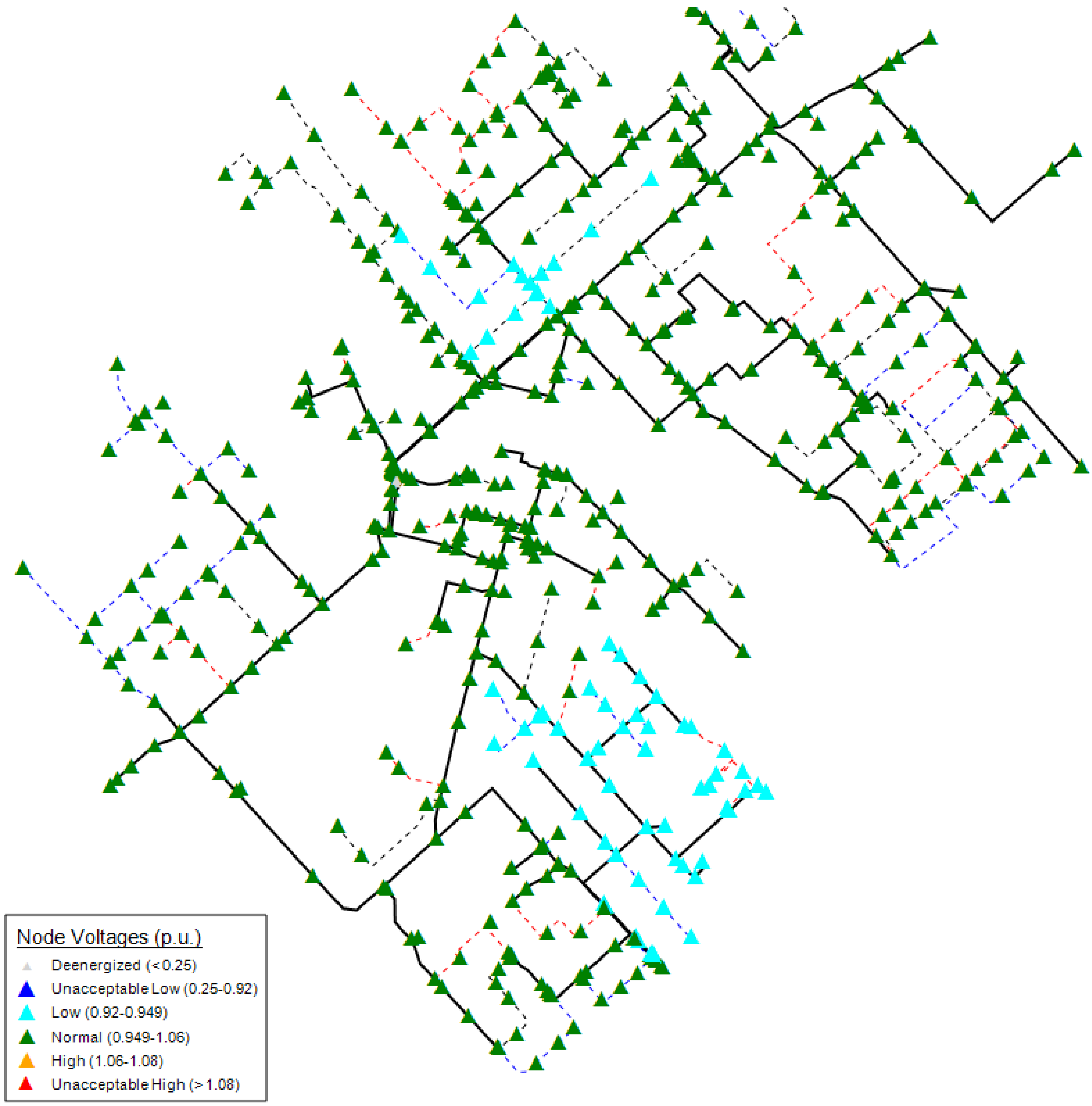
Results –88% of peak



Voltage Report MS#3 out of service at 88% Peak Load

3c – Peak load conditions. Decrease off- load taps on HV side of station transformers to increase secondary voltage

