Bulk Electric System Radial Exclusion (E1)
Low Voltage Loop Threshold

Executive Summary

The Project 2010-17 Standard Drafting Team (SDT) conducted a two-step study process to yield a technical justification for the establishment of a voltage threshold below which sub-100 kV loops do not affect the application of Exclusion E1. This analysis provides an equally effective and efficient alternative to address the Federal Energy Regulatory Commission's (Commission or FERC) directives expressed in Order No. 773 and 773-A. The analysis establishes that a 50 kV threshold for sub-100 kV loops does not affect the application of Exclusion E1. Furthermore, this approach will ease the administrative burden on entities to prove that they qualify for an exclusion.

Introduction

In Order No. 773 and 773A, the Commission expressed concerns that facilities operating below 100 kV may be required to support the reliable operation of the interconnected transmission system. The Commission also indicated that additional factors beyond impedance must be considered to demonstrate that looped or networked connections operating below 100 kV need not be considered in the application of Exclusion E1.[1] This document responds to the Commission's concerns and provides a technical justification for the establishment of a voltage threshold below which sub-100 kV equipment need not be considered in the evaluation of Exclusion E1.

NOTE: This justification does not address whether sub- 100 kV systems should be evaluated as Bulk Electrical System (BES) Facilities. Sub- 100 kV systems are already excluded from the BES under the core definition. Order 773, paragraph 155 states: "Thus, the Commission, while disagreeing with NERC's interpretation, does not propose to include the below 100 kV elements in figure 3 in the bulk electric system, unless determined otherwise in the exception process." This was reaffirmed by the Commission in Order 773A, paragraph 36: "Moreover, as noted in the Final Rule, the sub-100 kV elements comprising radial systems and local networks will not be included in the bulk electric system, unless determined otherwise in the exception process." Sub- 100 kV facilities will only be included as BES Facilities if justified under the NERC Rules of Procedure (ROP) Appendix 5C Exception Process.<u>Study Methodology</u>

The justification for establishing a lower voltage threshold for application of Exclusion E1 consisted of a two-step technical approach:

Step 1: A review was performed to determine the minimum voltage levels that are monitored by Balancing Authorities, Reliability Coordinators, and Transmission Operators for Interfaces, Paths, and Monitored Elements. This minimum voltage level reflects a value that industry experts consider necessary to monitor and facilitate the operation of the Bulk Electric System (BES). This step provided a technically sound approach to screen for a minimum voltage limit that served as a starting point for the technical analysis performed in Step 2 of this study.

Step 2: Technical studies modeling the physics of loop flows through sub-100 kV systems were performed to establish which voltage level, while less than 100 kV, should be considered in the evaluation of Exclusion E1.

[1] *Revisions to Electric Reliability Organization Definition of Bulk Electric System and Rules of Procedure*, Order No. 773, 141 FERC ¶ 61,236 at P155, n.139 (2012); *order on reh'g*, Order No. 773-A, 143 FERC ¶ 61,053 (2013).

Radial Systems Exclusion (E1)

The proposed definition (first posting) of radial systems in the Phase 2 BES Definition (Exclusion E1) was:

A group of contiguous transmission Elements that emanates from a single point of connection of 100 kV or higher and:

- *a) Only serves Load. Or,*
- *b) Only includes generation resources, not identified in Inclusions I2 and I3, with an aggregate capacity less than or equal to 75 MVA (gross nameplate rating). Or,*
- *c) Where the radial system serves Load and includes generation resources, not identified in Inclusions I2 and I3, with an aggregate capacity of non-retail generation less than or equal to 75 MVA (gross nameplate rating).*

Note 1 – A normally open switching device between radial systems, as depicted on prints or one-line diagrams for example, does not affect this exclusion.

Note 2 - The presence of a contiguous loop, operated at a voltage level of 30 kV or less[2], between configurations being considered as radial systems, does not affect this exclusion.

[2] The first posting of this Phase 2 definition used a threshold of 30 kV; however as a result of the study work described in this paper, the SDT has revised the threshold to 50 kV for subsequent industry consideration.

STEP 1 – Establishment of Minimum Monitored Regional Voltage Levels

All operating entities have guidelines to identify the elements they believe need to be monitored to facilitate the reliable operation of the interconnected transmission system. Pursuant to these guidelines, operating entities in each of the eight Regions in North America have identified and monitor key groupings of the transmission elements that limit the amount of power that can be reliably transferred across their systems. The groupings of these elements have different names: for instance, Paths in the Western Interconnection; Interfaces or Flowgates in the Eastern Interconnection; or Monitored Elements in the Electric Reliability Council of Texas (ERCOT). Nevertheless, they all constitute element groupings that operating entities (Reliability Coordinators, Balancing Authorities, and Transmission Operators) monitor because they understand that they are necessary to ensure the reliable operation of the interconnected transmission system under diverse operating conditions.

To provide information in determining a voltage level where the presence of a contiguous loop between system configurations may not affect the determination of radial systems under Exclusion E1 of the BES definition, voltage levels that are monitored on major Interfaces, Flowgates, Paths, and ERCOT Monitored Elements were examined. This examination focused on elements owned and operated by entities in the contiguous United States. The objective was to identify the lowest monitored voltage level on these key element groupings. The lowest monitored line voltage on the major element groupings provides an indication of the lower limit which operating entities have historically believed necessary to ensure the reliable operation of the interconnected transmission system. The results of this analysis provided a starting point for the technical analysis which was performed in Step 2 of this study.

Step 1 Approach

Each Region was requested to provide the key groupings of elements they monitor to ensure reliable operation of the interconnected transmission system. This list, contained in Appendix 1, was reviewed to identify the lowest voltage element in the major element groupings monitored by operating entities in the eight Regions. Identification of this lowest voltage level served as a starting point to begin a closer examination into the voltage level where the presence of a contiguous loop should not affect the evaluation of radial systems under Exclusion E1 of the BES definition.

Step 1 Results

An examination of the line listings of the U.S. operating entities revealed that the majority of operating entities do not monitor elements below 69 kV as shown in Table 1. However, in some instances elements with line voltages of 34.5 kV were included in monitored element groupings. In no instance was a transmission line element below 34.5 kV included in the monitored element groupings.

Region	Key Monitored Element Grouping	Lowest Line Element Voltage
FRCC	Southern Interface	115
MRO	NDEX	69
NPCC	Total East PJM (Rockland Electric) – Hudson Valley (Zone G)[1]	34.5
RFC	MWEX	69
SERC	VACAR IDC[2]	115
SPP RE	SPSNORTH_STH	115
TRE	Valley Import GTL	138
WECC	Path 52 Silver Peak – Control 55 kV	55

Notes:

1. Two interfaces in NPCC/NYISO have lines with 34.5 kV elements.
2. The TVA area in SERC was not included in the tables attached to this report; however, a review of the Flowgates in TVA revealed monitored elements no lower than 115 kV.

Table 1: Lowest Line Element Voltage Monitored by Region

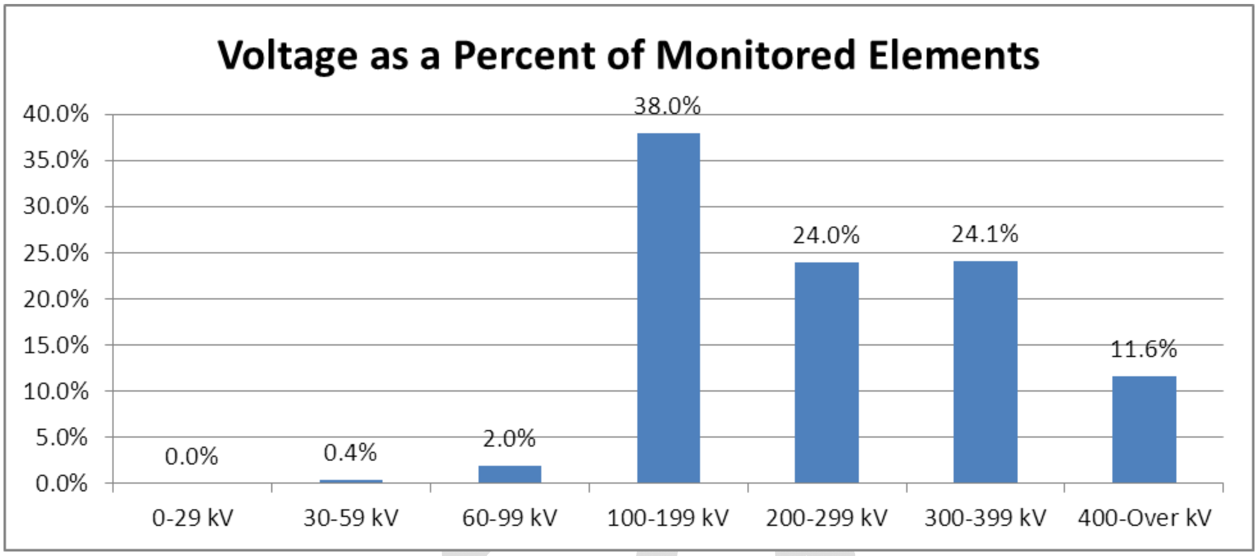
In a few rare occasions there were transformer elements with low-side windings lower than 30 kV included in the key monitored element groupings as shown in Table 2.

