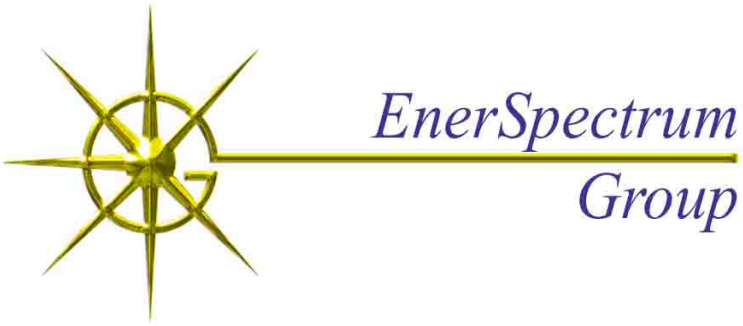
APPENDIX V



Lakefront Utilities Inc.

Conversion of F9 from 4160 V to 27,600 V

Distribution System Loss Assessment

E4019

January 21, 2005

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Introduction

On October 22, 2004, Lakefront Utilities Inc. contracted EnerSpectrum Group to provide an assessment of the effect on distribution losses of a feeder voltage conversion. The feeder, F9 from MS 2 in Cobourg, feeds a predominately residential neighbourhood in the central downtown area. The feeder is currently operated at 4,160V, supplied from a 5,000 kVA 44kV/4kV transformer at MS 2. Post-conversion, the feeder would operate at 27,600 V supplied from existing 27,600 facilities in the area.

This analysis is being made in support of Lakefront Utilities Inc. line loss mitigation program which is part of their Conservation and Demand Management Plan.

The following seven steps were undertaken to assemble data and model the impact of 27.6/16 kV conversion on the distribution system:

1. Identify existing feeder and load to be displaced through conversion
Physical route, electrical characteristics, load connection points and customer characteristics, and other relevant data were assembled for F9.

2. Identify 27.6/16 kV feeder to accommodate converted load
Routing and connection data pertaining to the existing 27.6/16 kV feeder F2 were reviewed.

3. Identify substation being off loaded
Electrical characteristics of MS 2 transformer and loading were reviewed.

4. Identify 27.6/16 kV substation accommodating converted load
Electrical characteristics of MS 28 – 1 transformer and loading were reviewed.

5. Assess 44kV system impacts
Routing and connection data pertaining to the 44 kV to both MS 28-1 and MS 2 were reviewed.

6. Model feeders
Created system models and entered data obtained from earlier steps to identify losses for F9 as a 4,160 V and as converted to a 27.6 KV feeder.

This report documents system impacts and the loss reduction in kW from conversions and estimates ranges of benefits from loss mitigation. This report can be used by Lakefront Utilities to support submissions to regulatory authorities.

F9 4,160 V Model

The 4,160 V feeder F9 was modeled in its existing configuration. The line layout for the model was derived from the AutoCAD information supplied. All overhead conductors were modeled as #3/0 copper. The underground section of F9 on Division Street was modeled as #4/0 Al XLPE.

The 5,000 kVA 44kV/4,160V supply transformer was modeled at MS 2 based on nameplate data. All distribution transformers were modeled using typical characteristics

for each size of transformer. The transformers of appropriate size and configuration were attached to the line sections based on location information supplied. Two single phase transformers near 437 John Street were lacking phase information. These were modeled on the red phase since this phase is the most heavily loaded. One transformer near 15 Swayne Street was supplied with an unknown kVA rating. This transformer was modeled as 50 kVA. All transformers were modeled on 100% tap.

Loads were assigned to each transformer based on the nameplate rating of the transformer. All loads were modeled as residential unless specifically identified as commercial. No industrial loads were identified. One modification was made when information was provided that two 250 kVA single phase pad mount transformers, off College Street north of King Street East, feed Seniors residences that had been converted to gas for heat and hot water. The loads on these transformers were reduced to half of nameplate rating.

F9 27,600 V Model

Once the 4,160 V model was developed, a copy was made and converted to 27,600 V, maintaining all load and line configurations. The 5,000 kVA supply transformer was replaced with a 27,600 V source at MS 2. All distribution transformers were replaced with 27,600 V transformers having typical characteristics.

Modeling Results

At a site visit to MS 2 on October 22, 2004, load readings were recorded for F9 as follows:
Time 10:00 AM

- Red Phase 310 Amps,
- White Phase 260 Amps,
- Blue Phase 300 Amps.

The first model run was performed by scaling the loads to produce an average current at 10:00 AM of 290 Amps to match the October 22 readings. The model was run for a full 24 hours for October 22, with the same load scaling for each hour as at 10:00 AM. The 26,600 V model was run for the same 24 hour period using the same load scaling. The resulting currents are shown in Figure 1 and 2 below. Figures 3 and 4 show the feeder load and the associated losses relating to these currents.

