ASSESSMENT OF HISTORICAL 2015 TRANSMISSION CONGESTION IN THE EASTERN INTERCONNECTION PILOT REPORT v0.2

DEPARTMENT OF ENERGY

MAY 2018

CONFIDENTIAL

OPEN ACCESS TECHNOLOGY INTERNATIONAL, INC.
3660 Technology Drive NE | Minneapolis, MN 55418 | Phone 763.201.2000 | Fax 763.201.5333 | www.oati.com

FUNDING ACKNOWLEDGEMENT

The work described in this report was funded by the Office of Electricity Delivery and Energy Reliability of the U.S. Department of Energy under Contract No. DE-AC02-05CH1123 through a subcontract with Open Access Technology International, administered by the Lawrence Berkeley National Laboratory.

Revision History

Version	Date	Comments	Author(s)
0.1	04/01/2018	Initial Draft	OATI
0.2	05/23/2018	Approved	OATI

Table of Contents

1 Introduction

The U.S. Department of Energy (DOE), through the Lawrence Berkeley National Laboratory (LBNL), issued a contract to Open Access Technology International, Inc. (OATI) to develop a historical transmission congestion analysis for the Eastern Interconnection. A methodology was developed and vetted by the industry experts before performing the historical data analysis using information from the Open Access Same Time Information System (OASIS), Interchange Distribution Calculator (IDC) data, and real time flow data provided by Transmission Operators (TOPs), with market postings to identify limitations on the Eastern Interconnection during 2015.

The project was performed in two phases to provide quick results in Phase I and then more detailed analysis in Phase II. Phase I of this project was completed in May 2015 and DOE published a report titled “ASSESSMENT OF HISTORICAL TRANSMISSION SCHEDULES AND FLOWS IN THE EASTERN INTERCONNECTION.” That report identified and aggregated schedules and actual flows between sub-regions that had been defined by the Eastern Interconnection Planning Collaborative (EIPC). DOE and OATI received several comments during review of the Phase I report by industry experts identified a need for further congestion analysis considering reservation, flowgates, schedule curtailment, and market data.

Therefore Phase II of this project is analyzing 2015 historical data reservation, flowgates, schedule curtailment, and market data to complement the results developed in Phase I.

Phase II work is further set to be performed in two parts:

1. Part 1: Development of congestion methodology working with industry experts and DOE. This was published and is included as Appendix A.
2. Part 2:
    a. Pilot congestion analysis for selected interfaces working with industry experts and DOE.
    b. Congestion analysis for remaining interfaces and report development.

Based on the comments the study team received during Phase I of the project, a draft methodology for congestion analysis was developed, and version 3.0 of this proposed methodology was presented to DOE and industry experts for their review and comments. A web seminar was held on February 19, 2016 to review version 3.0 of the draft proposal with industry experts. Subsequently, several meetings were conducted with industry experts from IDCWG, NYISO, ISONE, MISO, PJM, SOCO, and SPP to address any sub-regional comments. A second draft of the methodology document, version 4.0, incorporated changes and comments agreed to by industry experts and sub-region operations. A web seminar was held on August 25, 2016 to review version 4.0 of the draft proposal with industry experts. A new draft of the methodology document, version 5.0, incorporated comments from the August 25, 2016 web seminar. On October 05, 2016, PJM made a request to modify the methodology as real time (RT) data was not consistent with PJM settlements and market-to-market (MTM) credits; the document was modified as per their request. The methodology document version 5.0 agreed to by industry experts was approved, completing Part 1 of Phase II on October 05, 2016.

OATI is thankful for all the support and guidance provided by industry experts for the pilot study and looks forward to their guidance for the final study as well.

After the completion of Part 1 of Phase II, in discussions with the industry experts, a decision was made to conduct a pilot study on four interfaces and a sub-region. A fifth interface between two markets was also selected to calculate limited market metrics. The following sub-region and interfaces were selected for the pilot study. All the metrics were calculated in the direction of the given interfaces.

1. Sub-region:
   A. PJM
2. Interfaces:
   A. SOCO→MISO
   B. SOCO→TVA
   C. PJM→MISO
   D. MISO→SPP
   E. NYISO→PJM

The study was going to use the Locational Marginal Price (LMP) differential for calculating congestion metrics for the NYISO→PJM interface. However, the study team did not find sufficient data for calculating these metrics for year 2015 therefore this interface was not considered for the pilot study. Any Changes to the methodology (Appendix A) considered along with the metrics for this pilot study are presented in this report.

1.1 Purpose of the Pilot Study

The purpose of this pilot study was to verify and test the study methodology (Appendix A) on limited interfaces. The pilot study results were to be reviewed by the industry experts to validate the study methodology. If any changes to the methodology for improving the metrics were considered by the project team in generating results for all interfaces and markets.

1.2 Scope of the Pilot Study

The scope of the pilot study was to develop metrics defined in the study methodology for the PJM sub-region and the PJM to MISO, MISO to SPP, SOCO to MISO, and SOCO to TVA interfaces. Study results were reviewed with the study participants for validation of the study methodology, and necessary adjustments were made to the methodology based on these reviews.

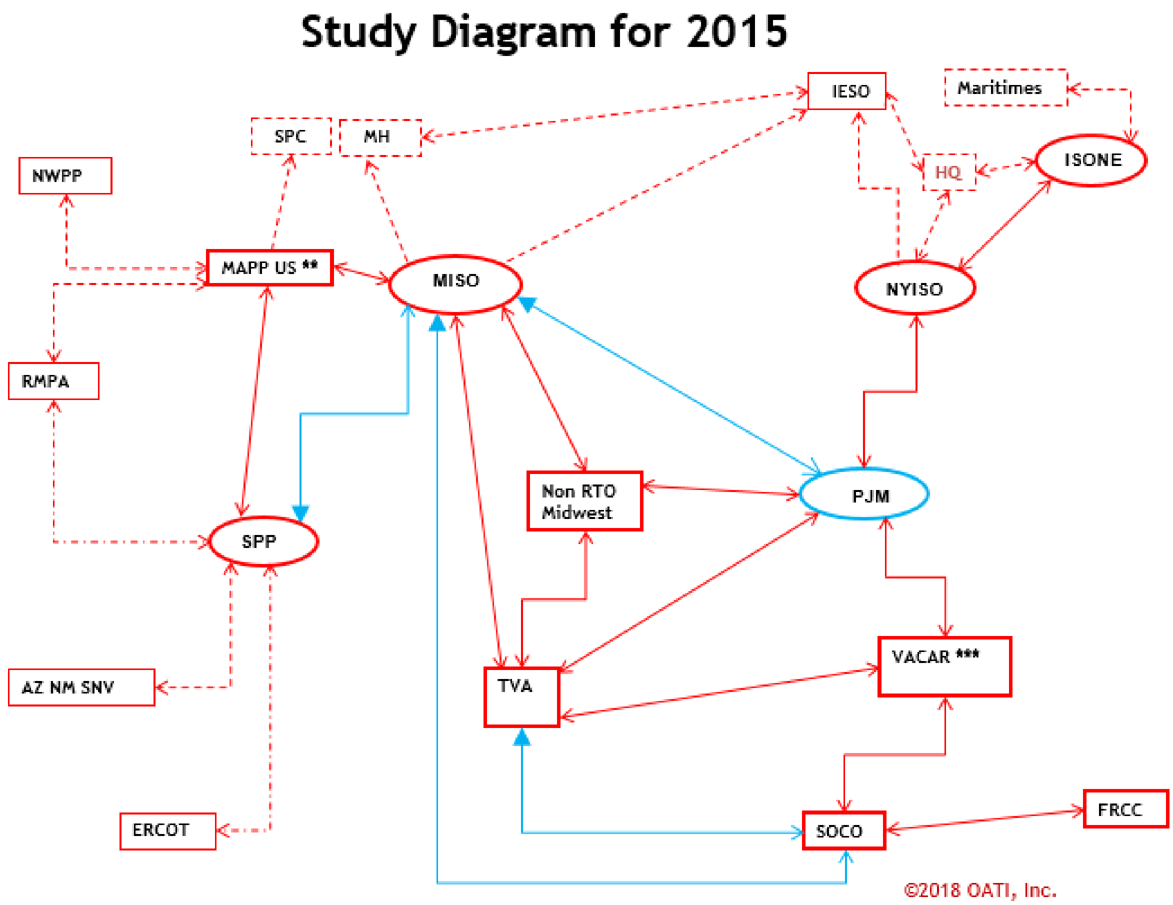
1.3 Data Sources and Analysis Methods

The study team collected publicly available data from the OASIS and Market web sites where data was available. In some cases, where the data was not posted, the data were provided by the Market and/or OASIS node operators. In addition, IDC data were obtained from OATI's data repository with permission from the individual IDC flowgate operators. PJM was unable provide permission to use IDC data, as PJM did not have the permission to release the IDC data owned by the Transmission Owners. The IDC data related to the PJM flowgates was collected from the North American Electric Reliability Corporation (NERC) public website for this study.

1.4 Study for Year 2015

Figure 1.4 shows the Eastern Interconnection, sub-regions, and interfaces for this study. Each node (shown by an ellipse or rectangle) is considered a sub-region for this study. The pilot study included interfaces between the blue colored connections between sub-region. In addition, the PJM sub-region was also considered for the pilot study. AS the actual flows and schedules are normally monitored between the Balancing Authorities (BAs) the relationship between the sub-region and the BAs is listed in appendix B. The blue colored arrows in the interfaces refers to the interfaces and the flow direction being studied as part of the pilot study. The remaining interfaces and sub-regions will be studied and reported in the final study report.

Figure 1.4: Sub-regions and Interfaces for Study



**MAPP US (WAPA) was transitioned to SPP on 10/01/2015.

***VACAR consists of DUK & Progress. For PJM-VACAR interface, VIRGINIA & DOMINION will be represented as part of PJM.

Blue colored lines and oval represent the interfaces and sub-region being analyzed for pilot study.

