Connecticut Cable Resonance Study for XLPE Alternative in Middletown to Norwalk Project

Summary Report
July 2004

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Foreword

This document was prepared by General Electric Company in Schenectady, New York. It is submitted to Northeast Utilities (NU). Technical and commercial questions and any correspondence concerning this document should be referred to:

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Introduction

GE Energy's Energy Consulting group has performed a resonance study of an XLPE alternative in the Northeast Utilities (NU) Middletown to Norwalk 345 kV transmission cable project that is proposed in southwestern Connecticut. In this study, the two cables between Norwalk and Singer and the two cables between Singer and East Devon were represented as 3000 kcmil XLPE cable rather than 2500 kcmil HPFF cable, and one of the two HPFF cables between Plumtree and Norwalk was removed.

The objectives of this study were

- to investigate the change in the first resonance with the above modifications as compared to the proposed HPFF double circuit configuration, and
- to investigate the effect of representing reduced generation in the area.

The study has been performed with the Electromagnetic Transients Program (ATP/EMTP), which is recognized as an industry standard for simulating the transient performance and frequency response of electric utility systems [www.emtp.org].

System Representation

The system model used in the Middletown to Norwalk study was used in this study with modifications. The charging capacitance of the 3000 kcmil XLPE cables is approximately 60% of that of the 2500 kcmil HPFF cables. The following parameters were used to represent the 3000 kcmil XLPE cables (per circuit in pu on a 100 MVA base):

<u>Singer to Norwalk - 15.5 miles</u>
Rpos=0.0003477 pu
Rzero=0.00358118 pu
Xpos=0.00416198 pu
Xneg=0.0023779 pu
Bposzero=1.9637 pu

<u>East Devon to Singer - 8.1 miles</u>
Rpos=0.0001817 pu
Rzero=0.0018715 pu
Xpos=0.00217497 pu
Xneg=0.0012426 pu
Bposzero=1.0261907 pu

In addition to the above changes, one of the two 9.7-mile HPFF cable circuits between Plumtree and Norwalk was removed. The overhead line between East Devon and Beseck was the same as in the Middletown to Norwalk project.

NU determined that the two capacitor banks at Norwalk 115 kV would be removed with the addition of the Middletown to Norwalk project, and were removed from the model accordingly. Table 1 shows the modified capacitor bank data for this study, and indicates the total MVAR at each bus and the capacitor bank MVAR in service under peak and light load conditions. This study considered conditions with all capacitor banks in service and all capacitor banks out of service. Table 2 shows the generators included in the original ASPEN file, and the modified status originally provided for the Middletown to Norwalk (M/N) project, which indicates the generators that are on or off during peak and light load conditions. An additional generator dispatch scenario is given for "Light Post-Project," which depicts a more realistic scenario with more local generation off. This study considered the original light load dispatch of generators and the Light Post-Project dispatch with more local generation off.

An additional shunt capacitor condition is shown in the last column of Table 1, where some 115 kV capacitor banks in the "All Banks In" condition (column 4 of Table 1) are taken out of service. This reduced bank condition has no capacitors on at Plumtree, only 205.6 MVAr at Frost Bridge, and only 75.6 MVAr at Glenbrook. This condition was considered in connection with the Light Post-Project generation dispatch and the original light load dispatch.

Table 1. Modified Shunt Capacitor Conditions for System Model

Shunt Capacitors			**All Banks**	**Peak Load**	**Light Load**	**Reduced Banks**
Substation	**Voltage (kV)**	**# Units**	**MVAR (total)**	**MVAR**	**MVAR**	**MVAR**
Southington 1	115	3	157.2	157.2		157.2
Southington 2	115	3	157.2	157.2		157.2
Frost Bridge	115	5	262.0	262.0		205.6
Berlin	115	3	132.0	132.0		132.0
Plumtree	115	2	92.2	0		0
Glenbrook	115	5	190.8*	151.2		75.6
Darien	115	1	39.6	39.6		39.6
Waterside	115	1	39.6	39.6		39.6
Norwalk	115	0	0	0		0
East Shore	115	2	84.0	84.0		84.0
No. Haven	115	1	42.0	42.0		42.0
Sackett	115	1	42.0	42.0		42.0
Rocky River	115	1	25.2	25.2		25.2
Stony Hill	115	1	25.2	25.2		25.2
Cross Sound Filters	200	3	103.0 (61 – 25th, 32 – 41st, 10 – 21st)	103.0	103.0	103.0

* Actual maximum including Glenbrook Statcom is 335 MVAR (additional MVAR not included in analysis)

Table 2. Modified Generator Conditions for System Model

GENERATOR	KV	ID	ST	STATUS (PEAK)	STATUS (LIGHT)	Light Post-Project	IDENTIFI-CATION NOTES
MILLSTON	22.8	1	1	on	on	On	
MILLSTON	22.8	1	1	on	on	On	
RESCO	115	1	1	on	on	On	Bridgeport
ROCKY RV	13.8	1	1	on	on	Off	
ROCKY RV	13.8	1	1	on	on	Off	
ROCKY RV	13.8	1	1	on	on	Off	
STEVENSO	6.9	1	1	off	off	Off	
NORWALK	27.6	1	0	off	off	Off	
BULLS BR	27.6	1	1	on	on	Off	
FORESTVI	13.8	1	1	on	on	On	
brdgphbr	18.4	2	1	off	off	Off	
brdgphbr	20.2	3	1	on	on	Off	
brdgphbr	13.68	jt	1	off	off	Off	
COSCOBGE	13.8	1	1	off	off	Off	
COSCOBGE	13.8	2	1	off	off	Off	
COSCOBGE	13.8	3	1	off	off	Off	
DEVON 11	13.8	1	1	off	off	Off	
DEVON 12	13.8	1	1	off	off	Off	
DEVON 13	13.8	1	1	off	off	Off	
DEVON 14	13.8	1	1	off	off	Off	
English	13.68	8	1	off	off	Off	
English	13.68	7	1	off	off	Off	
ESHOREGE	13.8	1	1	on	on	Off	New Haven
G1/G2	13.8	1	1	off	off	Off	Wallingford
G3/G4	13.8	1	1	off	off	Off	Wallingford
G5	13.8	1	1	off	off	Off	Wallingford
GT1 (11)	16	1	1	off	off	Off	BE
GT2 (12)	16	1	1	off	off	Off	BE
Middleto	22	1	1	on	off	Off	Middletown
Milford	20.9	1	1	on	on	Off	
Milford	20.9	1	1	off	off	Off	
one (Meriden)	21	1	1	on	off	Off	Meriden
Shepaug	13.8	1	1	on	on	Off	
so norwa	4.8	1	1	off	off	Off	
so norwa	4.8	1	1	off	off	Off	
so norwa	13.8	1	1	off	off	Off	
ST1 (10)	16	1	1	off	off	Off	BE
Temp Gen (Waterside)	13.8	3	0	off	off	Off	Waterside
Temp Gen (Waterside)	13.8	1	0	off	off	Off	Waterside
Temp Gen (Waterside)	13.8	2	0	off	off	Off	Waterside
three (Meriden)	21	1	1	on	off	Off	Meriden

GENERATOR	KV	ID	ST	STATUS (PEAK)	STATUS (LIGHT)	Light Post-Project	IDENTIFI-CATION NOTES
two (Meriden)	21	1	1	on	off	Off	Meriden
Unit 10	13.8	1	1	off	off	Off	Devon 10
Unit 6J- (Norwalk)	17.1	1	1	off	off	Off	Norwalk-1
Unit 6J- (Norwalk)	13.8	1	1	off	off	Off	Norwalk -10
Unit 6J- (Norwalk)	19	1	1	off	on	Off	Norwalk-2
Unit 7	13.2	1	1	on	off	Off	Devon
Unit 8	13.2	1	1	on	off	Off	Devon
walrecge	4.16	1	1	on	off	Off	

Resonance Results

The resonance effects of the XLPE alternative, including removal of one HPFF cable between Plumtree and Norwalk, was analyzed by evaluating the driving-point impedance versus frequency at various locations, with all capacitor banks in and out of service, and with the original light load and light post-project generator (local generation off) dispatches.

Table 3 shows the cases that were performed for the M/N-XLPE alternative and the resonant frequencies that were observed along with the corresponding impedance value at those frequencies, with the original light load generation dispatch. The resonant frequency is indicated by its harmonic number (HN), in per unit of 60 Hz, and impedance magnitude is in ohms. The corresponding driving-point impedance plots are provided in Appendix A. Table 4 shows the results with the local generation off (light post-project generator dispatch), and the corresponding driving-point impedance plots are provided in Appendix B. Tables 3 and 4 includes rows corresponding to the cases where some capacitor banks are taken out of service as shown in the last column of Table 1. This reduced capacitive shunt MVAr has an impact of raising the first resonance frequency in the order of 0.1-0.2 pu (6-12 Hz).

Figure 1 is a comparison plot of the system impedance characteristic versus frequency at Plumtree 345 kV, illustrating the impact of the XLPE alternative on the resonance characteristics as compared with the proposed M/N project having HPFF cable and two HPFF cable circuits between Plumtree and Norwalk. Figure 2 is a similar comparison plot at Norwalk 345 kV.

