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Classification of Bulk Power System Elements

Document A-10 Review

Phase 2 – Final Report

Revision 1

Prepared by

CP-11 Working Group on

Review of NPCC Basic Criteria

Submitted to

NPCC Task Force on Coordination of Planning

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1	Revised as per TFCP and TFSS Task Forces comments	November 23, 2018
0	Initial release	October 31, 2018

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Executive Summary

In accordance with the NPCC Reliability Assessment Program, a comprehensive review of the NPCC *Classification of Bulk Power System Elements* (Document A-10) was initiated in 2017 by the Task Force on Coordination of Planning (TFCP) and has been conducted by the TFCP Working Group on Review of Basic Criteria (CP-11).

The goal of the review was to consider existing and alternative methodologies to identify critical bulk power system facilities for the applicability of NPCC Directories, simplify methodology to a make it less resource-intensive, and improve consistency across Areas in application and outcomes of the methodology.

This report summarizes CP-11's Phase 2 findings and recommendations, which are based on the comprehensive research and testing of proposed methodologies developed during Phase 1 of this review.

The three methodologies that were proposed at the end of in Phase 1 were developed to identify critical elements for Directory 1 and Directory 4 applicability. The three proposed methodologies tested were:

- **Methodology 1: Revised Existing A-10 Test**. It includes revisions to the existing performance-based test such as changes to base case setup, testing assumptions, testing methodology, testing strategy, and performance requirements. Under this methodology, a single test would be used to identify critical facilities for Directory 1 and Directory 4 applicability.
- **Methodology 2: Performance-based Test**. This methodology encompasses two distinct tests: the revised existing A-10 test (as per Methodology 1) for applicability of Directory 4 requirements as well as a new flow-based test (the "flow test") for applicability of Directory 1 requirements.
- **Methodology 3: Connectivity-Based Methodology**. This methodology is a connectivity-based methodology, which is a combination of a voltage bright line, an active power generation threshold, and a point system based on number and type of elements connected to the bus under test. Under this methodology, a single test would be used to identify critical facilities for Directory 1 and Directory 4 applicability.

After evaluating the three proposed methodologies, and in accordance with Task 1 of the Phase 2 Action Plan, CP-11 recommends Methodology 1 as the preferred methodology for classification of BPS buses. The proposed methodology identifies facilities critical for the applicability of

Directory 4 and, by deploying the exclusion process, identifies facilities critical for the applicability of Directory 1.

This methodology complies with Principle 1 (identification of critical facilities for the applicability of NPCC Directories 1 and 4) and Principle 2 (consistency of application and outcomes) of the TFCP methodology evaluation criteria. The refinements to the existing A-10 methodology such as testing strategy, and treatment of DCB protections and of adjacent circuits on common towers support the third principle, simplicity.

The exclusion process of facilities not critical to Directory 1 will be applied on a voluntary basis. CP-11 recommends the automatic exclusion[1] of the following elements from Directory 1 applicability:

- Single-terminal elements connected to BPS buses
- Multi-terminal elements that connect BPS buses to non-BPS buses that are a part of a radial subsystem.

In addition, a study-based exclusion process in line with the existing Directory 1 exclusion provisions[2] for the remaining multi-terminal elements connected to BPS buses will be further investigated.

CP-11 recommends that the methodology produces two lists: a list of buses critical for Directory 4 applicability, and a list of elements critical for Directory 1 applicability (or a list of excluded elements).

In accordance with Task 2 of the Phase 2 Action Plan, CP-11 has reviewed the objectives of each NPCC Directory[3] in relation to identified BPS Elements. Based on this review, CP-11 recommends that NPCC clarify the common applicability language within Directories 2, 5, 6, 7, 11 and 12. More details are presented in section 4 of this report.

In accordance with Task 3 of the Phase 2 Action Plan, CP-11 has identified several direct and indirect consequences of the preferred methodology. The most consequential of these is an Area's change in the list of BPS Elements and the compliance to Directories 1, 4 and 11 requirements associated with those changes. It is expected that implementation plans will be

[1] Qualifications will be introduced in the A-10 Document for automatic exclusion to prevent inadvertent exclusion of elements that could have a material impact under certain system condition.
[2] Directory 1: "Loss of small or radial portions of the system is acceptable provided the performance requirements are not violated for the remaining bulk power system."
[3] CP-11 did not conduct a review of Directories 9 and 10 as the directories are approved to retire on July 1, 2019.

required if additional new BPS facilities are identified.[4] More details are presented in section 5 of this report.

After endorsement from both TFCP and RCC and in accordance with Task 4 of the Phase 2 Action Plan, CP-11 will revise NPCC Document A-10 to reflect these recommendations for formal Member comment within NPCC's Open Process.

[4] BPS lists produced as a result of CP-11's Phase 2 testing are not approved NPCC BPS facilities and are not to be used for compliance purposes.

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1. Introduction

This Phase 2 Final Report was prepared by the Working Group on Review of NPCC Basic Criteria (CP-11) for the Task Force on Coordination of Planning (TFCP).

The interconnected, international Bulk Electric System is a network without geographic or national boundaries and the failure of one portion of the network could propagate to other areas, potentially affecting several jurisdictions. Therefore, a common approach is required to identify and designate critical facilities. Within northeastern North America, the Northeast Power Coordinating Council (NPCC) Document A-10 provides a methodology for identifying Bulk Power System elements (BPS), or parts thereof, of the interconnected facilities in the NPCC Region that are critical to the reliable operation of the interconnected system. Figure 1 is a map of the NPCC Region illustrating its main Areas: New York, New England, the Maritimes, Québec and Ontario.

Figure 1: Map of NPCC

The Task Force on Coordination of Planning (TFCP) is currently reviewing the A-10 methodology and in March 2017, the CP-11 Working Group was formally tasked with a comprehensive review of the A-10 methodology. In its scope of work (refer to Appendix A), TFCP highlighted three main areas of interest to focus the effort:

1. Identify critical facilities for the applicability of NPCC Directories;
2. Simplify the existing methodology to make it less labor intensive;
3. Improve consistency across Areas in application and outcomes of the methodology.

In October 2017, CP-11 presented a Phase 1 report to the TFCP which included proposed revisions to the existing methodology and proposals for new alternative methodologies.

This report presents the evaluation of the different methodologies discussed in the Phase 1 report and selects the preferred methodology for identifying critical facilities. The preferred methodology is a revised existing methodology that makes a series of revisions to the existing A-10 methodology. Subsequent to TFCP and RCC approval of the selected methodology, CP-11 will revise NPCC Document A-10 for Member consideration in the NPCC Open Process.

CP-11 believes that the proposed revisions to the existing methodology will achieve the goal of better uniformity among the NPCC Areas in the application of the BPS classification test, while still identifying critical elements for the applicability of Directories 1 and 4. Although the proposed methodology remains labor-intensive, certain recommended revisions to the methodology are expected to have the impact of reducing the engineering effort required to identify those facilities critical to the interconnected Bulk Power System.

All NPCC Directory Applicability sections currently refer to facilities defined as NPCC BPS elements. As part of the Phase 2 effort, CP-11 has made applicability recommendations for some of the Directories as they relate to the list of identified facilities in accordance with the recommended A-10 methodology. CP-11 believes that the Applicability sections for the remaining NPCC Directories should be reviewed and revised to better reflect the individual intent of each Directory.

Commonly Used Terms:

Throughout this report the following terms will be utilized and are defined as follows:

Bulk Power System (BPS) - the NPCC Bulk Power System (BPS) which is the subject of this report is to be distinguished from the generalized definition of Bulk Power System as defined in the NERC Glossary. For the remainder of this report the term BPS facilities will be read or understood to include BPS Buses and BPS Elements using the NPCC definition for BPS Facilities either existing or proposed by the CP-11 Working Group.

Bus – as defined in the existing NPCC Document A-10

Uncleared locally – as defined in the existing NPCC Document A-10

Critical – the term critical is used in the report to describe elements or buses that are critical for NPCC Directory applicability, in line with the objective of CP-11 to “Identify critical facilities for the applicability of NPCC Directories”; it should not be interpreted as the same meaning as used in Directory 1 – Table 1 - Contingency Events.

2. Methodologies: Testing and Evaluation

2.1 Background

During Phase 1 of the CP-11 Working Group's efforts, several different methods of classifying buses and elements were examined. These included tests based on stability performance (like the existing A-10 test), steady-state power flow, topology, operating voltage, and short-circuit strength. While each of these ideas were considered, many were eliminated as preliminary testing showed that they were not adequately identifying critical locations within the NPCC power system. The Working Group eventually settled on three main methodologies that would eventually be brought forward for detailed testing in Phase 2 of the Working Group's efforts during 2018. These methodologies are as follows:

- Methodology 1: Like the existing A-10 test, applicability of both Directory 1 and Directory 4 are determined through the application of a three-phase fault at the bus under test, uncleared locally, with remote clearing. Incremental revisions in the existing A-10 test were made in the areas of base case setup, testing methodology, testing procedures, and performance requirements.
- Methodology 2: Directory 1 applicability would be determined through an examination of the steady-state real power flows through the bus under test. Directory 4 applicability would continue to be determined through a three-phase fault at the bus under test, uncleared locally, with remote clearing (as with the existing A-10 test). The Directory 4 applicability test would include the same incremental revisions proposed for Methodology 1.
- Methodology 3: Applicability of both Directory 1 and Directory 4 would be determined through a test based on a combination of a voltage bright line, an active power generation threshold, and a point system based on number and type of elements connected to the bus under test.

All three methodologies were evaluated against a set of criteria provided to CP-11 by TFCP.

During testing and evaluation of these proposals, CP-11 was committed to remaining true to the intent of the A-10 criteria (as stated below), which is to identify the critical facilities of the power system for which more stringent protection, planning and operating criteria should apply. Specifically, CP-11 evaluated the different methodologies to identify critical facilities for Directory 1 and Directory 4 applicability.

> *"The purpose of the A-10 methodology is to provide a uniform NPCC approach in the planning horizon to identify those critical power system facilities within the NPCC region where faults or disturbances can have a significant adverse impact outside of the local*

area. The outcome of the existing A-10 methodology is to determine to which facilities the NPCC protection, planning and operating criteria are applicable."

The methodologies discussed in this section were the focus of the Working Group's Phase 2 scope of work, including comprehensive testing of methodologies 1 and 2.

The full list of evaluation criteria from TFCP can be found in Appendix B.

2.2 Methodology 1

2.2.1 Description and Directory Applicability

Methodology 1 consists of a single test for both Directory 1 and Directory 4 applicability. The methodology identifies list of buses critical for Directory 4 applicability, and a well as a list of elements critical for Directory 1 applicability. This proposal retains the use of the locally uncleared three-phase fault test, as used in the existing A-10 methodology. CP-11 has retained this approach to BPS classification as one of the tested methodologies because it is a very good test for determining where robust protection, control and telecommunication facilities are required to assure reliable operation of the interconnected system, in accordance with NPCC Directory 4.

As part of the test, a three phase fault is applied at the bus under test and all elements connected to the bus are removed via remote clearing ties and the impacts on the remaining system are evaluated. This methodology can be a way to identify locations where Directory 1 contingencies could cause major impacts (widespread instability, cascading failure, etc.). CP-11 recognizes that the loss of all elements at the bus may not identify all worst-case scenarios, including N-1-1 loss of elements at different substations, contingencies on adjacent circuits on common towers that do not emanate from a single bus, and situations where leaving some elements at a bus connected may be worse than the loss of all elements at the bus. However, the locally uncleared three-phase fault test was determined to be a good proxy for determining buses that are critical locations for the application of Directory 1.

In addition, a refined, and voluntary, element-by-element classification is proposed to exclude facilities that are not critical to Directory 1 applicability.

Considering this, Methodology 1, in accordance with the TFCP Scope of Work, seeks to maintain the framework of the existing A-10 performance-based test, while improving the clarity and consistency of the testing procedure. This complies with Principle 1 (Identify Critical Facilities for the applicability of NPCC Directories – Directory 4 and Directory 1) of TFCP's evaluation criteria for the A-10 methodologies.

CP-11 has proposed changes to the setup of base cases for A-10 testing to use cases that are reflective of typical stressed operations, but not of the absolute worst-case conditions possible. While this could result in operation in a state that has not been tested for BPS classification, CP-11 has acknowledged that the BPS test is a classification test, and not a planning or operations criteria. No requirement in A-10 shall be construed to prohibit operation in a state unstudied in BPS classification testing or in a state where a locally uncleared three-phase fault would lead to unacceptable impacts outside of the Area.

While maintaining the overall framework of the test, CP-11 had also acknowledged a certain number of concerns of the methodology throughout Phase 1. These concerns were mainly related to the sensitivity of the test results to changes in base case setup and system conditions, the lack of consistency in input assumptions and results among NPCC Areas, and the amount of time and engineering analysis required to complete the test. To address these concerns, CP-11 has proposed several incremental changes to the existing methodology.

Figure 2: Methodology 1 Flowchart illustrates the overall summary of the BPS classification process. A short summary of the incremental revisions to the existing A-10 methodology as proposed by CP-11 follows. Additionally, a full description of each proposed revisions, along with the rationale for the change, can be found in Appendix C of this report.