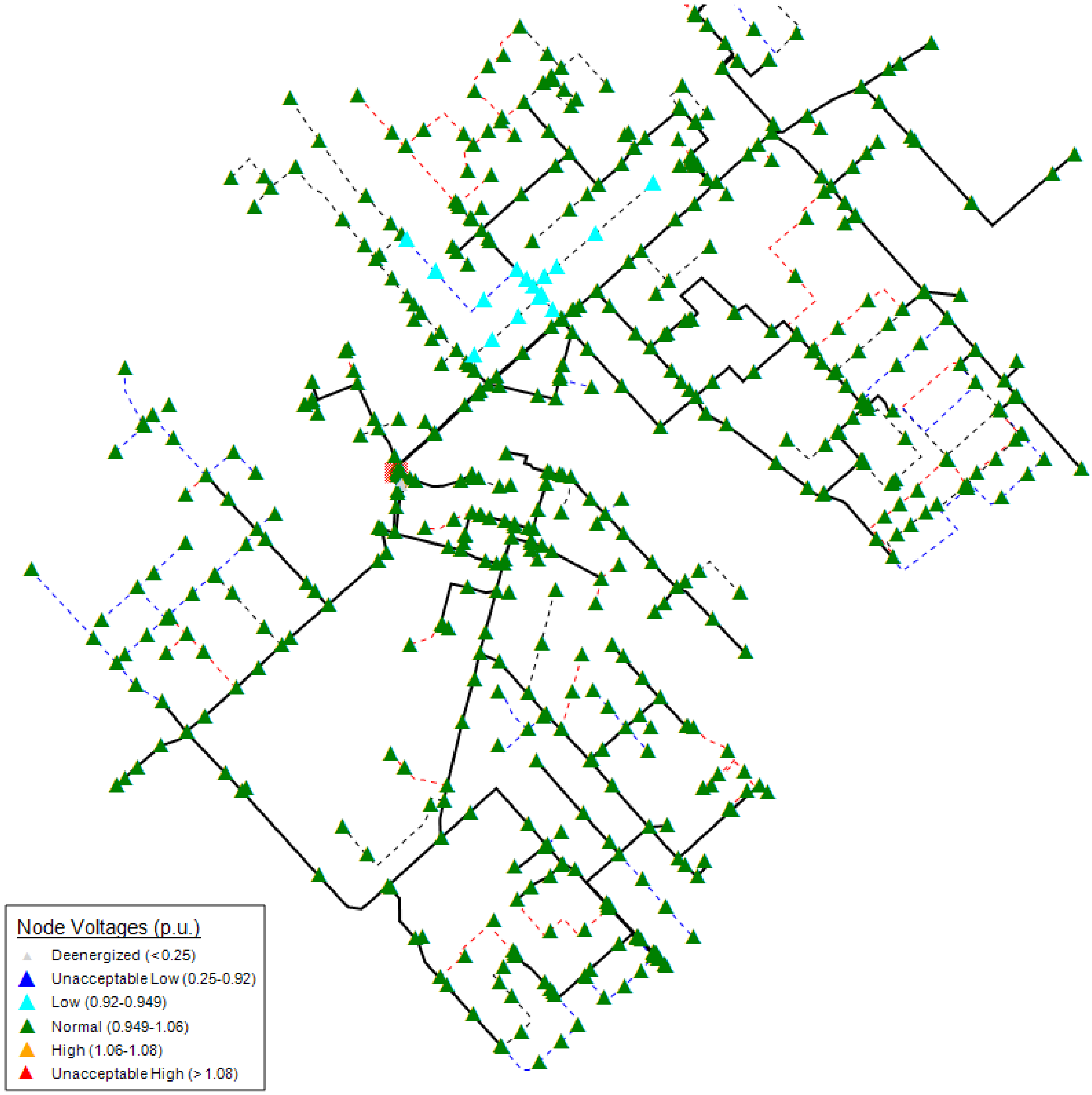
Results – Satisfactory voltage



Voltage Report at Peak Load MS#3 out of service with MS#2 Tapped at (97.5%)

3d – Voltage Regulators:

1. Perform switching as per Exercise 3a
2. Install voltage regulators on 1F2 and 1F3 feeders. +10% boost and -10% buck 32 steps at .625%. Six single phase regulators.



Voltage Report at peak load with regulators installed at MS#1

Exercise 4 – Tie Lines and Upgrades

The previous three exercises require voltage regulation either by station transformer tap changes or by adding voltage regulators at MS's 1 and 3. The purpose of this exercise is to add conductor as tie lines and upgrades to either reduce the load on the main feeders or provide alternative open point options. Peak winter conditions are used. 336 kcmil ACSR is used for new conductoring. Transformer taps will remain at existing settings and no regulators are installed.

The objective as with the previous exercises is to make the necessary changes that will allow removal from service each of the substations one at a time during peak load conditions.
The following system changes have been developed based on the system model and GIS data provided. They have not been field checked for practicality.

4a – Tie Line #1

Install 3 phase (336 kcmil ACSR) on Ottawa St from Martin St Nth to Harold St providing a new connection between MS#1 and MS#2 on feeders 1F3 and 2F1. (see figures 4a-1 and 4a-2)

