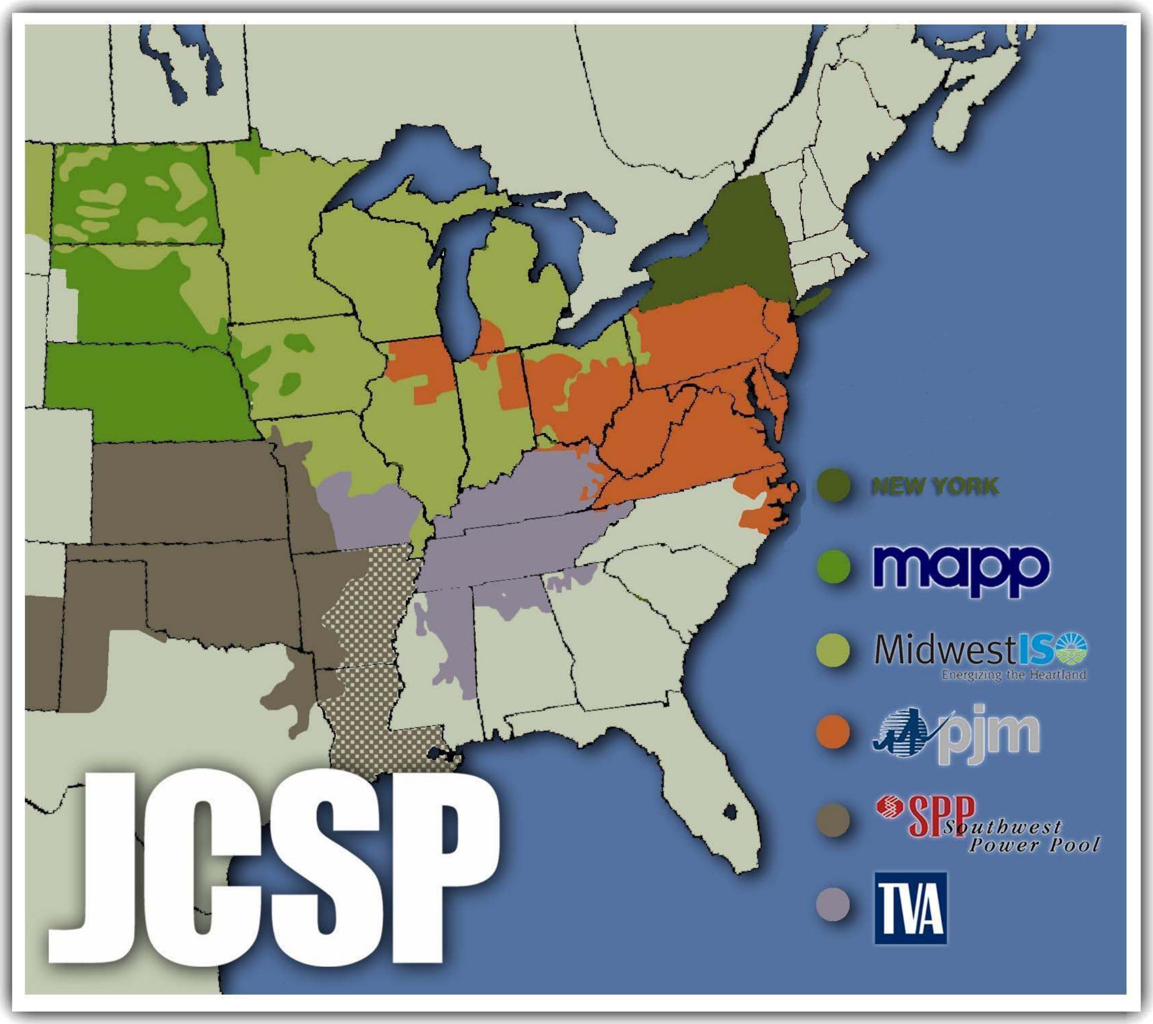
Joint Coordinated System Plan (JCSP)
2018 Summer Reliability Study Report



JOINT COORDINATED SYSTEM PLAN

February 2009

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I. EXECUTIVE SUMMARY

This study was initiated by Midwest ISO, PJM, SPP, and TVA in September 2007 on the basis of various agreements among these parties that stipulate periodic joint planning activities. A Joint Coordinated System Plan (JCSP) study, as a collaborative initiative between these parties, was viewed as an effective way to address joint planning needs and seams issues. These objectives were reinforced by the planning principles and compliance filings related to FERC Order 890. MAPP joined in the JCSP reliability study effort in a similar desire to address joint planning and seams issues. While not a formal participant, NYISO was asked to review the study setup and results; and as such, NYISO provided input into the base case, analysis procedures, study results, and this report.

The JCSP studies conducted during 2008 consisted of two tracts - a 2018 Summer Reliability Study and a 2024 Economic Study. **This report is intended to document the study process and findings for the JCSP 2018 Summer Reliability Study conducted in 2008. The JCSP 2024 Economic Study conducted in 2008 is documented in a separate companion document.** The transmission system model used for the JCSP 2018 Summer Reliability study was based on the ERAG Multi-Regional Modeling Working Group's (MMWG) 2007 power flow model series, with study participant updates as warranted within their respective study region. The transmission overlay scenarios postulated in the 2024 Economic Study were not analyzed as part of this 2018 reliability study.

The objective of the JCSP 2018 Summer Reliability Study was to assess steady-state performance of the projected bulk electric grid within a geographic footprint that can best be characterized as the area bounded by the Reliability Coordinator areas presently managed by the study participants within the Eastern Interconnection (see cover map). The study participants include both ISO/RTOs and non-ISO/RTOs. Canadian portions of the Eastern Interconnection, New England, and some portions of the southeastern United States, were not directly represented on the study group.

This study is intended to supplement the library of planning studies conducted by the participants at their individual region level. The 2018 time frame studied is at the outer bound of the traditional 10-year transmission planning horizon, and as such the system assumptions have a higher degree of uncertainty than closer in models. Transmission and generation facility additions incorporated in the study model represent the JCSP participant's best available projections at the time of study model development, and are documented in Appendix 2 of this report.

Due to the large geographic footprint being studied, the study scope was limited to monitoring transmission facilities rated 200 kV and above for steady-state thermal and voltage criteria violations under base case and selected contingency conditions. The following types of contingency events were simulated:

- N-1 Contingencies (200 kV and above transmission)

- Loss of Source Contingencies (generators 200 MW and above)
- N-1-1 Contingencies (selected transmission)
- Common Tower Contingencies (selected transmission)
- N-2 Contingencies (selected transmission)

The JCSP study participants, facilitated by PJM's processing and distribution of the results, conducted a review of all criteria violations identified for the base case and simulated contingency conditions. Many factors entered into this review process, which resulted in significant reductions to the initial output lists. For example, common reasons to eliminate results from the list included 1) an upgrade is planned that remedies the issue but was not included in the base case due to timing issues, 2) a result may be a valid, known issue that is being addressed in current planning processes, or 3) contingencies tested were not considered valid. Contingencies can be considered invalid for example if a relay scheme trips a transformer that overloads for the outage of another transmission element; or a result may not be valid if there is a special protection scheme or operating guide that is implemented for specific operating conditions. The resulting list of reported criteria violations are contained in Appendix 3, while each participant provides a synopsis of their findings in Section III of this report.

The JCSP 2018 Reliability Study represents a collaborative effort among the study participants to share information on future plans through the joint development of the 2018 study model. The contingency analysis conducted on the study case also allowed the participants to gain added insights into neighboring region's planning criteria. The following conclusions may be drawn from the JCSP 2018 Reliability Study:

- No significant new reliability issues were revealed
- 10-year plans appear to be well coordinated, as evidenced by minimal "seams" related problems
- Current plans and procedures were identified that address most observed problems
- Many results, particularly voltage related, are amenable to monitoring and shorter lead-time remedies as needed
- Some results are candidates for further analysis during Regional planning cycles or special studies

Inter-regional studies are increasing in importance and the need for coordinated studies of the planned future systems cannot be overemphasized. Individual participants in this study have developed their own system plans that have been coordinated inter-regionally through various studies. The JCSP 2018 Summer Reliability study has confirmed that these plans, in combination, are reliable and have been well coordinated on an inter-regional basis.

II. INTRODUCTION & STUDY PROCESS

Introduction

This study was initiated in September 2007 by representatives of Midwest ISO, PJM, SPP, and TVA in order to satisfy articles contained in various agreements among these parties relating to joint planning. These agreements are the:

- *Joint Operating Agreement (JOA) Between the Midwest Independent Transmission System Operator, Inc. and PJM Interconnection, L.L.C*
- *Joint Operating Agreement (JOA) Between the Midwest Independent Transmission System Operator, Inc. And Southwest Power Pool, Inc.*
- *Joint Reliability Coordination Agreement (JRCA) Among and Between Midwest Independent Transmission System Operator, Inc., PJM Interconnection, L.L.C. and Tennessee Valley Authority*

The four parties agreed to conduct a collaborative Joint Coordinated System Plan (JCSP) study during 2008 that would consist of a 2018 Summer Reliability Study and a 2024 Economic Study. MAPP joined in the JCSP reliability study effort in a similar desire to address joint planning and seams issues. While not a formal participant, NYISO was asked to review the study setup and results; and as such, NYISO provided input into the base case, analysis procedures, study results, and this report.

This report documents the study process and findings of the JCSP 2018 Summer Reliability Study. The JCSP 2024 Economic Study is documented in a separate companion document.

Study Process

The JCSP 2018 Summer Reliability Study process consisted of the following key activities:

Study Case Development - The study group used the 2018 summer peak power flow model developed by the ERAG MMWG (2007 case series) as the starting point case. Each study participant was responsible for submitting any desired updates for their defined region of the model (see Appendix 1, Table 1-2). SPP served as the coordinator for incorporating the updates submitted by the study participants, and issuing the final coordinated study model. Siemens PTI's PSS/E (version 30.3.1) software was used for study case development.