Region	Interface	Element	Voltage (kV)
NPCC/NYISO	WEST CENTRAL: Genesee (Zone B) – Central (Zone C)	(Farmtn 34.5/115kV&12/115 kV) #4 34.5/115 & 12/115	12/115
NPCC/ISO-NE	New England - Southwest Connecticut	SOTHNGTN 5X - Southington 115 kV /13.8 kV Transformer (4C-5X)	115/13.8
		SOTHNGTN 6X - Southington 115 kV /13.8 kV Transformer (4C-6X)	115/13.8
		SOTHNGTN 11X - Southington 115 kV /27.6 kV Transformer (4C-11X)	115/27.6

Table 2: Lowest Line Transformer Element Voltages Monitored by Region

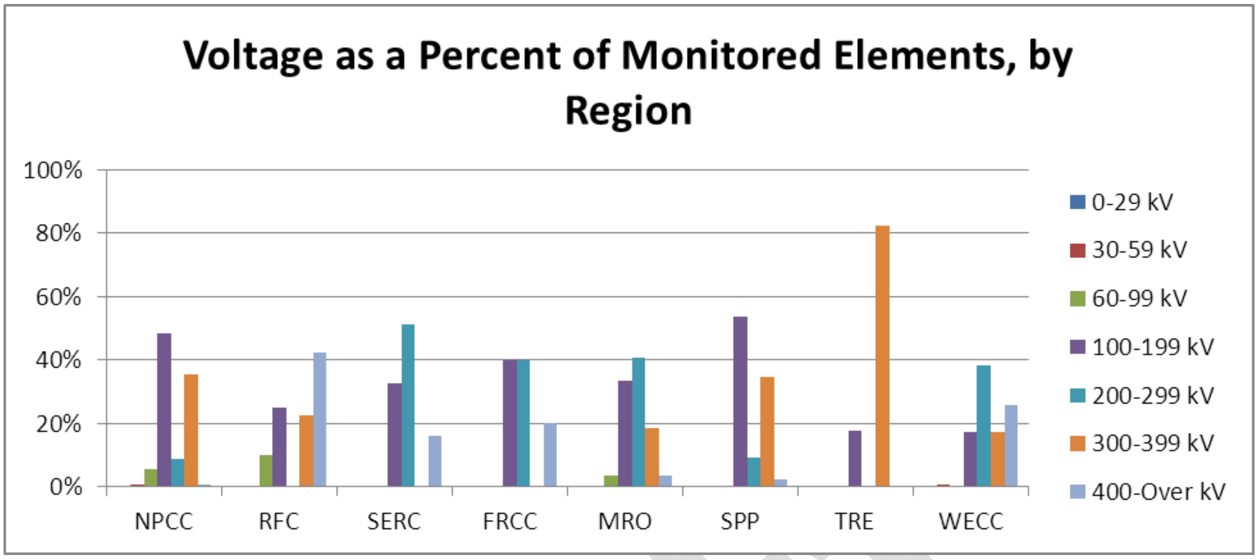
Upon closer investigation, for New England's Southwest Connecticut interface, it was determined that the inclusion of these elements was the result of longstanding, historical interface definitions and not for the purpose of addressing BES reliability concerns. Transformers serving lower voltage networks continue to be included based on familiarity with the existing interface rather than a specific technical concern. These transformers could be removed from the interface definition with no impact on the reliability of the interconnected transmission system. For the New York West Central interface, the low voltage element was included because the interface definition included boundary transmission lines between Transmission Owner control areas; hence, it was included for completeness to measure the power flow from one Transmission Owner control area to the other Transmission Owner control area.

Further examination of the information provided by the eight NERC regions revealed that half of the Regions only monitor transmission line elements with voltages above the 100 kV level. The other four Regions, NPCC, RFC, MRO, and WECC, monitor transmission line elements below 100 kV as part of key element groupings. However, in each of these cases, the number of below 100 kV transmission line elements comprised less than 2.5% of the total monitored key element groupings. Figures 1 and 2 below depict the results of Step 1 of this study.



Notes:
1. Data/Chart includes Transmission Lines only.
2. Data/Chart is a summary of individual elements (interfaces not included)

Figure 1: Voltage as Percent of Monitored Elements



Notes:
1. Data/Chart includes Transmission Lines only.
2. Data/Chart is a summary of individual elements (interfaces not included)

Figure 2: Voltage as Percent of Monitored Elements per Region

Step 1 Conclusion

The results of this Step 1 study regarding regional monitoring levels resulted in a determination that 30 kV was a reasonable voltage level to initiate the sensitivity analysis conducted in Step 2 of this study. This value is below any of the regional monitoring levels.

STEP 2 - Load Flows and Technical Considerations

The threshold of 30 kV was established in Step 1 as a reasonable starting point to initiate the technical sensitivity analysis in Step 2 of this study. The purpose of this step was to determine if there is a technical justification to support a voltage threshold for the purpose of determining whether facilities can be considered to be radial under the BES Definition Exclusion E1. If the resulting voltage threshold was deemed appropriate through technical study efforts, then contiguous loop connections operated at voltages below this value would not preclude the use of Exclusion E1. Conversely, contiguous loops connecting radial lines at voltages above this kV value would negate the ability for an entity to use Exclusion E1 for the subject facilities.

This study focused on two typical configurations: a distribution loop and a sub-transmission loop. The goal was to use these configurations and adjust the various loads, voltages, flows, and impedances to determine the level at which single contingencies on the transmission system would cause flows on the low voltage system. These studies provided the low voltage floor that can be used as a consideration for BES exclusion E1.

NOTE: This justification does not address whether sub- 100 kV systems should be evaluated as Bulk Electrical System (BES) Facilities. Sub- 100 kV systems are already excluded from the BES under the core definition. Order 773, paragraph 155 states: "Thus, the Commission, while disagreeing with NERC's interpretation, does not propose to include the below 100 kV elements in figure 3 in the bulk electric system, unless determined otherwise in the exception process." This was reaffirmed by the Commission in Order 773A, paragraph 36: "Moreover, as noted in the Final Rule, the sub-100 kV elements comprising radial systems and local networks will not be included in the bulk electric system, unless determined otherwise in the exception process." Sub- 100 kV facilities will only be included as BES Facilities if justified under the NERC Rules of Procedure (ROP) Appendix 5C Exception Process.

Analytical Approach – Distribution Circuit Loop Example

The Project 2010-17 SDT sought to examine the interaction and relative magnitude of flows on the 100 kV and above Facilities of the electric system and those of any underlying low voltage distribution loops. While not the determining factor leading to this study's recommendation, line outage distribution factors (LODF) were a useful tool in understanding the relationship between underlying systems and the BES elements. It illustrated the relative scale of interaction between the BES and the lower voltage systems and its review was a consideration when the study analysis was performed. As an example, the SDT considered a system similar to the one depicted in Figure 3 below. In this simplified depiction of a portion of an electric system, two radial 115 kV lines emanate from 115 kV substations A and B to serve distribution loads via 115 kV/distribution transformers at stations C and D. Stations C and D are "looped" together via either a distribution bus tie (zero impedance) or a feeder tie (modeled with typical distribution feeder impedances).

