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NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION

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

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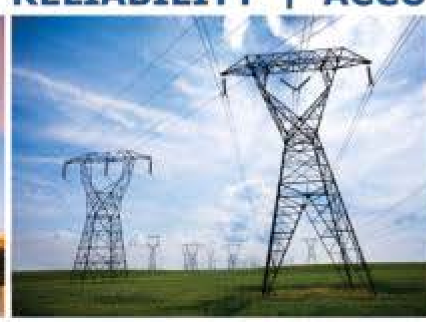
RELIABILITY | ACCOUNTABILITY






Project 2010-17: Definition of Bulk Electric System

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

Background

The definition of "Bulk Electric System" (BES) in the NERC Glossary consists of a core definition and a list of facilities configurations that will be included or excluded from the core definition. The core definition is used to establish the bright line of 100 kV, the overall demarcation point between BES and non-BES elements. Exclusion E1 applies to radial systems. In Order No. 773 and 773-A, the Federal Energy Regulatory Commission's (Commission or FERC) 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.*

[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).

Executive Summary

The Project 2010-17 Standard Drafting Team conducted a two-step process to establish a technical justification for the establishment of a voltage threshold below which sub-100 kV loops do not affect the application of Exclusion E1. 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.

The analysis establishes that a 50 kV threshold for sub-100 kV loops does not affect the application of Exclusion E1. This approach will ease the administrative burden on entities as it negates the necessity for an entity to prove that they qualify for Exclusion E1 if the sub-100 kV loop in question is less than or equal to 50 kV. This analysis provides an equally effective and efficient alternative to address the Commission's directives expressed in Order No. 773 and 773-A.

It should be noted that, although this study resulted in a technically justified 50 kV threshold based on proven analytic methods, there are other preventative loop flow methods that entities can apply on sub-100 kV loop systems to address physical equipment concerns. These methods include:

- Interlocked control schemes;
- Reverse power schemes;
- Transformer, feeder and bus tie protection; and
- Custom protection and control schemes.

These methods are discussed in detail in Appendix 4. The presence of such equipment does not alter the criteria developed in this white paper, nor does it influence the conclusions reached. Additionally, the presence of this equipment does not remove or lessen an entity's obligations associated with the bright-line application of the Bulk Electric System (BES) definition.

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.

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 North America. 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

[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 Standard Drafting Team has revised the threshold to 50 kV for subsequent industry consideration.

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 North American 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]	100
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. There were a number of Flowgates with 115 kV monitored elements in SERC, the monitored grouping listed is representative.

Table 1: Lowest Line Element Voltage Monitored by Region

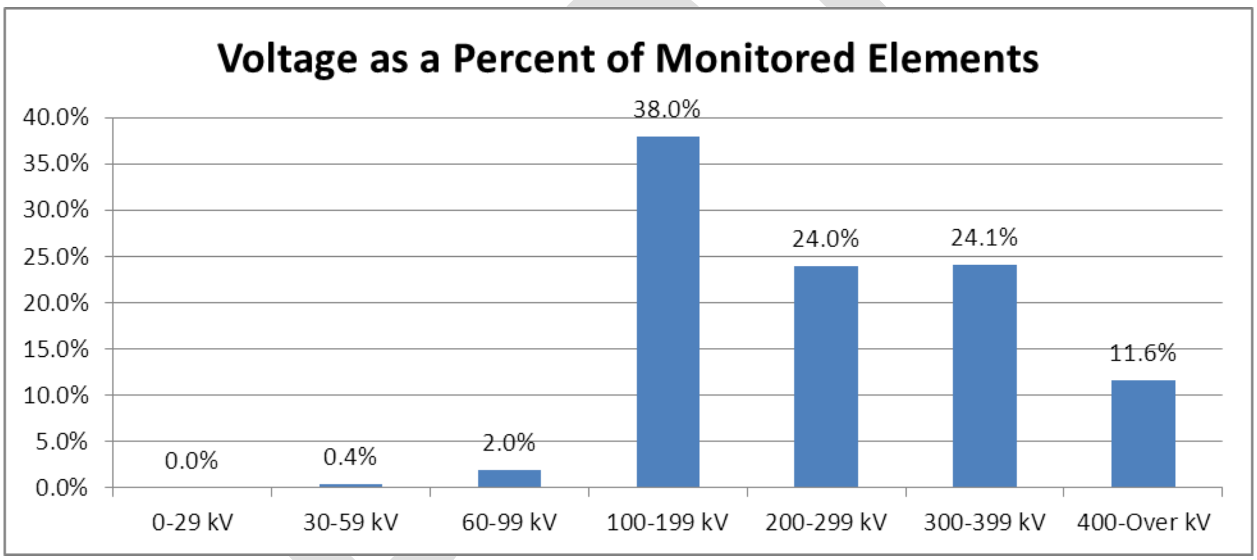
In a few rare occasions there were transformer elements with low-side windings lower than 30 kV included in the key monitored element groupings as shown in Table 2.

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

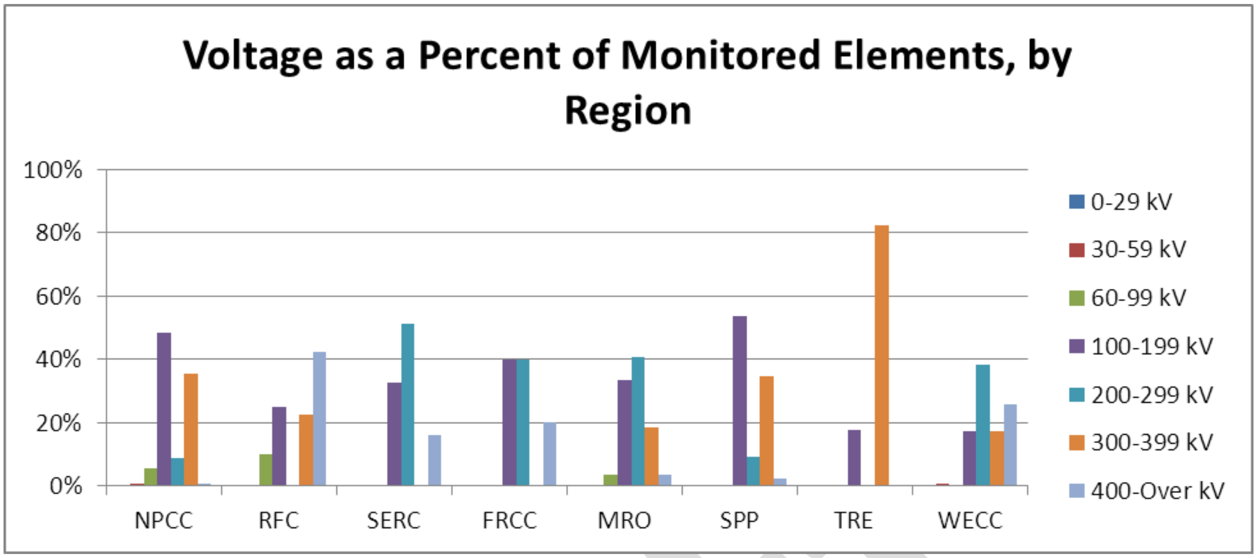
Upon closer investigation, for New England's Southwest Connecticut interface, it was determined that the inclusion of these elements was the result of longstanding, historical interface definitions and not for the purpose of addressing BES reliability concerns. Transformers serving lower voltage networks 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 monitoring 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 Step 1 of this 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. As noted herein, an examination of the line listings of the North American 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.

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 performed 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 greater than 100 kV 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 application 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.

Analytical Approach – Distribution Circuit Loop Example

The Project 2010-17 Standard Drafting Team 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 this study was performed. As an example, the Standard Drafting Team 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).

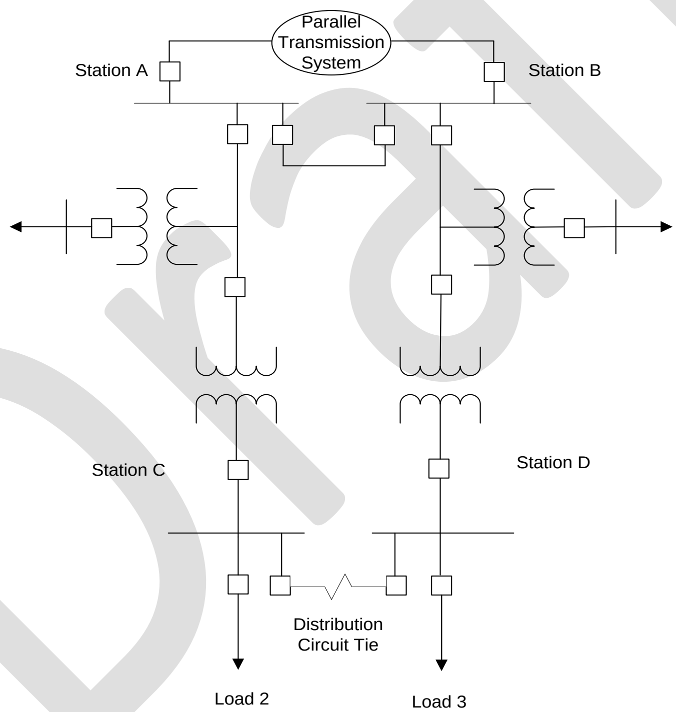


Figure 3: Example Radial Systems with Low Voltage Distribution Loop

With the example system, the Standard Drafting Team 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 flow 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 impedances 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 tapped off the 115 kV lines between stations A and C and between stations B and D and 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;
- Transfer impedance equivalent between stations A and B, representing the strength of the interconnected transmission network[3].

Within this model, parameters were modified to simulate differences in the length and impedance of the transmission lines, the amount of distribution load, the strength of the transmission network supplying stations A and B, the size of the distribution transformers and the character of the bus or feeder ties 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 the upper portion of Table 3. Sensitivity analysis was performed as indicated in the lower portion of the table.

[3] The relative strength of the surrounding transmission system network is a function of the quantity of parallel transmission paths and the impedance of those paths between the two source substations. A high number of parallel paths with low impedance translates to a low transfer impedance, which allows power to more readily flow between the stations. Conversely, a low number of parallel paths having higher impedance is represented by a relatively large transfer impedance.

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	Weak
		23	2 miles	20	80	
		34.5	5 miles	40		
Sensitivity Analysis:		46				Strong Medium

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 used to examine a series of cases simulating a power transfer on the 115 kV line[4] 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 at stations A and B 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

[4] 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.

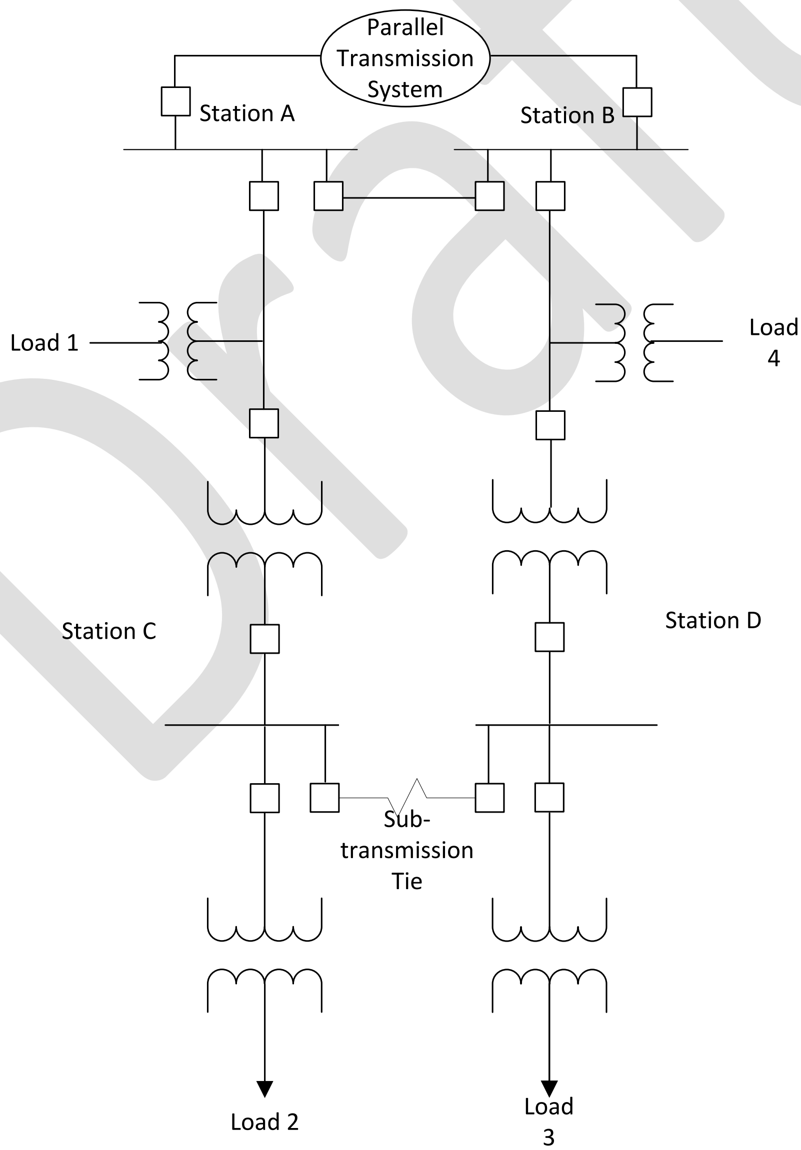


Figure 4: Example Radial Systems with Sub-transmission Loop

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, which was confirmed as conservative in the distribution system analysis.

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 modeling a 115 kV transmission system yield the most conservative results. 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. In no instance was a reversal of power flow observed in sub-transmission systems rated below 50 kV.

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

After conducting extensive simulations (included in Appendix 3), the results of Step 2 of this analysis indicates that 50 kV is the appropriate low voltage loop threshold below which sub-100 kV loops should not affect the application of Exclusion E1 of the BES Definition. 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.

As described throughout the preceding section, the scenarios and configurations utilized in this analysis represent the majority of cases that will be encountered in the industry. The models used in this analysis establish reasonable bounds and use conservative parameters in the scenarios. However, there may be actual cases that deviate from these modeled scenarios, and therefore, results could be somewhat different than the ranges of results from this analysis. Such deviations are expected to be rare and can be processed through the companion BES Exception Process.

Study Conclusion

The Project 2010-17 Standard Drafting Team 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.

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 objective of Step 1 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.

As a result of studying such regional monitoring levels, Step 1 concluded that 30 kV was a reasonable voltage level to initiate the sensitivity analysis conducted in Step 2. This is a conservative value as it is below any of the regional monitoring levels.

Using the conservative value established by Step 1, the Standard Drafting Team conducted extensive simulations of power flows which demonstrated that there is no power flow reversal into the BES when circuit loop operating voltages are below 50 kV. Therefore, the study concludes that low voltage circuit loops operated below 50 kV 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.

The scenarios and configurations utilized in this analysis represent the majority of cases that will be encountered in the industry. The models used in this analysis establish reasonable bounds and use conservative parameters in the scenarios. However, there may be actual cases that deviate from these modeled scenarios, and therefore, results could be somewhat different than the ranges of results from this analysis. Such deviations are expected to be rare and can be processed through the companion BES Exception Process.

Appendix 1: Regional Elements

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

- FRCC
- MRO/MISO
- NPCC/ISO-NE
- NPCC/NYISO
- RFC/PJM
- SERC
- SPP
- TRE/ERCOT
- WECC (Existing Paths)

FRCC

Interface Name	Element Name	Interface Type	Voltage (kV)
FRCC-Southern Interface	**Lowest Voltage Line Element**		**115**
	Duval – Hatch	Line	500
	Duval - Thalmann	Line	500
	Duval - Kingsland	Line	230
	Crawfordville - Callaway	Line	230
	South Bainbridge - Sub 20	Line	230
	Suwannee - Pine Grove	Line	230
	Jasper – Tarver	Line	115
	Jasper - Pine Grove	Line	115
	Suwannee - Pine Grove	Line	115
	Woodruff - Scholz	Line	115

MRO/MISO

Interface Name	Element Name	Interface Type	Voltage (kV)
NDEX	**Lowest Voltage Line Element**		**69**
	Leland Olds – Ft Thompson 345kV	Line	345
	Leland Olds – Groton 345kV	Line	345
	(Antelope Valley –)Broadland 345 kV – Huron 230 kV	Line	230
	Sully Buttes – Oahe 230kV	Line	230
	Bison – Maurine 230kV	Line	230
	Big Stone – Blair 230kV	Line	230
	Morris – Granite Falls 230kV	Line	230
	Inman – Wing River 230kV	Line	230
	(Sheyenne –)Audubon – Hubbard 230kV	Line	230
	Drayton – Letellier 230kV	Line	230
	Rugby – Glenboro 230kV	Line	230
	Cass Lake – Boswell 230kV (Effective June 1, 2013)	Line	230
	Ellendale – Aberdeen Jct 115kV	Line	115
	Edgeley – Ordway 115kV	Line	115
	Forman – Summit 115kV	Line	115
	Canby – Granite Falls 115kV	Line	115
	Alexandria – Douglas Co 115kV	Line	115
	Laporte – Akeley 115kV	Line	115
	Kerkhoven – Kerkhoven Tap 115kV	Line	115
	Benson – Fibromin 115kV	Line	115
	Benson 115 kv – Benson 69 kV (Effective June 1, 2013)	Line	69
MHEX_N	**Lowest Voltage Line Element**		**230**
	Forbes – Dorsey 500kV	Line	500
	Drayton – Letellier 230kV	Line	230
	Moranville – Richer 230kV	Line	230
	Rugby – Glenboro 230kV	Line	230
PRI-BYN	**Lowest Voltage Line Element**		**345**
	Prairie Island – Byron 345kV	Line	345
SE_WI	**Lowest Voltage Line Element**		**138**
	Pleasant Prairie – Zion 345kV	Line	345
	Arcadian – Zion 345kV	Line	345
	Lakeview – Zion 138kV	Line	138

NPCC/ISO-NE

Interface Name	Element Name	Interface Type	Voltage (kV)
Connecticut Export	**Lowest Voltage Line Element**		**69**
	347 - Killingly – Sherman 345 kV (347)	Line	345
	398 - Long Mountain - Pleasant Valley 345 kV (398)	Line	345
	690 - Salisbury - Smithfield 69 kV (690)	Line	69
	1870S - Shunock - Wood River 115 kV (1870S)	Line	115
	3216 - North Bloomfiled - Agawam 345kV (3216)	Line	345
	3419 - Barbour Hill – Ludlow 345 kV (3419)	Line	345
Connecticut Import	**Lowest Voltage Line Element**		**69**
	330 - Lake Road - Card 345 kV (330)	Line	345
	398 - Pleasant Valley - Long Mountain 345 kV (398)	Line	345
	690 - Smithfield - Salisbury 69 kV (690)	Line	69
	1870S - Wood River - Shunock 115 kV (1870S)	Line	115
	Killingly 2X - Killingly 345 kV/115 kV Transformer	Other	345/115
	3216 - Agawam - North Bloomfield 345 kV (3216)	Line	345
	3419 - Ludlow - Barbour Hill 345 kV (3419)	Line	345
Highgate Export	**Lowest Voltage Line Element**		**0**
	1429 - Highgate Converter NE to Highgate converter HQ (1429)	Line	
Highgate Import	**Lowest Voltage Line Element**		**0**
	1429 - Highgate Converter HQ to Highgate converter NE (1429)	Line	
Keene Road Export	**Lowest Voltage Line Element**		**115**
	64BHE-1 - Enfield - Graham 115 kV (64BHE-1)	Line	115
	KEENE_RD T1 - Keene Road 115/345 kV Transformer (KEENE_RD T1)	Other	115/345
Maine - New Hampshire	**Lowest Voltage Line Element**		**115**
	385 - Buxton - Deerfield 345 kV (385)	Line	345
	391 - Buxton - Scobie 345 kV (391)	Line	345
	197 - Quaker Hill - Three Rivers 115 kV (197)	Line	115
	250 - Maguire - Three Rivers 115 kV (250)	Line	115
	214-3 - Lovell - Saco Valley 115 kV (214-3/K1214)	Line	115
New Brunswick - New England	**Lowest Voltage Line Element**		**345**
	3001 - Keswick - Keene Road 345 kV (3001)	Line	345
	390/3016 - Pt. Lepreau – Orrington 345 kV (390/3016)	Line	345
New England - Boston	**Lowest Voltage Line Element**		**115**
	337 - Sandy Pond - Tewksbury 345 kV (337)	Line	345
	394-1 - Seabrook - West Amesbury 345 kV (394-1)	Line	345
	3162 - Stoughton – K St. 345 kV (3162)	Line	345
	3163 - Stoughton – K St. 345 kV (3163)	Line	345
	3164 - Stoughton – Hyde Park 345 kV (3164)	Line	345
	274-509 - Medway - Sherborn 115 kV (274-509)	Line	115
	456-522 - West Walpole - Dover 115 (456-522)	Line	115
	513-507 - Northboro - West Framingham 115 kV (513-507)	Line	115
	M139-2 - Tewksbury - Billerica 115 kV (M139-2)	Line	115