Establishing Performance Criteria - Due to the large geographic footprint being studied, the study scope was limited to monitoring transmission facilities rated 200 kV and above for steady-state thermal and voltage criteria violations under base case and selected contingency conditions.

The study group adopted a common performance criterion for assessing thermal loading conditions:

- For base case conditions, facilities loaded above 100% of the modeled "Rate A" MVA rating were identified.

- For contingency conditions tested, facilities loaded above 100% of the modeled "Rate B" MVA rating were identified (Simulated N-1, N-1-1, N-2, common tower and Loss of Source outages)

For bus voltage criteria, each study participant provided the acceptable voltage range used within their study region for planning purposes. The voltage ranges varied slightly among the study regions, and are identified in Table 1 below.

Table 1 - Bus Voltage Range Criteria

Study Region	200 - 299 kV		300 - 499 kV		500kV - 765 kV	
	V Low (PU)	V High(PU)	V Low (PU)	V High(PU)	V Low (PU)	V High(PU)
MAPP	0.90	1.10	0.90	1.10	0.90	1.10
MISO	0.90	1.05	0.90	1.05	0.90	1.05
NYISO	0.95	1.05	0.95	1.05	0.95	1.05
PJM	0.92	1.05	0.92	1.05	0.97	1.10
SPP	0.95	1.05	0.95	1.05	0.95	1.05
TVA[1]						
AECI	0.90	1.05	0.92	1.10	0.92	1.10
BREC	0.95	1.05	0.95	1.05	N/A	
EKPC	0.90	1.10	0.90	1.10	N/A	
LGEE	0.90	1.05	0.90	1.05	N/A	
TVA	0.95	1.06	0.95	1.06	0.98	1.08

[1] Voltage criteria used for planning within the TVA study region vary by Transmission Owner.

Identifying Contingencies for Simulation - The following summarizes the contingency conditions that were identified for simulation.

N-1 Contingencies

All single transmission contingencies 200 kV and above within the JCSP study footprint, and ties to non-study areas, were tested automatically. In addition, participant specified contingencies based on breaker to breaker configurations and Special Protection System (SPS) schemes were tested. Transformers with low side voltages below 200 kV were not tested. Monitoring included all buses and branches rated 200 kV and above within the JCSP study footprint, and ties to non-study areas for steady-state thermal loadings and voltage magnitudes. This resulted in 4,361 contingencies tested while monitoring 4,202 branches and 2,976 buses. Following a simulated outage, DC taps, transformer taps, and switched shunts were adjusted and generator VAR limits were immediately applied while disabling area interchange control. The solution method used for the simulations was fixed slope decoupled Newton-Raphson method.

Loss of Source Contingencies

All generators rated 200 MW and greater in the study regions were evaluated. A total of 4,250 generators rated 200 MW and above were tested. During the outage of a source, the loss was picked up by other units based on system-wide inertia pickup. Following a simulated generator outage, DC taps, transformer taps, and switched shunts were adjusted and generator VAR limits were immediately applied while disabling area interchange control.

N-1-1 Contingencies

Selected N-1 contingencies provided by the study participants were combined to test N-1-1 conditions. All combinations of the N-1 contingencies taken two at a time were evaluated. There were a total of 588 N-1 contingencies provided by regions for N-1-1 evaluation. The test procedure was as follows

- Take first contingency and solve letting transformer taps, phase shifters, DC taps, and caps adjust while applying generator VAR limits immediately; then check for flows exceeding Rate A of the monitored facilities. If any branches 200kV and above are above their Rate A, then re-dispatch to bring it below rate A.

- Take second contingency and solve as before but this time lock phase shifters when solving and check flows against Rate B.

For N-1-1 analysis, a total of 4,202 branches 200kV and above were monitored for thermal flows. Bus voltages were not monitored for this step.

Common Tower Contingencies

Selected double circuit common tower contingencies provided by the study participants were tested. These are NERC category C events. There were a total of 794 contingencies evaluated in the study while monitoring 4,202 branches and 2,976 buses. The same solution method and options were applied when solving after taking the outage.

N-2 Contingencies

Selected N-2 contingencies that were provided by the study participants were tested. The selected contingencies may fall into the NERC category C or NERC category D categories depending on their severity. Any simulated NERC category D contingencies are of interest to test the strength of the system and are used only for informational purposes. There were a total of 1,631 contingencies evaluated in the study while monitoring 4,202 branches and 2,976 buses at 200 kV and above.

Performing Study Simulations - PJM served as the lead region in conducting the simulations for the JCSP 2018 Summer Reliability Study. The steady-state analysis was performed using Siemens PTI's MUST software. The following input files are required in conjunction with a solved power flow model to run the simulations in MUST, and they are briefly described below.

- Subsystem File
- Monitored file
- Contingency File
- Exclude file

Subsystem Data File

The subsystem file is generally used to define

- Source and sink for transaction purpose,
- Allows areas to be grouped by study region
- Provides automatic selection of certain large generators
- Categorize buses into zones and area to be used later in the monitor file for thermal and voltage analysis.
- Define participating factors of generators with certain threshold
- Automatic definition contingencies by selected area.

For the reliability analysis, the subsystem file groups the buses by common voltage criteria and secondly according to their RTO affiliation. The subsystem file was also used to define the kV level of monitored buses in each study area as 200 kV and above. This focuses the study monitoring and contingency analysis on branches 200 kV and above.

The loss of source study per the scope calls for considering generators of 200 MW and above, regardless of voltage connection level. The subsystem files provide for selection of large generators according to this criterion.

Monitored Element Data File

Monitored elements were specified via a monitored element file. The monitored file is used to monitor branches, interfaces, and flow gates. The monitored file filters for thermal, voltage magnitude, and voltage drop issues based on transmission owners' and regions' specific planning criteria. For thermal monitoring, PSSE/MUST uses two sets of ratings for every monitored branch: base case (Rate A) and contingency (Rate B). In the monitored file for thermal analysis, automatic branch specification was used to monitor lines and ties of JCSP study regions based on how they were grouped in the subsystem file per the previous discussion. Based on the grouping in the subsystem file, the monitor file also specifies monitoring for voltages. Region specified voltage criteria were used.

Contingency Description File

The contingency description data file allows for two ways to apply contingencies: one uses a block structure that defines contingencies according to a user definition; another uses automatic contingency selection of a group of single or double outage contingencies. For N-1 analysis, the automatic single contingency feature was used subject to the filters applied by preceding discussion of the subsystem file. Also the loss of source outage examined automatic single outages of plants 200 MW and above also as limited by the subsystem file filters.

Exclude Data file

The exclude data file allows for the adjustment of the monitored file or the contingency file during the course of the analysis, as may be appropriate based on exceptions to the blanket specifications of these files. For example, as noted for the N-1 analysis, an automatic single outage command was used that resulted in all single branches (bus to bus) rated 200 kV and above in the power flow case to be outaged. Based on actual system relaying and breaker configurations, such blanket screening can and often does result in invalid contingencies and results. These situations are addressed using the exclude file to eliminate these invalid scenarios from the analysis. A similar use can be applied to monitored branches that have unique circumstances

Assessing Results - PJM performed an initial high level screening of the results to filter down to a smaller subset of results to be addressed by the participant study regions. This initial screening involved 1) identification of base case issues, 2) elimination of lines loaded less than 100.5% of rating from the results lists, 3) elimination of buses less than .01 per unit voltage outside of voltage range criteria[1], and 4) elimination of duplicate

[1] For example if the low range of allowable voltage is .95 and the voltage result was .94, then this was not cited as a result requiring further scrutiny. Reactive modeling in power flows for more distant years in the planning horizon lacks the detail that would be required for a determination that such a precise result is an issue. Additionally, all routine voltage issues in more distant planning years are typically not of concern to inter-regional studies such as this JCSP study since remedies often have short lead times and issues can be monitored for years before a need to commit to upgrade remedies. Longer term studies examine reactive results to search for indications of serious issues that may require further study. This JCSP analysis found no such serious reactive issues.

results (for example, a facility loaded above its limits under N-1 conditions that is loaded similarly in the base case is not cited twice unless the N-1 result is judged significantly further out of limits than in the base case). The list of results remaining after this initial screening reduction was circulated to the study participants for closer examination. This began a review process during which each study participant further scrutinized the results for validity. Many factors entered into these reviews, which resulted in significant reductions to the initial results lists. For example, common reasons to eliminate results from the list include 1) an upgrade is planned that remedies the issue but was not included in the base case due to timing issues[2], 2) a result may be a valid, known issue that is being addressed in current planning processes, or 3) contingencies tested were not considered valid. Contingencies can be invalid for example if a relay scheme trips a transformer that overloads for the outage of another transmission element; or a result may not be valid if there is a special protection scheme or operating guide that is implemented for specific operating conditions.

The very process of this reliability model setup and evaluation proved an important result of this JCSP effort. The extensive scope of the evaluation is a unique characteristic. The base reliability case required time-consuming review of models and coordination of interchange and seams issues and is considered a significant accomplishment. This model and the discussions required for its development create increased understanding and coordination among the participating regions and can be extended to subsequent internal reviews. Additionally, the close examination of results provides another view of the system that complements internal reviews and provides a basis for comparison to results of internal regional studies. Further, this reliability analysis and subsequent discussions have heightened awareness that reliability issues on interregional seams require more understanding of adjacent regions planning processes, coordination among regions and specialized studies.

The preceding material generally describes the process that was undertaken by the study participants to perform a contingency analysis for the projected 2018 summer peak scenario. The final results from this contingency analysis are reported in Appendix 3 of this report. To the extent that the process or results of individual regions require additional discussion, section III of this report contains individual study region discussions.