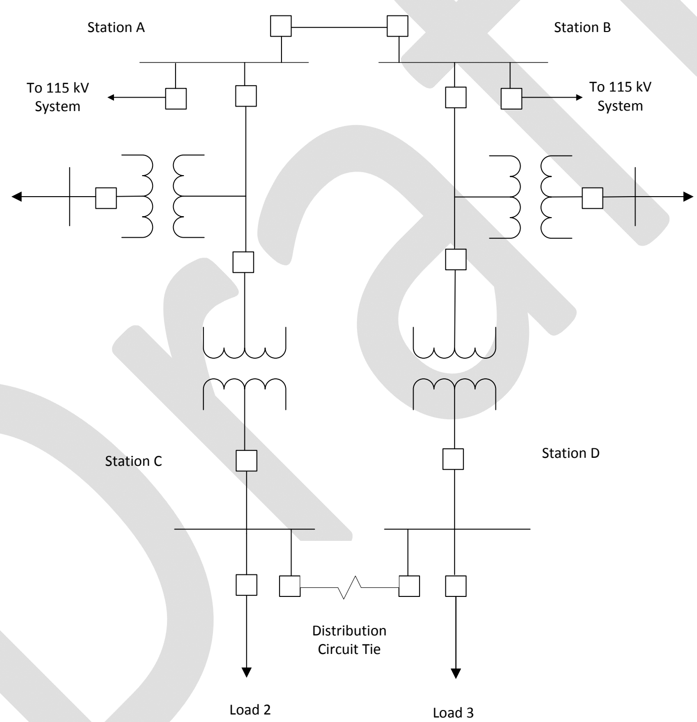


Figure 3: Example Radial Systems with Low Voltage Distribution Loop

With the example system, the SDT conducted power flow simulations to assess the performance of the power system under single contingency outages of the line between stations A and B. The analyses determined the LODF which represent the portion of the high voltage transmission flow that would distribute across the low voltage distribution circuit or bus ties under a single contingency outage of the line between stations A and B. To the extent that the LODF values were negligible, this indicated a minor or insignificant contribution of the distribution loops to the operation of the high voltage system. But, more importantly, the analyses determined whether any instances of power flow reversal, i.e., resultant flow delivered into the BES, would occur during contingent operating scenarios. Instances of flow reversal into the BES would indicate that the underlying distribution looped system is exhibiting behavior similar to a sub-transmission or transmission system, which would call into question the applicability of radial exclusion E1.

The study work in this approach examined the sensitivity of parallel circuit flow on the distribution elements to the size of the distribution transformers, the operating voltage of distribution delivery buses at stations C and D and the strength of the transmission network serving stations A and B as manifested in the variation of the transmission network transfer impedance used in the model.

In order to simply, yet accurately, represent this low voltage loop scenario between two radial circuits, a Power System Simulator for Engineering (PSSE) model was created. Elements represented in this model included the following:

- Radial 115 kV lines from station A to station C and station B to station D;
- Interconnecting transmission line from station A to station B;
- Distribution transformers between 115 kV and the distribution buses at stations C and D;
- Feeder tie impedance to represent a feeder tie (or zero impedance bus tie) between distribution buses at stations C and D;
- Network equivalent source impedances at source stations A and B;
- Transfer impedance equivalent between stations A and B, representing the strength of the interconnected transmission network.

Within this model, parameters were modified to simulate differences in the length and impedance of the transmission lines, amount of distribution load, strength of the transmission network supplying stations A and B, size of the distribution transformers, and the character of the bus or feeder tie at distribution Stations C and D.

Distribution Model Simulation

Table 3 below illustrates the domain of the various parameters that were simulated in this distribution circuit loop scenario. A parametric analysis was performed using all combinations of variables shown in each column of Table 3.

Trans KV	Trans Length	Dist KV	Dist Length	XFMR MVA	Dist Load % rating	Z Transfer
115	10 miles	12.5	0 (bus tie)	10	40	Strong
	30 miles	23	2 miles	20	80	Medium
		34.5	5 miles	40		Weak
		46				

Notes:

1. The "medium" value for transfer impedances was derived from an actual example system in the northeastern US. This was deemed to be representative of a network with typical, or medium, transmission strength. Variations of a stronger (more tightly coupled) and a weaker transmission network were selected for the "strong" and "weak" cases, respectively. Impedance values of X=0.54%, X=1.95%, and X=4.07% were applied for the strong, medium and weak cases, respectively.

Table 3: Model Parameters Varied

The model was exercised in a series of cases simulating a power transfer on the 115 kV line[3] from station A to station B of slightly more than 100 MW. Loads and impedances were simulated at the location shown in Figure 5 of Appendix 2. Two load levels were used in each scenario: 40% of the rating of the distribution transformer and 80% of the rating. Distribution transformer ratings were varied in three steps: 10 MVA, 20 MVA, and 40 MVA. Finally, the strength of the interconnected transmission network was varied in three steps representing a strong, medium, and weak transmission network. The choices of transfer impedance were based on typical networks in use across North America. A specific model from the New England area of the United States yielded an actual transfer impedance of 0.319 + j1.954%. This represents the 'medium' strength transmission system used in the analyses. The other values used in the study are minimum ('strong') and maximum ('weak') ends of the typical range of transfer impedances for 115 kV systems interconnected to the Bulk Electric System of North America. Distribution feeder connections were simulated in three different ways, first with zero impedance between the distribution buses at stations C and D, second with a 2-mile feeder connection with typical overhead conductor, and third with a 5-mile connection.

Distribution Model Results

23 kV Distribution System

The results show LODFs ranging from a low of 0.2% to a high of 6.7%. In all of the cases, the direction of power flow to the radial lines was *toward* stations C and D. In other words, there were no instances of flow reversal from the distribution system back to the 115 kV transmission system.

The lowest LODF was found in the case with the smallest distribution transformers (10 MVA), the 5-mile distribution circuit tie, and the strong transmission transfer impedance. The case with the highest LODF

[3] The threshold voltage of 115 kV provides conservative results. At a higher voltage, such as 230 kV, the reflection of distribution impedance to the transmission system is significantly larger, and hence, the amount of distribution power flow will be much smaller.

was that which used the largest distribution transformers (40 MVA) with the lightest load and the use of a zero-impedance bus tie between the two distribution stations.

12.5 kV Distribution System

As compared to the simulations using the 23 kV distribution system, the 12.5 kV system model yielded far lower LODF values. This result is reasonable, as the reflection of impedances on a 12.5 kV distribution system will be nearly four times as large as those for a 23 kV distribution system, and the transformer sizes in use at the 12.5 kV class are generally smaller, i.e., higher impedance. As with the cases simulated for the 23 kV system, the 12.5 kV system exhibited a power flow direction in the radial line terminals at stations A and B in the direction of the distribution stations C and D; no flow reversal was seen in any of the contingency cases.

Given the lower voltage of the distribution system, the cases studied at this low voltage level were limited to the scenario with the high transfer impedance value ('weak' transmission case). This is a conservative assumption as all cases with lower transfer impedance will yield far lower LODF values. With that, the range of LODF values was found to be 1.0% to 6.7%. When compared with the 23 kV system results in the weak transmission case, the range of LODF values was 1.8% to 6.7%. Higher LODF values were found in the cases with the largest transformer size, which is to be expected.

Table 4 below provides a sample of the results of the various simulations that were conducted. The full collection of results is provided in Appendix 3.

Case	D, KV	Z_{xfer}	Z_{Dist}	XFMR MVA	Load, MW	LODF
623a5	23	strong	5 mi	10	4	0.2%
623a5pk	23	strong	5 mi	10	8	0.3%
633b0pk	23	strong	0	20	16	0.4%
723c0	23	medium	0	40	16	3.4%
723c5pk	23	medium	5 mi	40	32	1.6%
823b0	23	weak	0	20	8	3.8%
823c0	23	weak	0	40	16	6.7%
812a5	12.5	weak	5 mi	10	4	1.0%
812b0	12.5	weak	0	20	8	3.8%
812b5pk	12.5	weak	5 mi	20	16	1.3%
812c0	12.5	weak	0	40	16	6.7%
834a5pk	34.5	weak	5 mi	10	8	1.7%
834b5pk	34.5	weak	5 mi	20	16	3.0%
834d0	34.5	weak	0	40	16	8.9%
834d0pk	34.5	weak	0	40	32	8.7%
846e0	46	weak	0	50	16	10.3%
846e2	46	weak	2 mi	50	20	9.0%
846e5	46	weak	5 mi	50	20	7.4%

Table 4: Select Sample of Study Results for Distribution Scenario

34.5 kV and 46 kV Distribution Systems

As with the analysis done for the 12.5 kV system, a conservative transfer impedance value, that of the 'weak' transmission network, was used in selecting the transfer impedance to be used in the simulations at 34.5 kV and 46 kV. With this conservative parameter, the simulation results show distribution factors (LODF) ranging from a low of 1.7% to a high of 10.3%. In all of the cases, the direction of power flow to the radial lines remained *from* stations A and B *toward* stations C and D. In other words, there were no instances of flow reversal from the distribution system back to the 115 kV transmission system.

