Attachment G: PJM Stability, Short Circuit and Special RTEP Practices and Procedures

STABILITY

PJM Planning conducts stability studies to ensure that the planned system can withstand NERC criteria disturbances and maintain stable operation throughout the PJM planning horizon.

NERC criteria disturbances are those required by the NERC planning criteria applicable to system normal, single element outage and common-mode multiple element outage conditions. These conditions are specified in the NERC approved Transmission Planning (TPL) Reliability Standards that can be found on the NERC website (www.NERC.com). Because these standards change from time to time they are included here by reference. In addition, PJM's analyses also satisfy the Transmission Owner specific stability practices and procedures as may be applicable when these are more demanding tests than the standard NERC criteria tests applied by PJM. All Transmission Owner specific information and criteria that exceed *standard testing of NERC criteria* and are applicable to PJM reliability based RTEP stability analyses are included or referenced in the Appendix to this Attachment. Transmission Owner stability criteria filed as FERC Form No. 715 and posted on PJM's website and not included in the Appendix may be used to support Transmission Owner funded upgrades. The currently approved version of this Appendix at the commencement of the annual RTEP process will be the basis for that baseline RTEP and related generator queue assessments. PJM's stability analyses verify satisfactory projected system performance over the range of anticipated load levels and identify any need for upgrades, operating guides, or special protection systems that may be indicated based on stability or short circuit testing as a primary driver. In general, the most appropriate remedy to NERC criteria violations is a system upgrade. In circumstances involving criteria that go beyond PJM's standard testing of NERC criteria, operating guides or special protection system remedies may also be considered as discussed further in this Attachment and its Appendix. New Special Protection Systems, however are generally avoided and, if considered, require case-by-case review and justification. Also certain specific areas of PJM have been identified through PJM or Transmission Owner analysis as stability limited areas of the system. In such areas of the system, stability operating guides may apply. For related information see PJM Manual 03 at http://www.pjm.com/documents/manuals.aspx.

1

System conditions most critical for stability analysis on the PJM system are generally characterized by light load. Peak load analysis is added for stability reviews that involve new connections of wind turbines and performance of low voltage ride through testing. In exceptional cases, PJM may add heavy load testing for other types of units when PJM determines that heavy load may be the critical load level for system stability for the limitation under review.

PJM’s stability analyses ensure the dual objectives of stability of new interconnection projects and system-wide stability. PJM, each year conducts dozens of interconnection queue project stability studies. These analyses ensure newly-connecting projects and nearby changes to the system configuration maintain the stability of the project and the system. Study of these projects located throughout PJM provides a thorough, ongoing review of PJM both at the project level and system-wide. In addition, each year, PJM conducts a re-study of one third of existing PJM generation stations. This results in a three-year cycle of on-going re-study of the entire PJM system. PJM also performs additional system-wide stability analyses during the annual RTEP review. In addition, as may be required from time to time, PJM conducts stability analyses to evaluate the dynamic performance of actual or possible major future system developments. For example a proposed new backbone transmission project or prolonged unexpected backbone transmission outage in a stability sensitive area would be cause for a specifically targeted system study. Another cause could be the need to evaluate system performance resulting from major developments affecting power and energy policy.

DYNAMICS PROCEDURES

This section provides a high level review of the process of setting up and performing dynamics analyses.

2

Dynamics Reference Cases

Reference power flow cases for stability analysis are created in a similar manner to that of the power flow reference cases. Additional information, however, is necessary for stability studies to simulate the combined dynamic responses of various power system components. Included in this additional information are dynamics models for generators, excitation systems, power system stabilizers, governors, loads and various other equipments. The required dynamic and other modeling information that must be supplied by generators interconnected to the PJM system is detailed in Manual 14A. A dynamic simulation links the system model or power flow information with the dynamic data or models to determine if the system and generators will remain stable for steady-state and various disturbances. The current RTEP summer peak case is used as a starting point to create new dynamics cases (light load and peak load.) For example the RTEP analysis is performed for the current year plus five (available early in each calendar year and updated for the five-year-out RTEP analyses in early fall of each calendar year). The stability case setup is for the same study year using the updated RTEP case. This updated RTEP power flow case and the associated stability case become the baseline cases for the impact study analyses (that begin in the fall of each year) that begin with the first interconnection queue of each calendar year and continue through each of the 3 subsequent annual queues.

Dynamics Analysis

The two dynamics cases Originate from the RTEP Power Flow Case that is created for the annual RTEP Plan analyses. The annual RTEP cycle is depicted in Manual 14B, Exhibit 1. The earliest availability for this annual RTEP reference power flow case is for the impact studies associated with the interconnection request queue that closes on January 31. For subsequent project queues that close later in the year, this reference RTEP case is updated to the most current data. The reference power flow case is reviewed and modified as necessary to correspond to the dynamics database (which includes external world dynamics data from the NERC System Dynamics Data Working Group as well as PJM data.) In addition, the case is modified to include generator step-up transformers and explicit modeling of generator station service power use along with gross generator rating. Also, because of the demands of dynamics analyses, power flow static load representations are replaced with their dynamic load model representations. PJM currently represents loads as 100% constant current real power and 100% constant impedance reactive power. In light load representations, pumped storage resources are in pumping mode.
This process is followed to develop stability setups for analysis of all PJM interconnection requests. In addition PJM's system stability analyses will use the most current available setup from this continuous development process.