Conceptual Overlay - Following the contingency analysis performed on the study base case, an additional effort was undertaken to develop and test "conceptual" enhancements that focused on a subset of analysis results centered on the PJM and MISO seam. The 2018 modeling analysis indicated a number of contingency line flows above thermal limits on the PJM-MISO seam[3]. A single 765 kV transmission loop was postulated from eastern MISO to eastern PJM (Figure 1). In Figure 1, solid lines represent "existing" or

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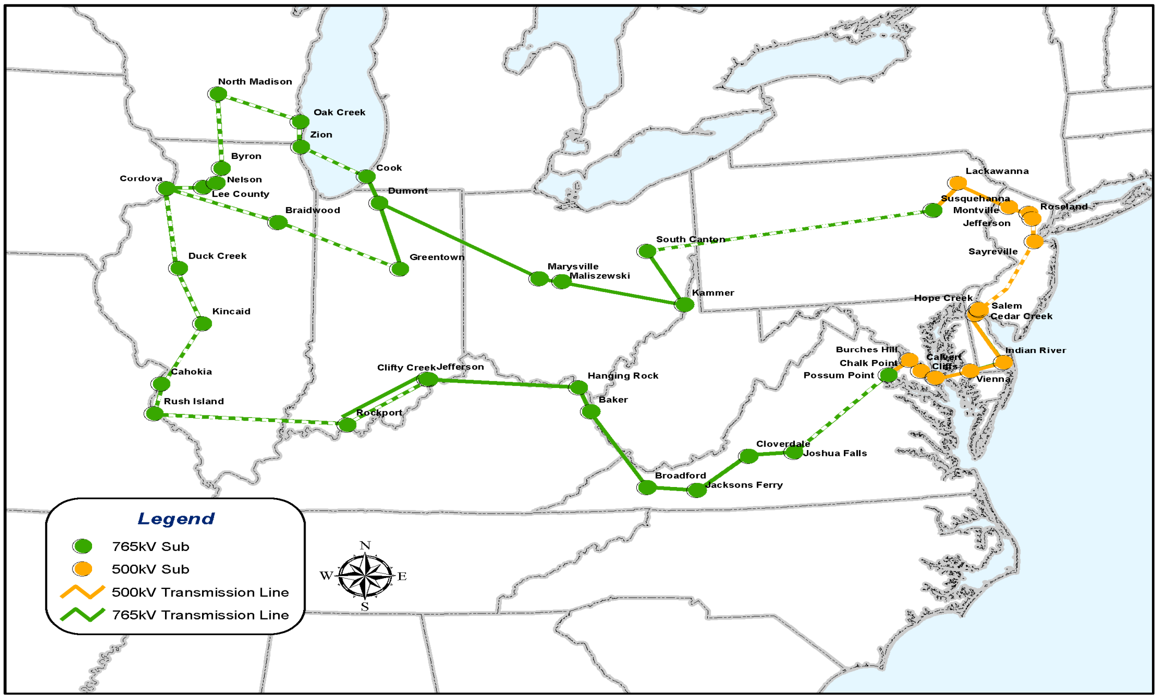
[2] This JCSP study effort involves many regions that each conduct detailed planning assessments addressing specific analyses based on each regions process and established timelines. Naturally, the JCSP cannot integrate or synchronize simultaneously with all of these diverse processes. Thus, the JCSP analysis synthesizes the best available information and analyzes standard NERC criteria.

[3] This Overlay analysis was conducted prior to final revisions of the list of thermal issues.

"approved" lines and dotted lines represent the elements of a conceptual overlay to form a high voltage loop. This loop does not indicate an actual plan or design but is presented only to test the potential effect of transmission overlays on underlying system contingency results. The loop was intentionally extended to eastern PJM consistent with designs under consideration for the economic phase of the JCSP study.

Figure 1 - HV Overlay on PJM-MISO Seam to Eastern PJM



A contingency analysis with this loop added to the model demonstrated a significant decrease in reported contingency results when compared to the results before the loop was modeled, as reflected in Table 2 below. In addition, there were no significant new contingency results created by the addition of the loop. Figures 2 and 3 depict the locations of contingency overloads before and after this conceptual overlay was modeled.

Table 2 - Summary of Contingency Results before and After Overlay (MISO-PJM Seam)

Contingency Type	Thermal Limits Before Conceptual Overlay	Thermal Limits After Conceptual Overlay
N-1 branch	5	2
N-1-1	10	3 (1 new)
N-2	7	4
Common Tower	3	1
Total	25	10

Figure 2 - PJM-MISO Seams Contingency Results Before Overlay

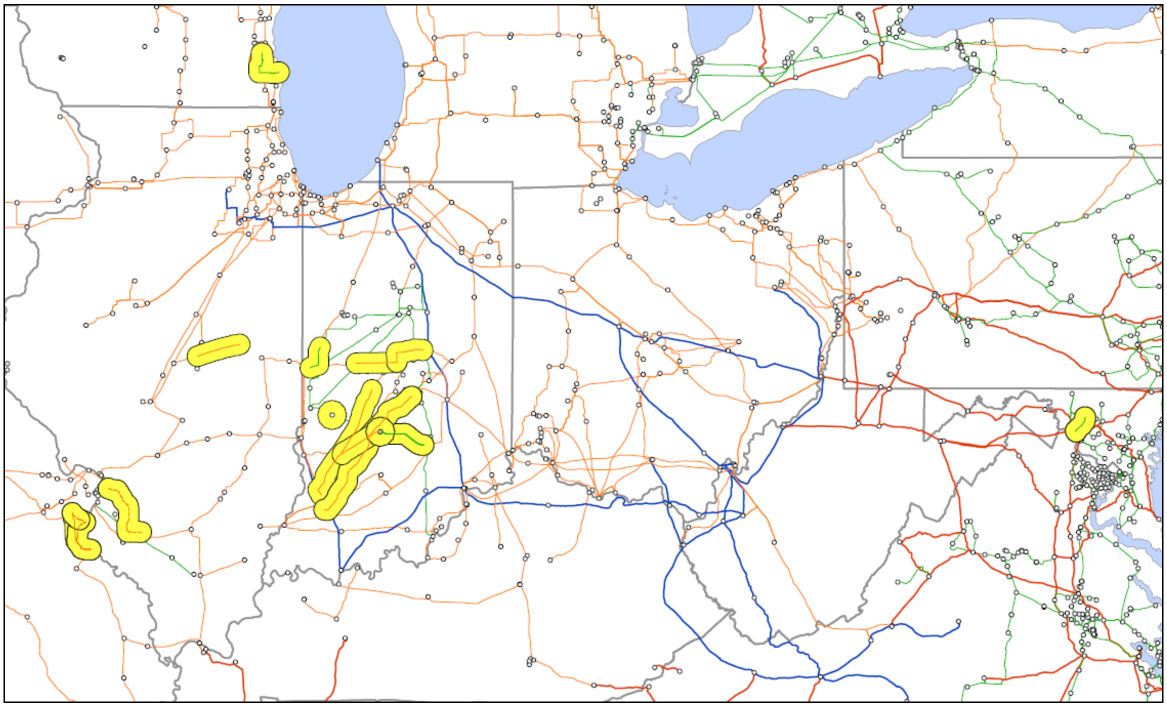


Figure 3 - PJM-MISO Seam Contingency Results after Overlay

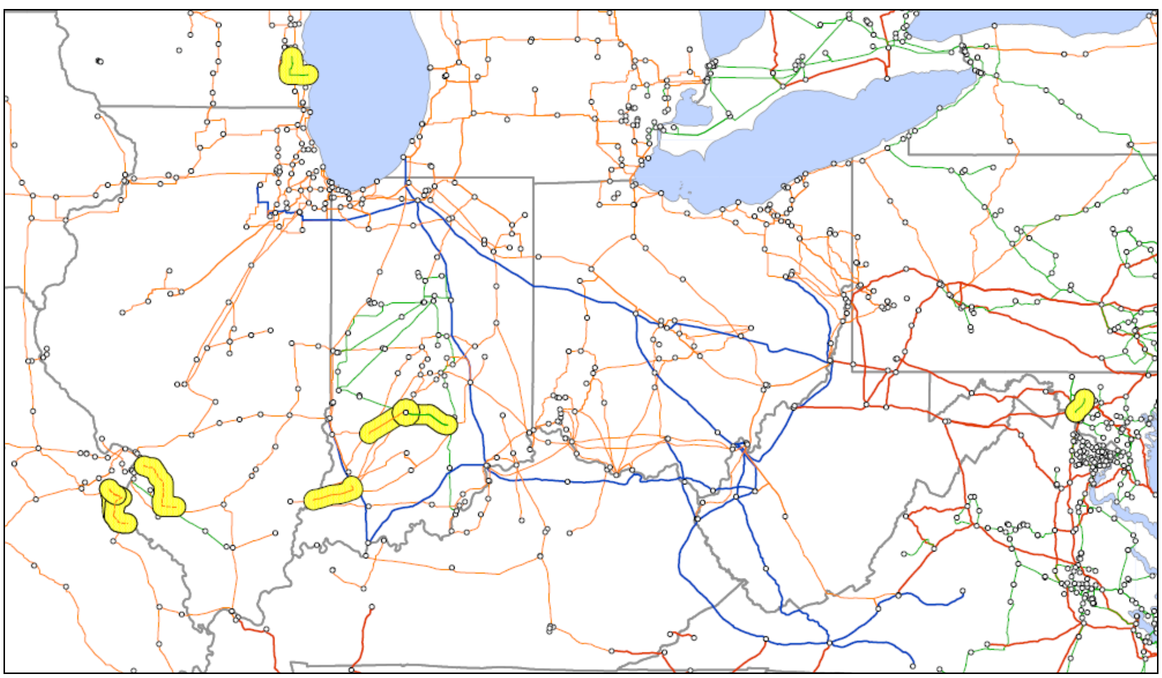


Table 3 below provides a detailed breakdown of the line segments and estimated mileages for the conceptual transmission overlay depicted in Figure 1. The overlay includes over 1,700 total miles of EHV transmission. The 2018 costs for the 765 kV transmission facilities are estimated to be $9.3 Billion, while the costs for the 500 kV transmission facilities are estimated to be $3.1 Billion (total combined cost of $12.4 Billion). The cost for the 500 kV facilities reflects a higher cost/mile, which is based on actual experience with construction in the densely populated area of eastern PJM. These cost estimates are based on recent work by PJM on its Regional Transmission Expansion Plan.