figure 4a-1

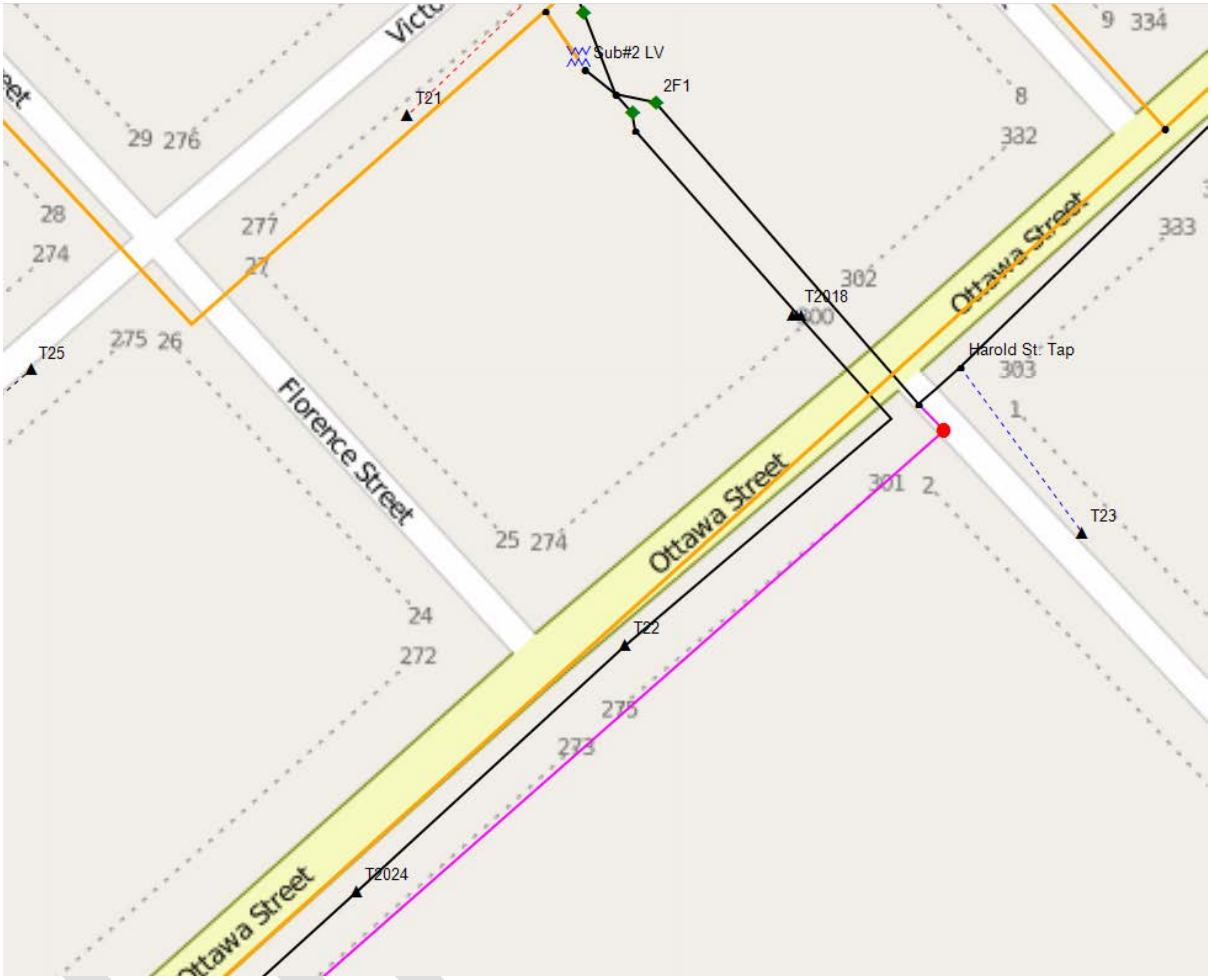

Sub#2 LV
2F1
T21
T25
T2018
Harold St. Tap
T23
T22
T2024
Florence Street
Ottawa Street
Ottawa Street
Ottawa Street

figure 4a-2

4b – Line Upgrade #1 (see figure 4b-1)

1. Replace 3 phase on from Martin St. from Ottawa St to Sw32, then north to Augusta St.
2. Replace 3 phase on Augusta St. from Martin St. Nth. going east to Marshall St.
3. Replace 3 phase on Marshall St. from Augusta St. to Maude St.
4. Replace 3 phase on Maude St. from Marshall St. to St. James St.
5. Replace 3 phase from Maude St. and St. James St. into MS#2 on 2F2.

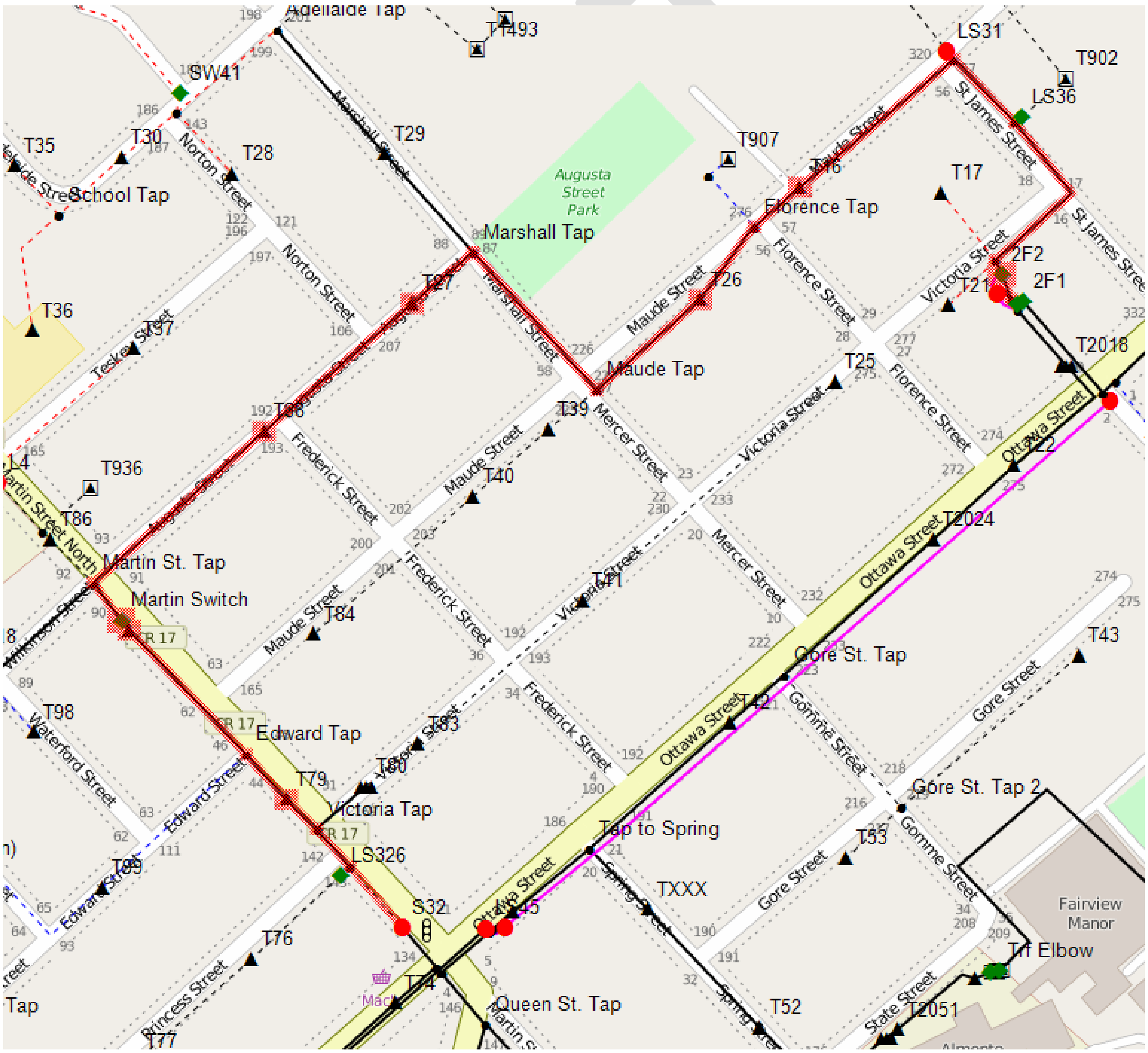


figure 4b-1

4c – Tie Line #2 (see figures 4c-1 and 4c-2)