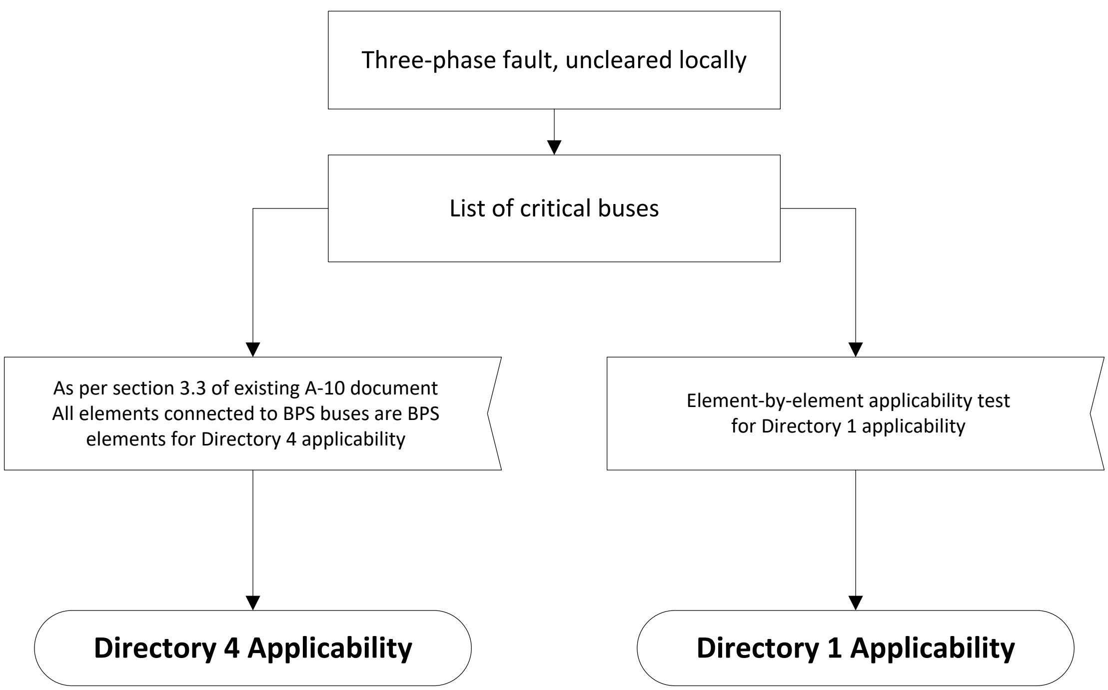

Figure 2: Methodology 1 Flowchart

2.2.2 Proposed Revisions to Existing A-10 Test

2.2.2.1 *Testing Strategy*

The existing A-10 states that each power system bus must be tested for BPS status, unless a bus "can be logically excluded from the bulk power system based on study results at other buses tested using this methodology." CP-11 found that this "logical exclusion" was not being applied consistently across all NPCC Areas. In some cases, the logical exclusion was being applied in a way such that a bus that may be designated as BPS may not be tested if it is not contiguous with other BPS buses.

Additionally, while the existing A-10 states that "Elements shall not automatically be included or excluded from the bulk power system based on voltage class," the requirements for testing low-voltage buses (at sub-transmission and distribution voltages) are not clear. CP-11 acknowledged that certain buses below transmission voltage should be tested, but also that it would be needlessly time-intensive to test every single bus at distribution and subtransmission voltages.

To address these inconsistencies and ensure that all buses which are likely to be classified as BPS are tested, CP-11 proposed a testing strategy that would more clearly state which buses must be tested for BPS status. In short, this strategy requires testing all buses operated at 200 kV or higher, as well as any bus below that voltage which may be BPS based on its connections to BPS buses, clearing times, and short circuit strength.

2.2.2.2 *Steady-State Testing Procedure*

The BPS classification test currently includes both a transient stability simulation and a steady state analysis to determine the extent of cascading (if any) following the loss of a bus with no local protection system action. While CP-11 was interested in retaining the steady-state test, a lack of consistency in the application of the steady-state test was observed between NPCC Areas. CP-11 has proposed to use the end state of the transient stability test as the starting point for the steady-state test. In other words, any generators or other elements that are assumed to trip during the transient simulation (due to out-of-step conditions, overspeed, undervoltage, etc.) are assumed to be out of service for the steady-state simulation as well. This change ensures that the steady-state test fully captures the effects of a locally uncleared three-phase fault. If a generator trips during the transient test, any thermal or voltage issues caused by the loss of that generator should be fully reflected in the steady-state test.

2.2.2.3 *Base Case Setup*

CP-11 observed that different NPCC Areas were taking different approaches to constructing the base cases used for BPS classification testing. The input assumptions to a performance-based test can be very impactful on the test's results. As a result, CP-11 devised requirements for base case setup that would provide consistent minimal system conditions for BPS classification among all NPCC Areas.

CP-11 has proposed that all buses shall be tested under both peak load conditions (defined as a load level that is equal to the 50/50 peak load forecast in Areas that create probabilistic forecasts) and light load conditions (as defined in the MMWG Procedure Manual – typical early morning load level, modeling at or near minimum load conditions). Major inter- and intra-Area interfaces shall be stressed to, at a minimum, the 98th percentile of historic interface flows. Given these load and transfer conditions, generation and reactive resources shall be dispatched in a manner that is credible and reflective of typical operating conditions.

2.2.2.4 *Performance Requirements*

Currently, Document A-10 specifies that buses shall be classified as part of the BPS if results of the test show "**significant adverse impact** outside of the **local area.**" Although the NPCC glossary provides definitions for the terms "significant adverse impact" and "local area," the definitions are somewhat open to interpretation. In the interest of improving consistency and reducing ambiguity in the BPS classification procedure, CP-11 has proposed a clearer and more easily defined set of performance requirements against which test results can be compared.

CP-11 has proposed that the occurrence of any of the following impacts should be deemed as significant and require classification of the tested bus as part of the BPS:

- System instability that cannot be demonstrably contained[5];
- Cascading that cannot be demonstrably contained (within the Area or a predefined/established portion of the system)[6]**;**
- Net Loss of Source or Loss of Load greater than an Area's threshold, if applicable.[7]

2.2.2.5 *Periodic Assessment of BPS Classification*

In the event of changes to the power system, the existing NPCC Document A-10 allows for a partial, "ad hoc" assessment of the BPS status of buses near the location of the system modification. CP-11 supports the idea of a partial assessment in affected areas only, and this will be retained as a part of Methodology 1. However, in certain NPCC Areas, experience has shown that a multitude of smaller changes in one portion of the system can eventually lead to a BPS

[5] Un-damped oscillations where an oscillatory response is not demonstrated to be clearly positively damped within 30 seconds of the initiating event

[6] Containment of cascading can be determined by examining sequential tripping caused by exceeding stability limits, voltage limits and/or transmission Element loading. When Cascading crosses to a neighboring Area, the affected Area shall be consulted to determine the severity of the impact on the performance of the system in the neighboring Area.

[7] An Area's Loss of Source and Loss of Load threshold will be determined by each Area with due consideration to impacts outside of the Area. The values are to be presented and approved by TFSS and TFCP. An Area may have different values for various conditions studied (e.g. summer vs. winter, light vs. peak loading, etc.).

classification change at a relatively remote bus. To ensure that these cumulative impacts are not overlooked, CP-11 has proposed a requirement for each NPCC Area to evaluate the need for a full re-assessment of BPS status once every five years (at a minimum). This will also provide a chance to re-study BPS classifications with updated historical data for interface flows. Retesting of previously classified BPS buses shall be on an as-required basis, while all previously identified non-BPS buses must be periodically reassessed.

2.2.2.6 *Transformer Tripping Assumptions*

For the transient stability test in the existing A-10 document, transformers connected to the bus under test are only tripped by the operation of independent remote protection groups capable of clearing a fault on the bus under test. If no such protection exists (for example, transformers protected by differential schemes only), this results in many cases of transformers being left in service, supplying the three phase fault at the bus under test for the entire duration of the transient simulation. The existing methodology does not provide guidance on handling this situation in the BPS classification test. As a result, different NPCC Areas currently treat faults at transformer terminals differently, leading to inconsistencies in test results from one NPCC Area to another.

CP-11 proposed language describing how transformers located at the bus under test will be assumed to fail and trip during the transient stability simulation. CP-11 proposed that, in the case where there is no remote protection that will trip a transformer(s) connected to a bus under test, the fault will be assumed to migrate to the other side of the transformer(s) after 5 seconds. This simulates the eventual failure of the transformer(s). CP-11's proposed assumptions will provide a unified method for simulating the eventual failure of these transformers and the migration of the fault to the opposite terminal.

2.2.2.7 *Treatment of Directional Comparison Blocking Schemes*

The existing Document A-10 allows for the reliance on faster clearing provided by directional comparison blocking (DCB) protection schemes, with the caveat that the fault must be placed at different points away from the bus under test where faster-acting DCB schemes may not be able to respond. CP-11 recognized that the worst-case scenario for a DCB protection scheme is often not the total failure of the protection system, but a partial failure such that the fault remains uncleared locally, but a blocking signal is sent to adjacent buses. To reflect this reality, the CP-11 proposes that BPS classification testing shall not rely on faster clearing from DCB schemes or the need to move the fault along the elements adjacent to the bus under test. This revision will lead to a reduction in the overall resource requirements for BPS classification.

2.2.2.8 *Testing Adjacent Circuits on Common Towers for BPS Classification*

CP-11 recognizes that the intent of the A-10 test is to identify critical facilities for criteria applicability, but the methodology used to identify the critical facilities should not be excessively onerous. One aspect of the existing BPS classification procedure is the test of adjacent circuits on common towers (ACCT) with protection failure at one of the terminal stations. In the interest of avoiding unnecessary testing that, to date, has not uniquely identified a critical facility, CP-11 has proposed that the ACCT test be removed from the BPS classification procedure. This reduces the resources required to run the BPS classification test without exposing the NPCC interconnected system to a significant additional reliability risk.

2.2.3 Analysis of Methodology 1 Test Results

CP-11 found that the list of buses identified in the first iteration of testing was a logical list of critical buses. In many NPCC Areas, the list of buses identified as critical was identical to or nearly identical to the existing BPS projection for the year 2022. Where changes did occur, they could be attributed to one of the assumptions that were changed in the first iteration of testing.

CP-11 believes that the results of locally uncleared three-phase fault testing match each NPCC Area's expectations for buses that are critical from a Directory 4 perspective.

However, the results of locally uncleared three-phase fault testing from a Directory 1 perspective (buses where contingencies listed in Directory 1 can cause widespread impacts) deviated from some Area's expectations for buses that are critical. CP-11 has found that it is overreaching in some Areas in which buses are captured through the three-phase fault test that are not expected to be impactful outside the area after the protection system redundancy that is required under Directory 4 is achieved. Additionally, although buses identified by this test may be critical for Directory 1 applicability, it is often the case that there are individual elements located at the bus in question that are not critical in maintaining inter-Area reliability. As a resolution to this issue, CP-11 has identified a need for an improved element-by-element classification for Directory 1 applicability to augment Methodology 1.

The modifications to the performance requirements proposed by CP-11 did not cause any differences from the threshold for BPS classification used in previous analyses. The overall performance requirements were acceptable to all Areas and were not considered a major change from those used in the existing performance-based test. CP-11 believes that the use of the proposed performance requirements does not cause any differences between previous BPS tests and the test results identified from Methodology 1.

CP-11 identified that the changes in the level of interface stresses will have impacts on the test results for some of the NPCC Areas. CP-11 also identified that some Areas are more sensitive to interface transfers, while others have less sensitivity. There is a correlation between interface stress and results in each Area. The 98th percentile values seemed to yield a reasonable list of BPS buses in the Areas that were most sensitive to transfer levels. The 98th percentile approach to stressing major interfaces is suggested to be used as a "floor;" In some situations (for example, to avoid unrealistic generation dispatches), Areas may choose to stress interfaces at levels above the 98th percentile. Any bus that shows a BPS-positive result in at least one base case tested should be considered BPS, even if it tests non-BPS in other cases tested. (This appears to be an existing practice in all Areas that use multiple base cases for BPS classification, but CP-11 recommends that this practice is formalized in the final revised A-10 document.)

CP-11 agreed to not rely on DCB protection for faster fault clearing, since this approach has good technical justification and decreases workload.

Testing results show that changes in the assumed load levels (standardizing peak load at the 50/50 forecast and mandating light load testing) would not have a significant change in the results of BPS classification testing. 50/50 load tends to be consistent with cases built by SS-37 and MMWG, and most Areas were either already testing at 50/50 load or did not observe sensitivity of test results to the exact load level.

CP-11 also agreed that there is good technical justification for the assumption on clearing of faults on transformer terminals, and changes in results due to this assumption matched expectations. In almost all cases, any effects of a fault have been observed well before 5 seconds have passed. The five-second assumption is a realistic, yet conservative, assumption.

2.3 Methodology 2

2.3.1 Description and Directory Applicability

Methodology 2 was devised to distinguish system elements that are critical from a Directory 1 perspective from system elements critical from a Directory 4 perspective. Methodology 2 uses the same three-phase locally uncleared fault analysis presented in Methodology 1 to determine Directory 4 applicability. It then uses a new test based on active power flow through system elements to determine which elements are critical in relation to Directory 1. Figure 3: Methodology 2 Flowchart illustrates the overall summary of the two methodology tests and their associated Directory applicability.

2.3.2 Flow Test – Detailed Description

Flow Test Principle

Directory 1, requires the application of criteria contingencies on BPS elements and the monitoring of the impact of criteria contingencies on BPS elements. The premise of the flow test is that the buses on the transmission system that transfer a significant amount of power are critical because:

- The elements connected to these buses participate in bulk power transfer and should be monitored for critical contingencies
- The loss of element(s) at the buses with high flows will redirect these flows to other parts of the bulk power system and the impacts of these redirected flows must be analyzed.

Calculation for Bus Flow

The amount of active power that flows through a bus may be calculated by adding the absolute MW values that flow on each element connected to the bus and dividing by 2 to avoid double counting flows.

Once this value is obtained, this number gives the level of active power transfer through the bus.

Selection of the Flow Test Threshold

Under the principles of the Flow Test, the Directory 1 contingencies at buses with high flows should be evaluated for impact. The amount of flow through a bus approximates the impact of contingencies at that bus. The worst-case impact of a Directory 1 contingency at a bus is assumed to disrupt the entire flow at a bus.

Each Area can approximate the maximum loss of load or maximum loss of source that the Area can withstand without impacting the neighboring Areas. If an Area has both a loss of load and a loss of source threshold, then the minimum of these two numbers would set the flow threshold for consideration.

If we consider that Directory 1 N-1-1 contingencies could occur involve an element out at one bus followed by a contingency at another bus, then the N-1-1 event could have a significant impact outside the area. The combined worst-case impact of an N-1-1 Directory 1 contingency pair at two separate buses can be approximated by adding the flows at the two buses. For the N-1-1 pair to have a "significant adverse impact," the combined impact of the N-1-1 event may be compared to an Area's maximum loss of load or loss of source threshold.

Therefore, by using half of an Area's loss of load/loss of source threshold as the maximum flow above which a bus would be considered critical for Directory 1 applicability, the methodology would identify at least one of the buses in a N-1-1 contingency pair where the total flows at the two buses would exceed an Area's loss of load/source threshold. For the sum of the flows at two buses to exceed an Area's loss of load or loss of source threshold, the flow through one of the two buses must meet or exceed half the Area's loss of load/source threshold.