Testing

After the dynamics model setup, an unperturbed dynamic simulation is run for 20 seconds. After case verification, the final, initialized set of power flows and the associated snap-shots, along with the associated dynamic run files are available to Interconnection Customers and others who have a legitimate need for the information, subject to applicable Confidentiality and Critical Energy Infrastructure Information processes (see PJM Operating Agreement §18.17 and http://www.pjm.com/documents/ferc-manuals/ceii.aspx .

Dispatch

The assumptions used for generation dispatch can be critical to the results. It is generally accepted that units operating at their highest possible power output and generating as little reactive power as necessary to maintain voltages are likely to be less stable. Normally, the units in the vicinity of the project under study will be turned on to their maximum real power output with unity power factor at the high side of the GSU's, or units' VAR output will be adjusted to hold scheduled voltages, depending on specific Transmission Owner criteria. Wind turbines are tested at light load for stability and peak load for low voltage ride through at 100% of their maximum energy value. In addition, stability test scenarios necessitated by any applicable

Transmission Owner operating guides will also factor into each analysis.

Simulations to determine required upgrades (also see the Appendix to this Attachment)

Fault Criteria:

a. Fault Types: For interconnection and system stability analyses, three phase faults, single line to ground faults with stuck breaker and single line to ground faults with the communications failure cleared within zone 2 time will be examined. Each analysis will include a determination of the most critical faults to apply.
b. Clearing Times: Dynamic simulation issues are identified using estimates of actual (nominal) clearing times, including relay trip times, breaker interrupting time, fault extinguishing time, intentional delay time, and a margin for error.
c. Reclosing: Only high speed reclosing is modeled if present.
d. Fault locations: For interconnection analysis, criteria faults at power flow busses including one bus removed from the interconnection point will be examined. When clusters of generating busses are studied, the most critical faults one bus removed from new generators in the cluster will be examined. In addition, other fault locations judged critical to cluster response will be added to the scope. For system analyses, the scope will determine the most critical locations to apply criteria faults.
e. Maintenance outages: Interconnection analyses of planned line maintenance outage conditions prior to fault application are system conditions that can be anticipated and that are generally of limited duration. The least cost remedy to issues during such system conditions is to require generation to curtail output. Such analyses are, therefore, of primary interest in the operating horizon and are not generally considered to determine upgrade facilities required prior to interconnection. Nevertheless, prior to commercial operation, or prior to completion of the facilities study at the request of the Interconnection Customer, Planning will screen critical faults for issues during line maintenance. The results of the line maintenance study will be conveyed to PJM Operations, the Interconnection Customer, and affected Transmission Owners.

   PJM addresses Power System Stabilizer (PSS) outages in a similar fashion. If there are existing PSS installations nearby a new interconnection or if PSS is required on the new interconnection, critical faults for the outage of these devices will be studied prior to commercial operation and the results will be conveyed to PJM Operations, the Interconnection Customer, and affected Transmission Owners.

Margins:

The margins applied by PJM are intended to be applied in impact study stability analysis that uses a project's final stability study data as further discussed below. As such, these margins account primarily for uncertainty in actual clearing times, and the final data represents the "as built" performance. With the machine modeled at net unity power factor at the high-side of the GSU (or unity power factor at the generator terminals for wind turbine installations), transient stability must be maintained for tested faults when the following margins are included:

a. Add 0.25 cycles to the nominal primary clearing time for 3 phase, normally cleared faults.
b. Add 0.25 cycles to the nominal primary clearing time for single-line-to-ground faults, plus an additional 0.5 cycles added to the nominal backup clearing time for stuck breaker (.75 cycle total clearing time margin).
c. Add 0.25 cycles to the nominal primary clearing time for single-line-to-ground faults, plus an additional 1.25 cycles to the nominal Zone 2 clearing time for failure of primary relaying (1.5 cycle total clearing time margin).

Monitoring requirements:

Rotor angle, Real power output, EFD, speed and terminal voltage of units under study are monitored. Bus Voltages in the same area are also monitored.

Acceptable Voltage Drop:

Following the disturbance, the voltages of the monitored buses maintain voltages within ±5% of the precontingency voltages

Acceptable Damping:

Following the disturbance, the oscillations of the monitored parameters display positive damping. The positive damping is determined with a damping coefficient calculation algorithm. This characterizes the degree of positive (damped) or negative (undamped) damping based on the damping trend, over the duration of the stability run, of the envelop of machine angle oscillation peaks. This trend can be observed by drawing an envelope connecting each succeeding peak or valley of the oscillation of the monitored element. An acceptable oscillation envelope will demonstrate a positive decay within the appropriate test period (normally 10 to 15 seconds). A sustained oscillatory system response, even if slightly damped, will cause the system to be in a vulnerable state and exposed to adverse impacts for subsequent changes to the system over some prolonged time. To limit this system exposure PJM uses a 3% damping margin. Such positive damping demonstrates an acceptable response by the system, and no further analysis is required. Failure to meet the damping standard will require application of some combination of power system stabilizers, excitation system upgrade and tuning, and system upgrade.