1. Install new feeder 3F3 at MS#3

2. Install new 3 phase on 3F3 from MS#3 to LS28-Farm Street as follows:
   a. Install 3 phase (336 kcmil ACSR) on King St. from MS#3 to Perth St.
   b. Install 3 phase (336 kcmil ACSR) on Perth St. from King St. to Bridge St.
   c. Install 3 phase (336 kcmil ACSR) on Bridge St from Perth St to Farm St providing a new load split on MS#3 between 3F1 and 3F2 and a new open point with 1F3

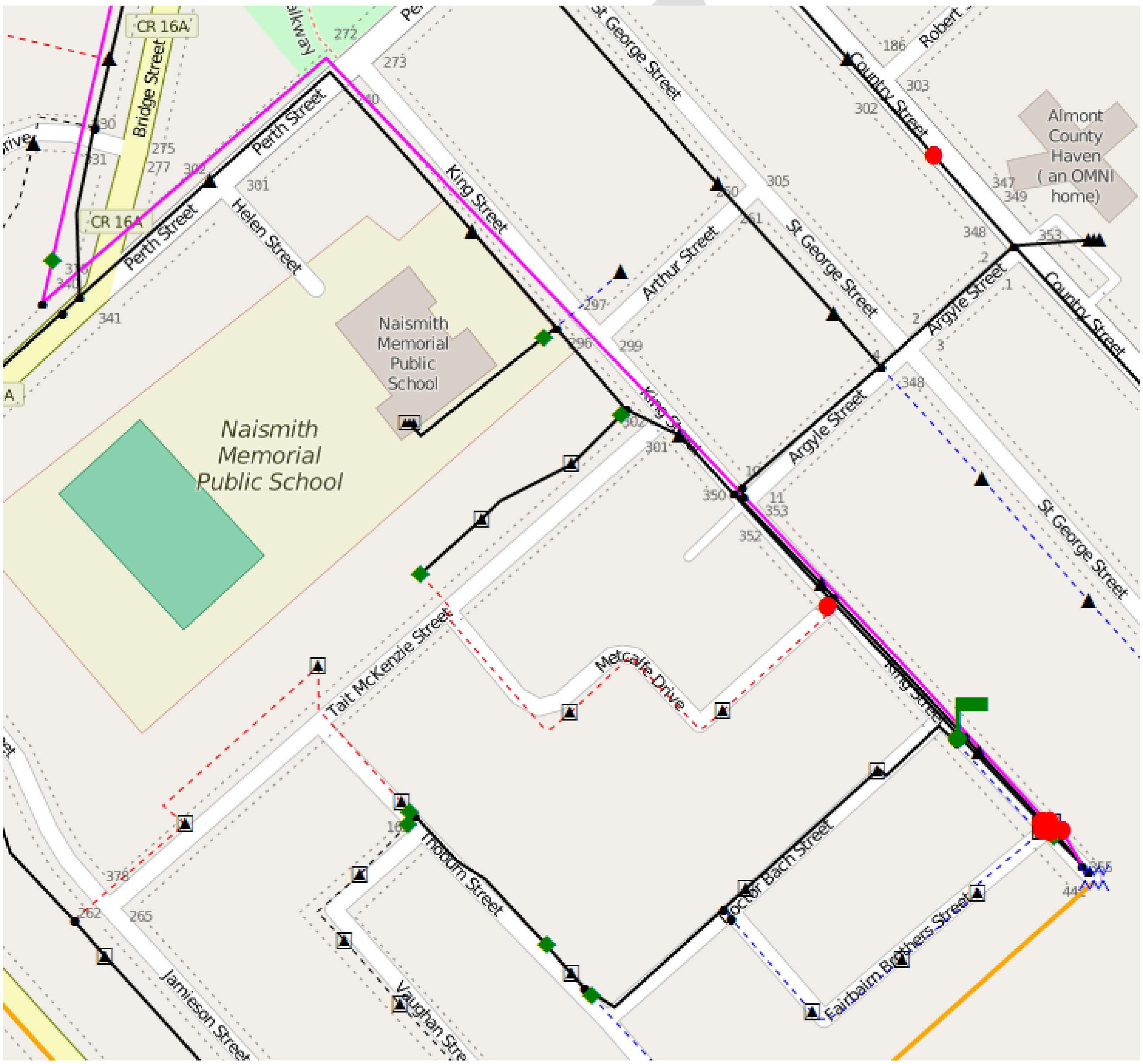


figure 4c-1


Farm Street
Charles Street
Brea Street
Colborne Street
Almonte Street
Bridge Street
High Street
Richey Street
Holy Name of Mary Parish
Almonte & District Community Centre
Tennis
Baseball
Almonte Bicycle Works
Almonte Car Wah
Country Street
Elgin Street
Ann St
Parkview Boulevard
CR 16A
Veterans Memorial Walkway
Naismith Drive
Perth Street
Church Street
St George St
Beer Store

figure 4c-2

4d – Tie Line #3 (see figure 4d-1)

1. Replace 1 phase line on John St. from High St. to Reserve St.
2. Install new 3 phase line on John St. from Reserve St. to Water St. providing a new tie between MS#3 and MS#1.