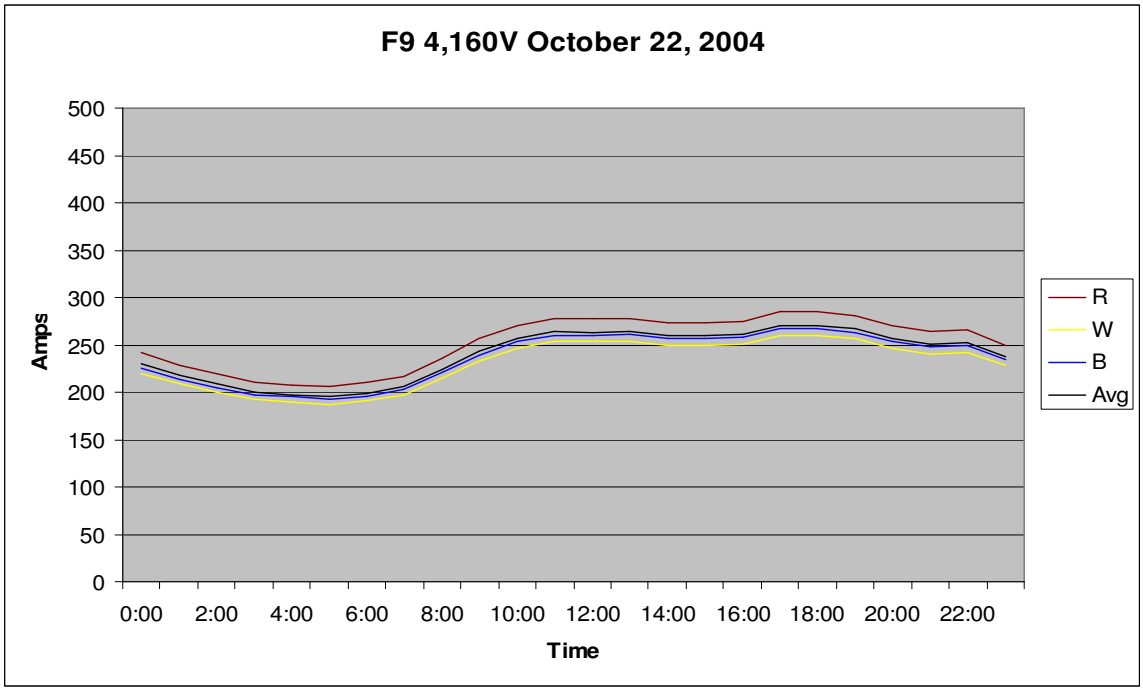

Figure 1
F9 4,160 V Model Adjusted to Match 10:00 AM Currents

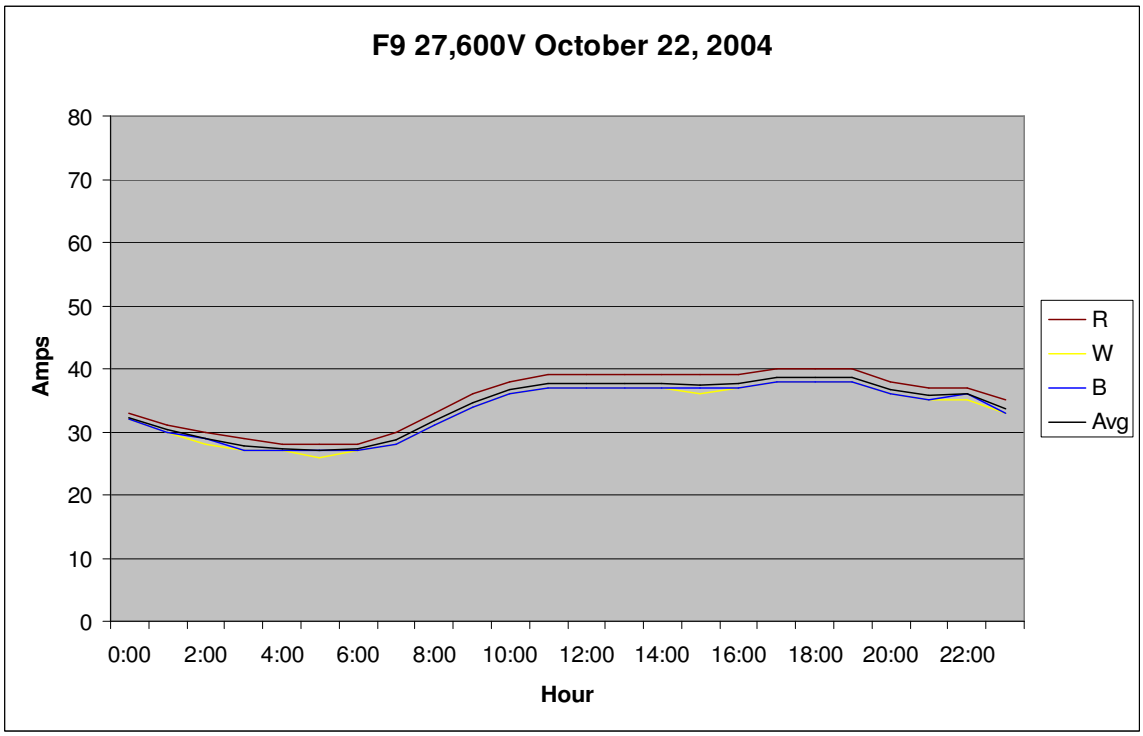

Figure 2
F9 27,600 V Model Equivalent, Adjusted to Match 10:00 AM Currents

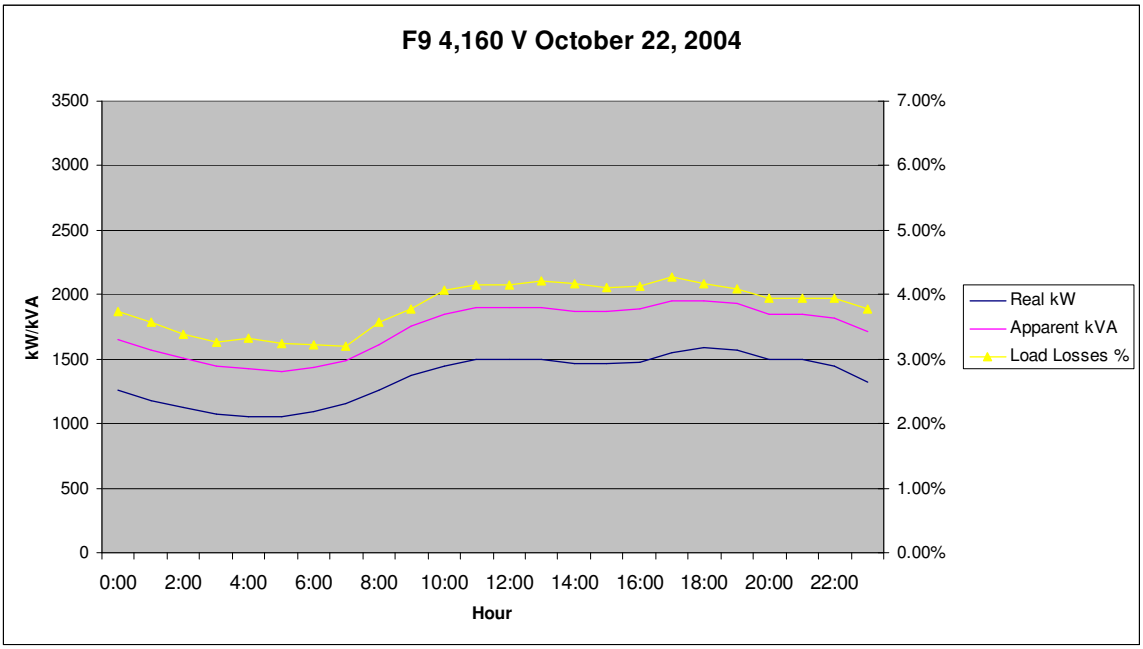

Figure 3
F9 4,160 V Model Adjusted to Match 10:00 AM Currents

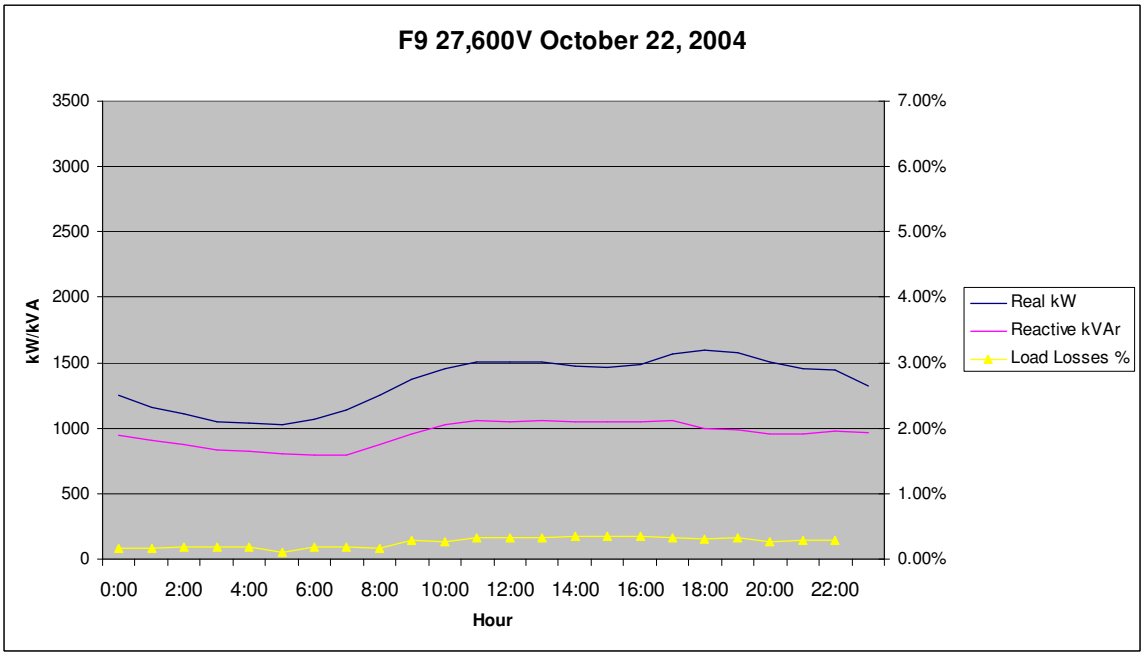

Figure 4
F9 27,600 V Model Equivalent, Adjusted to Match 10:00 AM Currents

The analysis shows that, for the 24 hour period modeled, on the 4,160 V system, 32,410 kWh were delivered, of which 1,249 kWh were losses, while on the equivalent 27,600 V system, 32,366 kWh were delivered, but losses were only 85 kWh. This is a decrease from 3.85% losses to 0.26% losses over the 24 hours.

A recording ammeter was installed to collect load data for F9. The period of recorded data runs from 3: PM (1500) on December 21 through 9:00 AM (0900) on December 23. The 24 hour period for December 22 was modeled and compared to the recorded values. Figures 5, 6 and 7 show the currents measured and modeled. The modeled energy and losses are shown in figures 8 and 9.