The original sub-region and paths published by the EIPC study were modified based on the changes in the various market footprint. These modifications to the regions and interfaces were due to the companies joining MISO, SPP, or PJM. Most of the MAPP US transitioned to SPP on 10/01/2015, therefore MISO-MAPP US, and SPP-MAPP US interfaces were studied only for January-September 2015. Appendix B lists the sub-path, Point of Receipt (POR), and Point of Delivery (POD) considered in each interface for this study.

The study metrics are calculated for the interfaces between sub-regions, but not for any inter-sub-region interfaces. The study included analysis of the selected flowgates and/or markets to capture limitations internal to the sub-region.

The EIPC diagram shows a single interface between PJM and MISO sub-regions. This interface has multiple electrical connections with each connection limited by the installed transfer capability, however the algebraic sum of these connections gives an unrealistically high total ratings for transfer. There are other operational and electrical considerations that make this transfer limit smaller. PJM advised that the limitations on this interface should be grouped into three relatively independent sub-paths. The PJM to MISO interface sub-paths were defined based on electrically similar connectivity to the PJM to MISO system. PJM does not apply path groupings when calculating Available Transfer Capability (ATC) or Total Transfer Capability (TTC) along the PJM-MISO interface as it only monitors flow gates for operation limitations. However, for the purposes of this study, the path groupings were used to represent the total interface capability. This path sub-grouping method identified as part of the pilot study will be discussed and used for the other paths for the final study if applicable.

1.5 Congestion Metrics Overview

1.5.1 OASIS Metrics

As a result of the Federal Energy Regulatory Commission (FERC) Orders 888 and 889, all TOPs are required to post ATC, Available Flowgate Capacity (AFC), and Transmission Service Request (TSR) information on OASIS. Transmission Customers use OASIS for reserving transmission service and checking transmission availability. Customers make transmission reservations for firm and non-firm transmission usage for varying time horizons, ranging from next-hour to several years in future.

For most of the Eastern Interconnection, “effective” ATC is posted for BA to BA interfaces (paths) which represent the available transfer capability on the interface. In addition to the ATC posting, AFC is also posted for flowgates to capture all transmission constraints. When customer makes a TSR request, the Transmission Provider (TP) will evaluate this TSR and approve or deny the TSR based on the ATC/AFC. A confirmed TSR is required for scheduling the energy for all intra BA transfers. The Real-Time (RT) operation may curtail these schedules to mitigate any transmission system over loads.

The study collected posted ATC and AFC data for the pilot interfaces and sub-region from their respective OASIS sites. Data related to the PJM sub-region and interface was provided by PJM.

The OASIS data was used to calculate the OASIS metrics, which indicate the availability of transmission capacity to make reservations for potential transfers of energy on an interface/path. A flowgate or path is fully subscribed if the ATC or AFC for that path or flowgate is equal or less than zero. The interface between PJM and MISO, due to being spread over a large geographical and electrical area, was separated into the following electrical three groups suggested by PJM for this analysis.

Group 1: PJM→MECS

Group 2: PJM→ALTE, PJM→ALTW, PJM→MEC, PJM→WEC

Group 3: PJM→NIPS, PJM→AMIL, PJM→IPL, PJM→CIN

The above subgroup approach was used rather than adding up all the segments for a single path to get the final hourly ATC and TTC value for the PJM to MISO interface. An average value was computed for each group of interties and then the values were added together to get a final hourly value for the PJM to MISO interface. Consider the following example of how TTC was calculated for PJM to MISO.

Table 1.5.1: Interface TTC

Group	Path	Historical TTC	Group Average TTC
1	PJM→MECS	3000	3000
2	PJM→ALTE	4500	2550
	PJM→ALTW	2500	
	PJM→MEC	2200	
	PJM→WEC	1000	
3	PJM→NIPS	5700	3850
	PJM→AMIL	4800	
	PJM→IPL	2200	
	PJM→CIN	2700	
Interface TTC			9400

The following OASIS metrics were developed for interfaces in this pilot study:

1. TSR Count metric: - This metric counts the number of firm and non-firm reservations which were refused and confirmed on each pilot interface. In this metric, refused TSR percentage was also calculated using the below formula.

$$\% \text{ Refusal} = \frac{\text{Refused TSR Count}}{\text{Refused TSR} + \text{Confirmed TSR count}} * 100$$

2. Transmission Reservation Utilization (TRU) 75 and 90 Count metrics: - These metrics count the number of instances when total firm or non-firm reservation on given interfaces were greater than 75% or 90%, respectively, of the TTC of that interface.
3. Zero ATC Count for interface: - This metric provides a total yearly count of zero ATC on each pilot interface.
4. Zero AFC Count for flowgate: - This metric counts the number of instances when the AFC for a sub-region was zero for a given hour, and identifies the five most limiting flowgates for the sub-region.

SOCO pointed out that there are some TSR metrics posted on OASIS, and requested OATI to review if those posted metrics could be used in place of the metrics being developed by the methodology for this study. OATI reviewed the TSR metrics posted on SOCO OASIS and found that posted reservation metrics combine both firm and non-firm approvals/refusals and these metrics are not specific to an interface. Therefore, this pilot study generated interface metrics based on the TSR approvals/refusals count for both firm and non-firm transmission service separately using the OASIS reservation data. For the PJM interface, the study used the approvals/refusal number posted on the PJM website to get the count.

These OASIS metrics are generally a good indicator of the transmission availability during the reservation time for transmission customers. However, these OASIS metrics should not be taken as an absolute measure of congestion for the following reasons:

Reservations are a prerequisite for scheduling energy across BAs. It should be noted that some schedules are due to grandfathered agreements, and no reservation or e-Tags are required to serve native load from generations within the BA. There is also a difference in reservation policies between market and non-market systems, and no reservations are required for an internal transaction within a market.

Second, unavailability of transmission (Zero ATC/AFC) does not necessarily mean transmission congestion, since a typical transmission system is planned only to accommodate the current level of committed confirmed firm transmission service. In addition Non-firm transmission services are provided for the unused firm capability.

Third, the availability of transmissions is affected by scheduled or unplanned outages, which might lead to congestion during the time of the outage, but not be reflective of a persistent condition of congestion.

1.5.2 Utilization Metrics for Schedule flow and Actual flow

There are significant differences in the way these schedules are determined by different transmission system operators and BAs. Transmission system operators within a Regional Transmission Operator (RTO) or Independent System Operator (ISO) rely on formal, centralized markets in which the schedules are developed based on competitive offers submitted by generators and loads. Transmission system operators in the non-markets rely on energy tags submitted by customers to develop schedules. However the centralized markets (operating as a BA) also rely on tag to schedule energy between two markets or between a market and non-market.

BAs also collect and store actual meter flows at the intertie points between BAs. This data is used to compute the actual flow levels between sub-regions. The metered flows at the BA interfaces is generally metered for each direction (Import (out) and Export (in)); however, some of the data collected from the BAs are net values. In case of the net values, it is assumed that the negative values are imports and the positive values are exports.

The following Schedule Utilization metrics and actual flow metrics were developed as part of this pilot study.

1. Utilization (U) 75 and 90 Count for the interface: - This metric counts the number of instances when total schedule and actual flow on the given interfaces were greater than 75% or 90% of the TTC of that interface.
2. Schedule Count above TTC Count for the interface: This metric counts the number of instances when the total schedule flow on the given interface was above TTC of that interface.

These Schedule Utilization Metrics and Actual flow Metrics are generally a good indicator of the transmission limitation during RT operation; however, any of the metrics in this report should not be taken individually as an absolute measure of limitations.

1. In most cases, interface between sub-regions consists of many transmission lines and hence the total transfer capability of the interface is significantly higher than actual transfer capability limitations due to limiting elements or flowgates on the path. Therefore, in addition to the schedule and actual flow metrics one must look at the IDC and market metrics that impact the flow on the interface.
2. Energy Schedules and actual flow on an interface could already be reduced by Transmission Loading Relief (TLR) calls or market dispatch. Therefore, we could not dismiss any interface congestion without examining the TLR metrics or market metric when these metrics indicate the schedule or actual flows are below the interface TTC
3. Transmission and generation outages could be another reason for the abnormal flow and schedules on the interface.

1.5.3 TLR Metrics

Eastern Interconnection uses IDC to manage system overloads. IDC provides the operators the ability to monitor certain power system equipment (flowgates) for overload. When an overload on a flowgate is detected, the operator of the flowgate calls TLR procedures identified by IDC to reduce the transfer of power through the flowgate. TLRs curtail scheduled transactions in order to modify power flows that would otherwise lead to violations of reliability criteria. These procedures are typically invoked when there exists potential for violations of reliability criteria from overscheduling and/or from unplanned outages.
TLRs identify the schedules/e-Tags and the amount of energy that must be curtailed due to transmission constraints during RT operation. There are established protocols that determine how the curtailments are allocated among the various classes of energy transactions (e.g., firm vs. non-firm service).

The following TLR metrics were developed as part of this pilot study:
1. TLR count on an interface for 2015.
2. TLR duration on an Interface for 2015.
3. MWh curtailed on an Interface for 2015.
4. Identified five most limiting flowgates for the interface.

This study reviewed all TLR called and resulting curtailed schedules. For TLR metrics for the interface, each curtailed schedules are further reviewed to determine the path (interface impacted) by examining the POR-POD of the schedule and developed the metrics along with the five most limiting flowgates.

This study also developed TLR metrics for the PJM sub-region, and identified the five most limiting flowgates. For TLRs called for the sub-region, all the TLRs were considered in which the impacted flowgates were PJM-owned.

For centralized markets, it should be noted that the RT constraints are also managed by RT market redispatch using the RT binding constraints.

1.5.4 Market Metric

This pilot study considered the PJM market to develop the market metrics. Binding constraints and associated congestion cost data was collected for the development of the market metrics. As discussed in the methodology, the study only developed RT market metrics.

The congestion cost of a binding transmission constraint on an interface is considered an indicator of congestion on that interface. The congestion cost of a binding constraint is a measure of the level of congestion. Higher cost indicates higher is the congestion level.

