construction of five miles of new 138 kV line. The route of this new line will ultimately be determined by the Public Utility Commission of Texas; however, for the purposes of this study the assumption was made that the line would be constructed in the same right-of-way as the existing 345kV Zenith to THW double circuit line.

Option 3a – Build a new 345/138kV substation 0.7miles west from the Gertie corner by looping the 345kV ckt.71 and ckt.98 from future Zenith to THW substation into the New Substation and building new double circuit from the New Substation to Gertie Row and connect to the existing 138kV double circuits to Gertie. Reconfigure the existing 138kV ckt.76 from Kluge to Addicks and ckt.21 from Kluge to Camron to create three new 138kV circuits: ckt.2 from New Substation to Kluge, ckt.1 from New Substation to Addicks and ckt.21 from Kluge to Camron (see Figure 4).

Option 3b – Build a new 345/138kV substation 0.7miles west from the Gertie corner by looping the 345kV ckt.98 from future Zenith to THW substation into the New Substation and building new double circuit from the New Substation to Gertie Row and connect to the existing 138kV double circuits to Gertie. Reconfigure the existing 138kV ckt.76 from Kluge to Addicks and ckt.21 from Kluge to Camron to create three new 138kV circuits: ckt.2 from New Substation to Kluge, ckt.1 from New Substation to Addicks and ckt.21 from Kluge to Camron (see Figure 5).

Option 3c – Build a new 345/138kV substation 0.7miles west from the Gertie corner by looping the 345kV ckt.71 from future Zenith to THW substation into the New Substation and building new double circuit from the New Substation to Gertie Row and connect to the existing 138kV double circuits to Gertie. Reconfigure the existing 138kV ckt.76 from Kluge to Addicks and ckt.21 from Kluge to Camron to create three new 138kV circuits: ckt.2 from New Substation to Kluge, ckt.1 from New Substation to Addicks and ckt.21 from Kluge to Camron (see Figure 6).

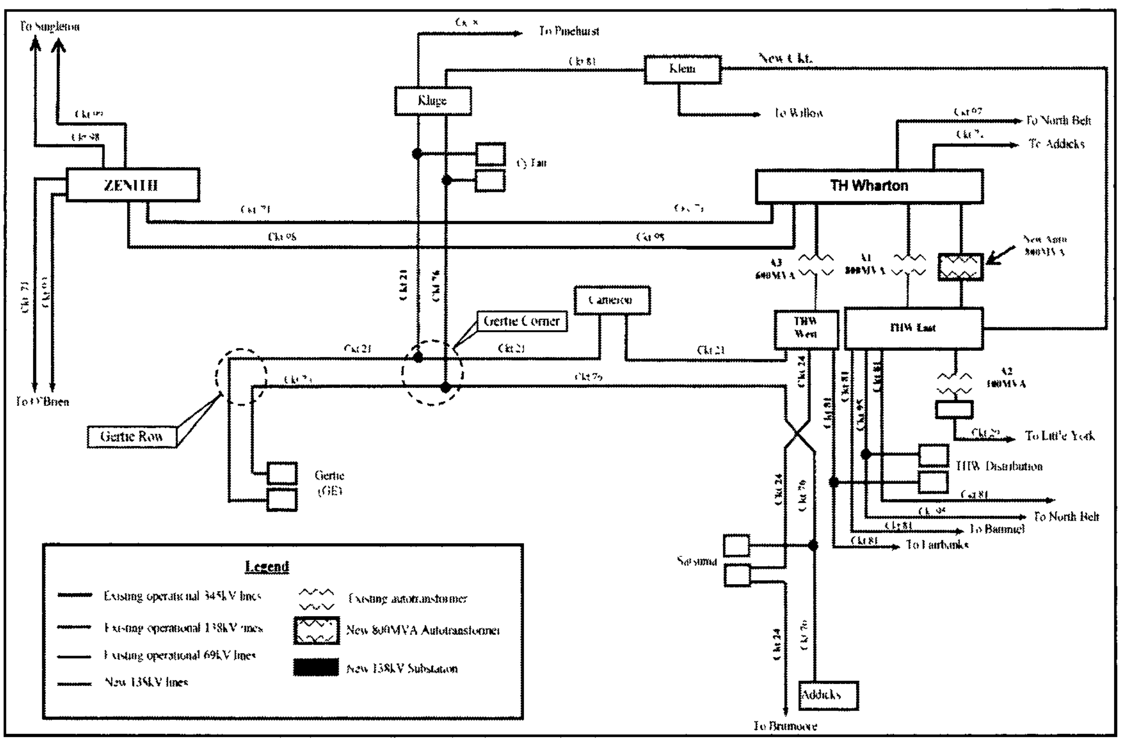

Figure 2: Option 1 – Possible Future System Configuration

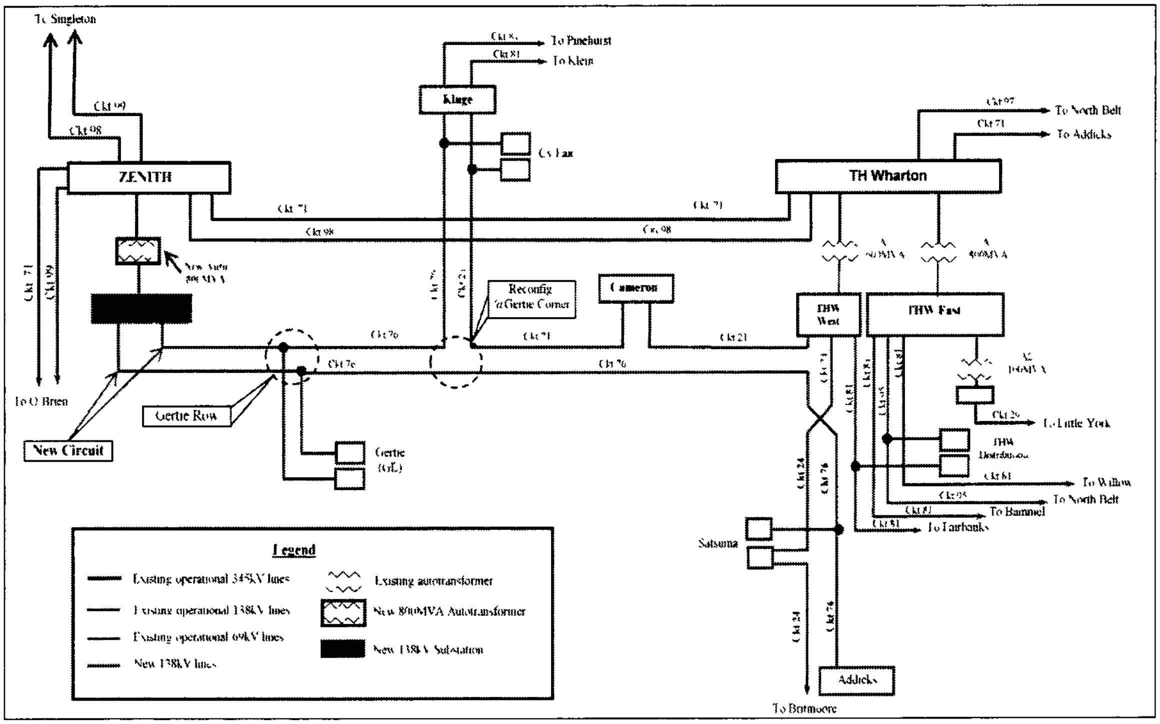

Figure 3: Option 2 – Possible Future System Configuration

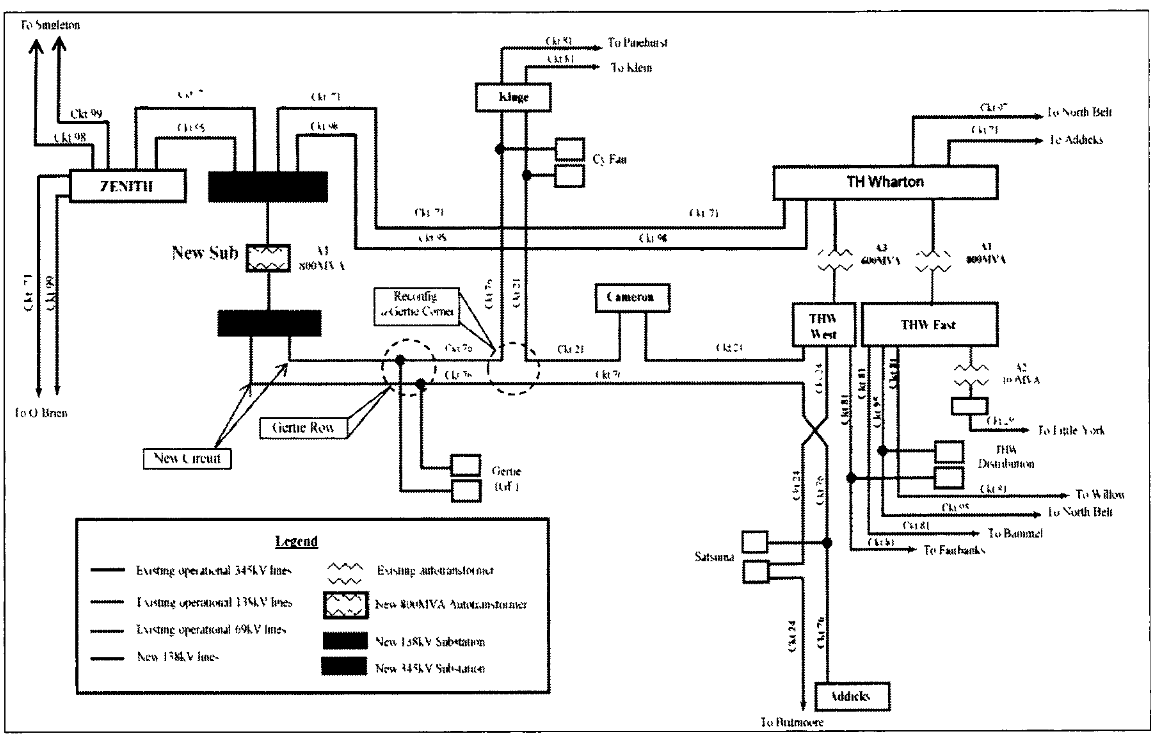

Figure 4: Option 3a – Possible Future System Configuration

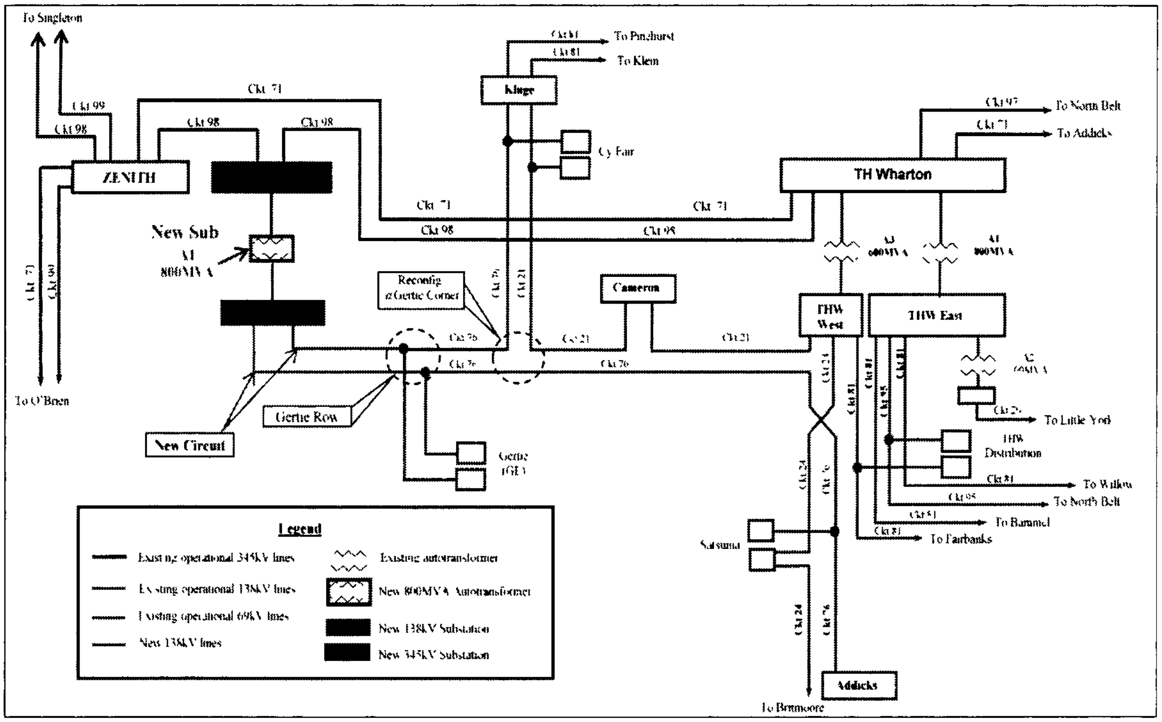

Figure 5: Option 3b – Possible Future System Configuration

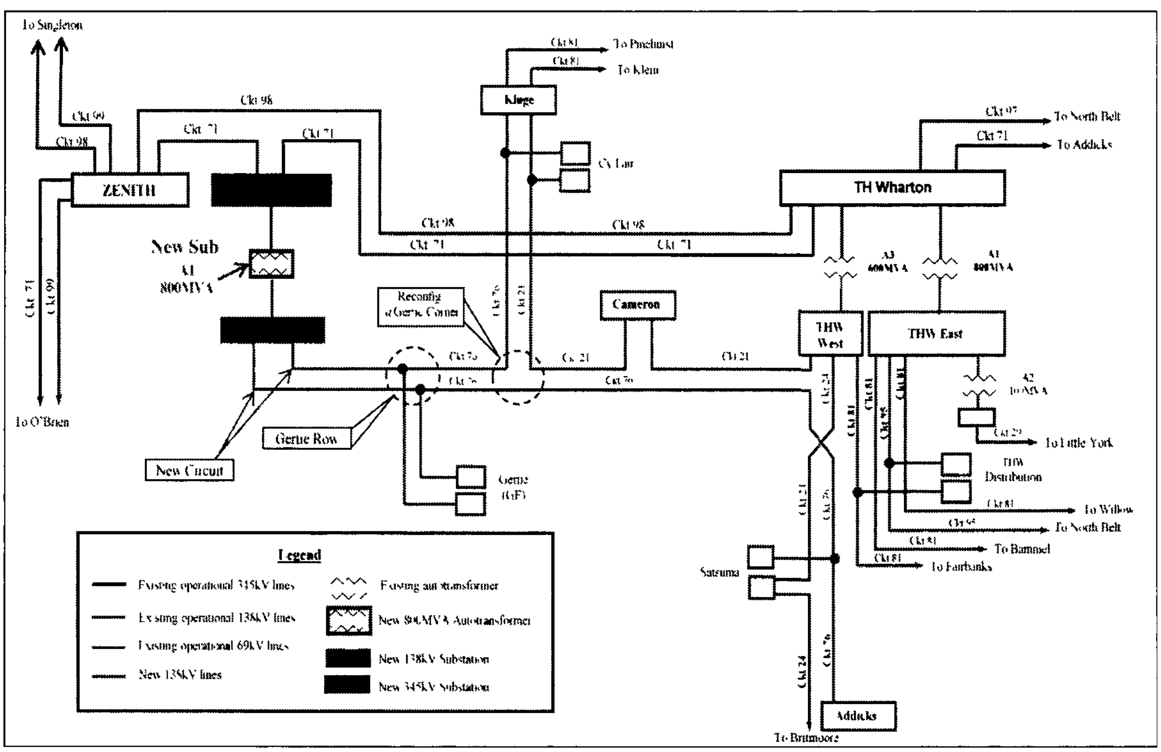

Figure 6: Option 3c – Possible Future System Configuration

5. Steady-State Load Flow Contingency Studies

Table 5 and Table 6 show the single contingency analysis results for the base case plus results for Option 1, Option 2, Option 3a, Option 3b, and Option 3c. For single contingency results, Rate A (continuous rating) is used as the comparative branch rating. Table 7 and 8 show common mode double contingency analysis results for the same options. For common mode double contingency results, Rate B (emergency rating) is used as the comparative branch rating. These tables show only those branches and system buses where either option had a non-trivial effect on the loading and bus voltage magnitude, respectively.

The Category B and Category C contingency analyses show that all five options are comparably effective in relieving the northwestern Houston area autotransformer thermal loading. The Zenith option (Option 2) is the most effective in resolving single and common mode double contingency thermal line loading and voltage problems in the northwestern Houston area. By 2013, the THW Auto #1 loading is approaching 100% again for all options, while O'Brien Auto #3 loading is approaching 100% for Option 1 indicating a continuing need for autotransformer capacity in the area beyond that being contemplated in this study. Several common mode voltage violations still exist in 2013 for all of the options although the number of violations is smaller for Option 2.

Steady-State Load Flow Category B Contingency Analysis Results

Table 5: Thermal loading results in % during single (category B) contingency.

Overloaded Line	Category B Contingency	kV	Rate A	11 Summer Peak						12 Summer Peak						13 Summer Peak					
				Base Case	Opt 1	Opt 2	Opt 3a	Opt 3b	Opt 3c	Base Case	Opt 1	Opt 2	Opt 3a	Opt 3b	Opt 3c	Base Case	Opt 1	Opt 2	Opt 3a	Opt 3b	Opt 3c
Ckt.76 Cyfair to Kluge	Ckt.21 TH Wharton to Camron	138	227	< 95	< 95	< 95	116	113.4	113.4	< 95	< 95	101	122	120	120	< 95	< 95	104.5	125	127	127
	Ckt&1 Camron - Kluge	138	227	< 95	106	N/A	N/A	N/A	N/A	102	137	N/A	N/A	N/A	N/A	104.4	141	N/A	N/A	N/A	N/A
CKT 76 Gertie to Cyfair	*Ckt.21 Camron-Cyfair-Kluge*	138	455	N/A	N/A	< 95	< 95	< 95	< 95	N/A	N/A	< 95	98.2	97.8	97.8	N/A	N/A	< 95	104.1	102.7	102.7
Ckt.76 Satsuma to Gertie	Ckt&1 Camron - Kluge	138	455	< 95	< 95	N/A	N/A	N/A	N/A	99.3	< 95	N/A	N/A	N/A	N/A	106.7	< 95	N/A	N/A	N/A	N/A
Ckt. 81 TH Wharton to TH Wharton tap	Ckt.&2 TH Wharton to N_Belt	138	478	< 95	< 95	< 95	< 95	< 95	< 95	< 95	95.2	< 95	< 95	< 95	< 95	< 95	98.5	< 95	< 95	< 95	< 95
A1 @ TH Wharton	Ckt.21 Camron to TH Wharton	345/138	800	107.6	< 95	< 95	< 95	< 95	< 95	117.3	< 95	< 95	< 95	< 95	< 95	125.1	< 95	100.5	96.6	96.4	96.4
	A4 @ TH Wharton			N/A	< 95	N/A	N/A	N/A	N/A	N/A	95.6	N/A	N/A	N/A	N/A	N/A	102	N/A	N/A	N/A	N/A
	A1 @New Substation			N/A	N/A	N/A	< 95	< 95	< 95	N/A	N/A	N/A	< 95	< 95	< 95	N/A	N/A	N/A	99.2	99.2	99.2
A4 @ TH Wharton	A1@ TH Wharton	345/138	800	N/A	< 95	N/A	N/A	N/A	N/A	N/A	98.8	N/A	N/A	N/A	N/A	N/A	102	N/A	N/A	N/A	N/A
A3 @O'Brien	A2 @O'Brien	345/138	400	95.4	< 95	< 95	< 95	< 95	< 95	98.3	97.7	< 95	< 95	< 95	< 95	99.2	98.6	95.3	95.4	95.5	95.5

Note: Contingency studied herein that were created due to the reconfiguration of the existing circuits or additions of the new substation are highlighted in yellow.

Table 6: Low voltage results during single (category B) contingency

Buses		Category B Contingency	kV	11 Summer Peak						12 Summer Peak						13 Summer Peak					
				Base Case	Opt 1	Opt 2	Opt 3a	Opt 3b	Opt 3c	Base Case	Opt 1	Opt 2	Opt 3a	Opt 3b	Opt 3c	Base Case	Opt 1	Opt 2	Opt 3a	Opt 3b	Opt 3c
45700	Camron	Ckt.21 THW to Camron	138	>0.95	>0.95	>0.95	>0.95	>0.95	>0.95	0 949	>0.95	>0.95	>0.95	>0.95	>0.95	0.941	>0.95	>0.95	>0.95	>0.95	>0.95
45711	Cyfair21		138	>0.95	>0.95	>0.95	>0.95	>0.95	>0.95	>0.95	>0.95	>0.95	>0.95	>0.95	>0.95	0.942	>0.95	>0.95	>0 95	>0.95	>0.95
45801	Gertie21		138	>0.95	>0 95	>0 95	>0.95	>0 95	>0.95	0 949	>0.95	>0.95	>0.95	>0.95	>0.95	0.941	>0.95	>0.95	>0.95	>0 95	>0.95
45712	Cyfair76	Ckt.21 Camron to Kluge	138	>0.95	>0.95	N/A	N/A	N/A	N/A	0.943	>0.95	N/A	N/A	N/A	N/A	**0.934**	>0.95	N/A	N/A	N/A	N/A
45802	Gertie76		138	>0.95	>0.95	N/A	N/A	N/A	N/A	0.946	>0.95	N/A	N/A	N/A	N/A	**0.937**	>0.95	N/A	N/A	N/A	N/A
45940	Klein	Ckt.81 THW to Willow	138	>0.95	>0.95	>0.95	>0.95	>0.95	>0.95	**0.928**	>0.95	>0.95	>0.95	>0.95	>0.95	**0.918**	>0.95	>0.95	>0.95	>0.95	>0.95
45952	Kluge		138	>0.95	>0.95	>0.95	>0.95	>0.95	>0.95	0.942	>0.95	>0.95	>0.95	>0.95	>0.95	**0.933**	>0.95	>0.95	>0.95	>0.95	>0.95
46660	Willow		138	0.950	>0.95	>0.95	>0.95	>0.95	>0.95	**0.927**	>0 95	>0 95	>0.95	>0 95	>0.95	**0.917**	>0.95	>0.95	>0.95	>0.95	>0.95
45971	Kuykendahl74	Ckt.74 King to Rothwood	345	0.965	>0.97	>0 97	>0.97	>0.97	>0 97	0.945	0.960	0.960	0.960	0.960	0.960	0.945	0.955	0.956	0.961	0 961	0 961
46500	Tomball		345	0.965	>0.97	>0.97	>0.97	>0.97	>0.97	0.944	0.961	0.960	0.961	0.961	0.961	0.944	0.954	0.955	0.961	0.961	0.961
46290	Rothwood		345	0.965	>0.97	>0.97	>0.97	>0.97	>0.97	0.946	0.960	0.960	0.961	0.961	0.961	0 946	0 955	0.956	0.961	0.961	0.961
46240	Pinehurst	Ckt.81 Pinehurst to Tomball	138	0.948	>0.95	>0.95	>0.95	>0.95	>0.95	**0.927**	>0.95	>0.95	>0.95	>0.95	>0.95	**0.915**	0.947	0.947	>0.95	>0.95	>0.95

One contingency that is not shown in the results, but has a significant impact on the system is the loss of the double circuit line proceeding south out of Kluge turning east towards Camron (ckt.76 Kluge to Addicks and ckt.21 Kluge to Camron). This contingency does not result in any system loading problems because all of the load at Gertie and Cyfair, which totaled 370MW in 2008, is dropped. Option 1 does not resolve the load loss for this contingency. Options 2, 3a, 3b, and 3c reconfigure the system in such a way as to eliminate all load loss if the contingency occurs between Camron and the Gertie corner and eliminates the loss of Gertie load (230 MW) for the outage between Gertie corner and Kluge.

