

additional facilities are also taken out of service in the contingency definition. For example, if a transformer is tapped off a line without a breaker, both the line and transformer are removed from service as a single contingency event.

Contingency definitions for double circuit towerline outages shall include any two adjacent (vertically or horizontally) circuits on a common structure, but shall exclude circuits that share a common structure for one mile or less. The loss of more than two circuits on a common structure constitutes a NERC extreme event.

2.3.6 Baseline Thermal Analysis

Baseline thermal analysis is a thorough analysis of the reference power flow to ensure thermal adequacy based on normal (applicable to system normal conditions prior to contingencies) and emergency (applicable after the occurrence of a contingency) thermal ratings specific to the Transmission Owner facilities being examined. It is based on a 50/50 load forecast from the latest available PJM Load Forecast Report (50% probability that the actual load is higher or lower than the projected load.) It encompasses an exhaustive analysis of all NERC category A, B and C events and the most critical common mode outages. Final results are supported with AC power flow solutions.

For normal conditions (NERC category A), all facilities shall be loaded within their normal thermal ratings. ~~After-For~~ each single contingency (NERC category B), all facilities shall be loaded within their emergency thermal ratings. After each single contingency and allowing existing and planned control devices equipment is are allowed to adjust such as transformer tap changers, switching reactive devices except phase shifter, re-dispatch and topology changes to be made, (phase shifter is locked at constant angle) and the post-contingency loadings of all facilities shall be within their applicable emergency normal thermal ratings. (long term or short term)

For the more severe NERC category C contingencies, along with only transformer tap and switched shung adjustments enabled, all existing and planned control devices are allowed to adjust such as transformer tap changers, switched reactive devices except phase shifter (phase shifter is at constant angle) such that the post-contingency loadings of all facilities shall be within their applicable emergency thermal ratings as required by the PJM or the Transmission Owner planning criteria. The study procedure for the NERC category C.3 contingencies (N-1-1) is described in detail in section 2.3.x.

2.3.7 Baseline Voltage Analysis

Baseline voltage analysis parallels the thermal analysis. It uses the same power flow and examines voltage criteria for all the same NERC category A, B, and C events. PJM examines system performance for both a voltage drop criteria (where applicable) and an absolute voltage criteria. The voltage drop is calculated as the decrease in bus voltage from the initial steady state power flow to the post-contingency power flow. The post-contingency power flow is solved with generators holding a local generator bus voltage to a pre-contingency level consistent with specific Transmission Owner specifications. In most instances this is the pre-contingency generator bus voltage. Additionally, all phase shifters, transformer taps, switched shunts, and DC lines are locked for the post-contingency solution. SVC's are allowed to regulate and fast switched capacitors are enabled.

The absolute voltage criteria is examined for the same contingency set by allowing transformer taps, switched shunts and SVC's to regulate, locking phase shifters and

allowing generators to hold steady state voltage criteria (generally an agreed upon voltage on the high voltage bus at the generator location.)

In all instances, specific Transmission Owner voltage criteria are observed. All violations are recorded and reported and tentative solutions will be developed. These study results will be presented to and reviewed with stakeholders.

2.3.X NERC Category C3 “N-1-1” Analysis

Purpose:

N-1-1 studies are conducted as part of the annual RTEP to determine if all monitored facilities can be operated:

- Within normal thermal and voltage limits after N-1 (single) contingency assuming after redispatch and system adjustments, and
- Within the applicable emergency thermal ratings and voltage limits after an additional single-contingency (N-1-1) condition.

All violations of the applicable thermal ratings are recorded and reported and tentative solutions will be developed. These study results will be presented to and reviewed with stakeholders.

Model:

Annually, the N-1-1 study is conducted on a 50/50 non-diversified summer peak case. The case building details are defined in Attachment C (C7 3.0 Step 1: Develop Base Case). Non-firm Merchant Transmission TX withdrawals can be removed. All BES facilities in PJM and ties to PJM will be monitored. Areas of the system that become radial post-contingency will be excluded from monitoring, with the following exceptions

- If the radial system contains greater than 300 MW of load, or
- Specific local TO Planning Criteria requires that it be monitored.

Contingencies considered:

- All BES single contingencies as defined in NERC category C.3 as well as lower voltage facilities that are monitored by PJM Operations will be tested included in the assesment. Non-BES contingencies, -defined by Transmission Owners, need to be included to check for greater than 300 MW load loss. Non-BES facilities that are included in the assesment will also have corresponding contingencies defined.

AC Solution Options in the PSS/E program:

- For the first single contingency (N-1 Condition) and to ensure the system remains within emergency thermal ratings
 - Transformer tap adjustment enabled

- Phase shifter adjustment enabled
- Switched shunt adjustment enabled
- After the first single contingency (N-1 Condition) and to return the system back within normal thermal ratings
 - Phase shifter adjustment enabled
 - System re-dispatched
 - Topology changes implemented
- For the second single contingency (N-1-1 Condition) – Voltage Drop Test (if applicable)
 - Transformer tap adjustment disabled
 - Phase shifters locked to control angle, not flow
 - Switched shunt adjustment disabled except for fast switched capacitors
 - Generators are set to regulate their terminal bus
 - SVC's are allowed to regulate
 - Automatic shunt adjustment disabled
- For the second single contingency (N-1-1 Condition) – Thermal and Voltage Magnitude Test
 - Transformer tap adjustment enabled
 - Phase shifters locked to control angle, not flow
 - Switched shunt adjustment enabled
 - Automatic shunt adjustment enabled