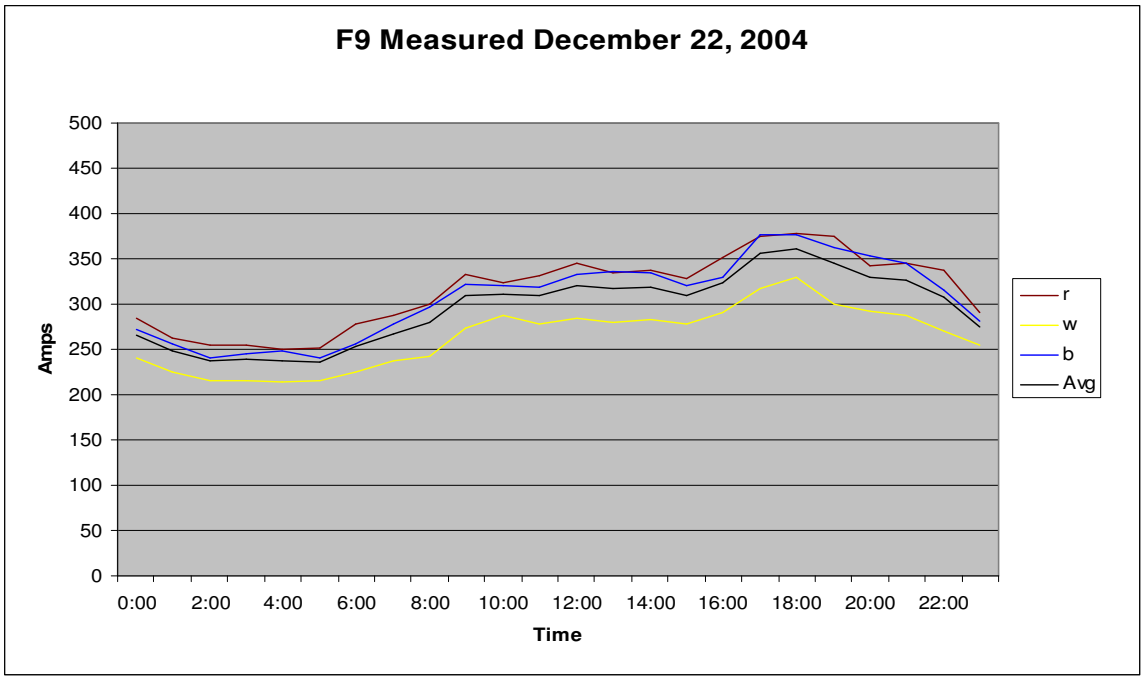

Figure 5
F9 4,160 V Measured Current December 22, 2004

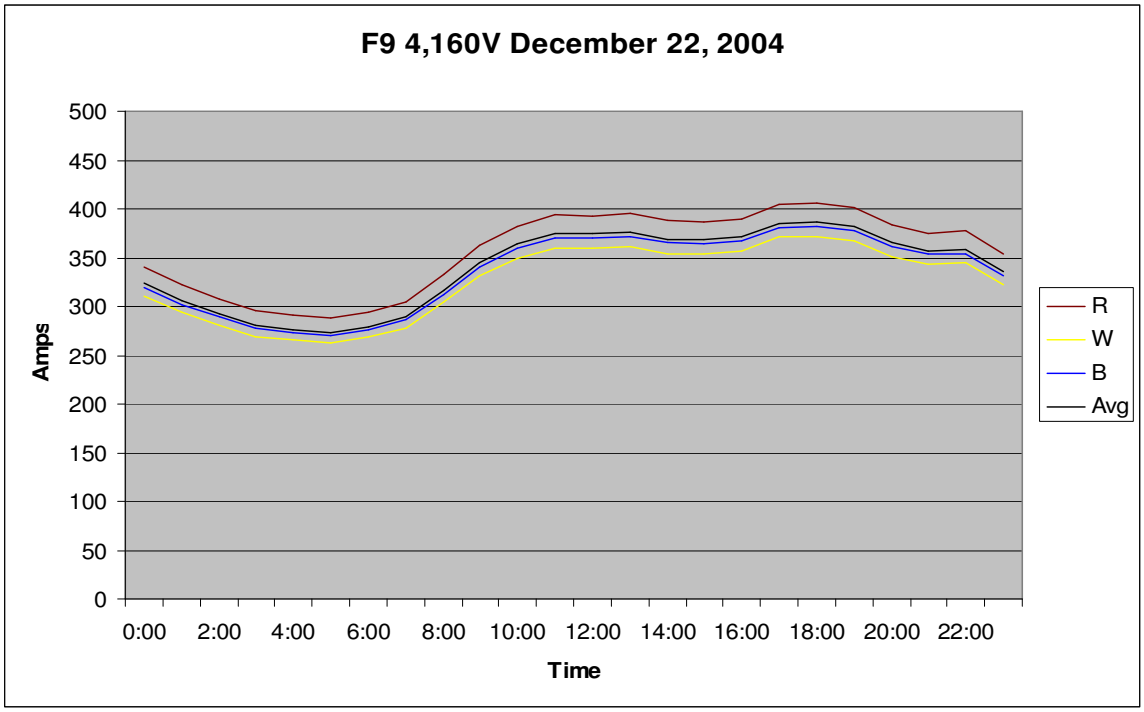

Figure 6
F9 4,160 V Modeled Current December 22, 2004

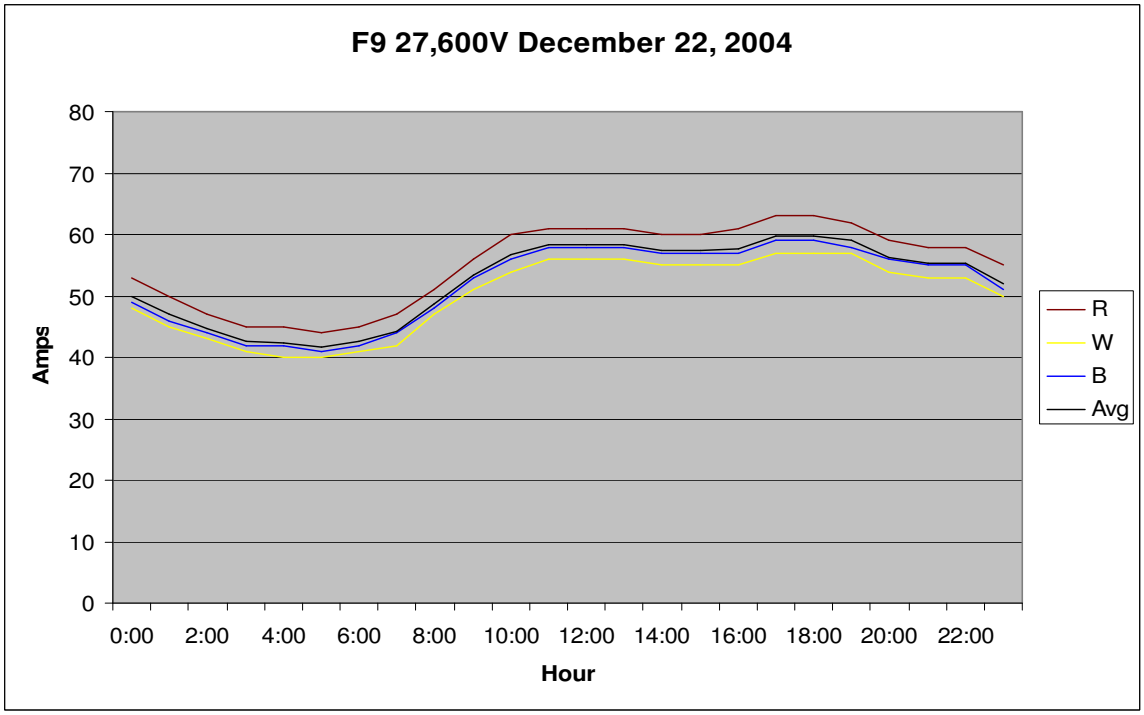

Figure 7
F9 27,600 V Modeled Current December 22, 2004

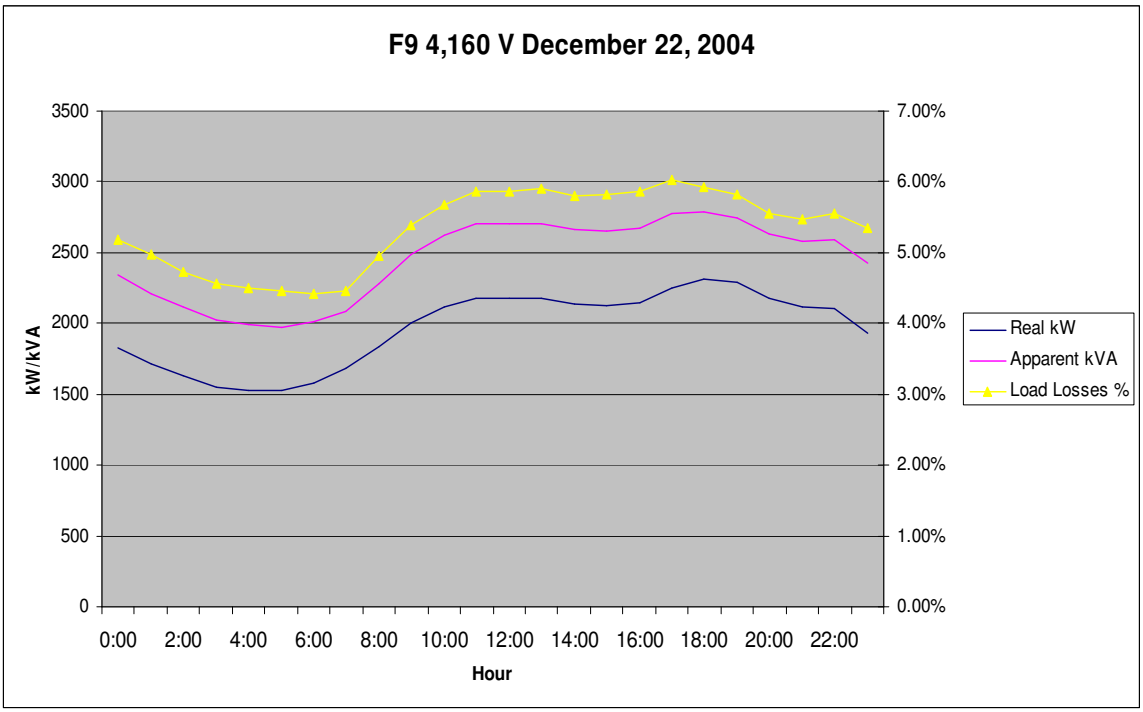

Figure 8
F9 4,160 V Modeled Energy and Loss December 22, 2004

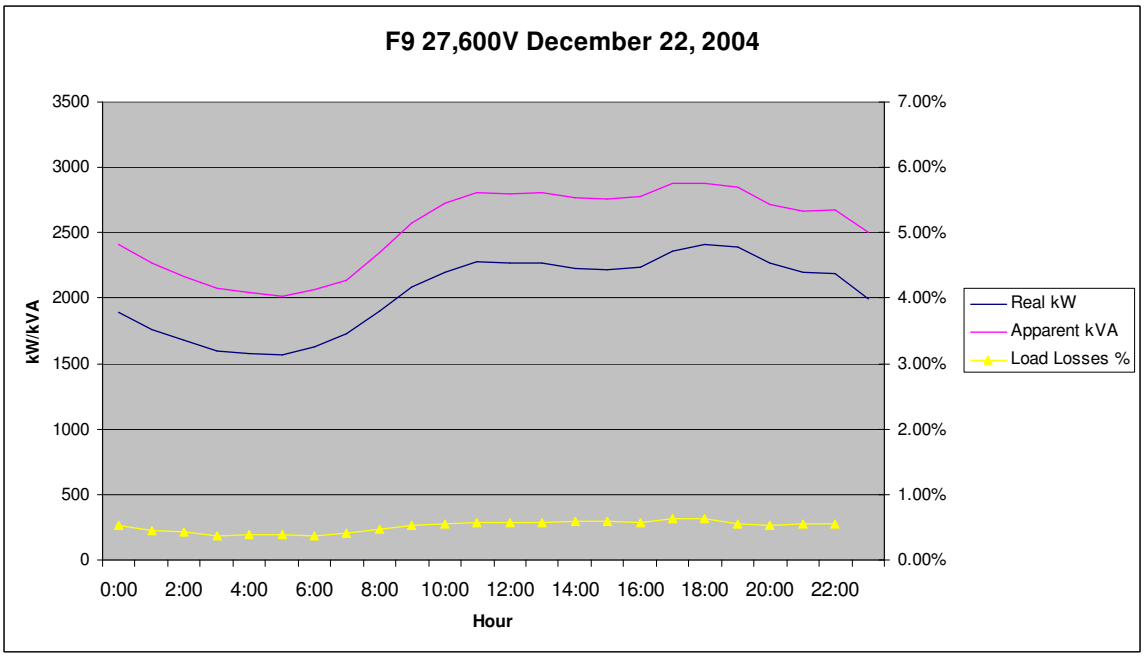

Figure 9
F9 27,600 V Modeled Energy and Loss December 22, 2004

The analysis shows that, for the 24 hour period of December 22, 2004, on the 4,160 V system model, 41,191 kWh were delivered, of which 1,969 kWh were losses, while on the equivalent 27,600 V system, 42,552 kWh were delivered, but losses were only 193 kWh. This is a decrease from 4.78% losses to 0.42% losses over the 24 hours.

The average current over the 24 hour period of December 22, 2004 for the measured and modeled cases is fairly well correlated. This is shown in Figure 10. The modeled average current has a slightly flatter curve over the 24 hour period than the measured values.

The individual phase currents are shown in Figures 5 and 6. The measured phase currents have a larger dispersion between phases than the model provides. To assess the affects of this, the model was run using a method which adjusts the resulting currents to closely match the measured phase currents. This was done for 08:00 where the average currents are very closely aligned. The results are as follows:

R	W	B	Avg	
300	242	297	280	Measured data
300	240	298	279	Data Adjusted Model
294	268	275	279	Model

The impact of this adjustment on the energy delivered and loss sustained is:

	Delivered	Load Losses		
Hour	kW	kW	%	
8:00	1608	71	4.42%	Data Adjusted Model
	1606	70	4.36%	Model

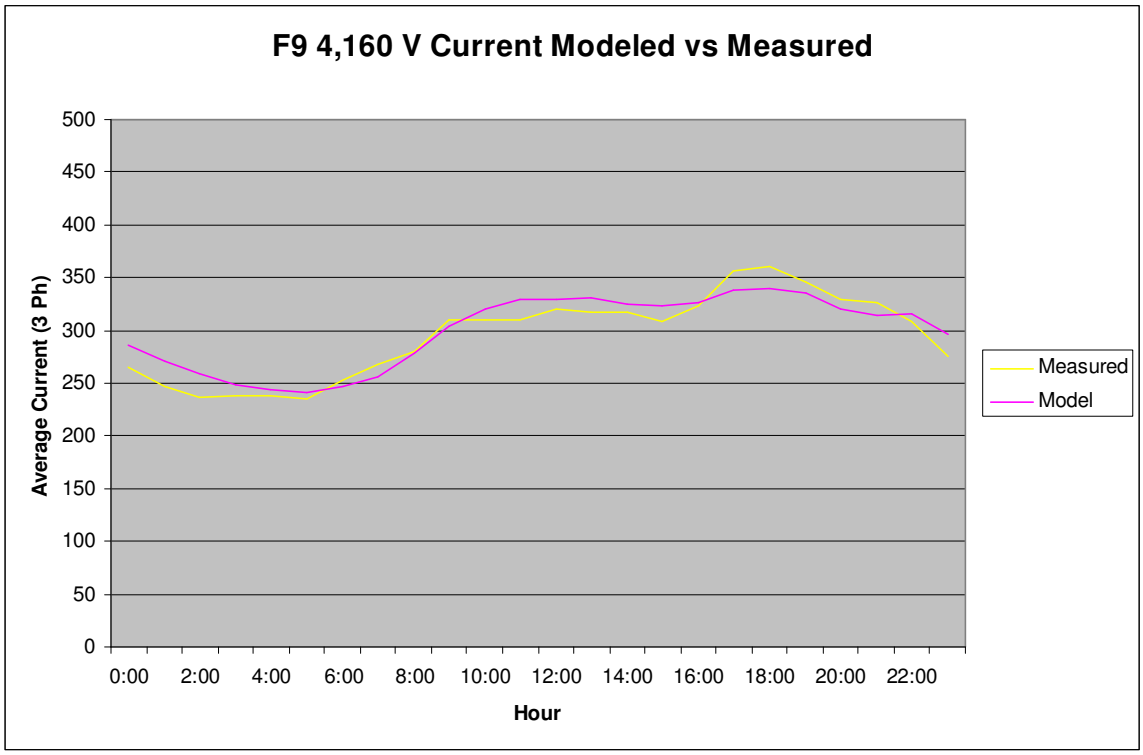

Figure 10
F9 Average Current Modeled vs. Measured

The above analysis indicates that the model is a fair representation of the system.

The October 22 analysis results in a peak transformer loading of 1,952 kVA. This is 39% of the 5,000 kVA rating. The December 22 analysis produces a peak loading of 2,449 kVA which is 49% of transformer rating. Two further analyses were performed to provide a range of coverage of supply transformer loading. A low load scenario was run at 30% of supply transformer rating. This drops the 27,600 V line loss below 1 kW. The second scenario increased load until the 120 V secondary voltage dropped to 108 V along King Street East. This resulted in a 2,967 kVA load on the supply transformer, 59% of rating. These results are shown in Figures 11 through 18.