Interface Name	Element Name	Interface Type	Voltage (kV)
	S145-1 - Tewksbury - East Tewksbury 115 kV #1 (S145-1)	Line	115
	T146-1 - Tewksbury - East Tewksbury 115 kV #2 (T146-1)	Line	115
	Y151-3 - Dracut Jct. - West Methuen 115 kV (Y151-3)	Line	115
	N140-1 - Tewksbury - Pinehurst 115 kV (N140-1)	Line	115
	WMedway345A - W.Medway A 345 kV / 230 kV Transformer (WMedway345A)	Other	345/230
	WMedway345B - W.Medway B 345 kV / 230 kV Transformer (WMedway345B)	Other	345/230
New England - New Brunswick	**Lowest Voltage Line Element**		**345**
	3001 - Keene Road - Keswick 345 kV (3001)	Line	345
	390/3016 - Orrington – Pt. Lepreau 345 kV (390/3016)	Line	345
New England - New York	**Lowest Voltage Line Element**		**69**
	393 - Berkshire - Alps 345 kV (393)	Line	345
	398 - Long Mountain - Pleasant Valley 345 kV (398)	Line	345
	E205W - Bear Swamp - Rotterdam 230 kV (E205W)	Line	230
	K6 - Bennington - Hoosick 115 kV (K6)	Line	115
	K7 - Blissville - Whitehall 115 kV (K7)	Line	115
	PV20-2 - South Hero - Plattsburgh 115 kV (PV20-2)	Line	115
	690 - Salisbury-Smithfield 69 kV (690)	Line	69
New England - Norwalk Stamford	**Lowest Voltage Line Element**		**115**
	NORWALK 8X - Norwalk 345 kV/115 kV Transformer (NORWALK 8X)	Other	345/115
	NORWALK 9X - Norwalk 345 kV/115 kV Transformer (NORWALK 9X)	Other	345/115
	1565-1 - Plumtree - Ridgefield Jct. 115 kV (1565-1)	Line	115
	1710-2 - Trumbull Jct.- Old Town 115 kV (1710-2)	Line	115
	91001-2 - Bridgeport Resco Tap - Ashcreek (91001-2)	Line	
	1130 - Pequonnock - Compo 115 kV (1130)	Line	115
	1714 - Trumbull - Weston 115 kV (1714)	Line	115
New England - Southwest Connecticut	**Lowest Voltage Line Element**		**115**
	1163-1 - Frost Bridge - Noera Tap 115 kV (1163-1)	Line	115
	1238 - Frost Bridge - Carmel Hill115 kV (1238)	Line	115
	1445 - Frost Bridge - Shaws Hill 115 kV (1445)	Line	115
	1550-1 - Frost Bridge - Noera Tap 115 kV (1550-1)	Line	115
	1721 - Frost Bridge - Freight 115 kV (1721)	Line	115
	1990-1 - Frost Bridge - Baldwin Tap 115 kV (1990-1)	Line	115
	1208 - Southington - Wallingford 115 kV (1208)	Line	115
	1610-1 - Southington - Glen Lake 115 kV (1610-1)	Line	115
	1910 - Southington - Todd 115 kV (1910)	Line	115
	1950 - Southington - Canal 115 kV (1950)	Line	115

Interface Name	Element Name	Interface Type	Voltage (kV)
	321 - Long Mountain - Plumtree 345 kV (321)	Line	345
	1738 - Stepstone - Branford 115 kV (1738)	Line	115
	1460 - East Shore - Branford RR 115 kV (1460)	Line	115
	8100 - East Shore - Grand Ave 115 kV (8100)	Line	115
	8200 - East Shore - Grand Ave 115 kV (8200)	Line	115
	SOTHNGTN 5X - Southington 115 kV /13.8 kV Transformer (4C-5X)	Other	115/13.8
	SOTHNGTN 6X - Southington 115 kV /13.8 kV Transformer (4C-6X)	Other	115/13.8
	SOTHNGTN 11X - Southington 115 kV /27.6 kV Transformer (4C-11X)	Other	115/27.6
	3827 - Beseck – East Devon 345kV (3827)	Line	345
New England East -West	**Lowest Voltage Line Element**		**115**
	F206 - Comerford - Granite 230 kV (F206)	Line	230
	60 - Littleton - St. Johnsbury 115 kV (60)	Line	115
	K174 - North Road -Ascutney 115 kV (K174)	Line	115
	L163 - Jackman - Keene 115 kV (L163)	Line	115
	380 - Scobie - Amherst 345 kV (380)	Line	345
	E205E - Pratts Jct. - Bear Swamp 230 kV (E205E)	Line	230
	I135S - Pratts Jct. - Flagg Pond 115 kV (I135S)	Line	115
	J136S-3 - Pratts Jct. - Litchfield 115 kV (J136S-3)	Line	115
	A127-6 - Millbury - Tower 510 115 kV (A127-6)	Line	115
	B128-5 - Millbury-Tower 510 115 kV (B128-5)	Line	115
	302 - Millbury - Carpenter Hill 345 kV (302)	Line	345
	V174-2 - Millbury -Oxford 115 kV (V174)	Line	115
	330 - Lake Road - Card 345 kV (330)	Line	345
	1870S - Wood River-Shunock 115 kV (1870S)	Line	115
	Killingly 2X - Killingly 345 kV/115 kV Transformer (Killingly 2X)	Other	345/115
New England West -East	**Lowest Voltage Line Element**		**115**
	F206 - Granite - Comerford 230 kV (F206)	Line	230
	60 - St. Johnsbury - Littleton 115 kV(60)	Line	115
	K174 - Ascutney -North Road 115 kV (K174)	Line	115
	L163 - Keene - Jackman 115 kV (L163)	Line	115
	380 - Amherst - Scobie 345 kV (380)	Line	345
	E205E - Bear Swamp -Pratts Jct. 230 kV (E205E)	Line	230
	I135S - Flagg Pond - Pratts Jct. 115 kV (I135S)	Line	115
	J136S-3 - Litchfield-Pratts Jct. 115 kV (J136S-3)	Line	115
	A127-6 - Tower 510 - Millbury 115 kV (A127-6)	Line	115
	B128-5 - Tower 510 - Millbury 115 kV (B128-5)	Line	115
	302 - Carpenter Hill - Millbury 345 kV (302)	Line	345
	V174-2 - Oxford-Millbury 115 kV (V174-2)	Line	115
	347 - Card - Lake Road 345 kV (330)	Line	345
	1870S - Shunock-Wood River 115 kV (1870S)	Line	115
	Killingly 2X - Killingly 345 kV/115 kV Transformer	Other	345/115
New Hampshire-Maine	**Lowest Voltage Line Element**		**115**
	385 - Deerfield - Buxton 345 kV (385)	Line	345
	391 - Scobie - Buxton 345 kV (391)	Line	345

Interface Name	Element Name	Interface Type	Voltage (kV)
	197 - Three Rivers - Quaker Hill 115 kV (197)	Line	115
	250 - Three Rivers -Maguire 115 kV (250)	Line	115
	214-3 - Saco Valley - Lovell 115 kV (K1214/214-3)	Line	115
North - South	**Lowest Voltage Element**		**115**
	326-1 - Scobie - Lawrence 345 kV (326-1)	Line	345
	381 - Vt Yankee - Northfield 345 kV (381)	Line	345
	394-1 - Seabrook - West Amesbury 345 kV (394-1)	Line	345
	N214 - North Litchfield - Tewksbury 230 kV (N214)	Line	230
	O215 - North Litchfield - Tewksbury 230 kV (O215)	Line	230
	Y151-5 - Power St. - Pelham 115 kV (Y151-5)	Line	115
	J136N-1 - Bellows Falls - E. Winchendon 115 kV (J136N-1)	Line	115
	I135-6 - Fitzwilliam-E. Winchendon Tap 115 kV (I135-6)	Line	115
Northern New England Scobie 345kV - Scobie + 394	**Lowest Voltage Line Element**		**345**
	373 - Deerfield - Scobie 345 kV (373)	Line	345
	391 - Buxton - Scobie 345 kV (391)	Line	345
	363 - Seabrook - Scobie 345 kV (363)	Line	345
	394-1 - Seabrook - West Amesbury 345 kV (394)	Line	345
Orrington - South	**Lowest Voltage Line Element**		**115**
	388 - Orrington -Maxcy's 345 kV (388)	Line	345
	3023 - Orrington - Albion Rd 345 kV (3023)	Line	345
	86-1 - Bucksport - Belfast 115 kV (86-1)	Line	115
	203 - Bucksport - Detroit 115 kV (203)	Line	115
Sandy Pond - South	**Lowest Voltage Line Element**		**345**
	314 - Sandy Pond - Wachusett 345 kV #1 (314)	Line	345
	337 - Sandy Pond - Tewksbury 345 kV (337)	Line	345
	343 - Sandy Pond - Wachusett 345 kV #2 (343)	Line	345
	Sandy Pd 1XB - Sandy Pond 345 kV/115 kV #1 Transformer (Sandy Pd 1XB)	Other	345/115
	Sandy Pd 2XE - Sandy Pond 345 kV/115 kV #2 Transformer (Sandy Pd 2XE)	Other	345/115
Seabrook - South	**Lowest Voltage Line Element**		**345**
	363 - Seabrook - Scobie 345 kV (363)	Line	345
	394-1 - Seabrook - West Amesbury 345 kV (394-1)	Line	345
Surowiec - South	**Lowest Voltage Line Element**		**115**
	3020 - Surowiec - Raven Farm 345kV (3020)	Line	345
	3038 - Surowiec - Buxton 345kV (3038)	Line	345
	374 - Surowiec - Buxton 345 kV (374)	Line	345
	166 - Surowiec - Spring Street 115 kV (166)	Line	115
	167-1 - Surowiec - S167A Tap 115 kV (167-1)	Line	115
	214-3 - Lovell-Saco Valley 115kV (214-3/K1214)	Line	115
Western Connecticut Import	**Lowest Voltage Line Element**		**69**
	1784-1 - North Bloomfield-Northeast Simsbury 115 kV(1784 -1)	Line	115

Interface Name	Element Name	Interface Type	Voltage (kV)
	1783-1 - Farmington - Newington 115 kV (1783)	Line	115
	1773 - South Meadow - Rocky Hill 115 kV (1773)	Line	115
	1767 - Manchester - Hopewell 115 kV (1767)	Line	115
	3533 - Kleen - Scovill Rock 345 kV (3533)	Line	345
	364 - Montville - Haddam Neck 345 kV (364)	Line	345
	348-1 - Millstone-Haddam 345 kV (348-1)	Line	345
	398 - Pleasant Valley - Long Mountain 345 kV (398)	Line	345
	690 - Smithfield - Salisbury 69 kV (690)	Line	69
Sandy Pond Import	**Lowest Voltage Line Element**		**N/A**
	451 - Radisson-Nicolet-Sandy Pond Hvdc	Line	+/- 450 HVDC
	452 - Radisson-Nicolet-Sandy Pond Hvdc	Line	+/- 450 HVDC
Sandy Pond Export	**Lowest Voltage Element**		N/A
	451 - Sandy Pond - Radisson-Nicolet Hvdc	Line	+/- 450 HVDC
	452 - Sandy Pond - Radisson-Nicolet Hvdc	Line	+/- 450 HVDC
NNC	**Lowest Voltage Line Element**		**138**
	601 - Norwalk Harbor - Northport 138 kV (601)	Line	138
	602 - Norwalk Harbor - Northport 138 kV (602)	Line	138
	603 - Norwalk Harbor - Northport 138 kV (603)	Line	138
CSC	**Lowest Voltage Line Element**		**150**
	481 - Tomson (Shoreham)-Halvarsson +/- 150 kV (481)	Line	150

NPCC/NYISO

Interface Name	Element Name	Interface Type	Voltage (kV)
DYSINGER EAST			
West (Zone A) – Genesee (Zone B)	**Lowest Voltage Line Element**		**115**
	*Somerset-Rochester (Station 80) SR1-39 345	Line	345
	Niagara-Rochester* NR2 345	Line	345
	*Andover - Palmiter 932 115	Line	115
	*Lockport-Batavia 107 115	Line	115
	*Lockport-N. Akron 108 115	Line	115
	*Lockport-Oakfield 112 115	Line	115
	*Lockport-Sweden 1 111 115	Line	115
	*Lockport-Sweden 3 113 115	Line	115
	*Lockport-Telegraph 114 115	Line	115
West (Zone A) – Central (Zone C)	**Lowest Voltage Line Element**		**230**
	*Stolle Road – High Sheldon 67 230	Line	230
WEST CENTRAL			
Genesee (Zone B) – Central (Zone C)	**Lowest Voltage Line Element**		**115**
	Pannell Rd-Clay* PC1 345	Line	345
	Pannell Rd-Clay* PC2 345	Line	345
	*Andover - Palmiter 932 115	Line	115
	*Quaker-Macedon 930 115	Line	115
	*Mortimer-Hook Rd- Elbridge 1/7 115	Line	115
	*Mortimer-Elbridge 2 115	Line	115
	*Pannell-Farmington 4 115	Line	115
	*Quaker-Sleight Rd 13 115	Line	115
	*St. 162 - S. Perry 906 115	Line	115
	Hook Rd (RGE-NGRID) TB#3 34.5/115	Other	34.5/115
	Clyde TR1 34.5/115	Other	34.5/115
	(Farmington 34.5/115kV) #7 34.5/115	Other	34.5/115
	(Farmtn 34.5/115kV&12/115 kV) #4 34.5/115 & 12/115	Other	12/115
West (Zone A) – Central (Zone C)	**Lowest Voltage Line Element**		**230**
	*Stolle Road – High Sheldon 67 230		230
CENTRAL EAST			
Mohawk Valley (Zone E) – Capital (Zone F)	**Lowest Voltage Line Element**		**115**
	Edic-New Scotland* 14 345	Line	345
	Marcy-New Scotland* 18 345	Line	345
	Porter-Rotterdam* 30 230	Line	230
	Porter-Rotterdam* 31 230	Line	230
	East Springfield - Inghams* 942 115	Line	115
	Inghams PAR PAR 115	Line	115
	Inghams Bus Tie R81 115	Line	115
North (Zone D) – ISONE (Zone N)	**Lowest Voltage Line Element**		**115**

Interface Name	Element Name	Interface Type	Voltage (kV)
	*Plattsburgh - Grand Isle PV-20 115	Line	115
TOTAL EAST			
Mohawk Valley (Zone E) – Capital (Zone F)	**Lowest Voltage Line Element**		**115**
	Edic-New Scotland* 14 345	Line	345
	Marcy-New Scotland* 18 345	Line	345
	*Fraser-Gilboa 35 345	Line	345
	Porter-Rotterdam* 30 230	Line	230
	Porter-Rotterdam* 31 230	Line	230
	East Springfield - Inghams* 942 115	Line	115
	Inghams PAR PAR 115	Line	115
	Inghams Bus Tie R81 115	Line	115
Mohawk Valley (Zone E) – Hudson Valley (Zone G)	**Lowest Voltage Line Element**		**345**
	Coopers-Middletown* CCRT-34 345	Line	345
	Coopers-Rock Tavern* CCRT-42 345	Line	345
	West Woodbourne*115/69 T152 115/69	Other	115/69
North (Zone D) – ISONE (Zone N)	**Lowest Voltage Line Element**		**115**
	*Plattsburgh-Grand Isle PV20 115	Line	115
PJM East (Zone P) – Hudson Valley (Zone G)	**Lowest Voltage Line Element**		**345**
	Branchburg-Ramapo* 5018 500	Line	500
	*Waldwick- S.Mahwah J3410 345	Line	345
	*Waldwick-S.Mahwah K3411 345	Line	345
PJM East (Zone P) – NYC (Zone J)	**Lowest Voltage Line Element**		**230**
	Hudson-Farragut* C3403 345	Line	345
	Hudson-Farragut* B3402 345	Line	345
	Linden-Goethals* A2253 230	Line	230
PJM (Rockland Electric) – Hudson Valley (Zone G)	**Lowest Voltage Line Element**		**34.5**
	*Cresskill – Sparkill 751 69	Line	69
	*Harings Corners – W. Nyack 701 69	Line	69
	*Harings Corners – Corporate Drive 703 138	Line	138
	*Montvale – Bluehill 44 69	Line	69
	*Montvale – Bluehill 43 69	Line	69
	*Montvale – Pearl River 491 69	Line	69
	*Harings Corners – Pearl River 45 34	Line	34.5
	*S. Mahwah – Ramapo 51 138	Line	138
	*S. Mahwah - Hilburn 65 69	Line	69
	S. Mahwah 138/345 BK258 138/345	Other	138/345
MOSES SOUTH			
North (Zone D) – Mohawk Valley (Zone E)	**Lowest Voltage Line Element**		**115**
	*Massena-Marcy MSU1 765	Line	765

Interface Name	Element Name	Interface Type	Voltage (kV)
	*Moses-Adirondack MA1 230	Line	230
	*Moses-Adirondack MA2 230	Line	230
	*Dennison-Colton 4 115	Line	115
	*Dennison-Colton 5 115	Line	115
	*Alcoa-N. Ogdensburg 13 115	Line	115
	Malone-Colton* 3 115	Line	115
UPNY-CONED			
Hudson Valley (Zone G) – Millwood (Zone H)	**Lowest Voltage Line Element**		**115**
	*Ladentown-Buchanan South Y88 345	Line	345
	*Pleasant Valley-Wood St. F30 345	Line	345
	*Pleasant Valley-Millwood F31 345	Line	345
	*Pleasant Valley-E. Fishkill F36 345	Line	345
	*Pleasant Valley-E. Fishkill F37 345	Line	345
	*Ramapo-Buchanan North Y94 345	Line	345
	Roseton-E. Fishkill* 305 345	Line	345
	*Fishkill Plains–Sylvan Lake A/990 115	Line	115
	East Fishkill 115/345 115/345	Other	115/345
SPRAIN BROOK-DUNWOODIE SOUTH			
Dunwoodie (Zone I) – NYC (Zone J)	**Lowest Voltage Line Element**		**138**
	*Dunwoodie-Mott Haven 71 345	Line	345
	*Dunwoodie-Mott Haven 72 345	Line	345
	Sprain Brook-Tremont* 28 345	Line	345
	*Sprain Brook-West 49th Street M51 345	Line	345
	*Sprain Brook-West 49th Street M52 345	Line	345
	*Sprain Brook-Academy M29 345	Line	345
	*Dunwoodie-Sherman Creek 99031 138	Line	138
	*Dunwoodie-Sherman Creek 99032 138	Line	138
	*Dunwoodie-East 179th Street 99153 138	Line	138
Long Island (Zone K) – NYC (Zone J)	**Lowest Voltage Line Element**		**138**
	*Lake Success-Jamaica 903 138	Line	138
	*Valley Stream-Jamaica 901L/M 138	Line	138
CONED - LIPA			
Dunwoodie (Zone I) – Long Island (Zone K)	**Lowest Voltage Line Element**		**345**
	*Dunwoodie-Shore Road Y50 345	Line	345
	*Sprain Brook-East Garden City Y49 345	Line	345
NYC (Zone J) – Long Island (Zone K)	**Lowest Voltage Line Element**		**138**
	Jamaica-Valley Stream* 901L/M 138	Line	138
	Jamaica-Lake Success* 903 138	Line	138
NYISO-ISONE			
North (Zone D) – ISONE (Zone N)	**Lowest Voltage Line Element**		**115**
	*Plattsburgh-Grand Isle PV20 115	Line	115
Capital (Zone F) – ISONE	**Lowest Voltage Line Element**		**115**