Table 3. Resonant Frequencies for M/N-XLPE Project with Light Load Generation

Case	Location	Capacitor Banks	Resonant Frequency & Impedance (pu of 60Hz, Ohm)					
			Low		Middle		High	
			HN	Z(Ω)	HN	Z(Ω)	HN	Z(Ω)
M/N-XLPE_1A	Plumtree 345 kV	Light Load	-	-	-	-	-	-
M/N-XLPE_1B	Plumtree 345 kV	All in Service	2.8	131	5.6	99	13.5	1495
M/N-XLPE_1C	Plumtree 345 kV	All Out of Service	3.5	220			11.8	349
M/N-XLPE_1D	Plumtree 345 kV	Some Out of Service	2.9	137			11.6 13.9	254 428
M/N-XLPE_2A	Plumtree 115 kV	Light Load	-	-	-	-	-	-
M/N-XLPE_2B	Plumtree 115 kV	All in Service	2.7	19	6.8	78	9.7	63
M/N-XLPE_2C	Plumtree 115 kV	All Out of Service	3.5	22			11.7 14.9	128 98
M/N-XLPE_2D	Plumtree 115 kV	Some Out of Service	2.9	17	7.6	32	11.6	104
M/N-XLPE_3A	Norwalk 345 kV	Light Load	-	-	-	-	-	-
M/N-XLPE_3B	Norwalk 345 kV	All in Service	2.8	150	5.7	160		
M/N-XLPE_3C	Norwalk 345 kV	All Out of Service	3.5	288				
M/N-XLPE_3D	Norwalk 345 kV	Some Out of Service	3.0	164	4.9 6.3	86 78		
M/N-XLPE_4A	Norwalk 115 kV	Light Load	-	-	-	-	-	-
M/N-XLPE_4B	Norwalk 115 kV	All in Service	2.8	15	4.6	15		

M/N-XLPE_4C	Norwalk 115 kV	All Out of Service	3.5	19			8.3 16.0	24 33
M/N-XLPE_4D	Norwalk 115 kV	Some Out of Service	2.9	14	4.8 6.2	13 19	2.6	13
M/N-XLPE_5A	Southington 345 kV	Light Load	-	-	-	-	-	-
M/N-XLPE_5B	Southington 345 kV	All in Service	2.8	77	4.5	62	8.2 12.4	87 115
M/N-XLPE_5C	Southington 345 kV	All Out of Service	3.5	73			10.6	260
M/N-XLPE_5D	Southington 345 kV	Some Out of Service	2.9	86	4.8	68	8.7 12.5	57 110
M/N-XLPE_6A	Southington 115 kV	Light Load	-	-	-	-	-	-
M/N-XLPE_6B	Southington 115 kV	All in Service	2.7	11	4.5 5.3	24 32	9.4	127
M/N-XLPE_6C	Southington 115 kV	All Out of Service	3.4	9			10.3	29
M/N-XLPE_6D	Southington 115 kV	Some Out of Service	2.9	13	4.8	36	9.5	122
M/N-XLPE_7A	East Shore 345 kV	Light Load	-	-	-	-	-	-
M/N-XLPE_7B	East Shore 345 kV	All in Service	2.7	62	6.2	224	12.4 14.6	247 515
M/N-XLPE_7C	East Shore 345 kV	All Out of Service	3.4	66			10.3	245
M/N-XLPE_7D	East Shore 345 kV	Some Out of Service	2.9	68	6.2	226	12.4 14.6	243 515
M/N-XLPE_8A	Devon 115 kV	Light Load	-	-	-	-	-	-
M/N-XLPE_8B	Devon 115 kV	All in Service	2.7	11				
M/N-XLPE_8C	Devon 115 kV	All Out of Service	3.5	14				
M/N-XLPE_8D	Devon 115 kV	Some Out of Service	2.9	12				
M/N-XLPE_9A	Frost Bridge 115 kV	Light Load	-	-	-	-	-	-
M/N-XLPE_9B	Frost Bridge 115 kV	All in Service	2.8	18	4.5 5.6	26 43	8.3	34
M/N-XLPE_9C	Frost Bridge 115 kV	All Out of Service	3.4	12			10.3	27
M/N-XLPE_9D	Frost Bridge 115 kV	Some Out of Service	2.9	19	5.7	59	8.8	50
M/N-XLPE_10A	Glenbrook 115 kV	Light Load	-	-	-	-	-	-
M/N-XLPE_10B	Glenbrook 115 kV	All in Service	2.7	16	4.5 5.7	27 42		
M/N-XLPE_10C	Glenbrook 115 kV	All Out of Service	3.5	17	8.3	44	16.1	55
M/N-XLPE_10D	Glenbrook 115 kV	Some Out of Service	2.9	14	4.8 6.3	19 51		
M/N-XLPE_11A	Singer 345 kV	Light Load	-	-	-	-	-	-
M/N-XLPE_11B	Singer 345 kV	All in Service	2.8	146	5.6	177	13.5	391
M/N-XLPE_11C	Singer 345 kV	All Out of Service	3.5	286				
M/N-XLPE_11D	Singer 345 kV	Some Out of Service	3.0	162				
M/N-XLPE_12A	Devon 345 kV	Light Load	-	-	-	-	-	-
M/N-XLPE_12B	Devon 345 kV	All in Service	2.8	141	5.6	162	13.5	512
M/N-XLPE_12C	Devon 345 kV	All Out of Service	3.5	270				
M/N-XLPE_12D	Devon 345 kV	Some Out of Service	3.0	156				
M/N-XLPE_13A	Beseck 345 kV	Light Load	-	-	-	-	-	-
M/N-XLPE_13B	Beseck 345 kV	All in Service	2.8	69			12.5	308
M/N-XLPE_13C	Beseck 345 kV	All Out of Service	3.5	82			10.6	264
M/N-XLPE_13D	Beseck 345 kV	Some Out of Service	2.9	77			12.5	274

Table 4. Resonant Frequencies for M/N-XLPE Project with Local Generators Off

Case	Location	Capacitor Banks	Resonant Frequency & Impedance (pu of 60Hz, Ohm)					
			Low		Middle		High	
			HN	Z(Ω)	HN	Z(Ω)	HN	Z(Ω)
M/N-XLPE2_1A	Plumtree 345 kV	Light Load	-	-	-	-	-	-
M/N-XLPE2_1B	Plumtree 345 kV	All in Service	2.5	103	5.6	102	13.5	1453
M/N-XLPE2_1C	Plumtree 345 kV	All Out of Service	3.3	161			11.7	313
M/N-XLPE2_1D	Plumtree 345 kV	Some Out of Service	2.7	107			11.5 13.8	227 412
M/N-XLPE2_2A	Plumtree 115 kV	Light Load	-	-	-	-	-	-
M/N-XLPE2_2B	Plumtree 115 kV	All in Service	2.5	16	6.7	66	9.5	62
M/N-XLPE2_2C	Plumtree 115 kV	All Out of Service	3.2	18			11.7 14.9	119 89
M/N-XLPE2_2D	Plumtree 115 kV	Some Out of Service	2.6	14	7.4	30	11.5	97
M/N-XLPE2_3A	Norwalk 345 kV	Light Load	-	-	-	-	-	-
M/N-XLPE2_3B	Norwalk 345 kV	All in Service	2.5	121	5.6	167		
M/N-XLPE2_3C	Norwalk 345 kV	All Out of Service	3.3	210				
M/N-XLPE2_3D	Norwalk 345 kV	Some Out of Service	2.7	129	4.8 6.2	76 89		
M/N-XLPE2_4A	Norwalk 115 kV	Light Load	-	-	-	-	-	-
M/N-XLPE2_4B	Norwalk 115 kV	All in Service	2.5	13	4.5	14		
M/N-XLPE2_4C	Norwalk 115 kV	All Out of Service	3.2	16			8.0 16.0	23 32
M/N-XLPE2_4D	Norwalk 115 kV	Some Out of Service	2.6	13	4.7 6.2	13 17		
M/N-XLPE2_5A	Southington 345 kV	Light Load	-	-	-	-	-	-
M/N-XLPE2_5B	Southington 345 kV	All in Service	2.5	63	4.5	59	8.2 12.4	92 113
M/N-XLPE2_5C	Southington 345 kV	All Out of Service	3.2	62			10.4	238
M/N-XLPE2_5D	Southington 345 kV	Some Out of Service	2.6	69	4.8	63	8.6 12.4	63 107
M/N-XLPE2_6A	Southington 115 kV	Light Load	-	-	-	-	-	-
M/N-XLPE2_6B	Southington 115 kV	All in Service	2.4	10	4.5 5.2	23 26	9.4	119
M/N-XLPE2_6C	Southington 115 kV	All Out of Service	3.1	8			10.1	28
M/N-XLPE2_6D	Southington 115 kV	Some Out of Service	2.6	11	4.8	33	9.4	115
M/N-XLPE2_7A	East Shore 345 kV	Light Load	-	-	-	-	-	-
M/N-XLPE2_7B	East Shore 345 kV	All in Service	2.4	69	6.1	249	12.4 14.2	266 375
M/N-XLPE2_7C	East Shore 345 kV	All Out of Service	3.1	72			10.1	274
M/N-XLPE2_7D	East Shore 345 kV	Some Out of Service	2.6	75	6.1	248	12.4 14.2	262 374
M/N-XLPE2_8A	Devon 115 kV	Light Load	-	-	-	-	-	-
M/N-XLPE2_8B	Devon 115 kV	All in Service	2.5	12				
M/N-XLPE2_8C	Devon 115 kV	All Out of Service	3.2	15				
M/N-XLPE2_8D	Devon 115 kV	Some Out of Service	2.6	13				
M/N-XLPE2_9A	Frost Bridge 115 kV	Light Load	-	-	-	-	-	-
M/N-XLPE2_9B	Frost Bridge 115 kV	All in Service	2.5	14	4.5 5.6	24 42	8.3	35
M/N-XLPE2_9C	Frost Bridge 115 kV	All Out of Service	3.1	11			10.1	26