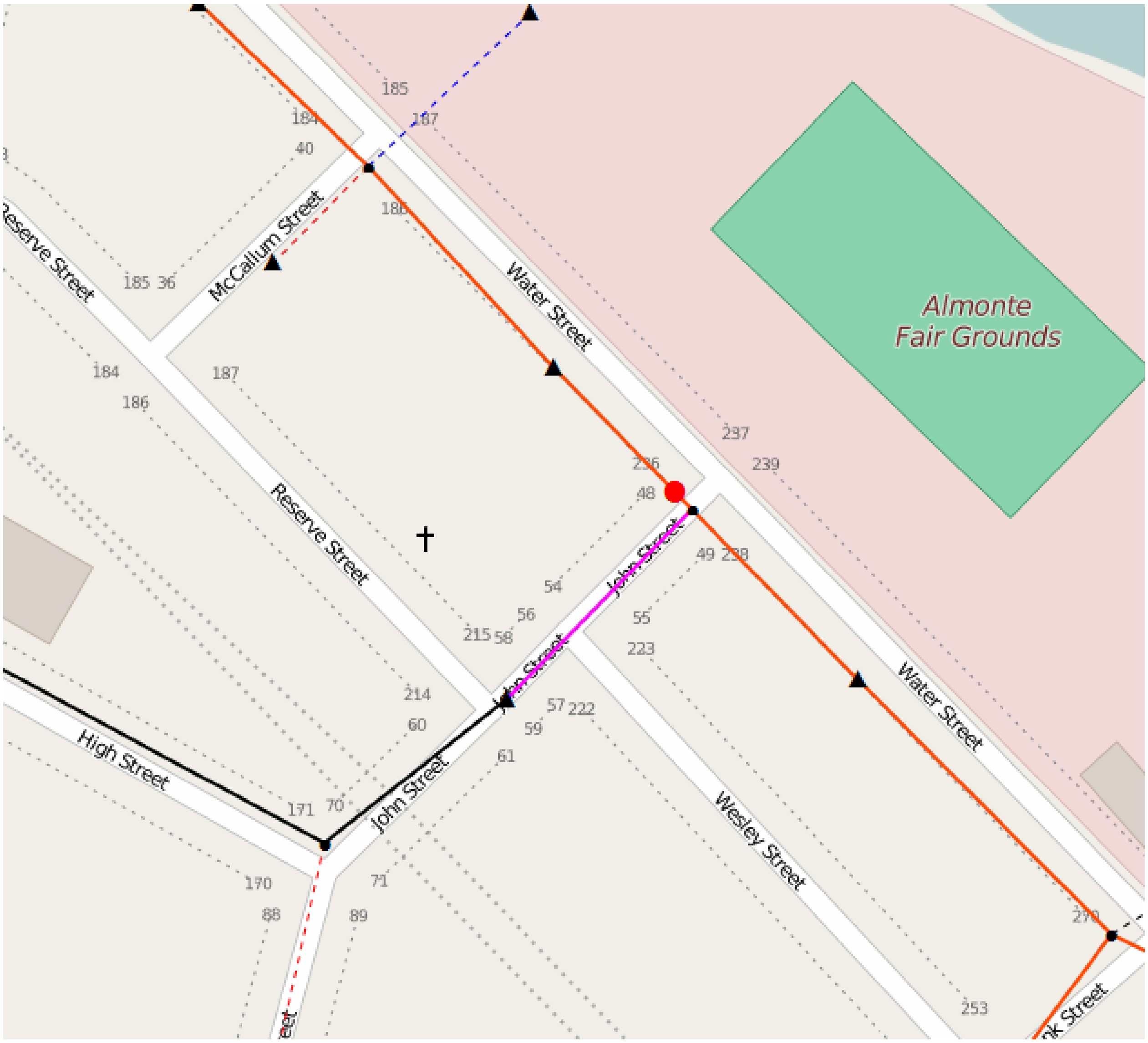


figure 4d-1

Tie Line Summary:

The tie line and upgrades described above produced positive results when simulated during peak conditions. The results require no tap changes or voltage regulators.

Exercise 5 – New Development

The purpose of this exercise is to add load on the northeast and northwest quadrants of the town and develop a system expansion strategy for servicing the new load that takes into consideration the substation out of service requirements.

Study Criteria and Constraints:

1. Actual load for the study is forecasted based on:
    a. Town of Mississippi Mills Planning Department, estimated development
    b. Load characteristics of existing system in Almonte
    c. Installed capacity for backfeeding MS's during outages
2. New Municipal roads in and out of the developments are not known so spot loads are situated in central locations. This provides benchmark locations for each side (northeast and northwest) of the expanded town boundary.
3. Study assumes MS#3 has been upgraded to 5 MVA.
4. For the purpose of this exercise, 4 MVA has been used as the rural development load. 2 MW's per quadrant.

Study Results:

Based on 4 MVA as the forecasted development load, a new substation will be required as the load comes on stream. As with any new substation project acquisition of adequate property is not always the preferred location. However since new lot and road plans are not known or submitted yet, finding a suitable location in the near future makes sense. Sticking with the more major roads for access and functionality also makes sense.

A three feeder 5 MVA substation (MS#4) on Appleton Sideroad, east of Industrial Drive was chosen as a central location for the modeling exercise. Three feeders provide feeds to east and west with a tie to MS#2 directly south of the station. (see figures 5-1 and 5-2)

The 44kV feed to the station was extended from Pike's Substation on Industrial Drive to Appleton SR. (see figure 5-3)

MS#4 Out of Service:

Since MS#1, MS#2 and MS#3 share out of service strategies, MS#4 should also have an out of service switching and feeder tie line plan. One tie to MS#2 on Industrial Drive does not provide enough capacity to accomplish this. A tie line built on Ottawa St., north Appleton SR (see figure 5-4) and a third line built from MS#2 tapping to the 2F2 on St James St. to Maude St., then northwest to the proposed development load. (see figure 5-5)

