Separation of Multiple Circuits in a Corridor
Reliability Subcommittee
November 6, 2012

Assignment

During the development of Project WECC-0071- TPL-001-WECC-CRT-2 System Performance Criterion PacifiCorp provided comments to Posting 3 and expressed concern about the revisions to the **Adjacent Transmission Circuits** definition and retirement of the **Common Corridor** definition (see Exhibit 1). Particularly, PacifiCorp is concerned with the revisions related to the spacing between center lines of Adjacent Transmission Circuits from "structure centerline separation less than the longest span length of the two transmission circuits at the point of separation or 500 feet, whichever is greater, between the transmission circuits" to "two transmission circuits with separation between their center lines less than 250 feet at the point of separation." (See Exhibit 1.) PacifiCorp believes that with a reduced separation, from 500 feet to 250 feet centerline, there is the potential for building more transmission lines within common right-of-way potentially resulting in more lines along a transmission corridor. The changes to the definitions were approved by WECC and the WECC Board of Directors on December 1, 2011, and in turn the definition became effective April 1, 2012. At its December 2011 meeting the WECC Board of Directors requested that the Planning Coordination Committee (PCC) review PacifiCorp's issue. Accordingly PCC gave the Reliability Subcommittee the following assignment.

1. Review and address the issue of reliability impact of high power flow with reduced separation,
2. Identify if there is a maximum amount of capacity in a corridor.

Reliability Subcommittee Analysis

Background

The issues of more than three lines in a corridor or in a close geographic area are not addressed by the old TPL – (001 thru 004) – WECC – CRT – 1 – System Performance Criteria or the new TPL-001-WECC-CRT-2 – System Performance Criterion. Current design practices are to design to an n-1-1 contingency event required by NERC Reliability Standards and under limited circumstances to a simultaneous n-2 contingency event WECC Criteria. There are provisions in NERC Standard TPL-004-1 in Requirement R1 that requires the planning authority (now planning coordinator) to demonstrate through a valid assessment that its portion of the interconnected transmission system is evaluated for the risks and consequences in compliance with the system performance requirement for Category D contingencies of Table I.[1] Such assessments are required to be made annually. The current system is not to specifically design for corridor outages, although in Requirement R1.3.1 NERC requires a rationale for the contingencies selected and an explanation of why remaining simulation would produce less severe system results.

[1] See NERC Reliability Standards for the Bulk Electric System of North America updated October 19, 2012 for TPL-004-0 requirements.

Reasons for Adoption of TPL-001-WECC-CRT-2

The reason for the adoption of the new Adjacent Transmission Circuits definition with a separation distance between center lines of 250 feet is to encourage transmission owners and transmission site regulators to consider placing adjacent circuits on separate tower structures rather than using double circuit towers. The justification for the change in centerline distance is provided in Exhibit 2 where the average annual outage data show that the number of two circuit outages within a 10 minute period reduces from 0.288 outages per 100 miles on a common structure to 0.136 outages per 100 miles on separate structures in a common right-of way. The data also suggest the average annual outage frequency for two circuits in a common right-of-way on separate towers is even less than the average annual outage frequency for two circuits not in a common right-of-way.

Causes of Outages for Multiple Transmission Elements

In the Western Interconnection the data indicate fire-caused outages are the most common cause for n-4 circuit outages related to corridors (see Exhibit 3). The Reliability Subcommittee recognizes there may be some reliability benefit by increasing the distance between circuits to address wildfires as recommended in the PacifiCorp comments. In our research we found that the wildfire forward-rate-of-spread varies depending upon fuel, moisture, humidity, topography, and temperature. Typically the forward-rate-of-spread is 6.7 miles-per-hour (690 ft/minute) when burning through forests and 14 miles-per-hour (1232 feet/ minute) when burning through grassland.[2] Keeping the separation distance between circuit centerlines to between 500 to 1500 feet may reduce the number of circuits lost during a 10 minute period as a result of fire. It may also allow system operators more time to adjust transfers and generation. However, operating centers typically either have procedures in place to be notified of wildfires by fire fighting organizations or by monitoring the news media. Thus system operators are quickly notified of most fire danger. As a result, today system operators know when there is a fire in the area and take corrective action in advance to minimize any adverse impact. The Reliability Subcommittee and entities in the Western Interconnection by their approval of TPL-001-WECC-CRT-2 – System Performance Criterion felt that the benefits obtained by encouraging entities to build parallel circuits on separate structures rather than on double circuit towers; however, results do not show enough justification for requiring separation distance between centerlines greater than 250 feet even when wildfire risks are considered.