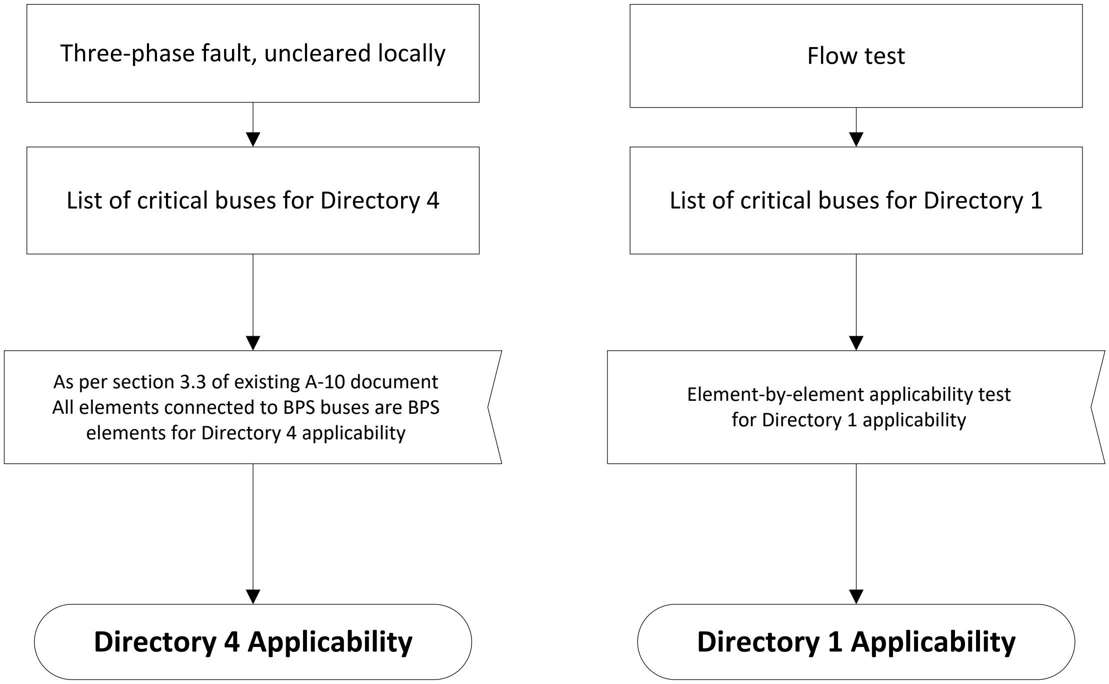

Figure 3: Methodology 2 Flowchart

2.3.3 Testing Parameters

2.3.3.1 *First iteration parameters*

The agreed upon parameters for the first iteration of the flow test, for Directory 1 applicability, were as follows:

- Flow test applied to the same base cases developed for Directory 4 testing in Methodology 1 (see section 2.2). The highest flow for the bus under test from all the base cases tested will be compared to the Area's flow test threshold.
- Flow test threshold is 50% of the lesser of the Loss of Load or Loss of Source (Performance Requirements used for the Methodology 1 and Methodology 2 Directory 4 test).

For Directory 4 applicability, the test used in Methodology 2 is identical to the test used in Methodology 1. As a result, the testing and results for Directory 4 applicability are identical to what is described in Section 2.2 of this report and will not be repeated here.

2.3.3.2 *Second iteration parameters*

The agreed upon parameters of the second iteration flow test were as follows:

- Flow test applied to base cases used for the Area's most recent Directory 1 analysis (such as a Comprehensive Area Transmission Review). The highest flow for the bus under test from all the base cases tested will be compared to the Area's flow test threshold.
- Flow test threshold is 50% of the lesser of the Loss of Load or Loss of Source (Performance Requirements used for the Methodology 1 and Methodology 2 Directory 4 test).

The main difference between the first and second iteration testing was with system dispatch. Fairly recent Directory 1 cases were readily available for most Areas (the Directory 1 cases by definition must use credible combinations of system conditions which stress the system).

2.3.4 Analysis of Test Results

2.3.4.1 *Evaluation of the Flow Test*

The flow test was evaluated to determine how effectively it could identify buses where Directory 1 contingencies would result in widespread impacts. Results were measured based upon how many of the non-critical buses the flow test captured, how many of the critical buses it successfully captured, and how many of the critical buses it failed to capture. The test was also evaluated to see if there were instances where the flow test removed buses that were not critical to Directory 1 but that were previously captured by the performance test.

In all Areas, the flow test 'over-reaches' and captures buses for which Directory 1 contingencies do not have widespread impacts. In some Areas, this over-reach picked up buses that were part of a local subsystem and that exist primarily to serve localized load. Over-reach was not limited to 115kV or 138kV buses, but also occurred on some 230kV and 500kV buses. Observations from the first iteration of testing included:

- The threshold of 50% of Loss of Source or Loss of Load for the flow test is not necessarily indicative of which contingencies will result in widespread impacts and is somewhat arbitrary.
- Results can be greatly impacted by phase angle regulator (PAR) schedules, generation dispatch, and load.
- The flow test tends to capture buses located at medium-sized generation stations where generation is between 50% and 100% of the Loss of Source Threshold for testing. The system is already planned and operated with loss of these units as a contingency, and other contingencies at these generation stations don't typically cause inter-Area impacts.

- There were several 138 kV buses identified as critical for Directory 1 applicability that would not typically be considered critical from a Directory 1 perspective (remote from interfaces, not critical for transferring bulk power, and impacting only local areas).

In all Areas, the flow test also ‘under-reaches’ and does not capture all buses where faults can impact stability on a widespread basis and that are considered critical for Directory 1 applicability. Observations from the first iteration of testing included:

- There are critical locations where the flow test fails to capture critical buses when tie bus breakers are operated ‘normally open,’ due to the flow being split among the two halves of the critical bus.
- Certain 230 kV and 345 kV stations in multiple NPCC Areas were not identified as “critical,” even though these buses are considered a part of those Areas’ transmission backbones and events at these buses could have the potential to cause inter-Area impacts.
- Some buses had low flow, but large stability impacts due to their electrical proximity to the backbone of the transmission system, and these were not captured by the flow test.

In general, the following points were also noted:

- Adjusting the flow test threshold to reduce under-reach, also results in an increase in over-reach, and vice versa. Thus, simply adjusting the flow test threshold will not result in a more acceptable list of critical facilities for Directory 1 applicability.
- Results were greatly impacted by generator dispatch. Simply turning on a generator with a size greater than the flow test threshold would automatically add the generator’s point of interconnection to the BPS list for Directory 1 applicability. Additionally, some Areas had concerns regarding the appropriate level of dispatch for renewable and intermittent generation and observed that this choice could significantly impact flow test results.
- The Flow test does not consider the topology characteristics of the bus being evaluated (i.e., a bus located in a radial portion of network is not significant, even if flows are high).
- Some Areas do not have official loss of load/loss of source thresholds. In some cases, those limits are only operational limits and not planning limits.
- Flow test does not decipher between the number and loading of elements connected to a bus (e.g. 2 heavily loaded lines versus 8 lightly loaded lines). CP-11 considered looking at % loading on lines at the bus rather than absolute megawatt flows but was unable to develop an alternative using this approach.

The results for the second iteration of flow testing were like that of the first iteration. All Areas continued to experience both ‘over-reach’ and ‘under-reach’, although results were slightly improved. The second iteration of the flow test did a better job of identifying certain buses in some, but not all, NPCC Areas located on the transmission system backbone as critical.

2.4 Methodology 3

2.4.1 Description and Applicability

Methodology 3 was an attempt to devise a BPS classification test that would rely solely on system topology and voltage level, rather than a performance-based test, to determine a bus's BPS status. The following steps outline the details of the connectivity-based methodology as it was originally proposed in Phase 1 of the CP-11 Working Group's efforts. Although some modifications to this approach were proposed to address its shortcomings, no modifications were finalized before the methodology was ultimately dropped from further consideration.

Step 1: Identification via Bus Voltage Filter and Resource Capacity Filter

In this methodology, the first step in the classification of a bus as BPS or non-BPS is a voltage-based filter. Any bus with a bus voltage above 330 kV is automatically classified as a BPS bus. A filter on directly-connected generation is also used; any bus with an amount of directly-connected resources (generation or HVDC connections to another interconnection) exceeding a given threshold in each Area is also automatically classified as a BPS bus. (This generation threshold varies from Area to Area but is determined in a consistent manner; details are included below.) Buses which do not meet either of these criteria continue through the methodology to be classified by other means.

This step identifies critical facilities as those at the highest voltage level(s) in each Area. These facilities are those where faults are most likely to have a widespread impact on the interconnected power system, and those that typically are involved in the transfer of higher amounts of bulk power. The inclusion of buses with a large amount of connected generation also accounts for the impacts that a large loss of source would have on the interconnected power system, especially on neighboring Areas within and outside of NPCC.

The resource capacity test is based on the concept of "directly-connected resources," which are resources which would be disconnected from the power system through direct protection system action due to a fault on the bus under test, uncleared locally and cleared by remote terminals. This includes resources which only are connected to the rest of the interconnection via the bus under test, as well as any resources tapped off lines connected to the bus under test and disconnected by configuration.

The proposal for a threshold for the resource capacity test was based on the list of "probable contingencies" for determination of reserves, which is required to be maintained by NERC BAL-005 and NPCC Directory 5. For each of the five NPCC Areas, the threshold for identifying a bus as BPS based on the generation capacity filter would be set as the smallest loss-of-source contingency on the Area's list. The use of the smallest loss-of-source contingency on this list ensures that, if the loss of a bus results in more generation lost than an Area is expecting due to single contingencies (even during time periods when the largest single source is out of service), the bus will be classified as a BPS bus. Although some NPCC Areas had concerns with this approach to a resource capacity threshold, a better method of determining a source loss threshold was not determined before Methodology 3 was eliminated.

Step 2: Identification via Topology of Connected Elements

For buses which are not automatically classified as BPS based on nominal voltage or directly-connected generation in Step 1, a topology-based test is used to determine their BPS classification. The number and type of transmission elements connected to each bus are used to determine a “point” total for the bus under test. If the total number of points for the bus under test exceeds a pre-determined threshold, the bus is classified as a BPS bus; if the total number of points is less than this threshold, the bus is classified as a non-BPS bus.

This step identifies critical buses by using the number and type of transmission elements connected to a bus as a measure of the interconnectedness of the bus under test. The proposal for the topology-based test put forward in Phase 1 of CP-11’s efforts was the following:

- Each transmission element (transmission line or transformer) connected to the bus under test, which is not a radial element or a part of a local subsystem, is assigned one point.
- Each transformer connected to a bus with nominal voltage at 330 kV or higher is assigned two additional points, beyond the one point per networked element.
- Each transmission element which is a part of a major Interface is assigned one additional point, beyond the one point per networked element.
- Each transmission element which includes a series compensation device (series capacitor) or a flow control device (phase shifting transformer or series FACTS device) is assigned one additional point, beyond the one point per networked element.
- Each 100 MVAR of shunt reactive resources (whether switched static or dynamic) at a single bus is assigned one point. The total of capacitive and inductive resources at a bus is added up to obtain a total amount of reactive resources, and then divided by 100.

The initial proposal for a threshold for a BPS determination was a value of 10 points or higher. This would include buses with a large number of networked transmission elements, as well as buses with a smaller number of networked elements which are considered more critical (EHV transformers, series-compensated elements, etc.).

2.4.2 Shortcomings of Methodology 3

The most severe shortcomings of Methodology 3 were related to its inability to account for a bus’s location and actual impacts of events at the bus under test. The results of Methodology 3 would sometimes deem a bus as non-critical simply because it had a smaller number of elements connected, even though that bus was connected directly to the backbone of an Area's transmission system, and faults or contingency events on that element had the potential for impacts on other NPCC Areas. Conversely, buses with many elements connected were identified as critical by Methodology 3, even when they existed only to serve local load and did not contribute substantially to bulk power transfer capability or to the reliability of the interconnected NPCC system.

Additionally, it proved difficult to rationalize the weighting of various types of elements in the point-based system and the point threshold used to delineate BPS buses from non-BPS buses. Values for these parameters that produced a reasonable list of critical buses in one NPCC Area often would not produce a reasonable list of critical buses in another NPCC Area.

2.4.3 Attempts at an Interface-Based BPS Classification Methodology

Although the original proposal for Methodology 3 did not appear to be viable, certain aspects of this proposal, including the reduction in engineering effort required for BPS classification, were still considered helpful. As a result, development continued on a new approach which attempted to focus primarily on the applicability of Directory 1. This new approach continued the group's brainstorming on ways to best capture elements which are critical for Directory 1 applicability.

This new proposal would maintain the 330 kV bright-line voltage cutoff for Directory 1 applicability. For buses below 330 kV, CP-11 was polled to determine what elements were truly critical to Directory 1 applicability. The most prominent type of elements that would be critical to Directory 1 applicability were those that would affect interface transfer capability: either elements on which contingencies tended to be the most limiting contingencies on a given major interface, or elements where post-contingency flows tended to limit interface transfer capability. To attempt to capture these elements, a test was proposed that would analyze each interface within an NPCC Area for which the loss of the entire interface would cause inter-Area impacts. For each of these interfaces, the elements that were either included in the limiting contingency or were the limiting monitored element would be considered BPS for Directory 1 applicability.

While the basic framework of this test initially showed promise, CP-11 was reluctant to adopt it for a number of reasons. This test may not have yielded a list of buses, but rather a list of elements for Directory 1 applicability, which would be a substantial departure from today's approach to Directory 1. These elements would likely be non-contiguous. Additionally, concerns were raised that the elements upstream or downstream from a major interface may be just as impactful as those that cross the interface, but would not be identified by this test. Finally, this approach may have required changes in the way that interface limits are calculated, because an interface limit would have to be calculated before a pre-determined list of Directory 1-applicable elements was created.

Because of these shortcomings, the interface-based BPS classification methodology was not developed further.

2.5 Selected Methodology

2.5.1 Overall Conclusions of Methodology 1

The results of Methodology 1 showed only incremental changes from the list of buses identified as BPS under the existing A-10 test. In many NPCC Areas, the list of buses identified as critical was identical or nearly identical to today's BPS list. The most significant changes observed were in New England, where approximately thirty buses which are identified as BPS today were not identified as BPS when tested under Methodology 1. These changes were primarily attributed to the use of the 98th percentile approach to interface stresses, which is a notable change from the interface stresses used by New England in BPS testing today. CP-11 reported that this methodology was successful at identifying critical locations for the application of Directory 4. For identification of critical elements for the application of Directory 1, the methodology is regarded as adequate.

Some of the previously identified shortcomings of the existing A-10 test were still observed throughout the testing of Methodology 1. The sensitivity of test outcomes to small changes in system conditions appeared to be reduced, although not entirely eliminated; any performance-based test is bound to be dependent on system conditions, so fully eliminating this sensitivity will not be possible as long as the framework of the classification test is a performance-based test (especially one based on transient stability testing). Finally, although the amount of time and engineering resources involved in the stability-based performance test was still substantial, some NPCC Areas reported a reduction in total testing time required. This reduction was due to the changes in base case setup procedures (due to a lower number of base cases required for testing in most NPCC Areas), and also due to the use of fault file definitions and automation set up for previous A-10 assessments. The elimination of certain tests, such as testing protection failures for faults on adjacent circuits on common towers and the simplification of the treatment of Directional Comparison Blocking schemes, also helped to reduce the total amount of engineering efforts required to determine BPS classification.