Analytical Approach – Sub-transmission Example

In addition to the distribution circuit loop example described above, the study examined the performance of systems typically described as 'sub-transmission'. The study sought to examine the interaction and relative magnitude of flows on the 100 kV and above Facilities of the interconnected transmission system and those of the underlying parallel sub-transmission facilities. The study considered a system similar to the one depicted in Figure 4 below. In this simplified depiction of a portion of a transmission and sub-transmission system, a 40-mile transmission line connecting two sources with transfer impedance between the two sources representing the parallel transmission network. Each source also supplies a 10-mile transmission line with a load tap at the mid-point of the line, each serving a load of 16 MW. At the end of each of these lines is a step-down transformer to the sub-transmission voltage, where an additional load is served. The two sub-transmission stations are connected by a 25-mile sub-transmission tie line. Loads and impedances were simulated at the location shown in Figure 6 of Appendix 2.

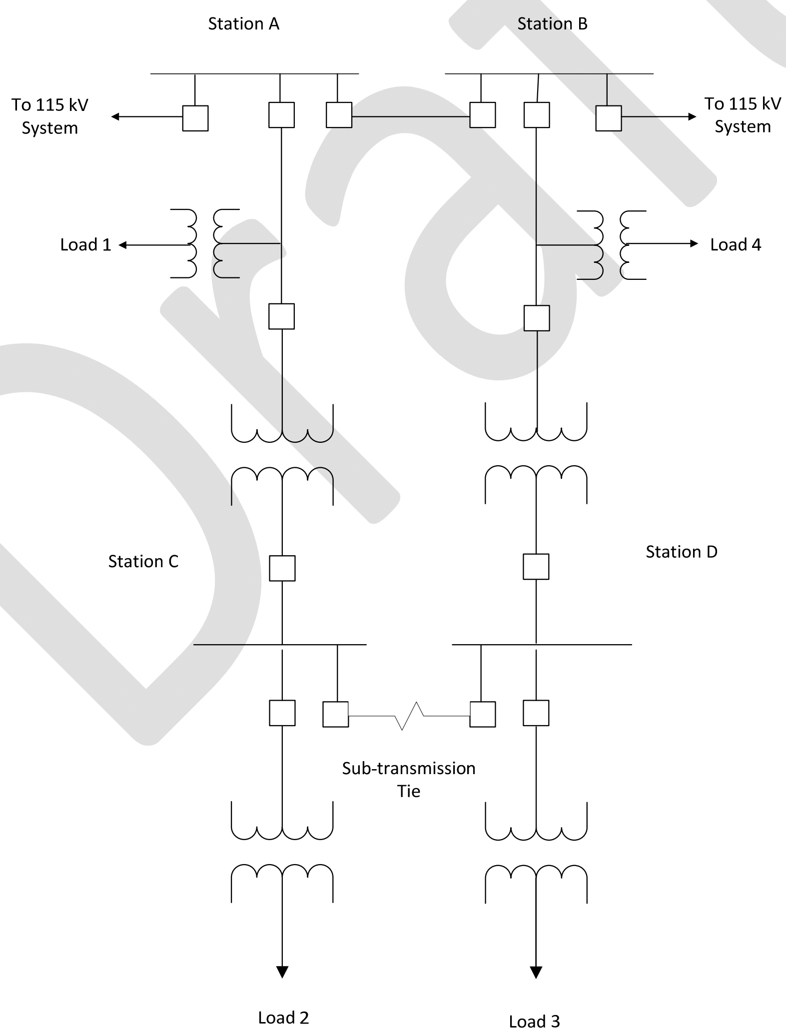


Figure 4: Example Radial Systems with Sub-transmission Loop

Given this example sub-transmission system, a PSSE model was created to simulate the power flow characteristics of the system during a contingency outage of the transmission line between stations A and B. Within this model, parameters were modified to simulate differences in the amount of load being served, transformer size and the amount of pre-contingent power flow on the transmission line. All simulations were performed with a transfer impedance representative of a 'weak' transmission network.

Sub-transmission Model Simulation

Simulations were performed for each sub-transmission voltage (34.5 kV, 46 kV, 55 kV, and 69 kV) using a transmission voltage of 115 kV. This analysis identified the potential for power flowing back to the transmission system only for sub-transmission voltages of 55 kV and 69 kV. Sensitivity analysis was performed using higher transmission voltages to confirm that cases with 115 kV transmission are the most conservative. Therefore, it was not necessary to perform sensitivity analysis for sub-transmission voltages of 34.5 kV and 46 kV for transmission voltages higher than 115 kV.

Table 5 below illustrates the domain of the various parameters that were simulated in this sub-transmission circuit loop scenario. A parametric analysis was performed using combinations of variables shown in each column of Table 5.

Trans KV	Trans Length	Sub-T KV	Sub-T Length	XFMR MVA	Dist Load % rating	Trans MW Preload
115	40 miles	34.5	25 miles	40	40	115
		46		50		
		55		60		
		69				
Sensitivity Analyses:						
138	40 miles	55	25 miles	50	40	115
161		69		60		135
230						150
						220

Table 5: Model Parameters and Sensitivities

Sub-transmission Model Results

115 kV Transmission System with 34.5-69 kV Sub-transmission

The results for cases depicting a 115 kV transmission system voltage and ranges of 34.5 kV to 69 kV sub-transmission voltages show line outage distribution factors (LODF) in the range of 9% to slightly higher than 20%. Several cases show a reversal of power flow in the post-contingent system such that power flow is delivered from the sub-transmission system *into the 115 kV BES*. The worst case is found in the 69 kV sub-transmission voltage class. This result is as expected, given that the impedance of the 69 kV sub-transmission system is less than the impedances of lower voltage systems.

138 kV and 161 kV Transmission Systems with 55-69 kV Sub-transmission

The results for cases of 138 kV and 161 kV transmission system voltages supplying sub-transmission voltages of 55 kV and 69 kV show LODFs ranging from 9% to 16% These cases also result in reversal of power flows in the post-contingent system such that power flow is delivered from the sub-transmission system into the 115 kV BES.

230 kV Transmission System with 55-69 kV Sub-transmission

By simulating a higher BES source voltage of 230 kV paired with sub-transmission voltages of 55 kV and 69 kV, the transformation ratio is sufficiently large to result in a significant increase to the reflected sub-transmission system impedance. Therefore, in these cases, LODFs range from 5% to 7%, and these cases also show no reversal of power flow toward the BES in the post-contingent system.

Table 6 below provides a sample of the results of the various simulations that were conducted. All results are provided in Appendix 3.

Case	T, KV	S-T, KV	Trans Pre-load, MW	XFMR MVA	Load, MW	LODF	Flow Rev to BES?
834d25	115	34.5	115	40	20	9.4%	
846e25	115	46	114	50	20	13.3%	
855e25	115	55	112	50	20	15.7%	Yes
869f25	115	69	110	60	24	20.3%	Yes
855e25-138	138	55	114	50	20	11.7%	
855e25-138’	138	55	134	60	20	11.9%	Yes
869f25-138	138	69	112	60	24	15.6%	Yes
869f25-138’	138	69	132	60	24	15.8%	Yes
855e25-161	161	55	114	50	20	9.1%	
855e25-161’	161	55	155	60	20	9.2%	
869f25-161	161	69	113	60	24	12.5%	
869f25-161’	161	69	153	60	24	12.6%	Yes
855e25-230	230	55	116	50	20	4.9%	
855e25-230’	230	55	219	60	20	5.0%	
869f25-230	230	69	116	60	24	7.0%	
869f25-230’	230	69	218	60	24	7.0%	

Table 6: Select Sample of Study Results for Sub-transmission Scenario

Step 2 Conclusion

Step 2 of this analysis concludes that 50 kV is the appropriate low voltage loop threshold below which sub-100 kV loops should not affect the application of Exclusion E1. Simulations of power flows for the cases modeled in this study show there is no power flow reversal into the BES when circuit loop operating voltages are below 50 kV. This study also finds, for loop voltages above 50 kV, certain cases result in power flow toward the BES. Therefore, the study concludes that low voltage circuit loops operated below 50 kV should not affect the application of Exclusion E1.

Study Conclusion

The Project 2010-17 SDT conducted a two-step study process to yield a technical justification for the establishment of a voltage threshold below which sub-100 kV loops should not affect the application of Exclusion E1. This analysis provides an equally effective and efficient alternative to address the Commission's directives expressed in Order No. 773 and 773-A. It establishes that a 50 kV threshold for sub-100 kV loops does not affect the application of Exclusion E1.

Appendix 1

The information contained in Appendix 1 could be confidential and sensitive to entities and regional organizations and is removed from this draft report.