The transmission outage data in Exhibit 3 suggest the likelihood of a substation-caused event resulting in the loss of multiple transmission lines is almost as common as wildfire-caused events. Many transmission owners have implemented substation design practices to try to minimize the loss of more than two transmission elements. Despite these efforts substation equipment continues to be a major cause of multiple transmission element outages. The substation-caused event frequency will not be improved by keeping the old centerline separation distance.

[2] Billing, P. Victoria Department of Sustainability and Environment. Otways Fire No. 22 - 1982/83 Aspects of fire behaviour. Research Report No.20 [PDF]; June 1983 [cited 2009-06-26].

The Reliability Subcommittee conducted an inventory of the existing transmission system to determine the number of transmission corridors with three or more transmission lines in the corridor and a rating greater than 3000 MVA. We found there are currently at least 23 corridors in existence with current ratings up to 5100 MW where circuits are within five miles of each other.[3] In addition to 23 corridors there are many substations that if lost would also result in the loss of large amounts of capacity. Current requirements mandate the studying of the loss of these corridors and substations. Transmission planners and planning coordinators are to conduct an evaluation for risk and consequences of the outage. Events resulting in the loss of a corridor or substation would generally rely on underfrequency or undervoltage load shedding to protect the Interconnection. If requirements were added to necessitate additional performance measures, such as requiring a safety net protection system to address the corridor or substation loss, the addition of the scheme may increase the likelihood of the event occurring because of added system complexity. Requiring safety net protection systems to address the loss of the corridor does not seem better than the load shedding requirements upon which we rely. The maximum amount of capacity to be allowed in a corridor depends upon the unloaded parallel transmission and the amount of load that entities are willing to shed. Since NERC and FERC accept the current load shedding practice to address multiple transmission element outages, proposing additional requirements does not seem warranted at this time.

The probability of extreme weather events, such as tornadoes that may cause multiple lines in a corridor to go out of service, is low in the Western Interconnection. The outage data in Exhibit 3 indicate lightning caused events and weather other than lighting associated with weather do happen. From a review of the inventory of existing corridors with three or more transmission lines with a rating greater than 3000 MVA, the areas do not seem prone to a large number of tornadoes. Most of the Western US experiences less than one tornado per year per 10,000 square miles.[4] Although the Interconnection experience several events caused by weather other than lightning, several of these multiple outage events also included failed AC substation equipment, which ultimately was responsible for the loss of multiple elements. As indicated in Exhibit 3 lightning caused events are often momentary outages and do not result in disturbance reports. Therefore, the current transmission system appears to be designed to address such outages resulting in an acceptable level of reliability for the Western Interconnection.

There are many transmission line and substation design refinements that could be proposed that may reduce the frequency of multiple transmission element outages and further reduce the risk posed by including multiple transmission circuits in a corridor. These include but are not limited to robust line design, increased separation between circuit center lines, enhancing lightning protection, or modifying reserve requirements. It might be appropriate to change to an n-2-1 design philosophy if the industry desires additional margin in the transmission system. It would be very difficult to determine through some type of study, which of those proposals might best address the concerns while at the same time

[3] It should be noted that it may be possible to have two lines with a rating greater than or equal to 3000 MVA, but it is assumed that the 250 feet separation definition applies most of these corridors. In addition n-2 outages are address in the outage rates of Exhibit 2. Therefore, n-2 outages greater than 3000 MVA were not included in this analysis.

[4] See National Climatic Data Center at http://www1.ncdc.noaa.gov/pub/data/cmb/images/tornado/clim/avg-ef0-ef5-torn1991-2010.gif.

deal with any environmental and societal concerns. These proposals may not foster an efficient use of the transmission facilities.

Each existing and proposed transmission element must comply with the current system performance requirements of the NERC Reliability Standards and WECC System Performance Criteria. If there are reliability concerns, transmission planners and planning coordinators may establish additional criteria to address those concerns. With the transmission studies currently required, potential system performance for common corridor outages should well known. The Reliability Subcommittee believes that the existing system and compliance with current requirements provides an acceptable level of reliability and is not proposing any additional enhancements.

Conclusions

In response to the PCC assignment and the review conducted above the Reliability Subcommittee believes that:

For the issue of reliability impact of high power flow with reduced separation

1. Fire is the most common cause of corridor related events. As shown in Exhibit 3, this has occurred 11 times. Current system operator procedures are used to mitigate the impact of fire on the Interconnection.
2. It is just as likely for multiple line outages to be caused by an event in a substation as it is for an event in the corridor. Requiring additional design measures without addressing many other possible system design enhancements does not appear to be prudent.
3. The outage data suggest that the frequency of double circuits outages per 100 mile is reduced by going from a double circuit tower to two single circuit towers, even when the towers are in a common right-of-way. Thus the intent of the refinements made to the TPL-001-WECC-CRT-2 is to encourage transmission owners to build more parallel circuits on separate towers. The outage data also suggest that requiring further separation would not provide a significant reduction in the outage frequency.
4. The separation distance between centerlines is just one of a myriad of factors that may cause multiple contingency outages. Multiple contingency outages are evaluated for risk and consequences.