Steady-State Load Flow Category C (Common Mode Double) Contingency Analysis Results

Table 7: Thermal loading results in % during common mode double (category C) contingency

Overloaded Line	Category C Contingency	kV	Rate B	11 Summer Peak						12 Summer Peak						13 Summer Peak					
				Base Case	Opt 1	Opt 2	Opt 3a	Opt 3b	Opt 3c	Base Case	Opt 1	Opt 2	Opt 3a	Opt 3b	Opt 3c	Base Case	Opt 1	Opt 2	Opt 3a	Opt 3b	Opt 3c
Ckt.09 Britmore to Addicks	Ckt 24 THW to Satsuma & Ckt.1 Addicks to Zenith	138	478	N/A	N/A	98.6	N/A	N/A	N/A	N/A	N/A	101.8	N/A	N/A	N/A	N/A	N/A	99.1	N/A	N/A	N/A
	Ckt.24 THW to Satsuma & Ckt.1 Addicks to New Sub			N/A	N/A	N/A	98.3	98.2	98.2	N/A	N/A	N/A	101.4	101.4	101.4	N/A	N/A	N/A	98.8	98.8	98.8
Ckt.76 Addicks to Satsuma	Ckt.21 Kluge to Camron & Ckt.81 Kluge to Klein	138	789	< 95	< 95	N/A	N/A	N/A	N/A	102.3	102	< 95	N/A	N/A	N/A	109.7	109.4	N/A	N/A	N/A	N/A
Ckt.76 Cyfair to Kluge	A1 @Zenith & Ckt.1 Zenith to Addicks	138	290	N/A	N/A	120.3	N/A	N/A	N/A	N/A	N/A	154.9	N/A	N/A	N/A	N/A	N/A	163.6	N/A	N/A	N/A
	Ckt.21 Camron to THW & Ckt 21 Camron to Kluge			< 95	< 95	N/A	N/A	N/A	N/A	< 95	107	N/A	N/A	N/A	N/A	< 95	110	N/A	N/A	N/A	N/A
	A1 @New Sub & Ckt.1 New Sub to Addicks			N/A	N/A	N/A	120	120	120	N/A	N/A	N/A	155	155	155	N/A	N/A	N/A	164	164	164
Ckt.76 Satsuma to Gertie	Ckt 21 Kluge to Camron & Ckt 81 Kluge to Klein	138	580	< 95	< 95	N/A	N/A	N/A	N/A	115	115	N/A	N/A	N/A	N/A	125	124	N/A	N/A	N/A	N/A
Ckt 81 T.H Wharton to Willow	Ckt.21 Camron to THW & Ckt.76 Addicks to Kluge	138	717	109	< 95	N/A	N/A	N/A	N/A	137	< 95	N/A	N/A	N/A	N/A	154	< 95	N/A	N/A	N/A	N/A
Ckt 81 T.H Wharton to Fairbanks	Ckt 21 Camron to THW & Ckt.24 T_H_W to Satsuma	138	441	103	99.9	98 7	98 0	98 1	98 1	104	101	99.7	98.8	98.8	98.8	104	100	99.1	98 1	98 3	98.3
Ckt 81 Klein to Willow	Ckt 21 Camron to THW & Ckt 76 Addicks to Kluge	138	789	< 95	< 95	N/A	N/A	N/A	N/A	119	< 95	N/A	N/A	N/A	N/A	134	< 95	N/A	N/A	N/A	N/A
Ckt.81 Kluge to Pinehurst	Ckt.21 Camron to THW & Ckt 76 Addicks to Kluge	138	455	< 95	< 95	N/A	N/A	N/A	N/A	103	< 95	N/A	N/A	N/A	N/A	114	< 95	N/A	N/A	N/A	N/A
A1 @ T H Wharton	Ckt 21 Kluge to Camron & Ckt 81 Kluge to Pinehurst	345/ 138	914	103	< 95	N/A	N/A	N/A	N/A	115	< 95	N/A	N/A	N/A	N/A	117	< 95	N/A	N/A	N/A	N/A
	Ckt 21 Camron to THW & Ckt 76 Addicks to Kluge			120	< 95	N/A	N/A	N/A	N/A	134	< 95	N/A	N/A	N/A	N/A	140	< 95	N/A	N/A	N/A	N/A
	A1 @Zenith & Ckt.1 Zenith to Addicks			N/A	N/A	< 95	N/A	N/A	N/A	N/A	N/A	< 95	N/A	N/A	N/A	N/A	N/A	101	N/A	N/A	N/A
	A1 @New Sub & Ckt 1New Sub to Addicks			N/A	N/A	N/A	< 95	< 95	< 95	N/A	N/A	N/A	< 95	< 95	< 95	N/A	N/A	N/A	101	101	101
A2 @ North Belt	A3 @N_Belt & A1_@N_Belt	345/ 138	672	99.8	< 95	96.2	95.4	95.5	95.5	103	< 95	98 7	97.9	98 0	98.0	105	< 95	100	99.6	99.7	99.7

Table 8: Low voltage results during common mode double (category C) contingency

Buses		Category C Contingency	kV	11 Summer Peak						12 Summer Peak						13 Summer Peak					
				Base Case	Opt 1	Opt 2	Opt 3a	Opt 3b	Opt 3c	Base Case	Opt 1	Opt 2	Opt 3a	Opt 3b	Opt 3c	Base Case	Opt 1	Opt 2	Opt 3a	Opt 3b	Opt 3c
44910	ZENITH	A1 @Zenith & Ckt 1 Zenith to Addicks	138	N/A	N/A	>0.93	N/A	N/A	N/A	N/A	N/A	0.9121	N/A	N/A	N/A	N/A	N/A	0.8982	N/A	N/A	N/A
44950	NEW SUB	Ckt.71 Zenith to NEW SUB & Ckt.71 Zenith to THW	345	N/A	N/A	N/A	>0.93	N/A	0.8948	N/A	N/A	N/A	>0.93	N/A	0.8842	N/A	N/A	N/A	>0.93	N/A	0 8822
		Ckt 98 Zenith to Singleton & Ckt 98 Zenith to NEW SUB		N/A	N/A	N/A	>0.93	0 8948	N/A	N/A	N/A	N/A	>0.93	0 8842	N/A	N/A	N/A	N/A	>0.93	0 8822	N/A
44955	NEW SUB	A1 @NEW SUB & Ckt.1_NEW SUB to Addicks	138	N/A	N/A	N/A	>0.93	>0 93	>0.93	N/A	N/A	N/A	0 9116	0.9116	0 9116	N/A	N/A	N/A	0 8978	0 8978	0 8978
45700	CAMRON	Ckt 21 Camron to THW & Ckt 76 Addicks to Kluge	138	0 8912	> 0.93	N/A	N/A	N/A	N/A	0.7925	0.9121	N/A	N/A	N/A	N/A	0.7284	0.8969	N/A	N/A	N/A	N/A
45711	CYFAIR21	Ckt 76 Addicks to Kluge & Ckt 81 Kluge to Klein	138	> 0.93	> 0 93	N/A	N/A	N/A	N/A	0 9202	> 0 93	N/A	N/A	N/A	N/A	0 9071	> 0 93	N/A	N/A	N/A	N/A
		Ckt 21 Camron to THW & Ckt.76 Addicks to Kluge		0 8973	> 0.93	N/A	N/A	N/A	N/A	0 8019	0 9200	N/A	N/A	N/A	N/A	0 7393	0 9054	N/A	N/A	N/A	N/A
45712	CYFAIR76	Ckt.21 Kluge to Camron & Ckt 81 Kluge to Klein	138	0 9094	0 9112	N/A	N/A	N/A	N/A	0 8701	0 8699	N/A	N/A	N/A	N/A	0 8533	0 9086	N/A	N/A	N/A	N/A
		A1 @NEW SUB & Ckt.1_NEW SUB to Addicks		N/A	N/A	N/A	>0.93	>0.93	>0.93	N/A	N/A	N/A	0.9241	0 9240	0 9240	N/A	N/A	N/A	0.9142	0 9110	0.9110
		A1 @Zenith & Ckt.1 Zenith to Addicks		N/A	N/A	>0.93	N/A	N/A	N/A	N/A	N/A	0 9243	N/A	N/A	N/A	N/A	N/A	0.9113	N/A	N/A	N/A
45801	GERTIE21	Ckt&1 Addicks to Kluge & Ckt&1 Kluge to Klein	138	> 0 93	> 0 93	N/A	N/A	N/A	N/A	0 9307	> 0.93	N/A	N/A	N/A	N/A	0 9182	0 9232	N/A	N/A	N/A	N/A
		Ckt.21 Camron to THW & Ckt.76 Addicks to Kluge		0 8915	> 0.93	N/A	N/A	N/A	N/A	0.7929	0 9124	N/A	N/A	N/A	N/A	0.7288	0 8972	N/A	N/A	N/A	N/A
		A1 @NEW SUB & Ckt.1_NEW SUB to Addicks		N/A	N/A	N/A	>0.93	>0.93	>0.93	N/A	N/A	N/A	0.9116	0.9116	0 9116	N/A	N/A	N/A	0 8978	0.8978	0.8978
		A1 @Zenith & Ckt.1 Zenith to Addicks		N/A	N/A	>0.93	N/A	N/A	N/A	N/A	N/A	0.912	N/A	N/A	N/A	N/A	N/A	0.8982	N/A	N/A	N/A
45802	GERTIE76	Ckt.21 Kluge to Camron & Ckt.81 Kluge to Klein	138	0 9175	0.9194	N/A	N/A	N/A	N/A	0 8803	0 8801	N/A	N/A	N/A	N/A	0 8647	0 8644	N/A	N/A	N/A	N/A
45940	KLEIN	Ckt.21 Camron to THW & Ckt 76 Addicks to Kluge	138	> 0 93	> 0 93	N/A	N/A	N/A	N/A	0 8851	> 0 93	N/A	N/A	N/A	N/A	0 8403	> 0 93	N/A	N/A	N/A	N/A
45952	KLUGE	Ckt 21 Kluge to Camron & Ckt 81 Kluge to Klein	138	0.9087	0.9104	N/A	N/A	N/A	N/A	0 8729	0 8729	N/A	N/A	N/A	N/A	0 8557	0 8557	N/A	N/A	N/A	N/A
		Ckt.76 Addicks to Kluge & Ckt.81 Kluge to Klein		0 925	> 0 93	N/A	N/A	N/A	N/A	0 9172	0 9223	N/A	N/A	N/A	N/A	0 9052	0 9097	N/A	N/A	N/A	N/A
46240	PINHUR_	Ckt.66 Hockley to Tomball & Ckt 81 Tomball to Pinehurst	138	> 0 93	> 0.93	> 0.93	> 0.93	> 0.93	> 0 93	0 9258	> 0 93	> 0 93	> 0 93	> 0 93	> 0 93	0 9142	> 0 93	> 0 93	> 0 93	> 0 93	> 0 93
46660	WILLOW_	Ckt.21 Camron to THW & Ckt.76 Addicks to Kluge	138	> 0.93	> 0.93	N/A	N/A	N/A	N/A	0 9179	> 0 93	N/A	N/A	N/A	N/A	0 8798	> 0 93	N/A	N/A	N/A	N/A

6. Short Circuit Analysis

Both three-phase (3PH) and single-line-to-ground (1PH) fault analysis was performed on the 2013 short circuit study case and Option 1, Option 2, Option 3a, Option 3b, and Option 3c to determine the required fault duty ratings and to identify any upgrades that may be necessary. The short-circuit analysis results are presented in Table 9.

Table 9: Short Circuit Analysis Results

Bus			Interr.	Study Case				Option 1				Option 2				Option 3a				Option 3b				Option 3c			
			Rating,	3PH Fault		1PH Fault		3PH Fault		1PH Fault		3PH Fault		1PH Fault		3PH Fault		1PH Fault		3PH Fault		1PH Fault		3PH Fault		1PH Fault	
Number	Name	KV	kA	kA	%	kA	%	kA	%	kA	%	kA	%	kA	%	kA	%	kA	%	kA	%	kA	%	kA	%	kA	%
44900	ZENITH	345	New	39 6	N/A	28.2	N/A	39.7	N/A	28.3	N/A	40.8	N/A	29.2	N/A	40.5	N/A	28 9	N/A	40 4	N/A	28.9	N/A	40.4	N/A	28.9	N/A
44910	ZENITH	138	New	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	32.4	N/A	26.6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
44950	NEW_SUB	345	New	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	39 8	N/A	29 2	N/A	34.2	N/A	24.4	N/A	N/A	N/A	N/A	N/A
44955	NEW_SUB	138	New	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	34 8	N/A	28.2	N/A	34.0	N/A	27.0	N/A	34.0	N/A	27 0	N/A
44120	Britmoore	138	63	55.1	87.4	37 9	60 1	55 2	87 6	37 9	60 2	55 5	88 1	38 2	60.6	55 8	88.5	38.3	60.8	55.7	88.5	38.3	60 8	55.7	88 5	38 3	60.8
44500	O'Brien	345	50	43 4	86 8	32.0	64.1	43.4	86.9	32.1	64.2	43 6	87 2	32 2	64 4	43.5	87 1	32.1	64 3	43 5	87 1	32 1	64 3	43.5	87 1	32 1	64 3
44510	O'Brien	138	63	53.6	85.1	43 0	68.3	53.7	85 2	43 1	68 4	53 7	85.2	43 1	68 4	53 7	85.2	43.1	68.4	53.7	85.2	43.1	68.4	53.7	85 2	43 1	68 4
45500	T.H Wharton	345	50	44.3	88 6	36 7	73 4	44.7	89.4	37.0	74.0	44.3	88 7	36.7	73 5	44.5	88 9	36 8	73 6	44 5	88 9	36 8	73 6	44 5	88 9	36 8	73 6
45510	T H. Wharton	138	63	38 6	61.3	32.5	51 6	49.9	79 2	42.0	66 7	38 9	61 7	32 8	52 0	39 0	61.9	32.8	52.1	39.0	61.9	32.8	52.1	39.0	61.9	32 8	52 1
45515	T.H. Wharton E	138	52 3	46 2	73.4	45.6	72 4	46.3	73.5	45.7	72.5	46.5	73.7	45.8	72.8	46 6	73 9	46 0	72 9	46 6	73 9	45 9	72 9	46 6	73 9	45 9	72 9
45530	T.H Wharton	69	31.5	15 3	48.4	17.0	53.8	15.8	50.2	17 7	56 2	15 5	49 1	17 2	54.7	15 5	49.1	17 2	54 7	15.5	49.1	17 2	54.7	15.5	49.1	17.2	54.7
45600	Addicks	345	40	37.6	93.9	27 6	69 0	37 6	94 1	27.7	69.3	37.5	93.8	27.6	69.1	37.6	93 9	27.7	69.2	37.6	93.9	27 7	69 2	37 6	93 9	27 7	69 2
45610	**Addicks**	**138**	**63**	**61.8**	**98.1**	**46.7**	**74.2**	**61.9**	**98.5**	**46.9**	**74.4**	**62.3**	**98.9**	**47.2**	**74.9**	**63.0**	**99.96**	**47.7**	**75.6**	**62.9**	**99.9**	**47.6**	**75.6**	**62.9**	**99.9**	**47.6**	**75.6**
45651	Bammel	138	50	24 0	47.9	15.1	30.1	26.2	52.4	16 1	32.2	24 0	48 0	15 1	30.2	24 0	48.1	15.1	30 2	24.0	48.1	15.1	30.2	24.0	48.1	15.1	30.2
46100	North Belt	345	50	40.3	80.7	29.6	59.2	40 4	80 7	29.6	59.2	40.3	80.7	29.6	59.2	40.3	80.7	29.6	59.2	40.3	80 7	29 6	59 2	40 3	80.7	29.6	59.2
46110	North Belt	138	63	56 1	89 0	44 3	70.3	57.3	91.0	45 3	71.9	56 2	89 2	44 4	70.5	56 3	89.3	44 5	70 6	56.2	89 3	44.5	70 6	56.2	89 3	44 5	70 6
46660	Willow	138	63	24 2	38.5	14 7	23.3	28.9	45.9	18 1	28 8	24 6	39 0	15 0	23 8	25 0	39 6	15 3	24 2	25 0	39 6	15.3	24 2	25.0	39 6	15 3	24 2

As seen in Table 9, the Addicks 138 kV bus is at 98.1% in the base case and increases for each of the options studied. In all three options, the estimated fault duty at the Addicks 138 kV bus is close enough to the breaker ratings to justify upgrading the impacted breakers.

7. Cost Estimates

From the steady-state power flow and fault duty analysis results, cost estimates were developed for each option to relieve the thermal overloading of the autotransformers and transmission lines and eliminate low voltage problems in the northwestern part of CenterPoint Energy's transmission system. Table 10 shows the itemized list of anticipated expenses required to implement each of the proposed options. Based on these anticipated expenses, Option 2 to expand Zenith to a 345/138kV substation offers the most cost-effective solution ($26,640,000) of all the options. Option 1 to add new 345/138kV 800MVA autotransformer at THW with other system improvements is the next most cost-effective option at $28,247,000.

Table 10: Cost Estimates for the Proposed Options.

Study Option	Recommended Solution	kV	Miles	Transmission Cost, $$	Substation Cost, $$
Option 1	Add New 800/1000MVA Auto @TH Wharton parallel to existing Auto #1	345/138		$0	$12,300,000
	Reconductor Ckt.76 Cy-Fair to Kluge with 2-959 ACSS (838/838 MVA)	138	4.63	$1,300,000	$0
	Upgrade Ckt 76 Addicks to Satsuma to 717/870MVA rating.	138	4.25	$100,000	$85,000
	Reconductor Ckt.76 Satsuma to Gertie with 2-959 ACSS (838/838 MVA).	138	9.93	$2,800,000	$0
	Build New Ckt.1 Klein to TH Wharton	138	7.12	$5,000,000	$780,000
	Convert Klein into breaker substation, replace line relaying between Klein and Willow and add 80MVAR cap bank @Klein.	138		$175,000	$3,207,000
	Upgrade 138kV breakers @Addicks with 80KA.	138			$2,500,000
	Sub Total Cost			**$9,275,000**	**$18,872,000**
	Total Cost.			**$28,247,000**	
Option 2	Expand Zenith to a 345/138kV substation: Loop Ckt 76 Addicks to Kluge and Ckt.21 Camron to Kluge @Gertie corner to Zenith 138kV bus to create two new circuits and reconfigure Ckt.21 from Camron to Kluge :	138		$4,900,000	$0
	Ckt.1 Zenith to Gertie to Satsuma to Addicks:	138			
	Reconductor Ckt.1 Gertie to Satsuma with 2-795 ACSR (455/580 MVA).	138	1.49	$440,000	$0
	Build Ckt.1 Zenith to Gertie	138	4.93	Included in Loop ckts to Zenith	$0
	Ckt.2 Zenith to Gertie to Cy-Fair to Kluge	138			
	Build Ckt.2 Zenith to Gertie	138	4.93		$0
	Reconductor Ckt.2 Gertie to Cy-Fair with 2-959 ACSS (838/838 MVA)	138	2.35	$700,000	$0
	Reconductor Ckt.2 Cy-Fair to Kluge with 2-959 ACSS (838/838 MVA)	138	4.63	$1,300,000	$0
	Add New 800/1000 MVA Auto @Zenith substation	345/138		$0	$ 16,800,000
	Upgrade 138kV breakers @Addicks to min 80KA	138			$2,500,000
	Sub Total Cost			**$7,340,000**	**$ 19,300,000**
	Total Cost			**$26,640,000**	

Study Option	Recommended Solution	kV	Miles	Transmission Cost, $$	Substation Cost, $$
Option 3a	Build a New 345/138kV substation at Gertie Corner:				
	Loop 345kV Ckt.71 and Ckt.98 TH Wharton to Zenith @Gertie corner to New Sub 345kV bus	345		$3,650,000	$0
	Loop Ckt.76 Addicks to Kluge and Ckt.21 Camron to Kluge to New Sub 138kV bus to create 2 new circuits and reconfigure Ckt.21 to Camron to Kluge :	138			$0
	Ckt.1 New Sub to Gertie to Satsuma to Addicks:	138			
	Build Ckt.1 New Sub to Gertie	138	0.4	$1,150,000	$0
	Reconductor Ckt.1 Gertie to Satsuma with 2-795 ACSR (455/580 MVA).	138	1 49	$440,000	$0
	Ckt.2 New Sub to Gertie to Cy-Fair to Kluge	138			
	Build Ckt.2 New Sub to Gertie	138	0.4	Included in Build Ckt.1 New Sub to Gertie	$0
	Reconductor Ckt.2 Gertie to Cy-Fair with 2-959 ACSS (838/838 MVA)	138	2.35	$700,000	$0
	Reconductor Ckt.2 Cy-Fair to Kluge with 2-959 ACSS (838/838 MVA).	138	4.63	$1,300,000	$0
	Add 800/1000MVA Auto @New Substation at Gertie Corner	345/ 138		$0	$25,700,000
	Upgrade 138kV breakers @Addicks to min 80KA	138			$2,500,000
	Sub Total Cost			**$7,240,000**	**$28,200,000**
	Total Cost			**$35,440,000**	
Option 3b	Build a New 345/138kV substation at Gertie Corner:				
	Loop 345kV Ckt.98 TH Wharton to Zenith to New Sub 345kV bus	345		$2,450,000	$0
	Loop Ckt.76 Addicks to Kluge and Ckt.21 Camron to Kluge to New Sub 138kVbus to create 2 new circuits and reconfigure Ckt.21 to Camron to Kluge :	138			
	Ckt 1 New Sub to Gertie to Satsuma to Addicks.	138			
	Build Ckt 1 New Sub to Gertie	138	0.4	$1,150,000	$0
	Reconductor Ckt.1 Gertie to Satsuma with 2-795 ACSR (455/580 MVA).	138	1.49	$440,000	$0
	Ckt.2 New Sub to Gertie to Cy-Fair to Kluge	138			
	Build Ckt.2 New Sub to Gertie	138	0.4	Included in Build Ckt 1 New Sub to Gertie	$0
	Reconductor Ckt.2 Gertie to Cy-Fair with 2-959 ACSS (838/838 MVA).	138	2.35	$700,000	$0
	Reconductor Ckt.2 Cy-Fair to Kluge with 2-959 ACSS (838/838 MVA).	138	4 63	$1,300,000	$0
	Add 800/1000MVA Auto @New Substation at Gertie Corner	345/ 138		$0	$23,900,000
	Upgrade 138kV breakers @Addicks to min 80KA	138			$2,500,000
	Sub Total Cost			**$6,040,000**	**$26,400,000**
	Total Cost			**$32,440,000**	
Option 3c	Build a New 345/138kV substation at Gertie Corner:				
	Loop 345kV Ckt.71 TH Wharton to Zenith to New Sub 345kV bus.	345		$2,450,000	$0
	Loop Ckt 76 Addicks to Kluge and Ckt.21 Camron to Kluge to New Sub 138kV bus to create two new circuits and reconfigure Ckt.21 to Camron to Kluge :	138			
	Ckt.1 New Sub to Gertie to Satsuma to Addicks:	138			
	Build Ckt.1 New Sub to Gertie	138	0.4	$1,150,000	$0
	Reconductor Ckt.1 Gertie to Satsuma with 2-795 ACSR (455/580 MVA).	138	1.49	$440,000	$0
	Ckt 2 New Sub to Gertie to Cy-Fair to Kluge	138			
	Build Ckt.2 New Sub to Gertie	138	0 4	Included in Build Ckt.1 New Sub to Gertie	$0
	Reconductor Ckt.2 Gertie to Cy-Fair with 2-959 ACSS (838/838 MVA).	138	2.35	$700,000	$0
	Reconductor Ckt.2 Cy-Fair to Kluge with 2-959 ACSS (838/838 MVA).	138	4.63	$1,300,000	$0
	Add 800/1000MVA Auto @New Substation at Gertie Corner	345/ 138		$0	$23,900,000
	Upgrade 138kV breakers @Addicks to min 80KA	138			$2,500,000
	Sub Total Cost			**$6,040,000**	**$26,400,000**
	Total Cost			**$32,440,000**	

To summarize, Option 2 is estimated to cost $26,640,000 which is less than Option 1 ($28,247,000), Option 3a ($35,440,000), and Options 3b and Option 3c ($32,440,000). Option 1 and Option 2 are superior from a stand point of estimated cost; therefore, none of the Option 3 alternatives will be considered further.

8. Sensitivity Study

While Option 2 is the most cost-effective option, Option 1 is close enough in cost and performance to merit additional consideration. To that end, a sensitivity study was undertaken to consider the long-term performance of Options 1 and 2. The 2013 northwestern load was increased by an additional 10% and contingency analysis was again performed. Tables A and B list the single contingency line loading and voltage violations from the analysis. Tables C and D list the common mode contingency line loading and voltage violations from the analysis.

Table A: Thermal loading results in % during single (category B) contingency.

Overloaded Line	Category B Contingency	kV	Rate A	2013 Base Case w/ increased load	
				Opt 1	Opt 2
Ckt 21 Camron to Cyfair	Ckt.81 THW to Willow	138	455	N/A	99.0
A1 @ TH Wharton	Ckt.21 THW to Camron	345/138	800	97.1	101.4
	A4 @ THW			104.3	N/A
A2 @O'Brien	A1 @O'Brien	345/138	400	98.8	95.5
A3 @O'Brien	A2 @O'Brien	345/138	400	104.2	100.6

Table B: Low voltage results during single (category B) contingency.

Buses		Category B Contingency	kV	2013 Base Case w/ increased load	
				Opt 1	Opt 2
45711	Cyfair21	Ckt.81 Kluge to Klein	138	0.947	>0.95
45712	Cyfair76	Ckt.81 THW to Willow	138	0.920	>0.95
		Ckt.81 Kluge to Klein		0.937	>0.95
45802	Gertie76	Ckt.81 Kluge to Klein	138	0.941	>0.95
45940	Klein	Ckt.81 THW to Willow	138	>0.95	0.944
45952	Kluge	Ckt.81 Kluge to Klein	138	0.938	>0.95
46660	Willow	Ckt.81 THW to Willow	138	>0.95	0.943

Table C: Thermal loading results in % during single (category C) contingency.

Overloaded Line	Category C Contingency	kV	Rate B	2013 Base Case w/ increased load Opt 1	2013 Base Case w/ increased load Opt 2
Ckt.21 THW to Camron	Ckt.81 Kluge to Klein & Ckt.76 Kluge to Addicks	138	789	114.3	N/A
Ckt.21 Camron to Gertie	Ckt.81 Kluge to Klein & Ckt 76 Kluge to Addicks	138	893	99.4	N/A
Ckt.76 Addicks to Satsuma	Ckt.21 Kluge to Camron & Ckt.81 Kluge to Klein	138	789	132.8	N/A
Ckt 76 Satsuma to Gertie	Ckt.21 Kluge to Camron & Ckt 81 Kluge to Klein	138	580	153.0	N/A
Ckt.81 Klein to Kluge	Ckt 21 Camron to THW & Ckt 76 Addicks to Kluge	138	789	117.2	N/A
Ckt.81 Kluge to Pinehurst	Ckt.21 Kluge to Camron & Ckt.81 Kluge to Klein	138	455	110	N/A
A1 @ THW	A1 @Zenith & Ckt.1 Zenith to Addicks	345/138	914	N/A	106
A2 @ North Belt	A3 @N_Belt & A1_@N_Belt	345/138	672	98.5	103.9

Table D: Low voltage results during single (category C) contingency.

Buses		Category C Contingency	kV	2013 Base Case w/ increased load Opt 1	2013 Base Case w/ increased load Opt 2
44910	Zenith	A1 @Zenith & Ckt.1 Zenith to Addicks	138	N/A	0.8773
45700	Camron	Ckt.21 Camron to THW_E & Ckt.76 Kluge to Addicks	138	0.8636	N/A
45711	Cyfair21	Ckt.81 Kluge to Klein & Ckt.76 Kluge to Addicks	138	0.8509	N/A
		Ckt 21 Camron to THW_E & Ckt 76 Kluge to Addicks		0.8738	N/A
45712	Cyfair76	Ckt.21 Kluge to Camron & Ckt.81 Kluge to Klein	138	0.7824	N/A
		A1 @Zenith & Ckt.1 Zenith to Addicks		N/A	0.893
45801	Gertie21	Ckt 21 Camron to THW_E & Ckt.76 Kluge to Addicks	138	0.8639	N/A
		A1 @Zenith & Ckt.1 Zenith to Addicks		N/A	0.8772
45802	Gertie76	Ckt.21 Kluge to Camron & Ckt.81 Kluge to Klein	138	0.7976	N/A
45940	Klein	Ckt.81 THW to Willow & Ckt.1 THW to Klein	138	0.9078	N/A
45952	Kluge	Ckt.21 Kluge to Camron & Ckt.81 Kluge to Klein	138	0.7829	N/A
		Ckt.2 Zenith to Kluge & Ckt.81 Kluge to Klein		N/A	0.9166
46240	Pinehurst	Ckt.21 Kluge to Camron & Ckt.81 Kluge to Klein	138	0.8990	N/A
		Ckt.21 Camron to THW_E & Ckt 76 Kluge to Addicks		0.8636	N/A
46660	Willow	Ckt.81 THW to Willow & Ckt.1 THW to Klein	138	0.9071	N/A

The single contingency results from Table A do not show a large difference in performance between the options and the results indicate that additional autotransformer capacity will be needed in the future. The single contingency voltages from Table B show Option 1 with several violations as low as 0.92pu indicating a need for additional capacitor banks on the system. Option 2 only shows a couple of voltages that are slightly below 0.95pu and those could be remedied by adding a smaller capacitor bank.