System Impact Study and Initial Study Stability Procedures

Generating unit stability analysis is performed by PJM as a part of the System Impact Study for proposed generation interconnection to the PJM system. PJM also conducts annual system stability analysis of the PJM system in compliance with applicable NERC transmission planning criteria. PJM's standards for stability analyses satisfy NERC criteria and are the generally applicable criteria for all PJM stability analyses. In addition, Transmission Owner stability criteria may apply. Certain specific areas of PJM have been identified by PJM or Transmission Owner analysis as stability limited areas of the system. In such areas of the system, stability operating guides may apply. See PJM Manual 03 at http://www.pjm.com/documents/manuals.aspx for more information on PJM stability operating guides.

STABILITY DATA REQUIREMENTS

a. Submission of Project Stability Study Data

   Stability study data is included in the data required for the series of studies generally required for a System Impact Study. A System Impact Study typically includes a short circuit study, power flow study and stability study. As required by the PJM Tariff, and detailed in PJM Manual 14A, all data for the System Impact Study, including stability analysis data, must be submitted by the Interconnection Customer as part of a completed System Impact Study Agreement. System Impact Study Agreements are not complete until the required agreement is fully executed and all associated data for the complete series of studies is received. Upon PJM's acceptance of a completed System Impact Study Agreement, all associated data becomes the Interconnection Customer's final data for the System Impact Study and any subsequently necessary Facilities Study.

b. Final Stability Study Data

Prior to beginning any of the studies generally required for a System Impact Study, PJM will accommodate modifications to submitted data unless, in PJM's judgment, such modification would adversely impact subsequently queued projects. It is the Interconnection Customer's responsibility to establish and maintain communication with the assigned PJM Project Manager to determine the latest date that specific data changes can be accommodated. Interconnection Customers are encouraged to work closely with their Project Managers to determine if any anticipated project changes can be accommodated without adversely affecting subsequent projects. After acceptance of the System Impact Study Agreement, PJM is under no obligation to accept any changes in data and may proceed through the System Impact Study, Facilities Study and the Interconnection Service Agreement processes on the basis of the final data. This final data is considered consistent with the "as built" representation of the system. As such, it should represent the actual equipment that will be installed and commissioning settings that can be achieved.

c. Changes to Stability Data After Commencement of Stability Study

This section addresses project changes that affect the stability study and often the short circuit study. Such changes typically involve the electrical, configuration and physical parameters of the generator and associated electrical equipment between the connection to the networked power system and the generator. While some configuration changes could necessitate power flow re-study, the changes that are discussed here only cause stability and possibly short circuit re-study.

After the start of the stability study PJM will complete the stability study, issue the System Impact Study report, complete any necessary Facilities Study and issue the Interconnection Service Agreement. After the start of the stability study, changes to electrical parameters that will require stability re-study, will be accommodated by PJM as resources are available and in a manner that does not negatively impact later queued projects. In addition, certain parameter changes may also require new short circuit studies. Necessary re-study caused by parameter changes may be performed by contractors. The re-study will be performed on the system model that includes all project studies completed at the time of the re-study. The scope of the re-study will determine all necessary incremental system facilities necessitated by the parameter changes.

d. Cost of Incremental Facilities Caused by Re-study

The Interconnection Customer that makes the parameter changes that cause re-study will be responsible for the costs of re-study and the cost of the incremental facilities that are specified by the re-study, including facilities that are revealed by the short circuit re-study.

System Impact Study Stability Scope and Process

These procedures apply to stability studies required as part of System Impact or Initial Studies. These stability studies determine the project's cost responsibility for upgrades due to interconnection stability issues. These upgrade responsibilities become part of a project's Interconnection Service Agreement (ISA.)

Stability study start dates, generally, are at least six months after the close of a queue. This allows time to complete feasibility studies and the power flow and short circuit phases of the impact study. This section outlines the process of coordination and execution of the stability study among the representatives of PJM, the Interconnection Customers and Transmission Owners.

1. PJM will develop a study scope at the beginning of each project stability analysis. This scope will include but not be limited to the following items:

    1.1. The MW Size of the project. Developers may reduce the project maximum output, based on tariff terms, from the feasibility request. Stability will study projects at their maximum outputs regardless of the project's value for capacity markets.
    1.2. The electrical Point of Interconnection (POI) of the project. For projects that tap an existing transmission line, the feasibility power flow generally assumes a line POI is at the line midpoint. Stability analysis will require the actual location information to determine the tap point.
    1.3. A detailed fault list testing all applicable NERC and Transmission Owner criteria faults. Fault specification will include fault:
        1.3.1. location
        1.3.2. phase involvement
        1.3.3. impedance
        1.3.4. actual timing for clearing and reclosing
        1.3.5. explicit timing or other margins to be added
        1.3.6. justification of any procedures that exceed PJM standard methods
    1.4. Dispatch in the vicinity of the study location.
    1.5. Selection of the appropriate base case, light load or peak load, for study of the interconnection request.