For the issue of identifying if there is a maximum amount of capacity in a corridor

1. Current design and study practices along with compliance with the NERC Reliability Standards provide an acceptable level of reliability for the Western Interconnection. The current NERC study requirements address the loss of multiple transmission elements.
2. There are a few existing corridors with a large amount of capacity operating in the Western Interconnection. The mitigation for the loss of these multiple circuits is being addressed by undervoltage and underfrequency load shedding protection.

3. The maximum amount of capacity to be allowed in a corridor depends upon the unloaded parallel transmission and the amount of load that entities are willing to shed.

For the reasons summarized above, the Reliability Subcommittee does not believe it is necessary to take any action in reference to the issues raised by PacifiCorp at this time.

Exhibit 1

Definitions

New Definition

Adjacent Transmission Circuits Definition:

Adjacent Transmission Circuits are two transmission circuits with separation between their center lines less than 250 feet at the point of separation with no Bulk Electric System circuit between them. Transmission circuits that cross, but are otherwise separated by 250 feet or more between their centerlines, are not Adjacent Transmission Circuits.[5]

Retired Definitions

Common Corridor:

Contiguous right-of-way or two parallel right-of-ways with structure centerline separation less than the longest span length of the two transmission circuits at the point of separation or 500 feet, whichever is greater, between the transmission circuits. This separation requirement does not apply to the last five spans of the transmission circuits entering into a substation.

Adjacent Transmission Circuits:

Transmission circuits within a Common Corridor with no other transmission circuits between them. Transmission Lines that cross but are otherwise on separate corridors are not Adjacent Transmission Circuits.

Minority Opinion:

Darrell Gerrard, PacifiCorp

PacifiCorp thanks the WECC-0071 drafting team for the considerable effort that was put into the most recent draft and ballot. While PacifiCorp agrees with and supports some proposed changes, PacifiCorp cannot support the entirety of this proposed revision until the following concerns stated below can be adequately addressed.

New and proposed EHV (300KV and above) high capacity AC (1500MW) and DC lines (3000MW) are the essential components for a reliable BES. While the total number of line miles of EHV kV AC and DC lines are dwarfed by the number of miles of lower voltage transmission lines in the WECC, many High Capacity EHV lines are essential to the reliability and

[5] Project WECC-0071- TPL-001-WECC-CRT-2 System Performance Criterion

interconnected operation of the BES. As such, every effort must be taken to ensure they are operated to a high standard of reliability, and we must ensure that all new 500 kV or higher lines are constructed in such a manner so as to minimize the likelihood of common mode failure. In PacifiCorp's view, this cannot be accomplished if the physical separation requirement for the highest capacity lines is reduced generally. This is particularly important if the long range corridor plans for new transmission lines are considered. For example, in eastern Wyoming and Southwest Utah, multiple new EHV AC and DC lines have been proposed to move power from renewable and from other resources to load centers elsewhere in the Western Interconnection. A number of new or expanded existing line corridors have been proposed and are being analyzed in the NEPA process; if lines are sited via this proposed new criterion, several proposed corridors could contain existing and planned transmission lines with total transfer capacity in excess of 6000 MW. PacifiCorp is concerned that these corridors containing multiple High Capacity EHV lines will not be just "pinch points" or "physically constrained areas" but may run for hundreds of miles through geographic areas with a known history of fires, severe weather conditions and man-made interference. In order to accommodate these new lines, land use regulatory agencies have developed or are proposing new corridors intended to minimize physical and visual impacts of transmission lines. However, unless there are clearly defined and proscriptive separation requirements, one potential outcome will be to constrict all lines, regardless of their impact to the Western Interconnection, into as narrow a land space as possible. This may be desirable if only land management and environmental issues are considered; however, it would be counterproductive with respect to BES reliability to allow multiple EHV high capacity lines to share a corridor unless the separation between lines is significant. And, in PacifiCorp's view, 250 feet is not significant.

PacifiCorp agrees that adjacent circuits on separate structures below 300 kV can be moved from Category C to Category D when considering the consequences of simultaneous common mode outage without a significant impact to BES reliability. However, when High Capacity EHV AC or DC lines are considered, it is PacifiCorp's view that the criterion proposed in this ballot are not adequate to promote and maintain reliability for EHV lines as part of the BES.