The common mode contingency results in Table C indicate Option 1 with significant overloading problems in the area, such as ckt.76 Satsuma to Gertie tap at 153% of 580 MVA, ckt.76 Addicks to Satsuma at 133% of 789 MVA, ckt.81 Kluge to Klein at 117% of 789 MVA, and ckt.21 THW to Camron at 114% of 789 MVA. Reaching these loading levels would require CenterPoint Energy to undertake another costly and involved project such as another new line, reconfiguration, or reconductoring with even higher capacity conductors. The results for Option 2 show that it performs significantly better under these higher load levels as can be seen in Table C. Only two autotransformer overloads are seen (THW Auto #1 and North Belt Auto #2); however, the single contingency analysis already indicated that more autotransformer capacity is eventually needed for both Options 1 and 2. The voltage violations shown in Table D correspond with the line loading results by indicating severe problems with Option 1. Numerous voltages are below 0.9pu with three substations (Cyfair, Gertie, Kluge) below 0.8pu. Table D also shows three voltage violations below 0.9pu for Option 2, which would have to be remedied, most likely with a 138 kV capacitor bank at the Zenith substation.

9. Conclusion

A number of factors, beyond the estimated cost, argue for choosing Option 2 over Option 1, such as the fact that the loss of the tower shared by 138kV ckt.76 from Addicks to Kluge and ckt.21 from Kluge to Camron for an approximate length of 14 miles will cause the loss of both CenterPoint Energy distribution substations Gertie and Cyfair. The total load at these substations reached 370MW in the summer of 2008. Under the system reconfiguration proposed in Option 2, there is no common mode contingency that will result in the loss of both of these distribution substations. Also, Option 2 solves the common mode contingency resulting in the highest overloading, which is the loss of the tower shared by 138kV ckt.76 from Addicks to Kluge and ckt.21 TH Wharton to Camron for an approximate length of five miles. In addition, the sensitivity study that was performed to test performance beyond the five year planning horizon indicates a significant advantage in performance of Option 2 when compared to Option 1. These results show Option 2 to be the more robust solution.

Option 2 does not add autotransformer capacity to a site with two or more existing autotransformers. This reduces the risk associated with loss of a substation, which is a NERC Category D contingency. In addition, a new 345/138kV autotransformer installed at the Zenith substation will increase the transmission system flexibility in the northwestern Houston area. The Zenith substation is an excellent location to consider 138 kV expansion to the south and west to strengthen the system around the growing Katy area or to the north towards the Hockley area or both. Proceeding with Option 1 would not have this advantage, which simply adds one circuit and one autotransformer at existing locations.

Based on the results of the steady-state load flow studies comparing the capabilities of the existing infrastructure with several system upgrade proposals, CenterPoint Energy recommends building Option 2 as the most cost-effective solution to address the predicted reliability concerns within the northwestern Houston area.

CenterPoint Energy estimates completing all of the listed projects by summer peak 2012, which considers the lead times necessary to implement the proposed projects, including ERCOT review and approval, regulatory review and approval, and material and construction lead times. Overall schedule assumptions include the following:

- review and approval by ERCOT in the summer 2009
- submittal of a CCN to the Public Utility Commission in 1st quarter 2010
- approval of CCN in 1st quarter 2011 (one year review)
- material acquisition and construction completion by peak 2012.

Minor schedule adjustments are anticipated and should not impact the estimated in-service by summer peak 2012.

The project could be completed sooner in 2011 should ERCOT designate this project as "critical to reliability", which would shorten the project calendar by six months by shortening the CCN approval deadline from one year to six months. With the "ERCOT Critical" designation, the overall schedule assumptions include the following:

- review and approval by ERCOT in the summer 2009
- submittal of a CCN to the Public Utility Commission in 1st quarter 2010
- approval of CCN in 3rd quarter 2010 (6 months review)
- material acquisition and construction completion by peak 2011.

This schedule is highly dependent upon an expedited regulatory review process and could be delayed should ERCOT or the Public Utility Commission require additional review time to approve this project.

Appendix A.

Changes made to posted SSWG cases dated 12/04/2007

1. Changed circuit IDs for CenterPoint Energy tie lines.
2. Added zero sequence data for CenterPoint Energy system.
3. Moved swing bus to Oncor (Monticello #1703).
4. Added Unit #4 generation at Cedar Bayou Plant (#48583, #48584 & #48585).
5. Added customer owned Bender substation looped into ckt.86 Barhill to Crosby (#40155).
6. Disconnected and removed customer owned Simson substation from CenterPoint Energy's ckt.23 Deepwater to S.R. Bertron (#41460 removed).
7. Added Rothwood 345/138kV substation (#46290/#46295).
8. Converted Rayford 138kV substation into a loop tap connection (#46262 removed).
9. Upgraded 138kV ckt.66 Tomball to Rothwood to Rayford to Louetta.
10. Added Unit #4 generation at Cedar Bayou Plant (#48583, #48584 & #48585).
11. Added MLSE and CAPE updates for the TPIT February 1, 2008 submittal.

CenterPoint™ Energy

Jones Creek Project

July 1, 2014

Prepared by:

CenterPoint Energy Houston Electric, LLC

Transmission Planning

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Executive Summary

CenterPoint Energy Houston Electric, LLC (CenterPoint Energy) submits the Jones Creek Project for the Electric Reliability Council of Texas (ERCOT) Regional Planning Group (RPG) review. The proposed Jones Creek Project consists of the following:

- Construct a new 345/138 kV CenterPoint Energy "Jones Creek" Substation;
- Install two new 800 MVA normal rating / 1000 MVA emergency rating (800/1000 MVA) 345/138 kV autotransformers at the Jones Creek Substation;
- Loop the 345 kV Dow-STP circuit 18 into the Jones Creek Substation;
- Loop the 138 kV Freeport-Velasco circuit 59 into the Jones Creek Substation;
- Upgrade the Velasco 138 kV Substation to a fault duty rating of 63 kA;
- Split and reconfigure circuits in the Freeport area creating: 138 kV Velasco-SURFSI-Freeport-Jones Creek circuit 59, 138 kV Velasco-QNTANA-Jones Creek circuit 48, and 138 kV Velasco-Jones Creek circuit 59;
- Reconfigure 138 kV Velasco-Franklins Camp circuit 02 to create 138 kV Jones Creek-Franklins Camp circuit 02;
- Upgrade the 138 kV Jones Creek-QNTANA circuit 48 and 138 kV QNTANA-Velasco circuit 48 with 838 MVA normal rating / 894 MVA emergency rating (838/894 MVA); and,
- Install a new 138 kV 120 MVAR capacitor bank at the Jones Creek Substation.

The project (identified as Option 2 in this study) is recommended as the most cost-effective solution to serve future area load growth in the Freeport area. CenterPoint Energy considered and rejected two other options including adding additional 345/138 kV autotransformers at the Dow-Velasco Substation and constructing additional 138kV transmission lines from West Columbia and Angleton Substations to the Freeport area.

The Jones Creek Project is needed to serve a new 721 MW load associated with a proposed natural gas liquefaction and export facility being developed by Freeport LNG (the Customer) in the Freeport area. Freeport LNG is expected to sign a service extension agreement with CenterPoint Energy in the third quarter of 2014 for that facility with a planned operational date of the third quarter of 2017. Although the Customer has not executed the agreement, CenterPoint Energy has been provided the information to proceed with determining the transmission system requirements. The existing transmission system cannot reliably provide service to 721 MW of new load in the Freeport area without significant improvements. Therefore, CenterPoint Energy is submitting this project to the ERCOT RPG prior to the Customer's final investment decision, so that if the Customer securitizes the cost of the transmission project and signs a service extension agreement with CenterPoint Energy, the transmission project can be completed in time to serve the new Customer's load. The transmission project will only proceed if the Customer or other potential customers in the area securitize the cost of the transmission project.

CenterPoint Energy plans to complete the Jones Creek Project by the second quarter of 2017 in preparation for the Customer's load addition. This timeline takes into consideration the typical lead times necessary to implement the proposed projects, including ERCOT review and approval, and materials and construction lead times. The total estimated cost for the project is $79.78 million.

Background

The Freeport area is a highly industrialized area with several large chemical facilities as well as a major seaport on the Gulf of Mexico that is served by the CenterPoint Energy transmission system. CenterPoint Energy has received several inquiries involving significant load growth in the Freeport area. Of these, Freeport LNG has publicly announced their Liquefaction and Export Project in the Freeport area. Freeport LNG has also announced that agreements have been reached to provide liquefied natural gas (LNG) capacity using all three liquefaction trains contemplated by the project. A new 721 MW load is associated with the Project in the vicinity of Freeport LNG's QNTANA Substation and is planned to be operational in the third quarter of 2017 with full load by third quarter of 2018. Federal Energy Regulatory Commission (FERC) authorization to construct and operate the facility and a final investment decision by the Customer is expected in the third quarter of 2014.

Freeport LNG has also publicly announced their Pretreatment Facility (PTF) north of the Freeport area, which will be built in conjunction with the Liquefaction and Export Project. The PTF project requires building a new 138 kV transmission line to the new CenterPoint Energy Oyster Creek Substation to connect expected generation and load located at the Freeport LNG PTF site.[1] CenterPoint Energy filed an application for a Certificate of Convenience and Necessity (CCN) with the Public Utility Commission of Texas (PUC) to build the line to the Oyster Creek Substation and the application was approved on January 27, 2014 (see PUC Docket No. 41749 for the 138 kV Oyster Creek Project). Freeport LNG has signed a Standard Generator Interconnection Agreement. CenterPoint Energy plans to construct the 138 kV Oyster Creek Project before peak 2017 pending receipt of the Notice to Proceed from Freeport LNG.

The ERCOT RPG endorsed the "Freeport Area Upgrades" project in 2012 for completion in 2015. The Freeport Area Upgrades project includes the following upgrades:

- Convert and parallel bundle the 69 kV Velasco-SURFSI circuit 10 and the SURFSI-QNTANA-Freeport-Velasco circuit 47 to 138 kV operation by rebuilding the existing structures to a single circuit, parallel bundled 2-959 ACSS configuration (i.e. 4 wires per phase). Convert the 69 kV Freeport - BRYAN circuit 47 to 138kV operation;
- Convert the 69 kV Velasco-Retrieve-West Columbia 69kV circuit 47 to 138kV operation and parallel bundle with the existing 138 kV West Columbia-Lake Jackson-HOFMAN-BASF-Brazosport-Velasco circuit 02. Convert the Retrieve Substation to 138kV operation and move to the 138 kV circuit 02; and,
- Upgrade the 138 kV West Columbia–Retrieve–Lake Jackson circuit 02.

The ERCOT RPG also endorsed the "Dow–Velasco 345/138 kV Autotransformer Addition" in May 2014, which included the addition of a new 800 MVA normal rating / 1000 MVA emergency rating (800/1000 MVA) 345/138 kV autotransformer at the Dow-Velasco Substation in 2016.

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[1] ERCOT Generation Interconnection Request 16INR0003 and CenterPoint Energy Full Interconnection Study Report for New Generation, Freeport LNG Expansion, L.P., Pre-Treatment Facility (PTF), May 13, 2013.

Once the Freeport Area Upgrades project and Dow–Velasco 345/138 kV Autotransformer Addition project are complete, load in the Freeport area will be served by two long 138 kV circuits from Angleton, one long 138 kV circuit from West Columbia, and two 345/138 kV 800/1000 MVA autotransformers at the Dow-Velasco Substation as shown in Figure 1.

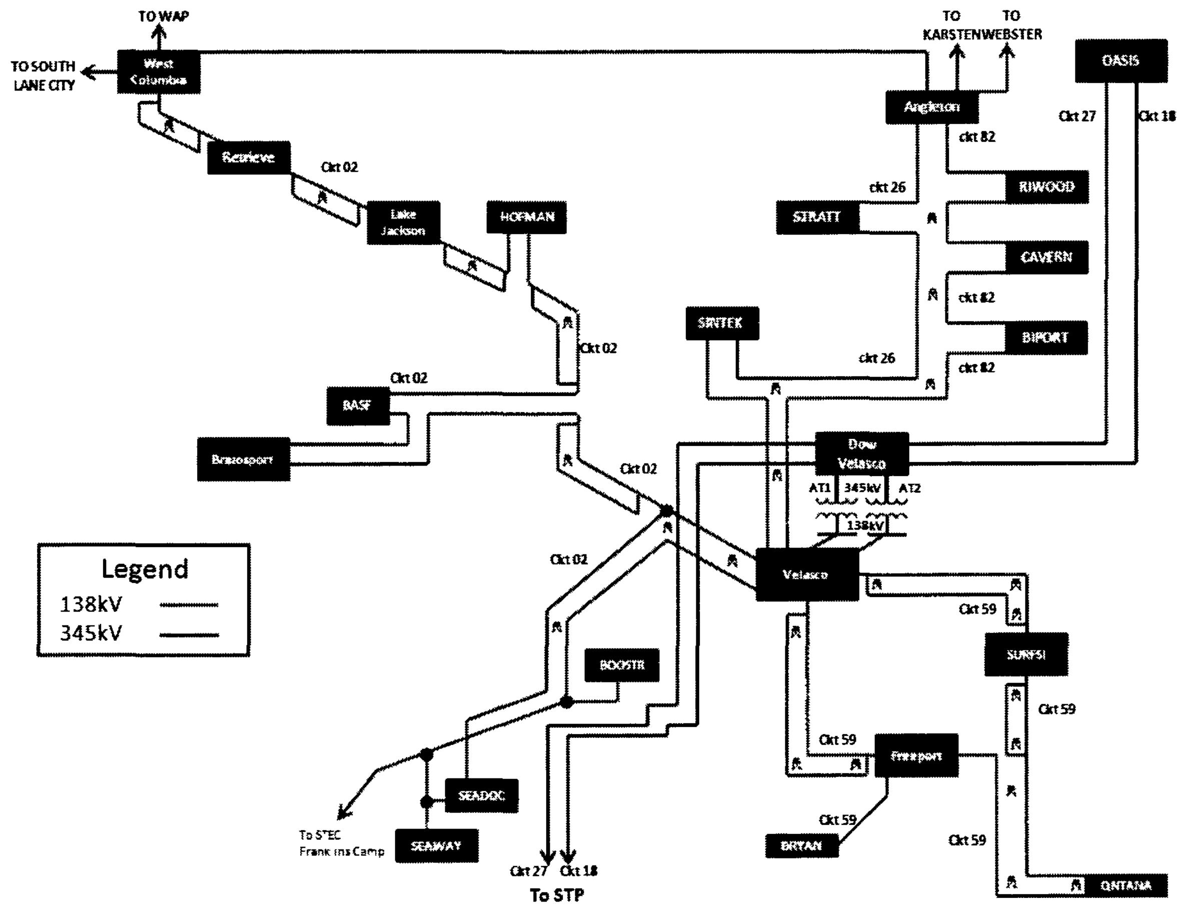


Figure 1: 2017 Freeport Area Summer Peak Configuration

Study Assumptions

The study is based on the load forecast, generation pattern, and network topology projected for 2017 summer peak conditions contained in the ERCOT Steady-state Working Group (SSWG) base cases posted on October 15, 2013. The base case used for this study was built off of the ERCOT SSWG 2017 summer peak base case (CNP_2017_SUM1_10152013_11152013) and contains the changes listed in Appendix A.

A study case was created from the 2017 summer peak case with the following revisions:

Study Case (Figure 2):

- Increased load at the 138 kV QNTANA Substation by 721 MW
- Increased generation ERCOT-wide to balance the new load
- Added Oyster Creek Substation with 109 MW load , 82 MW generator, and 40 MVAR capacitor bank

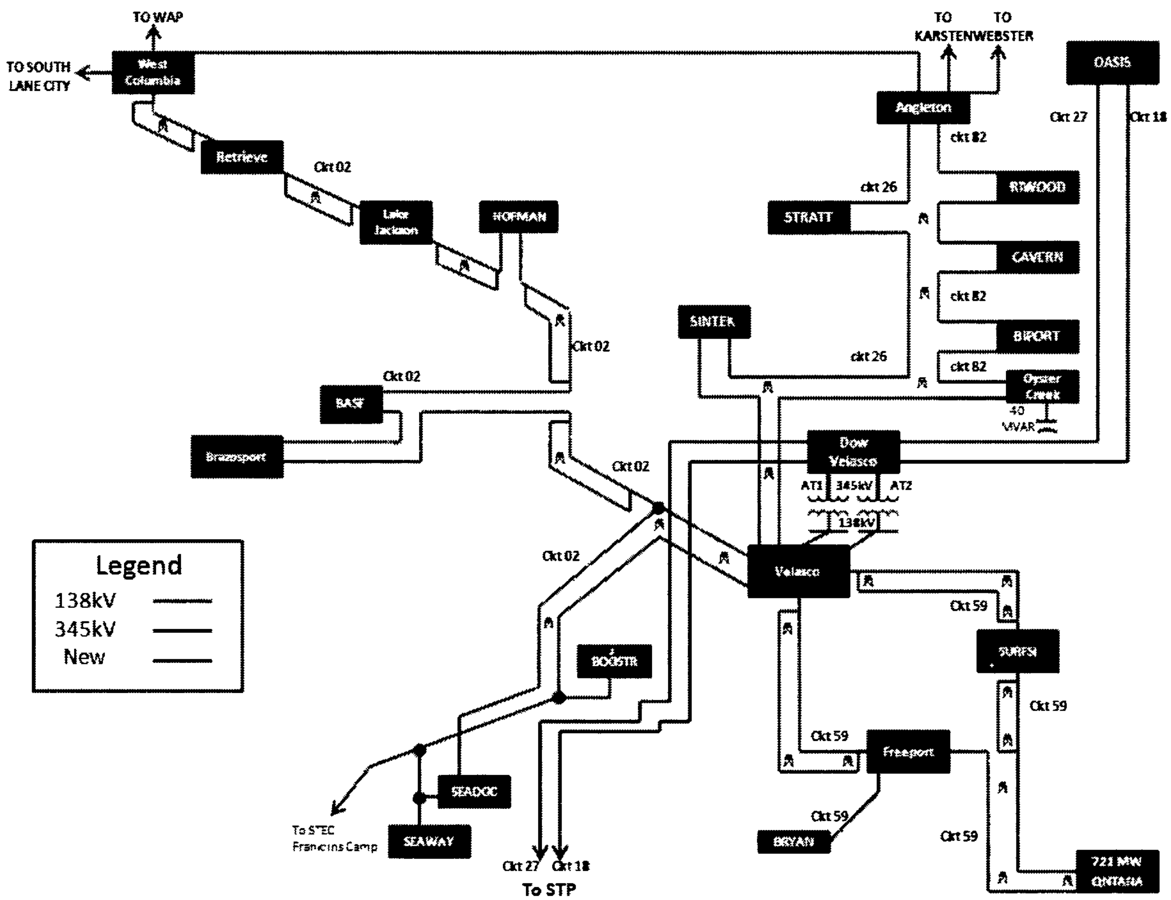


Figure 2: Study Case

Study Case Steady-State Results

CenterPoint Energy performed contingency analysis for NERC Category B (single) contingencies, NERC Category C (common mode) contingencies, and contingencies relating to the ERCOT autotransformer unavailability criteria in Section 4.1.1.2 of the ERCOT Planning Guides on the 2017 summer peak case as well as the Study Case detailed in the Study Assumptions above. The results are shown in Tables 1 through 4. For NERC Category B analysis, the normal rating was used as the applicable rating to determine thermal loading issues, and voltage less than 0.95 p.u. was used to identify low voltage issues. For analyses relating to NERC Category C and the ERCOT autotransformer unavailability criteria, the emergency rating was used as the applicable rating to determine thermal loading issues, and voltage less that 0.92 p.u. was used to identify low voltage issues.

			Loading % of Rating	
Overloaded Branch	**Rating (MVA)**	**Contingency**	**2017 Summer Peak Case**	**Study Case**
42515 - 43360 <CKT 83> DOW_____138A TO VLASCO__138A	853	DOW VELASCO AUTOTRANSFORMER A1	< 95.0 %	112.7%
DOW VELASCO AUTOTRANSFORMER A2	800		< 95.0 %	131.9%
DOW VELASCO AUTOTRANSFORMER A1	800	DOW VELASCO AUTOTRANSFORMER A2	< 95.0 %	132.5%
42510 - 43360 <CKT 82> DOW_____138B TO VLASCO__138A	853		< 95.0 %	113.2%
42640 - 43135 <CKT 47> FREEPT__138X TO QNTANA__138X	528	43310 - 43360 <CKT 59> SURFSI__138X TO VLASCO__138A	< 95.0 %	156.3%
42640 - 43360 <CKT 48> FREEPT__138X TO VLASCO__138A	838		< 95.0 %	102.4%
43135 - 43310 <CKT 59> QNTANA__138X TO SURFSI__138X	528	42640 - 43360 <CKT 48> FREEPT__138X TO VLASCO__138A	< 95.0 %	161.4%
43310 - 43360 <CKT 59> SURFSI__138X TO VLASCO__138A	838		< 95.0 %	103.2%

Table 1: Thermal loading results under NERC Category B contingency analysis

			Voltage in per unit	
BUSES	**Nominal Voltage**	**Contingency**	**2017 Summer Peak Case**	**Study Case**
42200 BRYAN___138X	138KV	42640 - 43360 <CKT 48> FREEPT__138X TO VLASCO__138A	> .950	0.933
42640 FREEPT__138X	138KV		> .950	0.933
43135 QNTANA__138X	138KV		> .950	0.933
43310 SURFSI__138X	138KV	43310 - 43360 <CKT 59> SURFSI__138X TO VLASCO__138A	> .950	0.933
43135 QNTANA__138X	138KV		> .950	0.934

Table 2: Voltage results under NERC Category B contingency analysis

Overloaded Branch	Rating (MVA)	Contingency	Loading % of Rating: 2017 Summer Peak Case	Loading % of Rating: Study Case
-	-	DOW VELASCO AUTOTRANSFORMER A1 AND DOW VELASCO AUTOTRANSFORMER A2	< 100.0 %	Did Not Solve
DOW VELASCO AUTOTRANSFORMER A2	1000	42510 - 43360 <CKT 82> DOW_____138B TO VLASCO__138A & 43310 - 43360 <CKT 59> SURFSI__138X TO VLASCO__138A	< 100.0 %	111.0%
42515 - 43360 <CKT 83> DOW_____138A TO VLASCO__138A	996		< 100 0 %	100 6%
42640 - 43135 <CKT 47> FREEPT__138X TO QNTANA__138X	562		< 100.0 %	148.0%
DOW VELASCO AUTOTRANSFORMER A2	1000	42510 - 43360 <CKT 82> DOW_____138B TO VLASCO__138A & 42640 - 43360 <CKT 48> FREEPT__138X TO VLASCO__138A	< 100.0 %	111.5 %
42515 - 43360 <CKT 83> DOW_____138A TO VLASCO__138A	996		< 100.0 %	101 2 %
43135 - 43310 <CKT 59> QNTANA__138X TO SURFSI__138X	562		< 100.0 %	153.1 %
43135 - 43310 <CKT 59> QNTANA__138X TO SURFSI__138X	562	DOW VELASCO AUTOTRANSFORMER A1 AND 42640 - 43360 <CKT 48> FREEPT__138X TO VLASCO__138A	< 100.0 %	153.1%
42515 - 43360 <CKT 83> DOW_____138A TO VLASCO__138A	996		< 100.0 %	101.2%
DOW VELASCO AUTOTRANSFORMER A2	1000		< 100.0 %	111 5%
42515 - 43360 <CKT 83> DOW_____138A TO VLASCO__138A	996	DOW VELASCO AUTOTRANSFORMER A1 AND 43145 - 43380 <CKT 02> RETREV__138 TO W_COL___8010	< 100 0 %	107.9%
DOW VELASCO AUTOTRANSFORMER A2	1000		< 100.0 %	119 1%
42640 - 43135 <CKT 47> FREEPT__138X TO QNTANA__138X	562	DOW VELASCO AUTOTRANSFORMER A1 AND 43310 - 43360 <CKT 59> SURFSI__138X TO VLASCO__138A	< 100 0 %	147.9 %
42515 - 43360 <CKT 83> DOW_____138A TO VLASCO__138A	996		< 100.0 %	100.6%
DOW VELASCO AUTOTRANSFORMER A2	1000		< 100 0 %	110 9%
42510 - 43360 <CKT 82> DOW_____138B TO VLASCO__138A	996	DOW VELASCO AUTOTRANSFORMER A2 AND 43145 - 43380 <CKT 02> RETREV__138 TO W_COL___8010	< 100.0 %	108.1%
DOW VELASCO AUTOTRANSFORMER A1	997		< 100.0 %	118.2%

Table 3: Thermal loading results under NERC Category C and ERCOT autotransformer unavailability contingency analysis

BUSES	Nominal Voltage	Contingency	Voltage in per unit	
			2017 Summer Peak Cae	Study Case
42500 DOW_____345A	345KV	5915 - 42500 <CKT 18> SO_TEX__345A TO DOW_____345A & 5915 - 42500 <CKT 27> SO_TEX__345A TO DOW_____345A	> .920	0.918
42500 DOW_____345A	345KV	THW AUTOTRANSFORMER A3 AND 5915 - 42500 <CKT 18> SO_TEX__345A TO DOW_____345A & 5915 - 42500 <CKT 27> SO_TEX__345A TO DOW_____345A	> .920	0.915

Table 4: Voltage results under NERC Category C and ERCOT autotransformer unavailability contingency analysis

Discussion of Steady-State Results

As seen in Tables 1 through 4, the significant new load added in the Freeport area causes severe loading and voltage concerns. For the Study Case, in which the Freeport Area Upgrades and the second Dow-Velasco 345/138 kV autotransformer are included, the 721 MW load addition at QNTANA Substation causes several overloads under Category B conditions. These include the overload of one Dow Velasco 800 MVA autotransformer for the loss of the other Dow Velasco autotransformer as well as the overload of 138 kV Freeport–QNTANA circuit 47 and 138 kV SURFSI–QNTANA circuit 59 when losing one side or the other of the 138 kV loop from Velasco. Also, severe overloading and voltage problems occur under N-1-1 scenarios where the first N-1 situation is the loss of the Dow Velasco Autotransformer #1. There is no additional generation in the area to dispatch that could mitigate these overloads. Finally, the case does not solve under the N-1-1 loss of both Dow-Velasco autotransformers, indicating a potential voltage collapse and the inability to serve the load. These results show that significant reinforcements on the system are needed, such as a new 345 kV injection point.