2.5.2 Overall Conclusions of Methodology 2

The results of Methodology 2 for Directory 1 applicability showed a more dramatic change from today's BPS list. The list of results for Directory 4 applicability was identical to the Methodology 1 results, as the same test was used; those results are described above and will not be restated here. Many Areas reported a significant number of buses which are non-BPS today with flows higher than the threshold used for the flow test. Additionally, many buses which are considered critical for Directory 1 applicability were not captured under the flow test. As a result, in most NPCC Areas, the Directory 1 applicability test in Methodology 2 was not found to identify an adequate list of critical locations for the application of Directory 1.

One of the more prominent reasons for the differences between the list of buses considered critical for Directory 1 applicability and the outcomes of Methodology 2 was the inability for Methodology 2 to consider stability performance. Many of the buses in question did not have large amounts of real power entering or leaving the bus (especially under the all-lines-in conditions examined), but are in close electrical proximity to the backbone of the transmission system. Faults on these buses could cause major power swings or widespread stability concerns; however, as the flow test is a static test only, these impacts were impossible to capture in the Directory 1 classification test. The failure to apply the transient stability requirements of Directory 1 to several of these buses is a shortcoming of Methodology 2.

Methodology 2 tended to be as sensitive as, if not more sensitive than, Methodology 1 with regard to base case setup and generation dispatch. The differences between the first and second iterations of testing on Methodology 2 illustrated the fact that varying degrees of interface stresses or varying generation dispatches would have major impacts on the outcomes of the test.

Methodology 2 also used a single threshold for an entire Area, and CP-11 observed that the use of a single threshold resulted in over-identification of buses in heavily networked portions of the system, and under-identification of buses in lightly networked portions of the system. The use of a single Area-wide threshold is a significant shortcoming in the methodology.

The Methodology 2 flow test is fairly straightforward to apply, with most Areas using a Python script or similar automation to avoid the need to manually add up flows at each bus. However, Methodology 2 still requires the analysis work involved in the three-phase fault test for Directory 4 applicability. As a result, the amount of analysis required for BPS classification with Methodology 2 is similar in magnitude to that required for BPS classification with Methodology 1.

2.5.3 Overall Conclusions of Methodology 3

As described previously, a full list of BPS facilities according to Methodology 3 was not assembled. However, preliminary testing on a number of sample buses was sufficient to show examples of situations where Methodology 3 failed to identify critical buses (or identified non-critical buses as critical).

The most prominent shortcoming of this methodology was its inability to adequately account for the effects of a bus's location on its performance. A bus with a given number and type of transmission elements could be located in an area with fairly sparse load density, far from the major backbone of the transmission system and far from any large generation clusters. In this case, faults at this bus would be unlikely to cause any impacts that were not very localized. However, a bus with the same number and type of elements could also be located near a large generation cluster or very electrically close to the backbone of an Area's transmission system. In this case, faults at that bus would be much more likely to have widespread adverse impacts, and the bus would be much more likely to be considered critical.

It was also difficult to rationalize the weighting of various types of elements in the point-based system and the points threshold used to delineate BPS buses from non-BPS buses. Values for these parameters that produced a reasonable list of critical buses in one NPCC Area often would not produce a reasonable list of critical buses in another NPCC Area.

Methodology 3, as proposed, would have had effectively no sensitivity to system conditions, and would have required much less engineering analysis and time to assemble a list of BPS buses. However, due to its failure to identify critical buses for the application of Directories 1 and 4, this methodology was not considered acceptable to CP-11.

2.5.4 Selection of Preferred Methodology

CP-11's consensus preference for a BPS classification methodology is Methodology 1. The group recognized a strong correlation between the three-phase locally uncleared fault test and the Directory 4 requirements for protection system redundancy, and thus quickly converged on the use of Methodology 1 for Directory 4 applicability. Although the correlation between the test and the planning and operational contingency analysis requirements of Directory 1 is less strong, the group still came to the agreement that this methodology was the best alternative considered for the identification of critical buses for Directory 1 applicability.

Although the core of the proposed methodology is similar to the existing BPS classification procedure as described in NPCC Document A-10, many revisions have been made to address some of the concerns of the existing methodology, and to meet the TFCP selection criteria provided to CP-11. Methodology 1 adequately satisfies the most critical of the three evaluation criteria, by identifying a list of critical buses for the application of Directories 1 and 4. By providing additional guidance around inputs to the analysis, such as base case setup and performance requirements, CP-11 has improved the consistency of its application and outcome and reduced its sensitivity to input assumptions. Finally, although the three-phase fault test at the core of this methodology is still somewhat labor-intensive, CP-11 has proposed certain changes to the analysis process (such as the elimination of the adjacent transmission circuits on a common tower test for BPS classification) that would serve to simplify the overall classification process.

It should be noted that, although CP-11 recommends Methodology 1 for the applicability of both Directory 1 and Directory 4, there remains debate as to whether separate tests are needed for Directory 1 and Directory 4 applicability. Several Working Group members stated that separate Directory 1 and Directory 4 applicability tests would be a logical outcome for their systems, but the separate tests analyzed to date for Directory 1 applicability (the flow test in Methodology 2 and the voltage- and topology-based tests in Methodology 3) simply were not identifying the appropriate critical buses.

2.5.5 Impacts on Testing Efficiency and Workload for BPS Classification

The amount of engineering resources necessary to administer the existing methodology was a concern highlighted in the TFCP Scope of Work for CP-11, as well as in the evaluation criteria. Although this was not a primary evaluation criterion (the primary evaluation criterion was the identification of critical elements), this was considered as CP-11 evaluated the revisions to the existing methodology and new methodologies. Because CP-11 considered the three-phase locally uncleared fault test to be a good test for Directory 4 applicability, this test would be run regardless of the methodology used for Directory 1 applicability.

CP-11 examined each of the individual recommended revisions made to the existing methodology and documented the efficiencies gained within each Area because of these changes. Although the benefit of individual methodology revisions varied across NPCC Areas, in aggregate these changes were observed to create marginal improvements in the overall efficiency of the existing methodology, on an NPCC-wide basis. The elimination of reliance on DCB protection schemes and the elimination of testing adjacent circuits on common towers, which are difficult to automate and require detailed analysis of protection settings, are considered to be significant gains in resource efficiency.

CP-11 also compared the overall time required to run the existing methodology (a full system assessment as opposed to ad hoc reviews for small system changes) with the amount of time required for an assessment that included the CP-11 recommended revisions to the existing methodology and determined that as a result of automation (script files) already in use the difference as expressed in person hours necessary to run the methodology was negligible.

In summary, although the recommended methodology is still somewhat labor intensive, CP-11 believes that certain revisions to the methodology may have the impact of reducing the engineering effort required to identify those buses that are critical to the interconnected NPCC power system.

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3. Identification of BPS Elements for Directory 1 and Directory 4 Applicability

3.1 Introduction

The preferred methodology identifies a list of critical buses (BPS buses) for Directory 1 and Directory 4 applicability. This is similar to the existing methodology. For Directory applicability, it is necessary to determine which Elements connected to the BPS bus are "critical" elements for the application of these Directories. For the purposes of this discussion, the term Element is consistent with the definition in the NPCC Glossary of Terms.

For Directory 1 applicability, a critical Element is defined in terms of the Directory 1 (Design and Operation of the Bulk Power System) objectives, which are:

1. To maintain a level of reliability that will not result in the loss or unintentional separation of a major portion of the system.
2. To avoid instability, voltage collapse, and widespread cascading outages or overloads.

For Directory 4 applicability, a critical Element is defined in terms of the Directory 4 (Bulk Power System Protection Criteria) objective, which is to ensure dependable and secure operation of the protection systems for the bulk power system. To meet this objective, all elements on which redundant protection systems are required need to be identified.

This section discusses the different approaches that were considered by CP-11 for the identification of BPS elements for Directory 1 and Directory 4 applicability, starting from a list of critical buses as identified by the preferred methodology.

3.1.1 Existing A-10 Core Assumption and Rationale

Within the existing Document A-10, the following method is used to classify BPS facilities on an Element-by-Element basis:

- *"An* ***element*** *with only one terminal such as a generator, shunt reactor, or capacitor bank, is classified as part of the* ***bulk power system*** *if the bus at which it is connected is classified as part of the* ***bulk power system****.*
- *An* ***element*** *with multiple terminals such as a transformer or transmission line is classified as part of the* ***bulk power system*** *if any terminal of the* ***element*** *is connected to a bus that is classified as part of the* ***bulk power system****. The* ***bulk power system*** *classification may be limited to only a portion of the* ***element*** *if all of the following conditions are met:*
    - *At least one terminal is connected to a bus that is not part of the* ***bulk power system****.*

- *The Steady State Test has been applied at the buses connected to all terminals of the **element** and none of these buses have been classified as part of the **bulk power system** based on results of the Steady State Test.*
- *The Transient Stability Test has been applied between the terminals of the element to identify those portions of the element for which the Transient Stability Test will not result in a significant adverse impact outside of the local area."*

3.1.2 Concerns with Existing Element-by-Element Classification

The primary concern with the current element-by-element approach is that a single element-by-element classification test is used for applicability for different directories. Additionally, information gathered from some of the members involved with the 2009 Document A-10 revision confirmed that the intent of the current element-by-element classification clauses of section 3.3 were written and aimed at Directory 4 applicability. The ensuing result of applying Directory 1 on every of the elements identified by section 3.3 is viewed by NPCC members as an incongruity of the current methodology. The current methodology does not recognize that once protection system redundancy as required by Directory 4 is achieved, there may not be a need to categorize every element as being critical for Directory 1 applicability.

The existing test to exclude multi-terminal elements from Directory applicability is focused on identifying portions of the multi-terminal element where Directory 4 protection system redundancy is not required. The exclusion aligns better with Directory 4 applicability and does not align with Directory 1.

From a Directory 4 perspective, CP-11 has identified a need to update the element-by-element classification to align with the preferred methodology. For Directory 4 applicability, the existing element-by-element classification will be retained for the most part with edits made to reflect the elimination of separate steady-state and transient stability tests.

From a Directory 1 perspective, CP-11 recognizes that even if all elements connected to a BPS bus are classified as BPS elements, the following language from Directory 1 performance requirement (ii) may be relied upon by entities to not respect violations on certain elements connected to BPS buses for Directory 1 contingencies:

> *"Loss of small or radial portions of the system is acceptable provided the performance requirements are not violated for the remaining **bulk power system.**"*

However, it may be onerous in planning and operating studies to demonstrate that the impact of design and operating contingencies is restricted to the "loss of small or radial portions of the system." By formally classifying these elements where impacts are restricted to the "loss of small or radial portions of the system" within the element-by-element classification, it is possible to significantly reduce the burden of ambiguous language on planners and operators.

Additionally, under the preferred methodology, a single test is used to identify buses critical for Directory 1 and Directory 4 applicability. However, this has potential for over-classification[8] if a single element-by-element applicability is used for all directories. It is possible that the directories are being applied to more elements than required to meet the objectives of the various directories.

In the absence of a separate Directory 1 test, an improved element-by-element classification that takes into account the objectives of Directory 1 would result in better alignment of the BPS classification of elements with Directory 1 applicability.

3.2 Element Classification for Applicability of Directory 4

3.2.1 Core Assumption

It has been NPCC's practice to identify the critical power system elements and make them subject to NPCC protection criteria to increase system reliability.

The preferred methodology for the identification of BPS buses relies on the application of a three phase fault at the bus under test, with no local protection system action. The fault is cleared remotely by using back-up protection systems, which usually entail design delays. The assumption is that the elements connected to the bus under the test are protected by non-redundant protection systems which may fail to detect and clear a local fault while they experience a single component failure.

If the bus does not pass this test, it is identified as critical and all protection systems installed on all elements (single-terminal and multi-terminal) connected to that bus will be subject to NPCC Directory 4. This is because if all elements are not protected by redundant protection systems, it is possible that a close-in fault with the failure of a non-redundant protection scheme could result in a major disturbance on the NPCC interconnected system.

3.2.2 Elimination of Partial BPS Status

The existing element-by-element applicability for Directories allows for only a portion of a multi-terminal element to be classified as BPS. CP-11 has considered this applicability and recommends that all elements connected to a BPS bus be subject to Directory 4 applicability and that the exemption for a portion of the element from Directory 4 applicability be eliminated.

[8] This was identified as a concern from TFCP in the CP-11 Scope of Work.

CP-11 reviewed the applicability of Directory 4 to multi-terminal elements and identified the only scenario where an entity might seek partial exemption from Directory 4 applicability to be multi-terminal elements that connect between BPS buses and non-BPS buses. For all multi-terminal elements connected between BPS buses, it is expected that the protection systems at both ends would be designed to meet Directory 4 requirements.

For a transformer that connects BPS buses to non-BPS buses, it is sufficient at a minimum to apply Directory 4 protection system requirements for only the terminal of the transformer that is connected to the BPS bus. This will ensure that faults on a BPS bus or in vicinity of it are cleared even if the protection systems protecting the transformer on the BPS terminal experience a single component failure.

The revisions made to the preferred methodology, where the three-phase fault on the non-BPS terminal is migrated to the BPS terminal after 5 seconds, verify that the failure of the protection system at the non-BPS terminal would not cause a significant adverse impact for faults on the BPS-to-non-BPS transformer. Therefore, it is not required to apply Directory 4 protection system requirements at the non-BPS terminal of a transformer.

For multi-terminal transmission lines, the clearing times for all faults within the Zone 1 reach of the BPS terminal are not expected to be impacted by protection system failures at the non-BPS terminal. Additionally, the fact that the non-BPS terminal has not been identified as a BPS bus indicates that a fault at the remote end of the element is not impactful to the NPCC interconnected system. The small portion of the line that is outside of the BPS terminal's Zone 1 reach (which is normally set 80 to 90 percent of the positive sequence impedance of the line) may be susceptible to longer clearing times due to the failure of a non-redundant relay at the non-BPS bus.

A complete assessment would require studying uncleared three phase faults occurring at the end of Zone 1 looking from the BPS bus towards non-BPS bus. In meeting Directory 4 protection system design requirements for multi-terminal transmission lines, CP-11 recommends to study uncleared three phase faults at the end of the Zone 1 reach only in instances when Zone 1 settings are below the normal setting (less than 80 percent of the positive sequence of the line - e.g. three terminal lines) to determine if Directory 4 protection system design requirements are required at the non-BPS end of the line. This assessment should be performed in conjunction with protection engineers to clearly identify the performance of the protection systems when faults along the lines are assessed and the non-redundant protection systems installed on the elements connected to the non-BPS experience a single component failure.