Interface Name	Element Name	Interface Type	Voltage (kV)
(Zone N)			
	*Alps-Berkshire 393 345	Line	345
	Rotterdam-Bear Swamp* E205W 230	Line	230
	*Hoosick -Bennington K6 115	Line	115
	*Whitehall-Blissville K7 115	Line	115
Hudson Valley (Zone G) – ISONE (Zone N)	**Lowest Voltage Line Element**		**69**
	*Pleasant Valley-Long Mountain 398 345	Line	345
	*Smithfield-Salisbury 690 69	Line	69
IESO (Ontario)-NYISO			
Ontario East (Zone O) – North (Zone D)	**Lowest Voltage Line Element**		**230**
	St. Lawrence-Moses* L33P 240	Line	240
	St. Lawrence-Moses* L34P 230	Line	230
Ontario South (Zone O) – West (Zone A)	**Lowest Voltage Line Element**		**115**
	Beck-Niagara* PA301 345	Line	345
	Beck-Niagara* PA302 345	Line	345
	Beck-Niagara* PA27 230	Line	230
	*Beck-Packard BP76 230	Line	230
	*Beck-Swan Rd. BL104 115	Line	115
PJM-NYISO			
PJM East (Zone P) – NYC (Zone J)	**Lowest Voltage Line Element**		**230**
	Hudson-Farragut* C3403 345	Line	345
	Hudson-Farragut* B3402 345	Line	345
	Linden-Goethals* A2253 230	Line	230
PJM West – Central (Zone C)	**Lowest Voltage Line Element**		**115**
	*Homer City-Watercure 30 345	Line	345
	E. Towanda-Hillside* 70 230	Line	230
	Laurel Lake-Goudey* 952 115	Line	115
	*E. Sayre-N. Waverly 956 115	Line	115
PJM West – West (Zone A)	**Lowest Voltage Line Element**		**115**
	*Homer City-Stolle Rd 37 345	Line	345
	Erie East - South Ripley* 69 230	Line	230
	*Warren-Falconer 171 115	Line	115
PJM East (Zone P) – Hudson Valley (Zone G)	**Lowest Voltage Line Element**		**345**
	Branchburg-Ramapo* 5018 500	Line	500
	*Waldwick-S.Mahwah J3410 345	Line	345
	*Waldwick-S.Mahwah K3411 345	Line	345
PJM (Rockland Electric) – Hudson Valley (Zone G)	**Lowest Voltage Line Element**		**34.5**
	*Cresskill – Sparkill 751 69	Line	69
	*Harings Corners – W. Nyack 701 69	Line	69

Interface Name	Element Name	Interface Type	Voltage (kV)
	*Harings Corners – Corporate Dr. 703 138	Line	138
	*Montvale-Bluehill 44 69	Line	69
	*Montvale-Bluehill 43 69	Line	69
	*Montvale – Pearl River 491 69	Line	69
	*Harings Corners – Pearl River 45 34.5	Line	34.5
	*S. Mahwah – Ramapo 51 138	Line	138
	*S. Mahwah - Hillburn 65 69	Line	69
	S. Mahwah 138/345 BK258 138/345	Other	138/345

RFC/PJM

Interface Name	Element Name	Interface Type	Voltage (kV)
Eastern	**Lowest Voltage Line Element**		**500**
	Wescosville – Alburtis	Line	500
	Juniata – Alburtis	Line	500
	TMI – Hosensack	Line	500
	Peach Bottom – Limerick	Line	500
	Rock Springs – Keeney	Line	500
Central	**Lowest Voltage Line Element**		**500**
	Keystone – Juniata	Line	500
	Conemaugh – Juniata	Line	500
	Conastone – Peach Bottom	Line	500
5004/5005	**Lowest Voltage Line Element**		**500**
	Keystone – Juniata	Line	500
	Conemaugh – Juniata	Line	500
Western	**Lowest Voltage Line Element**		**500**
	Keystone – Juniata	Line	500
	Conemaugh – Juniata	Line	500
	Conemaugh – Hunterstown	Line	500
	Doubs – Brighton	Line	500
Bedington – Black Oak	**Lowest Voltage Line Element**		**500**
	Black Oak – Bedington	Line	500
AP South	**Lowest Voltage Line Element**		**500**
	Mt Storm – Doubs	Line	500
	Greenland Gap – Meadowbrook	Line	500
	Mt Storm – Valley	Line	500
	Mt Storm – Meadowbrook (TrAIL)	Line	500
AEP - Domination	**Lowest Voltage Line Element**		**345**
	Kanawha River – Matt Funk	Line	345
	Wyoming – Jacksons Ferry	Line	765
	Baker – Broadford	Line	765
Cleveland	**Lowest Voltage Line Element**		**138**
	345kV Chamberlin – Harding	Line	345
	Hanna – Juniper	Line	345
	Star – Juniper	Line	345
	Davis Besse	Line	345
	Carlisle – Beaver	Line	345
	Erie West – Ashtabula	Line	345
	Ford – Beaver	Line	138
	Greenfield – Beaver	Line	138
	NASA – Beaver	Line	138
	Camden – Beaver	Line	138
	West Akron – Hickory	Line	138
	West Akron – Brush	Line	138
	Johnson – Beaver	Line	138
	Edgewater – Beaver	Line	138
	Johnson – Lorain	Line	138
	National – Lorain	Line	138

Interface Name	Element Name	Interface Type	Voltage (kV)
MWEX	**Lowest Voltage Line Element**		**69**
	Mauston – Hilltop	Line	69
	Council Creek Bus Tie	Line	69
	Oakdale - Council Creek	Line	69
	Monroe County - Council Creek	Line	69
	Arrowhead 230 kV Phase Shifter	Other	230
	King – Eau Claire 345kV	Line	345
	Arrowhead - Stone Lake 345kV	Line	345

SERC

Interface Name	Element Name	Interface Type	Voltage (kV)
VACAR-SOUTHERN	**Lowest Voltage Line Element**		**115**
	3DBL Branch 115.00 – 3JST-GA 115.00	Line	115
	3Evans 115.00 – 3JST-GA 115.00	Line	115
	3McIntosh 115.00 – 3Jasper T 115.00	Line	115
	6HW Energy 230.00 – 6R_Hartwell 230.00	Line	230
	6Lexington 230.00 – 6Russell 230.00	Line	230
	6Purrysburg 230.00 – 6McIntosh 230.00	Line	230
	6SRS2 230.00 – 6Vogtle +230.00	Line	230
	8Oconee 500.00 – 8S Hall 500.00	Line	500
SOCO-TVA	**Lowest Voltage Line Element**		**115**
	3KetonaTS 115.00 – 3Fultondale 115.00	Line	115
	5Attala5 161.00 – 5Albertville 161.00	Line	161
	5Phil Tap 161.00 – 5Wilson HP 161.00	Line	161
	5R_RockSp 161.00 – 5N GA Ogleth 161.00	Line	161
	5WVernon SS 161.00 – 5Lowndes MS 161.00	Line	161
	6E Dalton 230.00 – 6Rock Spg GA 230.00	Line	230
	6Loopers ITS 230.00 – 6Loopers Frm 230.00	Line	230
	6LoopersKGen 230.00 – 6 Loopers Frm 230.00	Line	230
	8Conasauga 500.00 – 8Bradley TN 500.00	Line	500
	8Miller8 500.00 – 8E Point AL 500.00	Line	500
	8WVern SS 500.00 – 8CoGen Caled 500.00	Line	500
	8WVern SS 500.00 – 8Valleyview 500.00	Line	500
SOCO-AEC	**Lowest Voltage Line Element**		**115**
	3ALTHA PS 115.00 - 3GASKIN 3 115.00	Line	115
	3BAY GAS TAP115.00 - 3CAES 115.00	Line	115
	3BOISE 115.00 - 3LOWMAN3 115.00	Line	115
	3BOISE TP 115.00 - 3LOWMAN3 115.00	Line	115
	3BONIFAY 115.00 - 3BONIFAY_PS 115.00	Line	115
	3CALLAWAY 115.00 - 3GASKIN 3 115.00	Line	115
	3CRSTLBCH 115.00 - 3BLUEWTER 115.00	Line	115
	3CYPRESS 115.00 - 3W GR RDG 115.00	Line	115
	3GEORGE DAM 115.00 - 3CAPPS SW 115.00	Line	115
	3GEORGE DAM 115.00 - 3JUDSN TP 115.00	Line	115
	3MCINOLIN 115.00 - 3CAES 115.00	Line	115
	3MTVERNTS 115.00 - 3CAES 115.00	Line	115
	3NICEVLE 115.00 - 3BLUEWTER 115.00	Line	115
	3PERDIDO 115.00 - 3ATMORE S 115.00	Line	115
	3RAT POND 115.00 - 3W GR RDG 115.00	Line	115
	3RF HENRY 115.00 - 3TRICKEM_JCT115.00	Line	115
	3S ATMORE 115.00 - 3ATMORE S 115.00	Line	115
	3W MCTSH3 115.00 - 3CAES 115.00	Line	115
	3W PT DAM 115.00 - 3ANDREWJT 115.00	Line	115
	6GREENVL6 230.00 - 6BELLVIL 230.00	Line	230
	6N BREW 6 230.00 - 6OPP 230.00	Line	230
	6PINCK 6 230.00 - 6OPP 230.00	Line	230
	6W MCTSH6 230.00 - 6LOWMAN 230.00	Line	230

Interface Name	Element Name	Interface Type	Voltage (kV)
Other	**Lowest Voltage Line Element**		**115**
	DK-SOCO flo Oconee-South Hall 500kV	Line	500
	Hartwell(SEHA)-Anderson(Duke) 230kV Line 1 flo Line 2	Line	230
	DanielSOCO-McKnight	Line	500
	8VOGTLE 500 8WMCINTH 500 1	Line	500
	8WMCINTH 500 6WMCNTH2 230 1	Line	230
	McIntosh-Purrysburg 230kV (flo) McIntosh 230/115 Bank	Other	230/115
	Vogtle(SOCO)-SRS(SCEG) 230kV	Line	230
	Gaston-Roopville 230kV line flo Conasauga-Mosteller Springs 500kV line	Line	230
	Bradley - Conasaga 500	Line	500
	Oglethorpe-RockSpring 161 flo Bradley-Conasaga 500	Line	161
	Miller-E.Point 500 FLO Miller-W.Vernon 500	Line	500
	Miller-W.Vernon 500 FLO Daniel-McKnight 500	Line	500
	Blountville-Guntersville115	Line	115
	Albertville-Attalla 161 flo Bradley-Conasaga 500	Line	161
	PhilCampbell-WilsonHydro 161 FLO Bradley-Conasauga 500	Line	161
	W.Vernon-Lowndes161 FLO Miller-W.Vernon 500	Line	161
	Norcross - South Hall 500kV Line	Line	500
	6VOGTLE 230 6S.R.P. 230 1	Line	230
	3MCINTOS 115 3JASPER 115 1	Line	115
	McIntosh(SOCO)-Purrysburg(Santee) 230kV flo Oconee(Duke)-South Hall(SOCO) 500kV	Line	230
	8HATCH 500 DUVAL 500 1	Line	500
	8THALMAN 500 DUVAL 500 1	Line	500
	6KINGSLAND 230.00 YULEE 230 1	Line	230
	6R_S BAINBRG230.00 SUB 20 230 1	Line	230
	6CALLAWAY 230.00 P ST JOE 230 1	Line	230
	6ERCO 230.00 SUWANNEE 230 1	Line	230
	3FOREST 115 MORTON 3 115 1 (NW Forest (SOCO) - Morton (EES) 115kV)	Line	115
	6HATBG S 230 BOGALUS6 230 1 (Hattiesburg (SOCO) - Angie (LAGN) 230kV)	Line	230
	3COLLINS 115 MAGEE 3 115 1 (Collins (SOCO) - Magee (EES) 115kV)	Line	115
	6LOGTWN 230 FRNBRA 6 230 1 (Logtown West (SOCO) - French Branch (LAGN) 230kV)	Line	230
	8DANIEL 550 MCKNT 8 500 1 (Daniel (SOCO) - Mc Knight (EES) 500kV)	Line	500
	8NORCROS 500 6NORCROS 230 1	Line	230
	8UNIONCITY 500 6UNIONCITY 230 1	Line	230
	8BOWEN 500 6BOWEN 230 1	Line	230
	6FARLEY 230 6S BAINB 230 1	Line	230
	6GASTON 230 6PWSYSDE 230 1	Line	230

Interface Name	Element Name	Interface Type	Voltage (kV)
	6MITCHEL 230 6N TIFTO 230 1	Line	230
	6BOYLESM 230 6MILLER 230	Line	230
	Gaston-Roopville 230kV line flo Farley-Raccoon Creek 500kV line	Line	230
	8KLONDIK 500 6KLONDIK 230	Line	230
	8MILLER 500 6MILLER 230	Line	230
	RockSprings-E.Dalton 230 flo Mosteller-Conasaga 500	Line	230
	RkSprgs-Ft.Oglthrp 161 flo Bwn-Seq and Norcross-Oconee 500kV	Line	161
	Dawson Crossing-Gainsville #1 115kV	Line	115
	SBainbridge-Thomasville 230kV flo Farley-RaccoonCrk 500kV	Line	230
	Lexington-Russell flo Norcross-Oconee & Bio-Hartwell Energy	Line	500
	Logtown-Slidell 230kV flo Daniel-McKnight 500kV	Line	230
	Big Shanty-Bull Sluice 500kV flo Klondike-Norcross 500kV	Line	500
	Hillabee-Danway 230kV flo Hillabee-North Opelika 230kV	Line	230
	Hillabee-North Opelika 230kV flo Hillabee-Danway 230kV	Line	230
	Gaston-PSDF 230kV flo South Bessemer-Billingsley 500kV	Line	230
	Gaston-PSDF 230kV flo Billingsley-Autauga 500kV	Line	230
	PSDF-County Line Road 230kV flo South Bessemer-Billingsley 500kV	Line	230
	PSDF-County Line Road 230kV flo Billingsley-Autauga 500kV	Line	230
	Hardeeville (SCEG)-McIntosh (SAV) 115kV flo Purrysburg (SC)-McIntosh (SAV) 230kV	Line	115
	Hartwell-Hartwell 230kV FLO South Hall-Norcross 500kV	Line	230
	Russell-Lexington 230kV FLO Oconee-South Hall 500kV	Line	230
	Bradley-Consauga 500 FLO S.Hall-Norcross 500	Line	500
	McIntosh(SOCO)-Purrysburg(Santee) 230kV flo Greenwood County-Newberry 230kV	Line	230
	Bogalusa-BarkersCorner 230 kV for the loss of Daniel-McKnight 500 kV	Line	500
	DUVAL 500 8HATCH 500 1	Line	500
	DUK-SOCO	Line	230
	SCEG-SOCO	Line	230
	SC-SOCO	Line	230
	SOCO-LAGN	Line	230
	SOCO-EES	Line	115
	McIntosh- Purysburg 230 FLO Vogtle- Sav River 230	Line	230
	Magee-Collins 115kV ftlo Angie-Hattiesburg 230kV	Line	230

Interface Name	Element Name	Interface Type	Voltage (kV)
	McIntosh (SAV) - Hardeeville (SCEG) 115kV flo McIntosh (SAV) - Purrysburg (SC) 230kV	Line	115
	Magee-Collins 115 (flo) HattiesburgSW-Purvis 230	Line	115
VACAR_IDC	**Lowest Voltage Line Element**		**100**
	Person-Halifax 230 kV line l/o Wake-Carson 500 kV	Line	230
	Person-Halifax 230kV Line l/o Cloverdale-Lexington 500kV Line and Lexington 3 500/230kV Xfmr	Line	230
	Wateree(SCEG)-Sumter(CPLE) 230kV flo Kingstree(Santee)-Kingstree(CPLE) 230kV	Line	230
	Kingstree(Santee)-Kingstree(CPLE) 230kV	Line	230
	Hemmingway(Santee)-Tupperware(CPLE) 115kV flo Kingstree(Santee)-Kingstree(CPLE) 230kV	Line	115
	Oakboro(Duke)-Lilesville(CPLE) 230kV flo Ansonville(CPLE)-Oakboro(Duke) 230kV	Line	230
	Asheville 230/115kV Bank-1 flo Canton-Pisgah 115kV	Line	115
	Asheville 230/115kV Banks 1 and 2 flo Nagel 500/230kV Bank 5	Other	230/115
	Asheville 230/115kV Bank-2 flo Asheville 230/115kV Bank-1	Other	230/115
	Asheville 230/115kV Bank-1 flo Asheville 230/115kV Bank-2	Other	230/115
	Roxboro-Person 230kV line 1 (Middle) flo Roxboro-Person line 3 (Ceffo)230kV	Line	230
	Roxboro-Person 230kV line 1 (Middle) flo Roxboro-Person 230kV line 2 (Hyco)	Line	230
	Raleigh Blueridge-Method 230kV flo Mayo-Durham 500kV	Line	230
	Lilesville- Phase Shifter 1B and 2W 230kV flo Newport-Richmond 500kV	Line	230
	Henderson-Henderson North Tap 115kV flo Person-Halifax 230kV	Line	115
	Henderson-Henderson North Tap 115kV flo Wake-Carson 500kV	Line	115
	Raleigh Blueridge-Method 230kV flo East Durham(Duke)-Durham(CPLE) 230kV	Line	230
	Asheville(CPLW)-Mills Rvr(Duke) 115kV flo Pisgah-Horseshoe Line 1 100kV	Line	115
	Mills Rvr(Duke)-Asheville(CPLW) 115kV flo Asheville 230/115kV Bank-1	Line	115
	Mills Rvr(Duke)-Asheville(CPLW) 115kV flo Asheville 230/115kV Bank-2	Line	115
	Pisgah-Canton 115kV flo Asheville 230/115kV Bank-1	Line	115
	Pisgah-Canton 115kV flo Asheville 230/115kV Bank-2	Line	115
	Rocky Mt-Battleboro 115 kV flo Wake-Carson 500 kV	Line	115
	Nagel(PJM)-Cane River(CPLW) 230kV	Line	230

Interface Name	Element Name	Interface Type	Voltage (kV)
	Antioch-Jacksons Ferry 500kV PJM-DK Tie	Line	500
	Newport(Duke)-Richmond(CPLE) 500kV	Line	500
	DK-SOCO flo Oconee-South Hall 500kV	Line	500
	Harrisburg-Oakboro (Harrisburg) 230kV Lines 1&2	Line	230
	Antioch-Mitchell Rvr (Clingman) 230kV Lines 1&2	Line	230
	Shiloh-Pisgah (Caesar) 230kV Lines 1&2	Line	230
	Oconee 500/230kV Bank-1	Other	500/230
	Hartwell(SEHA)-Anderson(Duke) 230kV Line 1 flo Line 2	Line	230
	McIntosh(SOCO)-Purrysburg(Santee) 230kV flo SRS(SCEG)-Vogtle(SOCO) 230kV	Line	230
	Bluffton-Limehouse Tap 115kV flo Bluffton-Yemassee 230kV	Line	115
	Lyles-Lexngt 115+Lyles+Slvrlk 115	Line	115
	Antioch 500/230kV Bank-1 flo Bank-2	Other	500/230
	Antioch 500/230kV Bank-1 flo Antioch-McGuire (Rock Springs) 500kV	Line	500
	East Durham(Duke)-Durham(CPLE) 230kV flo Blueridge-Method 230kV	Line	230
	Pl Garden-Parkwood (Parkwood) 500kV flo Pl Garden 500/230 Bank-5	Line	500
	East Durham(Duke)-Durham(CPLE) 230kV flo Newport(Duke)-Richmond(CPLE) 500kV	Line	230
	Riverview-Peach Vally (London Creek) 230kV Line 1 flo Line 2	Line	230
	Pl Garden-Parkwood (Parkwood) 500kV flo Newport-Richmond 500kV	Line	500
	Asheville(CPLW)-Pisgah(Duke) 230kV Line 1 flo Line 2	Line	230
	Asheville(CPLW)-Pisgah(Duke) 230kV Lines 1&2 flo Nagel(PJM)-Cane Rvr(CPLW) 230kV	Line	230
	CEC-Edenwood 230kV flo Wateree(SCEG)-Sumter(CPLE) 230kV	Line	230
	Tuckertown-High Rock 100kV flo Pleasant Garden 500/230kV Bank-5	Line	100
	VC Summer(SCEG)-Newport(Duke) 230kV flo Greenwood County-Newberry 230kV	Line	230
	Santeetlah(TVA)-Robbinsville(Duke) 161kV flo Fontana(TVA)-Nantahala(Duke) 161kV	Line	161
	Fontana(TVA)-Nantahala(Duke) 161kV flo Santeetlah(TVA)-Robbinsville(Duke) 161kV	Line	161
	TVA-Duke Interface (Santeetlah(TVA)-Robbinsville(Duke) 161kV and Fontana(TVA)-Nantahala(Duke) 161kV)	Line	161
	Shiloh-Pisgah (Caesar) 230kV Line 1 flo Line 2	Line	230
	Pisgah 115/100kV Bank-10 flo Pisgah 115/100kV Bank-9	Other	115/100
	Oakboro-Lilesville 230kV Lines 1&2 flo Newport-Richmond 500kV	Line	230