Options

The Freeport area is located at the far southern edge of the CenterPoint Energy service territory, and as noted above, is currently served by three long 138 kV lines from West Columbia and Angleton Substations and one 345 kV injection point through Dow-Velasco Substation. The severe voltage and loading problems identified in the steady state results above indicate the need for a strong new injection point. To address this need, the following options were evaluated:

Option 1: Build Additional 138 kV Circuits:

CenterPoint Energy considered building additional 138 kV lines to serve the 721 MW load addition. Expansion capabilities at the Velasco 138 kV Substation were restricted by the available property limitations. Therefore, the construction of a new 138 kV CenterPoint Energy substation was evaluated at a suitable location north of the Velasco 138 kV Substation. The following projects were identified as needed, at a minimum, to serve the load:

- Build a new 4 breaker 138 kV ring bus CenterPoint Energy substation (New Substation).
- Build a new 138 kV single circuit line (on double-circuit capable towers) from the Angleton Substation to New Substation (approximately 21 miles).
- Build a new 138 kV single circuit line (on double-circuit capable towers) from the West Columbia Substation to New Substation (approximately 21 miles).
- Build a new 138 kV double-circuit line from New Substation to the Freeport Substation (approximately 5 miles).
- Expand Freeport Substation and convert to 5 breaker ring bus configuration
- Install two new 120 MVAR capacitor banks at New Substation.
- Install three new 120 MVAR capacitor banks at the Freeport Substation.

The estimated cost for this minimum set of projects exceeded $125 million and would require the acquisition of new right-of-way. Additional 138 kV circuits would have to be installed if load continued to increase. Option 1 was rejected from further consideration due to its high cost when compared to Option 2. Also there is uncertainty that the 47 miles of new 138 kV line could be completed in time to meet the planned load addition in 2017.

Option 2: Build a New 345 kV / 138 kV Substation, "Jones Creek Project"

The only nearby 345 kV transmission line to the Freeport area is the double-circuit line from STP to Dow-Velasco to Oasis, circuits 18 and 27. The Customer's new load site is located more than 5 miles south from this 345 kV transmission line in the vicinity of the existing QNTANA Substation approximately 0.5 miles from the coastline of the Gulf of Mexico.

An optimal site for a new 345/138 kV substation was evaluated at various points along the existing 345 kV STP to Dow-Velasco to Oasis line in the vicinity of the Freeport 138 kV transmission loop serving QNTANA Substation. CenterPoint Energy selected a substation site, named the Jones Creek Substation site, which integrated well with the Freeport Area Upgrades Project and provided for transmission connections of less than one mile to the 345 kV STP to Dow-Velasco line and the 138 kV Freeport to Velasco line. CenterPoint Energy has existing right-of-way for the substation and transmission facility connections to the Jones Creek Substation.

As shown in Figure 3, the "Jones Creek Project" includes the following improvements:

- Construct a new 345/138 kV CenterPoint Energy "Jones Creek" Substation;
- Install two new 800 MVA normal rating / 1000 MVA emergency rating (800/1000 MVA) 345/138 kV autotransformers at the Jones Creek Substation;
- Loop the 345 kV Dow-STP circuit 18 into the Jones Creek Substation;
- Loop the 138 kV Freeport-Velasco circuit 59 into the Jones Creek Substation;
- Upgrade the Velasco 138 kV Substation to a fault duty rating of 63 kA;
- Split and reconfigure circuits in the Freeport area creating: 138 kV Velasco-SURFSI-Freeport-Jones Creek circuit 59, 138 kV Velasco-QNTANA-Jones Creek circuit 48, and 138 kV Velasco-Jones Creek circuit 59;

- Reconfigure 138 kV Velasco-Franklins Camp circuit 02 to create 138 kV Jones Creek-Franklins Camp circuit 02;
- Upgrade the 138 kV Jones Creek-QNTANA circuit 48 and 138 kV QNTANA-Velasco circuit 48 with 838 MVA normal rating / 894 MVA emergency rating (838/894 MVA) by reconductoring with high temperature conductor; and,
- Install a new 138 kV 120 MVAR capacitor bank at the Jones Creek Substation.

The estimated cost for the improvements listed above is $79.78 million. (See additional studies provided below and cost estimate in Table 15 for details.) CenterPoint Energy can construct these improvements in time to meet the Customer's planned load addition in third quarter of 2017. Option 2 provides a cost-effective 345kV injection point to serve the expected load growth in the area while minimizing new transmission line construction, minimizing landowner impact, and reducing the lead time to complete construction.

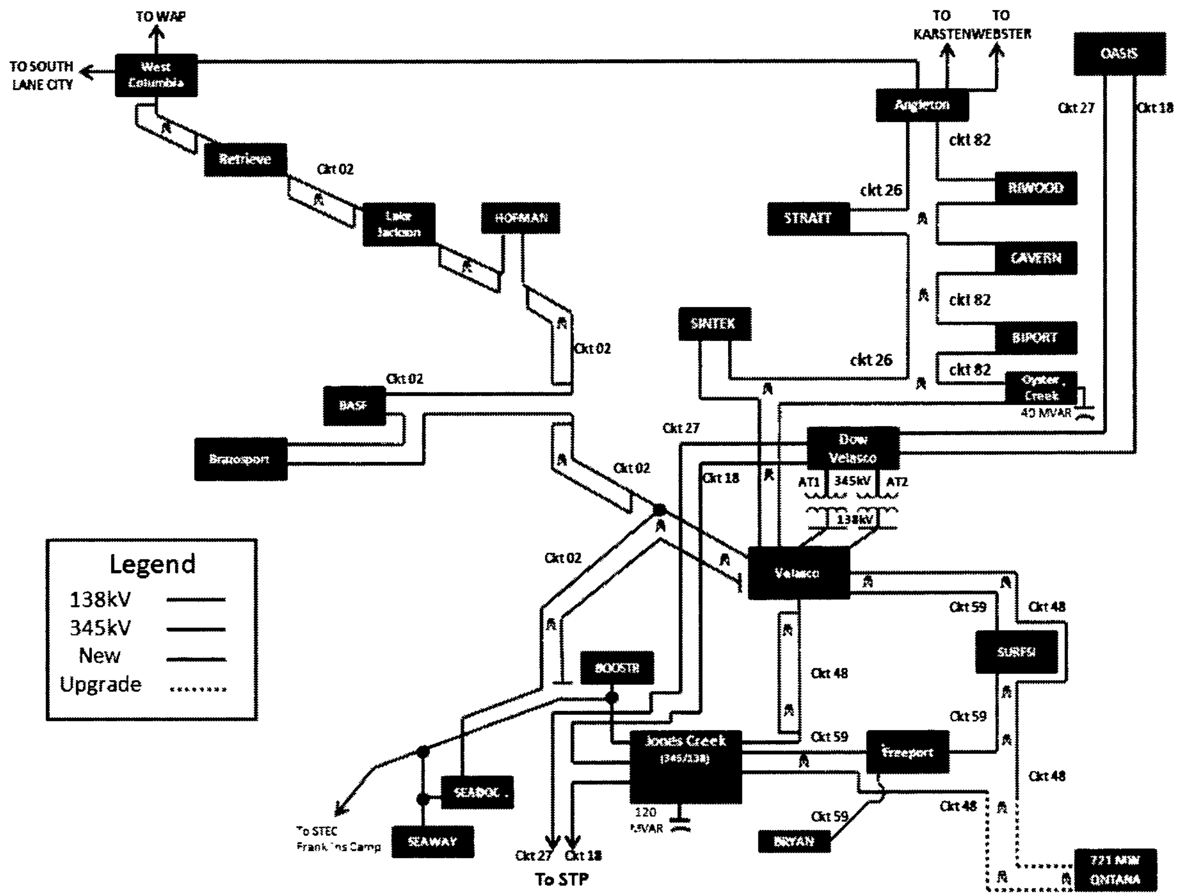


Figure 3: Jones Creek Project Configuration

Options that were eliminated prior to power flow studies

- Add Autotransformers at the Dow-Velasco Substation

CenterPoint Energy considered expanding the Dow-Velasco Substation beyond the two planned Dow-Velasco to Velasco 345/138 kV autotransformers and the three existing Dow-Velasco to Dow autotransformers. However, the Dow-Velasco substation cannot accommodate additional autotransformers. Also, by utilizing a geographically diverse site for the autotransformer additions, it limits the impact of the contingency loss of the 345 kV Dow –Velasco substation.

- Extend 345kV transmission to a site in the vicinity of the Freeport LNG site on Quintana Island and build a 345 kV to 138 kV substation.

This option was eliminated due to numerous disadvantages compared to the Jones Creek site.

- The integrity of the 345 kV transmission system is generally recognized as vital to the reliability of the bulk power system and the ability to transfer large amounts of power between regions.
    - Center Point Energy strives to locate its 345 kV assets away from areas with exposure to relatively higher risk of service disruptions. Due to extremely close proximity to open water, a 345 kV substation on Quintana Island would be more vulnerable to the tropical storms and associated storm surges and high winds as well as extremely high salt contamination.
- There is only one road for access to Quintana Island. A 345 kV substation at the Freeport LNG site could be inaccessible for an extended period in the event of either storm damage or bridge closure.
- As stated earlier, the customer's site on Quintana Island is 5 miles from the 345 kV line. The route of a 345kV transmission line to and from Quintana Island would have to circumnavigate numerous industrial facilities and water features, including Port Freeport, the Intracoastal Waterway, and a variety of marshes and wetlands.
- The Jones Creek location, in contrast to Quintana Island, provides a 345 kV injection point in the Freeport area with minor landowner impacts.
- The Jones Creek location for the 345 kV injection point, in contrast to Quintana Island, allows for more flexible 138 kV transmission service extensions as industrial development expands in the Freeport area

The need for the Jones Creek capacitor bank and 2nd autotransformer

CenterPoint Energy performed contingency analysis for NERC Category B (single) contingencies, NERC Category C (common mode) contingencies, and contingencies relating to the ERCOT autotransformer unavailability criteria on the 2017 summer peak case modeling Option 2, the Jones Creek Project, as detailed in the sections above but without the Jones Creek capacitor bank and 2nd autotransformer. Results of the analyses are shown in Tables 5 through

8. For NERC Category B analysis, the normal rating was used as the applicable rating to determine thermal loading issues, and voltage less than 0.95 p.u. was used to identify low voltage issues. For analyses relating to NERC Category C and the ERCOT autotransformer unavailability criteria, the emergency rating was used as the applicable rating to determine thermal loading issues, and voltage less that 0.92 p.u. was used to identify low voltage issues.

			Loading % of Rating
Overloaded Branch	**Rating (MVA)**	**Contingency**	**Jones Creek Project**
5915 - 42400 <CKT 18> SO_TEX__345A TO JONCRK__345A	1137	5915 - 42500 <CKT 27> SO_TEX__345A TO DOW____345A	101 3 %
5915 - 42500 <CKT 27> SO_TEX__345A TO DOW____345A	1137	5915 - 42400 <CKT 18> SO_TEX__345A TO JONCRK__345A	99.8 %

Table 5: Thermal loading results under NERC Category B contingency analysis

			Voltage in per unit
BUSES	**Nominal Voltage**	**Contingency**	**Jones Creek Project**
43135 QNTANA__138X	138KV	42410 - 43135 <CKT 59> JONCRK__138A TO QNTANA__138X	0.944

Table 6: Voltage results under NERC Category B contingency analysis

			Loading % of Rating
Overloaded Branch	**Rating (MVA)**	**Contingency**	**Jones Creek Project**
JONES CREEK AUTOTRANSFORMER A1	1000	DOW VELASCO AUTOTRANSFORMER A1 AND DOW VELASCO AUTOTRANSFORMER A2	102 8%
DOW VELASCO AUTOTRANSFORMER A1	1000	JONES CREEK AUTOTRANSFORMER A1 AND DOW VELASCO AUTOTRANSFORMER A2	105.9%
DOW VELASCO AUTOTRANSFORMER A2	1000	JONES CREEK AUTOTRANSFORMER A1 AND DOW VELASCO AUTOTRANSFORMER A1	108.2%

Table 7: Thermal loading results under ERCOT autotransformer unavailability contingency analysis

<table>
<tr><th></th><th></th><th></th><th>Voltage in per unit</th></tr>
<tr><th>BUSES</th><th>Nominal Voltage</th><th>Contingency</th><th>Jones Creek Project</th></tr>
<tr><td>42400
JONCRK__345A</td><td>345KV</td><td rowspan="2">5915 - 42400 <CKT 18>
SO_TEX__345A TO JONCRK__345A
&
5915 - 42500 <CKT 27></td><td>0.916</td></tr>
<tr><td>42500
DOW_____345A</td><td>345KV</td><td>0.919</td></tr>
<tr><td>42400
JONCRK__345A</td><td>345KV</td><td rowspan="2">THW AUTOTRANSFORMER A3
AND
5915 - 42400 <CKT 18>
SO_TEX__345A TO JONCRK__345A
&
5915 - 42500 <CKT 27>
SO_TEX__345A TO DOW_____345A</td><td>0.913</td></tr>
<tr><td>42500
DOW_____345A</td><td>345KV</td><td>0.916</td></tr>
<tr><td>43135
QNTANA__138X</td><td>138KV</td><td>JONES CREEK AUTOTRANSFORMER A1
AND
43310 - 43360 <CKT 48>
SURFSI__138X TO VLASCO__138A
&
43135 - 43360 <CKT 59>
QNTANA__138X TO VLASCO__138A</td><td>0.920</td></tr>
</table>

Table 8: Voltage results under NERC Category C and ERCOT autotransformer unavailability contingency analysis

NERC Category B analysis indicated an overload on 345 kV circuits STP-Dow circuit 27 and high loading on STP – Jones Creek circuit 18. This loading concern was analyzed in more detail in the Sensitivity Studies provided below (see Sensitivity Study 2).

Low voltage can be seen at the QNTANA 138 kV Substation under single contingency (Table 6) loss of 138 kV Jones Creek–QNTANA circuit 59. This outage leaves load at the QNTANA Substation served radially out of the Velasco Substation. Low voltage was also identified at the QNTANA 138 kV, Jones Creek 345 kV, and DOW 345 kV Substations under NERC Category C and ERCOT autotransformer unavailability analysis (Table 8). To solve the low voltage issues at the QNTANA, Jones Creek, and DOW Substations installation of a 138 kV 120 MVAR capacitor bank at the Jones Creek Substation is included in Option 2, the Jones Creek Project.

Under N-1-1 scenarios where the first N-1 situation is the loss of Jones Creek Autotransformer #1, followed by the loss of Dow-Velasco Autotransformer #1 or Autotransformer #2, overloads of the emergency rating of 1000 MVA can be seen on Dow-Velasco Autotransformer #2 and Autotransformer #1, respectively. As load in the area continues to grow, these overloads would increase in severity. Furthermore, CenterPoint Energy has received several inquiries from customers to add additional load in the Freeport area. As a result, to solve the overloading issues and to provide for potential future load growth, the installation of a second autotransformer at the proposed Jones Creek Substation is included in Option 2.

G-1+N-1 analysis

A G-1+N-1 consists of an outage of one generation unit (G-1) followed by a single or common mode contingency. CenterPoint Energy performed G-1+N-1 analysis for the Jones Creek Project. The following generator outages in the area were considered to identify the worst G-1 conditions.

- BASF Unit (71 MW)
- Oyster Creek Unit (82.25 MW)

No voltage issues or overload problems were identified under G-1+N-1 contingency analysis.

Sensitivity Studies

Sensitivity Study 1

After this study was initiated, CenterPoint Energy received an inquiry from a customer for a new project in the Freeport area with a new load of 100 MVA at 0.95pf with an expected in-service date of June 2015 for the substation and 2016 for the full load. Therefore, a sensitivity analysis was conducted with the Freeport LNG load increase and the Jones Creek Project modeled to determine if the recommended project would accommodate the 100 MVA load addition. The customer load addition was connected between the SURFSI Substation and the Freeport Substation on 138 kV circuit 59. The results of the analysis are shown in Tables 9 and 10 below. No overload conditions or voltage problems were identified under NERC Category C or ERCOT autotransformer unavailability contingency analysis.

			Loading % of Rating
Overloaded Branch	Rating (MVA)	Contingency	Jones Creek Project
5915 - 42400 <CKT 18> SO_TEX__345A TO JONCRK__345A	1137	5915 - 42500 <CKT 27> SO_TEX__345A TO DOW_____345A	104.3%
5915 - 42500 <CKT 27> SO_TEX__345A TO DOW_____345A	1137	5915 - 42400 <CKT 18> SO_TEX__345A TO JONCRK__345A	102.0%

Table 9: Thermal loading results under NERC Category B contingency analysis

			Voltage in per unit
BUSES	Nominal Voltage	Contingency	Jones Creek Project
43135 QNTANA__138X	138KV	42410 - 43135 <CKT 59> JONCRK__138A TO QNTANA__138X	0.948

Table 10: Voltage results under NERC Category B contingency analysis

The low voltage at the QNTANA 138 kV Substation under Category B contingency analysis can be mitigated by manually adjusting tap settings on the autotransformers at the Dow-Velasco Substation.

Sensitivity Study 2

During the creation of the Study Case, generation in the ERCOT region was increased to balance the increase in load caused by the addition of customer loads. This increase in generation resulted in increased flow on the North to Houston interface, South to Houston interface, and an overall increase in generation within the CenterPoint Energy service territory. As a result, NERC Category B analysis showed an overload on 345 kV circuits STP to Dow-Velasco circuit 27 and STP to Jones Creek circuit 18 with the Freeport LNG load and Jones Creek Project added. This loading is a concern under the CenterPoint Energy single contingency criteria that is based on normal rating, but is not a concern under the ERCOT Planning Criteria that is based on emergency rating.

Subsequent to creation of the Study Case, the ERCOT Board of Directors endorsed the Houston Import Project, which includes a new 345 kV North to Houston double-circuit tie-line from Limestone – Gibbons Creek – Zenith that would provide an additional power import path into the CenterPoint Energy service territory. CenterPoint Energy performed a sensitivity study to analyze the impact of adding this new tie-line. The results of this analysis can be seen in Table 11 below.

			Loading % of Rating	
Overloaded Branch	**Rating (MVA)**	**Contingency**	**Before LIM-GC-ZEN**	**After LIM-GC-ZEN**
5915 - 42400 <CKT 18> SO_TEX__345A TO JONCRK__345A	1137	5915 - 42500 <CKT 27> SO_TEX__345A TO DOW_____345A	104.3%	99.1%
5915 - 42500 <CKT 27> SO_TEX__345A TO DOW_____345A	1137	5915 - 42400 <CKT 18> SO_TEX__345A TO JONCRK__345A	102 0%	97.3%

Table 11: Line loading results under NERC Category B contingency sensitivity analysis

Adding the 345 kV Limestone-Gibbons Creek-Zenith double circuit tie-line lowers the loading on the STP circuits to below 100% of their normal rating. Additionally, the normal rating of these lines could potentially be thermally uprated as a low cost option. As a result, upgrading the 345 kV STP-Dow circuits 18 and 27 will not be required to accommodate the Customer's load increase. However, it is clear that increased imports into Houston may cause upgrades to these 345 kV circuits to be necessary in the future.

Sensitivity Study 3

The total load addition from the Customer's project is based on the addition of three trains of large electric motors. Each train will operate independently and will be constructed in stages with 6 months between energization of each subsequent train.

	Anticipated Commercial Operation Date	MVA	PF	MW	MVAR
1-Train	Q3 2017	275	0.95	261.25	85.87
2-Train	Q1 2018	519	0.95	493.05	162.06
3-Train	Q3 2018	759	0.95	721.05	237.00

Table 12: Proposed Load

The Jones Creek Project is based upon the Customer's total proposed load encompassing all three trains (721 MW). CenterPoint Energy studied two additional lower load cases considering the following reduced load scenarios:

Reduced Load Scenario A

Assumption: The Customer only builds one train (261 MW) and there are no other large customer load additions in the Freeport area.

Results: The Jones Creek Project can be deferred. However, the following system improvements will be needed:

- Install a new 138 kV 120 MVAR capacitor bank at the Velasco Substation
- Upgrade 138 kV HOFMAN – Lake Jackson circuit 02 to 300 MVA emergency rating.

Reduced Load Scenario B

Assumption: The Customer only builds only two trains (493 MW) and there are no other large customer load additions in the Freeport area.

Results: CenterPoint Energy will need to proceed with the Jones Creek Project. However, the following improvements can be deferred:

- Install 2nd 800 MVA normal rating / 1000 MVA emergency rating (800/1000 MVA) 345/138 kV autotransformers at the Jones Creek Substation
- Install a new 138 kV 120 MVAR capacitor bank at the Jones Creek Substation.

Fault Current Analysis

A study was performed to determine if any fault current problems at area substations occur for the proposed Jones Creek Project. Based on the findings from the steady state power flow analysis above, Jones Creek Autotransformer #2 was included in the fault duty analysis. The results are shown in Table 13. CenterPoint Energy Transmission System Design Criteria requires that fault current should not exceed 99% of any facility's short circuit rating.

	BUS		Rating (kA)	AsBuilt Case (kA)	AsBuilt Case %	Jones Creek Project (kA)	Jones Creek Project %
THREE PHASE FAULT	5915	[SO_TEX__345A345.00]	50	41 1	82.3%	41.4	82.7%
	42110	[ANGLTN__138A138.00]	40	19.4	48.5%	20.5	51.2%
	42150	[BASF____138A138.00]	63	15.6	24.7%	20.3	32.2%
	42195	[BOOSTR__8010138.00]	63	15.9	25.3%	41.1	65.2%
	42200	[BRYAN___138 138.00]	63	5.9	9.4%	21.2	33.6%
	42500	[DOW_____345A345 00]	50	26.3	52.7%	27.6	55.2%
	42510	[DOW_____138B138.00]	63	27.7	44.0%	43.2	68.5%
	42810	[HOFMAN__138X138.00]	55	13.2	24.1%	18.0	32.7%
	43135	[QNTANA__138 138.00]	63	7.3	11 5%	22 0	35 0%
	43220	[SEAWAY__8005138.00]	63	11.0	17.4%	17.8	28.3%
	43240	[SINTEK__138A138.00]	62.8	21.4	34 1%	30 3	48.3%
	43300	[STRATT__138A138.00]	63	13.1	20.8%	15.1	24.0%
	43310	[SURFSI__138 138 00]	50	9.8	19 6%	35 5	71 0%
	43360	[VLASCO__138A138.00]	40	27.2	68.1%	45.2	113.0%
	43380	[W_COL___8010138 00]	31.4	23.3	74.1%	25.0	79.7%
	42400	[JONCRK__345A345.00]	N/A	N/A	N/A	24.8	-
	42410	[JONCRK__138A138.00]	N/A	N/A	N/A	41.1	-
	43335	[OYSCRK__138X138.00]	N/A	N/A	N/A	21.5	-

	BUS		Rating (kA)	AsBuilt Case (kA)	AsBuilt Case %	Jones Creek Project (kA)	Jones Creek Project %
SINGLE LINE TO GROUND FAULT	5915	[SO_TEX__345A345.00]	50	46.8	93.6%	46.4	92.9%
	42110	[ANGLTN__138A138.00]	40	13.1	32.7%	13.3	33.3%
	42150	[BASF____138A138 00]	63	13.7	21.7%	16.5	26.1%
	42195	[BOOSTR__8010138.00]	63	12.3	19.5%	37.3	59.3%
	42200	[BRYAN___138 138.00]	63	4.5	7.1%	13.4	21.3%
	42500	[DOW_____345A345.00]	50	20 9	41.9%	23.6	47.2%
	42510	[DOW_____138B138.00]	63	27.0	42.9%	39.2	62.2%
	42810	[HOFMAN__138X138.00]	55	10.5	19.1%	13.0	23.6%
	43135	[QNTANA__138 138.00]	63	4.9	7.8%	14.1	22.4%
	43220	[SEAWAY__8005138.00]	63	7.8	12.4%	12.7	20.2%
	43240	[SINTEK__138A138.00]	62.8	18 6	29.6%	24.2	38.6%
	43300	[STRATT__138A138.00]	63	11.1	17.6%	12.2	19.4%
	43310	[SURFSI__138 138.00]	50	8.4	16.8%	25.4	50.7%
	43360	[VLASCO__138A138 00]	40	25.7	64.4%	41.0	102.5%
	43380	[W_COL___8010138.00]	31.4	14.6	46.3%	15.3	48.7%
	42400	[JONCRK__345A345.00]	N/A	N/A	N/A	20.8	-
	42410	[JONCRK__138A138.00]	N/A	N/A	N/A	37.3	-
	43335	[OYSCRK__138X138.00]	N/A	N/A	N/A	14.0	-

Table 13: Fault Duty Results

Fault duty upgrades will be needed at Velasco 138 kV Substation and are included in the Jones Creek Project.

Cost Estimates

The cost estimate for the Jones Creek Project is shown Table 14 below.