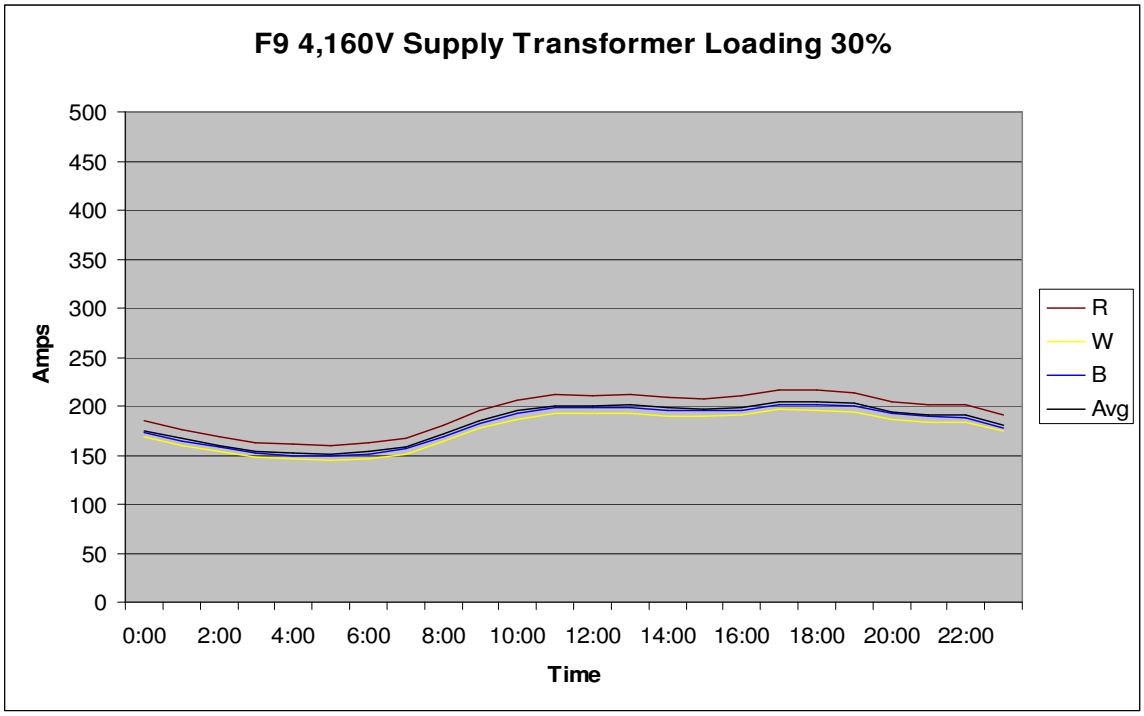

Figure 11
F9 4,160 Current at 30% Transformer Loading

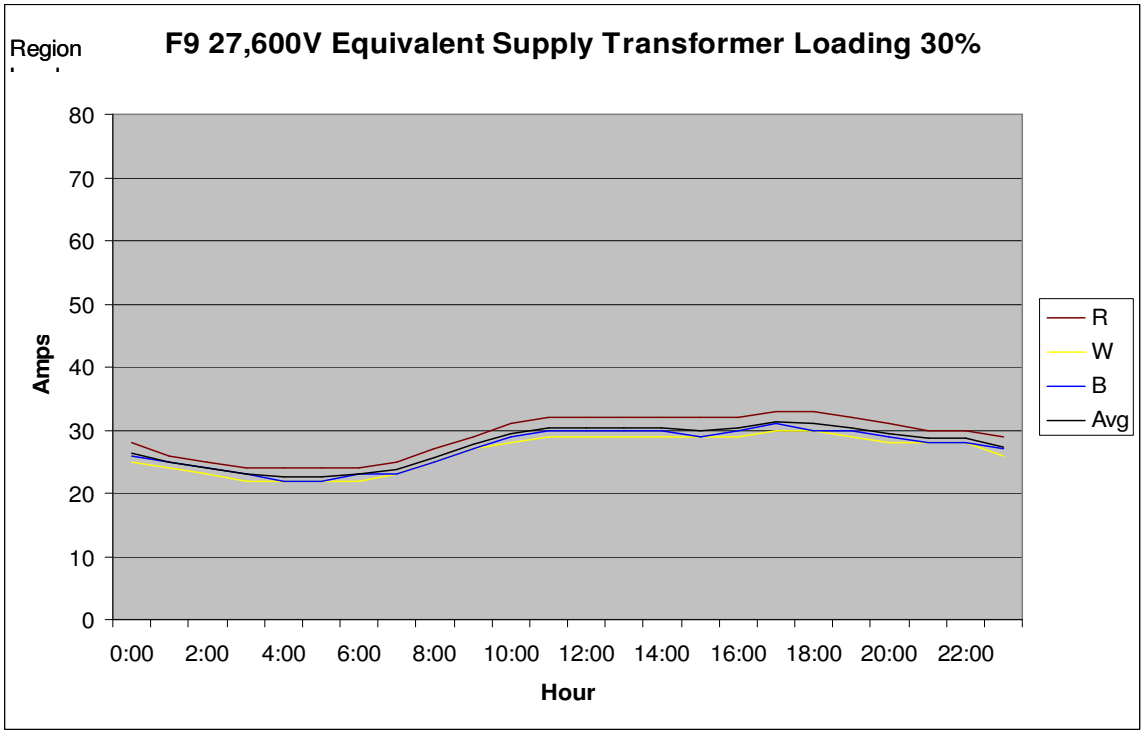

Figure 12
F9 27,600 Current at Equivalent 30% Transformer Loading

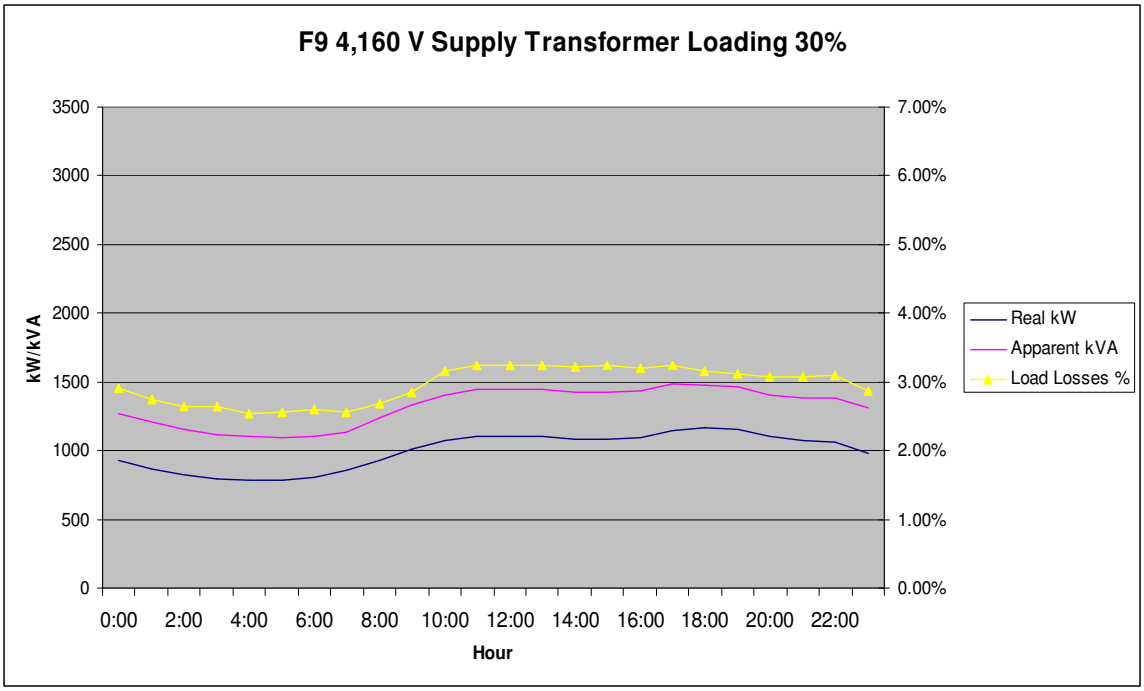

Figure 13
F9 4,160 Load and Loss at 30% Transformer Loading

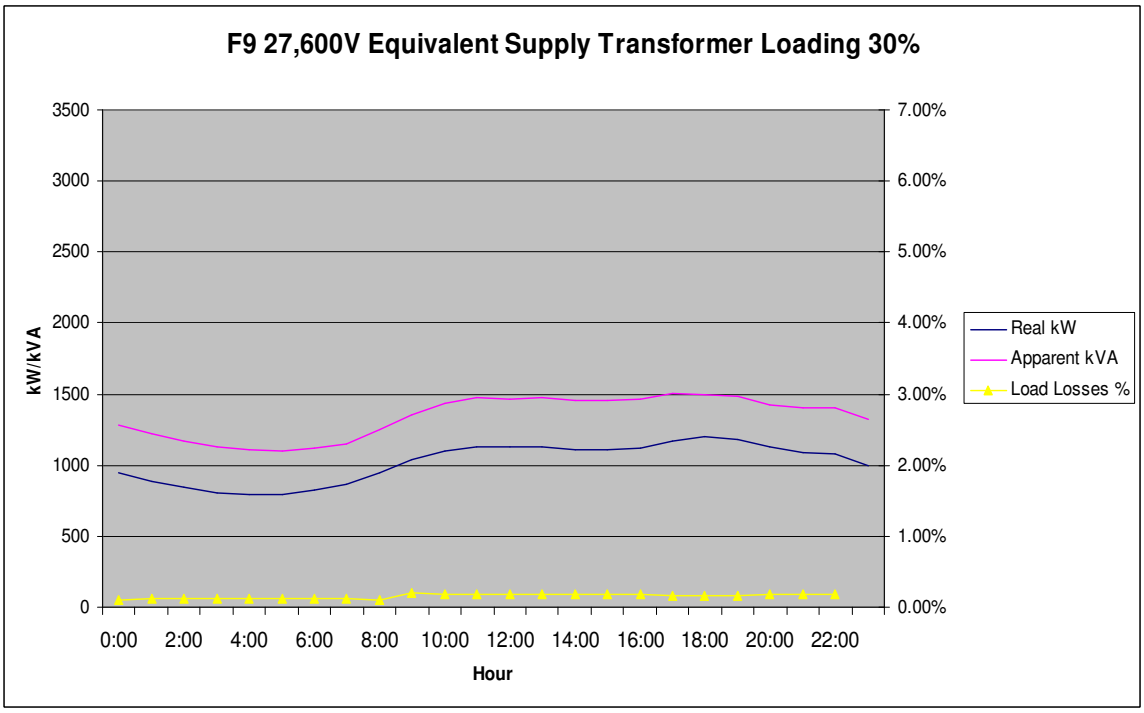

Figure 14
F9 27,600 Load and Loss at Equivalent 30% Transformer Loading

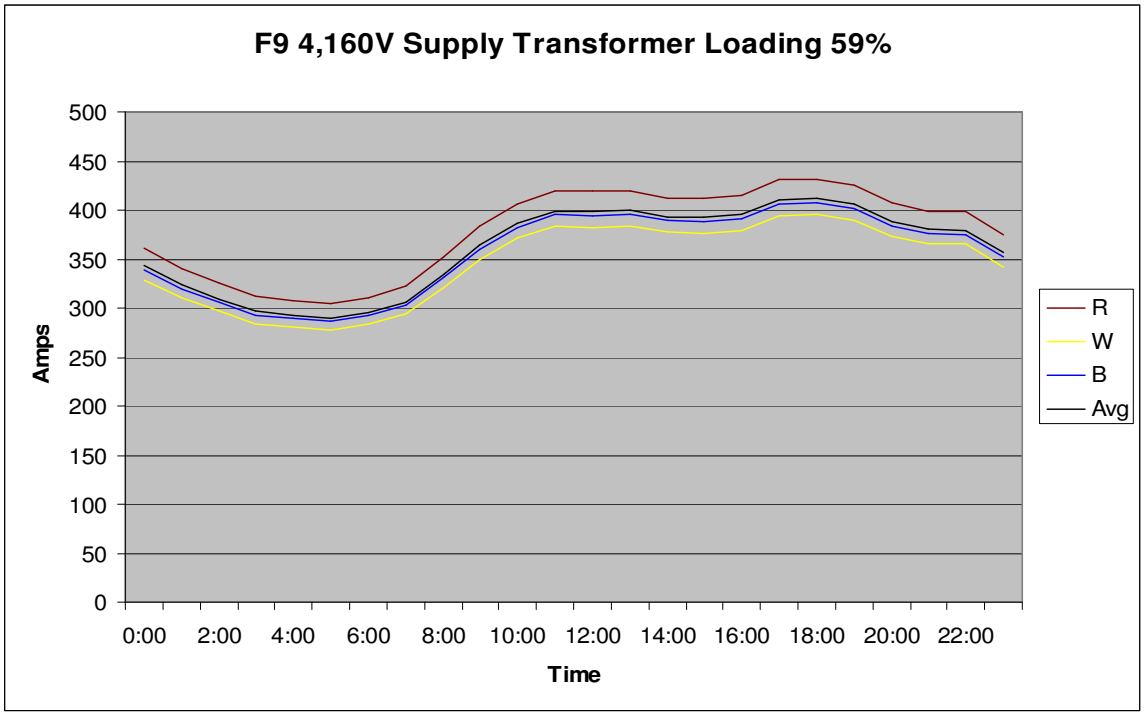

Figure 15
F9 4,160 Current at 59% Transformer Loading

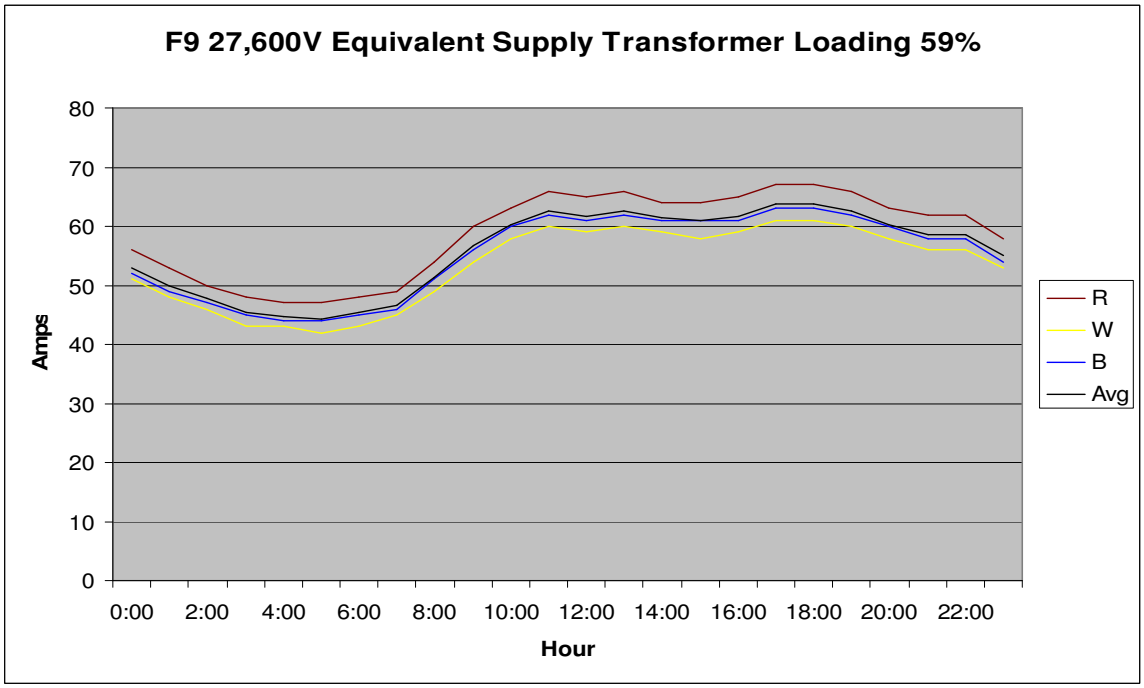

Figure 16
F9 27,600 Current at Equivalent 59% Transformer Loading