Using the hourly RT binding constraints and congestion costs provided by PJM, the following market congestion metrics for the PJM market were calculated:

1. Hourly binding count for PJM flowgates due to market flow impact.
2. Hourly Congestion Cost for PJM flowgates due to market flow impact.

1.6 Data Sources

The methodology required development these metrics for monthly, seasonal, and yearly analysis. However, PJM suggested only yearly metrics should be calculated for the study. Any shorter-term metric calculation would be skewed by the short-term congestion from normal operating issues such as outages. Therefore, it was decided the market metrics would be calculated on a yearly basis.

1.6.1 OASIS Data Collection

Hourly firm and non-firm ATC, AFC, TTC, and Transmission reservation data were collected from publicly-available OASIS sites. These data were not available on PJM's OASIS, therefore

PJM provided the data for this study. A list of the top 20 most limiting flowgates was also provided by PJM and MISO.

The ATC, AFC (for limiting flowgate identified by sub-region), TTC and Transmission Reservation data for the interfaces were taken from the respective sending end (source) sub-region OASIS. PJM provided the ATC value, Dfax (Distribution factor), and associated limiting flowgates. OASIS metric calculation for the PJM to MISO interface data were also provided by PJM.

1.6.2 Schedule Data (e-Tags)

Schedule (e-Tag) data were collected from the OATI webTag system with permission from the pilot participants. The study gathered the e-tag data, including e-Tag beginning time, ending time, POD, POR, and Schedule value. Interface schedules are determined based on the POR/ POD combination for the interface.

PJM was not able to give permission to use e-tag for developing these schedules for the interfaces originating from the PJM sub-region; however, PJM posts the schedule flows on their website, and the study used these posted schedules to calculate the flow metrics.

The pilot study only calculated the scheduled flow metrics for the selected direction of each interface as indicated by the selected interface in section 1 above.

1.6.3 Actual Flow Data (Metered Data)

BAs meter the flows with neighboring BAs. These actual flows (metered) on the BA-to-BA interconnections are monitored and recorded for inadvertent accounting. Actual metered data were provided by the transmission owners for each tie line. The study aggregated the tie lines that make up an interface. The tie line-to-BA relation is listed in appendix B. The actual flow for the PJM interfaces was collected from the PJM website.

The pilot study only calculated the actual flow metrics for the selected direction of each interface as indicated by the selected interface in section 1 above.

1.6.4 TLR Data Collection (IDC)

IDC data for TLR events were obtained from the IDC database. TLR information is maintained by Eastern Interconnect Data Sharing Network, Inc. (EIDSN). The study gathered the TLR information including the TLR flowgate details, hours these flowgates were under the TLR, TLR level, schedules impacted by TLRs. The study also collected the amount of MWhs curtailed due to the TLRs on these flowgates. The non-firm schedule curtailments were based on TLR levels 0-6 and the firm curtailments were calculated based on TLR level 7. MISO and SOCO gave permission to use IDC data. PJM did not give permission to use the IDC database. Therefore, for PJM, data on the NERC public website were used. It should be noted that PJM TLR Metrics are based on the first seven months of 2015 as PJM data was available only for this timeframe.

1.6.5 Market Data

PJM provided the market data for the study. The market data provided by PJM includes:

1. Time of the binding transmission constraint in PJM.
2. Binding Constraint ID and constraint name.
3. Flowgate ID of the flowgates associated with the binding constraint.
4. Congestion cost associated with the binding constraints.
5. Jointly Coordinated Market (JCM) flowgate name.
6. RT Congestion cost associated with JCM and JCM flowgate Owner.

2 Results

This section provides the metrics calculated for the interfaces and sub-region selected for the pilot study and listed in section 1.0 above.

2.1 OASIS Metrics

2.1.1 Transmission Service Request Metric

The results from Transmission Service Request Metric for the pilot interfaces are provided in Table 2.1.1a through Table 2.1.1d. These metrics counted the total number of firm and non-firm TSRs that were either confirmed or refused on the interfaces.

Table 2.1.1a: Non-Firm Confirmed TSR count

Interface	Non-Firm Confirmed TSR count
PJM→MISO	10748
SOCO→MISO	254
SOCO→TVA	141
MISO→SPP	984

Table 2.1.1b: Non-Firm Refused TSR count

Interface	Non-Firm Refused TSR count	% Refusal
PJM→MISO	10	**0.09**
SOCO→MISO	19	**6.96**
SOCO→TVA	4	**2.76**
MISO→SPP	444	**31.09**

Table 2.1.1c: Firm Confirmed TSR count

Interface	Firm Confirmed TSR count
PJM→MISO	323
SOCO→MISO	986
SOCO→TVA	271
MISO→SPP	33

Table 2.1.1d: Firm Refused TSR count

Interface	Firm Refused TSR count	% Refusal
PJM→MISO	26	7.45
SOCO→MISO	53	5.11
SOCO→TVA	30	9.97
MISO→SPP	9	21.43

2.1.2 Transmission Reservation Utilization Metric

Two transmission reservation utilization metrics are calculated for the interface for firm and non-firm reservations. The utilization metric TRU75 provides a total yearly count of when the reserved capacity exceeded 75 percent of the interface TTC. The utilization metric TRU90 is the number of hours when reserved capacity exceeded 90 percent of the TTC.

This study utilized the interface TTC from OASIS for each sub-region, which represents the maximum amount of power that can be transmitted across the interface between two sub-regions. For the interfaces except PJM to MISO, as explained in section 1.5.1, the final TTC was calculated by adding the TTCs on all paths.

The TSRs are made using a POR and POD. The study interfaces are also identified by the POR/POD as listed in appendix B. In calculating the reservations utilization metrics, care was taken to use only reservations with POR/POD matching interface paths to avoid any double-counting of any reservations. A count was generated for each interface when total reservation exceeds the TTC threshold.

The results from Transmission Service Utilization Metric for the pilot interfaces are provided in Table 2.1.2a through Table 2.1.2d.

Table 2.1.2a: TRU75 for firm reservation

Interface	Firm TRU75 Count
PJM→MISO	0
SOCO→MISO	136
SOCO→TVA	5816
MISO→SPP	0

Table 2.1.2b: TRU75 for non-firm reservation

Interface	Non-Firm TRU75 Count
PJM→MISO	167
SOCO→MISO	138
SOCO→TVA	8490
MISO→SPP	0

Table 2.1.2c: TRU90 for firm reservation

Interface	Firm TRU90 Count
PJM→MISO	0
SOCO→MISO	63
SOCO→TVA	2865
MISO→SPP	0

Table 2.1.2d: TRU90 for non-firm reservation

Interface	Non-Firm TRU90 Count
PJM→MISO	10
SOCO→MISO	63
SOCO→TVA	8365
MISO→SPP	0

2.1.3 Zero ATC Metrics

ATC is an indication of the capacity that is still available for requesting new transmission reservation. This capacity is directional, and is monitored separately for the firm and non-firm usage. Zero ATC metrics were developed for both firm and non-firm services. The ATC posted on OASIS is for various paths, and some of the study interfaces have more than one parallel path. For interfaces with more than one posted path interface, the interface ATC is the sum of the ATC for all paths included in the interface. Appendix B provides a table with the relationship between interface and paths posed on OASIS. For the PJM→MISO interface, the approach described in section 1.5.1 was used. An hourly ATC of zero indicates that there was no ATC available for that hour. The ATC metrics provide the total number of hours when this ATC was zero during 2015. In some cases, firm ATC values are posted as a single daily value instead of hourly values. These daily values were converted to hourly values by assigning the same daily value to each hour of the day.

The results from ATC Metric for the pilot interfaces are provided in Table 2.1.3a and Table 2.1.3b.

Table 2.1.3a: Firm Zero ATC Count

Interface	Firm Zero ATC Count
PJM→MISO	0
SOCO→MISO	233
SOCO→TVA	144
MISO→SPP	8563

Table 2.1.3b: Non-Firm Zero ATC Count

Interface	Non-Firm Zero ATC Count
PJM→MISO	0
SOCO→MISO	207
SOCO→TVA	22
MISO→SPP	3061

The limiting flowgate for the MISO to SPP interface is based on the limiting flowgate associated with the effective ATC posting taken from the MISO OASIS. No limiting flowgates were identified for the SOCO to MISO or SOCO to TVA interfaces, since SOCO's ATC calculation is not a flow-based methodology. The study also identified the five most limiting flowgates for the PJM to MISO and MISO to SPP interfaces. PJM provided limiting flowgate data along with ATC data for the PJM to MISO interface. Even though the PJM to MISO interface ATC count is zero for both firm and non-firm data, PJM suggested the study include the following five most limiting flowgates, provided in Table 2.1.3c.

The results from the five most limiting flowgates for the pilot interfaces are provided in Tables 2.1.3c and 2.1.3d.

Table 2.1.3c: PJM→MISO Top Five Limiting Flowgates

PJM-MISO	Firm		Non-Firm	
	Flowgate	Count	Flowgate	Count
Top 5 limiting flowgate for Zero ATC	LORETTO-WILTON 345 (FLO) DRESDEN-PONTIAC 345 + XFMR	2496	Kyger Creek-SPORNAEP ck2 345 (flo) SPORNAEP-Kyger Creek ck1 345	176
	155 Nelson 345/138kV TR82 l/o Byron-LeeCo 345kV	2424	17714-Hegewisch 138 l/o Burnham-Sheffield 345	103

PJM-MISO	Firm		Non-Firm	
	Flowgate	Count	Flowgate	Count
	Breed-Wheatland 345 (flo) Jefferson-Rockport 765	2160	Breed-Wheatland 345 (flo) Jefferson-Rockport 765	88
	124 Maryland-11902 138kV l/o Byron-LeeCo 345kV	2064	155 Nelson 345/138kV TR82 l/o Byron-LeeCo 345kV	55
	BROKAW-80PONTIAC 345 (FLO) BLUE MOUND-80PONTIAC 345	1176	Kyger Creek-SPORNAEP ckt2 345	50

Table 2.1.3d: MISO→SPP Top Five Limiting Flowgates

MISO-SPP	Firm		Non-Firm	
	Flowgate	Count	Flowgate	Count
Top 5 limiting flowgate for Zero ATC	RUERUSANOFSM; 446.00	3143	RUSDARANOFTS; 396.00	2666
	RUSDARANOFTS; 396.00	1730	TRU5C7OSIMSI; 217.00	2168
	WELLYDWELNWT; 1059.00	1090	TH_HILMTGY-O; 608.00	746
	NDEX; 2150.00	572	ASHCRALYDVAL; 278.00	672
	FTCAL_S; 803.00	482	PLSZIOARCZIO; 1526.00	383

The study also developed additional zero ATC graphs for visualizing and comparing ATC metrics between the pilot interfaces (see Figures 2.1.3a through 2.1.3d).