Appendix 2

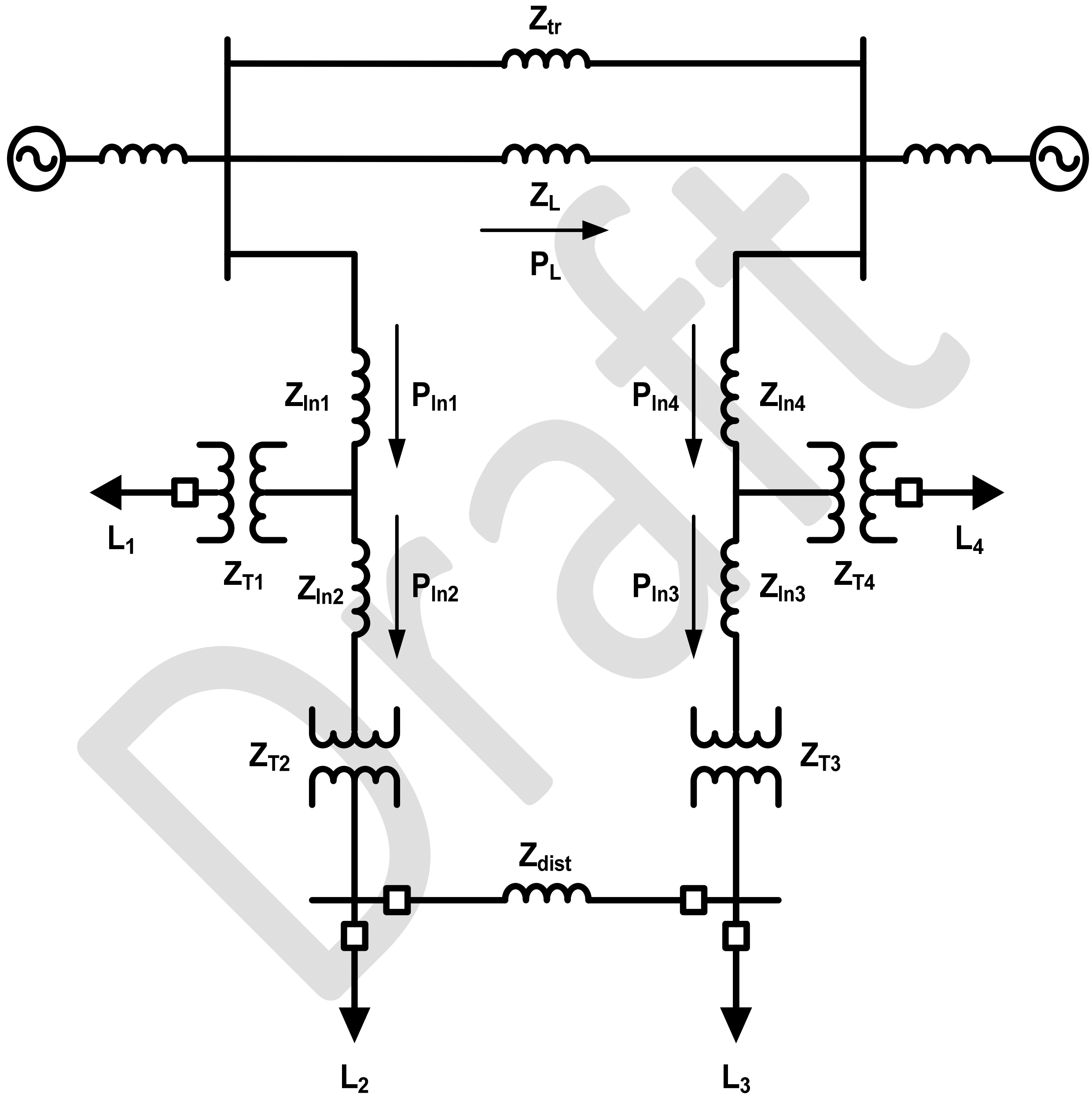


Figure 5: Example Radial Systems with Low Voltage Distribution Tie

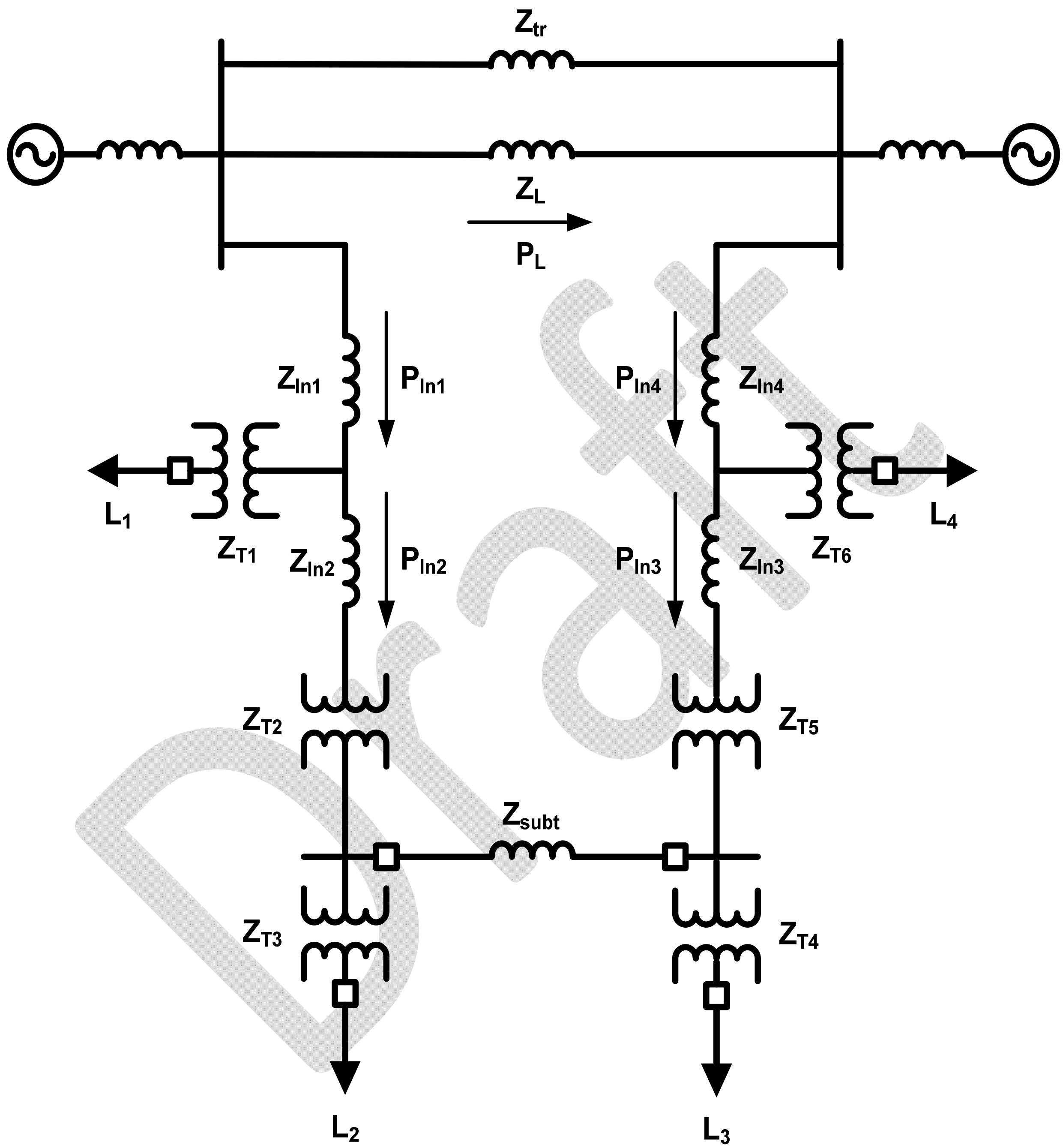


Figure 6: Example Radial Systems with Sub-transmission Tie

Appendix 3

								X------- HV Line "L" in-of-service -------X					X- HV Line "L" out-of-service -X				
Case	**Z_L**	**Z_{tr}**	**Z_{ln1-4}** (total)	**Z_{dist}**	**Z_{T1-4}** (Z/MVA)	**L_1, L_4**	**L_2, L_3**	**P_L**	**P_{ln1}**	**P_{ln2}**	**P_{ln3}**	**P_{ln4}**	**$P_{ln1'}$**	**$P_{ln2'}$**	**$P_{ln3'}$**	**$P_{ln4'}$**	**df**
23 kV Base Cases																	
623a0	10 mi	0.10xZ_L	15 mi	0	10%/10	4.0	4.0	110.7	10.9	6.9	1.1	5.1	11.2	7.2	0.8	4.8	0.003
623a2	10 mi	0.10xZ_L	15 mi	2 mi	10%/10	4.0	4.0	110.7	10.7	6.7	1.4	5.4	10.9	6.9	1.1	5.1	0.002
623a5	10 mi	0.10xZ_L	15 mi	5 mi	10%/10	4.0	4.0	110.7	10.3	6.3	1.7	5.7	10.5	6.5	1.5	5.5	0.002
623a0pk	10 mi	0.10xZ_L	15 mi	0	10%/10	8.0	8.0	111.4	19.0	10.9	5.1	13.1	19.3	11.2	4.8	12.8	0.003
623a2pk	10 mi	0.10xZ_L	15 mi	2 mi	10%/10	8.0	8.0	111.4	18.7	10.7	5.4	13.4	18.9	10.9	5.1	13.1	0.002
623a5pk	10 mi	0.10xZ_L	15 mi	5 mi	10%/10	8.0	8.0	111.5	18.3	10.3	5.7	13.7	18.6	10.5	5.5	13.5	0.003
623b0	10 mi	0.10xZ_L	15 mi	0	10%/20	8.0	8.0	111.1	21.7	13.7	2.3	10.3	22.3	14.2	1.8	9.8	0.005
623b2	10 mi	0.10xZ_L	15 mi	2 mi	10%/20	8.0	8.0	111.2	20.7	12.7	3.3	11.3	21.2	13.2	2.9	10.9	0.004
623b5	10 mi	0.10xZ_L	15 mi	5 mi	10%/20	8.0	8.0	111.3	19.7	11.7	4.3	12.3	20.1	12.1	4.0	12.0	0.004
623b0pk	10 mi	0.10xZ_L	15 mi	0	10%/20	16.0	16.0	112.6	37.8	21.7	10.3	26.3	38.3	22.3	9.7	25.8	0.004
623b2pk	10 mi	0.10xZ_L	15 mi	2 mi	10%/20	16.0	16.0	112.7	36.7	20.7	11.3	27.3	37.2	21.2	10.9	26.9	0.004
623b5pk	10 mi	0.10xZ_L	15 mi	5 mi	10%/20	16.0	16.0	112.8	35.7	19.7	12.3	28.4	36.1	20.1	12.0	28.0	0.004
623c0	10 mi	0.10xZ_L	15 mi	0	10%/40	16.0	16.0	112.2	42.7	26.6	5.4	21.4	43.7	27.7	4.3	20.3	0.009
623c2	10 mi	0.10xZ_L	15 mi	2 mi	10%/40	16.0	16.0	112.5	39.6	23.6	8.4	24.4	40.4	24.4	7.7	23.7	0.007

623c5	10 mi	$0.10xZ_L$	15 mi	5 mi	10%/40	16.0	16.0	112.7	37.3	21.3	10.8	26.8	37.8	21.8	10.3	26.3	0.004
623c0pk	10 mi	$0.10xZ_L$	15 mi	0	10%/40	32.0	32.0	115.1	74.9	42.8	21.2	53.3	76.0	43.9	20.2	52.2	0.010
623c2pk	10 mi	$0.10xZ_L$	15 mi	2 mi	10%/40	32.0	32.0	115.4	71.8	39.7	24.3	56.4	72.6	40.5	23.6	55.6	0.007
623c5pk	10 mi	$0.10xZ_L$	15 mi	5 mi	10%/40	32.0	32.0	115.6	69.4	37.4	26.7	58.8	70.0	37.9	26.2	58.3	0.005
723a0	10 mi	$0.36xZ_L$	15 mi	0	10%/10	4.0	4.0	108.3	10.9	6.9	1.1	5.1	11.9	7.9	0.1	4.1	0.009
723a2	10 mi	$0.36xZ_L$	15 mi	2 mi	10%/10	4.0	4.0	108.3	10.6	6.6	1.4	5.4	11.5	7.5	0.5	4.5	0.008
723a5	10 mi	$0.36xZ_L$	15 mi	5 mi	10%/10	4.0	4.0	108.4	10.3	6.3	1.8	5.8	11.1	7.1	1.0	5.0	0.007
723a0pk	10 mi	$0.36xZ_L$	15 mi	0	10%/10	8.0	8.0	110.4	18.9	10.9	5.1	13.1	20.0	12.0	4.0	12.1	0.010
723a2pk	10 mi	$0.36xZ_L$	15 mi	2 mi	10%/10	8.0	8.0	110.5	18.6	10.6	5.4	13.4	19.6	11.6	4.4	12.5	0.009
723a5pk	10 mi	$0.36xZ_L$	15 mi	5 mi	10%/10	8.0	8.0	110.6	18.3	10.3	5.7	13.7	19.1	11.1	4.9	12.9	0.007