2. Study scope will be supplied to the affected Transmission Owner. Affected parties have one week to provide input to the study scope after which time PJM will issue the final scope and a date that the study will begin. All special study conditions, scenarios or simulations, if any, required by guides or sensitive areas and accurate clearing times must be included in this final scope. The study will progress to completion based on the final scope document.
    2.1. The study scope for interconnection studies will consider *standard NERC criteria* faults and Transmission Owner criteria faults, as a general rule, including the POI bus and one bus away from that bus. In other words if a new POI is cut-in at the midpoint of an existing line, faults will be examined at the POI, and up to and including faults at the adjacent existing system substations and lines. If a project interconnects to an existing system bus location, then faults at that location and including adjacent substations and lines will be examined. When new interconnection requests are considered, in PJM’s judgment, in a cluster study, they will consider intervening bus location faults (further than one bus from any new interconnection) at PJM’s discretion when the electrical configuration indicates that the added locations could pose a more severe test and that a contributing cause of the stability concern is the new interconnection. In a similar fashion, PJM may use its judgment in any stability analysis to expand the fault locations outside the general “one bus removed” criteria when system electrical configurations dictate and the interconnecting project poses the concern.
    2.2. The stability scope for interconnections in areas affected by established operating guides or Special Protection Systems (SPS) (for example see Manual 03) may include scenarios designed to test the proper operation of the existing guides or SPS. In such cases, the scope may be augmented to examine and specify modified procedures or facilities that ensure the integrity of the system operation.

3. After completion of the study scope, PJM will transmit results and supporting information to the Transmission Owner. A review conference call between the Transmission Owner and PJM will be scheduled within a week of providing the results.
4. The transmission Owner will provide an estimated date for completion of its determination of system remedies for any issues identified in the stability results. Such remedies will include system impact cost estimates and the earliest feasible date to complete system modifications that accommodate the new interconnection.
5. Upon completion of the Transmission Owner review and estimates PJM will issue the final impact study report to the project developer.
6. In situations when the required system modifications or upgrades cannot be accomplished by the projected in-service date of the project, PJM will develop a scope and schedule to determine interim solutions and dates along with provided interim capability.

SYSTEM STABILITY STUDIES

In addition to the system impact stability analyses of new generating interconnections, the three year cycle testing of all existing generating units interconnected to the PJM system, and certain “ad hoc” stability testing required by special circumstances that occur from time to time, PJM also conducts system stability testing of its most critical stressed system conditions during the annual Regional Transmission Expansion Plan study cycle. The RTEP stability testing examines and ensures system performance within criteria for heavy system transfer conditions. Power flow criteria are ensured on a local and system-wide basis for heavy transfers during the application of PJM’s load deliverability testing (see Manual 14B Attachment C.) These test scenarios examine emergency conditions involving extreme generating outages and loads coupled with single transmission element outages. Such circumstances are critical when the system is stressed at heavy load, rather than light load.

Based on the results of each annual RTEP cycle and previously completed stability analyses, PJM determines the load delivery limits for the case that represents the most critical conditions for PJM system stability testing. The transfers into the selected Region emanate from external PJM and non-PJM generation. Imports from external areas are based on historical levels for heavy load. An example of the type of PJM scenario that could represent the critical study condition may have local load of 65,000 MW with a transfer into the area caused by the simultaneous outage about 10,000 MW of internal area generation. This may cause a thermal limit to transfers well in excess of 6000 MW.

The transmission outage that sets the limit for transfers during the Mid-Atlantic load delivery testing is modeled for stability to ensure that the region is not stability limited. PJM also determines several more critical three-phase and single-line-to-ground fault tests to apply from a stability perspective to ensure robust, stable and adequately damped system performance. Fault testing for system stability includes the most critical Bulk Electric System lines.

IMPACT STUDY PROCEDURES APPLICABLE TO WIND TURBINE ANALYSES

PJM follows a process of procedures and studies when handling requests to interconnect to the transmission system. These procedures are outlined in PJM Manuals and agreements, particularly PJM’s Manuals 14A and 14B and the PJM Open Access Transmission tariff (OATT.) In recognition of some of the unique characteristics and challenges posed by wind projects, however, the PJM OATT procedures include certain special provisions applicable to wind farm interconnection requests. Interconnection Customers should familiarize themselves with all applicable PJM procedures and requirements, in consultation with their assigned PJM project manager. Some provisions of particular interest to wind interconnection requests can be found in OATT PART IV, Subpart A, PART VI, Subpart A, and OATT Attachment O Schedule H.