Study Option	Work Description	Transmission Cost, $	Substation Cost, $
Jones Creek Project	Build a new 345/138 kV CenterPoint Energy "Jones Creek" Substation	-	$30,000,000
	Install two new 800 MVA normal rating / 1000 MVA emergency rating (800/1000 MVA) 345/138 kV autotransformers at the Jones Creek Substation	-	$17,200,000
	Loop the 345 kV DOW-STP circuit 18 0.5 miles into the Jones Creek Substation	$5,700,000	-
	Loop the 138 kV Velasco - Freeport circuit 59 0.5 miles into the Jones Creek Substation	$200,000	-
	Upgrade the Velasco 138kV Substation to 63kA	-	$350,000
	Split/Reconfigure circuits in the Freeport area creating: 138kV Velasco-SURFSI-Freeport-Jones Creek circuit 59, 138kV Velasco-QNTANA-Jones Creek circuit 48, and 138 kV Velasco-Jones Creek circuit 48	$200,000	$2,350,000
	Reconfigure 138kV Velasco - Franklins Camp circuit 02 to create 138 kV Jones Creek - Franklins Camp circuit 02	$3,750,000	$2,200,000
	Rebuild and Reconductor 3.8 mile section of 138kV Jones Creek-QNTANA ckt 48 and 138 kV QNTANA-Velasco ckt 48 with 838 MVA normal rating / 894 MVA emergency rating (838/894 MVA) 2-959 ACSS high temperature conductor.	$15,800,000	-
	Install a new 138 kV 120 MVAR Capbank at the Jones Creek Substation	-	$2,030,000
	TOTAL	$79,780,000	

Table 14: Cost Estimate[2]

Conclusion

CenterPoint Energy considered several options for serving a 721 MW load addition in the Freeport Area associated with the Freeport LNG Liquefaction and Export Project planned to be operational the third quarter of 2017. During initial screening of the options, it was determined that the most cost-effective option to serve the Customer's load was to build a new 345/138 kV injection point and make additional 138kV system improvements in the Freeport area in lieu of constructing new 138kV lines from more distant substations or further expansion at the 345kV Dow-Velasco Substation. The Jones Creek Project (Option 2) is the recommended option and includes the following improvements based on final analysis and sensitivity studies:

- Construct a new 345/138 kV CenterPoint Energy "Jones Creek" Substation;
- Install two new 800 MVA normal rating / 1000 MVA emergency rating (800/1000 MVA) 345/138 kV autotransformers at the Jones Creek Substation;
- Loop the 345 kV Dow-STP circuit 18 into the Jones Creek Substation;
- Loop the 138 kV Freeport-Velasco circuit 59 into the Jones Creek Substation;
- Upgrade the Velasco 138 kV Substation to a fault duty rating of 63 kA;
- Split and reconfigure circuits in the Freeport area creating: 138 kV Velasco-SURFSI-Freeport-Jones Creek circuit 59, 138 kV Velasco-QNTANA-Jones Creek circuit 48, and 138 kV Velasco-Jones Creek circuit 59;

[2] CenterPoint Energy expects to collect a Contribution In Aid of Construction from Freeport LNG for the upgrade of the section of 138 kV circuit 48 that loops to QNTANA estimated to cost $15.8 million.

- Reconfigure 138 kV Velasco-Franklins Camp circuit 02 to create 138 kV Jones Creek-Franklins Camp circuit 02;
- Upgrade the 138 kV Jones Creek-QNTANA circuit 48 and 138 kV QNTANA-Velasco circuit 48 with 838 MVA normal rating / 894 MVA emergency rating (838/894 MVA); and,
- Install a new 138 kV 120 MVAR capacitor bank at the Jones Creek Substation.

The Jones Creek Project successfully meets the design criteria requirements of the steady state power flow study and the fault current analysis with an estimated cost of $79.78 million. This project is recommended to be completed the second quarter of 2017 prior to the development of the Customer's loads and takes into consideration the typical lead times necessary to implement the proposed projects, including ERCOT review and approval, and materials and construction lead times.

Appendix A

The following changes were made to the ERCOT SSWG 2017 summer peak case (13DSB_2017_SUM1_FINAL_10152012) to create the CenterPoint Energy internal 2017 summer peak case (CNP_2017_SUM1_10152013_ 10312013):

- Move the swing bus from WAP Unit 5 to MNSES Unit 3
- Updated SRB A2 Transformer impedance
- Updated Jordan A1 Transformer impedance
- Circuit 48 40510 - 40511 - 40360 Multi-Section Line Added
- Updated AMOCO (42090) and MONSAN (42940) loads to match self-serve generation.
- Updated PHR A1 Transformer impedance
- Updated impedance and ratings for 138 kV FREEPT to QNTANA circuit 59
- Install a 2nd 800/1000 MVA 345/138 kV autotransformer at the Dow-Velasco Substation
- Build a 2nd autotransformer 138 kV lead from Dow-Velasco to Velasco Substation

CenterPoint Energy

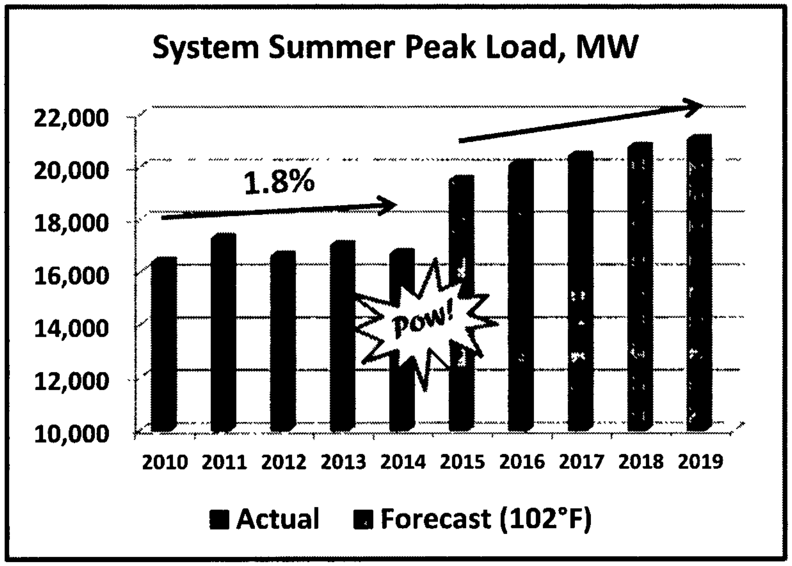
CenterPoint Energy

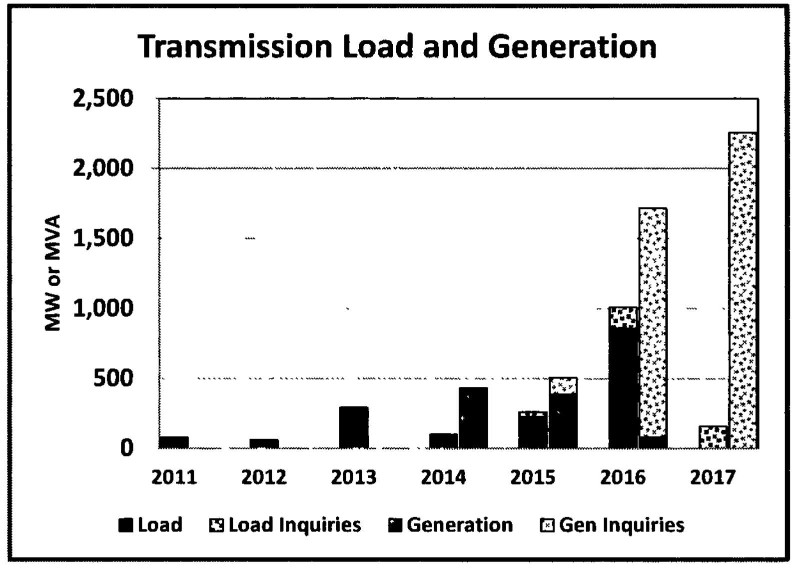
Building, Operating, and Growing: A HVPD perspective
Mike Pakeltis

We are experiencing growth at an exceptionally high rate.

CenterPoint Energy

Transmission Operations



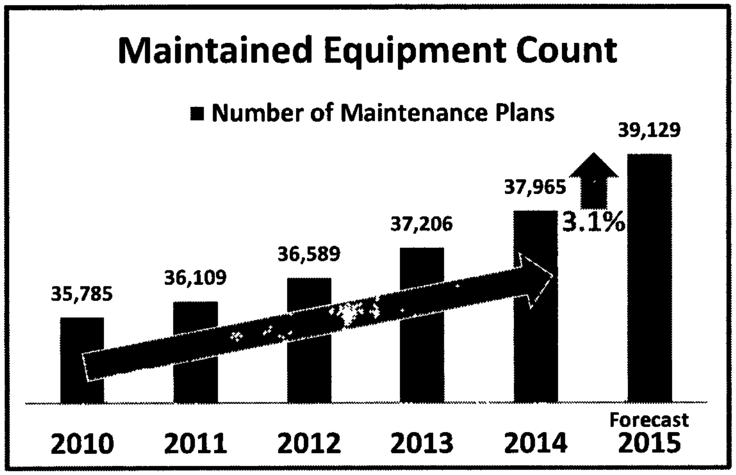


- We have been experiencing steady growth for the last 5 years.
- We are planning for accelerated growth for the next 5 years.
- The industrial sector is contributing to that growth, especially in the natural gas and chemical markets.
- Inquiries by new Generators are following the demand for more power in the Houston Region.

We are experiencing growth at an exceptionally high rate.

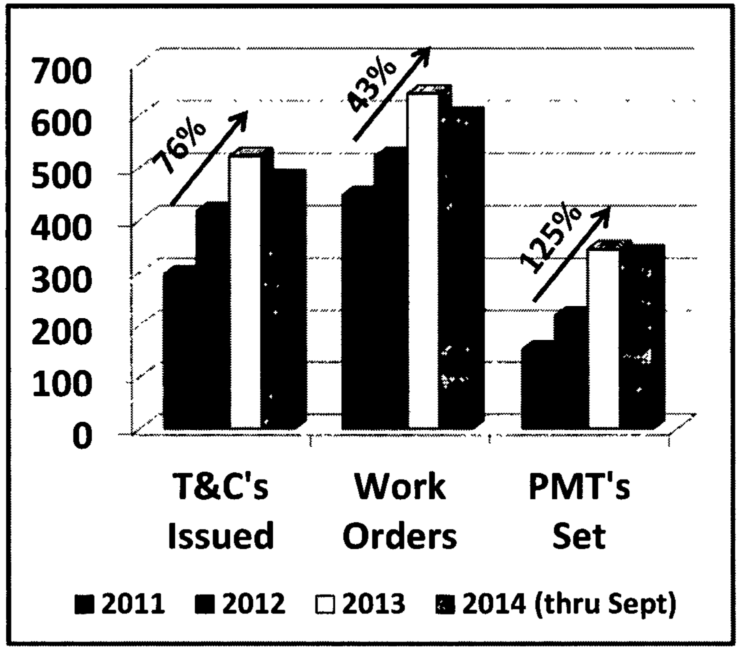
CenterPoint Energy

Substation Operations



- Total substation equipment count is approximately 80K

- **2010 to 2014**: 11 customer subs and 9 CNP subs installed, **4/year**
- **2015**: 8 customer subs and 2 CNP subs planned, **10/year**



- **2014** Padmount Trf's: Projecting 425 by year-end, a **23% increase over 2013** (Note: April 2012 included design criteria change.)

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WP MWN-4
Track Equipment 2014
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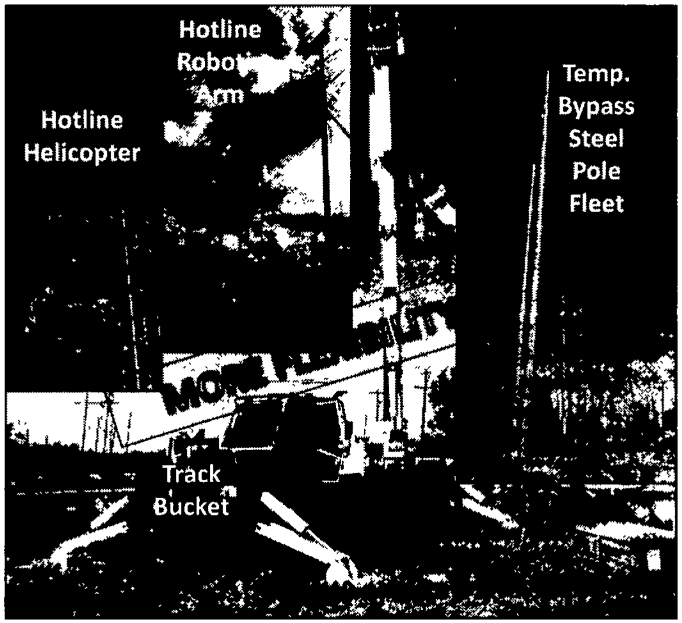
We are dealing with growth in exceptional ways.

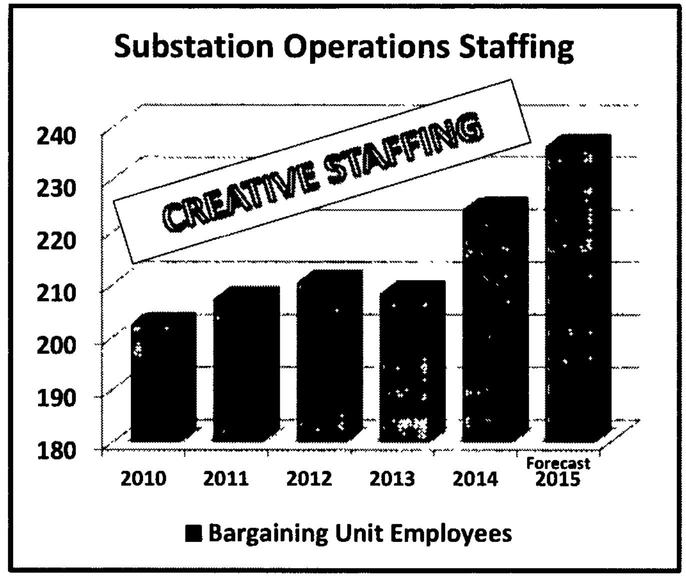
CenterPoint Energy

Transmission Operations



- Increased Contractor Resources: 2010 → 60 total; 2014 → 230 total
- Increased to 7 Independent Line Contractors

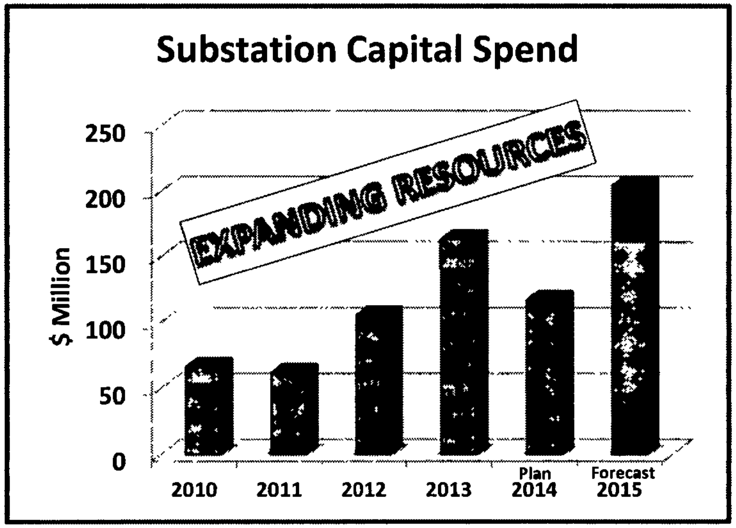
Substation Operations



We are dealing with growth in exceptional ways.

CenterPoint Energy

Substation Operations



Major Underground

- 2014: Began contracting specialized cable pulling and splicing for the first time
- 12 qualified contractors now working on CenterPoint Energy MUG projects

Panel Member

- Mike Pakeltis, Transmission Operations Director
- Rhonda Welch, Electric Engineering Director
- Paul Wilson, Service Area Director Greenspoint

Questions for our panel? Raise your hand and flag down a facilitator

CenterPoint Energy Proprietary and Confidential Information

CenterPoint. Energy

Improvements in Fault Location Capability at CenterPoint Energy to Reduce Response Time and Improve Accuracy of Fault Reporting

Michael J Pakeltis – Director of Operations, CenterPoint Energy

Jay Russell – Grid Performance, CenterPoint Energy

Elias Marquez – Grid Performance, CenterPoint Energy

David Cole – Qualitrol LLC

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- CNP Practice in 2006
- Improvement Goals Set
- Traveling Wave Method of Fault Location Adopted
- Deployment on 345 kV Network
- Deployment on 138 kV Network and Issues that were Overcome
- Identification of Failing Insulators
- Future Link to SCADA
- Summary

CNP Practice in 2006 After a Line Trip at 345 and 138 kV

For a Sustained trip

- Deploy ground and / or helicopter patrols
- Analyze fault location from DFR devices
- Run FALLS study
- Pinpoint location with patrols
- Implement repairs
- Submit a trouble report

CNP Practice in 2006 After a Line Trip at 345 and 138 kV

For a Momentary trip

- Analyze fault location from DFR devices
- Run FALLS study
- Deploy ground patrols next working day
- Pinpoint location with patrols
- Determine root cause
- Implement repairs if necessary
- Submit a trouble report

CNP Practice in 2006 After a Line Trip at 345 and 138 kV

Observations

- Effectiveness of finding the correct root cause depends on accurate fault locations, especially for momentary trips
- It is important to get to the site quickly to confirm avian issues before any evidence is removed
- Faulty insulators are hard to detect without exact structure locations.
- The causes of fault in the trouble reports were often 'unknown' making it difficult to initiate follow up.

40% of trouble reports had an 'unknown' cause of fault

Primary Method of Fault Location in 2006

- Off Line single ended impedance calculation from DFR records
- Not every line end was monitored but at least one and often two DFRs would trigger for every fault
- Records manually downloaded, analyzed and compared to FALLS lightning results
- Best accuracy for phase to phase faults was 1% of line length but 20% or higher was not unusual for phase to earth faults, where line ends were not monitored and where tees and branches exist on more complex feeders.
- Relay data was used as a backup but a relay tech had to go to site to collect data

It could take several hours to get a 'poor' fault location

Improvement Goal Set in 2006

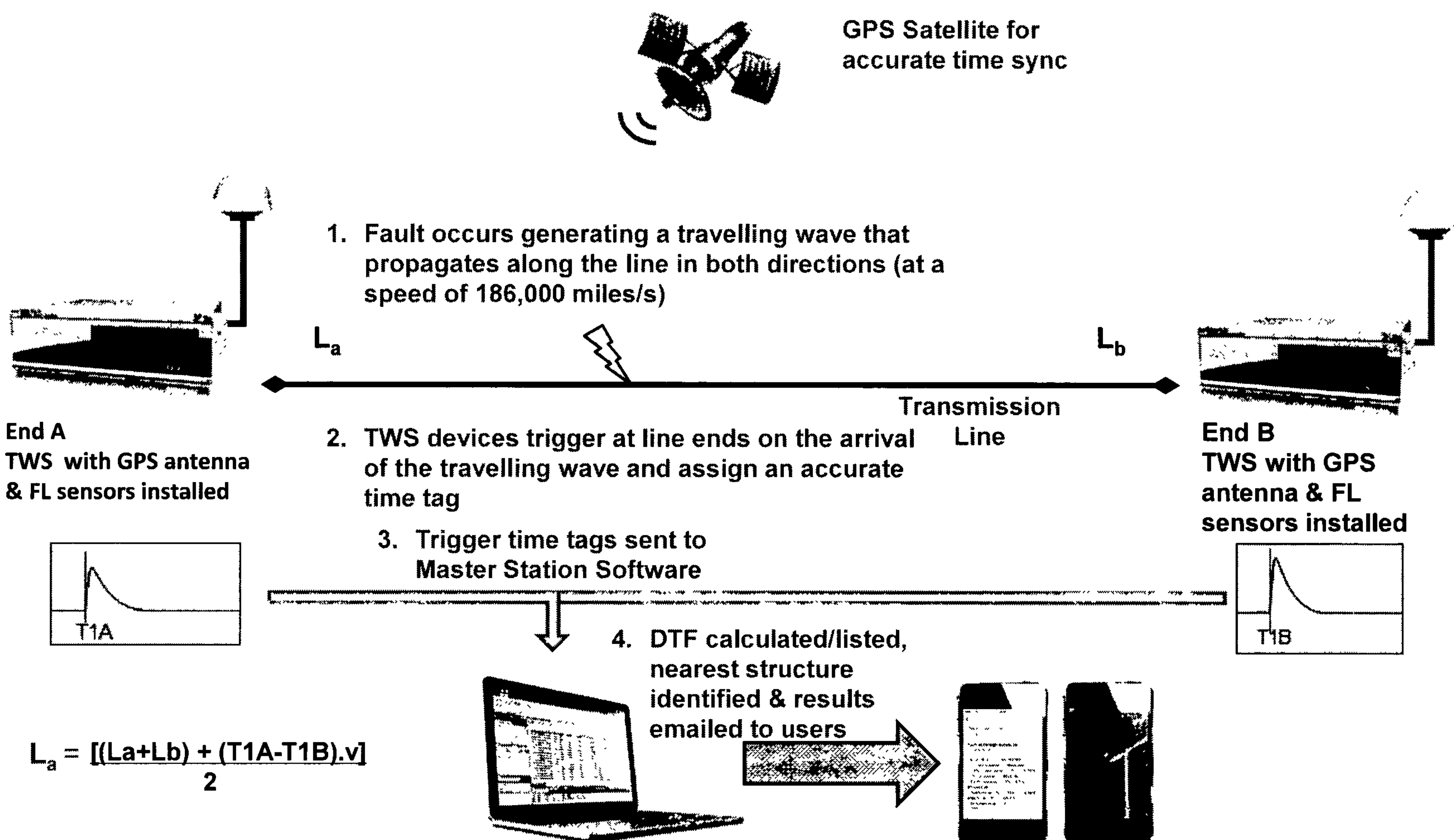
Reduce the number outages with an ‘unknown’ cause

Improve transmission reliability by getting to the fault site faster to start repairs.

To meet the goal, a method was needed to automatically deliver distance to fault results accurate to one span within minutes after a line trip.

The Traveling Wave method of fault location was considered the best method to achieve this goal.

Double Ended Traveling Wave Fault Location - Technique



Double Ended Traveling Wave Fault Location

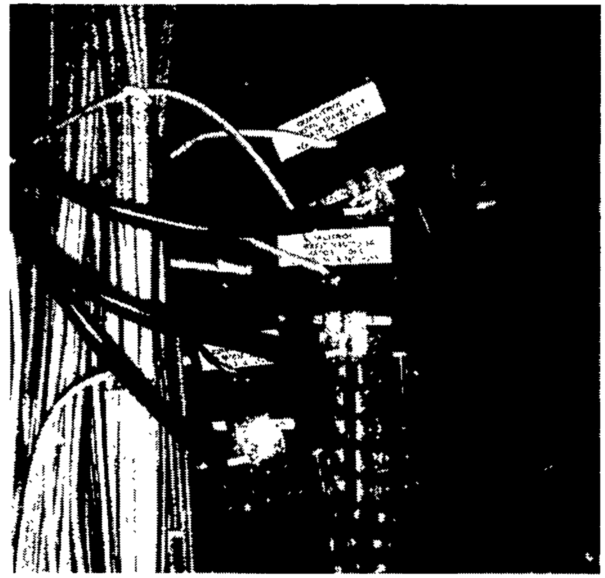
- Accuracy is dependent on the time stamp
- Legacy equipment was accurate to1μs with a resolution of 0.1 μs. Results accurate to 0.1 miles are achievable
- Newer devices have an accuracy of 100ns. The limit on fault location accuracy is now set by errors in the line length and correct identification of the arrival of the wave
- Each TW device can monitor up to 8 lines
- CNP use modems for remote access to the TW devices. Some network connections are available but not used until NERC security standards are better understood

Deployment on 345 kV Network

CNP first deployed TW devices at 345 kV

Network consists of simple 2 ended circuits terminating in substations where other 345 kV lines are connected to the busbar

The resultant low terminating impedance compared to the line means it is possible to monitor the current component of the traveling wave via the secondary of the protection CTs



Non intrusive split core linear couplers installed with the circuit live

Deployment on 345 kV Network

Deployment completed in 2010

Lines Monitored	Substations	TW Devices
54	31	33

From 2008 to 2011

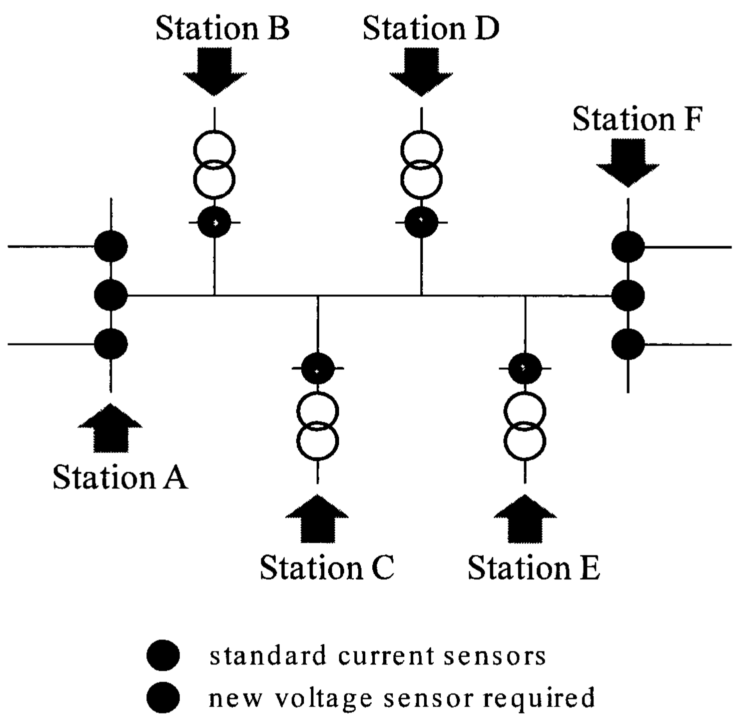
Faults	Successful Location	Cause Identified	Cause Unknown
100	93	56	37

(Data not available for 7 faults due to telecom or TW hardware issues)

All results are analyzed by the Grid Performance Division in CNP and compared to FALLS data