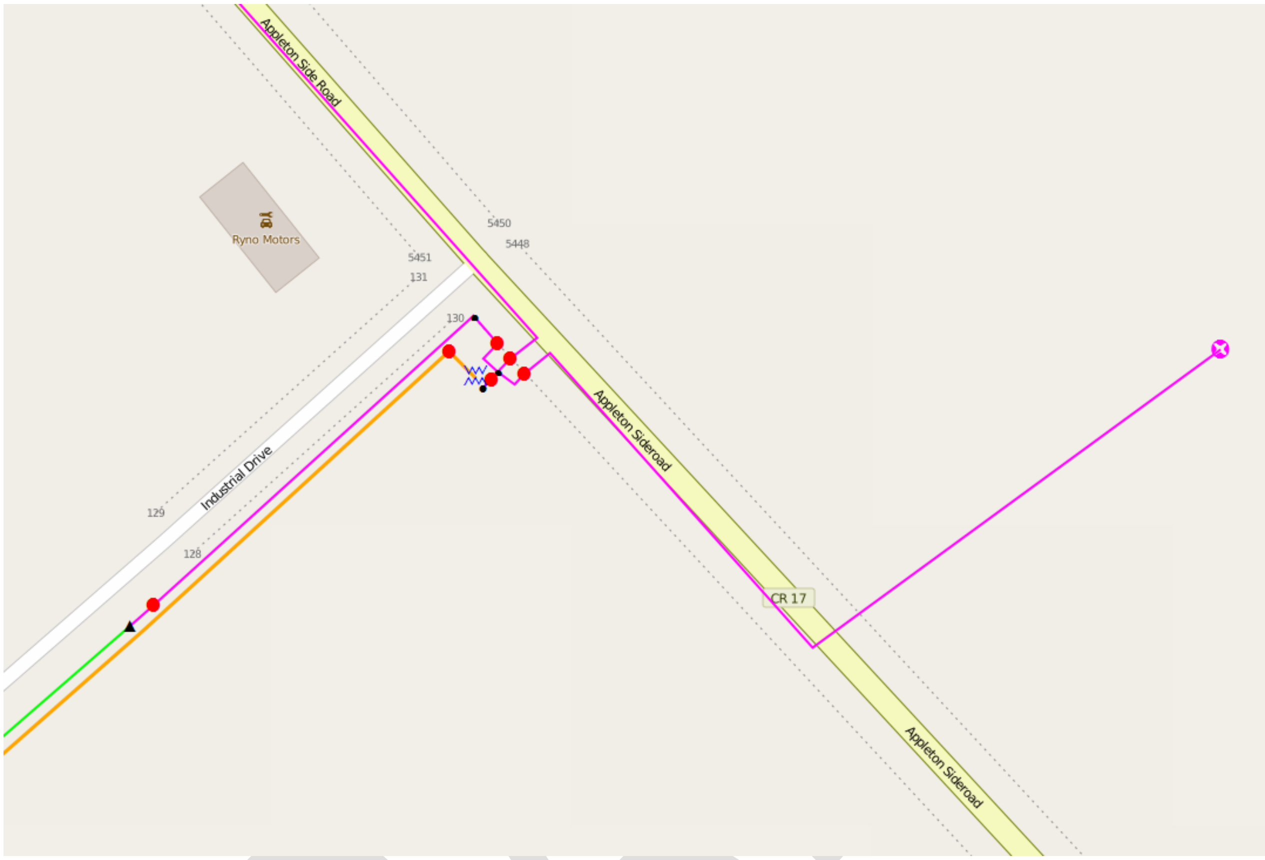

Appleton Side Road
Ryno Motors
5450
5448
5451
131
130
Industrial Drive
129
128
Appleton Sideroad
CR 17
Appleton Sideroad