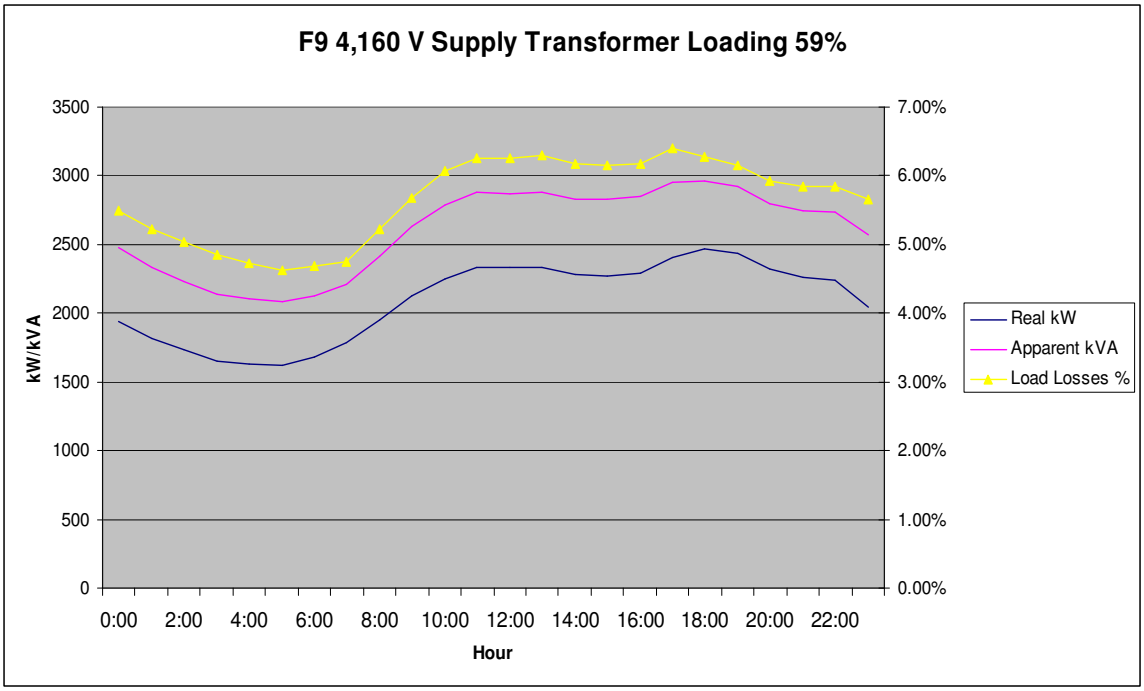

Figure 17
F9 4,160 Load and Loss at 59% Transformer Loading

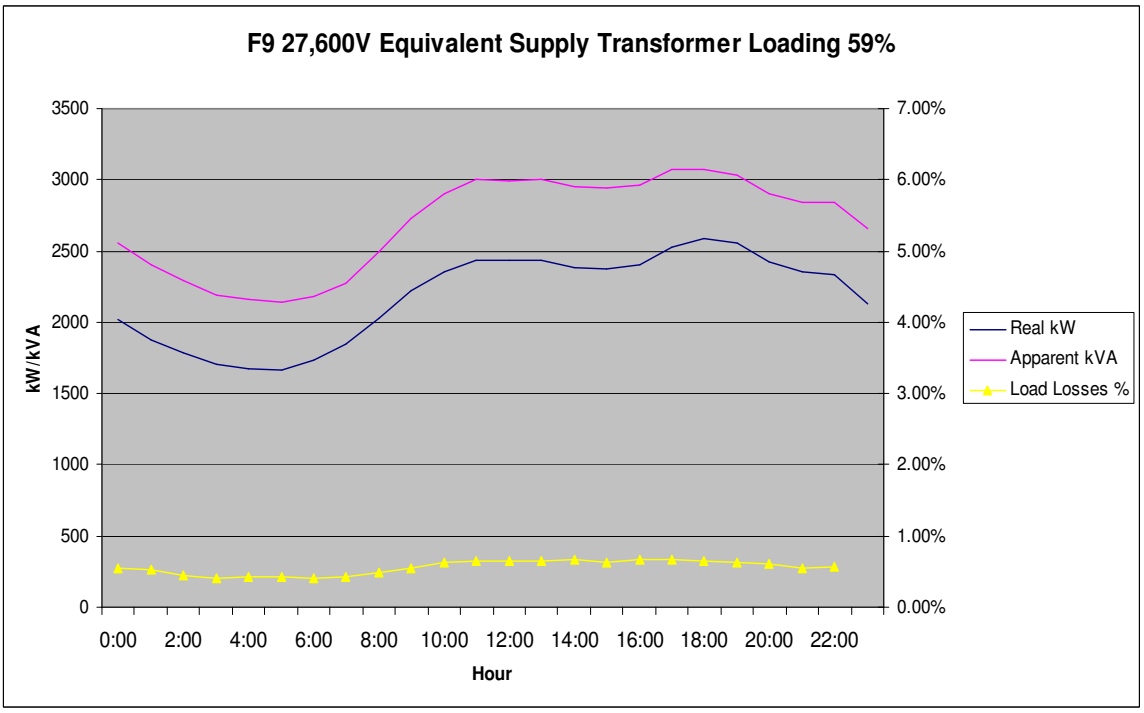

Figure 18
F9 27,600 Load and Loss at Equivalent 30% Transformer Loading

The four supply transformer loading scenarios are summarized in Figure 19. This graph plots the peak kW and kVA delivered and the losses associated with that supply level. Figure 20 plots the 24 hour energy delivered and associated losses for each of the four supply levels in figure 19. These graphs can be used to estimate the level of losses associated with any system peak loading within range of the study.

