

TPL-001-4

Transmission System Planning Extreme Event Analysis

Michael Herman
Transmission Planning
Special PC - CISO
September 22, 2020

- PJM has previously provided education on CIP-014 as part of the Special PC – CISO:
 - <https://www.pjm.com/-/media/committees-groups/committees/pc/2020/20200127-special/20200127-item-04-cip-014-2-standard-and-pjm-process-for-compliance.ashx>

- Background

- Consistent with the NERC TPL-001-4 Standard, PJM staff annually studies extreme events to evaluate their impact on the transmission system. Extreme events exceed the criteria associated with types of events studied in TPL-001-4 P0-P7 for Steady State & Stability Performance Planning Events. Extreme events are those defined by NERC in Table 1 – Steady State & Stability Performance Extreme Events of TPL-001-4.

- TPL-001-4 Requirement 3.2 & 3.5:
 - 3.2. Studies shall be performed to assess the impact of the extreme events which are identified by the list created in Requirement R3, Part 3.5.
 - 3.5. Those extreme events in Table 1 that are expected to produce more severe System impacts shall be identified and a list created of those events to be evaluated in Requirement R3, Part 3.2. If the analysis concludes there is cascading caused by the occurrence of extreme events, an evaluation of possible actions designed to reduce the likelihood or mitigate the consequences and adverse impacts of the event(s) shall be conducted.

- NERC TPL-001-4 Standard defines the following categories of extreme events related to steady state and stability performance:

Table 1 – Steady State & Stability Performance Extreme Events

Steady State & Stability

For all extreme events evaluated:

- Simulate the removal of all elements that Protection Systems and automatic controls are expected to disconnect for each Contingency.
- Simulate Normal Clearing unless otherwise specified.

Steady State

- Loss of a single generator, Transmission Circuit, single pole of a DC Line, shunt device, or transformer forced out of service followed by another single generator, Transmission Circuit, single pole of a different DC Line, shunt device, or transformer forced out of service prior to System adjustments.
- Local area events affecting the Transmission System such as:
 - Loss of a tower line with three or more circuits.¹¹
 - Loss of all Transmission lines on a common Right-of-Way¹¹.
 - Loss of a switching station or substation (loss of one voltage level plus transformers).
 - Loss of all generating units at a generating station.
 - Loss of a large Load or major Load center.
- Wide area events affecting the Transmission System based on System topology such as:
 - Loss of two generating stations resulting from conditions such as:
 - Loss of a large gas pipeline into a region or multiple regions that have significant gas-fired generation.
 - Loss of the use of a large body of water as the cooling source for generation.
 - Wildfires.
 - Severe weather, e.g., hurricanes, tornadoes, etc.
 - A successful cyber attack.
 - Shutdown of a nuclear power plant(s) and related facilities for a day or more for common causes such as problems with similarly designed plants.
 - Other events based upon operating experience that may result in wide area disturbances.

Stability

- With an initial condition of a single generator, Transmission circuit, single pole of a DC line, shunt device, or transformer forced out of service, apply a 3Ø fault on another single generator, Transmission circuit, single pole of a different DC line, shunt device, or transformer prior to System adjustments.
- Local or wide area events affecting the Transmission System such as:
 - 3Ø fault on generator with stuck breaker¹⁰ or a relay failure¹³ resulting in Delayed Fault Clearing.
 - 3Ø fault on Transmission circuit with stuck breaker¹⁰ or a relay failure¹³ resulting in Delayed Fault Clearing.
 - 3Ø fault on transformer with stuck breaker¹⁰ or a relay failure¹³ resulting in Delayed Fault Clearing.
 - 3Ø fault on bus section with stuck breaker¹⁰ or a relay failure¹³ resulting in Delayed Fault Clearing.
 - 3Ø internal breaker fault.
 - Other events based upon operating experience, such as consideration of initiating events that experience suggests may result in wide area disturbances

- **Non-Converged Contingencies**
 - These types of events may involve substantial loss of customer load and generation in a widespread area. The system may not achieve a new stable operating point following these types of events. If analysis concludes there is cascading caused by the occurrence of extreme events, PJM performs an evaluation of possible actions designed to reduce the likelihood or mitigate the consequences and adverse impacts of the event(s) by coordinating studies with PJM Operations based on the result of this analysis.

- **Stability Analysis**

- Analysis is conducted for a near-term (years one through five) study by a current 4 year out RTEP stability Case, which shows system performance following an Extreme Event contingency as listed in Table 1 of TPL-001-4.
- Analysis is performed annually regardless of system changes and includes existing and planned facilities as well as all projected firm transfers consistent with the corresponding RTEP case
- Reactive power resources are included consistent with the corresponding RTEP case to ensure that adequate reactive resources are available to meet system performance. All effects of existing and planned protection and control devices including backup and redundant systems are also studied.

- **Stability Monitored Elements and Contingencies**
 - PJM considers all contingencies applicable to TPL-001-4 Extreme Events
 - PJM works closely with its Transmission Owners to develop the list of contingencies to be studied as part of the Extreme Event Analysis testing.
 - PJM performs analysis of all extreme events, regardless of the expectation to produce more severe system impacts. PJM's rationale for using the above method is that by studying all events as defined in the stability portion of Table 1 in TPL-001-4, PJM will identify all potential results

- Annual results from planning analysis is reviewed with PJM operations to determine if actions designed to reduce the likelihood or mitigate the consequences and adverse impacts of the event(s) are needed.
- Extreme Event analysis results are documented in the annual Extreme Event analysis report.
- Contingency definitions, analytical results and report are all confidential

- CIP-014 approach identified “Less than 20” facilities
- Approximately 30% of “Less than 20” events overlap with existing extreme event contingencies
 - CIP-014 evaluates substations with single or multiple voltage levels
 - Extreme contingencies only look at single voltage level events at substations per TPL-001
- Extreme Event package, will likely identify a larger number of facilities (approximately 350 findings in 2019).
 - This number is reduced to approximately 250 facilities based on stakeholder suggestion to use load dump ratings, and reduces to approximately 40 facilities when using load dump and limit the analysis to only incorporating substation contingencies
 - 40 facilities leaves ~70% of CIP substations unidentified
 - All BES substations in PJM footprint exceeds 4000 stations
 - If multiple voltage levels or BES substations incorporated into extreme contingencies, number of violations is expected to increase significantly above 40

Appendix



Substation Extreme Events (Based on Load Dump Rating)

Contingency Event	Number of Thermal Overloads Lines (Rate C)	Number of Voltage Violations (Rate C)
Sub Event #1		2
Sub Event #2	1	
Sub Event #3		1
Sub Event #4		1
Sub Event #5	1	
Sub Event #6	1	
Sub Event #7		2
Sub Event #8		2
Sub Event #9	1	
Sub Event #10		2
Sub Event #11	1	2
Sub Event #12		1
Sub Event #13		2
Sub Event #14		1
Sub Event #15	1	
Sub Event #16	1	
Sub Event #17	1	2
Sub Event #18	1	
Sub Event #19		1
Sub Event #20	1	
Sub Event #21	1	2
Sub Event #22		1
Sub Event #23		1
Sub Event #24	1	
Sub Event #25		1
Sub Event #26		1
Sub Event #27		1
Sub Event #28		1
Sub Event #29		1
Sub Event #30		1
Sub Event #31	1	2
Sub Event #32	1	1
Sub Event #33		2