Furthermore, this partial exclusion of BPS elements has seldom been used in the 9 years since Document A-10 was revised, and the elimination of this partial BPS classification is not expected to have a major impact on BPS classification.

3.2.3 Summary of Directory 4 Applicability

Directory 4 includes specific design criteria to reduce the probability of a fault not being detected and cleared locally while a single protection system component fails to operate.

Directory 4 protection system criteria will apply to all elements connected to a BPS bus that is identified using the preferred methodology. There will be no provision to exclude any elements connected to a BPS bus from Directory 4 applicability.

The implementation of Directory 4 design criteria on the protection systems installed on all elements connected to a bus that failed the performance test will allow planners and operators to assume that faults occurring on the bus or in vicinity of it will be cleared by the local protection systems with a high degree of certainty, even if a single component failure is present. The certainty in clearing faults is important in both planning and operational activities, because power system studies for establishing transfer limits and determining system upgrades can rely on the operation of high-speed protection systems as per Directory 1.

3.3 Element Classification for Applicability of Directory 1

For the purposes of Directory 1 applicability, CP-11 has classified Elements into the following categories:

- Single-terminal Elements connected to BPS buses
- Radial multi-terminal Elements connecting BPS buses to non-BPS buses
- All other multi-terminal Elements connected to BPS buses

The following sections provide automatic exclusions from Directory 1 applicability for the first two categories of elements listed above. Following that, two approaches for excluding other multi-terminal Elements connected to BPS buses are provided. Note that all exclusions, including the automatic exclusions, are optional for use in the development of the list of Directory 1 critical facilities. An entity seeking to apply Directory 1 design requirements to all elements connected to a BPS bus may continue to apply the Directory 1 design requirements to all elements connected to BPS buses.

Note that the proposed element classification for Directory 1 takes into account that Directory 4 protection system design requirements would already apply to all elements connected to a BPS bus.

Regardless of the automatic exclusion depicted in sections 3.3.1 and 3.3.2, qualifications will be introduced in the A-10 Document for automatic exclusion to prevent inadvertent exclusion of elements that could have a material impact under certain system condition, , consistent with existing language in Directory 1[9].

3.3.1 Automatic Exclusion of Single-Terminal Elements

Single-terminal Elements (such as generators, shunt reactors, or capacitor banks) connected to BPS buses may be automatically excluded from Directory 1 applicability. In order for this exclusion to be utilized, the fault clearing times for close-in faults for both protection groups A and B on the single-terminal element(s) that are connected to the BPS bus must be equal to or faster than the slowest local clearing times on the non-excluded BPS element(s) at the same BPS bus.

The review of clearing times is done in order to ensure that faults on the excluded element will not have impacts worse than faults on non-excluded elements connected to the BPS bus. In the event that this is not the case, the entity seeking the exclusion must demonstrate that the protection on the element to be excluded is fast enough to meet Directory 1 performance requirements for faults on the element.

The rationale for the automatic exclusion is that:

- Critical contingencies are not expected to have an impact on single-terminal elements; therefore, there is no requirement to monitor single-terminal BPS elements for Directory 1 applicability.
- The impacts of critical multi-element contingencies on single-terminal BPS elements are not expected to be worse than the impacts of breaker failure contingencies on the BPS bus. Therefore, all breaker failure contingencies at the BPS bus that the element is connected to are to be considered as a part of Directory 1 evaluations.

3.3.2 Automatic Exclusion of BPS-to-non-BPS Radial Multi-Terminal Elements

Multi-terminal radial elements (such as transformers and transmission lines) connected between a BPS bus and a non-BPS bus may be automatically excluded from Directory 1 applicability. Figure 4 is a depiction of a BPS to non-BPS radial subsystem. For this exclusion to be utilized, the fault clearing times for close-in faults for both protection groups A and B on the excluded element(s) that are connected to the BPS bus must be equal to or faster than the slowest clearing times on the non-excluded BPS element(s) at the same BPS bus.

[9] "If an entity becomes aware of a contingency not on a bulk power system element that results in a significant adverse impact outside the local area, that entity must design and/or operate the system to respect that event."

The review of clearing times is done in order to ensure that faults on the excluded element will not have impacts worse than faults on non-excluded elements connected to the BPS bus. In the event that this is not the case, the entity seeking the exclusion must demonstrate that the protection on the element to be excluded is fast enough to meet Directory 1 performance requirements for faults on the element.

For purposes of the automatic exclusion, radial elements are defined using the following definition:

> **BPS to Non-BPS Radial Subsystem:** A subsystem that begins with element(s) that connect a single BPS bus to non-BPS[10] buses. The subsystem does not connect back to the interconnected system[11, 12]

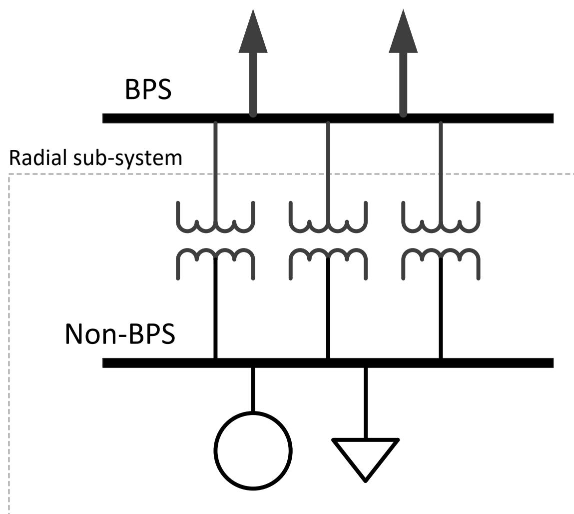

Figure 4: Depiction of BPS-to-non-BPS Radial Subsystem

The rationale for the automatic exclusion is that:

- The radial subsystem was not intended nor designed to participate in transfer for bulk power
- The impacts of critical multi-element contingencies within the radial subsystem would be no worse than breaker failure contingencies on the BPS bus (as required by Directory 1).

[10] The Non-BPS status of all buses within the radial subsystem must have been positively identified as such by the appropriate bus based BPS test methodology.

[11] A normally open switching device between radial subsystems, as depicted on prints or one-line diagrams for example, does not affect this exclusion.

[12] The presence of a contiguous loop, operated at a distribution level voltage (e.g. 50 kV or less), between configurations being considered as radial subsystems, does not affect this exclusion.

3.3.3 Other Multi-Terminal Elements

The following sections provide and discuss two element-by-element classification approaches for Directory 1 applicability for the remaining multi-terminal elements connected to BPS buses. Figure 5: Element-by-Element Directory 1 Applicability Approaches illustrates these.

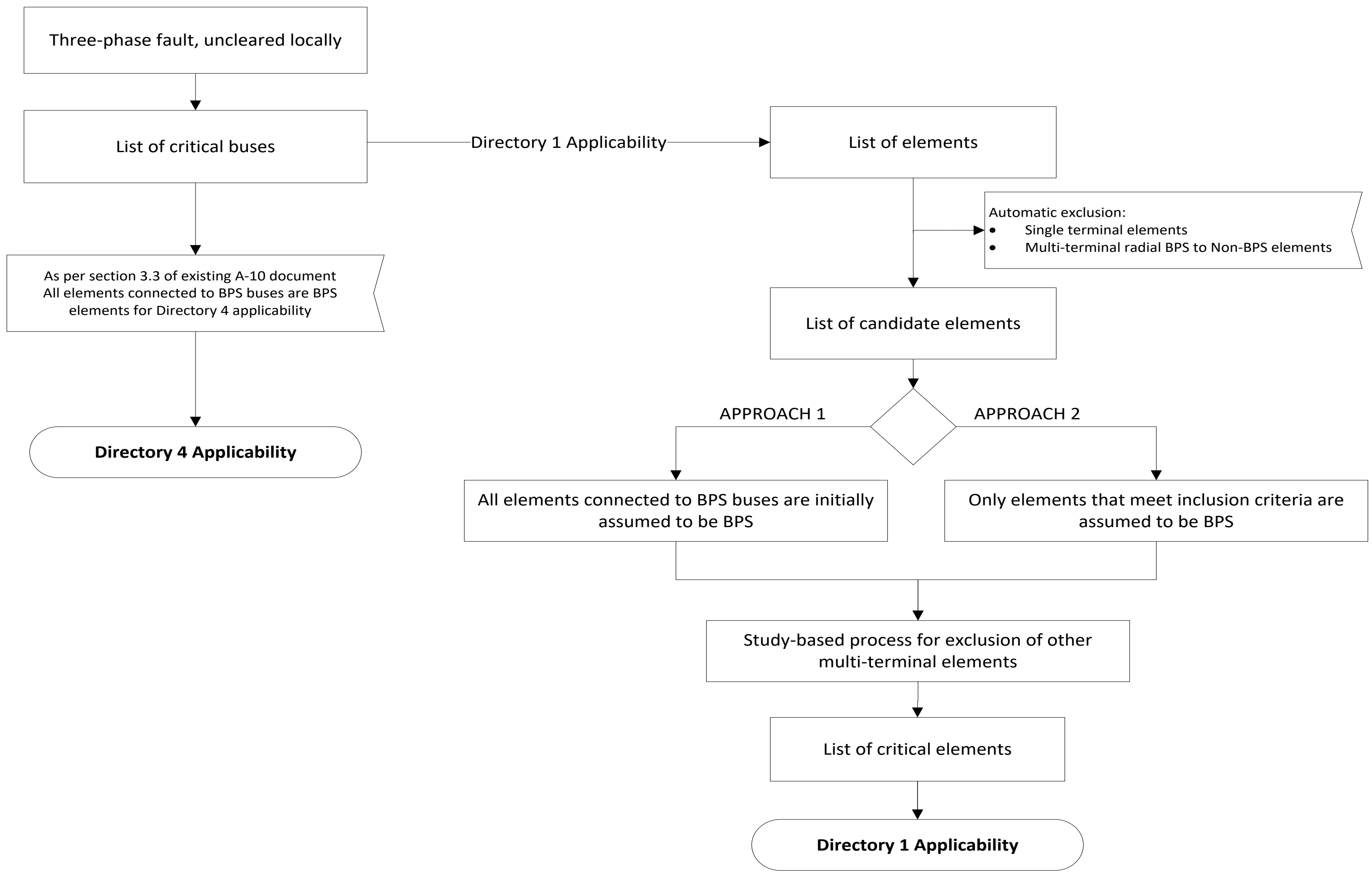

Figure 5: Element-by-Element Directory 1 Applicability Approaches

3.3.3.1 *Other Multi-Terminal Elements - Approach 1*

Under Approach 1, all other elements that are not automatically excluded from Directory 1 applicability that are connected to a BPS bus are considered BPS elements for Directory 1 applicability by default. However, an optional study-based test to exclude elements from Directory 1 applicability that are not otherwise automatically excluded will be further investigated. The study-based test is to formalize the existing flexibility already provided in Directory 1, Tables 1 & 3 performance requirement (ii):

> *"Loss of small or radial portions of the system is acceptable provided the performance requirements are not violated for the remaining* ***bulk power system."***

Under the study-based exclusion approach, bulk power system reliability needs to be maintained for Directory 1 contingencies that involve the excluded element under all foreseeable system conditions.

The study-based exclusion test would need to ensure that the impact of applicable contingencies is demonstrably contained[13] and the remaining BPS meets Directory 1 performance criteria[14,15]. The studied contingencies would be based on the topology in the vicinity of the candidate elements. Dispatches used for this test would represent the possible scenarios and not be limited to historical flows.

This study-based exclusion test would demonstrate that, if impacts of critical Directory 1 contingencies on or in the vicinity of the excluded elements are demonstrably contained, then it may be assumed that the impact of less critical Directory 1 contingencies would also be contained, and these candidate elements may be excluded from Directory 1 applicability. Examples of critical Directory 1 Table 1 contingencies considered for the assessment may include N-1-1, N-1-2, etc.

3.3.3.2 *Other Multi-Terminal Elements - Approach 2*

For multi-terminal elements with only one terminal connected to a BPS, a survey performed among the participating entities confirmed that:

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[13] This is consistent with Performance Requirement (ii) of Directory #1. This proposal allows analysis to be conducted as part of A-10 assessment and formalize the results for future use in Directory #1 analysis.

[14] All elements that have been identified as a part of the BPS for Directory 1 applicability must be monitored except for previously excluded Candidate Elements.

[15] Entities may rely on valid past assessments (including past Directory 1 Area Transmission Reviews) to support the exclusion of elements if it can be demonstrated that there are no significant system changes in the vicinity of the candidate element.

- The majority of these elements are part of local subsystems or radial subsystems and are considered non-Critical Elements (as defined above) to the reliability of both their remaining BPS and further less to the NPCC interconnections between NPCC Members and to other systems outside NPCC.
- A large majority of the multi-terminal elements captured by this clause are considered non-Critical Elements (as defined above) and therefore applying Directory 1 to these elements is considered an overreach of the methodology as it stands today.

Given that a large number of BPS-to-non-BPS elements that are identified as non-critical, this approach seeks to identify all multi-terminal elements with only one terminal connected to a BPS bus that would be critical from a Directory 1 perspective. This approach will be less labor-intensive than using a test-based exclusion procedure in conjunction with the existing approach in A-10 to exclude the non-critical multi-terminal elements with one terminal connected to a BPS bus.

3.3.3.2.1 Proposed Approach

The approach herein advocates for a new set of criteria to identify the elements considered critical to the reliable operation of the NPCC BPS within an NPCC Member's power system. It is based on the fact that reliability concerns for transmission elements connected between BPS and non-BPS buses will have been addressed by the application of Directory 4 (Bulk Power System Protection Criteria) on the BPS end of these elements.

This narrows the concern of BPS to non-BPS facilities that are significant transmission paths which are either:

- Critical because loss of these elements could redirect flows to other parts of the BPS and potentially cause reliability concerns

- Critical because loss of BPS elements could cause these elements to pick up significant flows and therefore these elements should be monitored when applying Directory 1 contingencies.

The few situations where other elements are, due to specific considerations, deemed critical will be captured by the clause 3 of the classification criteria below.