M/N-XLPE2_9D	Frost Bridge 115 kV	Some Out of Service	2.6	15	5.6	53	8.7	51
M/N-XLPE2_10A	Glenbrook 115 kV	Light Load	-	-	-	-	-	-
M/N-XLPE2_10B	Glenbrook 115 kV	All in Service	2.5	14	4.5 5.6	27 38		
M/N-XLPE2_10C	Glenbrook 115 kV	All Out of Service	3.2	15	8.1	42	16.1	53
M/N-XLPE2_10D	Glenbrook 115 kV	Some Out of Service	2.6	13	4.7 6.2	20 48		
M/N-XLPE2_11A	Singer 345 kV	Light Load	-	-	-	-	-	-
M/N-XLPE2_11B	Singer 345 kV	All in Service	2.5	119	5.6	184	13.5	377
M/N-XLPE2_11C	Singer 345 kV	All Out of Service	3.3	210				
M/N-XLPE2_11D	Singer 345 kV	Some Out of Service	2.7	129				
M/N-XLPE2_12A	Devon 345 kV	Light Load	-	-	-	-	-	-
M/N-XLPE2_12B	Devon 345 kV	All in Service	2.5	116	5.6	168	13.5	498
M/N-XLPE2_12C	Devon 345 kV	All Out of Service	3.3	200				
M/N-XLPE2_12D	Devon 345 kV	Some Out of Service	2.7	126				
M/N-XLPE2_13A	Beseck 345 kV	Light Load	-	-	-	-	-	-
M/N-XLPE2_13B	Beseck 345 kV	All in Service	2.5	57			12.4	297
M/N-XLPE2_13C	Beseck 345 kV	All Out of Service	3.2	67			10.4	238
M/N-XLPE2_13D	Beseck 345 kV	Some Out of Service	2.6	63			12.5	266

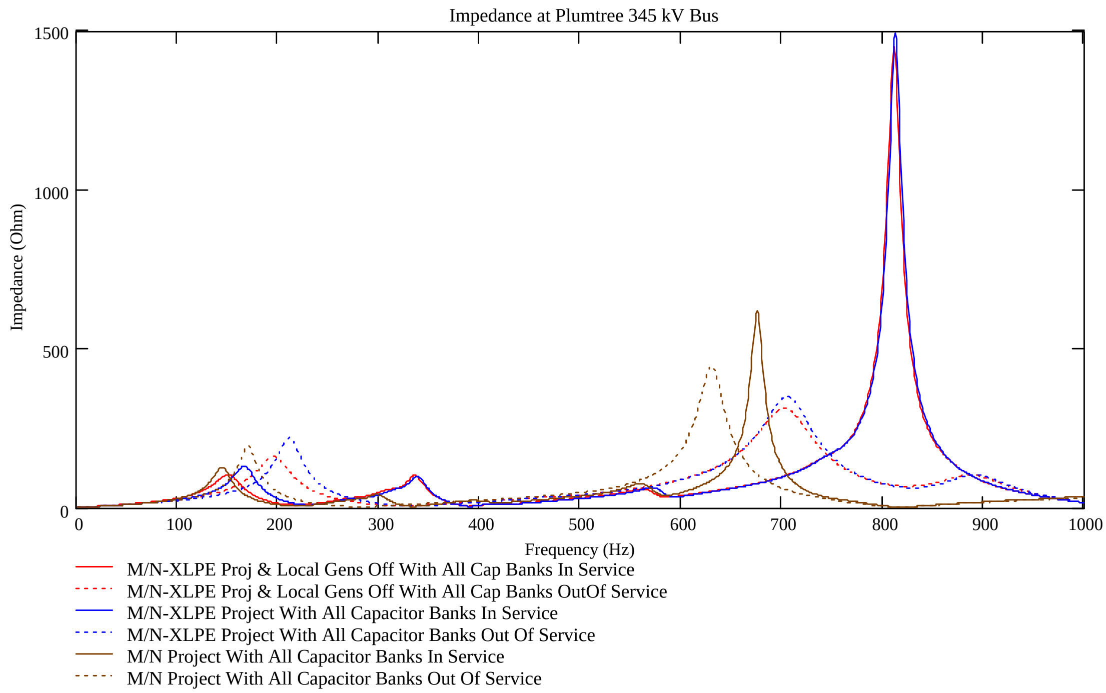


Figure 1. Impedance vs. Frequency at Plumtree 345 kV

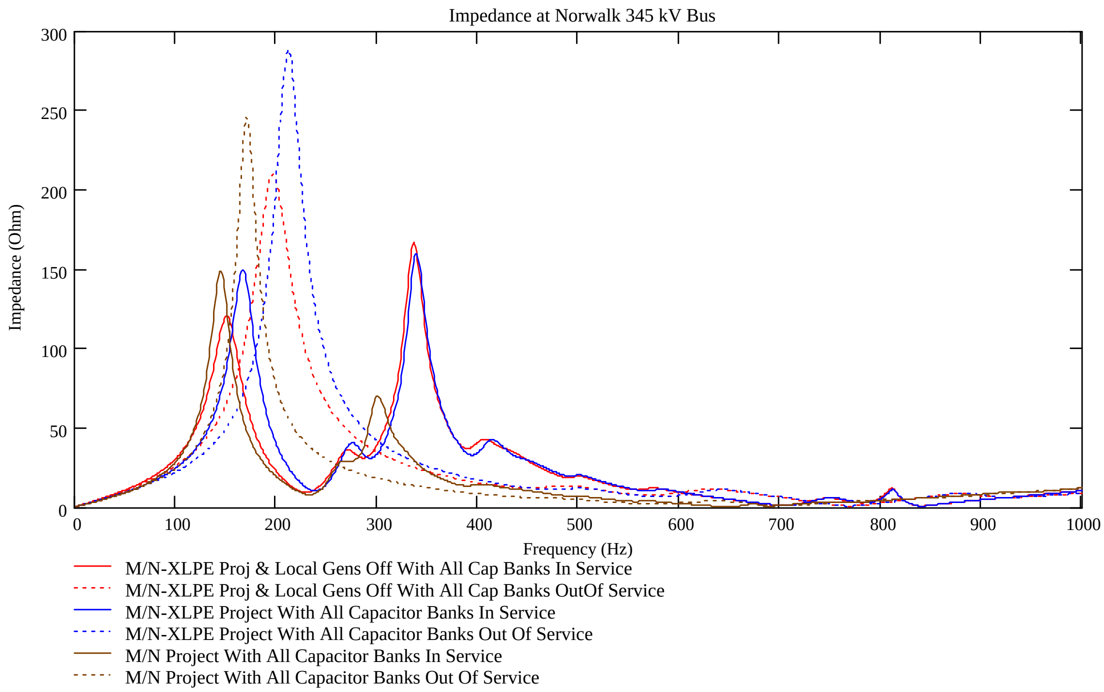


Figure 2. Impedance vs. Frequency at Norwalk 345 kV

Conclusions

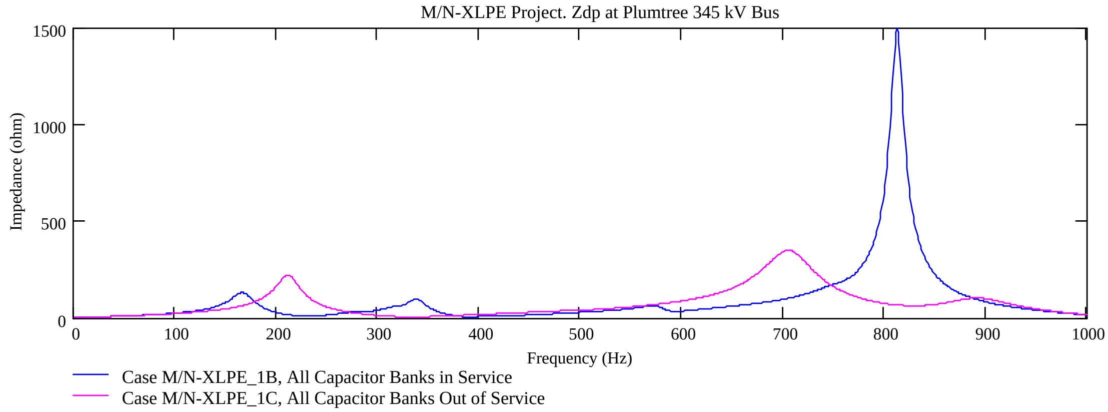
Table 5 summarizes the variation in frequencies of the first resonance points for the M/N project and for the XLPE alternative, with the original light load generator dispatch and with more local generation off. In the proposed M/N project previously studied, the first resonance was between 2.4 and 2.8 pu of 60 Hz at most 345 kV buses, with all capacitor banks in and out of service, respectively. With the XLPE alternative (removing about 600 MVAR of charging including the 9.7-mi HPFF section) and with the same generator dispatch, the first resonance is between 2.8 and 3.5 pu of 60 Hz at most 345 kV buses, with all capacitor banks in and out of service, respectively. With the XLPE alternative and with more local generation off, the first resonance is between 2.5 and 3.3 pu of 60 Hz at most 345 kV buses, with all capacitor banks in and out of service, respectively. Removing some 115 kV capacitor banks at Plumtree, Frost Bridge and Glenbrook (removing about 264 MVAR – or 409 MVAR including removal of Glenbrook Statcom) had only a minor impact on the first resonance points. It raises the first resonance frequency from 2.5 pu to 2.6 or 2.7 pu with local generators off, and from 2.8 pu to 2.9 or 3.0 pu with the original light load generator dispatch.