Interface Name	Element Name	Interface Type	Voltage (kV)
	Parkwood 500/230kV Bk-6 flo Parkwood 500/230kV Bk-5	Other	500/230
	McGuire-Riverbend (Norman) 230kV Lines 1&2	Line	230
	McGuire-Riverbend (Norman) 230kV Line 1 flo Line 2	Line	230
	N. Greensboro 230/100kV Bank-1 flo Bank-2	Other	230/100
	McIntosh-Purrysburg 230kV (flo) McIntosh 230/115 Bank	Line	230
	VCSummer(SCEG)-Blythewood(Santee) 230kV	Line	230
	Blythewood-Lugoff 230kV	Line	230
	Vogtle(SOCO)-SRS(SCEG) 230kV	Line	230
	McIntosh(SOCO)-Purrysburg(Santee) 230kV flo Broadford-Jacksons Ferry 765kV	Line	230
	McIntosh(SOCO)-Purrysburg(Santee) 230kV flo McIntosh 230/115kV	Line	230
	6VOGTLE 230 6S.R.P. 230 1	Line	230
	3MCINTOS 115 3JASPER 115 1	Line	115
	McIntosh(SOCO)-Purrysburg(Santee) 230kV flo Oconee(Duke)-South Hall(SOCO) 500kV	Line	230
	Person-Halifax 230 kV line	Line	230
	WAKE-CARSON 500	Line	500
	HALIFAX-PERSON 230/CARSON-WAKE 500	Line	500
	KERR-WARRN T 115/HALIFAX-PERSON 230	Line	230
	3Lyles-3Lexngt 115 flo Newberry-Bates 230kV and VCS1-Blythe 230kV	Line	230
	McIntosh(SOCO)-Purrysburg(Santee) 230kV flo Greenwood County-Newberry 230kV	Line	230
	VCS(SCEG)-Blythewood(Santee) 230kV flo Wateree-Sumter 230kV and Newport-Richmond 500kV	Line	230
	J Ferry-Antioch 500kV / Broadford-Sullivan 500 kV	Line	500
	McIntosh- Purysburg 230 FLO Vogtle- Sav River 230	Line	230
	McIntosh (SAV) - Hardeeville (SCEG) 115kV flo McIntosh (SAV) - Purrysburg (SC) 230kV	Line	115
	Richmond line 500 kV flo South Hall 500 kV	Line	500
	Catawba-Allen 230 ckt 1 flo Catawba-Allen 230 ckt 2	Line	230
	Lilesville - Rockingham Bl 230 flo Lilesville - Rockingham Wh 230	Line	230
	North Greenville-Tiger 100 ckt 1 flo North Greenville-Tiger 100 ckt 2	Line	100

SPP RE

Interface Name	Element Name	Interface Type	Voltage (kV)
NODMARSTJMID	**Lowest Voltage Line Element**		**161**
	MARYVILLE – NODWAY	Line	161
	ST JOE – MIDWAY	Line	161
BRKCLAVALPIT	**Lowest Voltage Line Element**		**138**
	BROKEN BOW DAM – CLAYTON	Line	138
	VALLIANT – PITTSBURG	Line	345
CATXFRCATXFR	**Lowest Voltage Line Element**		**N/A**
	CATOOSA - CATOOSA (XF1)	Other	161/138
	CATOOSA - CATOOSA (XF2)	Other	161/138
CRAASHVALLYD	**Lowest Voltage Line Element**		**138**
	CRAIG JCT - ASHDOWN WEST	Line	138
	VALLIANT - LYDIA	Line	345
EASTDC_NO_SO	**Lowest Voltage Line Element**		**345**
	WELSH - EAST DC TIE	Line	345
EASTDC_SO_NO	**Lowest Voltage Element**		**345**
	EAST DC TIE – WELSH	Line	345
ELKXFRTUCOKU	**Lowest Voltage Line Element**		**345**
	ELK CITY - ELK CITY	Other	230/138
	TUCO – OKLAUNION	Line	345
ELPFARWICWDR	**Lowest Voltage Line Element**		**138**
	EL PASO - FARBER	Line	138
	WOODRING – HUNTER	Line	345
KILCREWOOWIC	**Lowest Voltage Line Element**		**138**
	KILDARE – CRESWELL	Line	138
	WOODRING - WICHITA	Line	345
LACNEOLANWIC	**Lowest Voltage Line Element**		**345**
	LACYGNE – NEOSHO	Line	345
	LANG – WICHITA	Line	345
MANIPMDOLSWS	**Lowest Voltage Line Element**		**138**
	MANSFIELD - INT. PAPER	Line	138
	DOLET HILLS - S.W. SHREVEPORT	Line	345
NORDC_NO_SO	**Lowest Voltage Line Element**		**345**
	OKLAUNION - NORTH DC TIE	Line	345
NORDC_SO_NO	**Lowest Voltage Line Element**		**345**
	NORTH DC TIE – OKLAUNION	Line	345
NWTPATLYDVAL	**Lowest Voltage Line Element**		**138**
	N. W. TEXARKANA - PATTERSON	Line	138
	LYDIA – VALLIANT	Line	345
SJHALKNAIASC	**Lowest Voltage Line Element**		**161**
	ST JOE – HAWTHORN	Line	345
	LAKE RD. - NASHUA	Line	161
	IATAN - STRANGER CREEK	Line	345
SWSANASWSFTC	**Lowest Voltage Line Element**		**138**
	SOUTHWESTERN STA - ANADARKO	Line	138
	SOUTHWESTERN STA. - FT COBB NAT GAS	Line	138
NESONENESTUL	**Lowest Voltage Line Element**		**345**

Interface Name	Element Name	Interface Type	Voltage (kV)
	NORTHEASTERN STA. – ONETA	Line	345
	NORTHEASTERN STA. - TULSA NORTH	Line	345
WELFIXMUSPIT	**Lowest Voltage Line Element**		**138**
	WELEETKA - FIXICO TAP	Line	138
	MUSKOGEE - PITTSBURG	Line	345
BVSNBVNESDEL	**Lowest Voltage Line Element**		**138**
	BARTLESVILLE SE - N. BARTLESVILLE	Line	138
	NORTHEASTERN (N.E.S.) - DELAWARE	Line	345
CREKILWICWOO	**Lowest Voltage Line Element**		**138**
	CRESWELL - NEWKIRK / KILDARE	Line	138
	WOODRING – HUNTER	Line	345
SWSFTCOKUTUC	**Lowest Voltage Line Element**		**138**
	SOUTHWESTERN STA - FT COBB NAT GAS	Line	138
	OKLAUNION - TUCO	Line	345
DOLXFRELDXFR	**Lowest Voltage Line Element**		**N/A**
	DOLET HILLS - DOLET HILLS	Other	345/230
	ELDORADO - ELDORADO	Other	345/500
MIDFRNPHAWET	**Lowest Voltage Line Element**		**138**
	MIDWEST - FRANKLIN SWITCH	Line	138
	PHAROAH – WETUMKA	Line	138
PITSEMPITSUN	**Lowest Voltage Line Element**		**345**
	PITTSBURG – SEMINOLE	Line	345
	PITTSBURG - SUNNYSIDE	Line	345
SEMXFRSEMXFR	**Lowest Voltage Line Element**		**N/A**
	SEMINOLE - SEMINOLE (SEMINOL7 345)	Other	345/138
	SEMINOLE - SEMINOLE (SEMINOL4 138)	Other	345/138
WELFIXRIVRED	**Lowest Voltage Line Element**		**138**
	WELEETKA - FIXICO TAP	Line	138
	RIVERSIDE – REDBUD	Line	345
SPSNORTH_STH	**Lowest Voltage Line Element**		**115**
	BUSHLAND - DEAF SMITH	Line	230
	POTTER COUNTY - PLANT X	Line	230
	OSAGE SWITCH - CANYON	Line	115
	RANDALL COUNTY - PALODUR	Line	115
	AMARILLO SOUTH - SWISHER	Line	230
SILDIVNWSCIM	**Lowest Voltage Line Element**		**138**
	SILVERLAKE - DIVISION	Line	138
	NORTHWEST STATION - CIMARON	Line	345
VALHUGVALLYD	**Lowest Voltage Line Element**		**138**
	VALLIANT - HUGO-TAP / IDABEL	Line	138
	VALLIANT - LYDIA	Line	345
HPPVALPITVAL	**Lowest Voltage Line Element**		**138**
	HUGOPP4 - VALLIANT	Line	138
	PITTSBURG - VALLIANT	Line	345
REDARCREDARC	**Lowest Voltage Line Element**		**345**
	REDBUD - ARCADIA (REDBUD 7 345)	Line	345
	REDBUD - ARCADIA (ARCADIA7 345)	Line	345
LONSARPITVAL	**Lowest Voltage Line Element**		**138**

Interface Name	Element Name	Interface Type	Voltage (kV)
	LONE_OAK – SARDIS	Line	138
	PITTSBURG - VALLIANT	Line	345
SABSEMPIRDIA	**Lowest Voltage Line Element**		**138**
	SABINE MINING - SOUTHEAST MARSHALL	Line	138
	PIRKEY – DIANA	Line	345
WDRCIMSPRNRW	**Lowest Voltage Line Element**		**345**
	WOODRING - CIMARRON	Line	345
	ONEOK/SPRING CREEK - NORTHWEST STATION	Line	345
VALLYDELDLON	**Lowest Voltage Line Element**		**345**
	VALLIANT - LYDIA	Line	345
	SAREPTA - LONGWOOD	Line	345
MORSTISPRNOR	**Lowest Voltage Line Element**		**138**
	MORRISON TAP - STILLWATER	Line	138
	SPRINGCREEK/ONEOK - NORTHWEST	Line	345
ELDLONVALLYD	**Lowest Voltage Line Element**		**345**
	SAREPTA - LONGWOOD	Line	345
	VALLIANT - LYDIA	Line	345
BEAEURMONBRK	**Lowest Voltage Line Element**		**161**
	BEAVER - EUREKA SPRING	Line	161
	FLINTCREEK - BROOKLINE	Line	345
STIREDSTIPEC	**Lowest Voltage Line Element**		**161**
	STILWELL – REDEL	Line	161
	STILWELL - PECULIAR (GRAND OAKS)	Line	345
VALIANTLYDIA	**Lowest Voltage Line Element**		**345**
	VALIANT - LYDIA	Line	345
REDWILLMINGO	**Lowest Voltage Line Element**		**345**
	RED WILLOW - MINGO	Line	345
TAHH59MUSFTS	**Lowest Voltage Line Element**		**161**
	TAHLEQUAH - HIGHWAY 59	Line	161
	MUSKOGEE - FORT SMITH	Line	345
IASCLKNASJHA	**Lowest Voltage Line Element**		**161**
	IATAN - STRANGER CREEK	Line	345
	LAKE RD. - NASHUA	Line	161
	ST JOE – HAWTHORN	Line	345
LLAMAYNESONE	**Lowest Voltage Line Element**		**138**
	LYNN_LAN EAST TAP - MAYO ROAD	Line	138
	NORTHEASTERN (N.E.S.) - ONETA	Line	345
RSSOKMRSSEXP	**Lowest Voltage Line Element**		**138**
	RIVERSIDE STA. - OKMULGEE CITY	Line	138
	RIVERSIDE STA. - EXPLORER OKMULGEE	Line	138
ONEBANNESTUL	**Lowest Voltage Line Element**		**138**
	ONETA - Broken Arrow North	Line	138
	NORTHEASTERN STA. - TULSA NORTH	Line	345
OKMHENOKMKEL	**Lowest Voltage Line Element**		**138**
	OKMULGEE - HENRYETTA	Line	138
	OKMULGEE – KELCO	Line	138
ARCKAMARCNOR	**Lowest Voltage Line Element**		**138**
	ARCADIA - JONES KAMO	Line	138

Interface Name	Element Name	Interface Type	Voltage (kV)
	ARCADIA - NORTH WEST STATION	Line	345
SPPSPSTIES	**Lowest Voltage Line Element**		**115**
	OKLAUNION - TUCO	Line	345
	ELK CITY - GRAPEVINE	Line	230
	FINNEY – HITCHLAND	Line	345
	SHAMROCK - MCCLEAN	Line	115
	LIBERAL - TEXAS CO	Line	115
	JERICHO – KIRBY	Line	115
SPSSPPTIES	**Lowest Voltage Line Element**		**115**
	TUCO – OKLAUNION	Line	345
	GRAPEVINE - ELK CITY	Line	230
	HITCHLAND - FINNEY	Line	345
	MCCLEAN - SHAMROCK	Line	115
	TEXAS CO - LIBERAL	Line	115
	KIRBY – JERICHO	Line	115
FLCXFRFLCXFR	**Lowest Voltage Line Element**		**N/A**
	FLINTCREEK - FLINTCREEK	Other	345/161
SHAXFRELKXFR	**Lowest Voltage Line Element**		**N/A**
	SHAMROCK - SHAMROCK	Other	115/69
	ELK-CITY - ELK-CITY	Other	230/138
PITVALELDLON	**Lowest Voltage Line Element**		**345**
	PITTSBURG - VALIANT	Line	345
	SAREPTA - LONGWOOD	Line	345
COCCOUCOCVIL	**Lowest Voltage Line Element**		**230**
	COCODRIE - COUGHLIN	Other	230/138
	COCODRIE - VIL PLATTE	Line	230
FRSLMCFRWERC	**Lowest Voltage Line Element**		**230**
	FRONT STREET - SLIDELL	Line	230
	MC KNIGHT - FRANKLIN	Line	500
RUSDARANOFTS	**Lowest Voltage Line Element**		**161**
	RUSSELLVILLE - DARDANELLE	Line	161
	ARKANSAS NUCLEAR ONE - FT. SMITH	Line	500
VALXFRVALXFR	**Lowest Voltage Line Element**		**N/A**
	VALLIANT – VALLIANT	Other	345/138
POWLINSHVWES	**Lowest Voltage Line Element**		**138**
	POWELL – LINWOOD	Line	138
	SW SHREVEPORT - WESTERN ELECTRIC	Line	138
WELLYDWELNWT	**Lowest Voltage Line Element**		**345**
	WELSH - LYDIA	Line	345
	WELSH - NW TEXARKANA	Line	345
CEDCANMIDFRA	**Lowest Voltage Line Element**		**138**
	CEDAR LANE - CANADIAN	Line	138
	MIDWEST – FRANKLIN	Line	138
CIMHAYCIMCZE	**Lowest Voltage Line Element**		**138**
	CIMMARON - HAYMAKER	Line	138
	CIMMARON - CZECH HALL	Line	138
MORSUMJECSUM	**Lowest Voltage Line Element**		**230**
	MORRIS – SUMMIT	Line	230

Interface Name	Element Name	Interface Type	Voltage (kV)
	JEFFREY – SUMMIT	Line	345
PRABLURSSEXG	**Lowest Voltage Line Element**		**138**
	PRATTVILLE - BLUEBELL	Line	138
	RIVERSIDE - EXPLORER GLENPOOL	Line	138
SHAXFRTUCOKU	**Lowest Voltage Line Element**		**345**
	SHAMROCK - SHAMROCK	Other	115/69
	TUCO – OKLAUNION	Line	345
EROAVOFLIMON	**Lowest Voltage Line Element**		**161**
	E Rogers – AVOCA	Line	161
	FLINTCREEK – MONET	Line	345
CARHOBOKUTUC	**Lowest Voltage Line Element**		**138**
	CARNEGIE - HOBART JUNCTION	Line	138
	OKLAUNION - TUCO	Line	345
LONSARVALHUG	**Lowest Voltage Line Element**		**138**
	Lonoak - SARDIS	Line	138
	Valliant - HUGO-TAP / IDABEL	Line	138
NESTULNESONE	**Lowest Voltage Line Element**		**345**
	Northeast Station - TULSA NORTH	Line	345
	Northeast Station - ONETA	Line	345
NPLSTOGTLRED	**Lowest Voltage Line Element**		**115**
	NORTH PLATE - STOCKVILLE	Line	115
	GENTLEMAN - RED WILLOW	Line	345
SPPSPSTIEJ07	**Lowest Voltage Line Element**		**115**
	OKLAUNION - TUCO	Line	345
	ELK CITY – GRAPEVINE	Line	230
	SHAMROCK - MCCLEAN	Line	115
	LIBERAL - TEXAS CO	Line	115
	JERICHO – KIRBY	Line	115
RANPALAMASWI	**Lowest Voltage Line Element**		**115**
	PALO DURO - RANDALL	Line	115
	AMARILLO – SWISHER	Line	230
WDRWAUWDRFRE	**Lowest Voltage Line Element**		**138**
	WOODRING - WAUKO TAP	Line	138
	WOODRING - FERMAN TAP	Line	138
ANACORSWSNOR	**Lowest Voltage Line Element**		**138**
	ANADARKO - CORN TAP	Line	138
	SOUTHWESTERN STATION - NORGE	Line	138
BRKXF1BRKXF2	**Lowest Voltage Line Element**		**N/A**
	BROOKLINE – XFR	Other	345/161
MEDXFRREDMIN	**Lowest Voltage Line Element**		**345**
	MED-LD1 – XFR	Other	138/115
	REDWLO1 - MINGO1	Line	345
OSGCANBUSDEA	**Lowest Voltage Line Element**		**115**
	OSAGE – CANYON	Line	115
	BUSHLAND - DEAFSMITH	Line	230
MARXFRALTTIO	**Lowest Voltage Line Element**		**138**
	MARM – XFR	Other	161/69
	ALTO – TIOG	Line	138

Interface Name	Element Name	Interface Type	Voltage (kV)
NEORIVNEOMOR	**Lowest Voltage Line Element**		**161**
	NEOSHO - COLUMBUS	Line	161
	BLACKBERRY - JASPER	Line	345
IPMWALDOLSWS	**Lowest Voltage Line Element**		**138**
	IPMANS – WALLACE	Line	138
	DOLET - SW SHREVEPORT	Line	345
NEORIVNEODEL	**Lowest Voltage Line Element**		**161**
	NEOSHO - COLUMBUS	Line	161
	NEOSHO - DELAWARE	Line	345
LAKALAIATPLT	**Lowest Voltage Line Element**		**161**
	LAKE RD. – ALABAMA	Line	161
	IATAN - PLATE CITY	Line	161
PLTSMTIATSTR	**Lowest Voltage Line Element**		**161**
	PLATE CITY – IATAN	Line	161
	SMITHVILLE - STRANGER CREEK	Line	345
PLTSMTIATSTJ	**Lowest Voltage Line Element**		**161**
	PLATE CITY – IATAN	Line	161
	SMITHVILLE - ST JOE	Line	345
PLTSMTSTRCRA	**Lowest Voltage Line Element**		**161**
	PLATE CITY - STRANGER CREEK	Line	161
	STRANGER CREEK - 87TH STREET	Line	345
LAKALASTJHAW	**Lowest Voltage Line Element**		**161**
	LAKE RD. – ALABAMA	Line	161
	ST JOE – HAWTHORN	Line	345
WASXFRANAXFR	**Lowest Voltage Line Element**		**N/A**
	WASHITA – XFR	Other	138/69
	ANADARKO – XFR	Other	138/69
HOLPLYBUCSPE	**Lowest Voltage Line Element**		**115**
	HOLCOMB – PLYMEL	Line	115
	BUCKNER TAP - SPEARVILLE	Line	345
KSGHALWICREN	**Lowest Voltage Line Element**		**138**
	KSG – HALSTEAD	Line	138
	WICHITA – RENO	Line	345
CIRKNGIATSTJ	**Lowest Voltage Line Element**		**115**
	CIRCLEVILLE - KING HILL	Line	115
	IATAN - ST JOE	Line	345
DYEROGTONLOW	**Lowest Voltage Line Element**		**161**
	Dyess - E. Rogers	Line	161
	Tonitown – Lowell	Line	161
VERAMCNESOWA	**Lowest Voltage Line Element**		**138**
	NE_GAS – CLARTOK	Line	138
	Northeast – Owasso	Line	161
SPPSPSTIESWE	**Lowest Voltage Line Element**		**115**
	OKLAUNION - TUCO	Line	345
	HITCHLAND - POTTER COUNTY	Line	345
	SHAMROCK - MCLEAN	Line	115
	E LIBERAL - TEXAS CO	Line	115
	JERICHO – KIRBY	Line	115