Figure 5-1

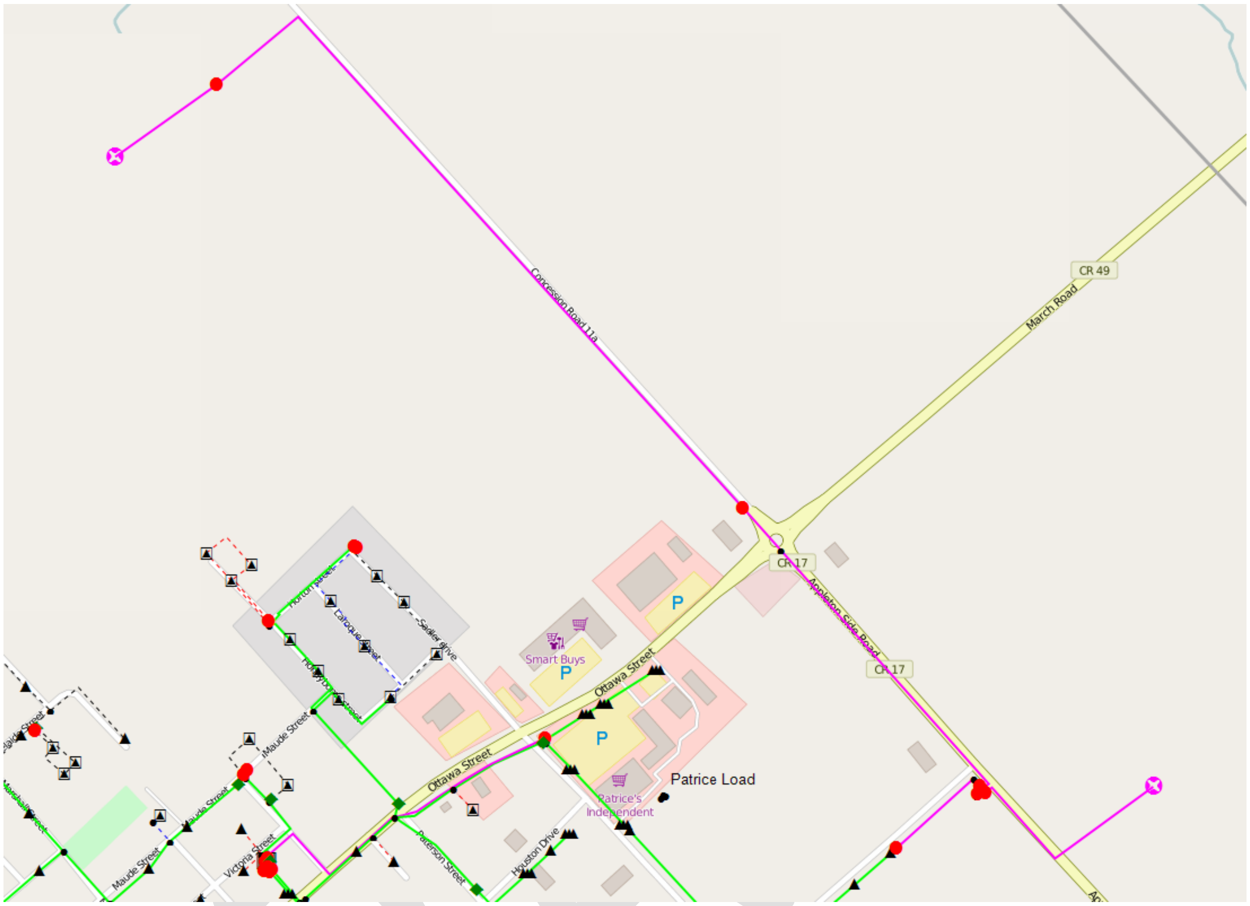

Concession Road 11a
March Road
CR 49
CR 17
Appleton Side Road
Smart Buys
P
Ottawa Street
Patrice Load
Patrice's Independent
Maude Street
Victoria Street
Paterson Street
Houston Drive

Figure 5-2

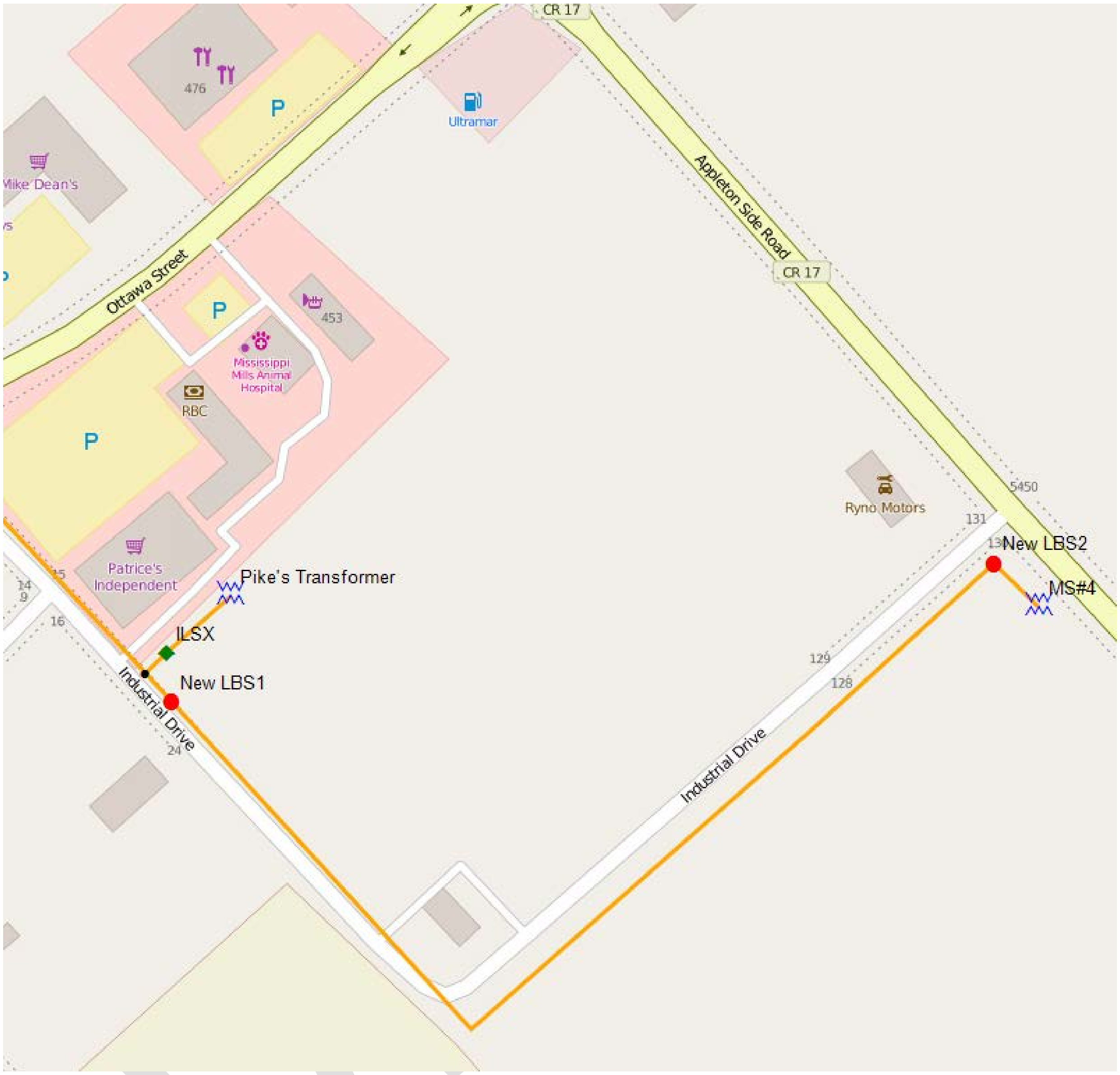

CR 17
476
P
Ultramar
Mike Dean's
Appleton Side Road
CR 17
Ottawa Street
P
453
Mississippi Mills Animal Hospital
RBC
P
5450
Ryno Motors
131
New LBS2
MS#4
Patrice's Independent
Pike's Transformer
ILSX
New LBS1
Industrial Drive
24
129
128
Industrial Drive
16

