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) 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 ratings. After each single contingency (NERC category B), all existing and planned control ~~equipment~~ devices are~~is~~ allowed to adjust such as transformer tap changers, switching reactive devices except phase shifter (phase shifter is constant angle) and the post-contingency loadings of all facilities shall be within their applicable emergency ratings (long-term or short-term).

For the more severe NERC category C contingencies, ~~all control equipment is allowed to adjust~~all existing and planned control devices are allowed to adjust such as transformer tap changers, switching 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 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 below and with more detail in section 2.3.x.

~~After the first contingency of a multiple-contingency event (NERC category C.3, also referred to as an "N-1-1" event), all system adjustments are allowed to achieve a new steady state power flow, including redispatch in preparation for the next contingency. Wind, solar, and other variable resources will be dispatchable up to their Maximum Facility Output if they contribute to simulated facility loadings and will be dispatchable up to their capacity delivery rights if they back off simulated facility loadings. Subsequent to redispatch and other system adjustments, all facilities must be within their normal ratings. After the second contingency of the pair, all control equipment is allowed to adjust except for phase shifters which are locked to control angle and do not adjust to hold flow. All facilities loadings must be within their applicable emergency ratings (long-term or short-term). All violations of the applicable ratings are recorded and reported and tentative solutions will be developed. These study results will be presented to and reviewed with stakeholders.~~

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.

~~In lieu of a voltage drop criteria, a more stringent voltage stability analysis can be conducted. Criteria violations will be based on post contingency system voltage instability instead of a pre-determined voltage drop value from a post-contingency voltage drop analysis.~~

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

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

Annually, the N-1-1 study is conducted on a 50/50 non-diversified summer peak case. Non-firm MTX 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 require 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 will be tested. Non-BES contingencies need to be included to check for greater than 300 MW load loss.

AC Solution Options in the PSS/E program:

- For the first single contingency (N-1 Condition)
  - Transformer tap adjustment enabled
  - Phase shifter adjustment enabled
  - Switched shunt adjustment enabled
- 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
  - 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:

1. The first step of the test is to ensure that post-contingency loadings of all facilities shall be within their normal ratings following the first N-1 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. 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 rating, the facility will be considered a reliability criteria violation and a mitigation plan will be needed.

2. For the second single contingency, every single contingency is taken on every optimized N-1 scenario case to model the N-1-1 condition. After the contingency, the thermal loading of any monitored facility that is above the applicable emergency 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 normal low voltage limit after the~~

~~first contingency (N-1 condition) and~~ the emergency low voltage limit after the second contingency (N-1-1 condition.)

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 as a severe reliability violation, and 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 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 redispatch to ensure that the redispatch 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, soalr 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 either be off line of 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