Interface Name	Element Name	Interface Type	Voltage (kV)
IATXFRIATSTR	**Lowest Voltage Line Element**		**345**
	IATAN – XFR	Other	345/161
	IATAN - STRANGER CREEK	Line	345
STJOE_INT	**Lowest Voltage Line Element**		**161**
	ST JOE – COOK	Line	161
	ST JOE – WOODBIN	Line	161
	NASHUA – ALABAMA	Line	161
KELLY_INT	**Lowest Voltage Line Element**		**115**
	WALDO - SMITH CENTER	Line	115
	PLAINVILLE - PHILLIPBURG	Line	115
	KELLY - S SENECA	Line	115
	ELM CREEK - CONCORDIA	Line	230
ARCXFRARCNOW	**Lowest Voltage Line Element**		**345**
	ARCADIA – ARCADIA	Other	345/138
	ARCADIA - NORTHWESTERN	Line	345
PLAKCISTRCRA	**Lowest Voltage Line Element**		**161**
	PLATT CITY – KCI	Line	161
	STRANGER CREEK - 87TH STREET	Line	345
STRCRASTJHAW	**Lowest Voltage Element**		**345**
	STRANGER CREEK - 87TH STREET	Line	345
	ST. JOE – HAWTHORN	Line	345
SSHWALDOLXFR	**Lowest Voltage Line Element**		**138**
	SSHREVE - WALLACG1565	Line	138
	DOLET – DOLET	Other	345/230
BRKXF2BRKXF1	**Lowest Voltage Line Element**		**N/A**
	BROOKLINE - BROOKLINE	Other	345/161
MEDSAWSPEMUL	**Lowest Voltage Line Element**		**115**
	MEDICINE LODG - SAWYER	Line	115
	SPEARVILLE - MULLERGREN	Line	230
AFTXFRAFTMIA	**Lowest Voltage Line Element**		**161**
	AFTON – AFTON	Other	161/69
	AFTON – MIAMI	Line	161
SHAHAYKNOXFR	**Lowest Voltage Line Element**		**115**
	SOUTH HAYS – HAYS	Line	115
	KNOLL – KNOLL	Other	230/115
PENMUNSTRCRA	**Lowest Voltage Line Element**		**115**
	PENTAGON – MUND	Line	115
	STRANGER CREEK - 87TH STREET	Line	345
NINSTJCLEGIL	**Lowest Voltage Line Element**		**115**
	NINESC - ST JOHN	Line	115
	CLEARWATER – GILL	Line	138
WDWFPLWDWTAT	**Lowest Voltage Line Element**		**138**
	WOODWARD - FPL SWITCH	Line	138
	WOODWARD EHV - TATONGA	Line	345
LYDVALVALPIT	**Lowest Voltage Line Element**		**345**
	LYDIA – VALLIANT	Line	345
	VALLIANT - PITTSBURB	Line	345
PITVALVALLYD	**Lowest Voltage Line Element**		**345**

Interface Name	Element Name	Interface Type	Voltage (kV)
	PITTSBURG - VALLIANT	Line	345
	VALLIANT - LYDIA	Line	345
NEGWATNEGRIC	**Lowest Voltage Line Element**		**138**
	NE_GAS – WATOVA	Line	138
	NE_GAS - RICE_C_A	Line	138
ONEBANCLKCHA	**Lowest Voltage Line Element**		**138**
	ONETA - BA_NORTH	Line	138
	CLARKSVILLE - CHAMBERS	Line	345
TUTCORGRALAW	**Lowest Voltage Line Element**		**138**
	TUTTLE – CORNVILLE	Line	138
	GRACEMONT - LAWSON EASTS	Line	345
ELPAFARB	**Lowest Voltage Line Element**		**138**
	EL PASO - FARBER	Line	138
MINXFRMINSET	**Lowest Voltage Line Element**		**345**
	MINGO – MINGO	Other	345/115
	MINGO – SETAB	Line	345
OKMKELRIVRED	**Lowest Voltage Line Element**		**138**
	OKMULGEE – KELCO	Line	138
	RIVERSIDE – REDBUD	Line	345
LYDIAVALIANT	**Lowest Voltage Line Element**		**345**
	LYDIA – VALLIANT	Line	345
POTXFRHITXFR	**Lowest Voltage Line Element**		**N/A**
	POTTER COUNTY - POTTER COUNTY	Other	345/230
	HITCHLAND - HITCHLAND	Other	345/230
GRAXFRGRANIC	**Lowest Voltage Line Element**		**230**
	GRAPEVINE - GRAPEVINE	Other	230/115
	GRAPEVINE - NICHOLS	Line	230
ELKXFRSWEWHE	**Lowest Voltage Line Element**		**230**
	ELK-CITY - ELK-CITY	Other	230/138
	SWEETWATER - WHEELER	Line	230
GRAXFRSWEELK	**Lowest Voltage Line Element**		**230**
	GRAPEVINE - GRAPEVINE	Other	230/115
	SWEETWATER - ELK CITY	Line	230
DOLXFRLONSAR	**Lowest Voltage Line Element**		**345**
	DOLET HILLS - DOLET HILLS	Other	345/230
	LONGWOOD - SAREPATA	Line	345
ASHCRALYDVAL	**Lowest Voltage Line Element**		**138**
	ASHDOWN WEST - CRAIG JUNCTION	Line	138
	LYDIA – VALLIANT	Line	345
FULPATLONSAR	**Lowest Voltage Line Element**		**115**
	FULTON – PATMOS	Line	115
	LONGWOOD - SAREPATA	Line	345
PENAFTGRDTON	**Lowest Voltage Line Element**		**161**
	PENSACOLA – AFTON	Line	161
	GRDA – TONECCE	Line	345
PENAFTNEOXFR	**Lowest Voltage Line Element**		**161**
	PENSACOLA – AFTON	Line	161
	NEOSHO - NEOSHO	Other	345/161

Interface Name	Element Name	Interface Type	Voltage (kV)
FIVTRBPECAGE	**Lowest Voltage Line Element**		**161**
	FIVE TRIBES - HANCOCK	Line	161
	PECAN CREEK - AGENCY	Line	161
FIVTRBAGEEUC	**Lowest Voltage Line Element**		**161**
	FIVE TRIBES - HANCOCK	Line	161
	AGENCY – EUCLID	Line	161
WOOFAIWOOWAU	**Lowest Voltage Line Element**		**138**
	WOODRING - FAIRMONT TAP	Line	138
	WOODRING - WAUKOMOS TAP	Line	138
CRTCRPSPEJUD	**Lowest Voltage Line Element**		**115**
	CIMMARON RIVER TAP - CIMMARON RIVER PLANT	Line	115
	SPEARVILLE - JUDSON LARGE	Line	115
FLAHARMEDXFR	**Lowest Voltage Line Element**		**138**
	FLATRIDGE – HARPER	Line	138
	MEDICINE LODGE - MEDICINE LODGE	Other	138/115
HOLFLEHOLPLY	**Lowest Voltage Line Element**		**115**
	HOLCOMB - FLETCHER	Line	115
	HOLCOMB – PLYMELL	Line	115
PIOSATSPEXFR	**Lowest Voltage Line Element**		**115**
	PIONEER TAP - SATANTA TAP	Line	115
	SPEARVILLE - SPEARVILLE	Other	230/115
SPEJUDHOLPLY	**Lowest Voltage Line Element**		**115**
	SPEARVILLE - JUDSON LARGE	Line	115
	HOLCOMB – PLYMELL	Line	115
CALNORANOFTS	**Lowest Voltage Line Element**		**161**
	CALICO ROCK - NORFORK	Line	161
	ARKANSAS NUCLEAR ONE - FT. SMITH	Line	500
CALNORHOLIND	**Lowest Voltage Line Element**		**161**
	CALICO ROCK - NORFORK	Line	161
	HOLLAND BOTTOM - INDEPENDENCE	Line	500
CALNORINDDEL	**Lowest Voltage Line Element**		**161**
	CALICO ROCK - NORFORK	Line	161
	INDEPENDENCE - DELL	Line	500
EDYXFREDYSEV	**Lowest Voltage Line Element**		**230**
	EDDY COUNTY - EDDY COUNTY	Other	230/115
	EDDY COUNTY - SEVEN RIVERS	Line	230
EDYXFRSEVXFR	**Lowest Voltage Line Element**		**N/A**
	EDDY COUNTY - EDDY COUNTY	Other	230/115
	SEVEN RIVERS - SEVEN RIVERS	Other	230/115
HOBXFRHOBLEA	**Lowest Voltage Line Element**		**230**
	HOBBS – HOBBS	Other	230/115
	HOBBS - LEA COUNTY	Line	230
TUCJONTUCCAR	**Lowest Voltage Line Element**		**230**
	TUCO - JONES	Line	230
	TUCO – CARLISLE	Line	230
SPRCLAHUBMOR	**Lowest Voltage Line Element**		**161**
	SPRINGFIELD – CLAY	Line	161
	HUBEN – MORGAN	Line	345

Interface Name	Element Name	Interface Type	Voltage (kV)
CIRHUTRENDAV	**Lowest Voltage Line Element**		**115**
	CIRCLE - HUTCHINSON ENERGY CENTER	Line	115
	RENO – DAVIS	Line	115
CIRKINTECXFR	**Lowest Voltage Line Element**		**115**
	CIRCLEVILLE - KING HILL	Line	115
	TECUMSEH HILL - TECUMSEH HILL	Other	230/115
CIRKINHOYSTR	**Lowest Voltage Line Element**		**115**
	CIRCLEVILLE - KING HILL	Line	115
	HOYT - STRANGER CREEK	Line	345
FTJWJCFTJJCT	**Lowest Voltage Line Element**		**115**
	FORT JUNCTION - WEST JUNCTION CITY CKT 2	Line	115
	FORT JUNCTION - JUNCTION CITY CKT 1	Line	115
HECHUNREDMIN	**Lowest Voltage Line Element**		**115**
	HUTCHINSON ENERGY CENTER - HUNTSVILLE	Line	115
	RED WILLOW - MINGO	Line	345
HECHUNMULGRE	**Lowest Voltage Line Element**		**115**
	HUTCHINSON ENERGY CENTER - HUNTSVILLE	Line	115
	MULLERGREN - GREAT BEND TAP	Line	115
NEORIVASBLIT	**Lowest Voltage Line Element**		**161**
	NEOSHO – RIVERTON	Line	161
	ASBURY – LITCHFIELD	Line	161
TECTECHOYSTR	**Lowest Voltage Line Element**		**115**
	TECUMSEH ENERGY CENTER - TECUMSEH HILL	Line	115
	HOYT - STRANGER CREEK	Line	345
CROLATTENLEB	**Lowest Voltage Line Element**		**138**
	CROCKET – LATEXO	Line	138
	LEBROCK - TENASKA SWITCH	Line	345
BONXFRBONACA	**Lowest Voltage Line Element**		**230**
	BONIN CKT 1 - BONIN CKT 1	Other	230/138
	BONIN CKT 1 - ACADIANA	Line	230
BONXFRACAFLA	**Lowest Voltage Line Element**		**230**
	BONIN CKT 1 – BONIN	Other	230/138
	ACADIANA - FLANDERS	Line	230
BONXFR	**Lowest Voltage Line Element**		**N/A**
	BONIN CKT 1 - BONIN CKT 1	Other	230/138
TURMARSTIRED	**Lowest Voltage Line Element**		**161**
	TURNER - HONEYWELL	Line	161
	STILLWELL – REDEL	Line	161
MEDXFRSPEJUD	**Lowest Voltage Line Element**		**N/A**
	MEDICINE LODGE - MEDICINE LODGE	Other	138/115
	SPEARVILLE - NORTH FORT DODGE	Other	138/115
TUCXFRHOLFIN	**Lowest Voltage Line Element**		**345**
	TUCO - TUCO	Other	345/230
	HOLCOMB – FINNEY	Line	345
MEDXFRSPEMUL	**Lowest Voltage Line Element**		**230**
	MEDICINE LODGE - MEDICINE LODGE	Other	115/138
	SPEARVILLE - MULLERGREN	Line	230
IATSTRIATSTJ	**Lowest Voltage Line Element**		**345**

Interface Name	Element Name	Interface Type	Voltage (kV)
	IATAN - STRANGER CREEK	Line	345
	IATAN - ST JOE	Line	345
DYEROGFLTGEN	**Lowest Voltage Line Element**		**161**
	DYESS - EAST ROGERS	Line	161
	FLINTCREEK – GENTRY	Line	161
NORBATGAVBLM	**Lowest Voltage Line Element**		**115**
	NORTH NORFOLK - BATTLECREEK	Line	115
	GAVINS - BLOOMFIELD	Line	115
NORBATCOLGEN	**Lowest Voltage Line Element**		**115**
	NORTH NORFOLK - BATTLECREEK	Line	115
	COLUMBUS – GENOA	Line	115
GGS	**Lowest Voltage Line Element**		**230**
	GENTLMAN - N.PLATTE	Line	230
	GENTLMAN - SWEETWATER	Line	345
	GENTLMAN - RED WILLOW	Line	345
GENTLMREDWIL	**Lowest Voltage Line Element**		**345**
	GENTLEMAN - RED WILLOW	Line	345
GRIS_LNC	**Lowest Voltage Line Element**		**230**
	PAULINE - MOORE (SHELDON)	Line	345
	GRAND ISLAND - COLUMBUS W.	Line	230
	GRAND ISLAND - MCCOOL	Line	345
COOPER_S	**Lowest Voltage Line Element**		**345**
	COOPER - ST. JOE	Line	345
	COOPER - FAIRPORT	Line	345
FTCAL_S	**Lowest Voltage Line Element**		**345**
	FT. CALHOUN - SUB 3459	Line	345
	FT. CALHOUN - SUB 3454	Line	345
	SUB 1251 - SUB 1297	Line	345
NEBCTYCOOPER	**Lowest Voltage Line Element**		**345**
	COOPER - NEBRASKA CITY	Line	345
RAUN_TEKAMAH	**Lowest Voltage Line Element**		**161**
	RAUN – TEKAMAH	Line	161
STJOE_MIDWAY	**Lowest Voltage Line Element**		**161**
	ST. JOE – MIDWAY	Line	161
IATAN_STJOE	**Lowest Voltage Line Element**		**345**
	IATAN - ST.JOE	Line	345
NPLATSTOCKVL	**Lowest Voltage Line Element**		**115**
	NORTH PLATE - STOCKVILLE	Line	115
SUBTEKRAUNEA	**Lowest Voltage Line Element**		**161**
	SUB 1226 – TEKAMHO	Line	161
SUBTEKFTCRAU	**Lowest Voltage Line Element**		**161**
	SUB 1226 – TEKAMHO	Line	161
	FORT CALHOUN - RAUN	Line	345
MEDILODGEXFR	**Lowest Voltage Line Element**		**N/A**
	MEDICINE LODGE - MEDICINE LODGE	Other	115/138
LAKALAIATSTR	**Lowest Voltage Line Element**		**161**
	LAKE RD. – ALABAMA	Line	161
	IATAN - STRANGER CREEK	Line	345

Interface Name	Element Name	Interface Type	Voltage (kV)
TEKRAUCOONEB	**Lowest Voltage Line Element**		**161**
	TEKAMAH – RAUN	Line	161
	FORT CALHOUN - RAUN	Line	345
FTCAL_RAUN	**Lowest Voltage Line Element**		**345**
	FORT CALHOUN - RAUN	Line	345
STMDSJFASJCO	**Lowest Voltage Line Element**		**161**
	ST. JOE – MIDWAY	Line	161
	ST. JOE – FAIRPORT	Line	345
	FAIRPORT – COOPER	Line	345
GRISLDMCCOOL	**Lowest Voltage Line Element**		**345**
	GRAND ISLAND - MCCOOL	Line	345
PAULINMMOORE	**Lowest Voltage Line Element**		**345**
	PAULINE - MARK T MOORE	Line	345
BLKW_W_E	**Lowest Voltage Line Element**		**N/A**
	BLACKWATER DC TIE WEST - BLACKWATER DC TIE EAST	Other	DC
EDDYCO_W_E	**Lowest Voltage Line Element**		**N/A**
	EDDY COUNTY DC TIE WEST - EDDY COUNTY DC TIE EAST	Other	DC
MARCLRMARCRE	**Lowest Voltage Line Element**		**161**
	MARYVILLE - CLARINDA	Line	161
	MARYVILLE - CRESTON	Line	161
LAMAR_W_E	**Lowest Voltage Line Element**		**N/A**
	LAMAR DC TIE WEST - LAMAR DC TIE EAST	Other	DC
LAMAR_E_W	**Lowest Voltage Line Element**		**N/A**
	LAMAR DC TIE EAST - LAMAR DC TIE WEST	Other	DC
EDDYCO_E_W	**Lowest Voltage Line Element**		**N/A**
	EDDY COUNTY DC TIE EAST - EDDY COUNTY DC TIE WEST	Other	DC
BLKW_E_W	**Lowest Voltage Line Element**		**N/A**
	BLACKWATER DC TIE EAST - BLACKWATER DC TIE WEST	Other	DC

TRE/ERCOT

Interface Name	Element Name	Interface Type	Voltage (kV)
North to Houston IROL (GTL) Monitored Elements	**Lowest Voltage Line Element**		**345**
	Singleton-Tomball 345kV	Line	345
	Singleton-Zenith 345kV	Line	345
	Singleton-Zenith 345kV	Line	345
	Roans Prairie-Kuykendahl 345kV	Line	345
West-North IROL (GTL) Monitored Elements	**Lowest Voltage Line Element**		**345**
	Tonkawa Switch-Graham SES 345kV	Line	345
	Long Creek-Graham SES 345kV	Line	345
	Cook Field Road Switch-Graham SES 345kV	Line	345
	Garvey Road Switch-Graham SES 345kV	Line	345
	Bowman Switch-Jacksboro Switch 345kV	Line	345
	Brown Switch-Comanche Switch 345kV	Line	345
	Brown Switch-Killeen Switch 345kV	Line	345
	Brown Switch-Killeen Switch 345kV	Line	345
	West Shackleford-Sam Switch 345kV	Line	345
	West Shackleford-Navarro 345kV	Line	345
Valley Import GTL Monitored Elements	**Lowest Voltage Line Element**		**138**
	Lon Hill-North Edinburg 345kV	Line	345
	Ajo-Rio Hondo 345kV	Line	345
	Yturria-Raymondville 138kV	Line	138
	North Edinburg-Rachal 138kV	Line	138
	Roma Switch-Falcon Switch 138kV	Line	138

WECC (Existing Paths)

Interface Name	Element Name	Interface Type	Voltage (kV)
1. Alberta - British Columbia	**Lowest Voltage Line Element**		**138**
	Langdon-Cranbrook	Line	500
	Pocaterra-Fording Coal Tap	Line	138
	Coleman-Natal	Line	138
2. Alberta - Saskatchewan	**Lowest Voltage Line Element**		**138**[5]
	McNeill AC-DC-AC tie	Line	138
3. Northwest - British Columbia	**Lowest Voltage Line Element**		**230**
	Custer (BPA)-Ingledow (BCH)	Line	500
	Boundary (BPA)-Waneta (TCEK)	Line	230
	Boundary (BPA)-Nelway (BCH)	Line	230
4. West of Cascades - North	**Lowest Voltage Line Element**		**230**
	Chief Joseph-Monroe	Line	500
	Schultz-Raver 1, 3, 4	Line	500
	Chief Joe-Snohomish	Line	345
	Rocky Reach-Maple Valley	Line	345
	Coulee-Olympia	Line	287
	Rocky Reach-Cascade	Line	230
	Bettas Road-Covington No. 1	Line	230
	Schultz-Echo Lake	Line	500
5. West of Cascades - South	**Lowest Voltage Line Element**		**230**
	Big Eddy-Ostrander	Line	500
	Ashe-Marion	Line	500
	Buckley-Marion	Line	500
	Wautoma-Ostrander	Line	500
	John Day-Marion	Line	500
	McNary-Ross	Line	345
	Big Eddy-McLoughlin	Line	230
	Big Eddy-Chemawa	Line	230
	Midway-N. Bonneville	Line	230
	Jones Canyon-Santiam	Line	230
	Big Eddy-Troutdale	Line	230
	Round Butte-Bethel	Line	230
6. West of Hatwai	**Lowest Voltage Line Element**		**115**
	Hatwai (BPA)-Lower Granite (BPA)	Line	500
	Bell (BPA)-Coulee (USBR)	Line	230
	Westside (AVA)- GrandCoulee (BPA)	Line	230
	Dry Creek (AVA) – Talbot (PAC)	Line	230
	Bell (BPA)-Creston (BPA)	Line	115
	N. Lewiston (AVA)-Tucannon River (BPA)	Line	115

[5] Note: The 42.2 kV is the DC link voltage, the lowest line voltage is the McNeil Converter which is 138 kV.