3.3.3.2.2 Criteria

An **element** is classified as part of the **bulk power system** if any of the following conditions are met:

1. Multi-terminal elements such as transformers or transmission lines are classified as part of the bulk power system if two or more terminals of the element are connected to buses that are classified as part of the bulk power system[16,17].
2. Multi-terminal elements, such as transformers or transmission lines with only one terminal connected to a bus that is classified as part of the bulk power system, are classified as part of the bulk power system if one of the following conditions are met:
    a. Any element that offers a significant power flow path for the loss of major interface elements.
    b. Any element on which a contingency results in an adverse impact a neighboring system through an inter-Area intertie.[18]
    c. Any elements connecting to a large amount of generation and on which a contingency results in an adverse impact on the remaining BPS.
    d. Any known Element on which a Directory 1 **contingency** may results in a performance criteria violation that may significantly impact an NPCC member BPS system.

Similar to Approach 1, elements identified by these conditions may be excluded when demonstration can be made that the element is non-critical for the applicability of Directory 1. The exclusion methods would be consistent with the exclusion procedures identified in Approach 1, section 3.3.3.1

3.3.3.3 *Preferred Element Applicability for Other Multi-Terminal Elements*

For multi-terminal elements that are not automatically excluded from Directory 1 applicability, CP-11 recommends Approach 1 for Directory 1 applicability.

Approach 1 is similar to the existing A-10 approach, where all multi-terminal elements that are not automatically excluded are considered BPS for Directory 1 applicability by default. An entity must demonstrate that the element is not critical for Directory 1 applicability using the proposed study-based exclusion requirement. While Approach 1 involves more engineering effort in excluding non-critical elements, the majority of the CP-11 was more comfortable with an exclusion method that would require testing to be performed to confirm that an element is not critical for Directory 1 applicability. Some members also believed that this approach may provide

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[16] E.g. for a 3-terminal transmission line, when 2 of the 3 terminals are classified as BPS it is good practice to classify the entire line as a BPS Element for Directory 1.

[17] Elements identified by these clauses maybe excluded when demonstration can be made to be non-critical by application of D1.

[18] As mutually agreed between the concerned NPCC Members (Reliability Coordinators and/or Transmission Owners/Operators)

additional reliability benefit for outage conditions that are beyond planning design criteria as specified in Directory 1.

Approach 2 leverages survey data from CP-11 members where the majority of the BPS to non-BPS multi-terminal elements were identified as not being critical for Directory 1 applicability. The automatic distinction of all non-critical multi-terminal elements with only one end connected to a BPS bus, within Approach 2, would be a more efficient method to exclude non-critical elements connected to a BPS bus than the study-based exclusion requirement under Approach 1. However, there was some concern with respect to a reliability risk in the automatic distinction of networked multi-terminal elements that may not meet the inclusion criteria under Approach 2.

3.3.3.4 *Periodic Reassessment of Excluded Elements*

Each entity shall reassess the validity of the Exclusion Test once every five years. This reassessment would coincide with the once every five years' Area-wide BPS reassessment that was discussed in section 2.2.2.5 of this report. Additionally, if there are significant system changes in the vicinity of the excluded elements, then the exclusion will need to be re-evaluated.

The TFCP suggested mandatory testing only for the non-BPS facilities on a periodic basis, while the BPS facilities would be tested on an as-required basis, when changes to the system may suggest that a previously identified BPS facility may have changed its status. This proposal would simplify the applicability of the A-10 test and significantly reduce the engineering hours for the evaluation.

4. Applicability of Other NPCC Directories to BPS Elements

Currently, all NPCC Directories have the following language under the applicability of NPCC Criteria:

> *"The requirements of an NPCC Directory apply only to those facilities defined as NPCC bulk power system elements as identified through the performance based methodology of NPCC Document A-10, "Classification of Bulk Power System Elements," the list of which is maintained by the NPCC Task Force on System Studies and approved by the NPCC Reliability Coordinating Committee."*

CP-11 reviewed the objectives of the NPCC directories to examine whether the common applicability language noted above and consequentially the list of BPS elements identified by the preferred methodology would be appropriate for each Directory's applicability.

The preferred methodology for the revised Document A-10 provides a list of elements for Directory 1 and Directory 4 applicability. The applicability sections of Directory 1 and Directory 4 may need to be amended based on the preferred methodology.

CP-11 identified 9 other directories for the review of the common applicability language.

Directory 9 (Verification of Generator Gross and Net Real Power Capability) and Directory 10 (Verification of Generator Gross and Net Reactive Power Capability) are retiring as of July 1, 2019 and therefore no detailed review of applicability for these directories was performed.

The following three Directories were identified as Directories that apply on a system-wide basis instead of an element-by-element basis and therefore the applicability of these directories is independent of the Document A-10 methodology that identified critical elements.

- Directory 5 – Reserve
- Directory 6 – Reserve Sharing Groups
- Directory 12 - Under Frequency Load Shedding Program Requirements

The following three Directories utilize the BPS elements identified based on the Document A-10 methodology, however, other parts of the Directory may apply to elements that are not classified as BPS elements. For each Directory, an example of a requirement that may apply to elements that are not identified by the A-10 methodology is also provided.

- Directory 2 - Emergency Operations: This Directory may be applied for system –wide actions line manual load shedding that may involve non-BPS facilities

- Directory 7 – Special Protection Systems: This Directory may be applied for the design of SPSs that are installed on non-BPS elements
- Directory 11 – Disturbance Monitoring Equipment Criteria: The BPS bus locations identified by the A-10 test are critical for the applicability of Directory 11. However, there are some requirements within Directory 11 that may apply to non-BPS elements adjacent to BPS buses (for example: R1 1.2).

Therefore, CP-11 recommends that NPCC clarify the common applicability language within these six directories to address the inconsistencies identified as a part of this review.

CP-11 reviewed the Directory 8 applicability and the applicability language appears to be customized to not apply exclusively to elements identified by the A-10 test. CP-11 has no recommendations on changes to applicability of Directory 8.

5. Potential Consequences of the Preferred Methodology

In accordance with the CP-11 Scope of Work in Appendix A, a list of potential consequences due to a revised A-10 methodology, both direct and indirect, has been identified. The list does not encompass all plausible consequences. CP-11 encourages individual NPCC members to review the list and self-reflect to identify any additional consequences a change in the A-10 methodology and its subsequent BPS classification results may have.

Potential consequences include but are not limited to the following:

- NPCC Directory 4 compliance at newly classified BPS buses
  - An implementation plan for these buses may be required
- NPCC Directory 1 compliance for newly classified BPS elements
  - An implementation plan for these elements may be required
- NPCC Directory 11 compliance at newly classified BPS buses
  - An implementation plan for these buses may be required
- NERC CIP-014 facilities list
  - Although there is no requirement to utilize NPCC Document A-10 BPS classification methodology to aid in determining facilities applicable to NERC CIP-014, many NPCC members do.
- Base cases utilized in Directory 1 - Area Transmission Reviews (ATR)
  - Although there is no requirement to utilize the same base cases for NPCC A-10 BPS classification and Directory 1 Area Transmission Review, many NPCC members do. While the 98th percentile requirement for stressing base cases is only a floor (Areas may opt to stress base cases further), some Areas may still wish to set up separate BPS classification and Area Transmission Review cases.
  - The proposed revised A-10 methodology better prescribes base case setup (system conditions). System conditions for BPS classification may not be suitable system conditions for Area Transmission Reviews.
- TFSS review and approval of element exclusions to Directory 1 applicability as part of BPS A-10 classification of a member system, including re-assessment at least once every five years
- Reformatting of the BPS list
  - A list of buses as well as list of elements that have been granted exclusions for Directory 1 purposes.
- NPCC member internal policies that prioritize and/or protect NPCC BPS elements.

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6. Conclusion

In accordance with the Scope of Work provided by the Task Force on Coordination of Planning, the CP-11 Working Group analyzed a number of different methodologies for Bulk Power System classification and the identification of critical elements for the application of Directory 1 and Directory 4.

CP-11 focused its efforts on two of the three methodologies proposed during Phase 1 of this review. These were Methodology 1, which maintains the locally uncleared three-phase fault test from the existing Document A-10 for applicability of both Directory 1 and Directory 4; and Methodology 2, which uses the same test for Directory 4 applicability but relies on a flow test for Directory 1 applicability.

The CP-11 Working Group recommends Methodology 1 as the preferred method for BPS classification. This methodology was found to generate the most representative list of critical facilities to which Directories 1 and 4 should apply. Many of the incremental revisions that CP-11 has made to this methodology will also address the concerns regarding consistency of application and outcomes, as well as the time and engineering effort required for BPS classification.

Further, to better align the objectives of Directory 1 and the elements identified as critical for Directory 1 applicability, an improved element-by-element classification methodology has been developed for Methodology 1.

Under this methodology, an entity may automatically exclude single-terminal elements connected to BPS buses and radial multi-terminal elements that connect BPS buses to non-BPS buses from Directory 1 applicability. Additionally, CP-11 recommends the development of a testing-based exclusion procedure for other multi-terminal elements connected to a BPS bus where, based on the fact that, once Directory 4 based protection system redundancy is achieved, some elements can be excluded from Directory 1 applicability.

The improved element-by-element applicability addresses the concerns raised by TFCP related to the over-classification of BPS elements for Directory 1 applicability that results from the use of a single test for Directory 1 and Directory 4 applicability.

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7. Recommendations

Based on Phase 2 testing of Phase 1 methodologies, and in accordance with the concerns outlined in the TFCP Scope of Work, CP-11's recommendations are:

1. Adoption of Methodology 1 (the revised existing A-10 test) for the identification of the NPCC Bulk Power System. The proposed methodology identifies facilities critical to Directory 4 and, by deploying the exclusion process, identifies facilities that are critical to Directory 1.

   The exclusion process of facilities not critical to Directory 1 applicability will be performed on a voluntary basis. CP-11 recommends the automatic exclusion of the following elements from Directory 1 applicability:

   - Single-terminal elements connected to BPS buses;
   - Multi-terminal elements that connect BPS buses to non-BPS buses that are a part of a radial subsystem.

   In addition, a study-based exclusion process for the remaining multi-terminal elements connected to BPS buses will be further investigated.

   The proposed methodology would produces two lists: a list of buses critical for Directory 4 applicability, and a list of elements critical for Directory 1 applicability (or a list of excluded elements, if more convenient).

2. The NPCC Task Forces responsible for Directories 2, 5, 6, 7, 11, and 12 review the language within the Directories to address inconsistencies in the applicability of Directories, as described in Section 4 of this report.

3. Individual NPCC members and NPCC Task Forces review the possible impact of the proposed methodology, as described in Section 5 of this report, and prepare plans for the implementation of the new methodology.

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Appendix A: Scope of Work from TFCP

Scope of Work – CP-11 Working Group

Review of the NPCC *Classification of Bulk Power System Elements* (NPCC Document A-10)

A. Objectives

Perform a comprehensive review, as required by the NPCC Reliability Assessment Program, of the NPCC *Classification of Bulk Power System Elements* (Document A-10), including revisiting the basic purpose and necessity of Document A-10. This review will:

1) Consider existing and alternative methodologies to:
   - Identify critical facilities for the applicability of NPCC Directories;
   - Simplify the existing methodology to make it less labor-intensive;
   - Improve consistency across Areas in application and outcomes of the methodology.

2) Consider conforming changes to NPCC documents to implement any necessary improvements as a result of the review.

B. Working Group Structure

A working group under the NPCC Task Force on Coordination of Planning (TFCP) will conduct this review. Additional reps on the Working Group will be solicited from the Coordination of Operation (TFCO), System Protection (TFSP), and System Studies (TFSS). In addition, TFCP may nominate additional experts on this Working Group.

C. Background

Identified concerns, issues, and possible areas of improvement to existing Methodology

TFCP has given a great deal of consideration to the Document A-10 and its application in consultation with TFCO, TFSP, and TFSS. Currently, Document A-10 provides a methodology to identify **bulk power system** (BPS) **elements** in the interconnected NPCC Region. Currently, all NPCC criteria apply to BPS facilities; however, there are questions as to whether this application produces the appropriate level of reliability in NPCC.

To provide a framework for addressing this concern, the following observations have been identified about the current methodology in Document A-10:

- The bus-based methodology has two tests that are performed: powerflow and stability. The failure of a particular test would likely result in only certain requirements of certain Directories needing to apply to gain perceived reliability benefits. An example of this could be the dynamic stability portion of the testing, which can suggest the criticality of fault-clearing, however, it does not necessarily mean the element is critical for steady state system performance.

- The methodology identifies critical elements through a performance-based approach, which can lead to study inconsistencies, whereas other methodologies, such as the NERC "bright-line" Bulk Electric System (BES) definition, employ a less complex deterministic approach for identifying critical elements.

- The methodology results in some system elements that are not critical to the reliability of the interconnected system, e.g. radial lines connected to a BPS bus, being classified as BPS. Yet, it also can result in some elements not being identified that may be considered critical to interconnected system reliability.

- The methodology is resource intensive and yields inconsistencies in outcomes, some due to different interpretations of **local area** and **significant adverse impact** by different entities and due to the sensitivity of results to small system changes.

- Protection system changes at buses adjacent to the tested bus can result in altering system performance which can impact the results of the testing, thereby excluding a bus from being considered BPS for all NPCC Directories. There are concerns about the reasonability of this outcome, in some instances in terms of Directory 1 and in other instances in terms of Directory 4.

- The individual NPCC directories have different focuses and objectives for pursuing enhanced system reliability (e.g., Directory 1 and Directory 4), and thus a performance based test for defining the applicability of one Directory may not be fully appropriate for the application of other Directories. For example, radial lines (elements), which can be classified as BPS (per current A-10) if any terminal of those elements connects to a BPS station, should not be subject to Directory 1. However, these same radial elements should be considered as part of the protection design under Directory 4. The necessity and effectiveness of these documents should all be collectively considered, especially in light of mandatory NERC reliability standards.

- The original intention of Directory 4 was to provide additional protection to buses important to the reliability of the system. The concept of determining important buses and facilities was broadened in A-10 to define the BPS for Directory 1 purposes prior to NERC’s current bright-line definition of the BES. Applying all requirements from all Directories to the BPS list developed from the A-10 methodology may infer a false sense of superior reliability, sometimes at a significantly higher cost, particularly when recognizing the inconsistencies described above.

D. Tasks

Phase 1

1. Meet with TFCP to discuss members' concerns and suggestions regarding Document A-10.

2. Discuss the basic purpose and necessity of the existing methodology.

3. Review each Area's interpretation of the terms **significant adverse impact** and **local area.** Consider revisions to these two terms to better allow for clear and consistent interpretation across the Areas.

4. Investigate opportunities to leverage existing available accepted methodologies for filtering and/or to identify NPCC critical elements (BPS). Examples may include the NERC BES, FERC 754, or other established relevant methodologies currently used to assess reliability risks. Considerations may include deterministic methods based on voltage class, number of connected circuits, MW of connected generation, etc. In support of this possible approach, **Attachment A** is provided for reference to communicate some TFCP discussions about the types of characteristics that may be considered relevant if a deterministic methodology can be found.