Figure 2.1.3a: Firm Zero ATC Count

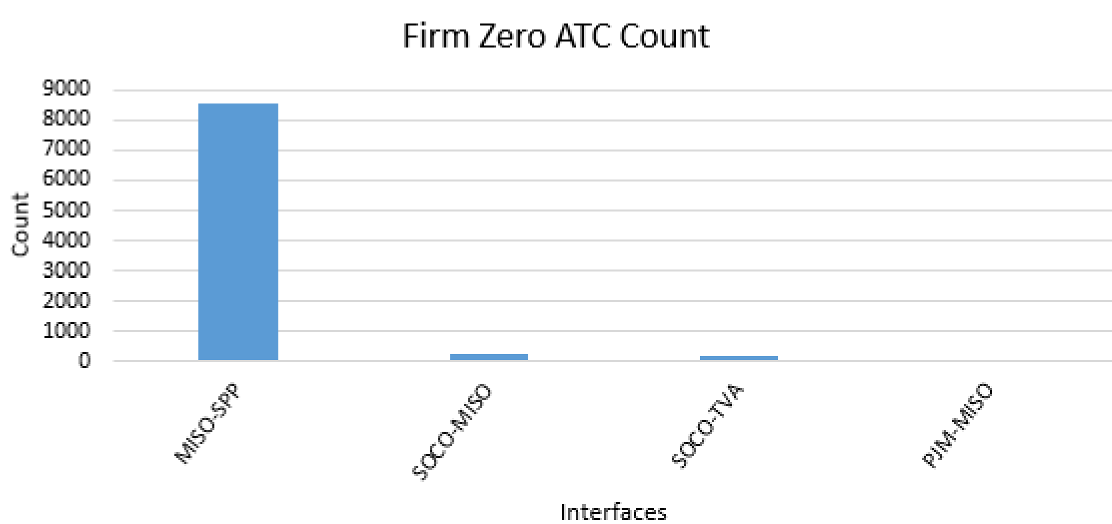


Figure 2.1.3b: Firm Zero ATC Count

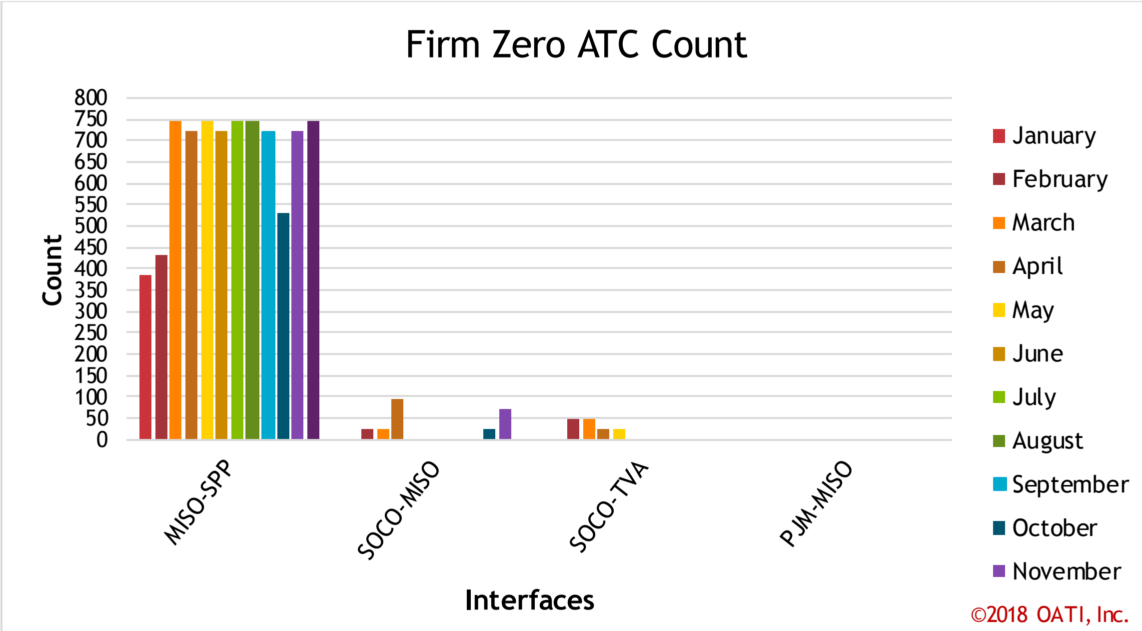


Figure 2.1.3c: Non-Firm Zero ATC Count

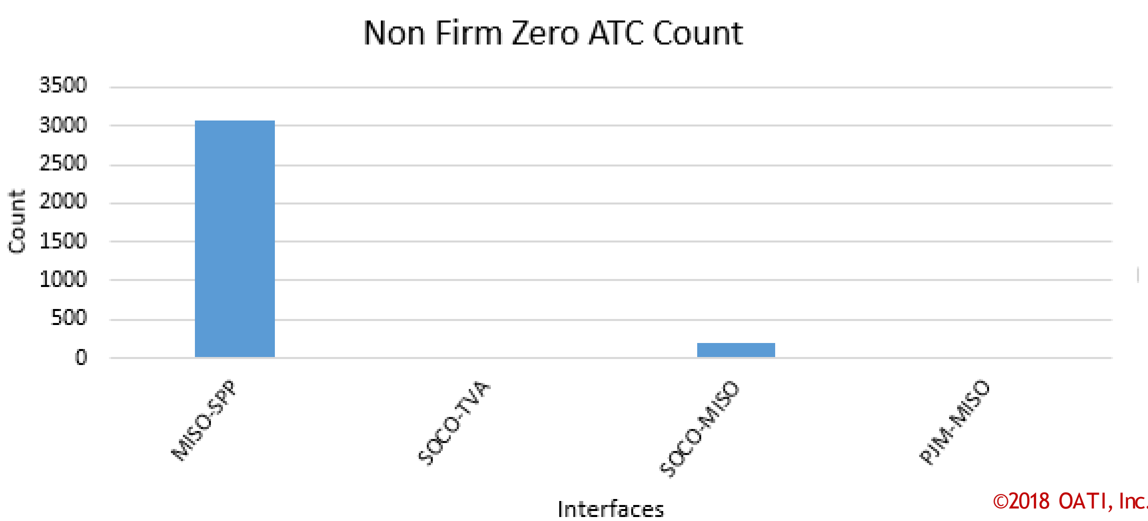
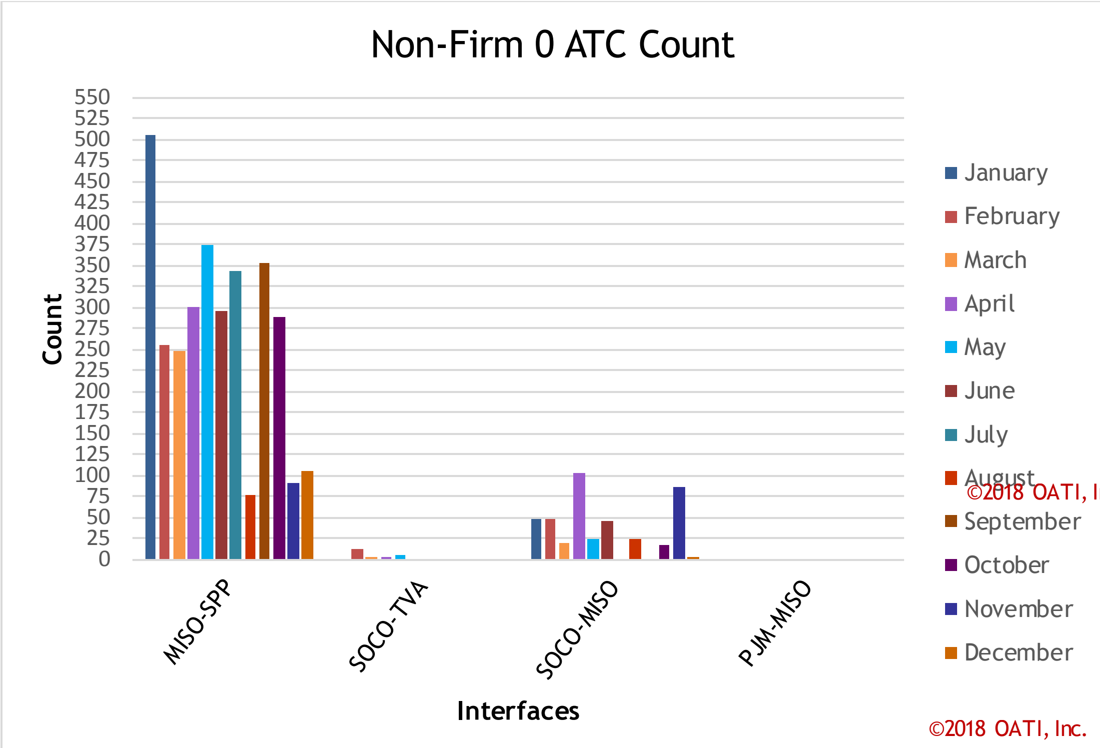


Figure 2.1.3d: Non-Firm Zero ATC Count



2.1.4 Zero AFC Metrics

PJM was the only sub-region considered for AFC metrics in this pilot study. PJM provided the ATC value, Distribution factor (Dfax) and associated limiting flowgates. Pseudo AFC was calculated by multiplying ATC and Dfax. The study ranked the flowgates based on the total number of zero AFC counts for the flowgate. The top five flowgates based on this ranking are listed in Table 2.1.4a.