Table 3- Conceptual Overlay Segments and Estimated Mileages

765 kV Loop	
Line Segment	Miles
Oak Creek - North Madison	82
North Madison - Byron	88
Byron - Nelson	18
Nelson - Lee County	13
Lee County - Cordova	39
Cordova - Duck Creek	78
Duck Creek - Kincaid	65
Kincaid - Chokia	81
Cahokia - Rush Island	36
Rush Island - Rockport	175
Rockport - Jefferson Ckt 2	100
Joshua Falls - Possum Point	124
Susquehanna - South Canton	260
Cook - Zion	125
Zion - Oak Creek	25
Cordova - Braidwood	107
Braidwood - Greentown	127
Sub-Total	**1,543**
500 kV Loop	
Line Segment	Miles
Sayreville - Roseland	41
Sayreville - Salem	118
Sub-Total	**159**
Total	**1,702**

Additional Efforts Related to JCSP 2024 Economic Study Overlays - The PROMOD modeling tool used for the 2024 Economic Study analysis evaluates a limited set of contingencies in its simulations due to performance constraints. The contingencies tested in the 2024 Economic Study were based on historical flowgate constraints in the Eastern Interconnection (starting with the NERC "book of flowgates"). Since the postulated transmission overlays and assumed generation expansion scenarios explored in the 2024 Economic Study could lead to significantly changed power flow patterns, the limitation on tested transmission contingencies was a concern of several study participants, especially since the 2024 transmission overlay scenarios were being "tested" against present day contingency sets.

While the JCSP 2018 Summer Reliability Study did not assess the reliability impacts of the transmission overlays postulated in the 2024 Economic Study on the 2018 summer study case (PSS/E power flow modeling environment), additional work was performed by SPP to test contingencies on the 2024 overlays using the PAT (PROMOD Analysis Tool) software product to identify potential constraints associated with the economic study analysis. The PAT tool was used to perform linear network analysis on the economic overlay models developed in PROMOD. MISO provided SPP with the PROMOD data corresponding to the overlays developed in the 2024 Economic Study. SPP staff utilized PAT to evaluate the effect of reliability contingencies on the network models corresponding to selected monthly peak-hour demand periods in the Eastern Interconnection. SPP tested all 200 kV and above N-1 transmission contingencies, consistent with the contingency selection criteria applied in the 2018 Summer Reliability Study. The number of thermal overloads identified through this screening is summarized in Table 4 below. The conclusion drawn from this exercise is that PAT can be a used to evaluate and refine the contingency sets that are included in the PROMOD models used to develop the economic overlays in order to ensure that new, potential reliability issues are taken into account.

Table 4 - PROMOD Analysis Tool (PAT) Contingency Screening Results

Date / Hour	Voltage Level	# of Thermal Overload Violations Identified	
		2024 Reference Overlay	2024 20% Wind Energy Overlay
5/31/2024, Hour 16	230 kV	426	804
	345 kV	123	326
	500 kV	16	36
	765 kV	6	28
6/24/2024, Hour 16	230 kV	425	409
	345 kV	204	187
	500 kV	12	11
	765 kV	5	7
7/31/2024, Hour 16	230 kV	530	463
	345 kV	223	174
	500 kV	19	16
	765 kV	9	10
8/1/2024, Hour 16	230 kV	554	466
	345 kV	203	184
	500 kV	18	14
	765 kV	13	10

Additional work was also performed by TVA to add the Reference Case overlay developed in the JCSP 2024 Economic Study process into the 2018 summer study power flow base case for further reliability analysis on that overlay scenario in the PSS/E modeling environment. All AC lines identified in the 2024 Reference Case overlay have been incorporated into a base case, while proper modeling of the DC lines is still under consideration. The future direction of these modeling efforts will be considered as the JCSP participants discuss “next steps” beyond the 2008 joint study effort. Future efforts should include an assessment of the reliability impacts of inter-regional transfers on the voltage and stability performance of the system, especially in those areas that would be affected by loop flow.

III. STUDY REGION DISCUSSIONS

A. MAPP

The MAPP study region covers the regions of Minnesota, Iowa, Dakotas, Nebraska, Wisconsin, and study coordination with Saskatchewan Power. Therefore, it includes the areas served by the following Transmission Owners: MPW, MEC, NPPD, OPPD, LES, WAPA, DPC, and coordination with SPC. For this JCSP reliability assessment, MAPP submitted a subset of contingencies that are used in the annual MAPP Transmission Assessment study performed by the Transmission Reliability Assessment Working Group of MAPP. This set of contingencies included common tower NERC Category C for voltage levels above 200 kV. The contingency simulations results performed in this JCSP study were reviewed by the MAPP Member owning the facilities. Most contingency violations revealed in the MAPP study region had mitigation schemes that the MAPP Members identified for the violation. The MAPP TRAWG is currently performing the MAPP 2009 Transmission Assessment and will review in greater detail any outstanding violations found in this JCSP Reliability Assessment.

B. Midwest ISO

Overall, this Joint Coordinated System Planning Study is a forward looking study to develop overlay concepts that may be required for meeting large volumes of new renewable generation as required by existing and future RPS's. The Reliability Analysis piece of the study serves to provide a first look at what reliability issues may exist in the 2018 timeframe, and will be followed up with more detailed studies within Midwest ISO through the near term MTEP process and provide opportunity for stakeholder input via our ongoing SPM's and Planning Subcommittees.

In this reliability study, several JCSP Economic Study "Reference Future" EGEAS (Electric Generation Expansion Analysis System) generators were modeled in the JCSP reliability case. As a result of implementation of a Midwest ISO wide Security Controlled Economic Dispatch, a number of these units were modeled as online. Local transmission interconnection related constraints seen as a result of these conceptual / fictitious units were documented internally to be investigated in additional detail as these generation sites firm up in due course.

In addition to including automated single contingencies throughout the Midwest ISO footprint, additional explicit single (NERC Cat-B), select multiple contingent events (NERC Cat C3 and C5) at and above 200 kV were also included for evaluation. The 2018 topology modeled in the JCSP case reflected most MTEP07 (Midwest ISO Transmission Expansion Plan) planned and proposed projects. Constraints seen after the JCSP reliability analyses that would otherwise be addressed by newer more recently approved (MTEP08) planned and proposed projects were tagged as such and not included in the final list of valid constraints. Valid constraints included in this report are defined as constraints for which there are no known firm mitigation plans at this time.

Twenty (20) thermal criteria violations were seen on 18 branches. Of these, loading on four were documented to be over 110% of rating. Additionally voltage criteria violations were seen on four substations.

Two base case overloads less than 110% were seen on Square Butte to Center and Antelope Valley to Charley Creek. A proposal to add a new 345 kV line from Leland Olds to Belfield in addition to a new 345/130 kV transformer at Leland Olds station is expected to mitigate loading on Antelope Valley to Charley Creek. Square Butte to Center 345 kV line overload is a newly developing issue due to new wind generation in the area. Impact of these wind additions are being studied in separate targeted studies such as RGOS (Regional Generation Outlet Study).

There were four single contingent overloads two of which on Bloomington to Denois 230 kV and Square Butte to Center were over 110%. In addition 107% overload on the two Bloomington 345/230 kV transformers was seen for loss of the other. Additionally, two double circuit tower contingent overloads were seen on Stanton to Leland Olds 230 kV and Dorsey to LaVerendrye 230 kV lines.

Twelve thermal overloads were observed for double contingencies (NERC Category-C3) two of which were above 110% on Nucor to Whitestown 345 kV and Bloomington to Denois 230 kV lines. All but one (101% overload on Amo to Edwardsport 345 kV) are limited by conductor. Amo to Edwardsport is limited by breaker, disconnect switches and wave trap and therefore would involve minimal upgrades to mitigate constraint. 105% overload on Petersburg to Star 345 kV line is expected to be mitigated by proposed upgrade of Petersburg Auto transformers. Star to Spenser 230 kV line overload of 107% is due to a radial distribution substation supply to which can switched to an alternate source at Cloverdale to mitigate overload. While generation redispatch is expected to mitigate all remaining overloads, feasibility and cost of redispatch will be evaluated against other transmission alternatives in separate near term Midwest ISO planning studies. Constraints seen that were driven by contingency pairs with one each in MISO and PJM will be investigated in separate coordinated ad hoc studies. Voltage violations were marginal and the needs for capacitor placement will be investigated further in near term planning studies. Reliability constraint details are documented in Appendix-3.

C. New York ISO

For this analysis, NYISO was not able to review the actual base cases because of non disclosure agreement issues. NYISO reviewed any violations noted on the NYCA system and provided instructions on base case modifications or steps to mitigate the potential violations.