Wind Project Final Impact Study Data

Upon entering the interconnection queue, wind generators may submit approximate data for the feasibility study that represents the wind farm as a single equivalent unit. Prior to commencement of the wind farm impact study the approximate data must be replaced with detailed design data including the detailed electrical layout of the wind farm. This data is required for wind farm projects, by tariff provisions, no later than six months after the filing of the interconnection request. As described in the general discussion of System Impact and Initial Study procedures, final impact study data is generally required at the beginning of the system impact study process which often will happen to be about six months after the close of the queue. In the case of wind projects, tariff requirements ensure that the data may be supplied up to six months from the initiation of the queue request. In practice the wind farm developer, as well as all project developers, should maintain good communications with the assigned project manager to determine when PJM is scheduled to begin a specific project's stability analysis.

Wind Project LVRT Requirements

In addition to all facets of the standard stability study scope previously discussed, wind generators will be studied during their impact study stability analysis for compliance with the Low Voltage Ride Through Criteria (LVRT.) The LVRT criteria tests the ability to the wind farm generator to maintain operation and interconnection with the system during events that cause extremely low voltage transients as measured at the high side of the transformer that steps up the Wind Farm's voltage to the transmission system (high side of the wind farm GSU.) Peak load conditions are the most stressful for maintaining system voltage so this analysis will be conducted on a peak load power flow model (in contrast to the standard stability analysis that is conducted on an off-peak model.) Based on the results of the standard stability analysis, PJM will determine the most critical three phase faults with normal clearing and phase to ground faults with delayed clearing. The wind generator will be required to maintain its power output to the system following three phase faults cleared in up through 9 cycles (9 cycles includes any applicable margins) and that produce a voltage as low as zero at the high side of the GSU. Actual clearing times plus applicable margins will be used, which may be less than 9 cycles and high side GSU voltages may be somewhat greater than zero. Also the wind farm must maintain output to the system following the most critical phase to ground faults with delayed clearing, using actual clearing times. Applicable clearing time margins will apply to the LVRT test.

Wind Project Reactive Power Modeling

Stability tests will be conducted on a system model with the GSU modeled and zero generator reactive power output (unity power factor.) When power flow analysis does not model the generator step up transformer, the zero generator reactive power output is applied at the collector bus. This base case and the stability analysis will establish power factor or reactive power delivery requirements only if impact study analysis is conducted that demonstrates that the safety or reliability of the system is impacted by the lack of the requirement. System transient, oscillatory, or voltage instability during any phase of the impact study is evidence of system safety or reliability impact. For such results, the least cost remedy that considers system protection, transmission upgrades, or reactive requirements will be determined and specified.

In the event that the transient or voltage instability only affects the wind project (for example when long radial interconnection facilities cause the inability of the wind facility to remain stably interconnected), the wind project will be notified and be requested to provide project design remedies. PJM's analysis of possible remedies will be limited to specifying the size of dynamic reactive device or increased transmission interconnection capacity if such a remedies are sufficient.

STABILITY ANALYSES OF STABILITY SENSITIVE LOCAL AREAS IN PJM

The PJM system generally operates to limits determined by thermal and reactive criteria. In some specific instances local areas of PJM or individual plants operate to stability limitations. The PJM transmission system conditions and procedures due to localized thermal, reactive and stability considerations are outlined in PJM Manual 03.

The PJM Transmission Owners are often owners of the facilities that are subject to these procedures and carry out PJM's operating instructions ensuring safe and reliable operation consistent with these guidelines and procedures. PJM, therefore, closely coordinates review of the stability guides and procedures with the Transmission Owners and, when appropriate, Transmission Owners may conduct analysis, subject to PJM's review.

Stability guides applicable to specific plants are reviewed as part of PJM's three year cycle of generator stability analysis that ensures continued compliance with NERC criteria. Local stability guides and procedures are reviewed as necessary when interconnections or transmission changes cause the need for review. Each review is specific to the area or plants operating procedures and guides and confirms or develops modifications to the guide and system upgrades, as appropriate, to maintain reliable operation within applicable criteria.

SHORT CIRCUIT

PJM performs short circuit analysis as part of the annual Regional Transmission Expansion Plan (RTEP) baseline assessment. This analysis includes a study of the entire PJM system based on its current configuration and equipment. In addition, PJM also performs the analysis on the planned system configuration using a 5-year out case. The generation and merchant transmission interconnection process (see Manual 14A) also includes short circuit analysis for each requested new interconnection project. The addition of new sources drives most breaker replacements. PJM Planning conducts short circuit analysis to ensure the high-voltage circuit breakers on the transmission system are sufficiently rated to safely interrupt fault currents. These short circuit studies are also referred to as breaker interrupting studies. Since new sources only become committed with relative assurance a few years before scheduled commercial operation and since breaker replacement lead times are only a few years, these analysis are only conducted within the 5-year planning horizon.
The short circuit analysis is performed in accordance with the following industry standards:

- ANSI/IEEE 551-2006 “IEEE Recommended Practice for Calculating Short-Circuit Currents in Industrial and Commercial Power Systems”
- ANSI/IEEE C37.04-1999 “IEEE Standard Rating Structure for AC High-Voltage Circuit Breakers”
- ANSI/IEEE C37.010-1999 “IEEE Application Guide for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis”
- ANSI/IEEE C37.5-1979 “IEEE Guide for Calculation of Fault Currents for Applications of AC High-Voltage Circuit Breakers Rated on a Total Current Basis”

The system condition most critical for short circuit analysis on the PJM system is all available generation in-service. This condition is modeled in short circuit reference cases that are specially configured for short circuit analysis. The PJM Transmission Planning Department maintains the following short circuit base case representations and associated data:

- 1 year planning representation consisting of the current system plus all facilities planned to be in-service within the next year.
- Current year plus 5 planning representation using the 1 year planning representation as the base model and including all system upgrades, generation projects, and merchant transmission projects planned to be in-service from years 1 through 5. This 5 year

planning representation is consistent with the PJM RTEP 5 year load flow base case.