5. Discuss and identify new measures that can be utilized to observe or predict **significant adverse impacts** outside a **local area**.

6. Summarize feasible methodologies to identify critical facilities to apply NPCC criteria.

Phase 2

These will be established at the end of Phase 1, in line with the Phase 2 Deliverables below.

E. Deliverables

Phase 1

1. Submit an action plan to TFCP for review that addresses the concerns of NPCC Members (Target date is end of May 2017).

2. Develop and propose for consideration methodologies for effectively identifying those critical facilities that are required to meet the applicable NPCC reliability criteria. Present recommendation to TFCP and RCC (best effort Target Date is end of December 2017).

Phase 2

1. Evaluate the effectiveness of the proposed methodologies in identifying critical elements

2. Propose applicability of identified critical system elements in NPCC Directories.

3. Identify potential indirect consequences of the proposed methodologies such as an impact to the list of facilities subject to NERC CIP-014 compliance.

4. Present draft methodology document(s) to TFCP for review and approval to post in NPCC Open Process.

5. Draft responses to comments received during Open Process posting period.

6. Revise document(s) as necessary as result of NPCC Open Process. Submit to TFCP for determination of need for second posting to NPCC Open Process. TFCP will solicit other Task Forces in making this determination.

F. Schedule

To be established by Working Group with proposed completion of Phase 1 by the end of 2017 and Phase 2 by the end of 2018.

Substation Bus Survey

Bulk Power System (A-10) / FERC Order 754

last update 2/17/2017 (Draft for CP-11 Working Group Reference)

Station Name	Transmission Owner	Planning Coordinator	Bus Voltage (kV)	FERC 754, Table A Characteristics (see Notes)				MW of generation directly connected to the bus (including through GSUs)	Is an Inter-Area Tie-Line Connected?	Existing A-10 BPS Status (BPS / non-BPS)	Comments
				Circuit Count (e.g. Lines, Auto's, Generator's, etc., per Table A Notes Below)		Is Bus 100kV or Higher and directly supplies off-site power to a nuclear generating station?	Is the bus necessary for the reliable operation of the bulk power system (If Yes, add comments, why)				
				100kV - 200kV	200kV and Higher						
				6 or more	4 or more	Yes	Yes	MW	Yes	BPS / non-BPS	
Station A	Owner A	NYISO	345		6					non-BPS	
Station B	Owner A	NYISO	345		4		Yes	1012		BPS	
Station C	Owner B	NYISO	138	12				1145		non-BPS	
Station D	Owner C	NYISO	138	14				1222		non-BPS	
Station E	Owner C	NYISO	138	7				1592	Yes	non-BPS	
Station F	Owner C	NYISO	230		12		Yes	428	Yes	BPS	

Notes:

1) Buses for Inclusion: Survey should include stations a) currently listed as BPS, and/or b) meet the FERC 754 Criteria for Buses to be Tested (Table 1.1)

2) **Order No. 754, Table A:** Single Point of Failure on Protection Systems, August 16, 2012

Table A: Criteria for Buses to be Tested
Buses operated at 200 kV or higher with 4 or more circuits
Buses operated at 100 kV to 200 kV with 6 or more circuits
Buses operated at 100 kV or higher that directly supply off-site power to a nuclear generating station
Any additional buses operated at 100 kV or higher that the Transmission Planner believes are necessary for the reliable operation of the bulk power system

Notes:

1. For the purpose of applying Table A, circuits include transmission lines, transmission transformers with the primary terminal and at least one secondary terminal operated at 100 kV or higher, and generator step-up transformers connecting generating resources with aggregate gross nameplate rating greater than 20 MVA.
2. For the purpose of applying Table A, a radial line is not counted as a circuit if the only Elements connected to the line are transformers that step down to a voltage below 100 kV.
3. These criteria apply to both BES and non-BES Elements.

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Appendix B: TFCP Methodology Evaluation Criteria

Task Force on Coordination of Planning
Criteria for Evaluating Existing and Alternative A-10 Methodologies

In 2017, the Task Force on Coordination of Planning tasked the CP-11 Working Group to perform a comprehensive review of the NPCC Document A-10, Classification of Bulk Power System Elements, including visiting the basic purpose and necessity of Document A-10.

CP-11 Working Group was asked to:

1) Consider existing and alternative methodologies to:
    a. Identify critical facilities for the applicability of NPCC Directories;
    b. Simplify the existing methodology to make it less labor-intensive;
    c. Improve consistency across NPCC Areas in the application and outcomes of the methodology.
2) Consider conforming changes to NPCC documents to implement any necessary improvements as a result of the review.

At the December 5, 2017 RCC meeting, CP-11 Working Group presented conceptual approaches to improve the existing A-10 methodology and proposed two alternative methodologies. The Working Group also presented the next steps for testing the proposed methodologies and selecting a preferred methodology.

In response to the RCC leadership's challenge, TFCP agreed at the January 12, 2018 teleconference to develop an initial set of criteria for selecting a preferred methodology based on the three proposed principles below, in line with the objectives described in the Scope of Work for the A-10 review. TFCP will coordinate with the RCC leadership and other Task Force Chairs to develop a final set of criteria to be used for selecting the preferred methodology.

Principle No. 1 - Identify Critical Facilities for the applicability of NPCC Directories
This principle is paramount to having a proper methodology, and must be met by any methodology to be accepted.

Criteria 1: The methodology identifies those facilities for which protection system failure to remove a fault will result in the violation of performance criteria[19] outside of the area in which the facility is located, and for which Directory 4 shall be applicable.

[19] If an external area is impacted by the event in the area in which the facility is located, the external area could deem the impact as acceptable.

Criteria 2: The methodology identifies those facilities for which failure to meet Directory 1 criteria will result in violation of performance criteria outside of the area in which the facility is located.

Principle No. 2 – Consistency

This principle must be met by any methodology to be accepted.

Criteria 1: The methodology can be uniformly applied across all NPCC Areas.

Criteria 2: The methodology provides consistent outcome, i.e:

- the outcome is not sensitive to minor topology changes;
- the outcome is not sensitive to minor changes in power flows;
- the outcome is not sensitive to minor changes in equipment settings (e.g., voltage set point, automatic switching set point, etc.);
- the outcome does not depend on the individual performing it.

Criteria 3: The result of the methodology is repeatable.

Principle No. 3 – Simplicity

This principle will be used to help differentiate among the methodologies that meet principle 1 and principle 2.

Criteria 1: The methodology is efficient in the use of engineering hours to perform.

Criteria 2: The result is auditable.

Appendix C: Methodology 1 Revision Details

Testing Strategy

The purpose of adding a "Testing Strategy" is to have a consistent NPCC-wide approach to where the BPS classification test needs to be performed. This approach will replace the language in the existing Document A-10, which states:

> *"Application of this methodology may be omitted at buses that can be logically excluded from the bulk power system based on study results at other buses tested using this methodology."*

With this testing strategy, there will be a consistent application of BPS classification among the NPCC Areas, ensuring that each Area is testing buses according to a consistent standard.

The locally uncleared three-phase fault test will be applied on the following buses:

- All buses operated at a voltage above 200 kV shall be tested.
- For buses operated at voltage levels between 50 kV and 200 kV, all buses adjacent to a BPS bus shall be tested. Testing shall continue into the 50-200 kV system until a non-BPS result is obtained. Once a non-BPS result is obtained, it is permitted to forgo testing of downstream buses unless one of the following considerations shows a need to test these buses:
    - Clearing times at downstream buses (down-stream buses may have slower remote clearing times, leading to the possibility of non-contiguous BPS buses)
    - Higher short-circuit levels (relative to the adjacent bus) at downstream buses (higher short-circuit levels could lead to greater impacts from three-phase faults and the possibility of non-contiguous BPS buses)
    - Any other factors that may produce a non-contiguous BPS result.
- Generator buses operated at voltages below 50 kV that are directly connected to a BPS bus through a transformer connection shall be tested.

Rationale

The CP-11 Working Group acknowledges that a non-contiguous BPS is possible, as evidenced by past and current test results that show non-contiguous buses failing the locally uncleared three-phase fault test. The factors for consideration before forgoing testing of buses downstream of non-BPS buses are expected to adequately capture these non-contiguous BPS determinations.

Test results so far, both prior to and as part of CP-11's efforts, have shown that distribution buses operated at voltages below 50 kV have never shown a BPS result. Not every NPCC Area explicitly models distribution transformers and the load buses at the low side of these transformers, and adding the requirement to test these buses would be burdensome to those Areas that would have to collect modeling data on these transformers and buses for the first time. The transformers connecting distribution buses to the transmission system are generally not large (rated under 100 MVA), and their larger impedance tends to insulate the transmission system from any effects of a three-phase fault on the distribution bus. The same is not true for generation buses, where the transformers are sometimes much larger and lower-impedance; as a result, CP-11 recommends a requirement to test generator terminal buses for BPS status.

Steady-State Testing Procedure

The CP-11 Working Group has proposed to keep the steady-state test as described in “Step 2” of the existing A-10 document. However, when running this test, all elements that were disconnected by the end of the transient run shall be disconnected as part of the starting conditions for the steady-state test. This includes generators or other elements that are disconnected due to equipment protection (such as under-voltage or over-speed protection), as well as any elements removed in order to clear the faulted bus remotely.

Base Case Setup

The existing NPCC Document A-10 contains the following language regarding base case setup for BPS classification testing:

> *Studies conducted for the purpose of determining the elements of the bulk power system shall assume the following conditions:*
>
> *3.1.1. Power flow transfers, load and generation patterns expected to exist for the period under study which stress the system in a manner critical to the classification of the bus to be tested. All reclosing facilities rendered inoperative.*

Members of the CP-11 Working Group acknowledged that this language is not very specific, leading to the opportunity for inconsistencies in application between NPCC Entities (as evidenced by differing practices for base case setup today). At the same time, the outcome of the locally uncleared three-phase fault test has been observed to be sensitive to the base case conditions chosen, meaning that these inconsistencies in test inputs could easily lead to inconsistencies in BPS classification results as well.

To address these inconsistencies, CP-11 proposed language that would provide more concrete guidance around base case setup. This language would serve as a “floor” for base case setup, providing a minimum level of system conditions that all NPCC Areas would have to meet in BPS classification testing. An Area could stress their cases beyond the level specified, or test other conditions, at their discretion.

Proposed language regarding load levels:

Each Area shall test at least two load levels when testing for BPS classification: a seasonal peak case (either winter or summer, whichever is higher in the Area under test) and a light load case. The seasonal peak load case shall model a load level equal to the Area's 50/50 seasonal peak load forecast, and the light load shall model a load level at or near minimum load conditions, such as early morning load levels. An Area may, at its own discretion, additionally test at other load levels to identify additional BPS buses.

Proposed language regarding interface stresses:

Ensure that at least one base case (at any load level) covers the 98th percentile of flow on each major interface on a year-round basis.

When calculating 98th percentile flows, ensure that the historical data used includes a sufficient number of years to reduce the effect of any unusual flows that may have occurred during the time period (for example, due to a lengthy generation outage for refurbishment). At a minimum, three years of data should be used.

As a voluntary guideline, the 98th percentile could be used on a seasonal basis (in other words, the light load case would be stressed at a level reflective of the 98th percentile of flows under light load conditions, and the peak load case would be stressed at a level reflective of the 98th percentile of flows under peak load conditions).

(The list of "major interfaces" to be stressed in this manner, as well as the criteria used to select those interfaces, shall be presented to TFSS as a part of the periodic review of an Area's BPS classifications. Interfaces not considered major may be stressed at the Area's discretion.)

If necessary, historical flows may be adjusted to reflect known future material system changes that are not reflected in the historical data. For example, the planned retirement of a certain generator may make it impossible to stress an interface in an export-limited area to the levels observed in the past.

Proposed language regarding generation patterns:

Given the load level and transfer conditions chosen for a particular base case, the generation dispatch chosen shall reflect credible generation dispatch patterns. Each area should consider adjusting the dispatch to identify critical buses which could cause a significant adverse impact.

Any future generator included in the base case shall be dispatched in a manner similar to existing units of the same type.

Rationale for load levels, interface stresses, and generation patterns

The 98th percentile requirement was chosen in recognition of the fact that many conditions are encountered in real-time operations that are not tested for BPS classification. For example, outages of transmission equipment are not studied in BPS classification tests. Additionally, some major interfaces rarely or never operate near their transfer limit, and thus it would be overly conservative to test for BPS classification at a level of system stress never observed in actual operations. Members of the CP-11 Working Group felt that it would be appropriate to allow an amount of risk in the level of interface stress comparable to that allowed by not studying equipment outages in BPS classification, and chose the 98th percentile as a reasonable level of system stress. This level of interface stress is also expected to reduce volatility in study conditions, in comparison to using a higher percentile value that could be more easily influenced from year to year by a few hours of unusual operating conditions.

Performance Requirements

The objective of the proposed performance requirements is to define what system impacts observed from the performance-based test results are sufficiently detrimental to system reliability to justify classifying the tested bus as a part of the Bulk Power System. The means by which each entity actually evaluates and measures the impacts is documented through technical guidelines and methods. For instance, transient voltage or damping criteria may be a mean to measure potential System Instability and containment of a certain level of Cascading may be analyzed through successive tripping of elements overloaded above Short Term Emergency ratings. In any case, the use of sound technical practices is required. In the absence of conclusive results that demonstrate that a specific level of system impact does not significantly impact neighboring areas (within or outside of NPCC), a conservative approach (e.g. use of adequate voltage criteria, no instability or cascading at all, etc.) shall be used.

Following application of the performance based test, the occurrence of any of the impacts below should be deemed as significant and require classification of the tested bus as part of the BPS.

- System instability that cannot be demonstrably contained[20]
- Cascading that cannot be demonstrably contained (within the Area or a predefined/established portion of the system)[21]
- Net Loss of Source or Loss of Load greater than an Area's threshold, if applicable.[22]

Rationale

System Instability shall be interpreted as the inability of the System to maintain a state of equilibrium following the disturbance from the performance test. The reference to "System" excludes instability that can be demonstrably contained, such as a voltage collapse affecting a small or radial subsystem, or generator instability for which technical analysis can reasonably show the instability does not propagate through the System (e.g. by modeling generator protections).

Cascading analysis can lead to three outcomes following the sequential tripping of elements: 1) it can be demonstrably contained to a relatively small portion of the system, 2) it can be demonstrably contained while causing the loss or unintentional separation of a portion of the system that results in the net loss of load or source greater than the Area's threshold, or 3) it may not be demonstrably contained. Outcomes 2 and 3 are violations of the performance requirement.