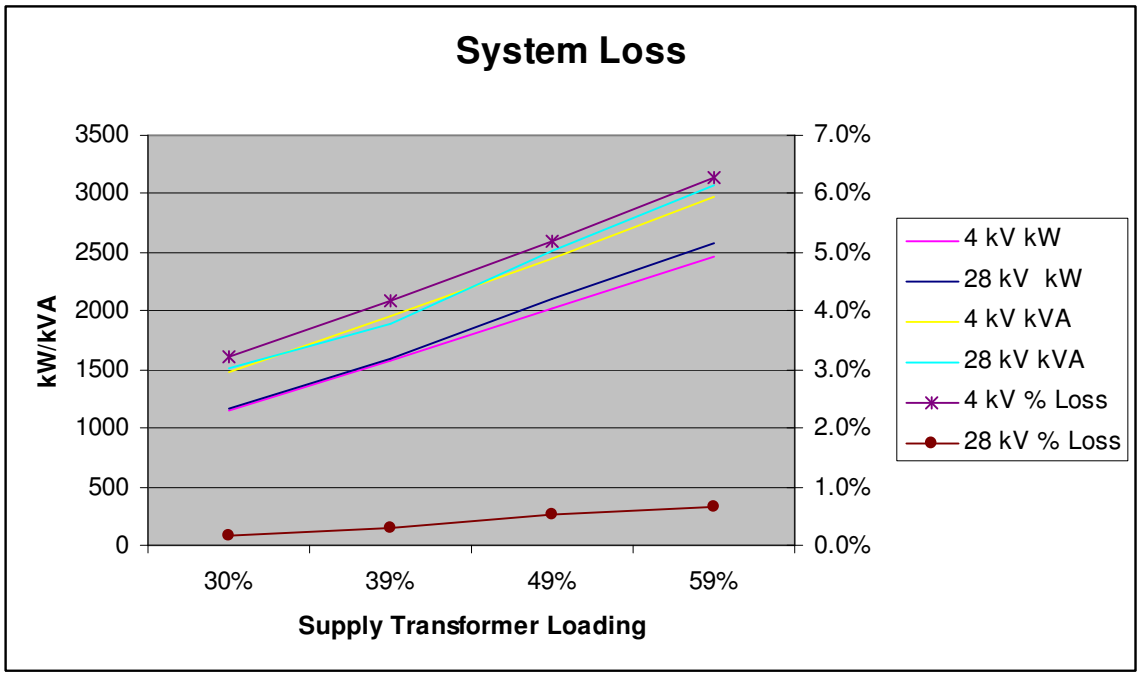

Figure 19
Peak Loss vs. Supply Transformer Loading

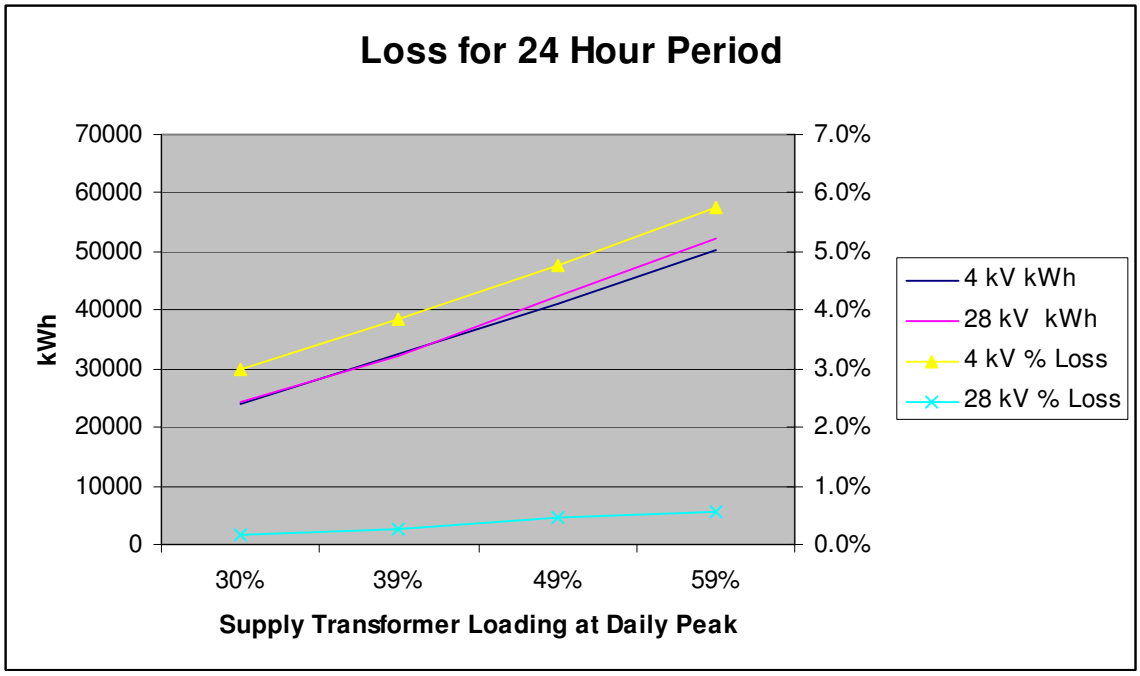

Figure 20
Energy Loss vs. Peak Transformer Loading

The above analysis demonstrates that voltage conversion of the F9 feeder from 4,160 V to 27,600 V will provide a range of loss reduction from just less than 3% for light load conditions to approximately 5% for more heavily loaded conditions.

27,600 V and 44,000 V Systems

The 27,600 V supply for the voltage conversion is from MS 28-1 through feeder F2. This feeder runs east from MS 28-1, along the railway right-of-way and south on Darcy Street past MS 2. The feeder length between the two stations is less than 2 km. This feeder is lightly loaded. The supply transformer at MS 28-1 is 20 MVA, 44 kV/27.6 kV. This transformer is also lightly loaded.

The 44,000 V supply to MS 2 and MS 28-1 stations is from the same 44,000 V feeder. This feeder runs from Highway 2, south near West Street, to the railroad. It then splits into two legs. One leg runs west to MS 28-1, the other east and south to MS 2. These runs are approximately 1 km in length with the run to MS 28-1 being less than 0.5 km longer that the leg to MS 2.

Based on the expected minimal impact that the total F9 load would have on the F2 losses and the minor changes to the 44,000 V system, no further upstream modeling was considered necessary; impacts were judged to be not material.

Conclusion

The validation process used to compare actual current measurements on F9 to the results of the model scenarios confirms that the model results are robust. To obtain greater accuracy would require the following:

- measurement and data collection of each individual load on F9;
- identification of transformer tap settings for all distribution transformers on F9;
- identification of distribution transformer characteristics;
- 365 day, hourly load profile for F9;
- identification of all load points on F2;
- measurement and data collection of each individual load on F2;
- transformer characteristics for F2;
- 365 day, hourly load profile for F9;
- similar data as above pertaining to the 44,000 V feeder

For the purposes of this analysis, the models are sufficiently accurate to estimate the loss reduction from a voltage conversion of F9 to 27600 V.

As the charts and analysis illustrate, there are significant line loss savings which would result from voltage conversion to 27,600 V for feeder F9. The range of line loss reduction (3% - 5%) translates into 35 to 105 kW savings. This would impact the demand charges to Lakefront Utilities. Associated with this is the energy savings which amount to 700 – 2000 kWh per day. At an average value of 1,500 kWh per day this translates into 547,000 kWh per year. At the current artificially low price of 4.7 cents/kWh this represents a savings of $25,700 each year.

In addition to the above savings, other, non-monetary benefits arise from a voltage conversion to 27,600 V. One of the supplemental benefits is the improvement in voltage support to the customers. On a feeder the length of F9, there will be no appreciable voltage drop between the supply point and the last customer at line end.

Recommendations

Based on the result of this study, it is recommended that Lakefront Utilities Inc:

- investigates the benefits of voltage conversion of F9 to 27,600 V against system investment required to complete the conversion;
- use this analysis as support for the system optimization aspects of your Conservation and Demand Management Plan;
- consider the analysis contained in this report as the foundation for reporting results to the Ontario Energy Board;
- continue to explore other loss mitigation opportunities, and
- continue to expand the model in this analysis to other portions of the distribution system to uncover other system optimization opportunities.

Appendix 1 – 4,160 V System Model

Appendix 2 – 27,600 V System Model

Appendix 3 – Model October 22, 2004

F9-0 to F9-2	4160V		50%, 50% Scaling 10 deg C			F9-1 to F9-2			27,600 kV		
Hour	R	W	B	Avg		Hour	R	W	B	Avg	
0:00	242	220	226	229	Amps	0:00	33	32	32	32	Amps
1:00	229	209	214	217		1:00	31	30	30	30	
2:00	220	200	205	208		2:00	30	28	29	29	
3:00	211	192	197	200		3:00	29	27	27	28	
4:00	208	189	195	197		4:00	28	27	27	27	
5:00	206	187	192	195		5:00	28	26	27	27	
6:00	210	191	196	199		6:00	28	27	27	27	
7:00	217	197	203	206		7:00	30	28	28	29	
8:00	236	215	221	224		8:00	33	31	31	32	
9:00	256	233	239	243		9:00	36	34	34	35	
10:00	270	246	253	256		10:00	38	36	36	37	
11:00	278	253	260	264		11:00	39	37	37	38	
12:00	277	253	260	263		12:00	39	37	37	38	
13:00	278	253	261	264		13:00	39	37	37	38	
14:00	273	249	257	260		14:00	39	37	37	38	
15:00	273	249	256	259		15:00	39	36	37	37	
16:00	275	251	258	261		16:00	39	37	37	38	
17:00	285	260	267	271		17:00	40	38	38	39	
18:00	285	260	267	271		18:00	40	38	38	39	
19:00	281	257	263	267		19:00	40	38	38	39	
20:00	270	246	253	256		20:00	38	36	36	37	
21:00	264	241	248	251		21:00	37	35	35	36	
22:00	265	242	249	252		22:00	37	35	36	36	
23:00	250	228	234	237		23:00	35	33	33	34	

		kVA Max	Transf Loading
F9	4160V incl 44kV/4160V Transf	1,952	39%

	Region Load				Region Load Losses				Distribution Transformer			
Hour	Real kW	Reactive kVAr	Apparent kVA	pf	Real kW	Reactive kVAr	Apparent kVA	pf	Load Losses kW	No Load Losses kW	Load Losses %	kW
0:00	1258	1076	1,655	0.76	44	95	105	0.42	3	106	3.74%	47
1:00	1176	1039	1,569	0.75	40	85	94	0.43	2	106	3.57%	42
2:00	1121	1003	1,504	0.75	36	78	86	0.42	2	106	3.39%	38
3:00	1071	968	1,444	0.74	33	72	79	0.42	2	106	3.27%	35
4:00	1056	957	1,425	0.74	33	70	77	0.43	2	106	3.31%	35
5:00	1050	939	1,409	0.75	32	69	76	0.42	2	106	3.24%	34
6:00	1090	934	1,435	0.76	33	71	78	0.42	2	106	3.21%	35
7:00	1156	929	1,483	0.78	35	76	84	0.42	2	106	3.20%	37
8:00	1262	1008	1,615	0.78	42	90	99	0.42	3	106	3.57%	45
9:00	1376	1085	1,752	0.79	49	106	117	0.42	3	106	3.78%	52
10:00	1450	1145	1,848	0.78	55	118	130	0.42	4	106	4.07%	59
11:00	1496	1175	1,902	0.79	58	125	138	0.42	4	106	4.14%	62
12:00	1496	1170	1,899	0.79	58	125	138	0.42	4	106	4.14%	62
13:00	1496	1179	1,905	0.79	59	126	139	0.42	4	106	4.21%	63
14:00	1465	1168	1,874	0.78	57	122	135	0.42	4	106	4.16%	61
15:00	1461	1168	1,870	0.78	56	121	133	0.42	4	106	4.11%	60
16:00	1476	1172	1,885	0.78	57	123	136	0.42	4	106	4.13%	61
17:00	1547	1189	1,951	0.79	61	132	145	0.42	5	106	4.27%	66
18:00	1585	1139	1,952	0.81	61	132	145	0.42	5	106	4.16%	66
19:00	1567	1121	1,927	0.81	60	129	142	0.42	4	106	4.08%	64
20:00	1494	1090	1,849	0.81	55	118	130	0.42	4	106	3.95%	59
21:00	1494	1090	1,849	0.81	55	118	130	0.42	4	106	3.95%	59
22:00	1444	1106	1,819	0.79	53	114	126	0.42	4	106	3.95%	57
23:00	1323	1090	1,714	0.77	47	102	112	0.42	3	106	3.78%	50
	32,410				1,169				80		3.85%	1,249

F9 27,600 V

Hour	Region Load Real kW	Region Load Reactive kVAr	Region Load Apparent kVA	Region Load pf	Region Load Losses Real kW	Region Load Losses Reactive kVAr	Region Load Losses Apparent kVA	Region Load Losses pf	Distribution Transformer Load Losses kW	Distribution Transformer No Load Losses kW	Distribution Transformer Load Losses %	Distribution Transformer Load Losses kW
0:00	1251	947	1,569	0.80	0	1	1	0.00	2	56	0.16%	2
1:00	1163	908	1,475	0.79	0	1	1	0.00	2	56	0.17%	2
2:00	1106	870	1,407	0.79	0	1	1	0.00	2	56	0.18%	2
3:00	1052	833	1,342	0.78	0	1	1	0.00	2	56	0.19%	2
4:00	1037	821	1,323	0.78	0	1	1	0.00	2	56	0.19%	2
5:00	1030	802	1,305	0.79	0	1	1	0.00	1	56	0.10%	1
6:00	1073	796	1,336	0.80	0	1	1	0.00	2	56	0.19%	2
7:00	1142	792	1,390	0.82	0	1	1	0.00	2	56	0.18%	2
8:00	1256	877	1,532	0.82	0	1	1	0.00	2	56	0.16%	2
9:00	1377	961	1,679	0.82	1	2	2	0.45	3	56	0.29%	4
10:00	1458	1027	1,783	0.82	1	2	2	0.45	3	56	0.27%	4
11:00	1508	1058	1,842	0.82	1	2	2	0.45	4	56	0.33%	5
12:00	1506	1048	1,835	0.82	1	2	2	0.45	4	56	0.33%	5
13:00	1506	1059	1,841	0.82	1	2	2	0.45	4	56	0.33%	5
14:00	1474	1050	1,810	0.81	1	2	2	0.45	4	56	0.34%	5
15:00	1469	1050	1,806	0.81	1	2	2	0.45	4	56	0.34%	5
16:00	1486	1051	1,820	0.82	1	2	2	0.45	4	56	0.34%	5
17:00	1562	1060	1,888	0.83	1	2	2	0.45	4	56	0.32%	5
18:00	1602	998	1,887	0.85	1	2	2	0.45	4	56	0.31%	5
19:00	1582	986	1,864	0.85	1	2	2	0.45	4	56	0.32%	5
20:00	1502	959	1,782	0.84	1	2	2	0.45	3	56	0.27%	4
21:00	1456	956	1,742	0.84	1	2	2	0.45	3	56	0.27%	4
22:00	1448	979	1,748	0.83	1	2	2	0.45	3	56	0.28%	4
23:00	1320	962	1,633	0.81	0	2	2	0.00	3	56	0.23%	3
	32,366				14				71		0.26%	85