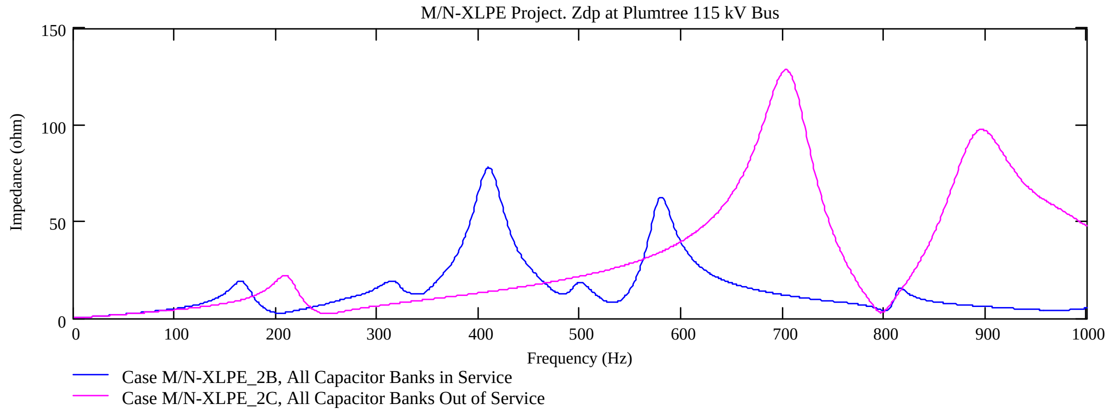
Table 5. Variation in Frequency of First Resonance Points (pu 60 Hz)

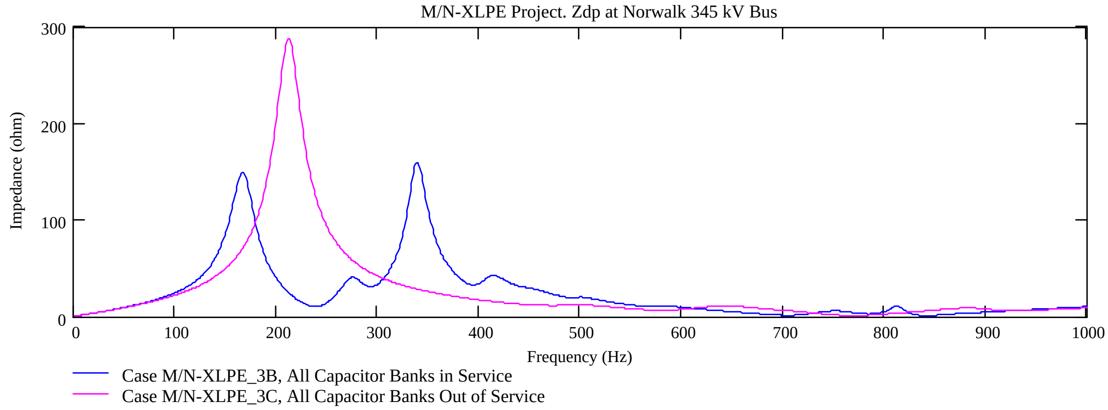
115 kV Capacitor Bank Conditions	M/N Project with HPFF Cable (Original Light Load Generator Dispatch)	M/N Project with XLPE Cable (Original Light Load Generator Dispatch)	M/N Project with XLPE Cable (Local Generators Off)
All in service	2.4	2.8	2.5
Reduced banks		2.9-3.0	2.6-2.7
All out of service	2.8	3.5	3.3

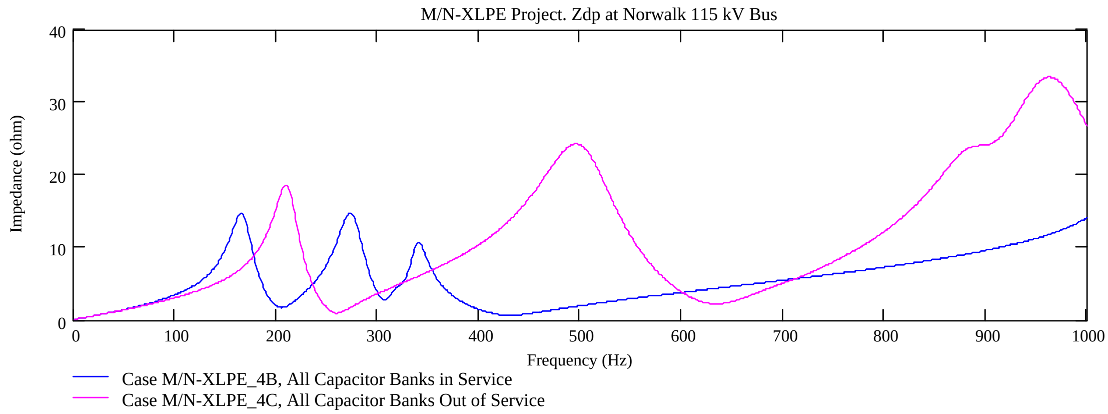
As expected, the XLPE alternative results in a higher frequency of the first resonance, and removal of more local generators results in a lower frequency. Risk of sustained overvoltages due to transformer inrush is increased when resonances are near 3rd harmonic or below. Variation of 115 kV capacitor banks results in resonances above and below 3rd harmonic. If alternate voltage support solutions were investigated, the number of 115 kV capacitor banks could possibly be reduced, given enough physical space, money, and time. System outages are another important consideration, since a variety of outages would similarly cause variation in resonant frequencies, because of the effect of changing either the strength of the system or the effective charging capacitance in the system. Consideration of minimum generator dispatches and system outages (such as an outage of the line from East Devon to Beseck) which would weaken the system together with the maximum allowable 115 kV capacitor bank dispatches and 345 kV cable charging capacitance would result in the lowest frequencies of the first resonance. If all first resonances were located above 3rd harmonic, under such a range of variations, the risk of sustained overvoltages due to transformer inrush would be reduced. However, if varying system conditions result in resonances below 3rd harmonic, then extensive transient studies should be performed to investigate transformer inrush scenarios, under a range of system conditions. Fault and clear scenarios are particularly critical since special circuit breaker closing enhancements have no effect. If the XLPE alternative studied here is to be considered, then extensive transient studies would be recommended.

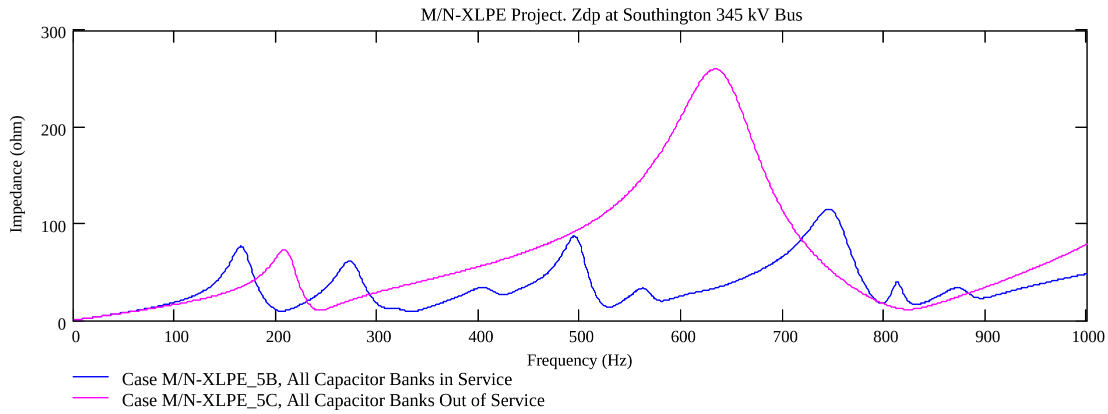
Appendix A Driving-Point Impedance Plots with Light Load Generation