Table 2.1.4a: PJM top Five limiting flowgate

PJM	Firm		Non-Firm	
	Flowgate	Count	Flowgate	Count
Top 5 limiting flowgate	LORETTO-WILTON 345 (FLO) DRESDEN-PONTIAC 345 + XFMR	2496	Kyger Creek-SPORNAEP ck2 345 (flo) SPORNAEP-Kyger Creek ck1 345	176
	155 Nelson 345/138kV TR82 l/o Byron-LeeCo 345kV	2424	17714-Hegewisch 138 l/o Burnham-Sheffield 345	103
	Breed-Wheatland 345 (flo) Jefferson-Rockport 765	2160	Breed-Wheatland 345 (flo) Jefferson-Rockport 765	88
	124 Maryland-11902 138kV l/o Byron-LeeCo 345kV	2064	155 Nelson 345/138kV TR82 l/o Byron-LeeCo 345kV	55
	BROKAW-80PONTIAC 345 (FLO) BLUE MOUND-80PONTIAC 345	1176	Kyger Creek-SPORNAEP ckt2 345	50

2.2 Schedule Utilization Metrics and Actual flow Utilization Metrics

Schedule utilization metrics and actual flow utilization metrics were calculated for the pilot interfaces. The utilization metric U75 provides total yearly count for an interface where the hourly schedule flow exceeds 75 percent of the TTC. The utilization metric U90 provides total yearly count for an interface where the hourly schedule/flow exceeds 90 percent of the TTC.

Total actual flow was calculated by summing up all the tie lines going in a given direction. For example, for the MISO to SPP interface, the total actual flow was calculated by summing up all actual flows only in the direction from MISO to SPP. If there was a reverse flow on the tie line (i.e., from SPP to MISO) it was ignored.

Schedule flow was calculated by summing up all the tags. For example, for schedule flow from SOCO to TVA, all the tags present in an hour from SOCO to TVA were summed up to get the schedule flow for that hour. For PJM to MISO, as tag data were not present, data from the PJM website were used. The data provide the schedule flow from PJM to MISO entities. Schedules in direction from PJM to MISO were summed up to get the schedule flow for PJM to MISO.

The results from schedule utilization metrics and actual flow metrics for the pilot interfaces are provided in Table 2.2a through Table 2.2d.

Table 2.2a: Phase I Utilization Metric U75 Schedule

Interface	U 75 Schedule Count
PJM→MISO	0
SOCO→MISO	82
SOCO→TVA	153
MISO→SPP	0

Table 2.2b: Phase I Utilization Metric U75 Actual

Interface	U 75 Actual Count
PJM→MISO	0
SOCO→MISO	3116
SOCO→TVA	2194
MISO→SPP	0

Table 2.2c: Phase I Utilization Metric U90 Schedule

Interface	U 90 Schedule Count
PJM→MISO	0
SOCO→MISO	2
SOCO→TVA	89
MISO→SPP	0

Table 2.2d: Phase I Utilization Metric U90 Actual

Interface	U 90 Actual Count
PJM→MISO	0
SOCO→MISO	1884
SOCO→TVA	1243
MISO→SPP	0

Including a new metrics for pilot interfaces based on schedule count above the TTC was also suggested. The results for the new metrics are provided in Table 2.2e.

Table 2.2e: Schedule Count above TTC

Interface	Schedule Count above TTC
PJM→MISO	0
SOCO→MISO	2
SOCO→TVA	75
MISO→SPP	0

The study also developed additional actual and schedule flow duration graphs for visualizing utilization and comparing results between the pilot interfaces (see Figures 2.2a through 2.2l).

The flow duration curves illustrate the variation of a flow versus the duration of time. Time is illustrated as percentage of the year.

Interface schedules and metered flows were plotted hourly for the year 2015 chronologically. On the same graph, duration curves were also plotted for both interface schedule and actual flows.

For each interface, three graphs were generated:

1. Duration curve - Schedule and Actual flow: This graph plots duration curves for both actual flow and directional schedule flow. For example, in Figure 2.2a, 50% of the time for the year 2015, the actual flow is greater than around 800MW for the SOCO to MISO interface. If we look into schedule flow, we can make a similar observation: 50% of the time for the year 2015, the schedule flow on the SOCO to MISO interface was greater than around 150 MW.
2. Actual flow duration curve and Hourly Schedule: This graph plots the duration curve for actual flow, and schedule flow is plotted chronologically. For example in figure 2.2b, 50% of time for the year 2015, the actual flow was greater than around 800MW for the SOCO to MISO interface. The schedule flow on an interface plotted chronologically shows the schedule variations across the whole year.
3. Schedule flow duration curve and Hourly Actual: This graph plots the duration curve for schedule flow, and total actual flow is plotted chronologically. For example in figure 2.2c, 50% of the time for the year 2015, schedule flow on the SOCO to MISO interface was greater than around 150 MW. The actual flow on an interface, plotted chronologically shows actual flow variation across the whole year.