Deployment on 138 kV Network

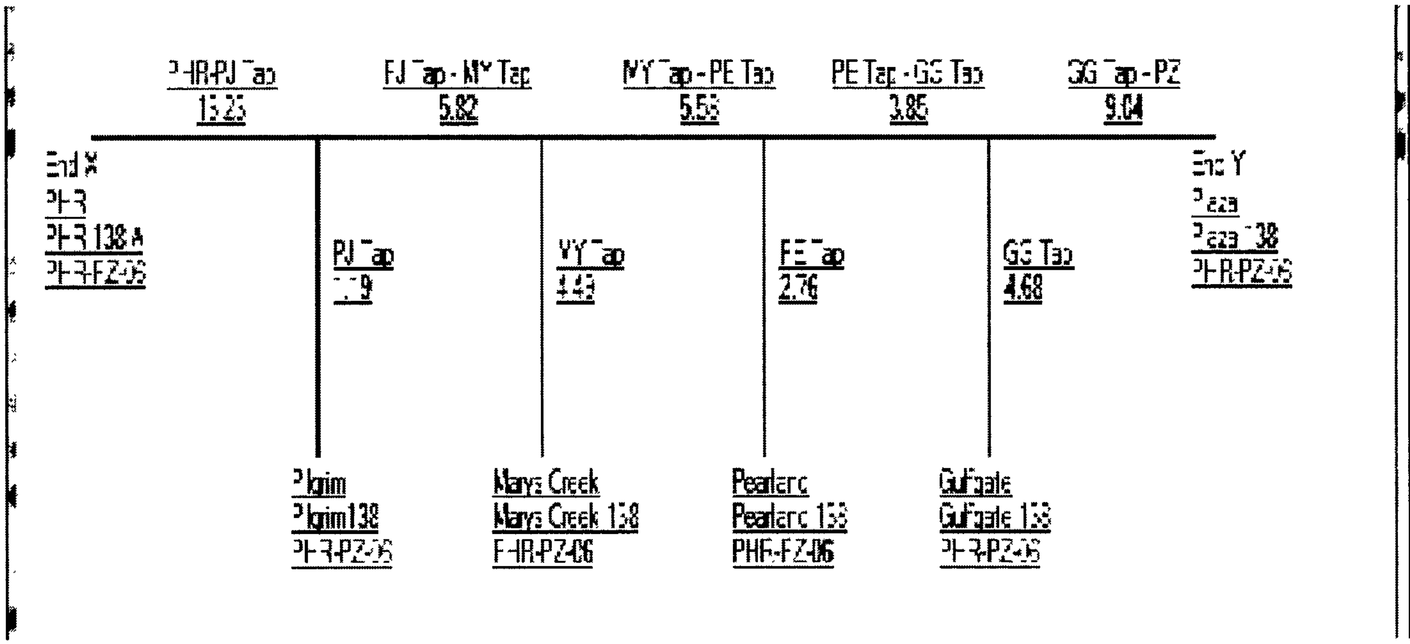
Commenced in 2011 – initially covered the 2 ended circuits terminating in a low impedance so current could be monitored



Rest of network contained multi ended circuits and lines terminating in 'high' impedance transformers meaning a voltage sensor had to be developed

Configuring Multi-Ended Circuits

Software was developed to manage circuits with up to 6 ends

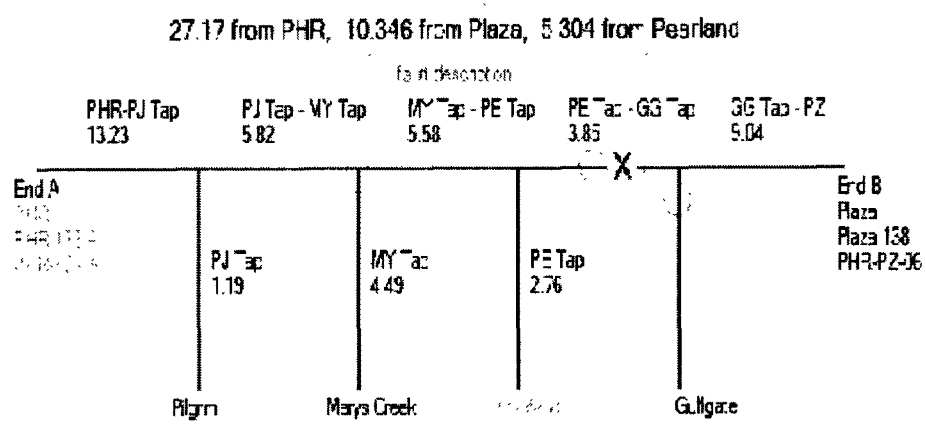


User selects the device at each line end, enters the distance to the nearest 'tee' position and enters a section name

Results from Multi-Ended Circuits

Not all devices will trigger for every fault as waves are attenuated as they passes through 'tee' joints

Software breaks the multi-ended circuit into the constituent 2 ended circuits, calculates a result for each and plots them on a graphical display

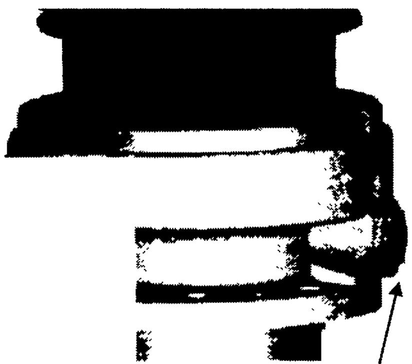


TW devices either side of the fault site return a correct location
TW devices the same side of the fault site return a distance to a 'tee'
Software identifies the actual fault site with a X and lists the distances

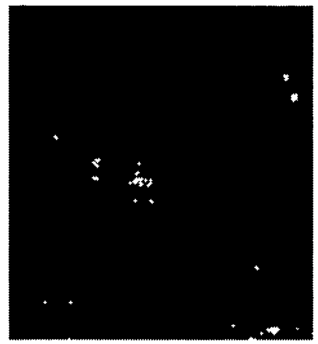
Monitoring Voltage at a Transformer Feeder

The easiest way to monitor the voltage wave is to measure the current through a capacitive path to ground.

The HV transformer bushing is a practical candidate. A coupler was developed for the test tap. Most CNP 138 kV bushings follow the ANSI standard.



Tap point on lower part of bushing



Different views of the bushing coupler (not to scale)

An alternative adapter has been designed for 5 older transformers with smaller tap points. About 70 transformers are being monitored.

Deployment on 132 kV Network to Date

Progress so Far

Lines Monitored	Substations	TW Devices Installed	TWS Devices Remaining
119	88	96	60

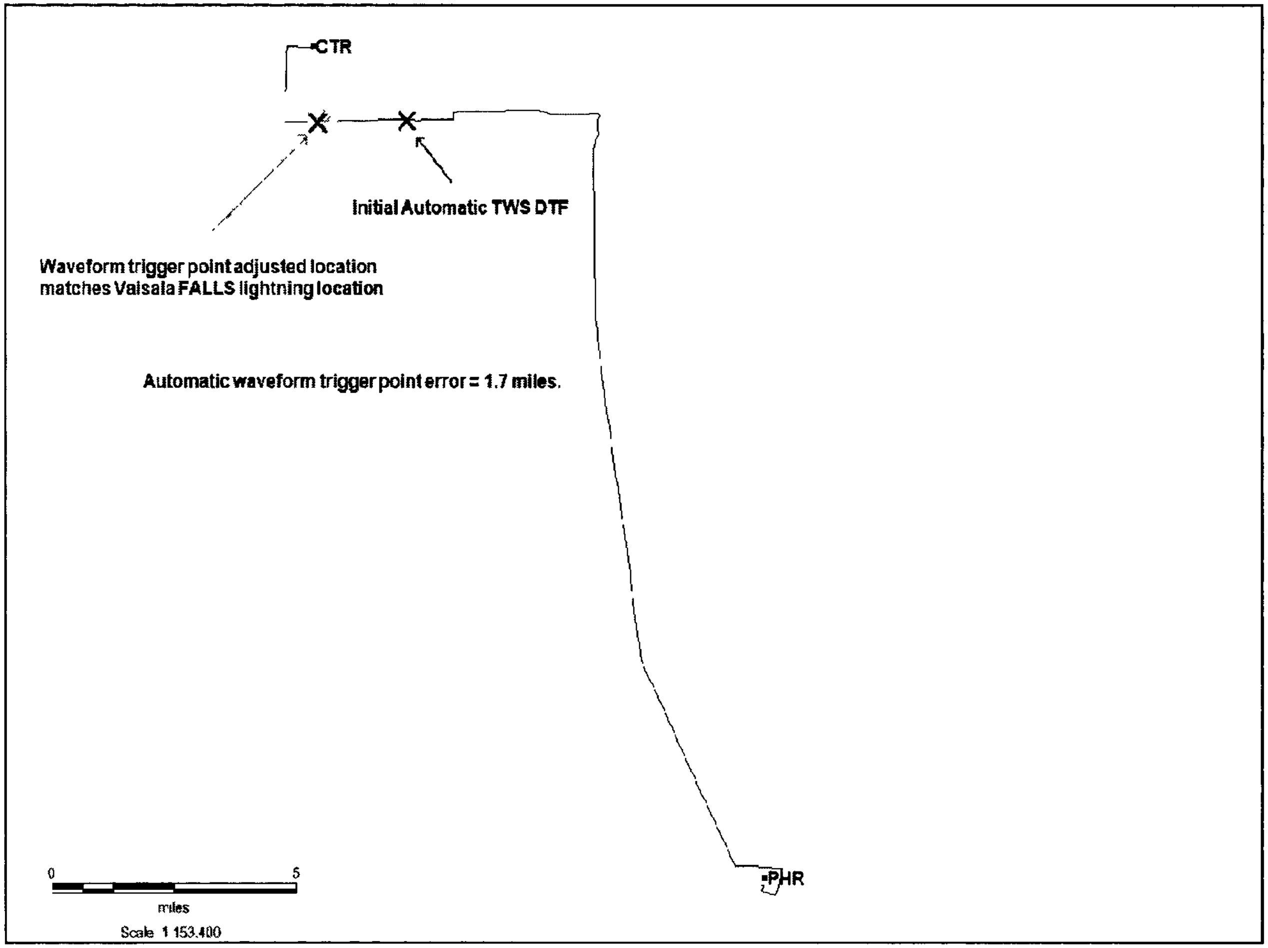
Faults Detected so Far	Typical Accuracy *
150	1 to 2 spans

* Accuracy more variable on some lightning faults

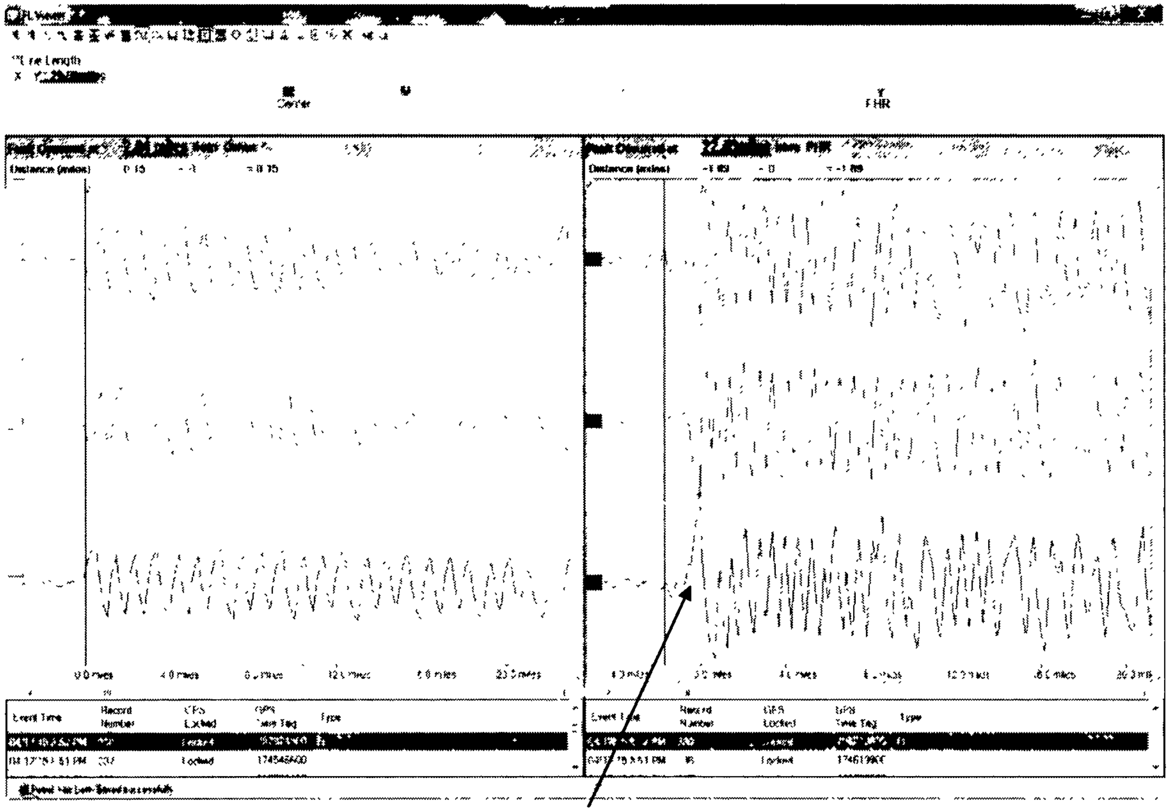
Issue with Some Lightning Events

- Certain lightning events have resulted in errors on the automatically calculated distance to fault of approximately 0.5 mile or greater
- Examination of the TW waveforms has shown a small leading transient prior to the main breakdown
- In many cases it is possible to manually adjust the trigger point to improve the fault location result
- A library of these events will be used to study the phenomena with the aim of producing an algorithm to automatically compensate the results.
- Lightning is an issue in the CenterPoint Energy operating area with 217,000 strikes being recorded in July 2014.

Example of Lightning Event Resulting in an Error



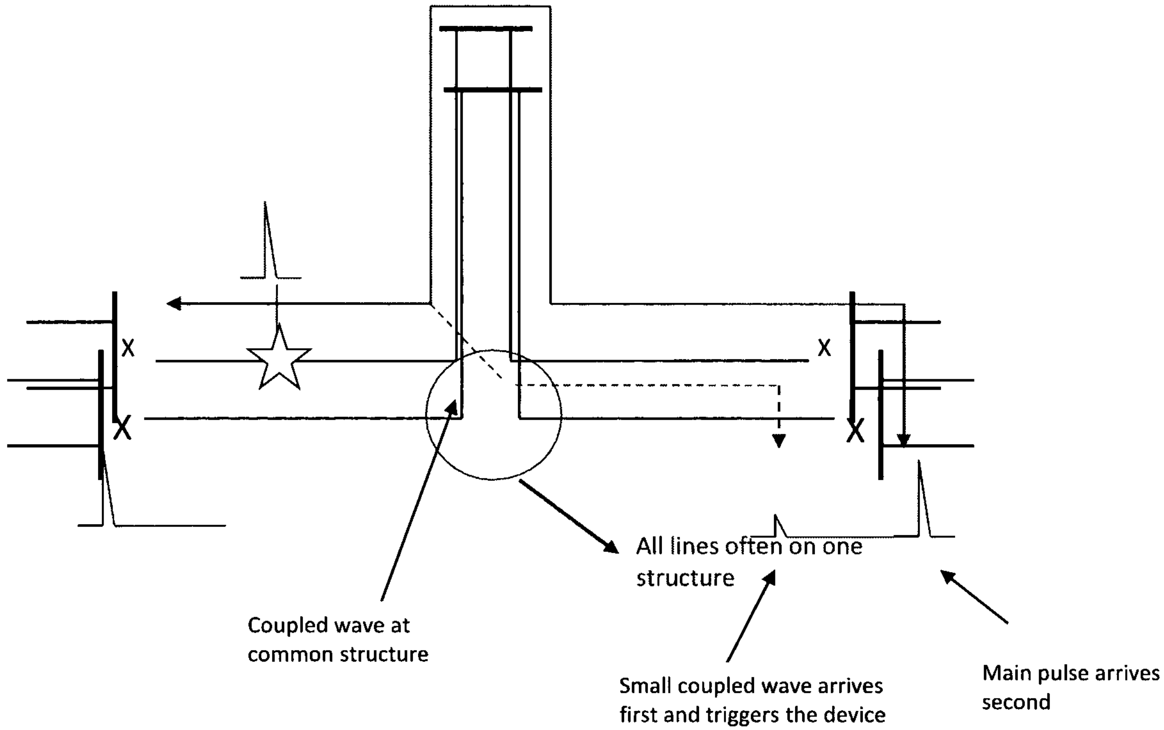
Accuracy Improved by Compensating Waveforms



Manually Compensated Trigger Point

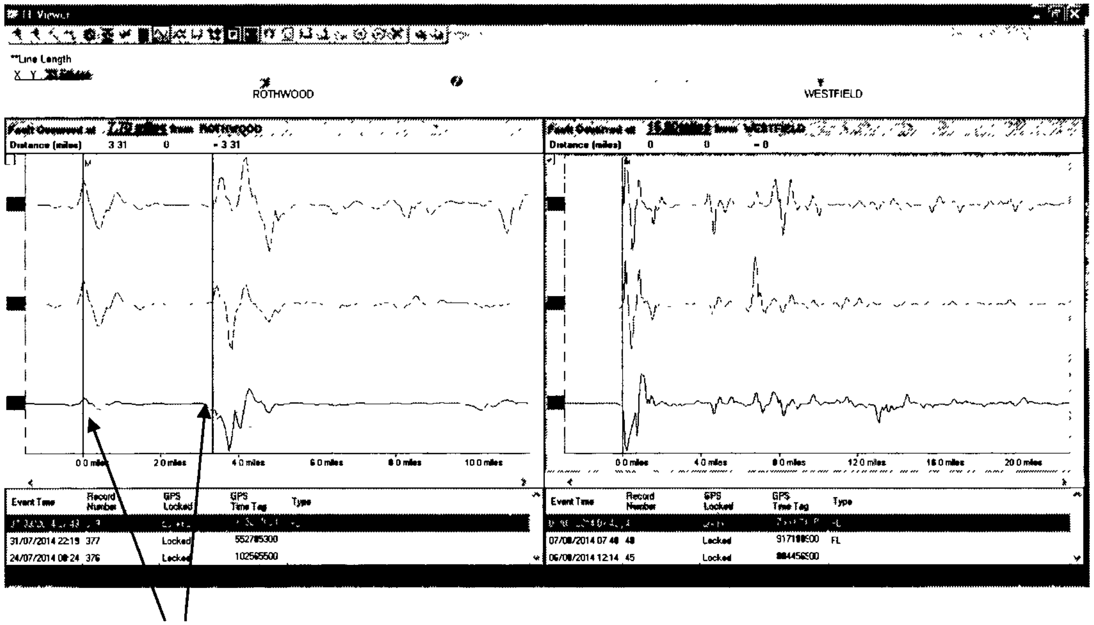
Looped Tees

One major fault at138 kV, where a crane hit a line, highlighted a problem on a two-ended circuit containing one or more looped tees.



TW device triggered early causing the error

Automatic Compensation for Looped Tee Issue



Difference in Coupled Wave and Main Pulse Equates to Error in Fault Location

Algorithm written and under evaluation to compensate for error

Location of Failing Insulators

- Accurate fault location allows identification of specific insulator strings that flash and cause momentary outages
- Multiple trips at the same location is indicative of non recoverable damage

Track Marks from Flashover

Flash marks clearly seen when laid on the ground but difficult to spot whilst still in service unless the specific structure is identified for close examination

Insulators replaced before they caused a sustained outage

Future Link to SCADA

- At present the results from the TW system are analyzed by the Grid Performance Division and passed on to the Control Room and patrol teams.
- The last stage in the automated link is to present results directly in the Control Center.
- The process to be deployed involves interface software that receives a signal from SCADA that a circuit has tripped. The TW software then polls the circuit ends, retrieves data and calculates the distance to fault. This value is then passed back to SCADA
- Implementation is expected the end of this year.

Summary

- In 2006, CenterPoint Energy faced two problems:
  - the long response time to pinpoint the fault site after a sustained outage meant it took longer to restore the line
  - the low accuracy of fault locations made it difficult on momentary faults to know the exact fault site meaning it was not always possible to determine a true root cause.
- To address these issues a traveling wave system for fault location was deployed across the 345 kV and 138 kV networks

Summary

- Fault location accuracy has been improved to 1 or 2 spans in most cases. Information is quickly passed to patrol teams.
- For all voltage classes, the percentage of outages with an ‘unknown’ cause has reduced to an average of 20% compared to 40%
- Future work will implement a direct link with SCADA and develop an algorithm to compensate for errors noted on some lightning events

Line Transient Overvoltage (TOV) Values for Determining Minimum Approach Distances (MAD) for 345 and 138 kV circuits

December 01, 2018

Prepared by:

CenterPoint Energy Houston Electric, LLC

Transmission Planning Division

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1 EXECUTIVE SUMMARY

In 2017, CenterPoint Energy (CNP) started a process to implement in-house transient overvoltage studies for CNP's 138 kV and 345 kV transmission lines, instead of customary relying on an external consultant.

These studies will be performed as requested by Transmission Operations on a continuous basis at which any time this document will be updated.

Maximum expected switching transient overvoltages are calculated for CenterPoint Energy's 138 kV and 345 kV transmission lines for which minimum approach distance (M.A.D.) should be calculated in accordance with OSHA standard 1910.269 (October 5, 2015).

The TOV study was performed using the PSCAD and ETRAN software.

Results for the maximum Transient Overvoltage for a fault with restrike for all the circuits shown in this report are shown in Table 1-1. CenterPoint has added to this maximum overvoltage a safety factor of 10%.

Table 1-1: Maximum TOV Values

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
STP	Dow	27	345	STP	2.76	3.04	2.20	2.42
STP	Dow	27	345	DOW	2.78	3.06	2.10	2.31
Jones Creek	Dow	18	345	Jones Creek	1.83	2 02	1 73	1.90
Jones Creek	Dow	18	345	Dow	2.10	2.31	1.73	1.90
STP	Jones Creek	18	345	STP	2.72	2 99	2 07	2 28
STP	Jones Creek	18	345	Jones Creek	2.82	3.11	2.09	2 30
W.A.Parish	Jenetta	72	345	W.A.Parish	2.70	2.97	2.23	2.45

[redacted]								
W.A.Parish	Jenetta	72	345	Jenetta	2.48	2.73	2.03	2.24
W.A.Parish	Jenetta	64	345	W.A.Parish	2.70	2 97	2.25	2.48
W.A.Parish	Jenetta	64	345	Jenetta	2 48	2.73	2.06	2.27
Gibbons Creek	Zenith	18	345	Gibbons Creek	2 87	3.16	2.38	2.62
Gibbons Creek	Zenith	18	345	Zenith	3 20	3.52	2 18	2.39
Gibbons Creek	Zenith	50	345	Gibbons Creek	2.93	3.23	2.40	2 64
Gibbons Creek	Zenith	50	345	Zenith	3.29	3 62	2.19	2.41
Singleton	Zenith	98	345	Singleton	2.96	3 26	2.30	2.53
Singleton	Zenith	98	345	Zenith	3.34	3.67	2.27	2.50
Singleton	Zenith	99	345	Singleton	2 97	3.27	2.27	2.50
Singleton	Zenith	99	345	Zenith	3.40	3.74	2.23	2.45
Center	P.H. Robinson	97	345	Center	3.03	3.34	2.37	2.61
Center	P.H. Robinson	97	345	P.H. Robinson	2.96	3.26	2.20	2.42
Center	Cedar Bayou Plant	97	345	Center	2.74	3.02	2.16	2.38
Center	Cedar Bayou Plant	97	345	Cedar Bayou Plant	2.67	2.94	2.07	2.28

2 BACKGROUND

This report provides an analysis and evaluation of CenterPoint Energy's (CNP) transmission network to determine the maximum switching transient overvoltages and minimum approach distances for live line maintenance. The analysis includes using engineering principles outlined in industry standards (IEEE) and commercially available transient analysis software for simulation (PSCAD).

In 2016, CenterPoint Energy created a taskforce to investigate the critical parameters that influence maximum TOV for a given circuit and to identify network conditions and characteristics under which it is technically justified using a sound engineering analysis to retain the old OSHA standard overvoltage values and where it would be prudent to perform site-specific studies or use the new OSHA standard values. The result of the work performed by the Task Force was a white paper "Guideline for Establishing Transient Overvoltage and Minimum Approach Distance". Recommendations of this whitepaper include:

Continue performing TOV studies for:

- New transmission lines 138 kV and above.
- Existing 138 kV lines and above when shorter MAD distances than those defined by the old OSHA ruling are required to perform the live-line work.

In this way CNP's TOV database of existing transmission lines and their per-unit transient overvoltages will continue to be built.

Establish the minimum approach distance based on either:

- The simulated per-unit transient overvoltage of the transmission network for each system condition.
- Old OSHA values, if the line has similar characteristics of an existing line as determined from CNP's TOV database.
- Establish written operating procedures as required by new OSHA ruling that requires and checks:
    - That no live maintenance would be performed under bad weather conditions especially if lightning is in the area.
    - That reclosing on the affected line, would be disabled and tagged.
    - That visually inspects substation line termination arresters for abnormalities (cracking) before doing any live line work.
    - That nearby capacitance switching would be disabled during live line maintenance.

Continue the existing SF_6 technology for circuit breaker procurement and the existing maintenance and inspection practices for circuit breakers.

Repeat the EMT studies for the circuits in the database every 10 years or when topology changes that necessitate a re-evaluation of TOV values.

3 OSHA Requirements for MAD distance

OSHA in its final 2014 ruling 1910.269 (l) (3)(i) to 1910.269 (l) (3)(iii) defined new basic minimum approach distances for workers operating in the vicinity of energized facilities (72.6 kV and above) in order to permit utilities to calculate minimum approach distances without requiring detailed electromagnetic transient (EMT) studies. The previous values originated in a ruling which had been published in 1972. The provisions were determined to be "out of date and inconsistent with the more recently promulgated general industry standard" [1] and new default values were determined. Table 3-1 presents both the previous and new default maximum overvoltage values and Table 3-2 the old and new OSHA calculated minimum approach distance for 0-900 feet altitude [1]. The overvoltage values labelled as 'previous' were valid till April 1, 2015 and the 'new' values were effective thereafter.