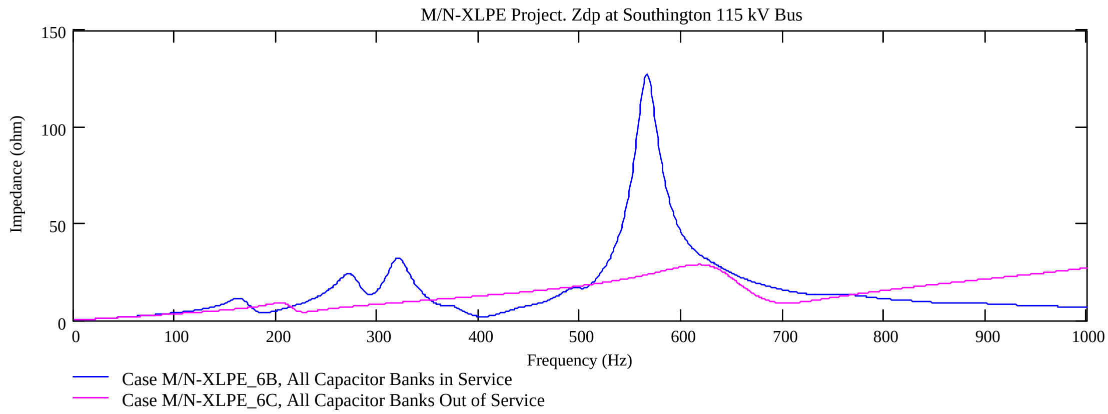


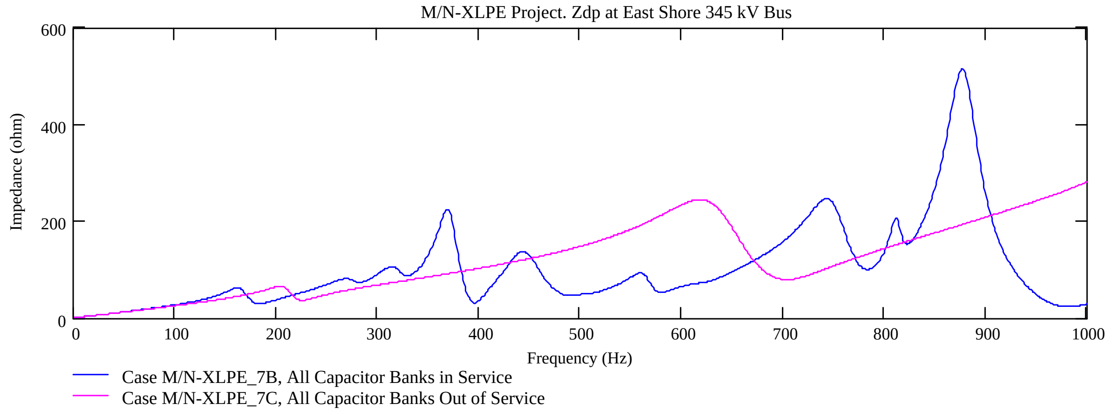


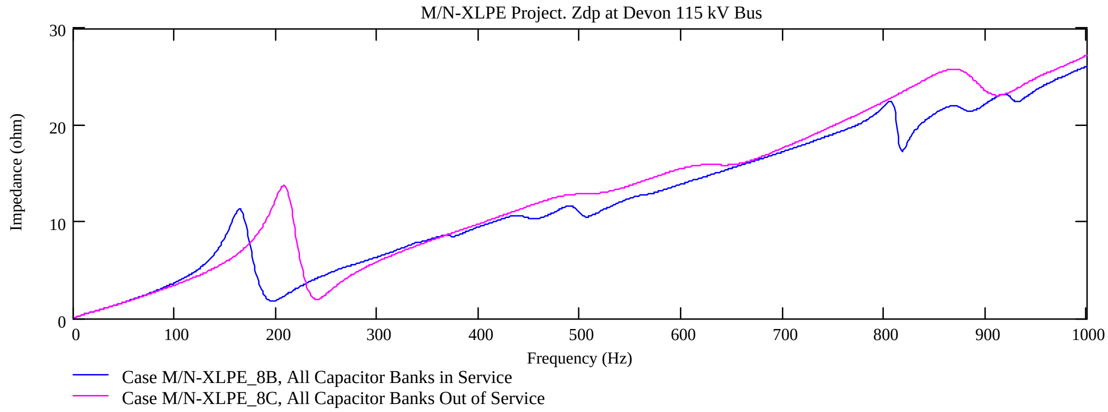


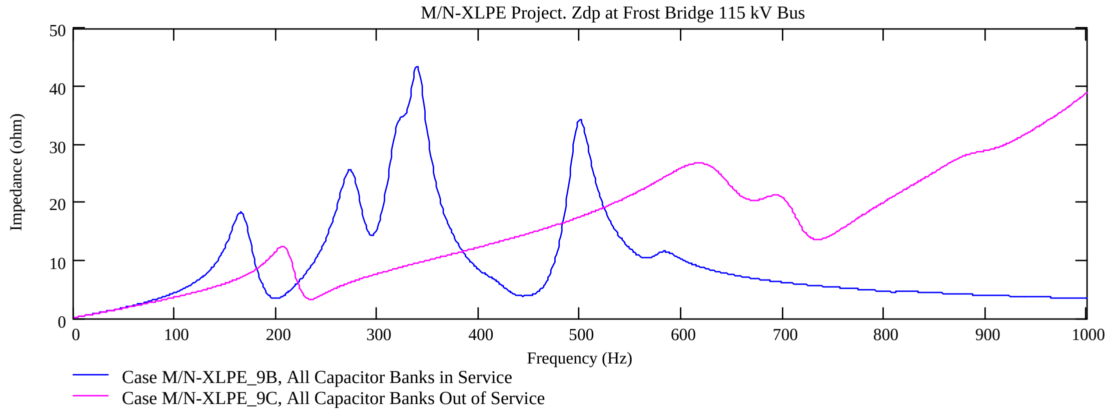

M/N-XLPE Project. Zdp at Norwalk 115 kV Bus
Impedance (ohm)
40
30
20
10
0
0
100
200
300
400
500
600
700
800
900
1000
Frequency (Hz)
Case M/N-XLPE_4B, All Capacitor Banks in Service
Case M/N-XLPE_4C, All Capacitor Banks Out of Service

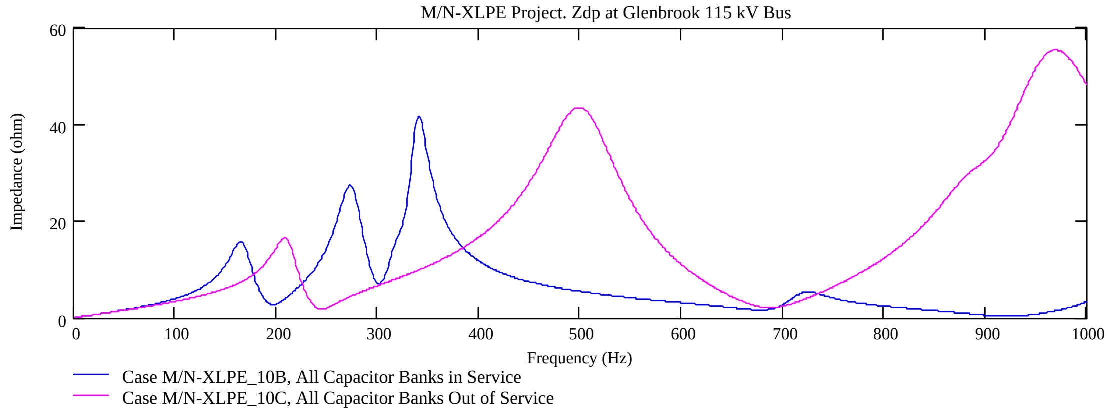

M/N-XLPE Project. Zdp at Southington 345 kV Bus
Impedance (ohm)
300
200
100
0
0
100
200
300
400
500
600
700
800
900
1000
Frequency (Hz)
Case M/N-XLPE_5B, All Capacitor Banks in Service
Case M/N-XLPE_5C, All Capacitor Banks Out of Service

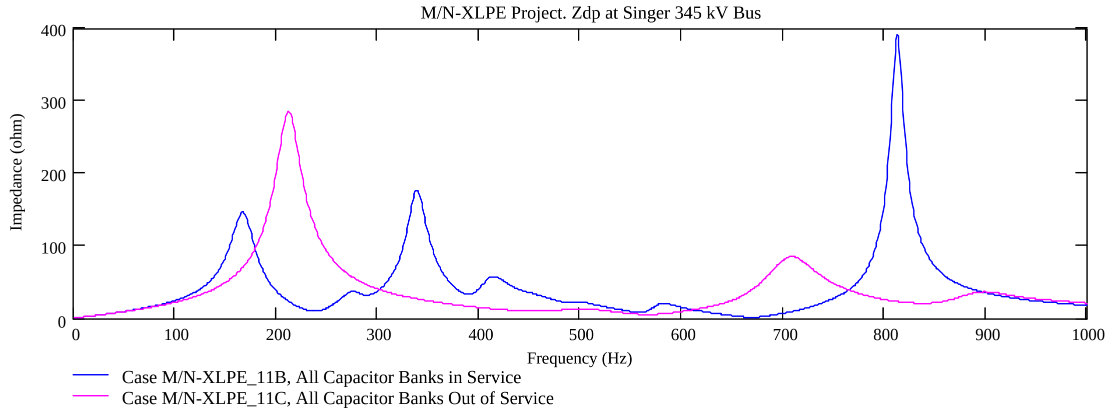

M/N-XLPE Project. Zdp at Southington 115 kV Bus
Impedance (ohm)
150
100
50
0
0
100
200
300
400
500
600
700
800
900
1000
Frequency (Hz)
Case M/N-XLPE_6B, All Capacitor Banks in Service
Case M/N-XLPE_6C, All Capacitor Banks Out of Service