Figure 2.2a: Duration Curve: Schedule and Actual flow

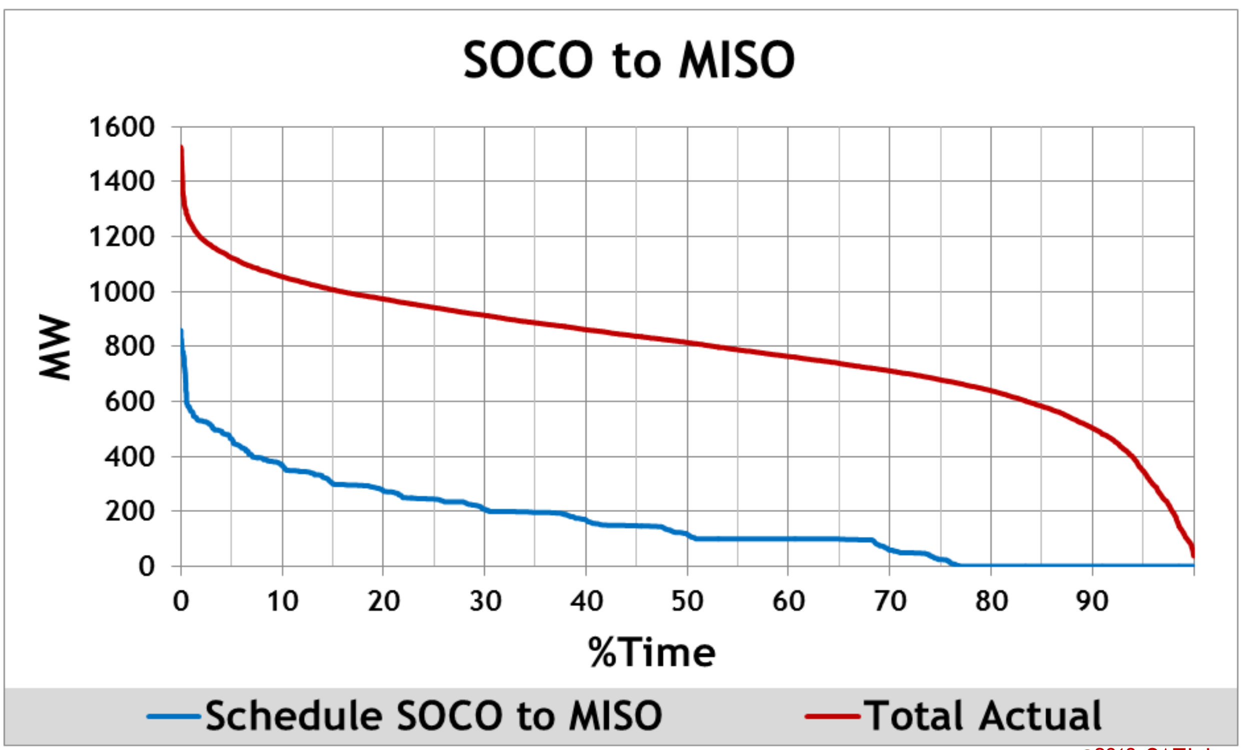


Figure 2.2b: Actual Flow Duration Curve and Hourly Schedule

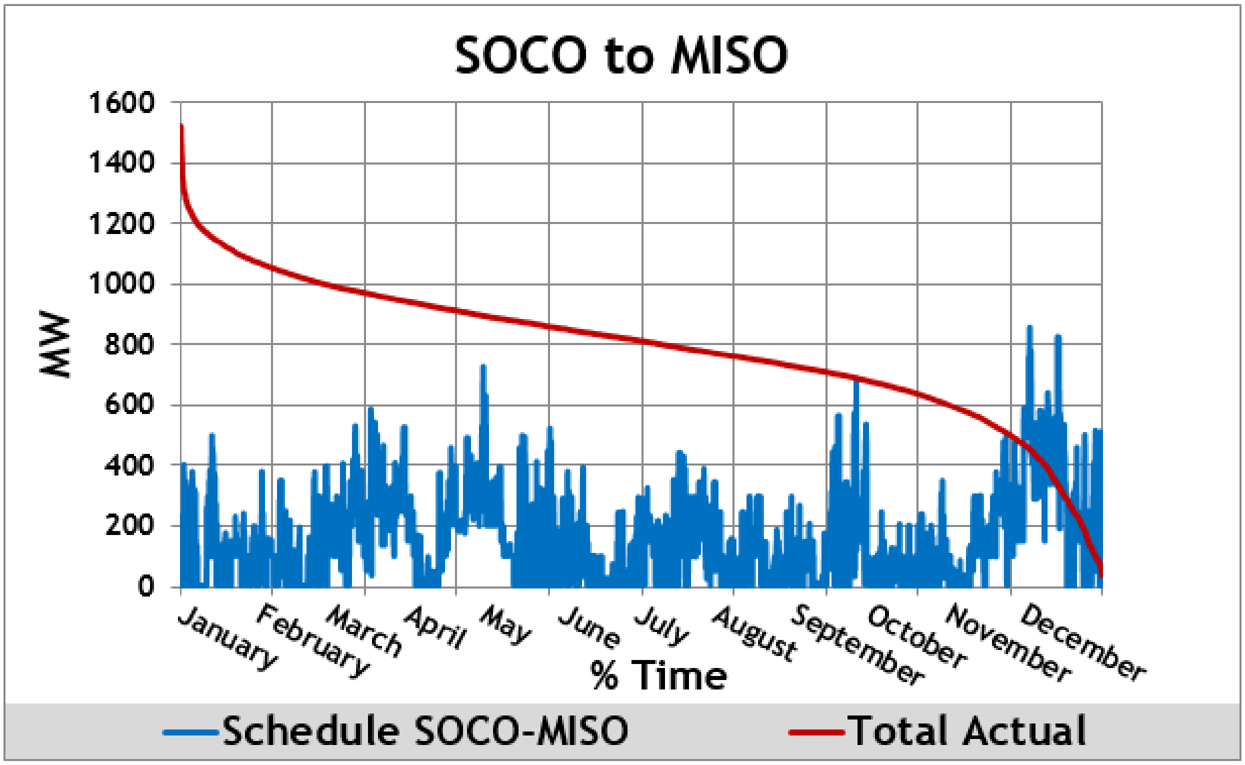


Figure 2.2c: Schedule Flow Duration Curve and Hourly Actual

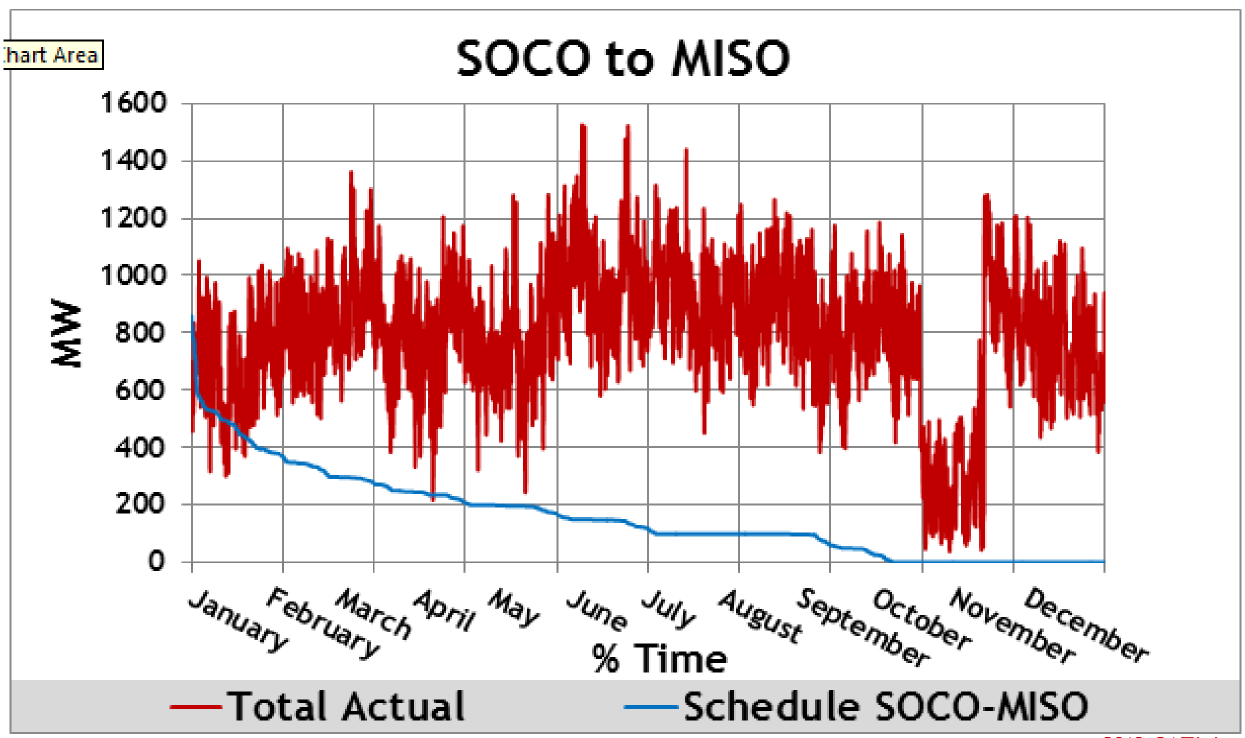
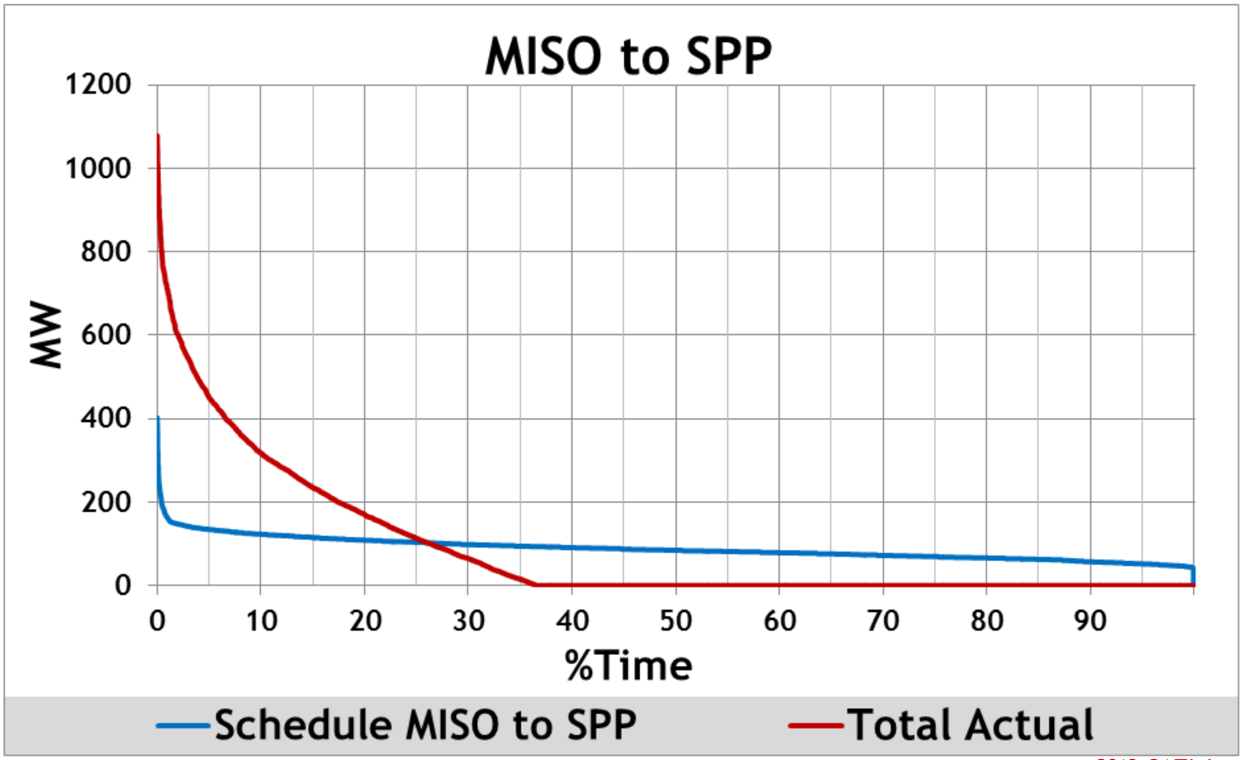
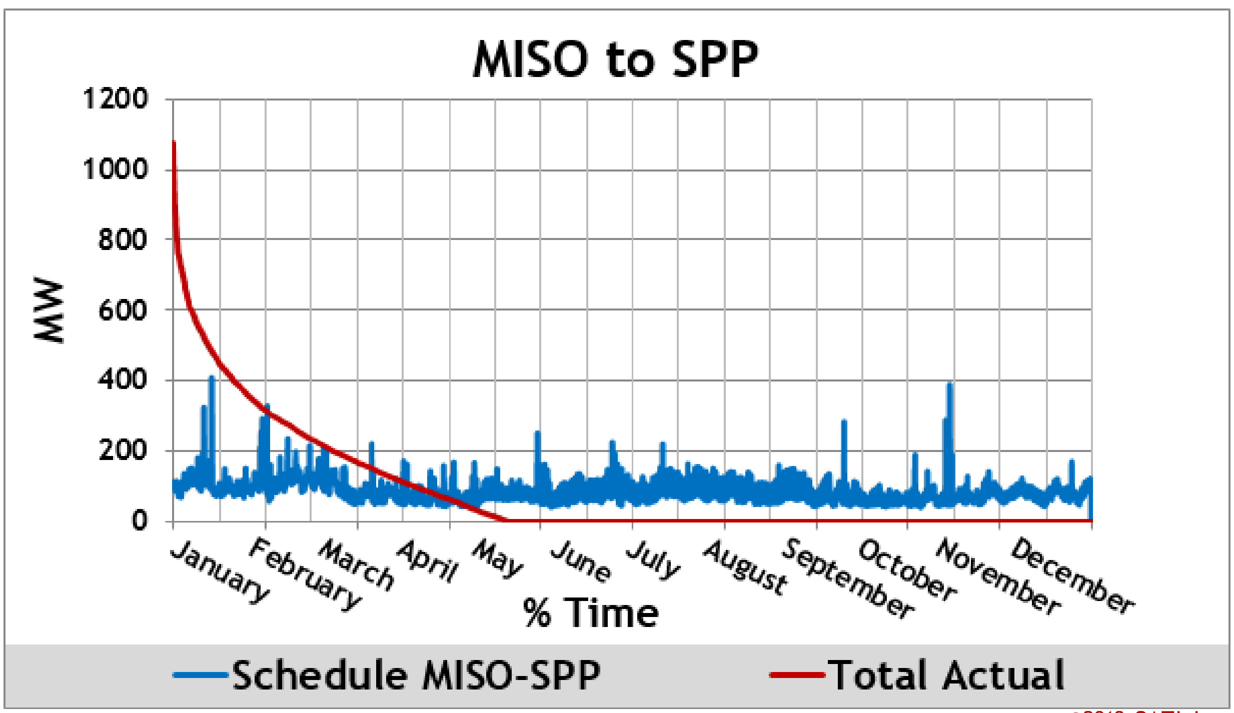


Figure 2.2d: Duration Curve: Schedule and Actual flow



©2018 OATI, Inc.