- Data file containing current circuit breaker interrupting ratings and other relevant circuit breaker nameplate data for all circuit breakers rated 230 kV and above.

The short circuit base cases are maintained using Aspen One Liner and short circuit analysis is performed using the Aspen Breaker Rating Module. The PJM short circuit 1 year planning representation is developed annually with the assistance of the designated transmission owner short circuit contacts and maintained by the PJM Transmission Planning Department.

NUCLEAR PLANT SPECIFIC IMPACT STUDY PROCEDURES

Stability analysis of nuclear facilities is conducted during PJM's three-year cycle of stability review of all existing generating units. Also, interconnections or transmission modifications in the vicinity of existing generating stations, including nuclear stations, may necessitate additional reviews. PJM conducts these reviews consistent with the NERC criteria and certain added criteria specified by the Transmission Owner or plant operator or owner. PJM stability studies take into account coordination with any applicable Special Protection Schemes. Results of PJM Planning analyses can be found under the "planning" tab material and "committees & groups" tab material on PJM.com particularly:

14

http://www.pjm.com/planning/planning-criteria.aspx
http://www.pjm.com/planning/rtep-development.aspx
http://www.pjm.com/planning/generation-interconnection.aspx
http://www.pjm.com/committees-and-groups/committees/teac.aspx

PJM will notify PJM System Operations and the affected Transmission Owner in the event that PJM's planning analyses indicate planning study results that violate PJM planning criteria or nuclear specific planning criteria. In addition, results of PJM Impact Studies affecting nuclear facilities are communicated to the affected Nuclear owner and operator.

PJM applies some nuclear plant study procedures that exceed *standard NERC criteria* to be consistent with certain regulatory and safety requirements specific to these facilities. Material contained in the Appendix to this Attachment G ~~and PJM Manual 39, Attachment B~~ provides Nuclear Plant Interface Requirements (NPIR) ~~that outline~~regarding the nuclear specific testing procedures applied by PJM and Transmission Owner Planning. ~~(http://www.pjm.com/documents/manuals.aspx.)~~

APPENDIX TO MANUAL 14B ATTACHMENT G

This appendix contains Transmission Owner specific criteria applicable to RTEP stability study analyses that may go beyond the NERC system stability performance tests routinely applied by PJM. PJM normal stability testing enforces the NERC criteria that are based on single contingencies and common-mode multiple contingencies. PJM does not permit planned load loss or interruption of firm transmission service for these events, even when such service curtailment may be permitted by the NERC standards. These contingencies are also referred to in this Attachment and Appendix as the "standard" NERC criteria and include the following events:

- System normal,
- Single phase and/or three phase fault (N-1),
- Single phase fault stuck breaker (N-2),
- Three phase fault tower (N-2), and
- Single Phase fault and communication failure (N-2).

More stringent NERC criteria that involve multi phase faults, non-common mode multiple contingencies, and higher order contingencies (also referred to as "beyond" *standard NERC criteria*) do not routinely form the basis for required PJM RTEP upgrades. Some Transmission Owner criteria, however, as detailed in this Appendix, go beyond the *standard* PJM stability screening criteria and do require remedies. These procedures, as applicable, are applied during PJM RTEP (including interconnection related) stability analyses in addition to PJM thorough testing of *standard NERC criteria* tests and system performance is verified to be stable and within criteria. The Transmission Owner specific criteria are limited to interconnections with the transmission facilities of the respective Transmission Owners.

All PJM testing applies the clearing margins and damping criteria discussed in Attachment G and more stringent criteria when the specific Transmission Owner criteria exceed these standard margins. In all cases PJM applies the criteria in a comparable and not unduly discriminatory fashion to new interconnection projects and existing generators. Violations based on *standard NERC criteria* and standard margins must be remedied by upgrade modifications to the system. Operating curtailments will generally be an available remedy for issues found for line maintenance outage tests.

Testing of Transmission Owner Criteria

For interconnection queue studies that pass the *standard* NERC and PJM criteria but produce localized violations based on criteria that are beyond the *standard NERC criteria* and/or margins that exceed standard PJM margins, PJM, in consultation with the affected Transmission Owners, will determine lower cost remedies. For these Transmission Owner tests, planned load loss or interruption of firm transmission service is not allowed when lower cost remedies are available. An available lower cost remedy will be required to address such violations. For example, lower cost remedies that may be considered include:

- Relaying modifications
- Sectionalizing schemes
- breaker upgrades
- Independent pole tripping
- High speed breaker failure schemes
- High speed reclosing
- Fast closing of steam intercept valves
- Braking resistors.