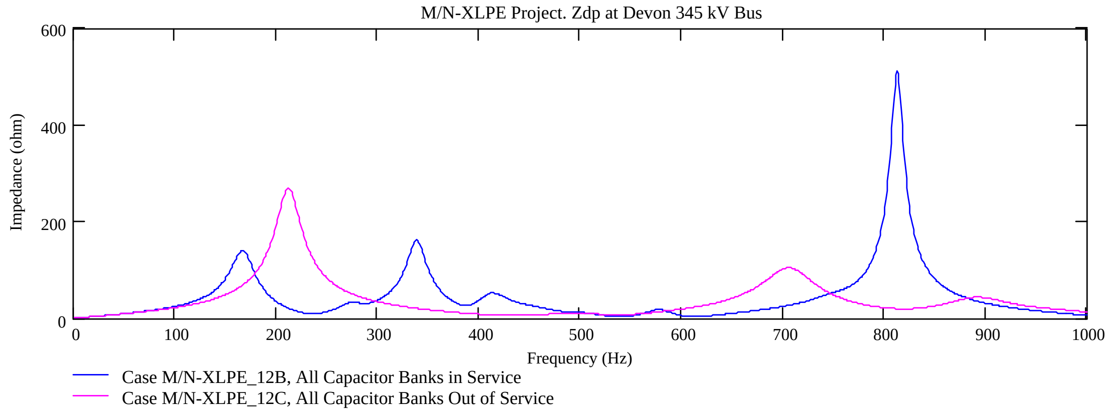

M/N-XLPE Project. Zdp at East Shore 345 kV Bus
Impedance (ohm)
Frequency (Hz)
Case M/N-XLPE_7B, All Capacitor Banks in Service
Case M/N-XLPE_7C, All Capacitor Banks Out of Service

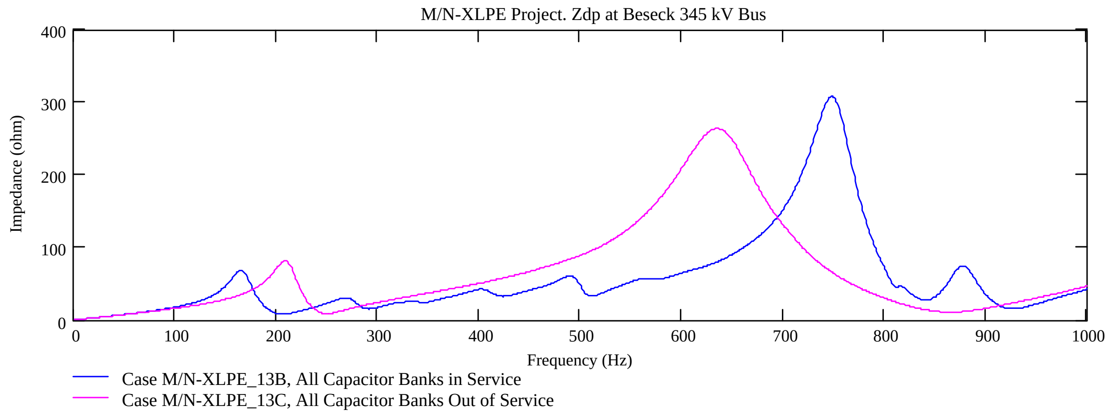

M/N-XLPE Project. Zdp at Devon 115 kV Bus
Impedance (ohm)
Frequency (Hz)
Case M/N-XLPE_8B, All Capacitor Banks in Service
Case M/N-XLPE_8C, All Capacitor Banks Out of Service


M/N-XLPE Project. Zdp at Frost Bridge 115 kV Bus
Impedance (ohm)
Frequency (Hz)
Case M/N-XLPE_9B, All Capacitor Banks in Service
Case M/N-XLPE_9C, All Capacitor Banks Out of Service

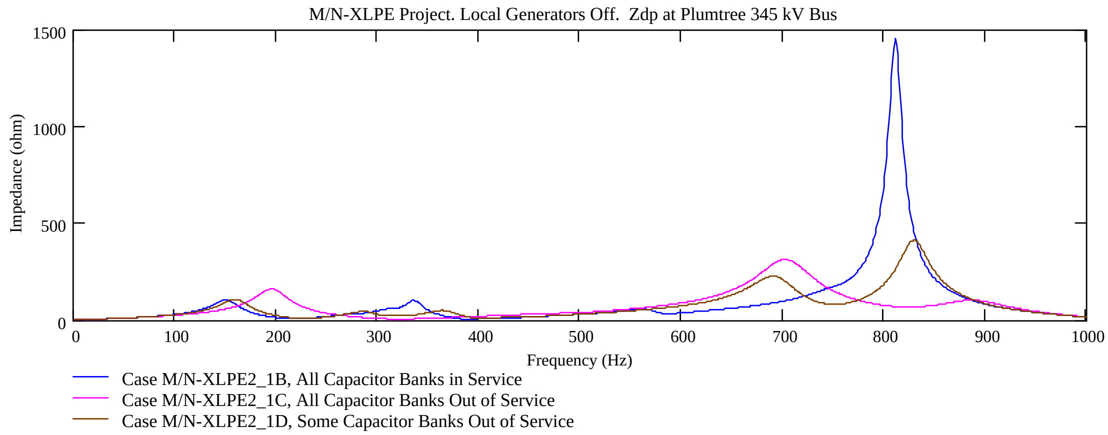

M/N-XLPE Project. Zdp at Glenbrook 115 kV Bus
Impedance (ohm)
0
20
40
60
0
100
200
300
400
500
600
700
800
900
1000
Frequency (Hz)
Case M/N-XLPE_10B, All Capacitor Banks in Service
Case M/N-XLPE_10C, All Capacitor Banks Out of Service

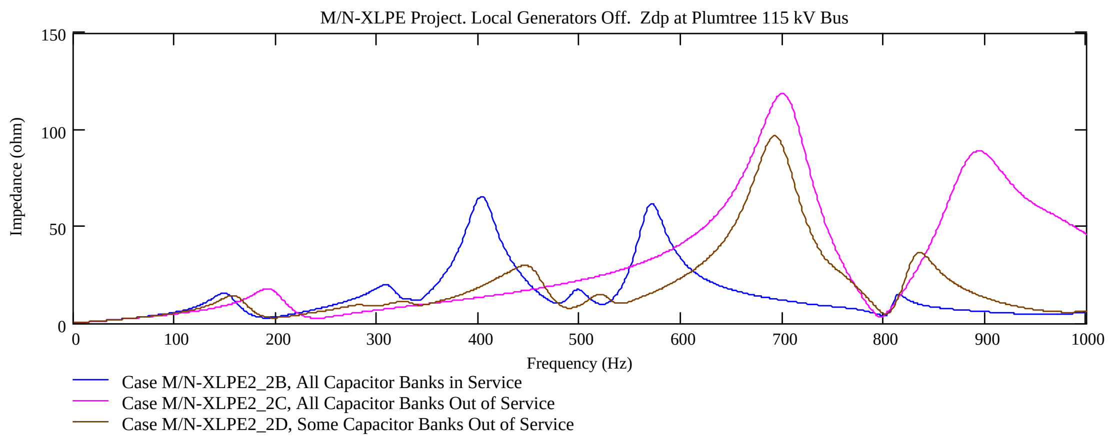

M/N-XLPE Project. Zdp at Singer 345 kV Bus
Impedance (ohm)
0
100
200
300
400
0
100
200
300
400
500
600
700
800
900
1000
Frequency (Hz)
Case M/N-XLPE_11B, All Capacitor Banks in Service
Case M/N-XLPE_11C, All Capacitor Banks Out of Service

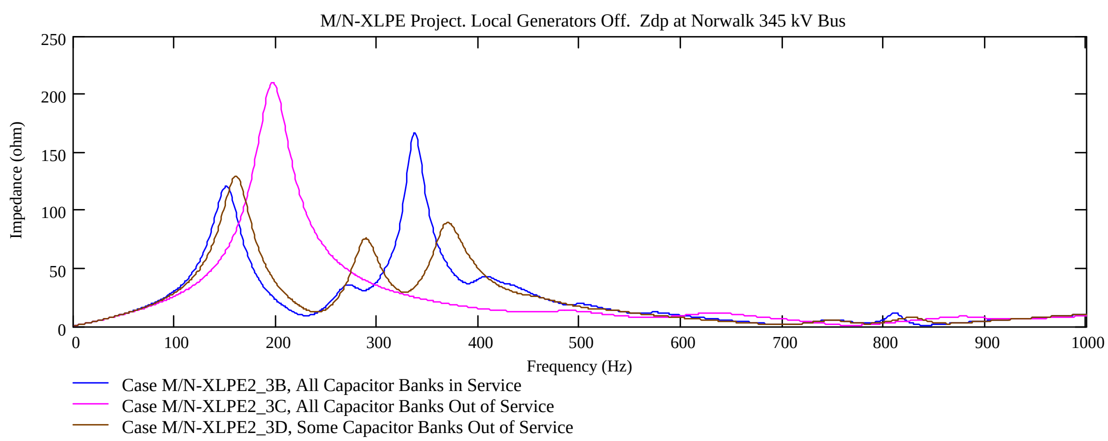

M/N-XLPE Project. Zdp at Devon 345 kV Bus
Impedance (ohm)
0
200
400
600
0
100
200
300
400
500
600
700
800
900
1000
Frequency (Hz)
Case M/N-XLPE_12B, All Capacitor Banks in Service
Case M/N-XLPE_12C, All Capacitor Banks Out of Service