This study has proved useful as a means of coordinating base case setups and analysis procedures that can be utilized for future inter-regional reliability studies. This first step will provide for the means to perform the required next steps in a comprehensive reliability analysis. This would include assessing the study system at a stressed transfer condition and performing transfer limit analysis for key interregional interfaces. When transfers are increased from the west to the east, loop flows will occur on the NYCA system, both for pre contingency conditions and especially for post contingency pickup. Many of these paths are phase angle regulator controlled and therefore the ability to maintain control and the impact of these loop flows must be determined in the next steps of the reliability study. This effort should be coordinated with other interregional studies including those by the Joint ISO/RTO Planning Committee (Northeast Coordinated System Plan), the Northeast Power Coordinating Council, NERC, and others. The study did not reveal any major issues of concern, as the timescale being analyzed coincides with the same timeframe looked at by the NYISO's Comprehensive Reliability Planning Process, and that transfers were not stressed. However, to complete the reliability impact analysis, the NYISO must emphasize the need to include a stressed transfer analysis to determine potential impacts of the change in flows on the NYCA system.

D. PJM

In addition to the single high voltage branch and large plant source contingency screen generally applied to all participants' systems, PJM also included its internal multiple contingency screens generally applied in its reliability analyses. These included PJM's double circuit tower outages, and its high voltage N-1-1 contingencies. Since PJM's base dispatch setup is not adjusted for operational security constraints, PJM expects the results of these fundamental screens to show single and multiple contingency thermal issues prior to security adjustments. PJM examines all such results to ensure that the response of generators to market price signals can mitigate these results.

PJM results also show significant numbers of base and contingency voltages out of expected limits. These results are all isolated, local reactive issues that can be remedied by attention to either tuning the reactive representation or through short term reactive remedies. None have been determined to be indicative of widespread problems.

PJM's results list and line-by-line initial assessments of results is contained in Appendix 3. PJM recognizes that these results are produced with a single snapshot of the system representing firm energy transfers. For this reason, all issues are discussed, remodeled, and monitored during the PJM internal planning process and more rigorous reviews as may be appropriate.

E. SPP

SPP included single branch contingencies (breaker-breaker, 200 kV and above), selected multiple contingency events (NERC category C, D), and common tower outages consistent with SPP's internal reliability assessments. SPP examined all out of limit conditions that resulted from the contingency screening performed by PJM. The screening resulted in several out of limit voltage conditions, but these conditions were not violations of SPP reliability criteria. SPP staff also evaluated several out of limit thermal conditions that were reported in the results of the initial screening. Staff determined that each condition had already been identified and mitigated via SPP's internal planning process either by a proposed project or an existing operating guide. SPP internal planning process continues to evaluate system impacts, as appropriate.

F. TVA Reliability Coordinator Area

The TVA study region for the purposes of this JCSP study was assumed to encompass the areas served by Transmission Owner/Operators within the TVA Reliability Coordinator footprint. These are AECI, BREC, EEI, EKPC, E.ON U.S, and TVA. The major generation and transmission (345 kV and above) additions modeled in the JCSP 2018 summer reliability study model are identified in Appendix 2. In some instances, these additions may not have reached a level of approval and permitting to be considered "firm" projects. However, at the time of study model development they were considered to be within a realm of feasibility for use in modeling this 2018 scenario. One future plant addition modeled, the 600 MW Norborne coal-fired facility in the AECI area, was canceled by the utility during the course of this study.

The contingency simulations performed in this JCSP reliability study did not reveal any significant new findings for the TVA study region. Several thermal overloads identified through the N-2 contingency screening were attributed to future nuclear plant additions modeled in the 2018 study case. The corresponding transmission upgrades that have been identified to interconnect these new resources were not reflected in the study model, thus driving the identification of these overloads.

IV. Appendices

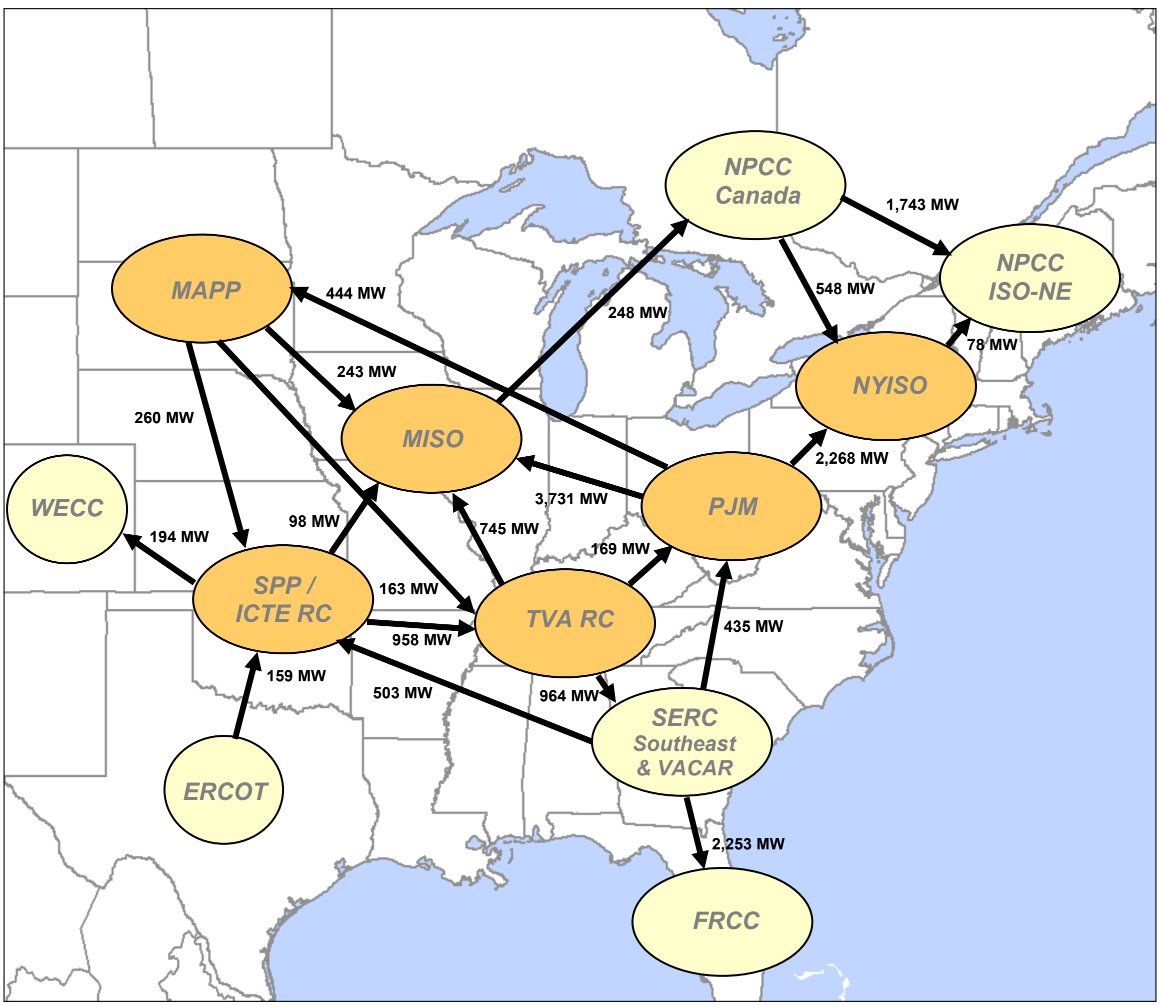
Appendix 1 - Base Case Summary Data

The starting point base case for the JCSP 2018 Summer Reliability Study was the ERAG MMWG 2018 summer base case, developed as part of the 2007 MMWG case series. The JCSP study participants identified the areas in the model that were within their respective "study region" area of responsibility (Table 1-2). The study participants then coordinated any desired changes to the inter-regional interchange assumptions, and submitted any updates to their respective model areas of responsibility to the study case coordinator (SPP). Model areas considered "external" to the study are identified in Table 1-4.

Table 1-1 - Study Regions Energy Balance Summary (MWs)

Study Region	Generation	Net Interchange	Load	Losses
MAPP	20,236	228	19,423	585
Midwest ISO	134,574	- 4,570	134,667	4,390
New York ISO	35,269	- 2,738	36,852	977
PJM	166,817	5,832	156,542	4,428
SPP / ICTE RC	87,449	360	84,839	2,261
TVA RC	62,198	733	59,903	1,519
Total	**506,543**	**- 155**	**492,226**	**14,160**

Figure 1-1 - Base Case Interface Flows (MWs)



Appendix 1 - Base Case Summary Data

Table 1-2 - Study Regions & Associated MMWG Model Areas

Study Region	Area #	Area Name
MAPP	633	MPW
	635	MEC
	640	NPPD
	645	OPPD
	650	LES
	652	WAPA
	680	DPC
Midwest ISO	202	FE
	207	HE
	208	DEM
	210	SIGE
	216	IPL
	217	NIPS
	218	METC
	219	ITC
	295	WEC
	333	CWLD
	356	AMMO
	357	AMIL
	360	CWLP
	361	SIPC
	600	XEL
	608	MP
	613	SMMPA
	615	GRE
	620	OTP
	627	ALTW
	667	MHEB
	694	ALTE
	696	WPS
	697	MGE
	698	UPPC
New York ISO	102	NYISO
PJM	201	AP
	205	AEP
	206	OVEC
	209	DAY
	215	DLCO
	220	IPRV
	222	CE
	225	PJM
	226	PENELEC
	227	METED
	228	JCP&L
PJM (cont.)	229	PPL
	230	PECO
	231	PSE&G
	232	BG&E
	233	PEPCO
	234	AE
	235	DP&L
	236	UGI
	237	RECO
	345	DVP
SPP / ICTE RC	331	BCA
	332	LAGN
	334	WESTMEMP
	335	CONWAY
	336	BUBA
	337	PUPP
	338	DERS
	339	DENL
	351	ENTERGY
	502	CELE
	503	LAFA
	504	LEPA
	515	SWPA
	520	AEPW
	523	GRDA
	524	OKGE
	525	WFEC
	526	SPS
	527	OMPA
	531	MIDW
	534	SUNC
	536	WERE
	539	MKEC
	540	MIPU
	541	KACP
	542	KACY
	544	EMDE
	545	INDN
	546	SPRM
TVA RC Area	314	BREC
	320	EKPC
	330	AECI
	347	TVA
	362	EEI
	363	LGEE