Figure 2.2e: Actual Flow Duration Curve and Hourly Schedule



©2018 OATI, Inc.

Figure 2.2f: Schedule Flow Duration Curve and Hourly Actual

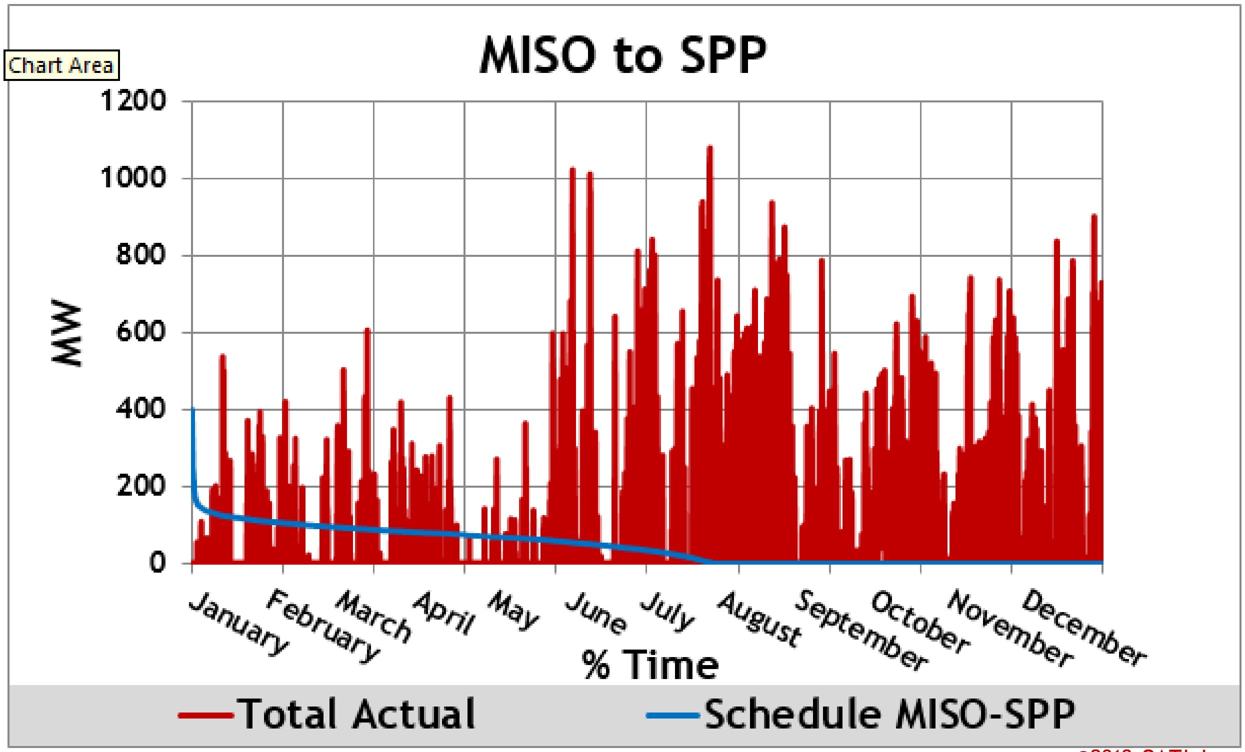


Figure 2.2g: Duration Curve: Schedule and Actual Flow

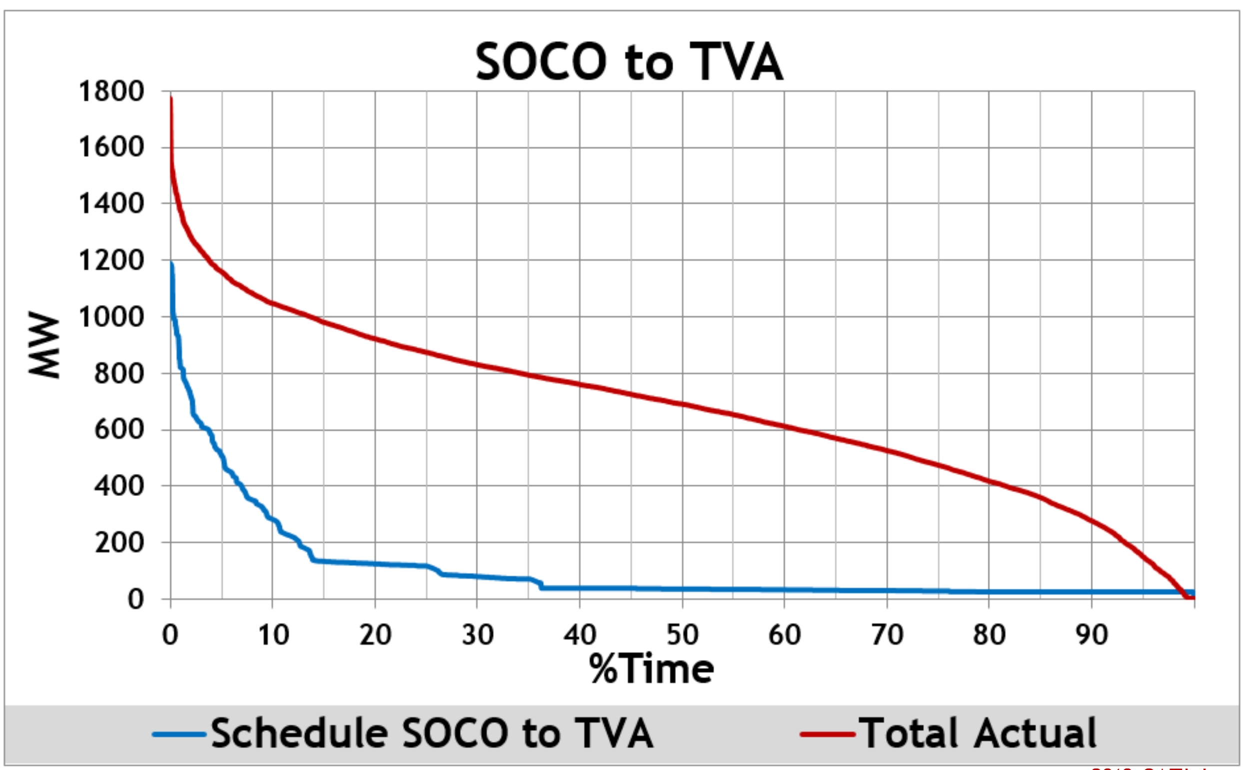
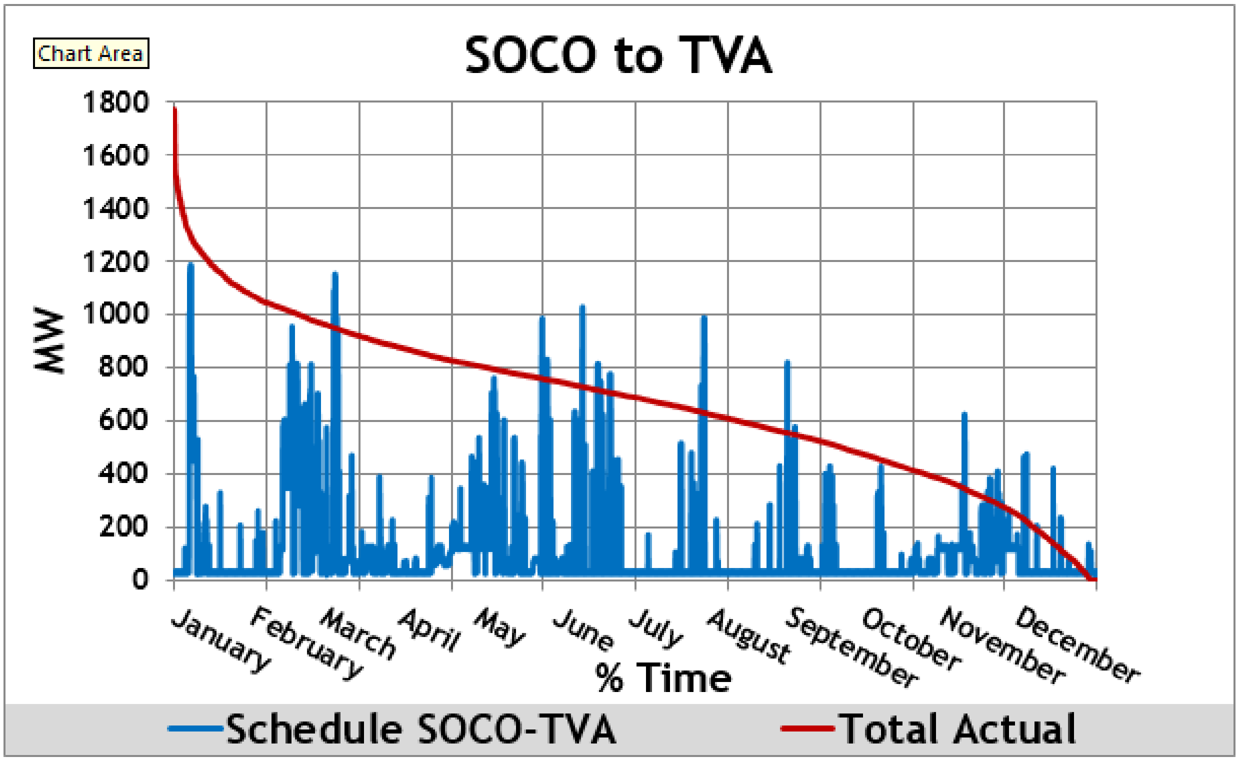
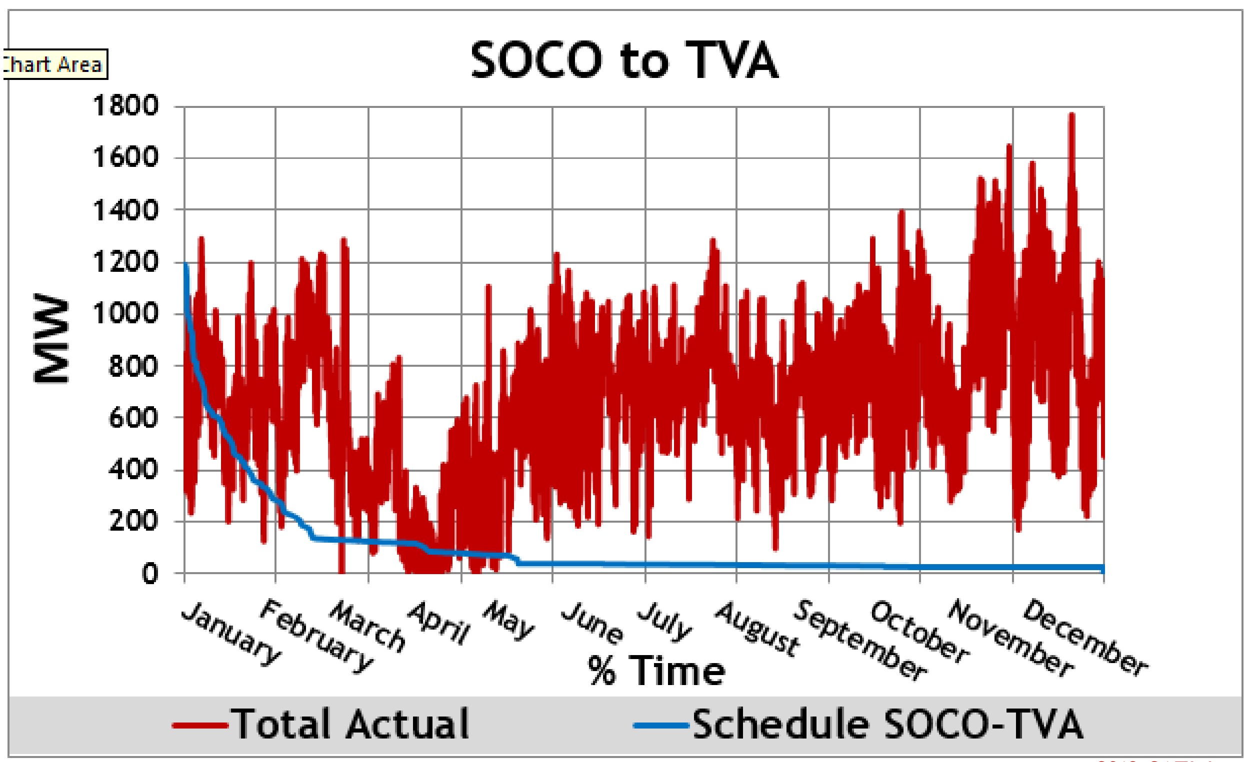