723b0	10 mi	$0.36xZ_L$	15 mi	0	10%/20	8.0	8.0	109.7	21.6	13.6	2.4	10.4	23.6	15.6	0.4	8.4	0.018
723b2	10 mi	$0.36xZ_L$	15 mi	2 mi	10%/20	8.0	8.0	110.0	20.6	12.6	3.4	11.4	22.3	14.3	1.7	9.8	0.015
723b5	10 mi	$0.36xZ_L$	15 mi	5 mi	10%/20	8.0	8.0	110.2	19.7	11.7	4.4	12.4	21.0	13.0	3.1	11.1	0.012
723b0pk	10 mi	$0.36xZ_L$	15 mi	0	10%/20	16.0	16.0	114.0	37.8	21.8	10.2	26.3	39.9	23.8	8.2	24.2	0.018
723b2pk	10 mi	$0.36xZ_L$	15 mi	2 mi	10%/20	16.0	16.0	114.3	36.8	20.8	11.3	27.3	38.5	22.5	9.6	25.6	0.015
723b5pk	10 mi	$0.36xZ_L$	15 mi	5 mi	10%/20	16.0	16.0	114.5	35.8	19.8	12.3	28.3	37.2	21.1	10.9	27.0	0.012
723c0	10 mi	$0.36xZ_L$	15 mi	0	10%/40	16.0	16.0	112.6	42.7	26.7	5.3	21.3	46.5	31.4	1.6	17.6	0.034
723c2	10 mi	$0.36xZ_L$	15 mi	2 mi	10%/40	16.0	16.0	113.5	39.7	23.7	8.4	24.4	42.4	26.4	5.7	21.7	0.024
723c5	10 mi	$0.36xZ_L$	15 mi	5 mi	10%/40	16.0	16.0	114.1	37.4	21.4	10.7	26.7	39.3	23.3	8.8	24.8	0.017

723c0pk	10 mi	$0.36xZ_L$	15 mi	0	10%/40	32.0	32.0	121.2	75.5	43.4	20.7	52.7	79.5	47.4	16.7	48.7	0.033
723c2pk	10 mi	$0.36xZ_L$	15 mi	2 mi	10%/40	32.0	32.0	122.0	72.2	40.1	23.9	55.9	75.2	43.1	21.1	53.1	0.025
723c5pk	10 mi	$0.36xZ_L$	15 mi	5 mi	10%/40	32.0	32.0	122.7	69.8	37.7	26.4	58.5	71.8	39.7	24.4	56.5	0.016
823a0	10 mi	$0.75xZ_L$	15 mi	0	10%/10	4.0	4.0	106.1	10.8	6.8	1.2	5.2	12.9	8.9	-0.9	3.1	0.020
823a2	10 mi	$0.75xZ_L$	15 mi	2 mi	10%/10	4.0	4.0	106.2	10.5	6.5	1.5	5.5	12.4	8.4	-0.4	3.6	0.018
823a5	10 mi	$0.75xZ_L$	15 mi	5 mi	10%/10	4.0	4.0	106.4	10.2	62.0	1.8	5.8	11.9	7.9	0.2	4.2	0.016
823a0pk	10 mi	$0.75xZ_L$	15 mi	0	10%/10	8.0	8.0	109.6	18.9	10.9	5.1	13.1	21.1	13.0	3.0	11.0	0.020
823a2pk	10 mi	$0.75xZ_L$	15 mi	2 mi	10%/10	8.0	8.0	109.7	18.6	10.6	5.4	13.4	20.6	12.6	3.5	11.5	0.018
823a5pk	10 mi	$0.75xZ_L$	15 mi	5 mi	10%/10	8.0	8.0	109.8	18.3	10.3	5.7	13.8	20.0	12.0	4.0	12.1	0.015
823b0	10 mi	$0.75xZ_L$	15 mi	0	10%/20	8.0	8.0	108.4	21.5	13.5	2.5	10.5	25.6	17.6	-1.6	6.4	0.038
823b2	10 mi	$0.75xZ_L$	15 mi	2 mi	10%/20	8.0	8.0	108.8	20.6	12.6	3.4	11.4	24.0	16.0	0.1	8.1	0.031
823b5	10 mi	$0.75xZ_L$	15 mi	5 mi	10%/20	8.0	8.0	109.2	19.6	11.6	4.4	12.4	22.3	14.3	1.8	9.8	0.025
823b0pk	10 mi	$0.75xZ_L$	15 mi	0	10%/20	16.0	16.0	115.3	37.9	21.9	10.2	26.2	42.2	26.1	5.9	21.9	0.037
823b2pk	10 mi	$0.75xZ_L$	15 mi	2 mi	10%/20	16.0	16.0	115.7	36.9	20.8	11.2	27.2	40.4	24.4	7.7	23.7	0.030
823b5pk	10 mi	$0.75xZ_L$	15 mi	5 mi	10%/20	16.0	16.0	116.2	35.9	19.8	12.2	28.2	38.7	22.7	9.4	25.5	0.024
823c0	10 mi	$0.75xZ_L$	15 mi	0	10%/40	16.0	16.0	113.1	42.7	26.7	5.3	21.3	50.3	34.3	-2.3	13.7	0.067
823c2	10 mi	$0.75xZ_L$	15 mi	2 mi	10%/40	16.0	16.0	114.4	39.7	23.7	8.3	24.3	45.4	29.3	2.8	18.8	0.050
823c5	10 mi	$0.75xZ_L$	15 mi	5 mi	10%/40	16.0	16.0	115.5	37.4	21.4	10.6	26.7	41.4	25.4	6.8	22.8	0.035
823c0pk	10 mi	$0.75xZ_L$	15 mi	0	10%/40	32.0	32.0	126.7	76.0	43.9	20.2	52.2	84.4	52.3	11.8	43.8	0.066
823c2pk	10 mi	$0.75xZ_L$	15 mi	2 mi	10%/40	32.0	32.0	128.2	72.7	40.6	23.5	55.6	78.9	48.6	17.4	49.5	0.048
823c5pk	10 mi	$0.75xZ_L$	15 mi	5 mi	10%/40	32.0	32.0	129.3	70.1	38.0	26.1	58.2	74.5	42.4	21.8	53.9	0.034