Due to the characteristics of some Areas, a net loss of source or load beyond a certain threshold may be deemed as significant for various reasons, such as frequency stability, reserve requirements, widespread electric interruption, overloads on tie lines, and so on.

Assumptions on Transformer Tripping

As testing efforts in Phase 2 of CP-11's efforts proceeded, it was observed that different NPCC Areas were making different assumptions regarding the treatment of transformers at the bus under test. In most cases, these transformers will be protected by differential protection. As a result, they will not be tripped due to a fault on the bus under test, since that fault will be outside

[20] Un-damped oscillations where an oscillatory response is not demonstrated to be clearly positively damped within 30 seconds of the initiating event

[21] Containment of cascading can be determined by examining sequential tripping caused by exceeding stability limits, voltage limits and/or transmission Element loading. When Cascading crosses to a neighboring Area, the affected Area shall be consulted to determine the severity of the impact on the performance of the system in the neighboring Area.

[22] An Area's Loss of Source and Loss of Load threshold will be determined by each Area with due consideration to impacts outside of the Area. The values are to be presented and approved by TFSS and TFCP. An Area may have different values for various conditions studied (e.g. summer vs. winter, light vs. peak loading, etc.).

of the differential scheme’s zone of protection. While other auxiliary protection schemes may eventually trip the transformer in reality, obtaining data for modeling these schemes may be more difficult than for other transmission elements.

In order to improve consistency in application of the BPS classification test, members of CP-11 standardized the assumptions around the treatment of these transformers. The standardized assumption was based on the premise that a transformer exposed to fault current would eventually fail, with the fault propagating to the unfaulted terminal of the transformer after five seconds. (The five-second delay is based on transformer design standards in IEEE Standard C57.109-1993.) The subsequent actions at the previously unfaulted terminal are dependent on the protection system design at that terminal.

If the previously unfaulted side of the transformer(s) is BPS or has no common-mode failures with the faulted side: Assume that some protection on the non-faulted side will act to clear the transformer(s) after five seconds, or faster if actual protection information is available. This assumption is safe because the non-faulted side has redundancy, so at least one system would still be able to act. In most cases, this will take the form of a bus fault on that bus, cleared in the time normally assumed for bus faults with no protection failures. This would apply to both transient and steady-state tests.

If the previously unfaulted side of the transformer(s) is non-BPS and/or common-mode failures with the faulted side do exist: Assume that the fault migrates to the non-faulted side of the transformer(s) after five seconds, and that elements connected to the non-faulted side also clear remotely. (This would take a similar form to a BPS classification test on the previously unfaulted terminal of the transformer.) This reflects the fact that no protection on the non-faulted side would be guaranteed to operate. A possible mitigation for this situation could be eliminate the common-mode failure that would also disable the non-faulted-side protection. This assumption would apply in both transient and steady-state tests.

Although this approach will improve consistency in the application of the A-10 test, it is not expected to drastically change the results for most buses. In most cases, any transient stability impacts of the initial fault will have occurred within the first five seconds, and the system will either be completely unstable or approaching a steady state by the time the fault migrates to the opposite terminal of the transformer.

Treatment of Directional Comparison Blocking Schemes

The existing NPCC Document A-10 allows for the use of clearing times faster than those provided by remote delayed clearing when directional comparison blocking (DCB) schemes or other similar protection schemes are used. Document A-10 contains the following language:

> *Some protection groups (e.g. directional comparison blocking) at remote terminals may provide high-speed fault clearing for faults at the bus under test. In order to test the effects of longer fault clearing times for fault conditions when these remote protection groups would not provide high speed fault clearing, for either test (1a) or (1b) above:*
>
> - *High-speed fault clearing at remote terminals must be ignored; or*
> - *Testing must vary the placement of the 3-phase fault on the elements connected to the bus under test to include locations beyond the reach of the high-speed tripping relay element at the remote terminal.*

While there are a number of cases where this provision is utilized today, members of the CP-11 Working Group brought up a number of concerns with the reliance on DCB schemes for faster clearing times in BPS classification. Those concerns included the following:

- A single component failure can be a more severe test for DCB failure than the complete failure of the local protection system at the bus under test. Communication failure of the blocking signal, as a partial failure of the local protection system, is not the most severe failure, and hence we should assume communication of the blocking signal between bus under test and remote buses remains intact. The most severe failure would be the transmission of a blocking signal along with the failure of another protection component at the bus under test that disables local tripping, leading to slow clearing despite the presence of a DCB scheme.
- For a close-in fault on one of the circuits connected to the bus under test with a failure of the non-redundant relay protecting that circuit, the fault will be cleared as follows. This indicates that a fault just outside of the station under test, with a failure of the protection on the faulted circuit, would still clear with a delay, and that counting on the DCB scheme's fast clearing would mask the effects of a fault just outside the station.
    - The remote end of the faulted circuit will trip quickly if it uses a DCB scheme, or more slowly if it uses a permissive scheme.
    - All remaining circuits connected to the bus under test will trip remotely with delayed clearing, regardless of the scheme, as described below:
        - The reverse-looking elements of each of the remaining circuits that use DCB schemes will initiate a blocking signal to their remote terminals preventing the remote terminals from tripping quickly.

- The permissive signals of each of the remaining circuits that use permissive schemes will not be initiated since the fault is reverse, and consequently, the remote terminals will trip with a delay associated with Zone 2 or Zone 3 clearing.

- While it might be possible to move the test fault along each circuit to verify the reach of all DCB schemes installed on circuits connected to the bus under test, moving the faults is difficult to accurately simulate by using planning tools and protection systems setting limitations due to the changing apparent impedance effect seen at the remote terminals. Therefore, assuming a locally uncleared three phase fault and delayed clearing at most remote terminals is consistent with the test performed for permissive schemes.

Recommendation

With the elimination of reliance on fast clearing from DCB schemes, moving faults along elements is no longer required while assuming delayed clearing regardless of the protection scheme(s) present. This assumption will lead to a reduction in the overall resource requirements to run the methodology, while ensuring that the effects of a partial protection system failure are captured more completely than they are in the existing A-10 methodology.

Elimination of Testing Adjacent Circuits on Common Towers

Within the existing A-10 methodology, both the transient stability and steady state tests include two events that may be simulated for each bus under test:

- Apply a three-phase fault at the bus under test which is uncleared locally (steps 1a and 1b in the transient stability test and 2a and 2b in the steady state test)
- If the bus under test has a circuit which is a part of two adjacent circuits on a tower where both circuits do not terminate at the bus under test, additional testing is performed by applying a simultaneous permanent phase to ground **faults** on different phases of each of two adjacent transmission circuits at critical common tower locations. The **fault** on the circuit associated with the *bus* under test which is *uncleared locally*, shall be simulated with **normal fault clearing** at the remote terminal and on the adjacent circuit (steps 1c in the transient stability test and 2c in the steady state test). This test will be referred to as the Adjacent Circuits on a Common Tower (ACCT) test for the purposes of this report.

Additional details on the testing conditions are provided in the existing A-10 document[23].

[23] https://www.npcc.org/Standards/Criteria/A-10-Revised%20Full%20Member%20Approved%20December%2001,%202009%20GJD.pdf

The existing Document A-10 contains the following justification for the inclusion of the ACCT test:

> *"Both **transient stability** and steady-state tests are used to determine the impact on system performance resulting from power system **faults**.*
>
> *Testing is based on application of a bus **fault** at a single voltage level that is uncleared locally. Tripping of un-faulted **elements** associated with clearing the test **fault** does not constitute a **significant adverse impact**.*
>
> *Depending on system configuration or topology, testing only **faults** at buses can fail to uncover **significant adverse impacts** arising <u>from a design criteria contingency involving the loss of two adjacent transmission circuits on a common tower</u> [emphasis added]. Hence, specific tests in 1c and 2c below are designed to assess this contingency for its potential **significant adverse impact** outside of the **local area**."*

The last paragraph of the previous excerpt provides the rationale for the inclusion of the Adjacent Circuits on a Common Tower Test within the existing methodology.

Background on the ACCT test's origins

The Adjacent Circuits on a Common Tower Test was included in the A-10 document in 2009 based on discussions that occurred in CP-11. Prior to this addition, the A-10 test only included a 3 phase fault at the bus under test which is uncleared locally.

The specific concern that led to the inclusion of the test was that the bus-based test (3 phase uncleared locally) could miss design contingencies that may be more severe, and that there was a need to augment the A-10 test to cover these potential scenarios.

The specific example that was raised was of loss of adjacent circuits on a common tower which may not be originating from the same substation.

In Figure 9 the individual bus-by-bus test involving a three-phase fault that is uncleared locally at any of the 4 buses (A, B, C or D) may not be as severe as the design contingency involving the loss of the two adjacent circuits (A-C and B-D) that are on a common tower.

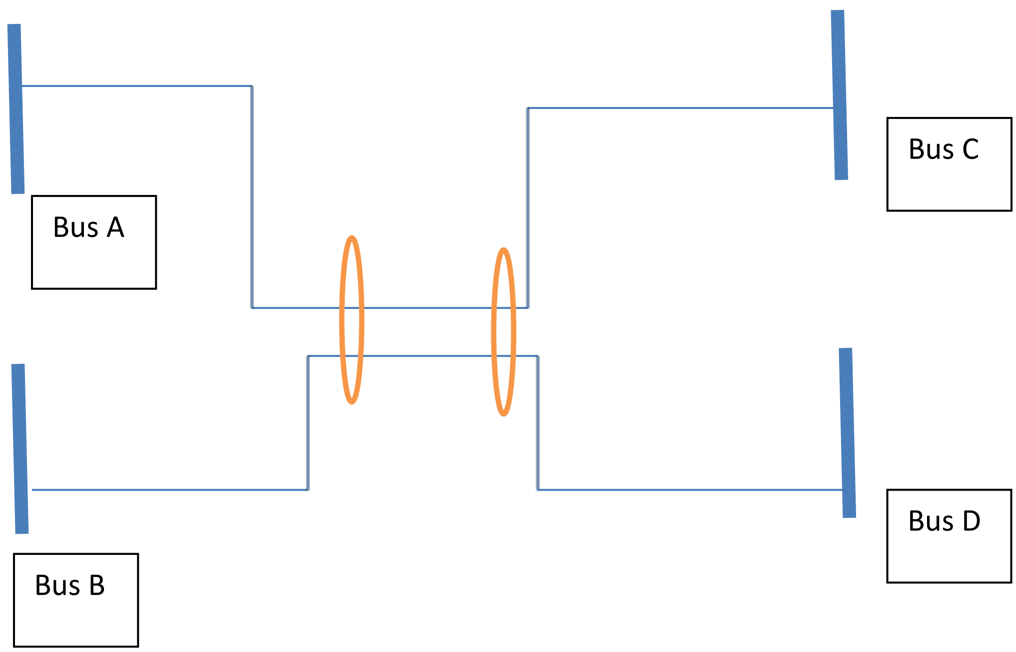

Figure 6: Example System with Adjacent Circuits on a Common Tower

In 2009, the group concluded that the bus-by-bus test would not uncover situations where the loss of adjacent circuits on a common tower may lead to a significant adverse impact outside the local area. On this basis, the ACCT test was included in the A-10 methodology.

Need for continued use of the ACCT test

As a part of the review that was initiated in 2017, one of the items that the Working Group has discussed is the continued need for the (ACCT) test. Going back to the origins of this test in Document A-10, the CP-11 Working Group contemplated the following additional design criteria contingencies that may be more severe than the bus-by-bus 3-phase faults that are uncleared locally:

- The bus-by-bus test would not uncover N-1-1 design contingencies where the two events occur at different buses.
- It is possible that at the bus under test, some design contingencies (N-1 or N-1-1) that do not disconnect all connected elements might have a significant adverse impact, which may be masked if all elements at the bus are cleared remotely

On this basis, there may be other additional events that may lead to a significant adverse impact outside the local area which are not covered by the combination of the 3phase bus fault uncleared locally and the ACCT test.

Further, when this test was added in 2009 to the A-10 document, the impact of the ACCT test on BPS classification was unknown. However, with over 8 years of experience in applying this test, CP-11 was unable to identify a single instance where the ACCT test resulted in a bus being classified as a BPS bus, which was previously unidentified using the three-phase bus fault that is uncleared locally.

Additionally, CP-11 noted that the application of this test was onerous because:

- Each instance of adjacent circuits on a common tower would lead to up to 4 substations requiring to be tested
- Determining accurate clearing times for a phase to ground fault combined with protection system failure at the bus under test is challenging. The protection system information required to correctly model this event is more detailed than the information required to model the design contingency involving adjacent circuits on a common tower.
- Finally, simulating a single-phase-to-ground fault on two different phases of two different transmission elements requires a full three-phase simulation, which is not possible in the simulation tool used for transient stability analysis (PSS/E). It is possible to approximate this fault by simulating phase-to-phase-to-ground faults on both transmission elements, but this is only an approximation of the event specified.

Finally, CP-11 believes that the following language and footnote from Directory 1 would permit each entity to apply contingencies on non-BPS facilities if the entity deems those facilities to have the potential for significant adverse impacts outside the local area.

> *If an entity becomes aware[1] of a **contingency** not on a **bulk power system** element that results in a **significant adverse impact** outside the **local area,** that entity must design and/or operate the system to respect that event.*
>
> *[1] NPCC Members shall strive to meet the reliability objectives in this document. However, there is no affirmative requirement for an NPCC Member to explicitly identify every potential non-BPS contingency that may impact the BPS.*

CP-11 recognizes that the intent of the A-10 test is to identify critical facilities for criteria applicability, but the methodology used to identify the critical facilities should not be excessively onerous. CP-11 recommends that the ACCT test be excluded from BPS classification testing on the following basis:

- Experience gained with the ACCT test has indicated that it has failed to identify additional BPS facilities that would not have been identified in its absence.
- The test is onerous in terms of the number of additional scenarios that are required to be analyzed and the extent of protection data details required to correctly simulate these additional scenarios. This would help achieve the objective of reducing resource requirements for the A-10 testing.

- The simulation tool used by NPCC members for transient stability analysis (PSS/E) does not allow the simulation of two simultaneous single-phase-to-ground faults on different phases, meaning that the test as defined in Document A-10 cannot be simulated exactly.
- Other design criteria contingencies may be more severe than the three-phase locally uncleared fault which are currently not captured by the BPS classification test. If it is acceptable to have a BPS classification test that does not explicitly identify those facilities, it should also be acceptable to exclude the adjacent circuits on a common tower from the testing.