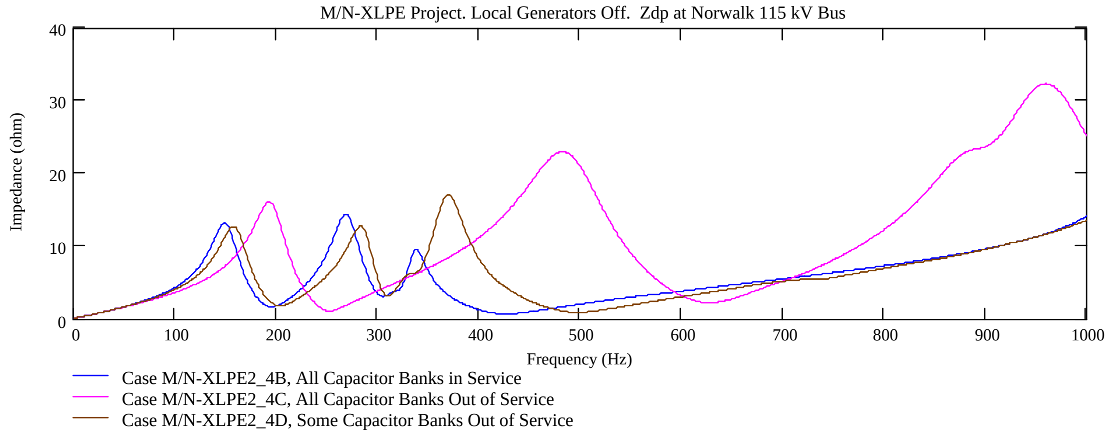

M/N-XLPE Project. Zdp at Beseck 345 kV Bus
Impedance (ohm)
400
300
200
100
0
0
100
200
300
400
500
600
700
800
900
1000
Frequency (Hz)
Case M/N-XLPE_13B, All Capacitor Banks in Service
Case M/N-XLPE_13C, All Capacitor Banks Out of Service

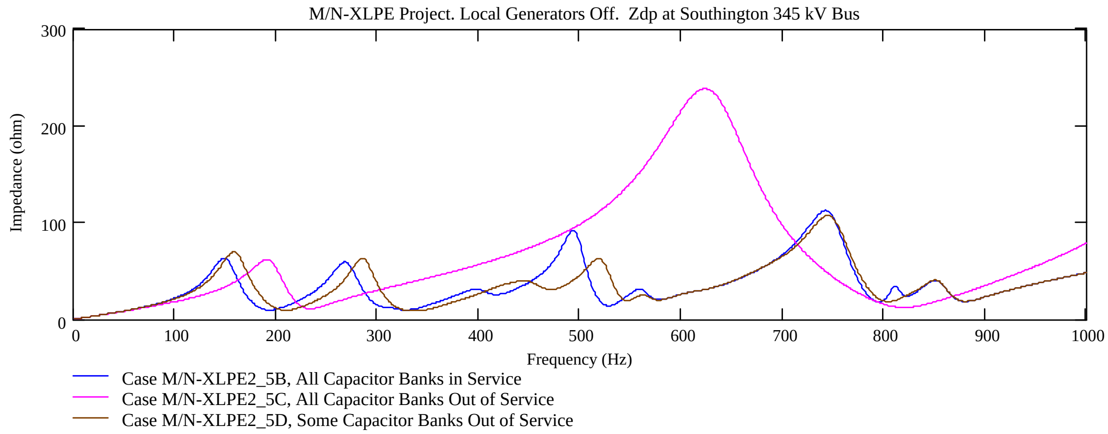
Appendix B Driving-Point Impedance Plots with Local Generators Off

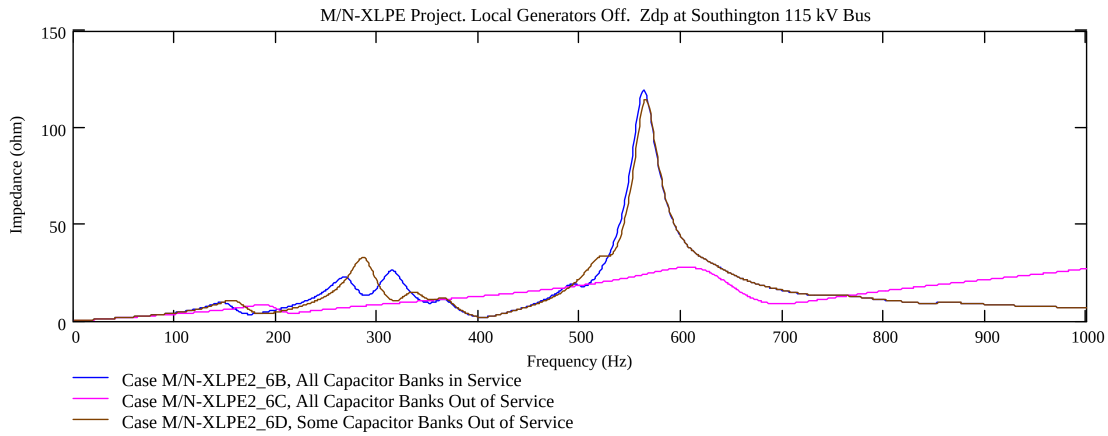


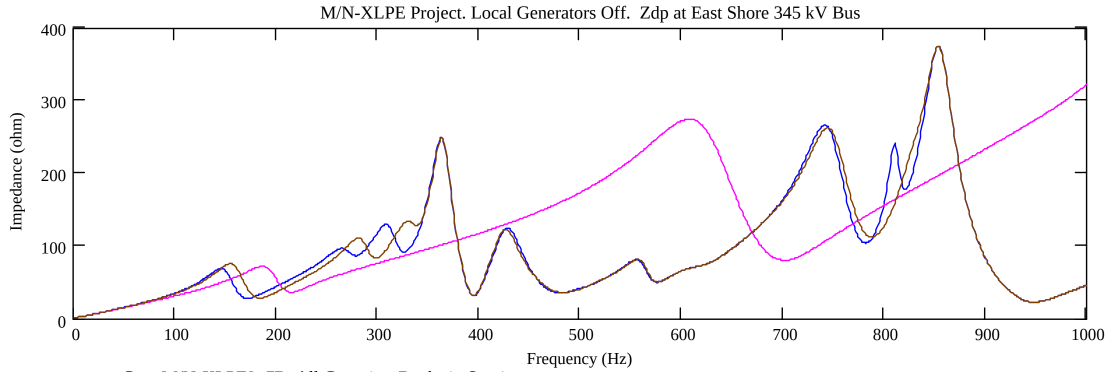




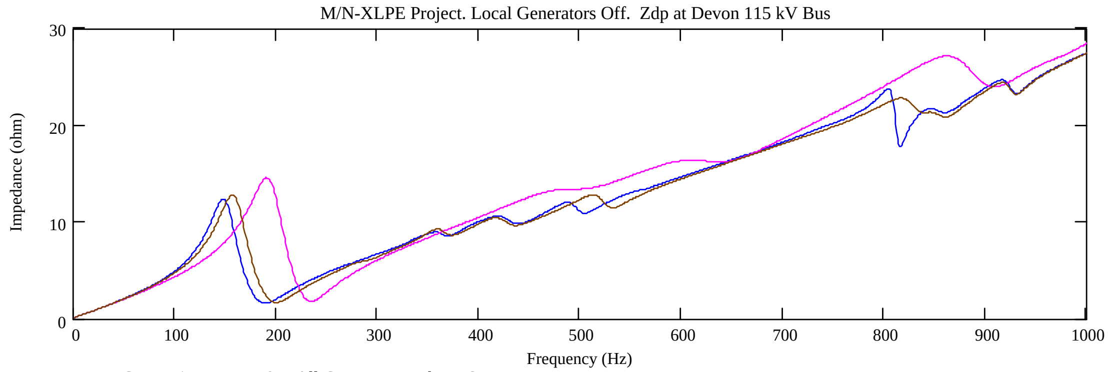

M/N-XLPE Project. Local Generators Off. Zdp at Norwalk 115 kV Bus
Impedance (ohm)
Frequency (Hz)
Case M/N-XLPE2_4B, All Capacitor Banks in Service
Case M/N-XLPE2_4C, All Capacitor Banks Out of Service
Case M/N-XLPE2_4D, Some Capacitor Banks Out of Service


M/N-XLPE Project. Local Generators Off. Zdp at Southington 345 kV Bus
Impedance (ohm)
Frequency (Hz)
Case M/N-XLPE2_5B, All Capacitor Banks in Service
Case M/N-XLPE2_5C, All Capacitor Banks Out of Service
Case M/N-XLPE2_5D, Some Capacitor Banks Out of Service