Sensitivity to Length of Lines 1-4

723a0_30	10 mi	$0.36xZ_L$	30 mi	0	10%/10	4.0	4.0	108.3	10.8	6.8	1.2	5.2	11.8	7.8	0.2	4.2	0.009
723a2_30	10 mi	$0.36xZ_L$	30 mi	2 mi	10%/10	4.0	4.0	108.4	10.5	6.5	1.5	5.5	11.4	7.4	0.6	4.6	0.008
723a5_30	10 mi	$0.36xZ_L$	30 mi	5 mi	10%/10	4.0	4.0	108.5	10.2	6.2	1.8	5.8	11.0	7.0	1.0	5.0	0.007

Selected 34.5 kV cases

834a0	10 mi	$0.75xZ_L$	15 mi	0	10%/10	4.0	4.0	106.1	10.8	6.8	1.2	5.2	12.9	8.9	-0.9	3.1	0.020
834a2	10 mi	$0.75xZ_L$	15 mi	2 mi	10%/10	4.0	4.0	106.1	10.7	6.7	1.3	5.3	12.7	8.7	-0.7	3.3	0.019
834a5	10 mi	$0.75xZ_L$	15 mi	5 mi	10%/10	4.0	4.0	106.2	10.5	6.5	1.5	5.5	12.4	8.4	-0.4	3.6	0.018
834a0pk	10 mi	$0.75xZ_L$	15 mi	0	10%/10	8.0	8.0	109.6	18.9	10.9	5.1	13.1	21.1	13.0	3.0	11.0	0.020
834a2pk	10 mi	$0.75xZ_L$	15 mi	2 mi	10%/10	8.0	8.0	109.6	18.8	10.8	5.2	13.3	20.8	12.8	3.2	11.2	0.018
834a5pk	10 mi	$0.75xZ_L$	15 mi	5 mi	10%/10	8.0	8.0	109.7	18.6	10.6	5.4	13.4	20.5	12.5	3.5	11.5	0.017
834b0	10 mi	$0.75xZ_L$	15 mi	0	10%/20	8.0	8.0	108.4	21.5	13.5	2.5	10.5	25.6	17.6	-1.6	6.4	0.038
834b2	10 mi	$0.75xZ_L$	15 mi	2 mi	10%/20	8.0	8.0	108.6	21.1	13.1	2.9	10.9	24.8	16.8	-0.7	7.3	0.034
834b5	10 mi	$0.75xZ_L$	15 mi	5 mi	10%/20	8.0	8.0	108.9	20.5	12.5	3.5	11.5	23.8	15.8	0.3	8.3	0.030
834b0pk	10 mi	$0.75xZ_L$	15 mi	0	10%/20	16.0	16.0	115.3	37.9	21.9	10.2	26.2	42.2	26.1	5.9	21.9	0.037
834b2pk	10 mi	$0.75xZ_L$	15 mi	2 mi	10%/20	16.0	16.0	115.5	37.4	21.4	10.7	26.7	41.3	25.3	6.8	22.8	0.034
834b5pk	10 mi	$0.75xZ_L$	15 mi	5 mi	10%/20	16.0	16.0	115.8	36.8	20.7	11.3	27.3	40.3	24.2	7.8	23.9	0.030
834c0	10 mi	$0.75xZ_L$	15 mi	0	10%/40	16.0	16.0	113.1	42.7	26.7	5.3	21.3	50.3	34.3	-2.3	13.7	0.067
834c2	10 mi	$0.75xZ_L$	15 mi	2 mi	10%/40	16.0	16.0	113.8	41.2	25.2	6.9	22.9	47.8	31.7	0.4	16.4	0.058
834c5	10 mi	$0.75xZ_L$	15 mi	5 mi	10%/40	16.0	16.0	114.6	39.5	23.5	8.5	24.6	45.0	29.0	3.2	19.2	0.048

834c0pk	10 mi	0.75xZ_L	15 mi	0	10%/40	32.0	32.0	126.7	76.0	43.9	20.2	52.2	84.4	52.3	11.8	43.8	0.066
834c2pk	10 mi	0.75xZ_L	15 mi	2 mi	10%/40	32.0	32.0	127.5	74.2	42.1	21.9	54.0	81.5	49.4	14.7	46.8	0.057
834c5pk	10 mi	0.75xZ_L	15 mi	5 mi	10%/40	32.0	32.0	128.3	72.4	40.3	23.8	55.8	78.5	46.4	17.9	49.9	0.048
834d0	10 mi	0.75xZ_L	15 mi	0	7%/40	16.0	16.0	111.6	46.3	30.3	1.7	17.7	56.2	40.1	-8.1	7.9	0.089
834d2	10 mi	0.75xZ_L	15 mi	2 mi	7%/40	16.0	16.0	112.8	43.6	27.6	4.4	20.4	51.8	35.8	-3.6	12.4	0.073
834d5	10 mi	0.75xZ_L	15 mi	5 mi	7%/40	16.0	16.0	113.9	41.1	25.1	7.0	23.0	47.6	31.6	0.6	16.6	0.057
834d0pk	10 mi	0.75xZ_L	15 mi	0	7%/40	32.0	32.0	124.9	80.0	47.9	16.2	48.2	90.9	58.8	5.3	37.3	0.087
834d2pk	10 mi	0.75xZ_L	15 mi	2 mi	7%/40	32.0	32.0	126.3	77.0	44.9	19.2	51.2	86.1	54.0	10.2	42.2	0.072
834d5pk	10 mi	0.75xZ_L	15 mi	5 mi	7%/40	32.0	32.0	127.5	74.2	42.1	22.0	54.1	81.4	49.3	15.0	47.0	0.056