Appendix 1 - Base Case Summary Data

Table 1-3 - Study Regions Assumed Net Interchange

Study Region	Interchange	Area Name
MAPP	0	MPW
	75	MEC
	- 651	NPPD
	408	OPPD
	- 650	LES
	1,031	WAPA
	15	DPC
Net	**228**	
Midwest ISO	-2,104	FE
	1,229	HE
	- 2,067	DEM
	- 594	SIGE
	- 559	IPL
	- 388	NIPS
	2,077	METC
	- 3,688	ITC
	88	WEC
	- 206	CWLD
	- 1,400	AMMO
	2,932	AMIL
	183	CWLP
	- 156	SIPC
	- 1,885	XEL
	- 357	MP
	- 322	SMMPA
	- 36	GRE
	329	OTP
	113	ALTW
	1,966	MHEB
	307	ALTE
	- 68	WPS
	169	MGE
	- 135	UPPC
Net	**- 4, 570**	
New York ISO	- 2,738	NYISO
Net	**- 2,738**	
PJM	2,829	AP
	6,009	AEP
	2,000	OVEC
	597	DAY
	- 36	DLCO
	789	IPRV
	- 2,658	CE
	16,947	PJM
	988	PENELEC
	- 223	METED
	- 3,964	JCP&L
	266	PPL

Study Region	Interchange	Area Name
PJM (cont.)	- 1,927	PECO
	- 5,145	PSE&G
	- 4,424	BG&E
	- 2,935	PEPCO
	- 1,940	AE
	- 1,129	DP&L
	- 127	UGI
	- 468	RECO
	383	DVP
Net	**5,832**	
SPP / ICTE RC	0	BCA
	241	LAGN
	- 104	WESTMEMP
	- 235	CONWAY
	- 102	BUBA
	0	PUPP
	- 15	DERS
	- 329	DENL
	989	ENTERGY
	601	CELE
	- 270	LAFA
	- 52	LEPA
	1,028	SWPA
	- 852	AEPW
	372	GRDA
	508	OKGE
	- 243	WFEC
	6	SPS
	- 594	OMPA
	- 283	MIDW
	201	SUNC
	- 268	WERE
	- 275	MKEC
	- 447	MIPU
	643	KACP
	17	KACY
	- 94	EMDE
	- 105	INDN
	21	SPRM
Net	**360**	
TVA RC Area	- 190	BREC
	- 16	EKPC
	- 608	AECI
	748	TVA
	1,235	EEI
	- 436	LGEE
Net	**733**	

Appendix 1 - Base Case Summary Data

Table 1-4 - Model Areas External to Study

Region	Area #	Area Name	Region	Area #	Area Name
NPCC	101	ISO NE	FRCC (cont.)	407	KEY
	103	IESO		409	LWU
	104	TE		410	NSB
	105	NB		411	OUC
	106	NS		412	SEC
	107	CORNWALL		414	STK
				415	TAL
SERC	340	CPLE		416	TEC
	341	CPLW		417	FMP
	342	DUKE		418	NUG
	343	SCEG		419	RCU
	344	SCPSA		421	TCEC
	346	SOUTHERN		426	OSC
	349	SMEPA		427	OLEANDER
	350	AEC		428	CALPINE
	352	YADKIN		431	VAN
	353	SEPA-HART		433	HPS
	354	SEPA-RJR		436	DESOTOGN
	355	SEPA-JST		438	IPP-REL
FRCC	401	FPL	MRO	672	SPC
	402	FPC			
	403	FTP	ERCOT	998	ERCOT
	404	GVL			
	405	HST	WECC	999	WECC
	406	JEA			

Appendix 2 - Major Generation and Transmission Facility Additions

The following tables identify the major generation and transmission additions that were modeled in the JCSP 2018 summer study case for the participating study regions. These represent the study participant's best projections at the time of study case development regarding future system expansion over the 2009 - 2018 timeframe.

Table 2-1 - Major Generation Additions Modeled in the Study Regions

Study Region	Model Area	Major Generation Additions Modeled	Pmax (MW)
MAPP	OPPD	Nebraska City #2	663
	OPPD	Cass County #3	160
	Resource Forecast (Reference Future) Units		
	NPPD	Cooper Wind	38
	WAPA	Fort Peck Wind	38
	WAPA	Fargo Wind	60
	WAPA	Baker Wind	53
	WAPA	Bowman Wind	30
	WAPA	McLaughlin Wind	15
Midwest ISO	WEC	Elm Road-Oak Creek (Coal)	1,300
	XEL	Buffalo Ridge (SW MN)	825
	OTP	Big Stone II	600
	MP	Mesaba	600
	WEC	Point Beach North Appleton 345kV line (Combined Cycle)	600
	MP	Blackberry 230/115kV Substation (Coal)	600
	WPS	Weston Substation 345 kV bus (Coal)	550
	NSP/GRE	Cannon Falls sub (Gas)	350
	Duke	Zimmer 345 kV Station (Coal)	330
	Resource Forecast (Reference Future) Units		
	FE	Beaver CT Gas	600
	FE	Midway CT Gas	600
	HE	Worthington CT Gas	600
	DEM	Dresser CT Gas	600
	DEM	Wheatland CT Gas	600
	METC	Renas CT Gas	600
	METC	Zeeland CT Gas	600
	AMMO	Rush CT Gas	600
	AMIL	Pawnee CT Gas	600
	AMIL	Brokaw CT Gas	600
	XEL	Sherco CT Gas	600
	FE	Sammis ST Coal	600
	METC	Hampton ST Coal	600
	METC	Livingston ST Coal	600
	OTP	Big Stone 4 ST Coal	600
	ALTW	Hazelton ST Coal	600
	OTP	Center ST Coal	600
	MGE	Coleman 345 ST Coal	600
	AMMO	Adair Wind	38
	AMIL	Coffeen Wind	75
	AMIL	Ramsey Wind	113
	AMIL	Maroa Wind	113
	XEL	Adams Wind	150
	XEL	Wilmarth Wind	75

Appendix 2 - Major Generation and Transmission Facility Additions

Midwest ISO (cont.)	XEL	Willow River Wind	30
	ALTW	Magnolia Wind	120
	ALTW	Lakefield Wind	60
	UPPC	Winona Wind	15
	WEC	Burlington Wind	15
	ALTE	Hillman Wind	15
	ALTE	South Fon du Lac Wind	120
New York ISO	NYISO	Besicorp	660
	NYISO	TransGas Energy	1100
	NYISO	Bergen	509
	NYISO	SCS Astoria Phase 2	500
	NYISO	Spagnoli Road	250
	NYISO	Caithness	310
	NYISO	Aggregate of New Wind Projects	1375
PJM	BGE	Calvert Cliffs	1,640
	DVP	North Anna	1,600
	PECO	Peach Bottom	550
	PPL	Susquehanna	1,600
	APS	Prexy Wind (not dispatched in study case)	3,300
	AEP	Dumont Wind (not dispatched in study case)	3,200
	CE	Quadcities Wind (not dispatched in study case)	3,300
	CE	Wilton Center Wind (not dispatched in study case)	3,300
	CE	Taswell Wind (not dispatched in study case)	3,300
SPP / ICTE RC	EES	LS Power	735
	CELE	Rodemacher	720
	AEPW	Arsenal Hill	198.9
	AEPW	Arsenal Hill	198.9
	AEPW	Arsenal Hill	195.5
	AEPW	Turk	713
	OKGE	Sooner	500
	OKGE	Seminole	500
	WFEC	Hugo	440
	SUNC	Holcomb	600
	WERE	Empec	189
	WERE	Empec	189
	KACP	Iatan	850
	SPRM	SWPS	275
	SPRM	McCartney	50
	SPRM	McCartney	50
TVA RC	AECI	Norborne 1 (MO)	600
	AECI	Maryville Wind	75
	EKPC	Spurlock 4 (KY)	299
	EKPC	Smith 1 (KY)	299
	EKPC	Smith CT 8-12 (KY)	375
	LGEE	Green River 5 (KY)	750
	LGEE	Trimble 2 (KY)	732
	LGEE	ESTLEP (KY)	120
	LGEE	Brown (KY)	160
	LGEE	Brown (KY)	160

Appendix 2 - Major Generation and Transmission Facility Additions

TVA RC (cont.)	TVA	Watts Bar 2 (TN)	1,201
	TVA	Lagoon Creek CC (TN)	590
	TVA	Gleason CC conversion (TN)	374
	TVA	Bellefonte 3 (AL)	1,262
	TVA	Bellefonte 4 (AL)	1,262
	TVA	Caledonia CT 1-6 (MS)	468

Appendix 2 - Major Generation and Transmission Facility Additions

Table 2-2 - Major Transmission Additions Modeled in the Study Regions (345 kV & above)