Table 3-1: OSHA Table Default Maximum TOV Distances

OSHA Values until April 1, 2015	
Grid Voltage (kV)	**Max Overvoltage (pu)**
<362.0 kV	3
500 to 550	2.4
765 to 800	2

OSHA Values after April 1, 2015	
Grid Voltage (kV)	**Max Overvoltage (pu)**
72.6 to 420	3.5
420.1 to 550	3
550.1 to 800	2.5

Table 3-2: OSHA Default Minimum Approach Distance

OSHA Values until April 1, 2015	
Grid Voltage (kV)	**OSHA MAD (ft)**
69	3
138	3.81
345	9.06

OSHA Values after April 1, 2015	
Grid Voltage (kV)	**OSHA MAD (ft)**
69	3.29
138	4.27
345	11.2

These new distances pose a significant problem when performing live-line maintenance as described in CNP's presentation [2] and attached in Appendix A, as the existing insulators lengths at 69 kV and 345 kV (Table 3-3) are shorter than the proposed new MAD distances. The shorter insulator lengths and new OSHA default values would prevent CNP to perform live-line maintenance.

As an alternative OSHA still allows employers (CNP) to determine through an "engineering analysis, the maximum anticipated per-unit transient overvoltage, phase-to-ground". This requires utilities to calculate

1 OSHA Calculator https://www.osha.gov/dsg/mad_calculator/mad_calculator.html

the system T-values and obtain the corresponding MAD distances. These maximum overvoltages are acceptable for live-line work, as they are calculated using generally accepted engineering principles. The effect of existing surge control equipment like arrestors can be considered when calculating the maximum TOV. For CNP, this lowers the TOV and the resulting MAD to a level that is acceptable for live-line maintenance work.

The MAD for phase-to-phase system voltages of more than 72.5 kV nominal, are then calculated using equation (3.1).

$$MAD = 0.3048(C+a)\,V_{LG}TA + M \qquad (3\text{-}1)$$

- M=0.31 m the inadvertent movement factor (ergonomic component, to account for inadvertent movement of the part relative to worker or the worker relative to the energized part)
- T = maximum anticipated per-unit transient overvoltage, $T = T_{LG}$ for phase to ground exposure and $T = 1.35{*}T_{LG} + 0.45$
- C=0.01 for phase-to-ground exposures
- A= altitude correction
- a=saturation factor

Table 3-3: Most Common CenterPoint Energy's Insulating Lengths

Grid Voltage (kV)	Insulators length (ft)
69	2.41 - 2.71
138	4.25 - 4.33
345	7.2 - 10.66

4 OSHA - Appendix B Technical Considerations

This section provides a summary of information outlined in Appendix B of the OSHA 1910 ruling. Appendix B of the ruling states that the information should assist employers in complying with the minimum approach distance requirements. Employers must use the technical criteria and methodology presented in the appendix in establishing minimum approach distances in accordance to 1910.261 (1) (3) (i) and Table R-3 and R-8 of the ruling [1]. Table numbers and pages discussed in this section refer to the ruling and corresponding Appendix B [1].

In this Appendix, OSHA describes the requirements **(in bold)** to follow to calculate the MAD based on known maximum-anticipated per-unit transient overvoltage especially if surge mitigation equipment is modeled in its calculation.

MAD based on known Maximum-anticipated per-unit TOV

Under 1910.269 (1)(3)(ii), the employer must determine the maximum anticipated per-unit (p.u.) transient overvoltage through an engineering analysis or must assume a maximum anticipated per-unit transient overvoltage (Table R-9). When the employer conducts an engineering analysis of the system and determines that the maximum transient overvoltage is lower than specified by Table R-9, the employer must ensure that any conditions assumed in the analysis for example, the employees block reclosing on a circuit or install PPGD are present during energized work. **To ensure that these conditions are present, the employer may need to institute new live-work procedures reflecting the conditions and limitations set by engineering analysis.**

An employer may take the following steps to reduce minimum approach distances when the maximum transient overvoltage on the system (w/o additional steps to control voltages) produces unacceptable large minimum approach distances.

Step 1: Determine maximum voltage (with respect to a given nominal voltage range) for the energized part.

Step 2: Determine the technique to use to control the maximum transient overvoltage that can exist at the worksite with that form of control in place and with a confidence level of 3σ. This voltage is the withstand voltage for the purpose of calculating the minimum approach distance.

Step 3: Direct employees to implement procedures to ensure that the control technique is in effect during the course of the work.

Step 4: Using the new value of transient overvoltage in per unit, calculate the required minimum approach distance from Table R-3.

5 STUDY ASSUMPTIONS

The simulation model used in the TOV analysis was constructed using the PSCAD Program based on the network topology in the CNP PSS/E AsBuilt case and the ETRAN program that creates the PSCAD case from a PSS/E case.

The following highlight the assumptions for this study.

6 Study Area

Users of electromagnetic transients (EMT) simulation programs (such as PSCAD/EMTDC) often face difficulties in obtaining data and developing cases suitable for their studies. Many utilities have the data available for their entire system in loadflow programs, but a great deal of effort is required to re-enter the network data for use in EMT programs.

There are three common challenges:

- Translation of circuit/network data (differences in p.u. systems, data entry, etc.)
- The generation of network equivalents
- Initialization of machines, generators or sources in large inter-connected network

CenterPoint Energy acquired in 2017 the E-TRAN tool developed by Electranix Corporation, this tool directly imports/translates PSS/E file into PSCAD files.

With the E-TRAN program, the user identifies a portion of the network for a direct translation into PSCAD models (i.e. the "kept" network), and E-TRAN creates a network equivalent of the rest of the network based on the available fundamental frequency impedance and powerflow information. The equivalent is a multi-port representation that will be correct for steady state as well as for open circuit and short circuit conditions and contains Thevenin voltage sources to match PQ flow and represent generation in the equivalent network.

In general, at minimum, the 138 kV study area should include substations within at least one bus from the study line terminal buses and the 345 kV study area should include substations within at least two buses from the study line terminal buses. For this analysis due to the relatively small number of buses in CenterPoint Energy's territory, all the area buses 69 kV and above, were kept intact in the PSCAD case and equivalents were placed two buses away from CNP's boundary buses

7 Study Scenarios

Based on previous research performed for CenterPoint Energy's whitepaper, TOV values are not dependent on system dispatch; therefore, the analysis was performed only for peak condition. The TOV levels were calculated for single restrike events during line de-energization with and without surge arresters. The single restrike events will result in severe TOV levels due to reclosing with trapped charges.

8 System Component Models

8.1 Transmission Lines

Importing the case using E-TRAN allows for the use of modeling the transmission lines either using a distributed pi- model or the Bergeron model. The Bergeron Model was used for the network except for the area surrounding the line to be switched. That particular area is modeled using detailed data available, with all frequency dependent parameters when applicable, for example geometric data for transmission lines suitable for a frequency dependent model, bundling information, conductor data from handbooks and right-of-way information.

8.2 Generators

The generators were modeled as a voltage source behind a sub-transient reactance and a generator step-up transformer. Terminal voltage and angles, as modeled in the loadflow case were used.

8.3 Loads

Loads in the PSS/E case were modeled in the EMTP model. However, switching studies performed in the 138 kV line will have 138 kV loads in the middle of the study lines assumed to be offline for the study because the TOV levels when the loads were online.

8.4 Boundary buses

Boundary buses were modeled as voltage sources behind Thevenin impedance seen from the bus into the rest of the system. This modeling is performed directly by the PSCAD import, but CenterPoint Energy checked the observed fault currents on the CNP buses for verification and in all the instances they closely matched the PSS/E values and thus, no boundary bus impedances were readjusted during the model verification process.

8.5 Model Verification

Model validation is performed by comparing transmission line flows and fault levels differences between PSS/E Base case and the PSCAD/ETRAN representation.

8.6 Surge Arresters

The surge arresters were also modeled in detail at the 138 kV and 345 kV study lines. Figure 11-2 shows the type of surge arresters included for this study. Complete Voltage-Current (V-I) characteristic curves are provided in Table 11-3.

9 PSCAD Cases

Two study models were developed for each circuit and they correspond to:

- Peak load without surge arrestors
- Peak load with surge arrestors

The following fault and switching scenarios were simulated:

- Line energization with and without surge arrestors (without closing resistor).
- Single restrike with one end of the line open.

Transmission line reclosing was not modeled as part of the simulation, in general reclosing on trapped charge produce very high overvoltages. As part of the hot-line maintenance procedure, CenterPoint Energy will continue its current practice disabling and tagging reclosing on the affected line.

Statistical switching was modeled in the case of restrike to simulate the random nature of the event to determine the highest overvoltage.

10 LIST OF CIRCUITS

The following is the list of circuits are evaluated, for some circuits a Rehabilitation Year/Qtr, has not been set, but have been analyzed and included in this report.

Table 10-1: Study lines for the Period 2018 to 2019

Ckt id	kV	From BUS	To BUS	Ckt miles	Rehab Year	Rehab Qtr
27A	345	DOW345 SUB	SOUTH TEXAS PLANT	45.34	2018	2nd
64A	345	JEANETTA SUB	W.A. PARISH PLANT	20.05	2018	2nd
72A	345	JEANETTA SUB	W.A. PARISH PLANT	20.06	2018	2nd
18A	345	JONES CREEK SUB	SOUTH TEXAS PLANT	43.05	2018	2nd
18D	345	DOW345 SUB	JONES CREEK SUB	3.92	2018	2nd
97F	345	CENTER SUB	P.H.ROBINSON PLANT	25.09	2018	4th
97D	345	CEDAR BAYOU PLANT	CENTER SUB	18.07	2018	4th
50A	345	BELLAIRE SUB	W. A. PARISH PLANT	24 96	2019	2nd
98B	345	OBRIEN SUB	W. A. PARISH PLANT	16.99	2019	2nd
99C	345	OBRIEN SUB	W. A. PARISH PLANT	17	2019	2nd
98A	345	BELLAIRE SUB	SMITHERS SUB	25.39	2019	2nd
98G	345	SMITHERS SUB	W. A. PARISH PLANT	0.52	2019	2nd
64C	345	HILLJE SUB	W.A. PARISH PLANT	48 94	2019	4th
39A	345	SOUTH TEXAS PLANT	W.A. PARISH PLANT	68 33	2019	4th

Ckt id	kV	From BUS	To BUS	Ckt miles	Rehab Year	Rehab Qtr
99E	345	MEADOW SUB	OASIS SUB	3.15	2019	4th
99A	345	MEADOW SUB	P.H.ROBINSON PLANT	17.37	2019	4th
72C	345	BAILEY SUB	W.A. PARISH PLANT	30.57	2019	4th
72D	345	BAILEY SUB	HILLJE SUB	18.72	2019	4th
18	345	GIBBONS CREEK	ZENITH	58.36	N/A	N/A
50	345	GIBBONS CREEK	ZENITH	58.33	N/A	N/A
98	345	SINGLETON	ZENITH	53.29	2020	4th
99	345	SINGLETON	ZENITH	53.30	2020	4th

11 System Modeling Elements

11.1 Tower Geometry

CenterPoint Energy uses either poles or lattice structure for all the 345 kV lines and for the majority of the 138 kV, as tower geometry depends on the circuit, data will be shown in each independent circuit analysis.

11.2 Conductor Parameters

Table 11-1 and Table 11-2, presents most common conductors used by CenterPoint Energy for its 345 kV and 138 kV.

Table 11-1: Phase Conductor Information

Conductor Type	kcmil	Stranding	Steel Strands	Number of Layers (Al)	Total Number of Inner Strands	Cross Sectional Area		Diameter				DC Resistance
						Al	Total	Al	Steel	Steel Core	Complete Cable	
						Sq In	Sq In	Inches	Inches	Inches	Inches	Ohms/Mile
Drake	795	26	7	2	10	0 6247	0 7264	[illegible]	0 136	0 408	1 108	0 1129
Suwannee/ACSS/TW	959 6	22	7	2	[illegible]	0 7537	0 8762	[illegible]		0 4479	1 11	0 0907
Kiwi	2167	72	7	4	[illegible]	1 7022	1 7758	[illegible]	0 1157	0 3471	1 735	0 0423

Table 11-2: Ground Wire Conductor Information

Conductor Type	kcmil	Number of Strands	Cross Sectional Area	Diameter		DC Resistance
			Steel	Steel	Complete Cable	
			Sq. In	Inches	Inches	Ohms/Mile
3/8 EHS		7	0 0792	0.12002415	0.36	6.63
7#8AW	115.6	7	0.09077	0.12849233	0.385	2.3538
3/8 HHS		7	0.0792	0.12002415	0.36	6.4

PSCAD in general requires additional data for stranded type of conductors as described in Figure 11-1, some of this information is not available in conductors' manufacturers manual as for example:

- Total number of strands: The total number of strands refers to all the stands in the conductor including aluminum and steel for ACSR conductors.
- Total number of outer strands: The total number of outer strands that line the circumference of the conductor assembly only. This information, it could be either counting the number of outer strands or using the following formula received from one manufacturer

  $N_{os} = (N_t - N_l * ((N_l - 1)^3))/N_l$, where:

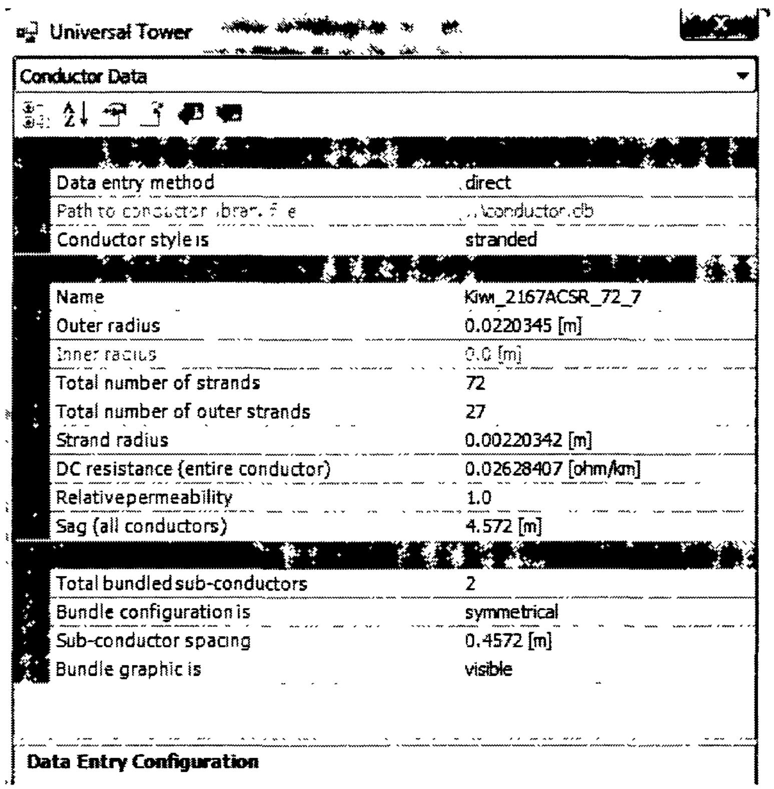
  N_{os} = Total number of outer strands

  N_t = Total number of aluminum strands

  N_l = Total number of aluminum layers

- Strand radius: In modeling a stranded conductor, only aluminum data is important. Hence, Aluminum strand radius is the strand conductor
- Outer radius: In modeling a stranded conductor, outer radius is the radius from the center to the edge of the outer strand

Figure 11-1: PSCAD Required Stranded Conductor Information



11.3 Surge Arrestors

CenterPoint Energy common practice is to install line surge arrestors at both end points. Almost all the existing 345 and 138 kV line surge arrestors have been replaced by MCOV porcelain surge arrestors. These types of arrestors are designed to provide years of successful service without recommended maintenance. When they fail, it will become shorted and conduct the available short circuit current to the ground grid in the substation. As a common practice, before performing hot line maintenance on a circuit, CNP will inspect line surge arrestors' conditions.

Line arrestors at Gibbons Creek were installed by CTT on the new circuits 18 and 50 from Gibbons Creek to Zenith, characteristics for these arrestors are given below on Table 11-4.

Figure 11-2: 345 kV CNP Line Surge Arrestors

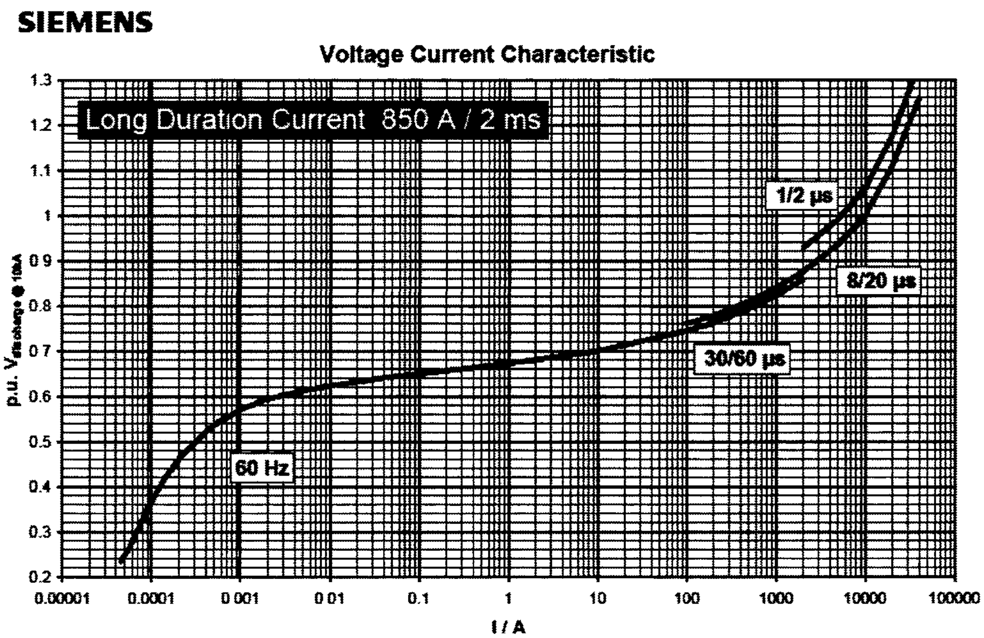


Table 11-3: CNP - 345 kV Line Surge Arrestors V-I Characteristics

Base Voltage (kVpeak)	Surge Arrester Rated Voltage (kVrms) MCOV	Surge Arrester Rated Voltage (kVpeak)	Current (A)	Current (kA)	Curve Used	Voltage (pu)	kVpeak	Voltage pu based upon Surge Arrester Rated Voltage
662	220	311.126984	0.0001	0.0000001	60 Hz	0.36	238.32	0.766
			0.001	0.000001	60 Hz	0.57	377.34	1.2128
			0.01	0.00001	60 Hz	0.625	413.75	1.3298
			0.1	0.0001	60 Hz	0.65	430.3	1.383
			1	0.001	60 Hz	0.675	446.85	1.4362
			10	0.01	60 Hz	0.7	463.4	1.4894
			100	0.1	60 Hz	0.74	489.88	1.5745
			200	0.2	60 Hz	0.76	503.12	1.6171
			300	0.3	30/60 us	0.77	509.74	1.6384
			500	0.5	30/60 us	0.8	529.6	1.7022
			1000	1	30/60 us	0.82	542.84	1.7448
			2000	2	30/60 us	0.86	569.32	1.8299
			5000	5	8/20 us	0.94	622.28	2.0001
			10000	10	8/20 us	1	662	2.1277
			20000	20	8/20 us	1.11	734.82	2.3618
			40000	40	8/20 us	1.26	834.12	2.681

Table 11-4: CTT - 345 kV Line Surge Arrestors V-I Characteristics

Base Voltage (kVpeak)	Surge Arrester Rated Voltage (kVrms) MCOV	Surge Arrester Rated Voltage (kVpeak)	Current (A)	Current (kA)	Curve Used	Voltage (pu)	kVpeak	
704	245	346.4823	0.01	0.00001	30/60 us	0.459	323.05	0.9324
			0.5	0.0005	8/20 us	0.556	391.4738	1.1299
			5	0.005	8/20 us	0.628	441.9503	1.2755
			50	0.05	8/20 us	0.720	507.009	1.4633
			80	0.08	8/20 us	0.726	511.2715	1.4756
			500	0.5	8/20 us	0.811	570.946	1.6478
			800	0.8	8/20 us	0.828	582.7239	1.6818
			1500	1.5	8/20 us	0.867	610.2056	1.7611
			2500	2.5	8/20 us	0.891	627.0311	1.8097
			3000	3	8/20 us	0.908	639.3698	1.8453
			5000	5	8/20 us	0.946	666.2906	1.923
			10000	10	8/20 us	1.012	712.2804	2.0557
			20000	20	8/20 us	1.098	772.8523	2.2306
			40000	40	8/20 us	1.220	859.2233	2.4798

11.4 Model Validation

Model validation is performed by comparing lines flows and short-circuits values between PSCAD/ETRAN model and the corresponding PSS/E power flow.

12 Analysis By circuit

This section summarizes all the data and TOV results for all the circuits listed on Table 10-1. The information per circuit is given in the following order:

- Circuit configuration
- TOV results
- TOV plots

12.1 345 kV STP to DOW ckt 27

The STP to Dow ckt 27 will be modeled in four independent sections of 3.10, 2.81, 8.01, and 31.43 miles as described in Table 12-1. The network topology is based upon the CNP 2017 AsBuilt Q4[2] case.

Basic Information for the divided circuit sections for modeling in the PSCAD program is given in Table 12-1, conductor's information is provided on Table 12-2 and Table 12-3, and tower geometry in Figure 12-1.

Table 12-1: STP – DOW ckt 27 – Configuration

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
DOW345-DWTURN	345DDT2	3/8EHS	3/8EHS	2-795ACSR_	0.03	1450*	1450
DWTURN-SI_COR	345DDT2	3/8EHS	3/8EHS	2-795ACSR_	1.65	1450*	1450
SI_COR-DOC_TP	345DDT2	3/8EHS	3/8EHS	2-795ACSR_	1.24	1450*	1450
DOC_TP-W__JCK	345DDT2	3/8EHS	3/8EHS	2-795ACSR_	0.18	1450*	1450
DOW345-W__JCK	345DDT2	3/8EHS	3/8EHS	2-795ACSR_	3.10	1450*	1450
W__JCK-DOCTPA	345DDT2	3/8EHS	3/8EHS	2-795ACSR_	2.71	1450*	1450
DOCTPA-SIS_SW	345DDT2	3/8EHS	3/8EHS	2-795ACSR_	0.13	1450*	1450
W__JCK-SIS_SW	345DDT2	3/8EHS	3/8EHS	2-795ACSR_	2.84	1450*	1450
SIS_SW-STECOR	345DDT2	3/8EHS	3/8EHS	2-795ACSR_	8.01	1450*	1450
STECOR-SO_TEX	345DDT2	3/8EHS	3/8EHS	2-795ACSR_	31.43	1450*	1450
DOW345-SO_TEX					45.38	1450*	1450
42500- 5915							

Table 12-2: PSCAD Input Data for Phase Conductor

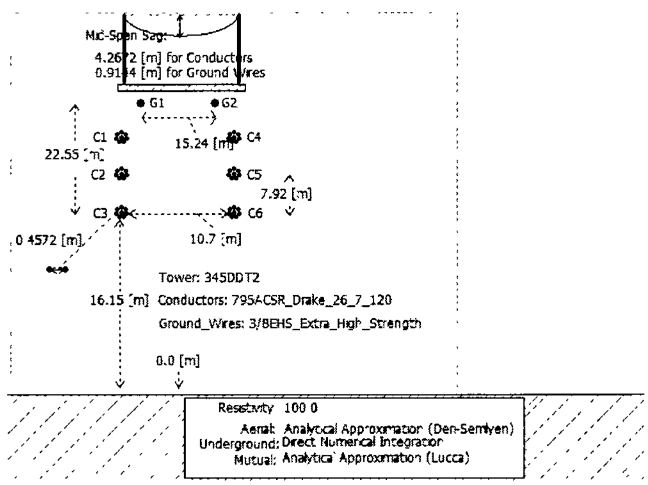
Conductor Type	kcmil	Stranding	Steel Strands	Number of Layers (Al)	Total Number of Inner Strands	Diameter		DC Resistance	PSCAD Entries				
						Al	Complete Cable		Total Number of Strands (AL Only)	Total Number of Outer Strands	Outer Radius	Strand Radius	DC Resistance
						Inches	Inches	Ohms/Mile			Meters	Meters	Ohm/km
Drake	795	26	7	2	[illegible]	[illegible]	1 108	0 1129	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

[2] Planning_AsBuilt_SCC_20180201.sav

Table 12-3: PSCAD Input Data for Ground Conductor

Conductor Type	kcmil	Number of Strands	Diameter		DC Resistance	PSCAD Entries		
			Steel	Complete Cable		Outer Radius	Strand Radius	DC Resistance
			Inches	Inches	Ohms/Mile	Meters	Meters	Ohm/km
3/8 EHS		7	0.12002415	0.36	6.63	0.004572	0.00152431	4.11970124

Figure 12-1: Tower Geometry (Tower type 345-DDT2)



Results for the maximum Transient Overvoltage for a Fault with restrike are shown in Table 12-4. CenterPoint has added to this maximum overvoltage a safety factor of 10%, which should be used in calculating the Minimum Approach Distance. The table also shows the location on the circuit where the maximum overvoltage was obtained (referred to Figure 12-2). TOV plots are shown from Figure 12-3 to Figure 12-6.

Table 12-4: Maximum TOV values STP-DOW ckt 27 (Fault with Restrike)

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
STP	Dow	27	345	STP	STPDOW27_STP	2 76	3 04	SIS_SW_27	2.20	2.42
STP	Dow	27	345	DOW	W__JCK_27	2.78	3.06	W__JCK_27	2.10	2.31

12.2 345 kV STP to Jones Creek ckt 18

The STP to Jones Creek ckt 18 will be modeled in four independent sections, three of the sections (W__JCK-SIS_SW, SIS_SW-STECOR, and W__JCK-SIS_SW) are on the same double circuit tower as ckt 27 and have the same conductors and tower geometry as those described in Table 12-2 and Figure 12-1. While the fourth section of 0.84 mi (JONES_-W__JCK) is only for ckt 18 on a double circuit tower in and out of Jones Creek substation. This small section has a different phase and ground wire conductor as described in Table 12-6 and Table 12-7. The network topology is based upon the CNP 2017 AsBuilt Q4[3] case.

Results for the maximum Transient Overvoltage for a Fault with restrike are shown in Table 12-8. CenterPoint has added to this maximum overvoltage a safety factor of 10%, which should be used in calculating the Minimum Approach Distance. The table also shows the location on the circuit where the maximum overvoltage was obtained (referred to Figure 12-2). TOV plots are shown from Figure 12-7 to Figure 12-10.