PJM NERC Category C3 “N-1-1” Methodology:

Thermal Test Methodology:

The PJM NERC Category C3 “N-1-1” Analysis will test the outage of every single contingency (N-1 condition)

1. The first step of the test is to ensure that post-contingency loadings of all facilities shall be within their normal emergency thermal ratings immediately following the first N-1 contingency event and subsequent system adjustments. The PJM NERC Category C3 “N-1-1” Analysis will test the outage of every single contingency (N-1 condition). After the first single contingency, system adjustment is allowed to bring the loading of all monitored facilities to within their normal ratings including redispatch in preparation for the next contingency. Allowable system adjustments include generation dispatch, phase shifter adjustment, system reconfiguration, and load throwover.
2. The second step of the test is to ensure that post contingency loadings of all facilities shall be within their normal thermal ratings after the first N-1 contingency and subsequent re-dispatch and system adjustments. Allowable system adjustments include generation dispatch, phase shifter adjustment, system reconfiguration and load throwover. Wind, solar, and other variable resources will be dispatchable up to their capacity delivery rights if they back off simulated facility loadings. The rest of resources can be either off line or dispatched between Pmin and (1 – PJM generator average outage rate) * Pmax If system adjustment cannot bring the loading of a

~~facility to within its normal ratings, the facility will be considered a reliability criteria violation and a mitigation plan will be needed.~~

3. ~~The third step is to take For the second N-1-1 single contingency.~~ ~~Every second N-1-1 single contingency is taken on every optimized N-1 scenario case to model the N-1-1 condition. After the second N-1-1 contingency, t~~ ~~The thermal loading of any monitored facility that is above the applicable emergency thermal ratings (long-term or short-term) is considered a reliability criteria violation and a mitigation plan will be needed.~~

Voltage Drop Test Methodology:

The N-1-1 Voltage Drop Test procedure follows a similar method as the thermal test method, except all monitored facilities are monitored for the emergency voltage drop limit after the second contingency (N-1-1 condition.) The calculation of voltage drop is defined in section 2.3.7.

Voltage Magnitude Test:

The N-1-1 Voltage Magnitude Test procedure follows a similar method as the thermal test method, except all monitored facilities are monitored for the emergency low limit after the second contingency (N-1-1 condition.)

Voltage Collapse:

Voltage collapse is considered ~~asto~~ be a severe reliability violation, and ~~consequently~~ each N-1-1 condition that exhibits voltage collapse needs to be investigated, validated, and resolved with remedial actions, or network upgrades.

System Adjustments:

Allowable System Adjustments following the first contingency (N-1 condition):

- Application of all effective actions and emergency procedures, with the exception of load ~~dump~~shedding
- Redispatch using only PJM generators with capacity rights during the generation redispatch process
- Application of a PJM pool-wide generation availability rate during generator re-dispatch to ensure that the re-dispatch is statistically possible
- Un-faulted facilities in multiple facility outages may be restored
- Manual system switching and re-configuration
 - Opening of transmission facilities
 - Including bus-ties
 - Closing of non-faulted transmission facilities
 - Including bus-ties
- Adjustment of Static Var Compensators (SVCs)
- Phase shifter adjustment
- ~~Acceptable load loss as defined in Attachment D-1~~

- [Wind, solar, and other variable resources will be dispatchable up to their capacity delivery rights if they back off simulated facility loadings.](#)
- [The rest of resources can be either off line or dispatched between Pmin and \(1- PJM generator average outage rate\)* Pmax](#)

[Non-Allowable System Adjustments following the first contingency \(N-1 condition\):](#)

- [Unacceptable load loss as defined in Attachment D-1](#)

[Allowable System Adjustments following the second contingency \(N-1-1 condition\):](#)

- [No manual system adjustments permitted](#)

2.3.8 Load Deliverability Analysis

The load deliverability tests are a unique set of analyses designed to ensure that the Transmission System provides a comparable transmission function throughout the system. These tests ensure that the Transmission System is adequate to deliver each load area's requirements from the aggregate of system generation. The tests develop an "expected value" of loading after testing an extensive array of probabilistic dispatches to determine thermal limits. A deterministic dispatch method is used to create imports for the voltage criteria test. The Transmission System reliability criterion used is 1 event of failure in 25 years. This is intended to design transmission so that it is not more limiting than the generation system which is planned to a reliability criterion of 1 failure event in 10 years.

Each load areas' deliverability target transfer level to achieve the transmission reliability criterion is separately developed using a probabilistic modeling of the load and generation system. The load deliverability tests described here measure the design transfer level supported by the Transmission System for comparison to the target transfer level. Transmission upgrades are specified by PJM to achieve the target transfer level as necessary. Details of the load deliverability procedure can be found in Attachment C.

Thermal

This test examines the deliverability under the stressed conditions of a 90/10 summer load forecast. That is, a forecast that only has a 10% chance of being exceeded. The transfer limit to the load is determined for system normal and all single contingencies (NERC category A and B criteria) under ten thousand load study area dispatches with calculated probabilities of occurrence. The dispatches are developed randomly based on the availability data for each generating unit. This results in an expected value of system transfer capability that is compared to the target level to determine system adequacy. As with all thermal transmission tests applied by PJM the applicable Transmission Owner normal and emergency ratings are applied. The steady state and single contingency power flows are solved consistent with the similar solutions described for the baseline thermal analyses.

Voltage

This testing procedure is similar to the thermal load deliverability test except that voltage criteria are evaluated and that a deterministic dispatch procedure is used to increase study