Study Region	Model Area	Major Transmission Additions Modeled	Rating (MVA)
MAPP	NPPD	Columbus East 345 kV project	1,195
MAPP - Midwest ISO	XEL/DPC/RPU	MISO PrID: 1024 SE Twin Cities - Rochester, MN - LaCrosse, WI 345 kV project	2,050
Midwest ISO	XEL/GRE	MISO PrID: 1203 Brookings, SD – SE Twin Cities 345 kV project	2,066
	ATC LLC	MISO PrID: 1 Arrowhead-Gardner Park 345 kV	1,092
	ITC	MISO PrID: 692 Bismark-Troy 345 kV line	700
	GRE/MPC/XEL/OTP/MP	MISO PrID: 286/287 Fargo, ND – St Cloud/Monticello, MN area 345 kV project	2,085
	ATC LLC	MISO PrID: 345 Morgan - Werner West 345 kV line (includes Clintonville-Werner West 138)	1,882
	ATC LLC	MISO PrID: 177 Gardner Park-Highway 22 345 kV line projects	1,776
	ATC LLC	MISO PrID: 1256 Paddock - Rockdale 345kV	1,430
	ATC LLC	MISO PrID: 352 Cranberry-Conover 115 kV and Conover-Plains conversion to 138 kV	400
	ATC LLC	MISO PrID: 341 Rockdale-Mill Road 345 kV line projects	1,200
	ALTW	MISO PrID: 1340 Build a new Hazleton - Lore - Salem 345 kV line with a Lore 345/161 kV 335/335 MVA transformer (option 2)	2,000
	ATC LLC	MISO PrID: 356 Rockdale-West Middleton 345 kV	1,200
	MPC/XEL/OTP/MP	MISO PrID: 279 Bemidji-Grand Rapids 230 kV Line	434
	Vectren (SIGE)	MISO PrID: 1257 New transmission line Gibson (Cinergy) to AB Brown to Reid (BREC) 345 kV	1,430
New York ISO	NYISO	Sprain Brook to Sherman Creek 345kV cable	521
PJM	JCP&L	Neptune DC tie to NYISO	685
	PSE&G	Linden VFT to NYISO	330
	PEPCO	Birches Hill 500/230kV Tx #3	1,340
	PJM500KV	Salem – Orchard – New Freedom – East Windsor 500 kV Circuit	3,040
	APS/DVP	502 Junction - Mt.Storm - Meadow Brook – Loundon 500 kV circuit	5,269
	PJM500kV	Susquehanna - Lackawanna - Jefferson - Montiville - Roseland 500 kV circuit	3,000
	APS/AEP	Amos 765kV - Bedington 765 kV - Bedington 500 kV (20101) - Kemptown 500 kV (20632) - 765 & 500 kV circuit	5,269
	PJM500kV	Possum Point - Calvert Cliffs – Vienna – Indian River – Cedar Creek – Salem 500 kV Circuit	2,219

Appendix 2 - Major Generation and Transmission Facility Additions

SPP / ICTE RC	EES	Dell - Shelby (TVA) 500 kV, loop into Plum Point	2,165
	AEPW	Flint Creek to Centerton 345 kV	1,220
	AEPW	Centerton to East Rogers 345 kV	1,220
	AEPW	Hempstead to NW Texarkana 345 kV	1,220
	AEPW	Valiant to Hugo 345 kV	913
	OKGE	Sooner to Rosehill 345 kV	1,611
	WERE	Empec to Swissval 345 kV	956
	WERE	Empec to Lang 345 kV	956
	WERE	Empec to Morris 345 kV	956
	WERE	Empec to Wichita 345 kV	956
	WERE	Reno to Wichita 345 kV	1,383
	WERE	Reno to Summit 345 kV	1,383
TVA RC	BREC	Reid - AB Brown (SIGE) 345 kV	1,430
	TVA	Maury - Rutherford 500 kV	1,732
	TVA	Rutherford 500/161 kV Substation	1,344
	TVA	Jackson 500/161 kV Trf. #2	773
	TVA	Clay 500/161 kV Substation	1,344
	TVA	Widows Creek - Madison 500 kV, restore loop to Bellefonte	1,732
	TVA	Widows Creek - East Point 500 kV, restore loop to Bellefonte	1,732

Appendix 3 - Results Tables

The following tables are contained in this section:

Appendix 3 - Results Tables

Table 3-1: Base Case Conditions (N-0), Thermal Overloads

Outaged Facility	Study Region	Overloaded Facility	Study Region	Rating (MVA)	Base Case Flow (MVA)	Loading (%)
None	N/A	SQBUTTE4 - CENTER 3 230/345 kV Trf.	MISO	336	343.9	102.4

Table 3-2: Base Case Conditions (N-0), Outside Voltage Criteria Range

Outaged Facility	Study Region	Facility	Study Region	Criteria Range (p.u)	Base Case Voltage (p.u.)
None	N/A	G22_VFT 230 kV	PJM	0.92 to 1.05	1.0709
None	N/A	RCSERCAP 230 kV	MAPP	0.9 to 1.1	1.1103

Appendix 3 - Results Tables

Table 3-3: Contingency Conditions (N-1), Thermal Overloads

Outaged Facility	Study Region	Overloaded Facility	Study Region	Rating (MVA)	Base Case Flow (MVA)	Post Contingency Flow (MVA)	Loading (%)
S3455 3 - S3740 3 345 kV	MAPP	S3456 3 - S3458 3 345 kV	MAPP	956.0	690.0	1,126.6	117.8
S3456 3 - S3458 3 345 kV	MAPP	S3455 3 - S3740 3 345 kV	MAPP	1,073.0	729.0	1,101.7	102.7
S3455 3 - S3456 3 345 kV	MAPP	S3456 3 - S3456T4T 345 kV	MAPP	500	430.3	508.7	101.7
GRE-STANTON4 - LELANDO4 230 kV	MISO	SQBUTTE4 - CENTER 3 230/345 kV Trf.	MISO	352.0	344.1	427.9	121.6
08BEDFRD - 08COLMBU 345 kV	MISO	08BLOOM - 08DENOIS 230 kV	MISO	478	431.5	534.6	111.8
07BLOMNG - 08BLOOM2 345/230 kV Trf. #2	MISO	07BLOMNG - 08BLOOM 345/230 kV Trf. #1	MISO	740	426.9	791.2	106.9
07BLOMNG - 08BLOOM 345/230 kV Trf. #1	MISO	07BLOMNG - 08BLOOM2 345/230 kV Trf. #2	MISO	740	426.9	790.8	106.9

Table 3-4: Contingency Conditions (N-1), Outside Voltage Criteria Range

Outaged Facility	Study Region	Facility	Study Region	Criteria Range (p.u)	Post Contingency Voltage (p.u.)
BD 4 - BDX 4 230 kV	MAPP	BDX 4 230 kV	MAPP	0.9 to 1.1	1.213
SIDNEYW4 - STEGALDC 230 kV	MAPP	STEGALDC 230 kV	MAPP	0.9 to 1.1	1.1379
SIDNEYW4 - STEGALDC 230 kV	MAPP	MBPP-1 230 kV	MAPP	0.9 to 1.1	1.1242
RUSHLAK4 - SWIFTCU4 230 kV	MAPP	RUSHLAK4 230 kV	MAPP	0.9 to 1.1	1.1133
MIDD JCT - STARMIDD 230 kV	PJM	STARMIDD 230 kV	PJM	0.92 to 1.05	1.1397
WALDWICK - FAIRL SH 230 kV	PJM	FAIRL SH 230 kV	PJM	0.92 to 1.05	1.1324
WALDWICK - FAIRL SH 230 kV	PJM	FAIRLAWN 230 kV	PJM	0.92 to 1.05	1.1319
TOSCO - G22_MTX5 230 kV	PJM	G22_MTX5 230 kV	PJM	0.92 to 1.05	1.0689
TOSCO - G22_MTX5 230 kV	PJM	WARINANC 230 kV	PJM	0.92 to 1.05	1.0673
BURCH230 - PALM093 230 kV	PJM	PALM093 230 kV	PJM	0.92 to 1.05	1.0673
BURCH230 - PALM093 230 kV	PJM	BLU23109 230 kV	PJM	0.92 to 1.05	1.0668
BURCH230 - PALM093 230 kV	PJM	C23107 230 kV	PJM	0.92 to 1.05	1.0665
RAPHAEL - OTTR PT1 230 kV	PJM	PERRY361 230 kV	PJM	0.92 to 1.05	1.0657
RAPHAEL - OTTR PT1 230 kV	PJM	OTTR PT1 230 kV	PJM	0.92 to 1.05	1.0655
BURCH230 - PALM093 230 kV	PJM	ALA 089 230 kV	PJM	0.92 to 1.05	1.0653
BURCH230 - PALM093 230 kV	PJM	BUZZ 026 230 kV	PJM	0.92 to 1.05	1.0635
PAR2 - N-MANH 345 kV	PJM	HUDSON2 345 kV	PJM	0.92 to 1.05	1.0615

Appendix 3 - Results Tables

Table 3-4: Contingency Conditions (N-1), Outside Voltage Criteria Range

Outaged Facility	Study Region	Facility	Study Region	Criteria Range (p.u)	Post Contingency Voltage (p.u.)
LINDEN - TOSCO 230 kV	PJM	TOSCO 230 kV	PJM	0.92 to 1.05	1.0609
HOWARD32 - PUMPHRY 230 kV	PJM	PUMPHRY 230 kV	PJM	0.92 to 1.05	1.0608
AVSDC7TY - AVSD11TY 345 kV	MAPP	AVSD12TY 345 kV	MAPP	0.9 to 1.1	0.889
NROC 3 - NLAX 3 345 kV	MAPP	NLAX 3 345 kV	MAPP	0.9 to 1.1	0.8725
RUSHLAK4 - SWIFTCU4 230 kV	MAPP	SWIFTCU4 230 kV	MAPP	0.9 to 1.1	0.8647
AVSDC7TY - AVSD11TY 345 kV	MAPP	AVSD11TY 345 kV	MAPP	0.9 to 1.1	0.8041
AVSDC1TY - AVSDC5TY 345 kV	MAPP	AVSDC5TY 345 kV	MAPP	0.9 to 1.1	0.8018
Jefferson - Rockport 765 kV	MISO	16GUION 345 kV	MISO	0.95 to 1.1	0.9384
Jefferson - Rockport 765 kV	MISO	08FIVE P 230 kV	MISO	0.9 to 1.1	0.8998
MONTVILE - ROSELAND 230 kV	PJM	MONTVILE 230 kV	PJM	0.92 to 1.05	0.8983
6PLAZA - 6SOUWEST 230 kV	PJM	6PLAZA 230 kV	PJM	0.92 to 1.05	0.8929
H.RDGE16 - SNOW18TP 230 kV	PJM	W.LAKE8A 230 kV	PJM	0.92 to 1.05	0.8915
H.RDGE16 - SNOW18TP 230 kV	PJM	COLUMB18 230 kV	PJM	0.92 to 1.05	0.8875
H.RDGE16 - SNOW18TP 230 kV	PJM	SNOW18TP 230 kV	PJM	0.92 to 1.05	0.8864
H.RDGE16 - SNOW18TP 230 kV	PJM	SNOW.R18 230 kV	PJM	0.92 to 1.05	0.884
GLADE TP - LEWIS RN 230 kV	PJM	LEWIS RN 230 kV	PJM	0.92 to 1.05	0.8734
6CORRCTN - 6LANEXA 230 kV	PJM	6SHACKLE 230 kV	PJM	0.92 to 1.05	0.8503
HOMER CT - QUEMAHON 230 kV	PJM	HOOVRSVL 230 kV	PJM	0.92 to 1.05	0.8501