~~If lower cost remedies are not available, where clearing margins exceed PJM's standard clearing margins, PJM will retest with the margins cut to the standard values as a possible remedy.~~ If the search for lower cost upgrades produces none, or in the case of wide-spread system violations such as may be encountered during RTEP baseline stability analysis, then PJM, in consultation with the affected Transmission Owners, will make a more detailed assessment of the violation(s) including factors such as the extent of violations, the events' likelihood, system impact and cost to remedy. Based on the gathered information, PJM will specify a remedy including possible consideration of operating guides, special protection systems, and more extensive high voltage upgrade options.

16

Nuclear Station Testing

With regard to nuclear station related planning stability analysis, in addition to the *standard NERC criteria* and specific Transmission Owner criteria testing, PJM reviews and enforces criteria testing that can be found under the Planning section of the Nuclear Plant Interface Requirement (NPIR) documents ~~contained in the Appendix to PJM Manual 39~~. In some cases the Transmission Owner also performs special nuclear unit stability testing as described in PJM Manual 39 and the NPIR. Together, the analyses that may be performed by the Transmission Owner and PJM's testing incorporate~~s~~ the voltage and stability requirements of the station. ~~In some cases the tests are consistent with standard testing but included to clearly document the specific tests requested and performed.~~ PJM ensures Transmission System performance to the specified criteria that enables the station equipment and systems to perform as designed. Nuclear voltage criteria at the Transmission System level, including any voltage drop criteria, are enforced on a system normal and post-contingency basis as described in the NPIR ~~documents~~planning requirements. Observed criteria violations during planning assessments affecting nuclear stations will be evaluated jointly by PJM Planning and PJM Operations consistent with procedures outlined in PJM

Manual 39. Appropriate remedies, consistent with this Attachment and the PJM Manuals and Agreements, will be specified to ensure applicable criteria are met. The nuclear owner will be responsible for reinforcements necessary to comply with criteria that are specific to the Nuclear Plant and that are more stringent than the standard PJM and Transmission Owner tests.

The specific nuclear unit planning criteria contained in the NPIR documents are included in the Appendix to this Attachment G when the nuclear plant owner has consented to these excerpts being included here for convenient planning reference. In any instances of a nuclear plant owner preference to maintain confidentiality of this information, it is not reproduced in this manual but is still evaluated and enforced during planning studies.

BG&E Specific Criteria

Additional stability testing applicable to interconnections with BG&E transmission facilities includes tests of three-phase faults at a point 80% of the circuit impedance away from the station under study with delayed (zone two) clearing.

ComEd Specific Criteria

Additional stability testing applicable to interconnections with ComEd transmission facilities includes:

- Three-phase fault on any transmission or generation element with delayed clearing due to a stuck breaker or other protective equipment failure. For situations involving independent pole operated breakers, it is assumed that only one phase of the breaker fails to open and the delayed clearing time is used for the remaining single-phase fault.
- Three-phase fault on any transmission or generation element with delayed clearing due to failure of a special protection system.
- Three-phase fault on all transmission lines on a multiple circuit tower with normal clearing.
- Three-phase fault on any transmission or generation element during the scheduled outage of any other transmission or generation element.

It should be noted that a one-cycle margin is included in all primary-clearing times for faults on the ComEd system, instead of the PJM margins. For more severe, lower probability events such as faults occurring during maintenance outages or faults cleared in delayed time, if lower cost remedies are not available, PJM will retest with the PJM's standard margins as a possible remedy.

PPL Specific Criteria

Additional stability testing applicable to interconnections with PPL transmission facilities includes:

- permanent three-phase faults at a point 80% of the line impedance away from the PPL zone generating facility under consideration with delayed (Zone 2) clearing times, including reclosing, if applicable.
- Permanent three phase fault with stuck breaker or other cause of delayed clearing.
- Permanent three phase fault on one line in the substations one substation removed from the interconnection point with an over-trip of another unfaulted line in the same station. Both the over-trip and clearing of the faulted line occur in normal primary clearing time. Reclosing sequences, if applicable, will be included.
- PPL EU applies a transient synchronous stability safety margin of 7% in the export limited Northern PPL area (see PJM Manual 03 at http://www.pjm.com/documents/manuals.aspx.) This implies that the net export limit based on stability will be reduced by 7% to account for a margin of error in the specified net export limit from the area.