figure 5-3


Ottawa Street
Appleton Side Road
CR 17
CR 17
Industrial Drive
Industrial Drive
Houston Drive
Patrice Load
Mike Dean's
Smart Buys
Rexall Pharma Plus
Ultramar
Mississippi Mills Animal Hospital
RBC
Patrice's Independent
Ryno Motors
476
453
5450
131
129

figure 5-4

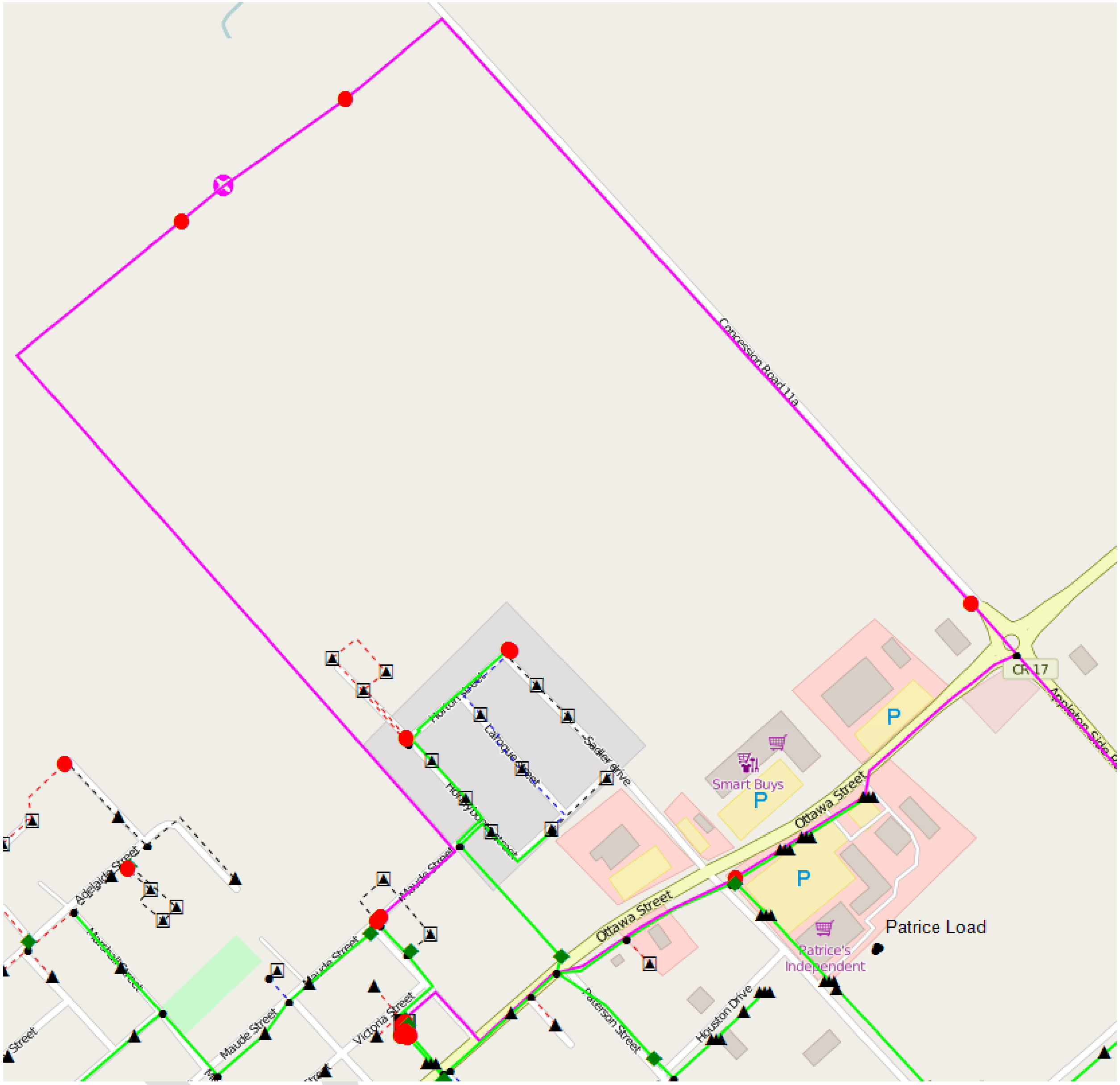

Concession Road 11a
Ottawa Street
Smart Buys
Patrice Load
Patrice's Independent
CR 17
Maude Street
Victoria Street
Paterson Street
Houston Drive
Adelaide Street
Marshall Street
Sadler drive
Horton Street

figure 5-5

Recommendations

1. Upgrade transformer at MS#3 to 5 MVA to provide backup relief for MS#1 as well as maintenance capacity.

2. HV primary tap changes for voltage support: Tap changes do not provide enough flexibility for increasing individual phases so it is common to see primary taps causing high voltage. Some utilities have seasonal tap programs where they adjust the manual taps based on the time of year to increase or decrease voltage. This requires a station outage each time. On load tap changers can be retrofitted on station transformers depending on design of the transformer, to provide automatic tap changes based on voltage drop, however all phases of all feeders are adjusted at the same time which is the same limitation of a manual tap change.

3. Voltage regulators provide individual phase control and during simulations fixed all of the low voltage situations. The model required regulators on the 1F2 and 1F3 at MS#1 and 3F1 and 3F2 at MS#3 to do this. Regulators are a straight forward device but nonetheless require significant work to integrate at these locations and perhaps more importantly they require ongoing maintenance because of the many moving parts they have.

4. Tie lines and upgrades are the most expensive options in terms of capital costs but offer the most benefits in terms of maintenance options and reliability. Voltage regulation equipment is an effective short term solution, but feeder development and conductor upgrading remains as the most effective way to deal with weather events, planned and unplanned interruptions and expanding the utility.

5. To maximize tie line capability a third feeder will be required at MS#3 (3F3).