Appendix 3 - Results Tables

Table 3-4: Contingency Conditions (N-1), Outside Voltage Criteria Range

Outaged Facility	Study Region	Facility	Study Region	Criteria Range (p.u)	Post Contingency Voltage (p.u.)
6CORRCTN - 6LANEXA 230 kV	PJM	6WEST PT 230 kV	PJM	0.92 to 1.05	0.8498
6CORRCTN - 6LANEXA 230 kV	PJM	6CORRCTN 230 kV	PJM	0.92 to 1.05	0.8495
HOMER CT - QUEMAHON 230 kV	PJM	QUEMAHON 230 kV	PJM	0.92 to 1.05	0.8493
6HARMONY - 6SHACKLE 230 kV	PJM	6HARMONY 230 kV	PJM	0.92 to 1.05	0.8446
6HEC3 - 6HARSBBG 230 kV	PJM	6ENDLCAV 230 kV	PJM	0.92 to 1.05	0.762
6HEC3 - 6HARSBBG 230 kV	PJM	6HEC3 230 kV	PJM	0.92 to 1.05	0.7463

Table 3-5: Contingency Conditions (N-1-1), Thermal Overloads

Outaged Facilities	Study Region	Overloaded Facility	Study Region	Rating (MVA)	Base Case Flow (MVA)	Post Contingency Flow (MVA)	Loading (%)
1) Bedford - Columbus 345kV, Bedford 345/138kV Trf. 2) Jefferson - Rockport 765 kV	MISO	08BLOOM - 08DENOIS 230 kV	MISO	478	566.2	652	136.4
1) GRE-WILLMAR4 - GRANITF4 230 kV 2) GRE-PANTHER4 - GRE-MCLEOD 4 230 kV	MISO	STARGRE - GRE-PANTHER4 230 kV	MISO	70	50,9	76.1	108.7
1) 7BROKAW T2 - 7CLINTON 345 kV, 7BROKAW T2 - 7BROKAW T1 345kV 2) 36277 BROKA; T - 7LANSVLAM 345 kV, BROKA;T - 7BROKAW T1 345 kV, BROKA; T - PONTI; R 345 kV	MISO	7GOOS_CRK - 7RISING 345 kV	MISO	448	386.7	481.9	107.6
1) 08BEDFRD-08GIBSON-345-138 2) BEDFORD - MITCHELL	MISO	STAR08SP - 08SPENCR 230 kV	MISO	70.4	68.5	75	106.6
1) Bedford - Columbus 345kV,Bedford 345/138kV Trf. 2) Jefferson - Rockport 765kV	MISO	16PETE - 16FRANCS 345 kV	MISO	956	847	1017.9	106.5
1) Jefferson - Rockport 765kV 2) 08WHITST-16GUION-16WSTLAN-345-138	MISO	08HORTVL - 08WHITST 345 kV	MISO	956	737	1008.7	105.5
1) 08BEDFRD-08LOST R-16PETE-08LST RV-345-138 2) Jefferson - Rockport 765kV	MISO	16PETE - STAR16PE 345 kV	MISO	140	128.2	147.5	105.4

Table 3-6: Contingency Conditions (Common Tower), Thermal Overloads

Outaged Facilities	Study Region	Overloaded Facility	Study Region	Rating (MVA)	Base Case Flow (MVA)	Post Contingency Flow (MVA)	Loading (%)
DORSEY - LAVERENDRYE 230 kV #1 and DORSEY - LAVERENDRYE-230 kV #2	MISO	DORSEY 4 - LAVEREN4 230 kV #3	MISO	503.5	293.9	640.4	127.2
Dak01Wapa.C5 : Disconect WASHBRN4 and HELKIN4	MISO	GRE-STANTON4 - LELANDO4 230 kV	MISO	430.2	336	451.7	105

Table 3-7: Contingency Conditions (Common Tower), Outside Voltage Criteria Range

Outaged Facilities	Study Region	Facility	Study Region	Criteria Range (p.u)	Post Contingency Voltage (p.u.)
DEANS - SEWAREN 230KV and METUCHEN - SEWAREN 138KV	PJM	PRSN AVS 230 kV	PJM	0.92 to 1.05	1.1295
TWR_40:LINE 15B.I. TO 15CRESCN 345 CK 1	PJM	15ARSENL 345 kV	PJM	0.92 to 1.05	1.0756
TWR_40:LINE 15B.I. TO 15CRESCN 345 CK 1	PJM	15CARSON 345 kV	PJM	0.92 to 1.05	1.0754
TWR_40:LINE 15B.I. TO 15CRESCN 345 CK 1	PJM	15B.I. 345 kV	PJM	0.92 to 1.05	1.0753
TWR_40:LINE 15B.I. TO 15CRESCN 345 CK 1	PJM	15BRADY 345 kV	PJM	0.92 to 1.05	1.0753
TWR_40:LINE 15B.I. TO 15CRESCN 345 CK 1	PJM	15LOGNFR 345 kV	PJM	0.92 to 1.05	1.0716
CHURCHLAND - SEWLSPT 230kV Ckt 1 & 2	PJM	6SEWLSPT 230 kV	PJM	0.92 to 1.05	0.8708
NEW JENKINS - STANTON #1 and JENKINS - STANTON #2	PJM	JENK_SQU 230 kV	PJM	0.92 to 1.05	0.8467

Table 3-8: Contingency Conditions (N-2), Thermal Overloads

Outaged Facilities	Study Region	Overloaded Facility	Study Region	Rating (MVA)	Base Case Flow (MVA)	Post Contingency Flow (MVA)	Loading (%)
1) WHITST - QUALTC 2) Jefferson - Rockport 765 kV	MISO	08NUCOR - 08WHITST 345 kV	MISO	956	715.7	1079.8	113
1) OC CRK7 -OC CRK6 1 2) OC CRK8 -OK CRK 1	MISO	OC CRK7 - BLUMND1 230 kV	MISO	535	208.5	573.7	107.2
07MEROM5 - 08DRESSR - 08GIBSON 345 kV	MISO	07WORTHN - 07BLOMNG 345 kV	MISO	1194	866.3	1274.5	106.7
1) Frankfort - Cayuga 2) Greentown - Jefferson 765kV	MISO	08CAYUGA - 08VDSBRG 230 kV	MISO	496	375.1	518	104.4
1) WHITST - Nucor 2) Jefferson - Rockport 756 kV	MISO	08AMO - 08EDWDSP 345 kV	MISO	1195	1014.8	1208	101.1
1) Watts Bar -Bull Run 500 kV 2) Watts Bar - Volunteer 500 kV	TVA	Watts Bar - Roane 500 kV	TVA	1732.1	1039.8	2398.1	138.5
1) Widows Creek - Crawfish Crk 230 kV 2) W. Ringgold - Concord 230 kV	TVA	Oglethorpe - Battlefield 230 kV	TVA	339	181	407.5	120.2
1) Bellefonte - Madison 500 kV 2) Widows Creek - Sequoyah 500 kV	TVA	Widows Creek - Crawfish Crk. 230 kV	TVA	631	450.6	691.6	109.6
1) Bellefonte - East Point 500 kV 2) Widows Creek - Sequoyah 500 kV	TVA	Bellefonte - Madison 500 kV	TVA	1732.1	664.3	1867.4	107.8
1) Bellefonte - Madison 500 kV 2) Widows Creek - Sequoyah 500 kV	TVA	Crawfish Creek - Kensington 230 kV	TVA	631	409.2	648.1	102.7

Table 3-9: Contingency Conditions (N-2), Outside Voltage Criteria Range

Outaged Facilities	Study Region	Facility	Study Region	Criteria Range (p.u)	Post Contingency Voltage (p.u.)
1) WHITST - Nucor 2) Jefferson - Rockport 765 kV	MISO	08CLARK 230 kV	MISO	0.9 - 1.1	0.8881
1) WHITST - Nucor 2) Jefferson - Rockport 765 kV	MISO	08FIVE P 230 kV	MISO	0.9 - 1.1	0.8819
08KOK HP - 08NEWLON 230kV, 08KOK HP - 08THRNTN 230kV, 08CAR JT - 08KOK HP 230kV	MISO	08KOK HP 230 kV	MISO	0.9 - 1.1	0.8285
08KOK HP - 08NEWLON 230kV, 08KOK HP - 08THRNTN 230kV, 08CAR JT - 08KOK HP 230kV	MISO	08KOKHP2 230 kV	MISO	0.9 - 1.1	0.8285
7FRANKS - 7BLAND 345kV, 7FRANKS - 7SALEM 345kV, 7FLETCH - 7SALEM 345kV	MISO	7SALEM 345 kV	TVA	0.92 - 1.1	0.9169