Comment [HCL1]: FOLLOWING TABLE MOVED TO APPENDIX TO ATT G - see accompanying document

SSES-FSAR		
TABLE 8.2-1		
SUSQUEHANNA UNIT #1 & #2		
STABILITY CASE LIST		
(SUMMER LIGHT LOAD CONDITIONS)		
CASE	**DESCRIPTION**	**Required Result**
R-1	3 phase fault at Susquehanna 500 kV on the Sunbury 500 kV line. Fault cleared in primary clearing time.	Stable
R-5	Phase-ground fault at Susquehanna 500 kV on Sunbury 500 kV line with Sunbury South 500 kV circuit breaker stuck. Clear remote terminal in primary time. Delayed clearing of Susquehanna.	Stable
R-6	3 phase fault at Susquehanna 230 kV on the Susquehanna 500/230 kV transformer. Fault cleared in primary clearing time.	Stable
R-7	3 phase fault at Montour 230 kV on Susquehanna 230 kV line. Fault cleared in normal primary clearing time.	Stable
R-13	Phase-ground fault at Susquehanna 500 kV on Susquehanna-Wescosville-Alburtis 500 kV line with Wescosville South 500 kV circuit breaker stuck. Clear remote terminal in primary time. Delayed clearing at Susquehanna.	Stable
R-18	3 phase fault at Susquehanna 230 kV on Harwood #1 & #2 Double Circuit. Fault cleared in primary clearing time.	Stable
-	**Fault Tests That Go *Beyond Standard NERC criteria* (8.2.1.5.C)**	-
N-2	3 phase fault at Susquehanna 500 kV on the Sunbury 500 kV line with one breaker pole stuck at Sunbury. Clear Susquehanna in primary time. Delayed clearing at remote terminal.	Stable
N-3	3 phase fault at Susquehanna 500 kV on the Susquehanna-Wescosville-Alburtis 500 kV line with one Susquehanna 500/230 kV transformer breaker pole stuck. Clear remote terminal in primary time. Delayed clearing of Susquehanna.	Stable
N-4	3 phase fault at Susquehanna 500 kV on the Sunbury 500 kV line with one Susquehanna 500/230 kV transformer breaker pole stuck. Clear remote terminal in primary time. Delayed clearing of Susquehanna.	Stable
N-8	3 phase fault at Susquehanna 230 kV on Montour line with stuck west bus breaker. Clear remote terminal in primary time, clear Susquehanna with delay (lose Stanton-Susquehanna #2 230 kV line).	Stable
N-9	3 phase fault at Susquehanna 230 kV on Jenkins line with stuck east bus breaker. Primary clearing at remote terminal. Delayed clearing at Susquehanna.	Stable

19

N-10	3 phase fault at Susquehanna 230 kV on the 500/230 kV transformer with stuck west bus breaker pole. Clear two poles in primary time. Primary clearing at remote terminal (Susquehanna 500 kV Switchyard). Clear stuck pole in delayed clearing time (lose Stanton-Susquehanna #2 230 kV line).	Stable
N-11	3 phase fault at Susquehanna 230 kV on Harwood #1 line with stuck tie breaker pole. Clear two poles in primary time. Clear stuck pole in delayed clearing time (lose Sunbury-Susquehanna 230 kV line).	Stable
N-12	3 phase fault at Susquehanna 230 kV on Harwood #2 line with one pole stuck on west bus breaker. Clear two poles in primary time. Clear stuck pole in delayed clearing time (lose Stanton-Susquehanna #2 230 kV line).	Stable
N-14	Susquehanna-Wescosville-Alburtis 500 kV and Susquehanna-Harwood #1 & #2 Double Circuit 230 kV crossing failure (3 phase fault on all circuits). Automatically trip Susquehanna Unit #1. Clear Susquehanna-Wescosville-Alburtis 500 Kv line in primary time. Clear Susquehanna- Harwood #1 & #2 230 kV lines in primary time.	Stable
N-15	3 phase fault near E. Palmerton on all lines in E. Palmerton-Harwood R/W corridor. Clear Susquehanna-Wescosville-Alburtis 500 kV line in primary time. Primary clearing of E. Palmerton-Susquehanna and Harwood-Siegfried 230 kV lines.	Stable
N-16	3 phase fault near Susquehanna on both lines in Sunbury-Susquehanna R/W corridor. Clear Sunbury-Susquehanna #2 500 kV line in primary time. Primary clearing of Sunbury-Susquehanna #1 230 kV line.	Stable
N-17	3 phase fault near Susquehanna 500 kV at Sunbury 230 kV line crossing. Trip Susquehanna –Wescosville-Alburtis 500 kV, Sunbury-Susquehanna #2 500 kV, and Unit #2 in primary time. Trip Sunbury-Susquehanna #1 230 kV in primary clearing time.	Stable
N-19	3 phase fault at Columbia-Frackville 230 kV line crossing. Trip Sunbury-Susquehanna #2 500 kV line in primary time. Trip Columbia-Frackville and Sunbury-Susquehanna #1 230 kV lines in primary time.	Stable
N-20	3 phase fault on 230 kV side of Unit #1 main transformer. Trip Unit #1 main transformer. Trip Unit #1 and overtrip Unit #2 in primary time.	Stable
N-21	3 phase fault at Susquehanna 230 kV on Unit #1 generator leads with a stuck west bus breaker. Trip Unit #1 and Stanton #2 line.	Stable
N-23	Sudden loss of all lines from Susquehanna 230 kV Switchyard.	Stable
N-24	3 Phase fault on Susquehanna-Jenkins 230 kV line 80% towards Jenkins with pilot relaying out. Fault cleared in Zone 2 (backup) time at Susquehanna and Zone 1 time at Jenkins.	Stable