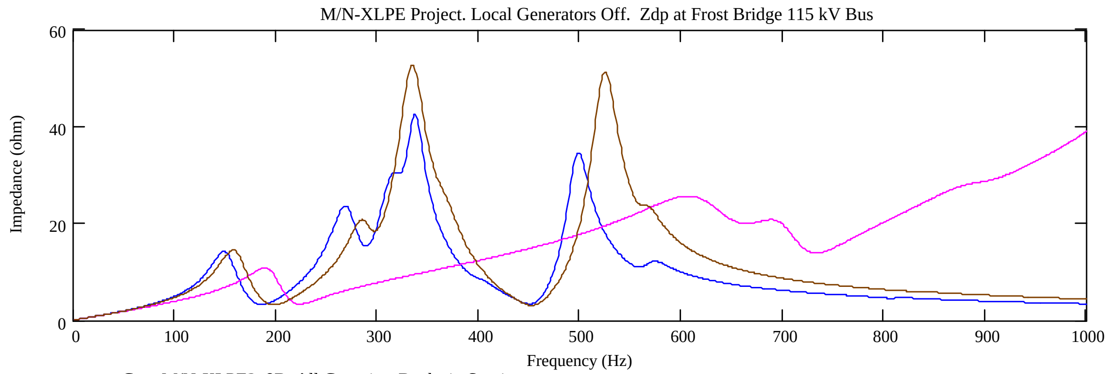

M/N-XLPE Project. Local Generators Off. Zdp at Southington 115 kV Bus
Impedance (ohm)
Frequency (Hz)
Case M/N-XLPE2_6B, All Capacitor Banks in Service
Case M/N-XLPE2_6C, All Capacitor Banks Out of Service
Case M/N-XLPE2_6D, Some Capacitor Banks Out of Service



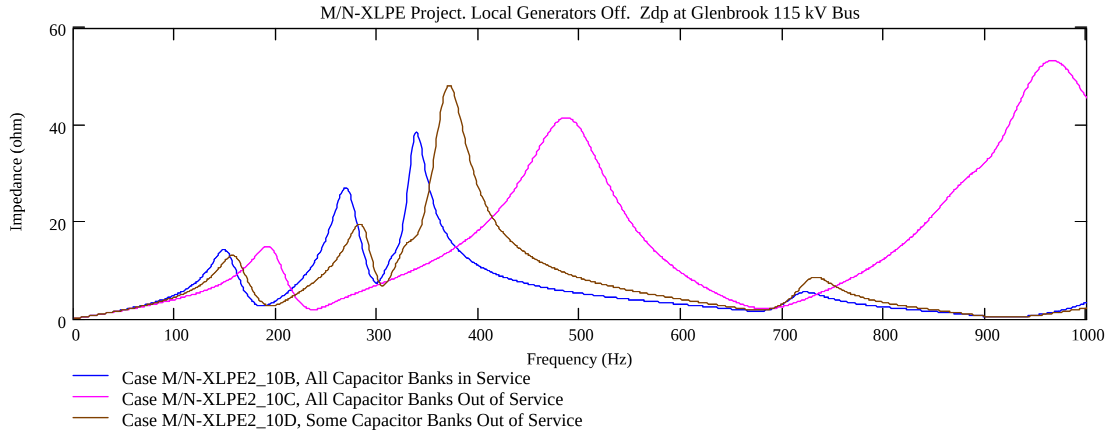
Case M/N-XLPE2_7B, All Capacitor Banks in Service
Case M/N-XLPE2_7C, All Capacitor Banks Out of Service
Case M/N-XLPE2_7D, Some Capacitor Banks Out of Service

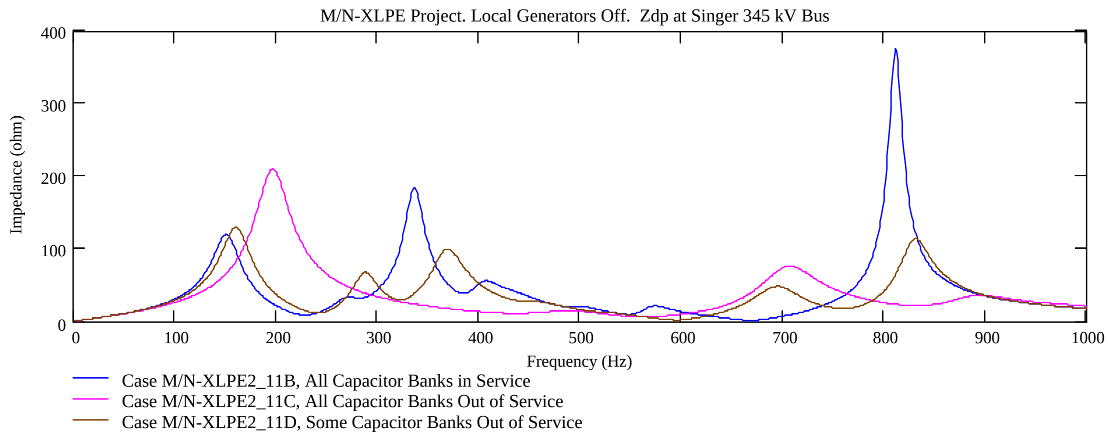


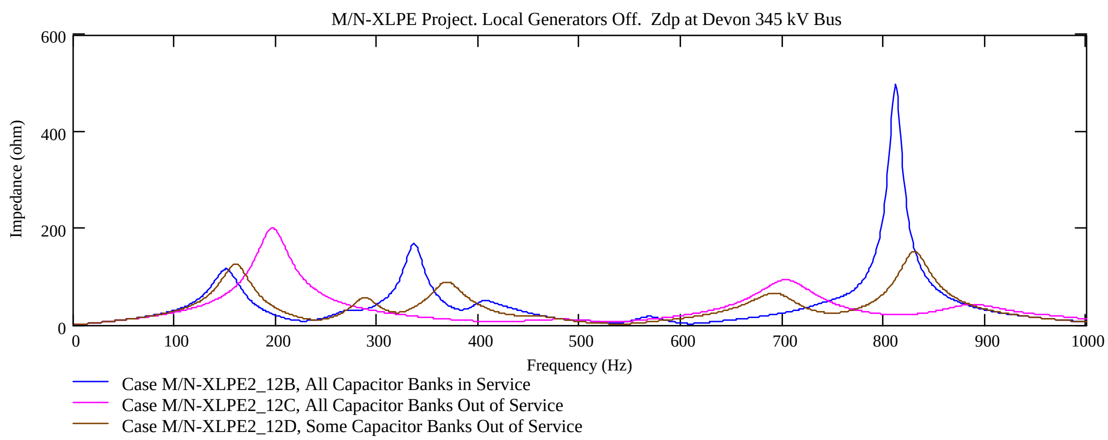
Case M/N-XLPE2_8B, All Capacitor Banks in Service
Case M/N-XLPE2_8C, All Capacitor Banks Out of Service
Case M/N-XLPE2_8D, Some Capacitor Banks Out of Service

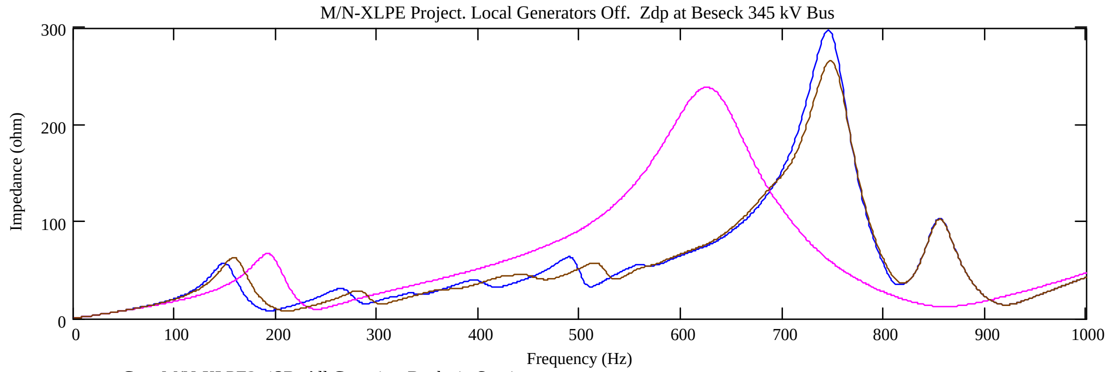


Case M/N-XLPE2_9B, All Capacitor Banks in Service
Case M/N-XLPE2_9C, All Capacitor Banks Out of Service
Case M/N-XLPE2_9D, Some Capacitor Banks Out of Service


M/N-XLPE Project. Local Generators Off. Zdp at Glenbrook 115 kV Bus
Impedance (ohm)
0
20
40
60
0
100
200
300
400
500
600
700
800
900
1000
Frequency (Hz)
Case M/N-XLPE2_10B, All Capacitor Banks in Service
Case M/N-XLPE2_10C, All Capacitor Banks Out of Service
Case M/N-XLPE2_10D, Some Capacitor Banks Out of Service


M/N-XLPE Project. Local Generators Off. Zdp at Singer 345 kV Bus
Impedance (ohm)
0
100
200
300
400
0
100
200
300
400
500
600
700
800
900
1000
Frequency (Hz)
Case M/N-XLPE2_11B, All Capacitor Banks in Service
Case M/N-XLPE2_11C, All Capacitor Banks Out of Service
Case M/N-XLPE2_11D, Some Capacitor Banks Out of Service


M/N-XLPE Project. Local Generators Off. Zdp at Devon 345 kV Bus
Impedance (ohm)
0
200
400
600
0
100
200
300
400
500
600
700
800
900
1000
Frequency (Hz)
Case M/N-XLPE2_12B, All Capacitor Banks in Service
Case M/N-XLPE2_12C, All Capacitor Banks Out of Service
Case M/N-XLPE2_12D, Some Capacitor Banks Out of Service



Case M/N-XLPE2_13B, All Capacitor Banks in Service
Case M/N-XLPE2_13C, All Capacitor Banks Out of Service
Case M/N-XLPE2_13D, Some Capacitor Banks Out of Service