Interface Name	Element Name	Interface Type	Voltage (kV)
	Harrington (AVA)-Odessa (AVA)	Line	115
	Lind (AVA)-Roxboro (AVA)	Line	115
	Dry Gulch (AVA) 115/69 kV (PAC) transformer	Other	115/69
	Bell (BPA) – Grand Coulee (USBR)	Line	500
8. Montana to Northwest	**Lowest Voltage Line Element**		**115**
	Broadview-Garrison #1 & #2	Line	500
	Mill Creek-Garrison	Line	230
	Mill Creek – Anaconda (BPA)	Line	230
	Ovando-Garrison	Line	230
	Placid Lake-Hot Springs	Line	230
	Rattlesnake 230/161 kV transformer	Other	230/161
	Kerr-Kalispell	Line	115
	Thompson Falls-Burke	Line	115
	Crow Creek-Burke	Line	115
9. West of Broadway	**Lowest Voltage Line Element**		**161**
	Broadview-Garrison	Line	500
	Broadview-Judith Gap South	Line	230
	Shorey Road-Wilsall	Line	230
	Columbus/Rapleje-Big Timber	Line	161
	Broadview 2-230/100 kV auto transformers	Other	230/100
10. West of Colstrip	**Lowest Voltage Line Element**		**115**
	Colstrip-Broadview	Line	500
	Colstrip-Hardin	Line	230
	Colstrip-Hardin	Line	115
11. West of Crossover	**Lowest Voltage Line Element**		**230**
	Colstrip-Broadview #1 & #2	Line	500
	Crossover-Huntley	Line	230
14. Idaho to Northwest	**Lowest Voltage Line Element**		**115**
	Hemingway-Summer Lake	Line	500
	Imnaha-Lolo	Line	230
	Hells Canyon-Hurricane	Line	230
	North Powder-LaGrande	Line	230
	Hines-Harney	Line	115
15. Midway to Los Banos	**Lowest Voltage Line Element**		**230**
	Midway-Los Banos	Line	500
	Gates-Los Banos # 1 and #3	Line	500
	Gates-Panoche #1 & #2	Line	230
	Gates-Gregg	Line	230
	Gates-McCall	Line	230
16. Idaho to Sierra	**Lowest Voltage Line Element**		**345**
	Midpoint (Idaho Power Co.) – Humboldt (SPPC)	Line	345
17. Borah West	**Lowest Voltage Line Element**		**138**
	Kinport-Midpoint	Line	345
	Borah-Adelaide-Midpoint #1	Line	345
	Borah-Adelaide #2	Line	345
	Borah-Hunt	Line	230

Interface Name	Element Name	Interface Type	Voltage (kV)
	AmFalls-Plst Vly-Minidoka	Line	138
18. Montana to Idaho	**Lowest Voltage Line Element**		**161**
	Dillon Salmon-Big Grassy	Line	161
	Peterson Flats-AMPS	Line	230
19. Bridger West	**Lowest Voltage Line Element**		**345**
	Jim Bridger-Three Mile Knoll	Line	345
	Jim Bridger-Populus #1	Line	345
	Jim Bridger-Populus #2	Line	345
20. Path C	**Lowest Voltage Line Element**		**138**
	Malad-American Falls	Line	138
	Ben Lomond-Populus* #1	Line	345
	Ben Lomond-Populus* #2	Line	345
	Terminal-Populus	Line	345
	Treasureton-SunBeam-Brady	Line	345
	FishCreek-Goshen	Line	161
	Threemile Knoll 138/345 * kV transformer	Other	138/345
	Threemile Knoll 138*/115 kV transformer	Other	138/115
22. Southwest to Four Corners (unqualified path)	**Lowest Voltage Line Element**		**345**
	Four Corners-Moenkopi	Line	500
	Four Corners-Cholla #1	Line	345
	Four Corners-Cholla #2	Line	345
23. Four Corners 345/500 Qualified Path	**Lowest Voltage Line Element**		**N/A**
	345/500 kV transformer	Other	345/500
24. PG&E to Sierra	**Lowest Voltage Line Element**		**60**
	Drum-Summit 1	Line	115
	Drum-Summit 2	Line	115
	Drum-Summit	Line	60
25. PacifiCorp/PG&E 115 kV Interconnection	**Lowest Voltage Line Element**		**115**
	Line 14, measured at Cascade	Line	115
26. Northern - Souther California	**Lowest Voltage Element**		**500**
	Midway-Vincent #1	Line	500
	Midway-Vincent #2	Line	500
	Midway-Whirlwind	Line	500
27. Intermountain Power Project DC Line	**Lowest Voltage Line Element**		**500**
	The IPPDC line is a ±500 kV DC bipole system. Power flow on the DC line is measured at the Intermountain end	Line	500
28. Intermountain - Mona 345 kV	**Lowest Voltage Line Element**		**345**
	Two 50-mile 345 kV transmission lines from the 345 kV IPF station to the 345 kV Mona station. The IPF 345 kV station is in the Los Angeles Department of	Line	345

Interface Name	Element Name	Interface Type	Voltage (kV)
	Water and Power (LDWP) control area, while the Mona 345 kV station is in the PacifiCorp control area		
29. Intermountain - Gonder 230 kV	**Lowest Voltage Line Element**		**230**
	A 144-mile 230 kV transmission line from the 230 kV IPF station to the Mt. Wheeler Power Cooperative's Gonder 230 kV station.	Line	230
30. TOT 1A	**Lowest Voltage Line Element**		**138**
	Bears Ears-Bonanza	Line	345
	Hayden-Artesia	Line	138
	Meeker-Rangely	Line	138
31. TOT 2A	**Lowest Voltage Line Element**		**115**
	Waterflow-San Juan	Line	345
	Hesperus-Glade Tap	Line	115
	Lost Canyon-Shiprock	Line	230
32. Pavant - Gonder 230 kV Intermountain - Gonder 230 kV	**Lowest Voltage Line Element**		**230**
	Gonder-Pavant	Line	230
	Gonder-Intermountain	Line	230
33. Bonanza West	**Lowest Voltage Line Element**		**138**
	Bonanza-Mona	Line	345
	Upalco-Carbon	Line	138
35. TOT 2C	**Lowest Voltage Line Element**		**345**
	Red Butte-Harry Allen	Line	345
	Harry Allen 345 kV phase shifting and 345/230 kV transformers	Other	345/230
36. TOT 3	**Lowest Voltage Line Element**		**115**
	Archer-Ault	Line	230
	Laramie River-Ault	Line	345
	Laramie River-Story	Line	345
	Cheyenne-Owl Creek	Line	115
	Sidney-Sterling	Line	115
	Sidney-Spring Canyon	Line	230
	Cheyenne-Ault	Line	230
37. TOT 4A	**Lowest Voltage Line Element**		**230**
	Riverton-Wyopo	Line	230
	Miners-Platte	Line	230
	Spence-Mustang	Line	230
38. TOT 4B	**Lowest Voltage Line Element**		**115**
	CarrDraw-Buffalo	Line	230
	Sheridan-Tongue River	Line	230
	Spence-Thermopolis	Line	230
	Alcova-Raderville	Line	115
	Casper-Midwest	Line	230
	Riverton-Thermopolis	Line	230
	Riverton-230/115 kV transformers	Other	230/115

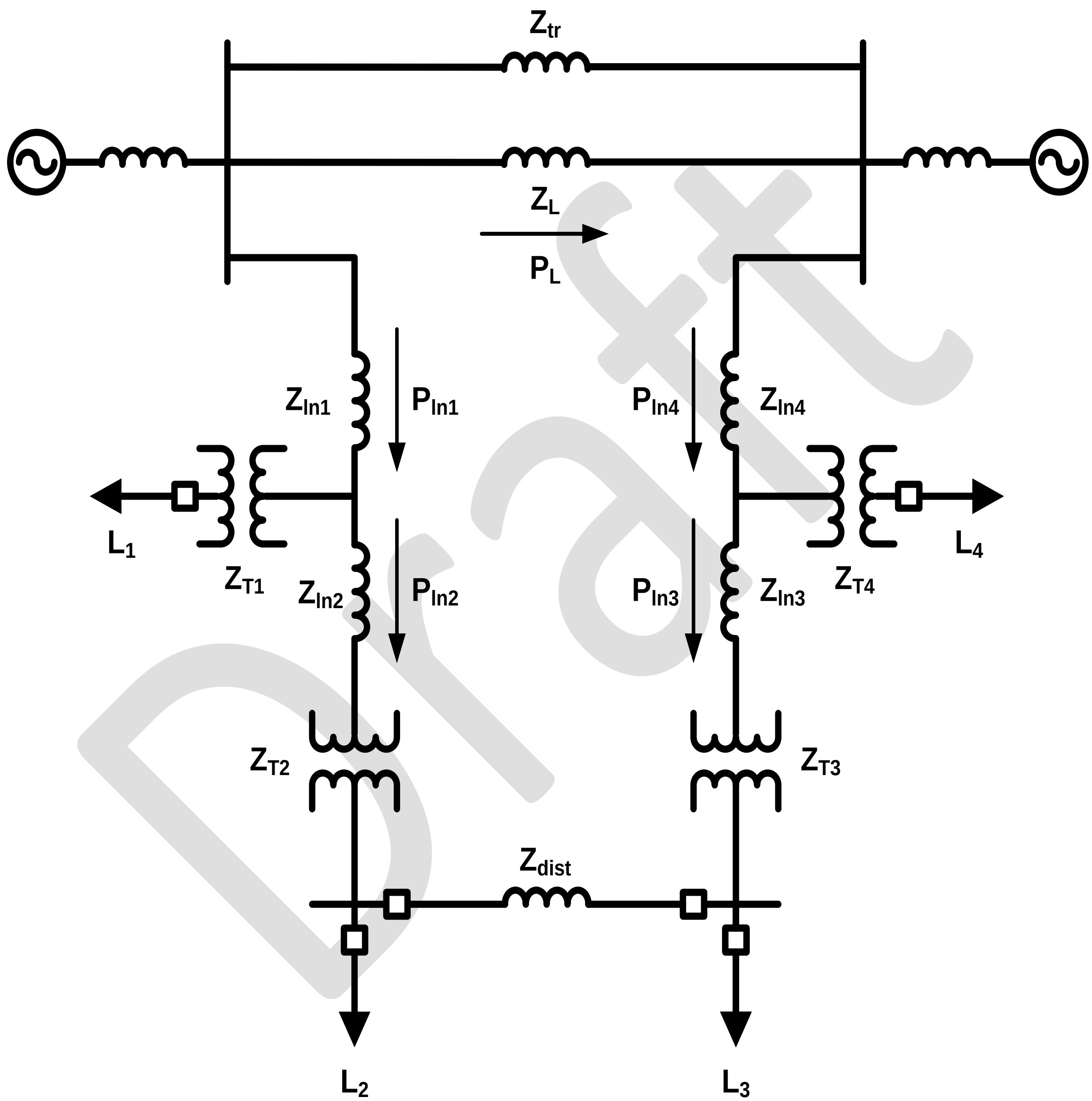
Interface Name	Element Name	Interface Type	Voltage (kV)
39. TOT 5	**Lowest Voltage Line Element**		**115**
	North Park-Archer	Line	230
	Craig-Ault	Line	345
	Hayden-Gore Pass	Line	230
	Hayden-Gore Pass	Line	138
	N. Gunnison-Salida (Poncha Jct.)	Line	115
	Curecanti-Poncha	Line	230
	Basalt-Malta	Line	230
	Hopkins-Malta	Line	230
40. TOT 7	**Lowest Voltage Line Element**		**230**
	Ault-Fort St. Vrain	Line	230
	Weld-Fort St. Vrain	Line	230
	Longs Peak-Fort St. Vrain	Line	230
41. Sylmar to SCE	**Lowest Voltage Line Element**		**220**
	Flows on three 220/230 kV transformer banks at Sylmar switching station.	Other	220/230
42. IID to SSC	**Lowest Voltage Line Element**		**230**
	Ramon-Mirage	Line	230
	Coachella-Devers	Line	230
43. North of San Onofre	**Lowest Voltage Line Element**		**230**
	SONGS-Santiago #1	Line	230
	SONGS-Santiago #2	Line	230
	SONGS-Serrano	Line	230
	SONGS-Viejo	Line	230
44. South of San Onofre	**Lowest Voltage Line Element**		**N/A**
	SONGS-San Luis Rey	Other	Not provided
	SONGS-San Luis Rey	Other	Not provided
	SONGS-San Luis Rey	Other	Not provided
	SONGS-Talega #1	Other	Not provided
	SONGS-Talega #2	Other	Not provided
45. SDG&E to CFE	**Lowest Voltage Element**		**N/A**
	Tijuana I-Otay Mesa	Other	Not provided
	La Rosita-Imperial Valley	Other	Not provided
46. West of Colorado River	**Lowest Voltage Line Element**		**230**
	(Northern System) Eldorado-Lugo	Line	500
	(Northern System) Eldorado-Cima-Pisgah 1 & 2	Line	230
	(Northern System) Mohave-Lugo	Line	500
	(Northern System) Julian Hinds-Mirage	Line	230
	(Northern System) McCullough-Victorville 1 & 2	Line	500
	(Northern System) Mead-Victorville	Line	287

Interface Name	Element Name	Interface Type	Voltage (kV)
	(Northern System) Marketplace-Adelanto	Line	500
	(Southern System) North Gila-Imperial Valley	Line	500
	(Southern System) Palo Verde-Devers	Line	500
	(Underlying System) El Centro-Imperial Valley	Line	230
	(Underlying System) Ramon-Mirage	Line	230
	(Underlying System) Coachella-Devers	Line	230
47. Southern New Mexico	**Lowest Voltage Line Element**		**115**
	West Mesa-Arroyo	Line	345
	Springerville-Luna	Line	345
	Greenlee-Hidalgo	Line	345
	Belen-Bernardo	Line	115
48. Northern New Mexico	**Lowest Voltage Line Element**		**230**
	Four Corners-West Mesa	Line	345
	San Juan-BA	Line	345
	San Juan-Ojo	Line	345
	McKinley/Yah-Ta-Hey	Other	345/115
	Bisti-Ambrosia	Line	230
	Walsenburg -Gladstone	Line	230
49. East of Colorado River	**Lowest Voltage Line Element**		**345**
	Navajo-Crystal	Line	500
	Moenkopi-Eldorado	Line	500
	Liberty-Peacock-Mead	Line	345
	Palo Verde-Devers	Line	500
	Hoodoo Wash – N.Gila	Line	500
	Perkins-Mead	Line	500
50. Cholla to Pinnacle Peak	**Lowest Voltage Line Element**		**345**
	Cholla-Preacher Canyon	Line	345
	Cholla-Pinnacle Peak	Line	345
51. Southern Navajo	**Lowest Voltage Element**		**500**
	Moenkopi-Cedar Mt.	Line	500
	Navajo-Dugas	Line	500
52. Silver Peak - Control 55 kV	**Lowest Voltage Line Element**		**55**
	Silver Peak-Control	Line	55
54. Coronado-Silver King 500 kV	**Lowest Voltage Line Element**		**500**
	Coronado-Silver King	Line	500
55. Brownlee East	**Lowest Voltage Line Element**		**138**
	Brownlee-Boise Bench #1	Line	230
	Brownlee-Boise Bench #2	Line	230
	Brownlee-Boise Bench #3	Line	230
	Brownlee-Horse Flat #4	Line	230
	Brownlee-Ontario	Line	230
	Oxbow-Starkey	Line	138

Interface Name	Element Name	Interface Type	Voltage (kV)
	Quartz-Ontario	Line	138
58. Eldorado - Mead 230 kV Lines	**Lowest Voltage Line Element**		**230**
	Flows on the Eldorado-Mead 230 kV transmission lines 1 and 2.	Line	230
59. WALC Blythe 161 kV Substation - SCE Blythe 161 kV Substation	**Lowest Voltage Line Element**		**161**
	The bus tie-line between WALC Blythe 161 kV substation and SCE Blythe 161 kV substation.	Line	161
60. Inyo - Control 115 kV Tie	**Lowest Voltage Line Element**		**115**
	The 115 kV phase shifter between SCE and LDWP.	Other	115
61. Lugo - Victorville 500 kV Line	**Lowest Voltage Line Element**		**500**
	Line is owned independently from the midpoint of the line to the respective service areas of SCE and LDWP.	Line	500
62. Eldorado - McCullough 500 kV Line	**Lowest Voltage Line Element**		**500**
	The line is owned by LDWP for the purpose of mutual support between LDWP and SCE.	Line	500
65. Pacific DC Intertie (PDCI)	**Lowest Voltage Line Element**		**500**
	The PDCI line is a ±500 kV DC multi-terminal system. This system is divided into the northern and southern systems, the demarcation point is the Nevada-Oregon state line border (NOB).	Line	500
66. COI	**Lowest Voltage Line Element**		**500**
	Malin to Round Mt.	Line	500
	Captain Jack-Olinda	Line	500
71. South of Allston	**Lowest Voltage Line Element**		**115**
	Clatsop	Other	230/115
	Allston-Keeler	Line	500
	Allston-Rainier	Line	115
	Astoria Tap-Seaside	Line	115
	Merwin-View	Line	115
	Trojan-Rivergate	Line	230
	Trojan-St Marys	Line	230
	Woodland Tap-Ross	Line	230
73. North of John Day	**Lowest Voltage Line Element**		**500**
	Raver-Paul	Line	500
	Wautoma-Ostrander	Line	500
	Wautoma-Rock Creek	Line	500
	Ashe-Marion	Line	500
	Ashe-Slatt	Line	500
	Lower Monumental-McNary	Line	500
75. Hemingway –	**Lowest Voltage Line Element**		**500**

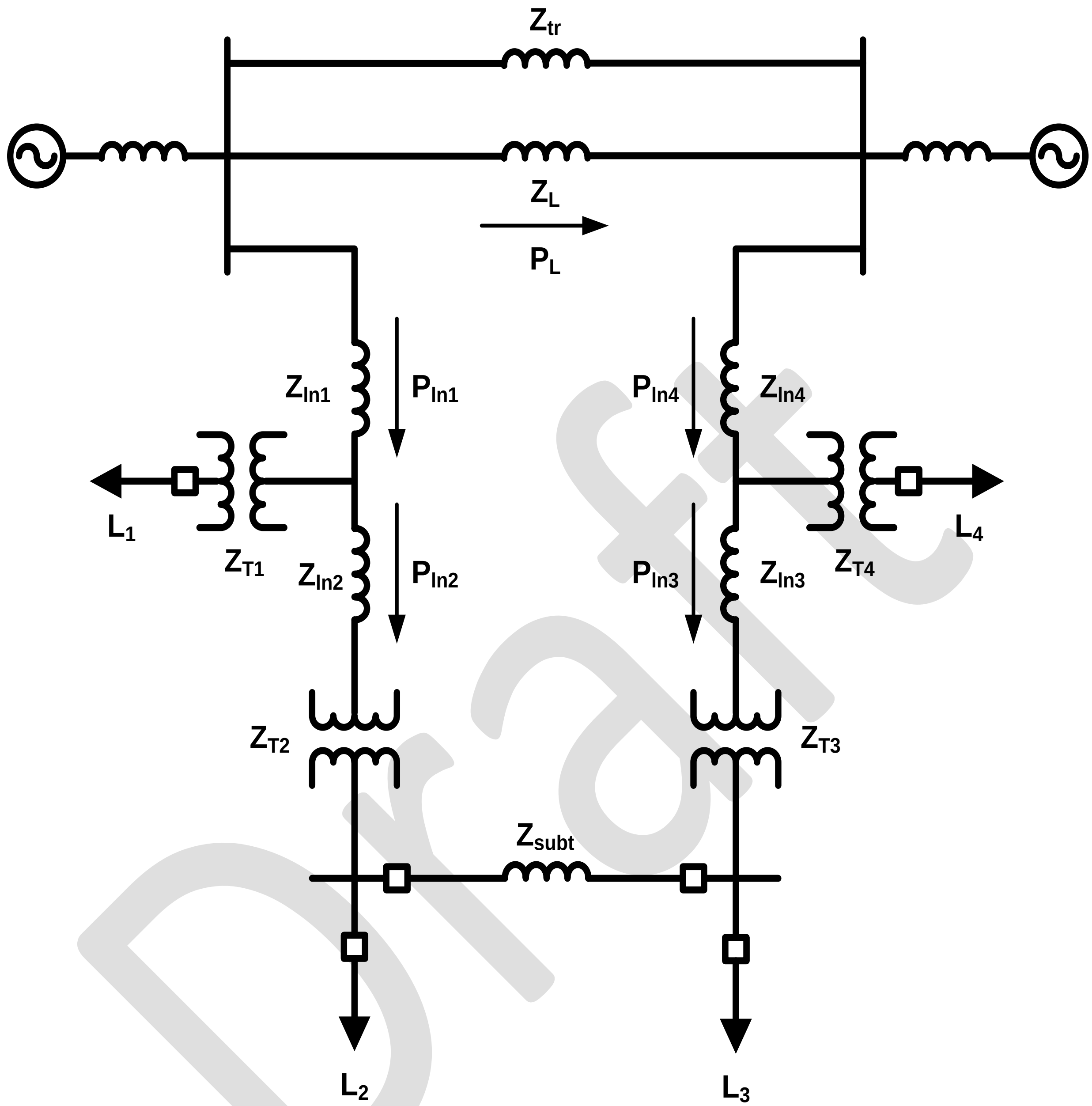
Interface Name	Element Name	Interface Type	Voltage (kV)
Summer Lake			
	Hemingway-Summer Lake 500 kV metered at the Hemingway 500 kV.	Line	500
76. Alturas Project	**Lowest Voltage Line Element**		**345**
	Hilltop (near existing Warner Substation) 230/345 kV-Bordertown 345 kV and Bordertown-N. Valley Road 345 kV. Point of interconnection between Bonneville Power Authority (BPA) and Sierra Pacific Power Company (Sierra) is the Hilltop 230 kV. Metered at Bordertown 345 kV.	Line	345
77. Crystal - Harry Allen	**Lowest Voltage Line Element**		**500**
	Sum of the flows on the two 500/230 kV transformer banks at Crystal switching station, metered at the 500 kV bus.	Line	500
78. TOT 2B1	**Lowest Voltage Line Element**		**230**
	Pinto-Four Corners	Line	345
	Sigurd-Glen Canyon	Line	230
79. TOT 2B2	**Lowest Voltage Line Element**		**230**
	Sigurd-Glen Canyon	Line	230
	Pinto –Four Corners	Line	345
80. Montana Southeast	**Lowest Voltage Line Element**		**161**
	Billings-Yellowtail	Line	230
	Rimrock-Yellowtail	Line	161
	Hardin-Crossover	Line	230
	Huntley-Crossover	Line	230
81. Centennial	**Lowest Voltage Line Element**		**500**
	Harry Allen-Crystal	Line	500
	Lenzie-Northwest	Line	500
	Harry Allen (or future Sunrise tap)-Mead	Line	500
82. TotBeast	**Lowest Voltage Line Element**		**138**
	Summer Lake - Hemingway	Line	500
	Brownlee-Boise Bench #1	Line	230
	Brownlee-Boise Bench #2	Line	230
	Brownlee-Boise Bench #3	Line	230
	Brownlee-Horse Flat #4	Line	230
	Brownlee-Ontario	Line	230
	Oxbow-Starkey	Line	138
	Quartz-Ontario	Line	138

Appendix 2: One-Line Diagrams



Note: Refer to the notes in Appendix 3 for a description of the symbols in this diagram.