Selected 12.47 kV cases

812a0	10 mi	0.75xZ_L	15 mi	0	10%/10	4.0	4.0	106.1	10.8	6.8	1.2	5.2	12.9	8.9	-0.9	3.1	0.020
812a2	10 mi	0.75xZ_L	15 mi	2 mi	10%/10	4.0	4.0	106.4	10.1	6.1	1.9	5.9	11.6	7.6	0.4	4.4	0.014
812a5	10 mi	0.75xZ_L	15 mi	5 mi	10%/10	4.0	4.0	106.7	9.4	5.4	2.6	6.6	10.5	6.5	1.5	5.5	0.010
812a0pk	10 mi	0.75xZ_L	15 mi	0	10%/10	8.0	8.0	109.6	18.9	10.9	5.1	13.1	21.1	13.0	3.0	11.0	0.020
812a2pk	10 mi	0.75xZ_L	15 mi	2 mi	10%/10	8.0	8.0	109.9	18.1	10.1	5.9	13.9	19.7	11.7	4.3	12.4	0.015
812a5pk	10 mi	0.75xZ_L	15 mi	5 mi	10%/10	8.0	8.0	110.2	17.5	9.5	6.5	14.5	18.6	10.6	5.5	13.5	0.010
812b0	10 mi	0.75xZ_L	15 mi	0	10%/20	8.0	8.0	108.4	21.5	13.5	2.5	10.5	25.6	17.6	-1.6	6.4	0.038
812b2	10 mi	0.75xZ_L	15 mi	2 mi	10%/20	8.0	8.0	109.4	19.2	11.2	4.8	12.8	21.7	13.6	2.5	10.5	0.023
812b5	10 mi	0.75xZ_L	15 mi	5 mi	10%/20	8.0	8.0	110.0	17.9	9.9	6.1	14.1	19.4	11.4	4.7	12.7	0.014
812b0pk	10 mi	0.75xZ_L	15 mi	0	10%/20	16.0	16.0	115.3	37.9	21.9	10.2	26.2	42.2	26.1	5.9	21.9	0.037

812b2pk	10 mi	0.75xZ_L	15 mi	2 mi	10%/20	16.0	16.0	116.4	35.4	19.4	12.6	28.6	38.0	22.0	10.2	26.2	0.022
812b5pk	10 mi	0.75xZ_L	15 mi	5 mi	10%/20	16.0	16.0	117.0	34.1	18.0	14.0	30.0	35.6	19.6	12.6	28.6	0.013
812c0	10 mi	0.75xZ_L	15 mi	0	10%/40	16.0	16.0	113.1	42.7	26.7	5.3	21.3	50.3	34.3	-2.3	13.7	0.067
812c2	10 mi	0.75xZ_L	15 mi	2 mi	10%/40	16.0	16.0	115.9	36.6	20.6	11.5	27.5	40.0	24.0	8.3	24.3	0.029
812c5	10 mi	0.75xZ_L	15 mi	5 mi	10%/40	16.0	16.0	116.8	34.4	18.4	13.7	29.7	36.2	20.2	12.0	28.0	0.015
812c0pk	10 mi	0.75xZ_L	15 mi	0	10%/40	32.0	32.0	126.7	76.0	43.9	20.2	52.2	84.4	52.3	11.8	43.8	0.066
812c2pk	10 mi	0.75xZ_L	15 mi	2 mi	10%/40	32.0	32.0	129.7	69.2	37.1	27.1	59.1	73.0	40.9	23.5	55.5	0.029
812c5pk	10 mi	0.75xZ_L	15 mi	5 mi	10%/40	32.0	32.0	130.8	66.7	34.7	29.4	61.5	68.8	36.7	27.6	59.6	0.016

Selected 46 kV cases

846e0	10 mi	0.75xZ_L	15 mi	0	7%/50	16.0	20.0	112.1	53.1	37.1	2.9	18.9	64.7	48.7	-8.6	7.4	0.103
846e2	10 mi	0.75xZ_L	15 mi	2 mi	7%/50	16.0	20.0	113.2	50.7	34.7	5.3	21.3	60.9	44.8	-4.7	11.3	0.090
846e5	10 mi	0.75xZ_L	15 mi	5 mi	7%/50	16.0	20.0	114.3	48.2	32.1	7.9	24.0	56.7	40.7	-0.4	15.6	0.074

Subtransmission cases

115-69 kV

669f25	40 mi	0.10xZ_L	20 mi	25 mi	7%/60	16.0	24.0	114.0	76.0	59.8	-10.8	5.2	79.6	63.4	-14.2	1.8	0.032
769f25	40 mi	0.36xZ_L	20 mi	25 mi	7%/60	16.0	24.0	111.7	75.3	59.1	-10.1	5.9	87.3	71.0	-21.2	-5.2	0.107
869f25	40 mi	0.75xZ_L	20 mi	25 mi	7%/60	16.0	24.0	109.8	74.7	58.5	-9.6	6.4	97.0	80.6	-30.0	-14.0	0.203

115-55 kV

655e25	40 mi	0.10xZ_L	20 mi	25 mi	7%/50	16.0	20.0	114.5	62.1	46.0	-5.0	11.0	64.8	48.7	-7.5	8.5	0.024
755e25	40 mi	0.36xZ_L	20 mi	25 mi	7%/50	16.0	20.0	113.3	61.8	45.7	-4.8	11.2	70.9	54.8	-13.0	3.0	0.080
855e25	40 mi	0.75xZ_L	20 mi	25 mi	7%/50	16.0	20.0	112.1	61.5	45.4	-4.5	11.5	79.1	62.9	-20.2	-4.2	0.157
855f25																	

115-46 kV																	
646e25	40 mi	$0.10xZ_L$	20 mi	25 mi	7%/50	16.0	20.0	115.0	57.3	41.2	-0.2	15.8	59.5	43.4	-2.1	13.9	0.019
746e25	40 mi	$0.36xZ_L$	20 mi	25 mi	7%/50	16.0	20.0	114.6	57.2	41.2	-0.1	15.9	64.9	48.8	-6.8	9.2	0.067
846e25	40 mi	$0.75xZ_L$	20 mi	25 mi	7%/50	16.0	20.0	114.2	57.2	41.1	0.0	16.0	72.4	56.2	-13.1	2.9	0.133
115-34.5 kV																	
634d25	40 mi	$0.10xZ_L$	20 mi	25 mi	7%/40	16.0	16.0	115.3	46.2	30.2	2.6	18.7	47.7	31.7	1.4	17.4	0.013
734d25	40 mi	$0.36xZ_L$	20 mi	25 mi	7%/40	16.0	16.0	115.4	46.3	30.2	2.6	18.6	51.5	35.5	-1.9	14.1	0.045
834d25	40 mi	$0.75xZ_L$	20 mi	25 mi	7%/40	16.0	16.0	115.5	46.3	30.2	2.6	18.6	57.1	41.0	-6.4	9.6	0.094
138-69 kV																	
869f25-138	40 mi	$0.75xZ_L$	20 mi	25 mi	7%/60	16.0	24.0	112.0	66.5	50.4	-1.8	14.2	84.0	67.9	-18.3	-2.3	0.156
869f25-138'	40 mi	$0.75xZ_L$	20 mi	25 mi	7%/60	16.0	24.0	131.9	71.1	55.0	-6.3	9.8	92.0	75.8	-25.6	-9.6	0.158
138-55 kV																	
855e25-138	40 mi	$0.75xZ_L$	20 mi	25 mi	7%/50	16.0	20.0	113.5	55.1	39.0	1.5	17.5	68.4	52.3	-10.8	5.2	0.117
855e25-138'	40 mi	$0.75xZ_L$	20 mi	25 mi	7%/60	16.0	20.0	134.0	58.5	42.4	-1.7	14.3	74.4	58.3	-16.2	-0.2	0.119
161-69 kV																	
869f25-161	40 mi	$0.75xZ_L$	20 mi	25 mi	7%/60	16.0	24.0	113.2	60.7	44.7	3.7	19.7	74.8	58.8	-9.8	6.2	0.125
869f25-161'	40 mi	$0.75xZ_L$	20 mi	25 mi	7%/60	16.0	24.0	153.0	68.0	52.0	-3.3	12.7	87.3	71.2	-21.4	-5.4	0.126
161-55 kV																	
855e25-161	40 mi	$0.75xZ_L$	20 mi	25 mi	7%/50	16.0	20.0	114.1	50.7	34.7	5.6	21.6	61.1	45.1	-4.2	11.8	0.091
855e25-161'	40 mi	$0.75xZ_L$	20 mi	25 mi	7%/60	16.0	20.0	154.8	56.0	40.0	0.6	16.6	70.3	54.3	-12.6	3.4	0.092
230-69 kV																	
869f25-230	40 mi	$0.75xZ_L$	20 mi	25 mi	7%/60	16.0	24.0	116.3	51.3	35.3	12.8	28.8	59.4	43.3	5.0	21.0	0.070
869f25-230'	40 mi	$0.75xZ_L$	20 mi	25 mi	7%/60	16.0	24.0	217.7	61.2	45.2	3.2	19.2	76.5	60.4	-11.4	4.7	0.070

230-55 kV

855e25-230	40 mi	0.75xZ_L	20 mi	25 mi	7%/50	16.0	20.0	116.1	43.8	27.8	12.3	28.3	49.5	33.5	6.7	22.8	0.049
855e25-230'	40 mi	0.75xZ_L	20 mi	25 mi	7%/60	16.0	20.0	218.7	50.8	34.8	5.6	21.6	61.7	45.7	-4.7	11.3	0.050