Appendix 4 – Model December 22, 2004

F9-0 to F9-2	4160V		50%, 65.5% Scaling Actual Temp			F9-1 to F9-2	27,600 kV				
Hour	R	W	B	Avg		Hour	R	W	B	Avg	
0:00	302	275	283	287	Amps	0:00	46	42	43	44	Amps
1:00	285	260	267	271		1:00	44	40	41	42	
2:00	273	249	256	259		2:00	42	38	39	40	
3:00	261	238	245	248		3:00	40	36	37	38	
4:00	258	235	241	245		4:00	39	36	37	37	
5:00	254	232	238	241		5:00	39	35	36	37	
6:00	260	237	243	247		6:00	40	36	37	38	
7:00	269	245	252	255		7:00	41	37	38	39	
8:00	294	268	275	279		8:00	45	41	42	43	
9:00	319	292	300	304		9:00	49	45	46	47	
10:00	337	308	316	320		10:00	52	47	49	49	
11:00	347	317	326	330		11:00	54	49	50	51	
12:00	346	316	326	329		12:00	54	49	50	51	
13:00	347	317	327	330		13:00	54	49	50	51	
14:00	341	312	321	325		14:00	53	48	50	50	
15:00	341	311	320	324		15:00	53	48	50	50	
16:00	343	314	323	327		16:00	53	48	50	50	
17:00	356	326	335	339		17:00	55	50	52	52	
18:00	357	326	335	339		18:00	55	50	52	52	
19:00	352	322	331	335		19:00	54	49	51	51	
20:00	337	308	317	321		20:00	52	47	49	49	
21:00	330	302	310	314		21:00	51	46	48	48	
22:00	332	303	311	315		22:00	51	47	48	49	
23:00	312	285	292	296		23:00	48	44	45	46	

		kVA Max	Transf Loading
F9	4160V incl 44kV/4160V Transf	2,449	49%

	Region Load				Region Load Losses				Distribution Transformer		Total	
Hour	Real kW	Reactive kVAr	Apparent kVA	pf	Real kW	Reactive kVAr	Apparent kVA	pf	Load Losses kW	No Load Losses kW	Load Losses %	Load Losses kW
0:00	1606	1305	2,069	0.78	69	148	163	0.42	5	106	4.61%	74
1:00	1498	1257	1,956	0.77	62	132	146	0.43	4	106	4.41%	66
2:00	1427	1210	1,871	0.76	56	121	133	0.42	4	106	4.20%	60
3:00	1362	1165	1,792	0.76	52	111	123	0.42	4	106	4.11%	56
4:00	1340	1149	1,765	0.76	50	108	119	0.42	3	106	3.96%	53
5:00	1331	1126	1,743	0.76	49	105	116	0.42	3	106	3.91%	52
6:00	1384	1119	1,780	0.78	51	110	121	0.42	4	106	3.97%	55
7:00	1470	1113	1,844	0.80	55	118	130	0.42	4	106	4.01%	59
8:00	1606	1213	2,013	0.80	65	140	154	0.42	5	106	4.36%	70
9:00	1752	1314	2,190	0.80	77	166	183	0.42	6	106	4.74%	83
10:00	1846	1390	2,311	0.80	86	185	204	0.42	7	106	5.04%	93
11:00	1907	1429	2,383	0.80	92	197	217	0.42	7	106	5.19%	99
12:00	1905	1422	2,377	0.80	91	196	216	0.42	7	106	5.14%	98
13:00	1905	1434	2,384	0.80	92	197	217	0.42	7	106	5.20%	99
14:00	1864	1419	2,343	0.80	89	190	210	0.42	7	106	5.15%	96
15:00	1859	1419	2,339	0.79	88	190	209	0.42	7	106	5.11%	95
16:00	1877	1424	2,356	0.80	90	192	212	0.42	7	106	5.17%	97
17:00	1969	1449	2,445	0.81	96	207	228	0.42	8	106	5.28%	104
18:00	2018	1388	2,449	0.82	97	208	230	0.42	8	106	5.20%	105
19:00	1996	1363	2,417	0.83	94	202	223	0.42	8	106	5.11%	102
20:00	1901	1320	2,314	0.82	86	186	205	0.42	7	106	4.89%	93
21:00	1847	1313	2,266	0.82	83	178	196	0.42	7	106	4.87%	90
22:00	1839	1341	2,276	0.81	83	179	197	0.42	7	106	4.89%	90
23:00	1682	1319	2,137	0.79	74	158	174	0.42	6	106	4.76%	80
	41,191				1,827				142		4.78%	1,969

	Region Load				Region Load Losses				Distribution Transformer		Total	
Hour	Real kW	Reactive kVAr	Apparent kVA	pf	Real kW	Reactive kVAr	Apparent kVA	pf	Load Losses kW	No Load Losses kW	Load Losses %	Load Losses kW
0:00	1654	1331	2,123	0.78	1	3	3	0.32	6	106	0.42%	7
1:00	1539	1280	2,002	0.77	1	2	2	0.45	5	106	0.39%	6
2:00	1464	1230	1,912	0.77	1	2	2	0.45	4	106	0.34%	5
3:00	1395	1182	1,828	0.76	1	2	2	0.45	4	106	0.36%	5
4:00	1372	1166	1,801	0.76	1	2	2	0.45	4	106	0.36%	5
5:00	1363	1141	1,778	0.77	1	2	2	0.45	4	106	0.37%	5
6:00	1418	1133	1,815	0.78	1	2	2	0.45	4	106	0.35%	5
7:00	1508	1128	1,883	0.80	1	2	2	0.45	4	106	0.33%	5
8:00	1654	1237	2,065	0.80	1	3	3	0.32	5	106	0.36%	6
9:00	1810	1345	2,255	0.80	1	3	3	0.32	7	106	0.44%	8
10:00	1914	1429	2,389	0.80	2	4	4	0.45	8	106	0.52%	10
11:00	1979	1470	2,465	0.80	2	4	4	0.45	8	106	0.51%	10
12:00	1975	1457	2,454	0.80	2	4	4	0.45	8	106	0.51%	10
13:00	1975	1470	2,462	0.80	2	4	4	0.45	8	106	0.51%	10
14:00	1932	1459	2,421	0.80	2	4	4	0.45	8	106	0.52%	10
15:00	1927	1459	2,417	0.80	2	4	4	0.45	8	106	0.52%	10
16:00	1948	1460	2,434	0.80	2	4	4	0.45	8	106	0.51%	10
17:00	2046	1473	2,521	0.81	2	4	4	0.45	9	106	0.54%	11
18:00	2096	1394	2,517	0.83	2	4	4	0.45	9	106	0.52%	11
19:00	2071	1378	2,488	0.83	2	4	4	0.45	8	106	0.48%	10
20:00	1969	1342	2,383	0.83	2	4	4	0.45	8	106	0.51%	10
21:00	1909	1338	2,331	0.82	1	4	4	0.24	7	106	0.42%	8
22:00	1900	1368	2,341	0.81	2	4	4	0.45	7	106	0.47%	9
23:00	1734	1345	2,194	0.79	1	3	3	0.32	6	106	0.40%	7
	42,552				36				157		0.45%	193

Appendix 5 – Model 30% Supply Transformer Loading

F9-0 to F9-2	4160V		50%, 35% Scaling 15 deg			F9-1 to F9-2	27,600 kV			
Hour	R	W	B	Avg		Hour	R	W	B	Avg
0:00	185	168	173	175	Amps	0:00	28	25	26	26
1:00	176	160	164	167		1:00	26	24	25	25
2:00	169	154	158	160		2:00	25	23	24	24
3:00	163	148	152	154		3:00	24	22	23	23
4:00	161	146	150	152		4:00	24	22	22	23
5:00	160	145	149	151		5:00	24	22	22	23
6:00	162	147	151	153		6:00	24	22	23	23
7:00	167	151	156	158		7:00	25	23	23	24
8:00	181	164	169	171		8:00	27	25	25	26
9:00	195	177	182	185		9:00	29	27	27	28
10:00	206	187	192	195		10:00	31	28	29	29
11:00	212	192	198	201		11:00	32	29	30	30
12:00	211	192	198	200		12:00	32	29	30	30
13:00	212	193	198	201		13:00	32	29	30	30
14:00	209	190	195	198		14:00	32	29	30	30
15:00	208	189	195	197		15:00	32	29	29	30
16:00	210	191	196	199		16:00	32	29	30	30
17:00	216	197	202	205		17:00	33	30	31	31
18:00	216	196	202	205		18:00	33	30	30	31
19:00	213	194	200	202		19:00	32	29	30	30
20:00	205	187	192	195		20:00	31	28	29	29
21:00	202	183	189	191		21:00	30	28	28	29
22:00	202	183	188	191		22:00	30	28	28	29
23:00	191	174	178	181		23:00	29	26	27	27

		kVA Max	Transf Loading
F9	4160V incl 44kV/4160V Transf	1,482	30%

	Region Load				Region Load Losses				Distribution Transformer		Total	
Hour	Real kW	Reactive kVAr	Apparent kVA	pf	Real kW	Reactive kVAr	Apparent kVA	pf	Load Losses kW	No Load Losses kW	Load Losses %	Load Losses kW
0:00	930	859	1,266	0.73	26	55	61	0.43	1	106	2.90%	27
1:00	871	832	1,205	0.72	23	50	55	0.42	1	106	2.76%	24
2:00	831	806	1,158	0.72	21	46	51	0.42	1	106	2.65%	22
3:00	796	781	1,115	0.71	20	43	47	0.42	1	106	2.64%	21
4:00	785	773	1,102	0.71	19	42	46	0.41	1	106	2.55%	20
5:00	781	761	1,090	0.72	19	41	45	0.42	1	106	2.56%	20
6:00	810	757	1,109	0.73	20	42	47	0.43	1	106	2.59%	21
7:00	857	753	1,141	0.75	21	45	50	0.42	1	106	2.57%	22
8:00	933	810	1,236	0.76	24	53	58	0.41	1	106	2.68%	25
9:00	1015	866	1,334	0.76	28	62	68	0.41	1	106	2.86%	29
10:00	1073	912	1,408	0.76	32	69	76	0.42	2	106	3.17%	34
11:00	1108	934	1,449	0.76	34	73	81	0.42	2	106	3.25%	36
12:00	1108	930	1,447	0.77	34	72	80	0.43	2	106	3.25%	36
13:00	1108	936	1,450	0.76	34	73	81	0.42	2	106	3.25%	36
14:00	1086	929	1,429	0.76	33	71	78	0.42	2	106	3.22%	35
15:00	1082	929	1,426	0.76	33	70	77	0.43	2	106	3.23%	35
16:00	1093	931	1,436	0.76	33	71	78	0.42	2	106	3.20%	35
17:00	1144	942	1,482	0.77	35	76	84	0.42	2	106	3.23%	37
18:00	1170	904	1,479	0.79	35	76	84	0.42	2	106	3.16%	37
19:00	1157	893	1,462	0.79	34	74	81	0.42	2	106	3.11%	36
20:00	1104	871	1,406	0.79	32	68	75	0.43	2	106	3.08%	34
21:00	1073	868	1,380	0.78	31	66	73	0.43	2	106	3.08%	33
22:00	1063	881	1,381	0.77	31	66	73	0.43	2	106	3.10%	33
23:00	977	869	1,308	0.75	27	59	65	0.42	1	106	2.87%	28
	23,955				679				37		2.99%	716