Figure 5: Example Radial Systems with Low Voltage Distribution Tie



Notes: Refer to the notes in Appendix 3 for a description of the symbols in this diagram.
Step-down transformers from sub-transmission voltage to distribution voltage were not explicitly modeled in the simulations.

Figure 6: Example Radial Systems with Sub-transmission Tie

Appendix 3: Simulation Results

Case	Z_L (mi.)	Z_{tr} (mi.)	Z_{ln1-4} (total mi.)	Z_{dist} (mi.)	Z_{T1}, Z_{T-4} (Z/MVA)	Z_{T2}, Z_{T3} (Z/MVA)	L_1, L_4 (MW)	L_2, L_3 (MW)	P_L (MVA)	P_{ln1} (MVA)	P_{ln2} (MVA)	P_{ln3} (MVA)	P_{ln4} (MVA)	$P_{ln1'}$ (MVA)	$P_{ln2'}$ (MVA)	$P_{ln3'}$ (MVA)	$P_{ln4'}$ (MVA)	LODF
										------------ HV Line "L" in-service ------------				-- HV Line "L" out-of-service --				
23 kV Base Cases																		
623a0	10	Strong	15	0	10%/10	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	Strong	15	2	10%/10	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	Strong	15	5	10%/10	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	Strong	15	0	10%/10	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	Strong	15	2	10%/10	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	Strong	15	5	10%/10	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	Strong	15	0	10%/20	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	Strong	15	2	10%/20	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	Strong	15	5	10%/20	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	Strong	15	0	10%/20	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	Strong	15	2	10%/20	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	Strong	15	5	10%/20	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

										HV Line "L" in-service				HV Line "L" out-of-service				
Case	Z_L (mi.)	Z_{tr} (mi.)	Z_{ln1-4} (total mi.)	Z_{dist} (mi.)	Z_{T1}, Z_{T-4} (Z/MVA)	Z_{T2}, Z_{T3} (Z/MVA)	L_1, L_4 (MW)	L_2, L_3 (MW)	P_L (MVA)	P_{ln1} (MVA)	P_{ln2} (MVA)	P_{ln3} (MVA)	P_{ln4} (MVA)	$P_{ln1'}$ (MVA)	$P_{ln2'}$ (MVA)	$P_{ln3'}$ (MVA)	$P_{ln4'}$ (MVA)	LODF
623c0	10	Strong	15	0	10%/40	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	Strong	15	2	10%/40	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	Strong	15	5	10%/40	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	Strong	15	0	10%/40	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	Strong	15	2	10%/40	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	Strong	15	5	10%/40	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	Medium	15	0	10%/10	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	Medium	15	2	10%/10	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	Medium	15	5	10%/10	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	Medium	15	0	10%/10	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	Medium	15	2	10%/10	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	Medium	15	5	10%/10	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	Medium	15	0	10%/20	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	Medium	15	2	10%/20	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	Medium	15	5	10%/20	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	Medium	15	0	10%/20	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	Medium	15	2	10%/20	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	Medium	15	5	10%/20	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

Case	Z_L (mi.)	Z_{tr} (mi.)	Z_{ln1-4} (total mi.)	Z_{dist} (mi.)	Z_{T1}, Z_{T-4} (Z/MVA)	Z_{T2}, Z_{T3} (Z/MVA)	L_1, L_4 (MW)	L_2, L_3 (MW)	P_L (MVA)	------------ HV Line "L" in-service ------------				-- HV Line "L" out-of-service --				LODF
										P_{ln1} (MVA)	P_{ln2} (MVA)	P_{ln3} (MVA)	P_{ln4} (MVA)	$P_{ln1'}$ (MVA)	$P_{ln2'}$ (MVA)	$P_{ln3'}$ (MVA)	$P_{ln4'}$ (MVA)	
723c0	10	Medium	15	0	10%/40	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	Medium	15	2	10%/40	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	Medium	15	5	10%/40	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	Medium	15	0	10%/40	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	Medium	15	2	10%/40	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	Medium	15	5	10%/40	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	Weak	15	0	10%/10	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	Weak	15	2	10%/10	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	Weak	15	5	10%/10	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	Weak	15	0	10%/10	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	Weak	15	2	10%/10	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	Weak	15	5	10%/10	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	Weak	15	0	10%/20	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	Weak	15	2	10%/20	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	Weak	15	5	10%/20	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	Weak	15	0	10%/20	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	Weak	15	2	10%/20	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	Weak	15	5	10%/20	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

										----------- HV Line "L" in-service -----------				-- HV Line "L" out-of-service --				
Case	**Z_L (mi.)**	**Z_{tr} (mi.)**	**Z_{ln1-4} (total mi.)**	**Z_{dist} (mi.)**	**Z_{T1}, Z_{T-4} (Z/MVA)**	**Z_{T2}, Z_{T3} (Z/MVA)**	**L_1, L_4 (MW)**	**L_2, L_3 (MW)**	**P_L (MVA)**	**P_{ln1} (MVA)**	**P_{ln2} (MVA)**	**P_{ln3} (MVA)**	**P_{ln4} (MVA)**	**$P_{ln1'}$ (MVA)**	**$P_{ln2'}$ (MVA)**	**$P_{ln3'}$ (MVA)**	**$P_{ln4'}$ (MVA)**	**LODF**
823c0	10	Weak	15	0	10%/40	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	Weak	15	2	10%/40	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	Weak	15	5	10%/40	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	Weak	15	0	10%/40	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	Weak	15	2	10%/40	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	Weak	15	5	10%/40	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	Medium	30	0	10%/10	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	Medium	30	2	10%/10	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	Medium	30	5	10%/10	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	Weak	15	0	10%/10	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	Weak	15	2	10%/10	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	Weak	15	5	10%/10	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	Weak	15	0	10%/10	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	Weak	15	2	10%/10	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	Weak	15	5	10%/10	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	Weak	15	0	10%/20	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

										----------- HV Line "L" in-service -----------				-- HV Line "L" out-of-service --				
Case	Z_L (mi.)	Z_{tr} (mi.)	Z_{ln1-4} (total mi.)	Z_{dist} (mi.)	Z_{T1}, Z_{T-4} (Z/MVA)	Z_{T2}, Z_{T3} (Z/MVA)	L_1, L_4 (MW)	L_2, L_3 (MW)	P_L (MVA)	P_{ln1} (MVA)	P_{ln2} (MVA)	P_{ln3} (MVA)	P_{ln4} (MVA)	$P_{ln1'}$ (MVA)	$P_{ln2'}$ (MVA)	$P_{ln3'}$ (MVA)	$P_{ln4'}$ (MVA)	LODF
834b2	10	Weak	15	2	10%/20	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	Weak	15	5	10%/20	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	Weak	15	0	10%/20	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	Weak	15	2	10%/20	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	Weak	15	5	10%/20	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	Weak	15	0	10%/40	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	Weak	15	2	10%/40	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	Weak	15	5	10%/40	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	Weak	15	0	10%/40	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	Weak	15	2	10%/40	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	Weak	15	5	10%/40	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	Weak	15	0	7%/40	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	Weak	15	2	7%/40	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	Weak	15	5	7%/40	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	Weak	15	0	7%/40	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	Weak	15	2	7%/40	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	Weak	15	5	7%/40	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

										----------- HV Line "L" in-service -----------				-- HV Line "L" out-of-service --				
Case	**Z_L (mi.)**	**Z_{tr} (mi.)**	**Z_{ln1-4} (total mi.)**	**Z_{dist} (mi.)**	**Z_{T1}, Z_{T-4} (Z/MVA)**	**Z_{T2}, Z_{T3} (Z/MVA)**	**L_1, L_4 (MW)**	**L_2, L_3 (MW)**	**P_L (MVA)**	**P_{ln1} (MVA)**	**P_{ln2} (MVA)**	**P_{ln3} (MVA)**	**P_{ln4} (MVA)**	**$P_{ln1'}$ (MVA)**	**$P_{ln2'}$ (MVA)**	**$P_{ln3'}$ (MVA)**	**$P_{ln4'}$ (MVA)**	**LODF**
Selected 12.47 kV cases																		
812a0	10	Weak	15	0	10%/10	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	Weak	15	2	10%/10	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	Weak	15	5	10%/10	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	Weak	15	0	10%/10	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	Weak	15	2	10%/10	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	Weak	15	5	10%/10	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	Weak	15	0	10%/20	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	Weak	15	2	10%/20	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	Weak	15	5	10%/20	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	Weak	15	0	10%/20	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	Weak	15	2	10%/20	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	Weak	15	5	10%/20	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	Weak	15	0	10%/40	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	Weak	15	2	10%/40	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	Weak	15	5	10%/40	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	Weak	15	0	10%/40	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	Weak	15	2	10%/40	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

Case	Z_L (mi.)	Z_{tr} (mi.)	Z_{ln1-4} (total mi.)	Z_{dist} (mi.)	Z_{T1}, Z_{T-4} (Z/MVA)	Z_{T2}, Z_{T3} (Z/MVA)	L_1, L_4 (MW)	L_2, L_3 (MW)	P_L (MVA)	----------- HV Line "L" in-service ----------- P_{ln1} (MVA)	P_{ln2} (MVA)	P_{ln3} (MVA)	P_{ln4} (MVA)	-- HV Line "L" out-of-service -- $P_{ln1'}$ (MVA)	$P_{ln2'}$ (MVA)	$P_{ln3'}$ (MVA)	$P_{ln4'}$ (MVA)	LODF
812c5pk	10	Weak	15	5	10%/40	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	Weak	15	0	10%/40	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	Weak	15	2	10%/40	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	Weak	15	5	10%/40	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
Sub-transmission cases																		
115-69 kV																		
669f25	40	Strong	20	25	10%/40	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	Medium	20	25	10%/40	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	Weak	20	25	10%/40	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	Strong	20	25	10%/40	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	Medium	20	25	10%/40	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	Weak	20	25	10%/40	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	Strong	20	25	10%/40	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	Medium	20	25	10%/40	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	Weak	20	25	10%/40	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	Strong	20	25	10%/40	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

										----------- HV Line "L" in-service -----------				-- HV Line "L" out-of-service --				
Case	**Z_L (mi.)**	**Z_{tr} (mi.)**	**Z_{ln1-4} (total mi.)**	**Z_{dist} (mi.)**	**Z_{T1}, Z_{T-4} (Z/MVA)**	**Z_{T2}, Z_{T3} (Z/MVA)**	**L_1, L_4 (MW)**	**L_2, L_3 (MW)**	**P_L (MVA)**	**P_{ln1} (MVA)**	**P_{ln2} (MVA)**	**P_{ln3} (MVA)**	**P_{ln4} (MVA)**	**$P_{ln1'}$ (MVA)**	**$P_{ln2'}$ (MVA)**	**$P_{ln3'}$ (MVA)**	**$P_{ln4'}$ (MVA)**	**LODF**
734d25	40	Medium	20	25	10%/40	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	Weak	20	25	10%/40	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	Weak	20	25	10%/40	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	Weak	20	25	10%/40	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	Weak	20	25	10%/40	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	Weak	20	25	10%/40	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	Weak	20	25	10%/40	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	Weak	20	25	10%/40	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	Weak	20	25	10%/40	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	Weak	20	25	10%/40	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	Weak	20	25	10%/40	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	Weak	20	25	10%/40	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	Weak	20	25	10%/40	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	Weak	20	25	10%/40	7%/50	16.0	20.0	218.7	50.8	34.8	5.6	21.6	61.7	45.7	-4.7	11.3	0.050

Notes:

The following notes provide information to understand the meaning of each column heading and underlying assumptions used in the analysis. See also the one-line diagrams in Figures 5 and 6 of Appendix 2 for additional information.

Z_L

The table provides the length of line "L" in miles to provide a high-level, qualitative understanding of the line impedance. The line impedance (Z_L) is the length of the line in miles times the per mile impedance. Assumptions used in determining the per mile impedance are as follows:

Voltage (kV)	Conductor	Phase Spacing	GMD	Impedance (Ω/mile)	Impedance (p.u./mile)
230	954 ACSR	20' H-frame	25.20'	0.100 + j0.786	0.000189 + J 0.00149
161	954 ACSR	16' H-frame	20.16'	0.100 + j0.759	0.000384 + j 0.00293
138	795 ACSR	13' H-frame	16.38'	0.117 + j0.738	0.000615 + j 0.00388
115	795 ACSR	11' H-frame	13.86'	0.117 + j0.718	0.000886 + j 0.00543

Z_{tr}

The transfer impedance (Z_{tr}) represents the impedance of the system in parallel with the subsystem under study. Analysis was performed for three levels of parallel transfer impedance which have been characterized as strong, medium, and weak. The strong system has relatively low impedance and thus will pick up more power flow when line "L" is tripped. The weak system has relatively high impedance and thus will pick up less power flow when line "L" is tripped. The medium system has a mid-range impedance value. The actual values of the transfer impedance vary between the distribution cases and the sub-transmission cases.

	Z_{tr} in distribution cases (p.u.)	Z_{tr} in sub-transmission cases (p.u.)
Strong	0.00089 + j 0.00543	0.00354 + j 0.0217
Medium	0.00319 + j 0.0195	0.0128 + j 0.0782
Weak	0.00664 + j 0.0407	0.0266 + j 0.163

Z_{ln1-4}

The table provides the total length of lines "ln1" through "ln4." In all simulations these four lines have equal length. The total length in miles provides a high-level, qualitative understanding of the line impedance. The line impedances are the length of each line in miles times the per mile impedance. Assumptions used in determining the per mile impedance are the same as provided above for line "L."

Z_{dist}

The table provides the length of the line in miles to provide a high-level, qualitative understanding of the line impedance. The impedance of the distribution system or sub-transmission system (Z_{dist}) is the length of the distribution tie or sub-transmission line in miles times the per mile impedance. A value of zero miles is used when the distribution tie is a solid bus tie. Assumptions used in determining the per mile impedance are as follows:

Voltage (kV)	Conductor	Phase Spacing	GMD	Impedance (Ω/mile)	Impedance (p.u./mile)
69	636 ACSR	6' Horizontal	7.56'	0.145 + j0.657	0.00305 + j 0.0138
55	556 ACSR	6' Horizontal	7.56'	0.168 + j0.677	0.00555 + j 0.0224
46	477 ACSR	6' Triangular	6.00'	0.193 + j0.647	0.00913 + j 0.0306
34.5	477 ACSR	4' Triangular	4.00'	0.193 + j0.598	0.0162 + j 0.0503
23	477 ACSR	4' Triangular	4.00'	0.193 + j0.598	0.0365 + j 0.113
12.47	336 ACSR	2' Horizontal	2.52'	0.274 + j0.563	0.176 + j 0.362

$Z_{T1\text{-}4}$

The transformer impedance is reported as percent impedance on the transformer MVA base. Each transformer has three ratings: OA (oil and air), FA (forced air – i.e., fans), and FOA (forced oil and air – i.e., pumps and fans). The transformer MVA base rating is the OA rating. The FA rating is 133% of the OA rating and the FOA rating is 167% of the OA rating (e.g., a 20 MVA transformer has a 20 MVA OA rating, 26.7 MVA FA rating, and 33.3 MVA FOA rating, typically identified as a nameplate of 20/26.7/33.3 MVA).

The transformer impedance and rating for each voltage level are based on typical values. Distribution transformer impedance is generally higher to limit current on the distribution equipment. Secondary current typically is not a concern on sub-transmission transformers, so impedance is typically lower to limit reactive power losses and voltage drop.

L_1, L_2, L_3, L_4

The transformer load is based on the transformer OA rating. Transformers are loaded at 80 percent of the transformer base MVA in the simulations modeling a peak system load condition. The substations modeled have two transformers, with each transformer able to supply the total station load. Thus, if one transformer is forced out-of-service, the load on the remaining transformer will be 160 percent of its base rating, which is approximately equal to its FOA rating.

Transformers are loaded at 40 percent of the transformer base MVA in the simulations modeling a light system load condition.

HV Line "L" in-service: P_L, P_{ln1}, , P_{ln2}, P_{ln3}, P_{ln4}

The loading on each line, with all lines in service, is listed in MVA. The loading on line "L" is the power that is redistributed between the parallel transmission system and the distribution or sub-transmission system when line "L" is taken out of service.

HV Line "L" out-of-service: P_{ln1}, , P_{ln2}, P_{ln3}, P_{ln4}

The loading on each line, with line "L" out-of-service, is listed in MVA.

LODF

The Line Outage Distribution Factor (LODF) is the fraction of the load on line "L" that is picked up on the distribution or sub-transmission system. This information is included for illustrative purposes to understand the analysis, but was not used in identifying the voltage threshold for Exclusion E1.

Appendix 4: Summary of Loop Flow Issue Through Systems <50 kV

In the course of developing 'real-world' scenarios for the analysis of potential sub-100 kV loop flows, the Standard Drafting Team found that the industry has employed various measures to minimize the subject loop flows. Some of these methods that were found to be applied by entities on sub-100 kV loop systems are described below. However, it is important to note that the presence of the equipment in the following examples does not remove or lessen an entity's obligations associated with the bright-line application of the Bulk Electric System (BES) definition.

Sustained power flow through substation power transformers and low voltage loops is generally undesirable and, in some instances injurious. For this reason, power system engineers typically address this issue in their design, operating, and planning criteria and apply methods to prevent this condition from occurring. The high impedance of transformers and low voltage elements inherently prevent excessive flow, but in many instances this flow can exceed ratings of equipment. For these reasons entities develop control schemes, add relaying, and provide operational and planning guidelines to prevent this loop flow. Figure 7 depicts two systems that could provide a possible loop flow across the low voltage system and back up to the high voltage system. The loop flow in these diagrams is increased when the breaker on the high voltage side (breaker B) is opened.

The diagrams presented below depict a generic power system. The higher voltage and lower voltage circuit breakers and bus arrangements will, in practice, vary (i.e., straight bus, half-breaker, ring bus, breaker-and-a-half, etc.), but the concepts remain the same.

Specifically, Figure 7, shown below, depicts segments of an electrical power system. They consist of a greater than 100 kV system and a sub-100 kV system. Figure 7 depicts the power flow through the electrical system under the condition that all circuit breakers are closed (normal condition). In the event that circuit breaker B opens (i.e., manually, supervisory control, or protective device operation) and (1) and either of the sub-100 kV line circuit breakers (A or C) or (2) either of the low-side transformer circuit breakers (D or F) or (3) the low-side bus tie circuit breaker (E) does not open, a condition could occur where some amount of flow will occur through the sub-100 kV system to the greater than 100 kV system. This flow is severely limited by the high impedance of the two transformers in series and the sub-100 kV system impedance. This condition, however, may be deemed undesirable from an equipment standpoint and precautions may be taken to prevent it. Subsequent sections of this appendix show some of the physical schemes that entities can employ in this regard.