Table 12-5: STP – Jones Creek ckt 18 – Configuration

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
JONES_-W__JCK	345DDT2	7#8AW	7#8AW	3-959ACSST	0.84	3146	3352
W__JCK-DOCTPA	345DDT2	3/8EHS	3/8EHS	2-795ACSR_	2.70	1450*	1450
DOCTPA-SIS_SW	345DDT2	3/8EHS	3/8EHS	2-795ACSR_	0.13	1450*	1450
W__JCK-SIS_SW	345DDT2	3/8EHS	3/8EHS	2-795ACSR_	2.83	1450*	1450
SIS_SW-STECOR	345DDT2	3/8EHS	3/8EHS	2-795ACSR_	8.01	1450*	1450
STECOR-SO_TEX	345DDT2	3/8EHS	3/8EHS	2-795ACSR_	31.43	1450*	1450
JONES_-SO_TEX					43.11	1450*	1450
42530- 5915							

Table 12-6: PSCAD Input Data for Phase Conductor for ckt 18 Section JONES_-W__JCK

Conductor Type	kcmil	Stranding	Steel Strands	Number of Layers (Al)	Total Number of Inner Strands	Diameter		DC Resistance	PSCAD Entries				
						Al	Complete Cable		Total Number of Strands (AL Only)	Total Number of Outer Strands	Outer Radius	Strand Radius	DC Resistance
						Inches	Inches	Ohms/Mile			Meters	Meters	Ohm/km
Suwannee/ACSS/TW	959 6	22	7	2	8	0.20885409	1 11	0 0907	22	14	0.014097	0 00265245	0.05675851

[3] Planning_AsBuilt_SCC_20180201.sav

Table 12-7: PSCAD Input Data for Ground Conductor for ckt 18 Section JONES_-W__JCK

Conductor Type	kcmil	Number of Strands	Diameter		DC Resistance	PSCAD Entries		
			Steel	Complete Cable		Outer Radius	Strand Radius	DC Resistance
			Inches	Inches	Ohms/Mile	Meters	Meters	Ohm/km
7#8AW	115.6	7	0.12849233	0.385	2.3538	0.0048895	0.00163185	1.46258715

Table 12-8: Maximum TOV values STP-Jones Creek ckt 18 (Fault with Restrike)

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
STP	Jones Creek	18	345	STP	STPJCK18_STP	2 72	2.99	STECOR_18	2 07	2.28
STP	Jones Creek	18	345	Jones Creek	STPJCK18_JCK	2.82	3.11	STECOR_18	2.09	2.30

12.3 345 kV Jones Creek – DOW ckt 18

The STP to Jones Creek ckt 18 will be modeled in two independent sections of 3.06, and 0.86 miles as described in Table 12-9. The network topology is based upon the CNP 2017 AsBuilt Q4[4] case.

Tower configuration is in Figure 12-1 and conducts are in Table 12-2 to Table 12-7.

Results for the maximum Transient Overvoltage for a Fault with restrike are shown in Table 12-10. CenterPoint has added to this maximum overvoltage a safety factor of 10%, which should be used in calculating the Minimum Approach Distance. The table also shows the location on the circuit where the maximum overvoltage was obtained (referred to Figure 12-2). TOV plots are shown from Figure 12-11 to Figure 12-14. With and without surge arrestors, the maximum overvoltage is similar as due to the low values there is no surge arrestor operation. This result is typical due to the short length of the circuits.

Table 12-9: Dow – Jones Creek ckt 18 – Configuration

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
DOW345-DWTURN	345DDT2	3/8EHS	3/8EHS	2-795ACSR_	0.03	1450*	1450
DWTURN-SI_COR	345DDT2	3/8EHS	3/8EHS	2-795ACSR_	1.65	1450*	1450
SI_COR-DOC_TP	345DDT2	3/8EHS	3/8EHS	2-795ACSR_	1.24	1450*	1450
DOC_TP-W__JCK	345DDT2	3/8EHS	3/8EHS	2-795ACSR_	0.14	1450*	1450
DOW345-W__JCK	345DDT2	3/8EHS	3/8EHS	2-795ACSR_	3.06	1450*	1450
W__JCK-JONES_	345DDT2	7#8AW	7#8AW	3-959ACSST	0.86	3146	3352
W__JCK-JONES_	345DDT2	3/8EHS	3/8EHS	2-795ACSR_	0.86	3146	3352
42500- 42530							

Table 12-10: Maximum TOV values Jones Creek – Dow ckt 18 (Fault with Restrike)

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Jones Creek	Dow	18	345	Jones Creek	JCKDOW18_JCK	1.83	2 02	W__JCK_18O	1.73	1.90
Jones Creek	Dow	18	345	Dow	JCKDOW18_DOW	2.10	2.31	JCKDOW18_DOW	1.73	1.90

[4] Planning_AsBuilt_SCC_20180201.sav

Figure 12-2: PSCAD MODEL STP – DOW ckt 27 and STP-Jones Creek-DOW ckt 18

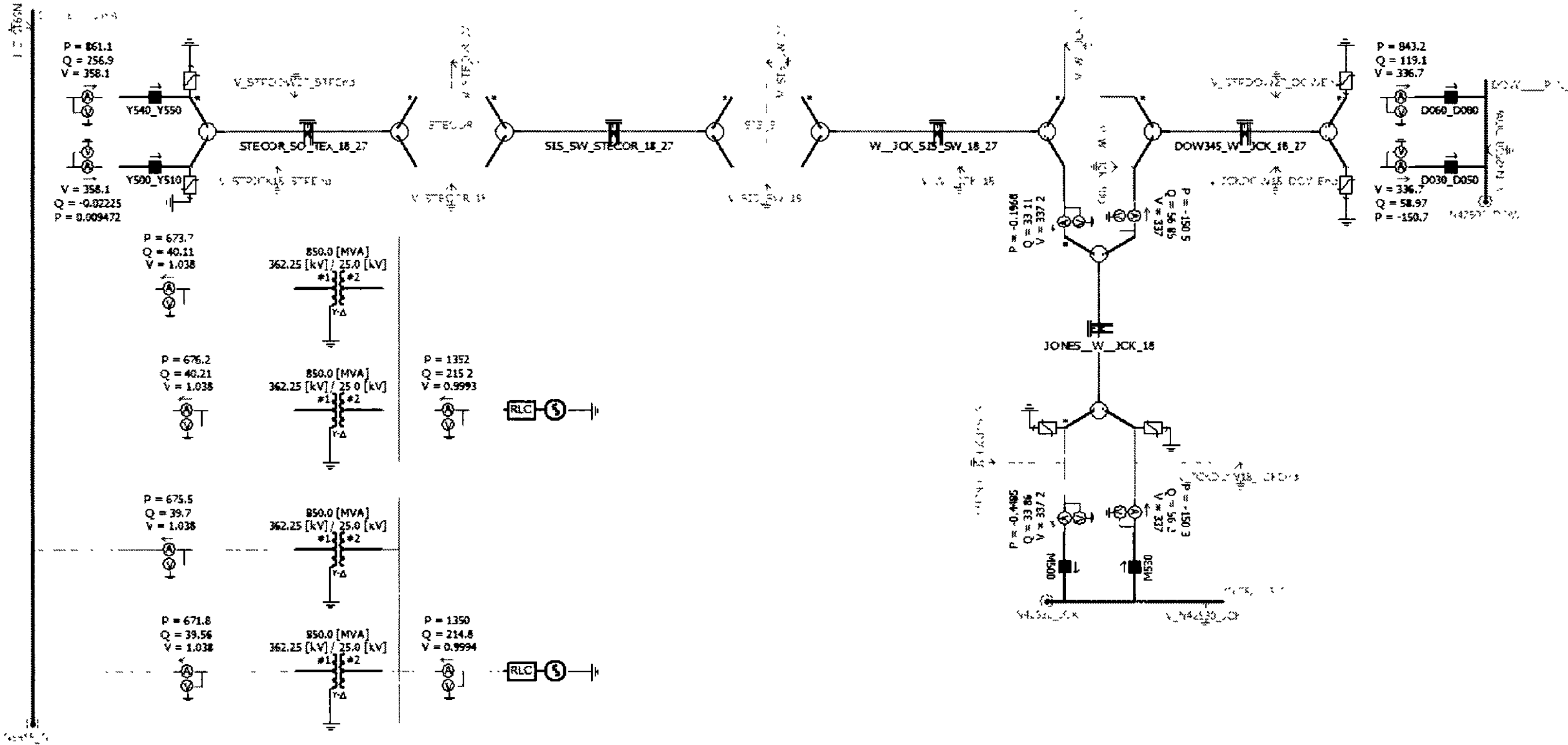


Figure 12-3: Maximum Overvoltage for STP-DOW ckt 27 – STP side open without Line-Arrestor

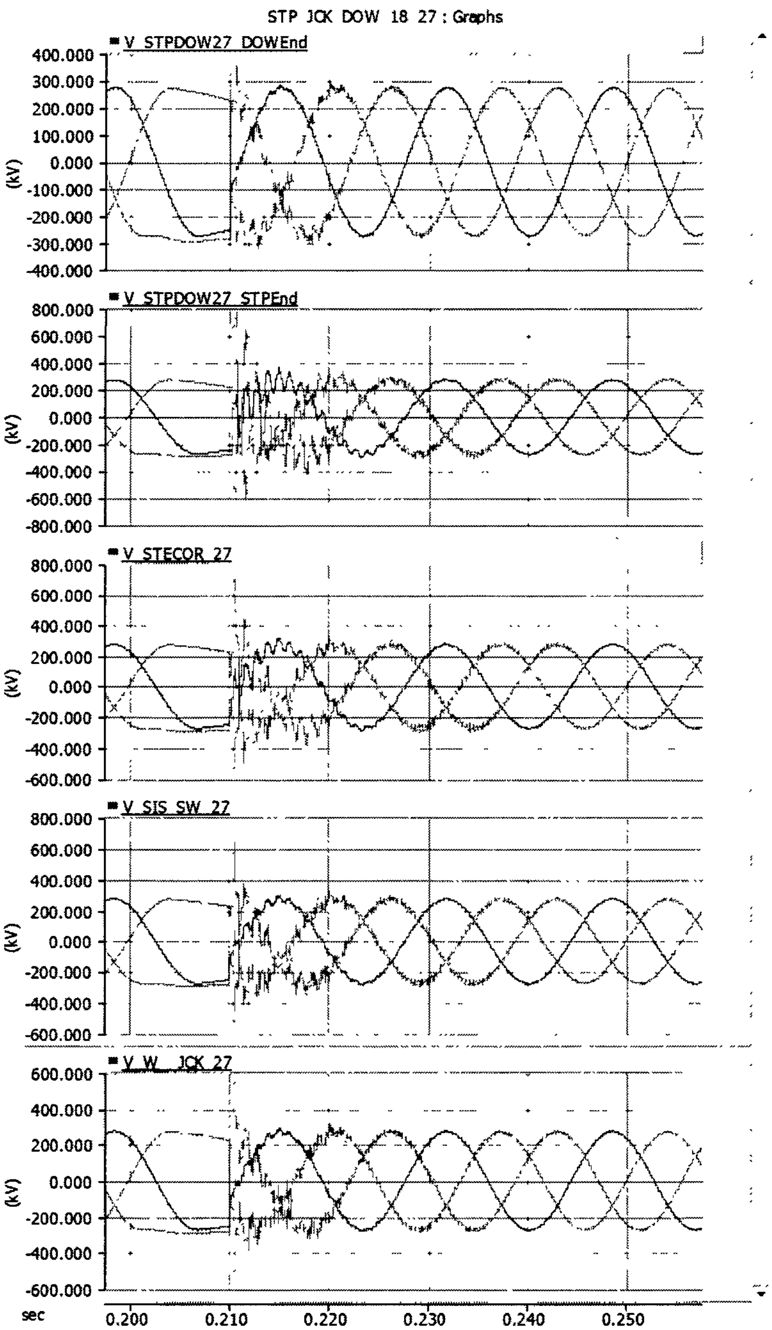


Figure 12-4: Maximum Overvoltage for STP-DOW ckt 27 – STP side open with Line-Arrestor

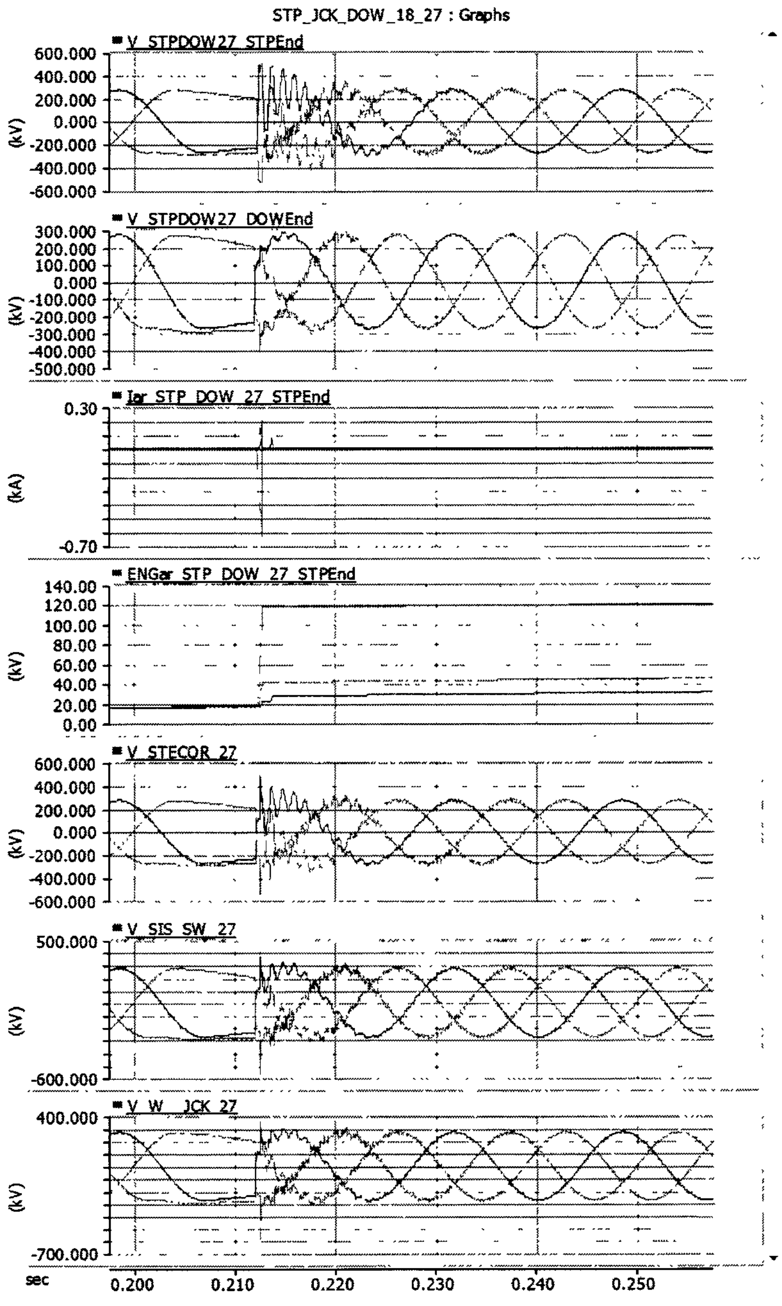


Figure 12-5: Maximum Overvoltage for STP-DOW ckt 27 – DOW side open without Line-Arrestor

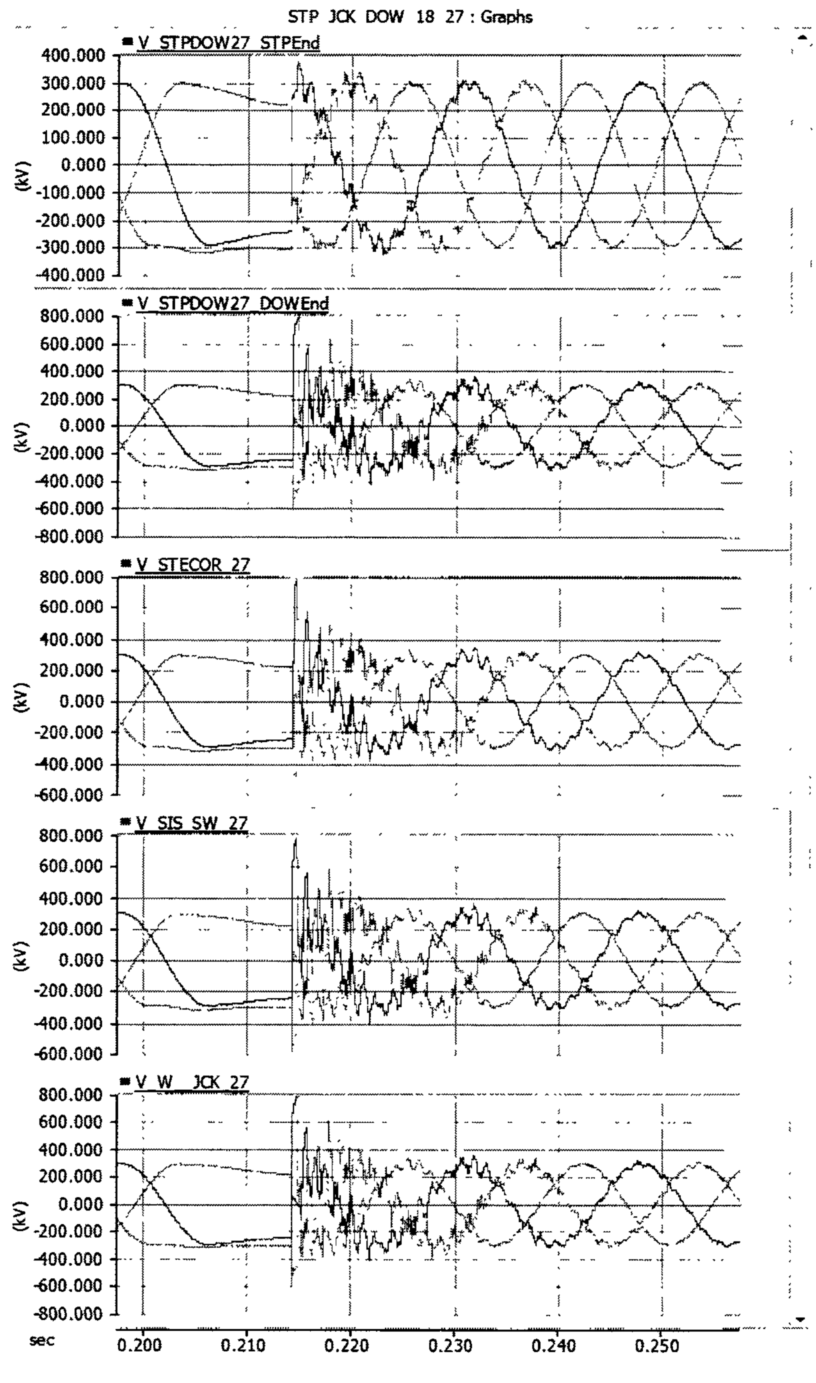


Figure 12-6: Maximum Overvoltage for STP-DOW ckt 27 – DOW side open with Line-Arrestor

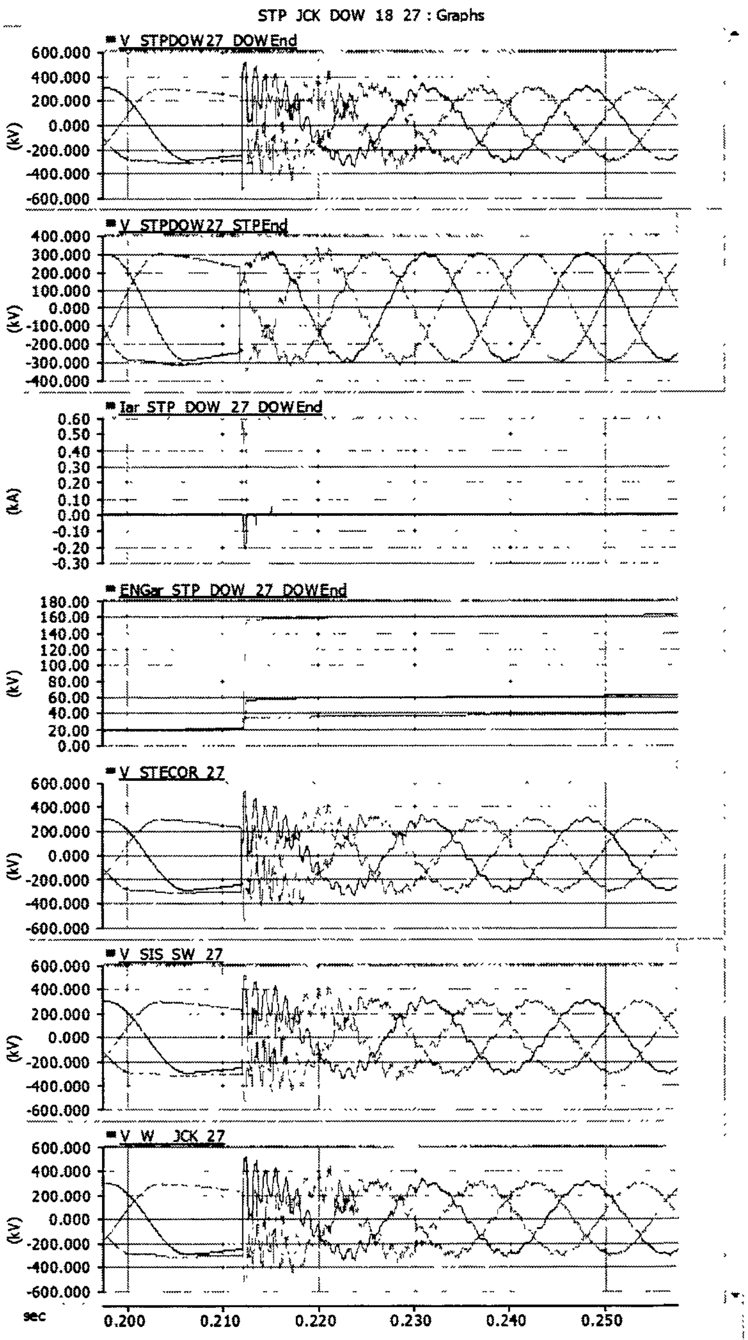


Figure 12-7: Maximum Overvoltage for STP-Jones Creek ckt 18 – STP side open without Line-Arrestor

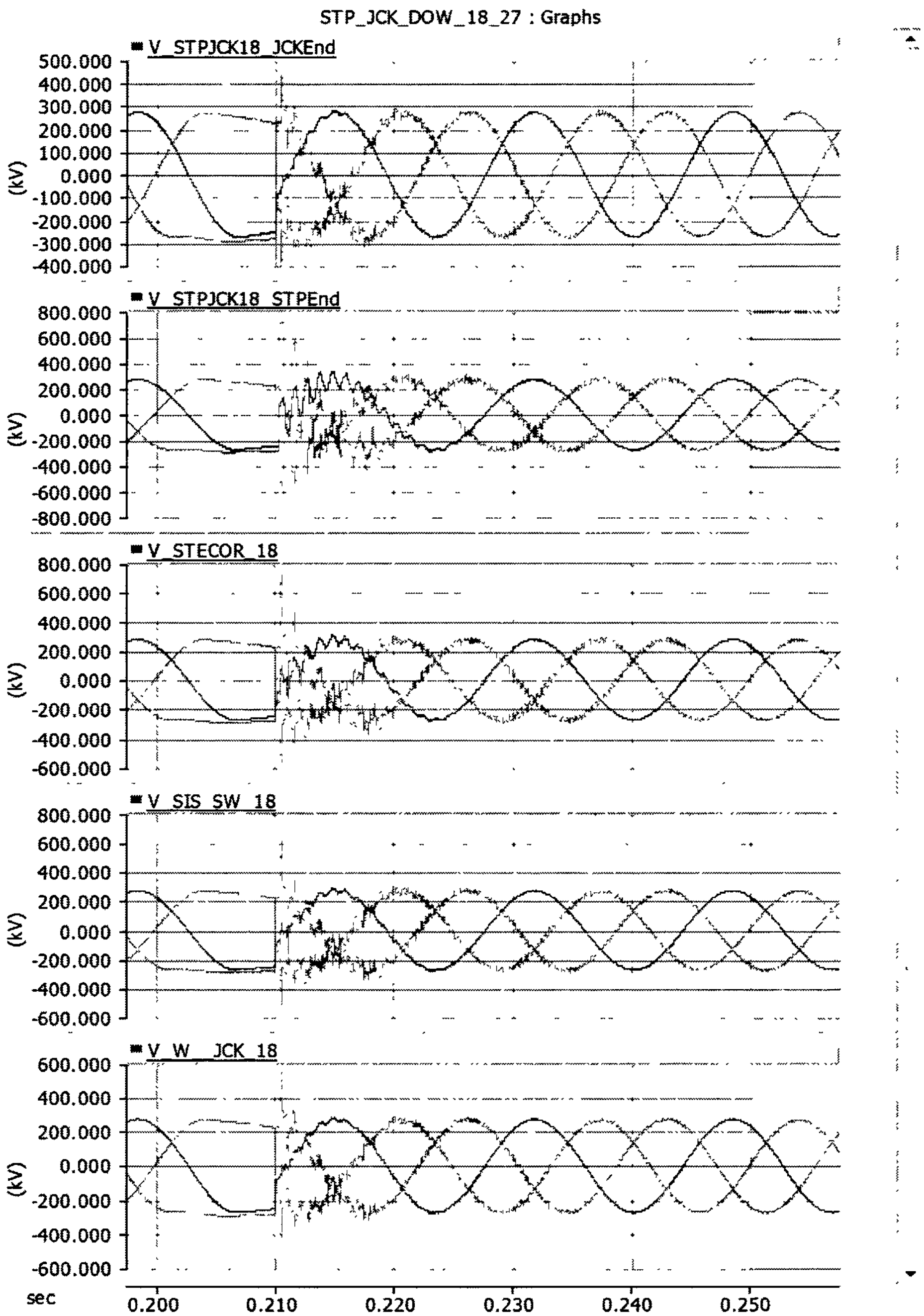


Figure 12-8: Maximum Overvoltage for STP-Jones Creek ckt 18 – STP side open with Line-Arrestor