PacifiCorp has previously suggested that detailed study and reporting of impacts due to Category (D) events, particularly "loss of entire corridor" events, be made a formal part of the WECC Three Phase Rating and Review Process and Policy. This would allow WECC and all interconnected parties to be made aware of the impacts related to multiple transmission lines in corridor outages, and to prudently avoid that risk where viable alternatives exist to do so. Therefore, PacifiCorp urges the drafting team to revisit this aspect of the proposed modification in this criterion with regard to High Capacity EHV transmission lines and its potential reliability impact to the Western Interconnection.[6]

[6] PacifiCorp Comments to Project WECC-0071 posting 3 October 6, 2011 and Minority Opinion from Darrell Gerrard, PacifiCorp submitted to WECC BOD for December 1, 2011 meeting.

Exhibit 2

Common Cause Outage Events[7]
For Transmission 230 kV and above
August 18, 2012

Event means two or more circuits went out of service.

		Circuits on Common Structure	Circuits on Common Right-of-Way Separate Structures	Circuits not on Common ROW or Structure
2011	Transmission miles	9,085	14,336	53,032
	Number of Events	17(16)[8]	20(19)[7]	107
	Number of Different commonalities	26(16)[7]	23(22)[7]	NA
	No. of Events/ 100 miles of line	0.187(0.176)[7]	0.139(0.132)[7]	0.202
2010	Transmission miles	9,219	14,954	52,734
	Number of Events	31	23	126
	No. of Events / 100 miles of line	0.336	0.153	0.239
2009	Transmission miles	8,386	15,530	50,709
	Number of Events	20	14	79
	No. of Events / 100 miles of line	0.238	0.090	0.155
2008	Transmission miles	8,386	15,530	47,975
	Number of Events	33	25	87
	No. of Events / 100 miles of line	0.393	0.160	0.181
Average	Transmission miles	8,769	15,088	51,113
	Number of Events	25.3	20.5	99.8
	No. of Outages/ 100 miles of line	0.288	0.136	0.195

[7] Common cause outage events:

1. Include momentary outages,
2. Include outages that are within 10 minutes of start time that became at least an n-2,
3. Do not include events with a transformer and circuit but include events with transformer and 2 circuit outages.
4. From WECC Transmission Reliability Data

[8] The numbers in parentheses are excluding the Southwest Outage.

Exhibit 3

Outage Summary

The Reliability Subcommittee further reviewed the Common Cause Outage Events data and if available disturbance reports of those events where there was the loss of four or more transmission lines within 10 minutes. During the 2008-2011 periods, there were 30 events (see Substation/Corridor Outage Summary below).

Substation/Corridor Outage Summary[9]
For Transmission 230 kV and above

Year	*Outage Events with 4 or more Transmission Elements Lost*	*Event Involved loss of Substation Equipment*	*Event Involved Lightning*	*Event involved Fire*	*Other Causes - Unknown, Weather excluding lighting, or Earthquake*
2008	15	8	1	3	3
2009	7	1	3	0	3
2010	14	4	0	8	2
2011	12	4	3	1	4

The following summary of the 2009-2011 outage events was developed.

1. **Lightning:** Lightning caused events are often momentary outages and do not have disturbance reports. However, there was one 2011 lightning report indicating the loss of 1,040 MW of generation and no load.
2. **Fire:** The 2008 fire events were as a result of two fires. The disturbance report indicates that 211 MW of load and 342 MW of generation were lost with the outages. All but one of the fire events in 2010 occurred over a two day period. The disturbance report indicates the loss of 518 MW of interruptible load and 656 MW of generation. The other unrelated 2010 fire event resulted in the loss of 1,600 MW of interruptible load and 2,529 MW of generation. In 2011 the one n-7 fire event resulted in the loss of 2,427 MW of generation and no load. The 2011 fire event resulted in the loss of 230 kV, 500 kV AC, and 500 kV DC lines.
3. **Earthquake:** The 2010 earthquake event resulted in the loss of 470 MW of load and 1,679 MW of generation.
4. **Unknown:** One of the unknown events in 2010 resulted in the loss of 2,122 MW of generation and 246 MW of load. One of the 2011 other events resulted in the loss of 37 MW of load and no generation. Another 2011 n-8 other event resulted in the loss of 558 MW of generation. This n-8 event had the loss of only 230 kV lines.

[9] With 48 events in four years meeting the selection criteria, any conclusions drawn from the data should be used cautiously. This is a very limited sample.

5. **San Diego:** The 2011 San Diego event resulted in the loss of approximately 7,400 MW of load and 7,000 MW of generation.
6. **Substation:** Events related to substations equally affect transmission on common towers, common rights-of-way, and not on common rights-of-way.
7. **General:** During the two years there were four momentary outages that did not generate a disturbance report. Where no disturbance report is developed, there was probably no loss of load or generation.
8. **Weather other than lightning events:** Several of the multiple outage events with a cause of weather other than lightning also included failed AC substation equipment, which ultimately was responsible for the loss of multiple circuits.