	Region Load				Region Load Losses				Distribution Transformer		Total	
Hour	Real kW	Reactive kVAr	Apparent kVA	pf	Real kW	Reactive kVAr	Apparent kVA	pf	Load Losses kW	No Load Losses kW	Load Losses %	Load Losses kW
0:00	945	865	1,281	0.74	0	1	1	0.00	1	106	0.11%	1
1:00	884	838	1,218	0.73	0	1	1	0.00	1	106	0.11%	1
2:00	843	811	1,170	0.72	0	1	1	0.00	1	106	0.12%	1
3:00	806	785	1,125	0.72	0	0	-	#DIV/0!	1	106	0.12%	1
4:00	795	777	1,112	0.72	0	0	-	#DIV/0!	1	106	0.13%	1
5:00	791	764	1,100	0.72	0	0	-	#DIV/0!	1	106	0.13%	1
6:00	821	759	1,118	0.73	0	0	-	#DIV/0!	1	106	0.12%	1
7:00	869	757	1,152	0.75	0	0	-	#DIV/0!	1	106	0.12%	1
8:00	949	817	1,252	0.76	0	1	1	0.00	1	106	0.11%	1
9:00	1034	875	1,355	0.76	0	1	1	0.00	2	106	0.19%	2
10:00	1095	924	1,433	0.76	0	1	1	0.00	2	106	0.18%	2
11:00	1131	946	1,474	0.77	0	1	1	0.00	2	106	0.18%	2
12:00	1130	940	1,470	0.77	0	1	1	0.00	2	106	0.18%	2
13:00	1130	947	1,474	0.77	0	1	1	0.00	2	106	0.18%	2
14:00	1108	942	1,454	0.76	0	1	1	0.00	2	106	0.18%	2
15:00	1104	941	1,451	0.76	0	1	1	0.00	2	106	0.18%	2
16:00	1116	942	1,460	0.76	0	1	1	0.00	2	106	0.18%	2
17:00	1169	948	1,505	0.78	0	1	1	0.00	2	106	0.17%	2
18:00	1196	905	1,500	0.80	0	1	1	0.00	2	106	0.17%	2
19:00	1181	896	1,482	0.80	0	1	1	0.00	2	106	0.17%	2
20:00	1126	877	1,427	0.79	0	1	1	0.00	2	106	0.18%	2
21:00	1093	875	1,400	0.78	0	1	1	0.00	2	106	0.18%	2
22:00	1083	888	1,401	0.77	0	1	1	0.00	2	106	0.18%	2
23:00	993	876	1,324	0.75	0	1	1	0.00	1	106	0.10%	1
	24,392				-				38		0.16%	38

Appendix 6 – Model 59% Supply Transformer Loading

F9-0 to F9-2	4160V		50%, 80% Scaling 15 deg			F9-1 to F9-2	27,600 kV				
Hour	R	W	B	Avg		Hour	R	W	B	Avg	
0:00	361	329	339	343	Amps	0:00	56	51	52	53	Amps
1:00	341	311	320	324		1:00	53	48	49	50	
2:00	326	297	306	310		2:00	50	46	47	48	
3:00	312	284	293	296		3:00	48	43	45	45	
4:00	308	281	289	293		4:00	47	43	44	45	
5:00	304	277	286	289		5:00	47	42	44	44	
6:00	311	283	292	295		6:00	48	43	45	45	
7:00	322	294	303	306		7:00	49	45	46	47	
8:00	352	321	331	335		8:00	54	49	51	51	
9:00	383	350	360	364		9:00	60	54	56	57	
10:00	406	371	382	386		10:00	63	58	60	60	
11:00	419	383	395	399		11:00	66	60	62	63	
12:00	419	382	394	398		12:00	65	59	61	62	
13:00	420	384	396	400		13:00	66	60	62	63	
14:00	412	377	389	393		14:00	64	59	61	61	
15:00	412	376	388	392		15:00	64	58	61	61	
16:00	415	379	391	395		16:00	65	59	61	62	
17:00	431	394	406	410		17:00	67	61	63	64	
18:00	432	395	407	411		18:00	67	61	63	64	
19:00	426	390	401	406		19:00	66	60	62	63	
20:00	408	373	384	388		20:00	63	58	60	60	
21:00	399	365	376	380		21:00	62	56	58	59	
22:00	399	365	375	380		22:00	62	56	58	59	
23:00	374	342	352	356		23:00	58	53	54	55	

		kVA Max	Transf Loading
F9	4160V incl 44kV/4160V Transf	2,967	59%

	Region Load				Region Load Losses				Distribution Transformer		Total	
Hour	Real kW	Reactive kVAr	Apparent kVA	pf	Real kW	Reactive kVAr	Apparent kVA	pf	Load Losses kW	No Load Losses kW	Load Losses %	Load Losses kW
0:00	1946	1528	2,474	0.79	99	212	234	0.42	8	106	5.50%	107
1:00	1816	1471	2,337	0.78	88	189	208	0.42	7	106	5.23%	95
2:00	1730	1413	2,234	0.77	81	173	191	0.42	6	106	5.03%	87
3:00	1651	1358	2,138	0.77	74	159	175	0.42	6	106	4.85%	80
4:00	1628	1341	2,109	0.77	72	154	170	0.42	5	106	4.73%	77
5:00	1619	1314	2,085	0.78	70	151	166	0.42	5	106	4.63%	75
6:00	1683	1306	2,130	0.79	73	158	174	0.42	6	106	4.69%	79
7:00	1789	1298	2,210	0.81	79	169	187	0.42	6	106	4.75%	85
8:00	1954	1420	2,415	0.81	94	202	223	0.42	8	106	5.22%	102
9:00	2130	1541	2,629	0.81	112	240	265	0.42	9	106	5.68%	121
10:00	2255	1639	2,788	0.81	126	269	297	0.42	11	106	6.08%	137
11:00	2330	1687	2,877	0.81	134	287	317	0.42	12	106	6.27%	146
12:00	2330	1682	2,874	0.81	134	287	317	0.42	12	106	6.27%	146
13:00	2331	1697	2,883	0.81	135	289	319	0.42	12	106	6.31%	147
14:00	2282	1677	2,832	0.81	130	279	308	0.42	11	106	6.18%	141
15:00	2275	1678	2,827	0.80	129	277	306	0.42	11	106	6.15%	140
16:00	2297	1684	2,848	0.81	131	282	311	0.42	11	106	6.18%	142
17:00	2407	1719	2,958	0.81	142	303	335	0.42	12	106	6.40%	154
18:00	2467	1648	2,967	0.83	142	305	336	0.42	13	106	6.28%	155
19:00	2441	1615	2,927	0.83	138	297	327	0.42	12	106	6.15%	150
20:00	2326	1561	2,801	0.83	127	272	300	0.42	11	106	5.93%	138
21:00	2260	1552	2,742	0.82	122	261	288	0.42	10	106	5.84%	132
22:00	2239	1578	2,739	0.82	121	260	287	0.42	10	106	5.85%	131
23:00	2048	1551	2,569	0.80	107	229	253	0.42	9	106	5.66%	116
	50,234				2,660				223		5.74%	2,883

	Region Load				Region Load Losses				Distribution Transformer		Total	
Hour	Real kW	Reactive kVAr	Apparent kVA	pf	Real kW	Reactive kVAr	Apparent kVA	pf	Load Losses kW	No Load Losses kW	Load Losses %	Load Losses kW
0:00	2018	1567	2,555	0.79	2	4	4	0.45	9	106	0.55%	11
1:00	1878	1504	2,406	0.78	2	4	4	0.45	8	106	0.53%	10
2:00	1786	1443	2,296	0.78	1	3	3	0.32	7	106	0.45%	8
3:00	1701	1385	2,194	0.78	1	3	3	0.32	6	106	0.41%	7
4:00	1676	1367	2,163	0.77	1	3	3	0.32	6	106	0.42%	7
5:00	1667	1337	2,137	0.78	1	3	3	0.32	6	106	0.42%	7
6:00	1734	1327	2,184	0.79	1	3	3	0.32	6	106	0.40%	7
7:00	1844	1321	2,268	0.81	1	3	3	0.32	7	106	0.43%	8
8:00	2026	1456	2,495	0.81	2	4	4	0.45	8	106	0.49%	10
9:00	2218	1588	2,728	0.81	2	5	5	0.37	10	106	0.54%	12
10:00	2357	1698	2,905	0.81	3	6	7	0.45	12	106	0.64%	15
11:00	2438	1749	3,000	0.81	3	6	7	0.45	13	106	0.66%	16
12:00	2437	1735	2,992	0.81	3	6	7	0.45	13	106	0.66%	16
13:00	2437	1751	3,001	0.81	3	6	7	0.45	13	106	0.66%	16
14:00	2385	1738	2,951	0.81	3	6	7	0.45	13	106	0.67%	16
15:00	2377	1737	2,944	0.81	3	6	7	0.45	12	106	0.63%	15
16:00	2404	1739	2,967	0.81	3	6	7	0.45	13	106	0.67%	16
17:00	2523	1756	3,074	0.82	3	7	8	0.39	14	106	0.67%	17
18:00	2585	1660	3,072	0.84	3	7	8	0.39	14	106	0.66%	17
19:00	2553	1639	3,034	0.84	3	6	7	0.45	13	106	0.63%	16
20:00	2427	1594	2,904	0.84	3	6	7	0.45	12	106	0.62%	15
21:00	2353	1588	2,839	0.83	2	6	6	0.32	11	106	0.55%	13
22:00	2329	1619	2,836	0.82	2	6	6	0.32	11	106	0.56%	13
23:00	2127	1591	2,656	0.80	2	5	5	0.37	10	106	0.56%	12
	52,280				53				247		0.57%	300

Appendix 7 – Measured Currents December 22, 2004

Hour	R	W	B	Avg
22/12/2004 0:00	284	240	272	265
22/12/2004 1:00	262	225	256	248
22/12/2004 2:00	255	215	241	237
22/12/2004 3:00	254	216	245	238
22/12/2004 4:00	250	214	248	237
22/12/2004 5:00	251	215	241	236
22/12/2004 6:00	278	225	257	253
22/12/2004 7:00	287	237	278	267
22/12/2004 8:00	300	242	297	280
22/12/2004 9:00	333	273	322	309
22/12/2004 10:00	323	287	321	310
22/12/2004 11:00	332	278	319	310
22/12/2004 12:00	345	285	333	321
22/12/2004 13:00	335	280	336	317
22/12/2004 14:00	337	283	334	318
22/12/2004 15:00	328	278	321	309
22/12/2004 16:00	351	291	330	324
22/12/2004 17:00	375	317	377	356
22/12/2004 18:00	378	330	376	361
22/12/2004 19:00	375	300	362	346
22/12/2004 20:00	342	292	353	329
22/12/2004 21:00	346	288	346	327
22/12/2004 22:00	338	270	315	308
22/12/2004 23:00	290	254	282	275