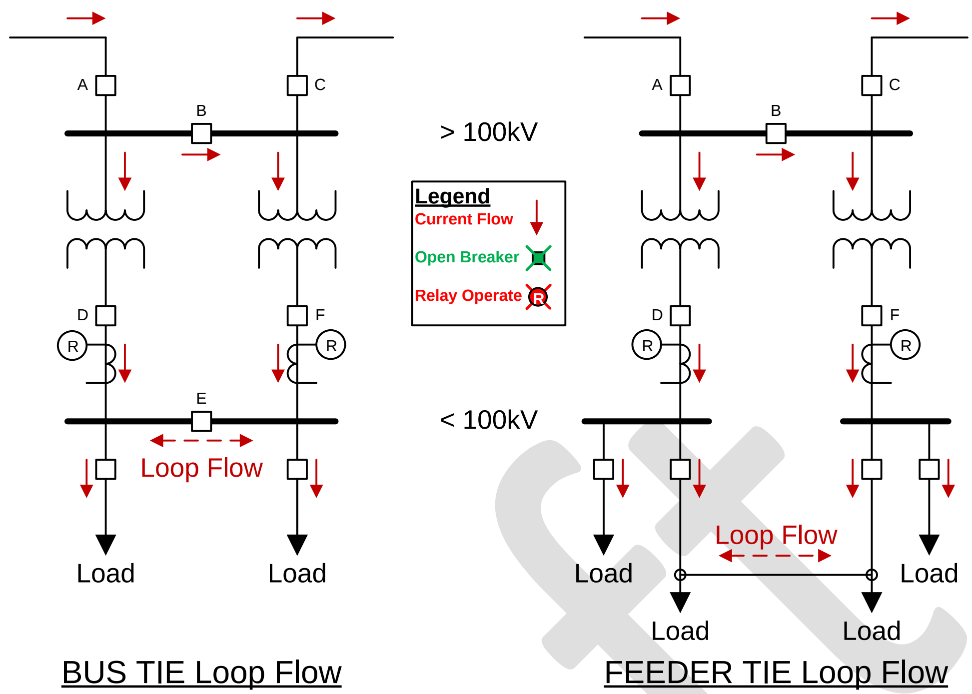


Figure 7. Summary of Loop Flow

Interlocked Control Schemes

Interlocking control schemes can be used to prevent low voltage loop flow. One method to preclude sustained power flow from the lower voltage to the higher voltage portion of the system is to include control system interlocks which will cross-trip certain circuit breaker(s) when other specified circuit breakers are opened. This condition is generally rare since bus designs and protective relay system operations generally do not result in this condition occurring. Operational guidelines usually instruct personnel to avoid the use of the interlocking schemes during normal or planned switching. However, unplanned actions can cause breakers to open and result in the desirable operation of the interlocking schemes. This method, therefore, is considered to be conservative but, never-the-less, it is applied in some instances.

Figure 8 below shows how an interlock scheme would function to prevent low voltage loop flow. When the high side breaker (breaker B) is opened, the low side breaker (breaker E) is also opened. This action prevents low side loop flow. The interlocking scheme could be applied in various combinations and the figure below is a simplified illustration of such a scheme.

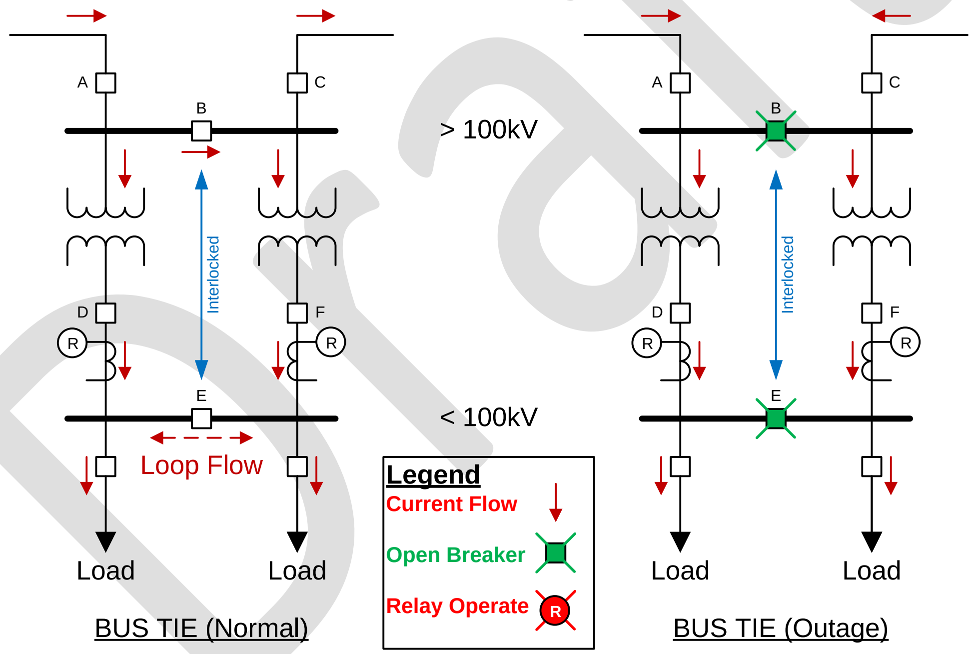


Figure 8. Interlocking Schemes

Reverse Power Schemes

Protection schemes can also be deployed to prevent sustained loop flows through the sub-100 kV system. Reverse power applications are one example of a protection scheme that prevents sustained undesirable low voltage loop flow. In some instances, protective devices will preclude sustained loop flows due to their settings and in other instances protective schemes are specifically applied to preclude this undesirable operating condition.

Figure 9 below shows how a reverse power scheme would function to prevent sub-100 kV loop flow. When the high side breaker (breaker B) is opened, current may flow from the high voltage side (breaker A) through the low voltage bus and back to the high voltage side (breaker C). A relay on breaker F is applied to sense the reverse flow (relay shown in yellow in the diagram) and will operate if this flow continues (relay shown in red in the diagram). When the reverse power relay operates it will trip breaker F. This action prevents reverse power flow through the transformer and low voltage loop flow. The reverse power scheme is set to sense a minimum amount of power flowing in a reverse direction and is usually set much less than the transformer rating. The figure below is a simplified illustration of a reverse power scheme.

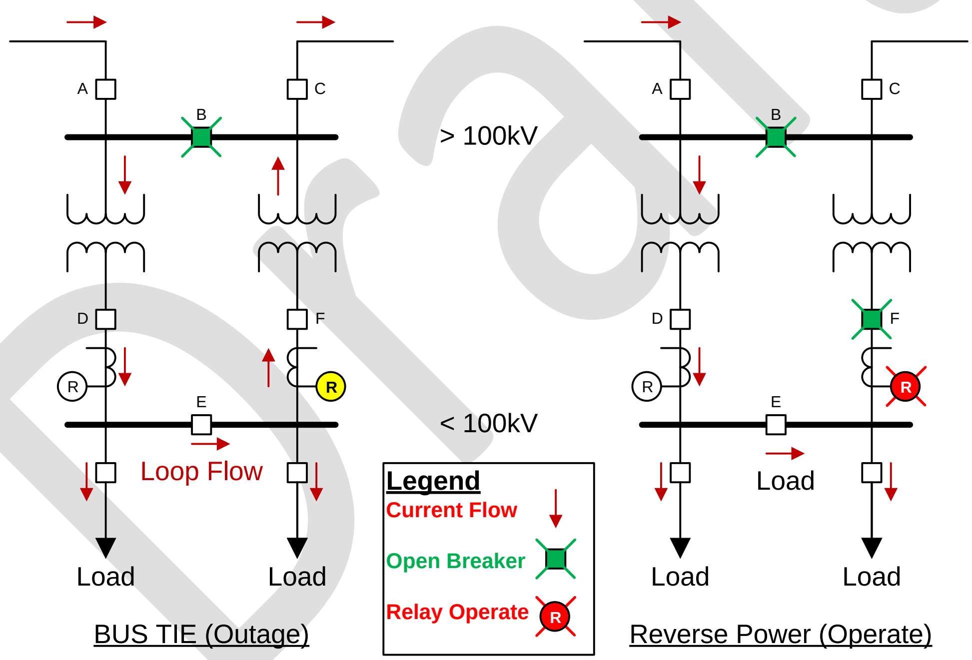


Figure 9. Reverse Power Schemes

Transformer Overcurrent Limitations

Transformer overcurrent protection schemes can also be deployed to prevent sustained loop flows through the sub-100 kV system. Figure 10 below shows how a transformer overcurrent scheme would function to prevent sub-100 kV loop flow. When the high side breaker (breaker B) is opened, current may flow from the high voltage side (breaker A) through the low voltage bus and back to the high voltage side (breaker C). The relay on the transformer and breaker D is applied to protect the transformer from excessive overloads and faults on the low voltage system. If a fault occurs or the transformer is over-loaded then the relay on breaker D will sense this excessive flow (relay shown in yellow in the diagram) and will operate if this flow continues (relay shown in red in the diagram). When the transformer overcurrent relay operates it will trip breaker D. This action unloads the transformer in question and prevents low voltage loop flow. The transformer overcurrent relay is typically set to allow the transformer to be loaded to the emergency rating of the transformer plus a small safety margin. The figure below is a simplified illustration of a transformer overcurrent scheme.

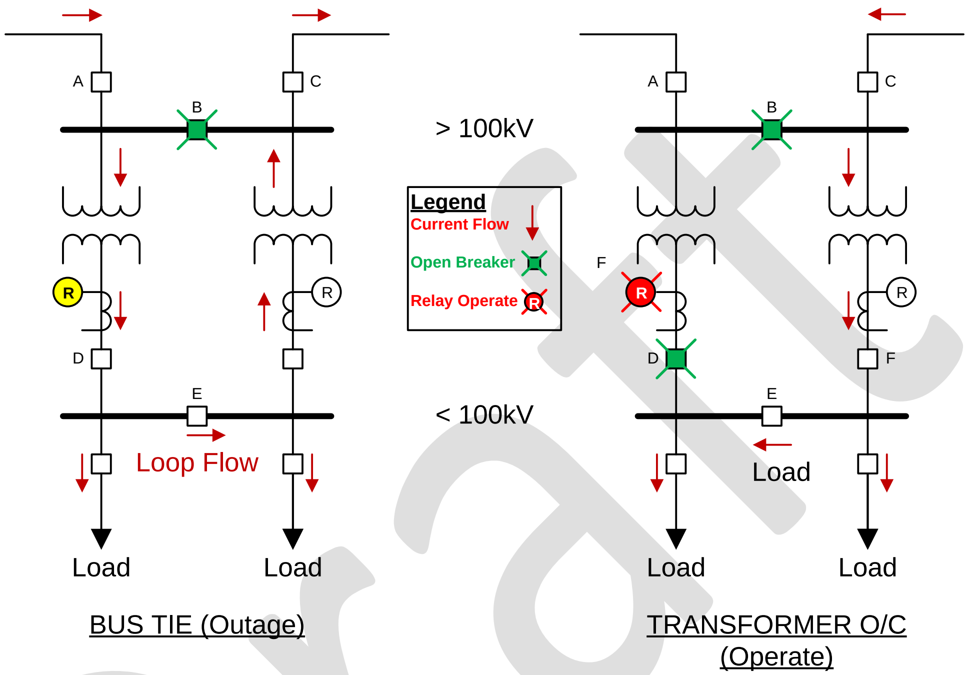


Figure 10. Transformer Overcurrent Limitations

Feeder Overcurrent Limitations

Feeder overcurrent protection schemes can also be deployed to prevent sustained loop flows through the sub-100 kV system. Figure 11 below shows how a feeder overcurrent scheme would function to prevent sub-100 kV loop flow. When the high side breaker (breaker B) is opened, current may flow from the high voltage side (breaker A) through the low voltage feeder, through a feeder tie, and back to the high voltage side (breaker C). The relay on the feeder and breaker G is applied to protect the feeder from excessive overloads and faults on the low voltage feeder. If a fault occurs or the feeder is over loaded, the relay on breaker G will sense this excessive flow (relay shown in yellow in the diagram) and will operate if this flow continues (relay shown in red in the diagram). When the feeder overcurrent relay operates it will trip breaker G. This action opens the feeder breaker and prevents low voltage loop flow. The feeder overcurrent relay is typically set to allow the feeder to be loaded to the emergency rating of the feeder rating plus a small safety margin. The figure below is a simplified illustration of a feeder overcurrent power scheme.

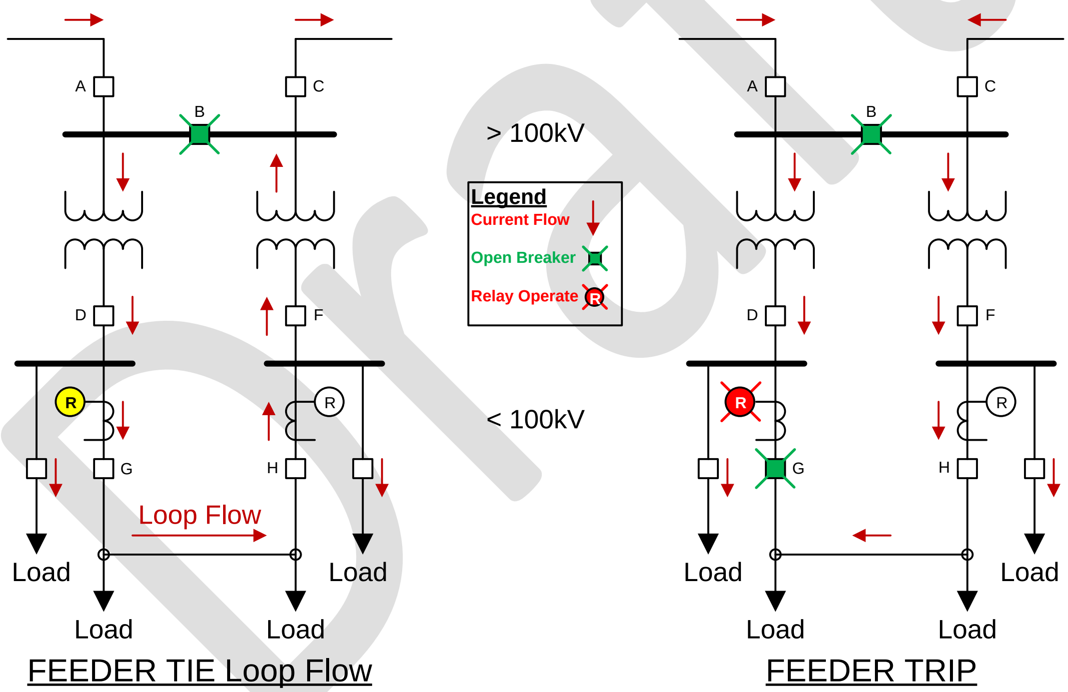


Figure 11. Feeder Overcurrent Limitations

Bus Tie Overcurrent Limitations

Bus tie overcurrent protection schemes can also be deployed to prevent sustained loop flows through the sub-100 kV system. Figure 12 below shows how a bus tie overcurrent scheme would function to prevent sub-100 kV loop flow. When the high side breaker (breaker B) is opened, current may flow from the high voltage side (breaker A) through the low voltage bus and back to the high voltage side (breaker C). The relay on the bus tie and breaker E is applied to protect the bus from excessive overloads and faults on the low voltage bus(ses). If a fault occurs or the bus is over loaded, then the overcurrent relay on breaker E will sense this excessive flow (relay shown in yellow in the diagram) and will operate if this flow continues (relay shown in red in the diagram). When the bus tie overcurrent relay operates, it will trip breaker E. This action opens the bus tie breaker and prevents sustained low voltage loop flow. The bus tie overcurrent relay is typically set to allow the bus to be loaded to the emergency rating plus a small safety margin. The figure below is a simplified illustration of a bus tie overcurrent power scheme.

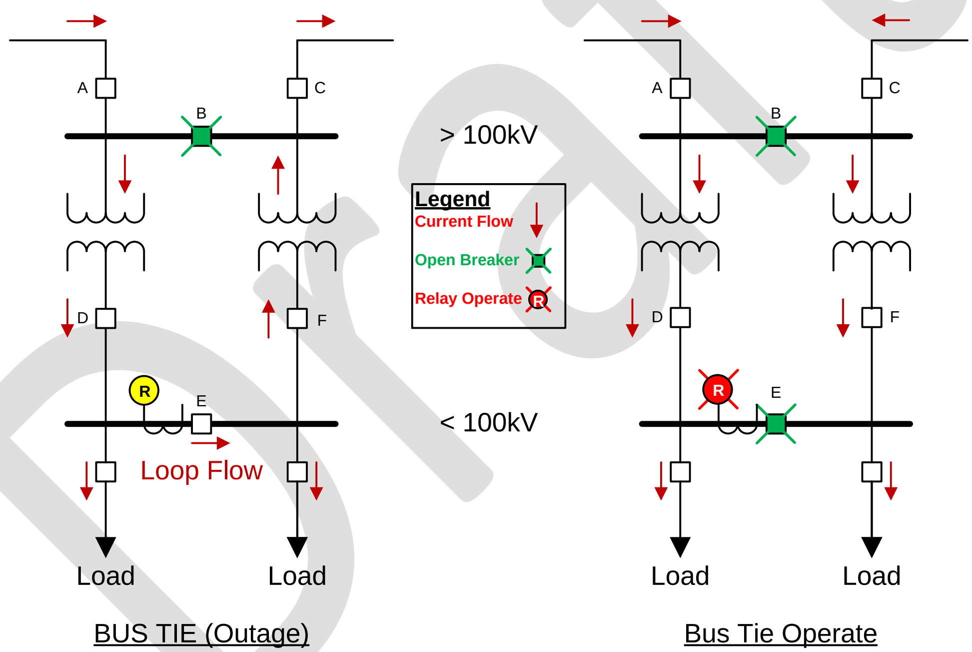


Figure 12. Bus Tie Overcurrent Limitations

Custom Protection and Control Schemes

Custom protection and control schemes may also be deployed to prevent loop flows through the sub-100 kV system. Figure 13 below shows how such schemes would function to prevent sub-100 kV loop flow. When the greater than 100 kV line 1 breakers (breakers D and G) open, current may flow from the high voltage side (breaker E) through the low voltage bus and back to the high voltage side (breaker H). The custom scheme implemented at the substation will trip or run back generation to prevent over loads and sustained loop flows on the low voltage system.

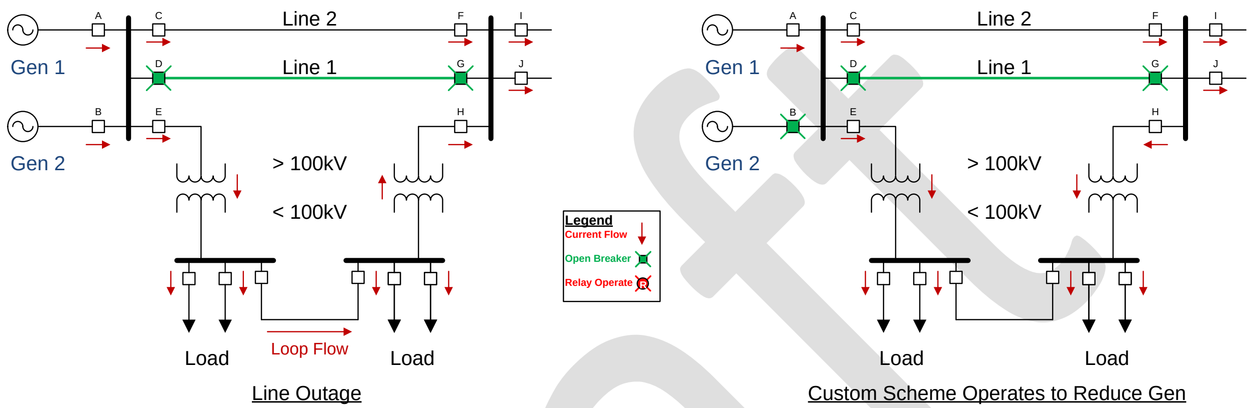


Figure 13. Custom Scheme Operations

Appendix 4 Summary

The issues and methods described in Appendix 4 are reflective of why, in most instances, conditions of sustained loop flows through sub-100 kV systems are alleviated. When the low voltage is much less than 100 kV, the design considerations shown above become even more pertinent and preventative methods are employed; BES reliability is not the main concern, protecting the equipment from physical damage is the primary concern. In the vast majority of cases, robust planning and operating criteria and procedures will alleviate any concerns regarding sustained loop flows.