Figure 2.2h: Actual Flow Duration Curve and Hourly Schedule



©2018 OATI, Inc.

Figure 2.2i: Schedule Flow Duration Curve and Hourly Actual



©2018 OATI, Inc.

Figure 2.2j: Duration Curve: Schedule and Actual Flow

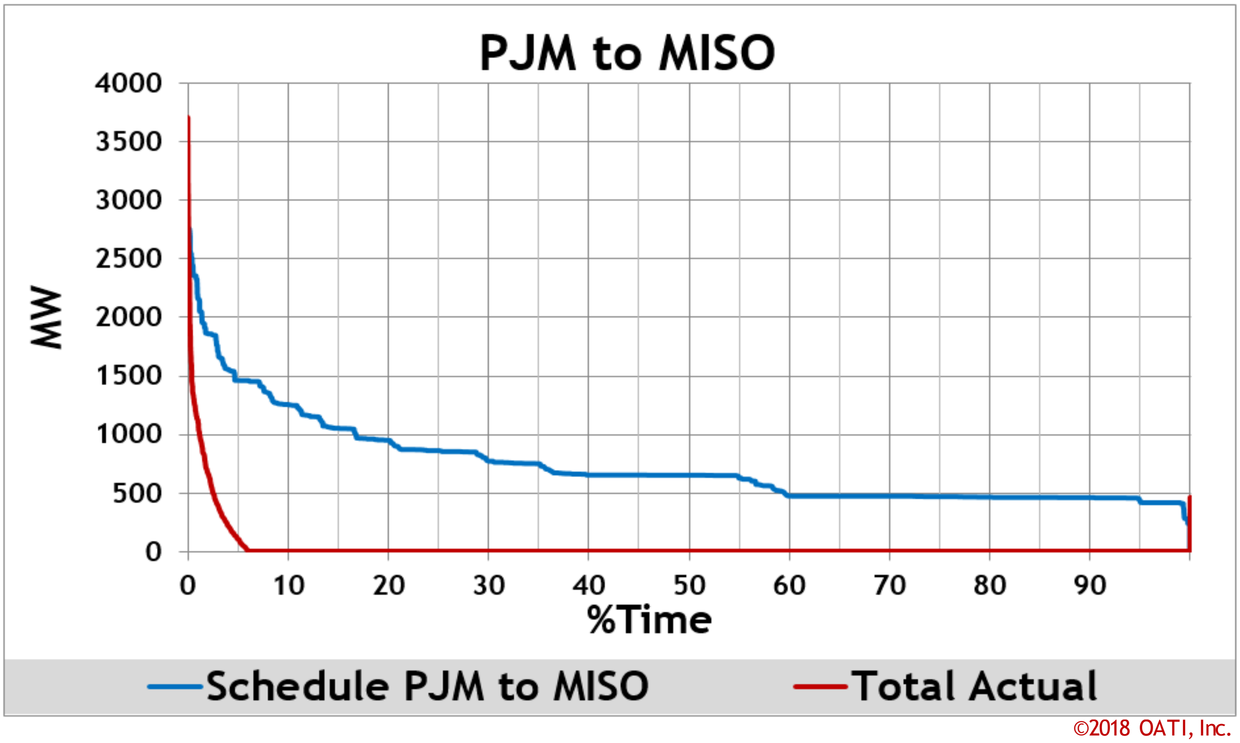


Figure 2.2k: Actual Flow Duration Curve and Hourly Schedule

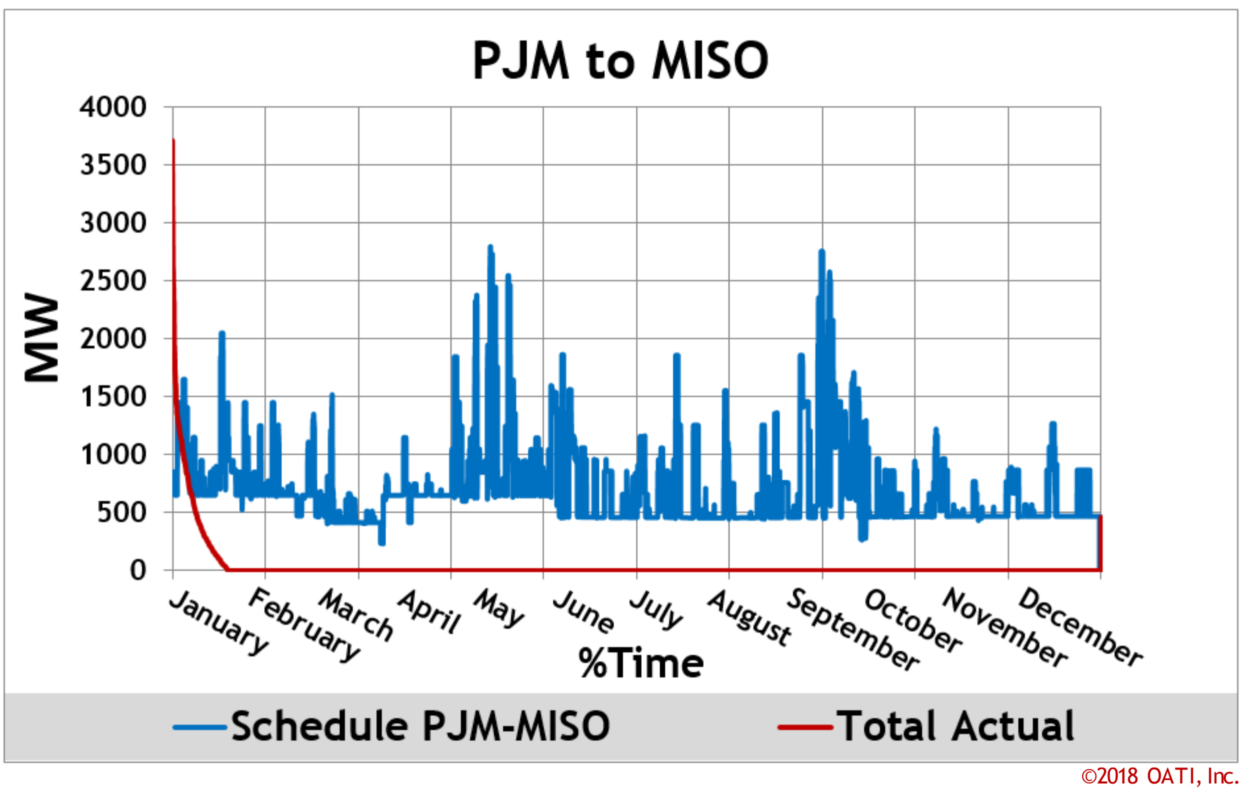
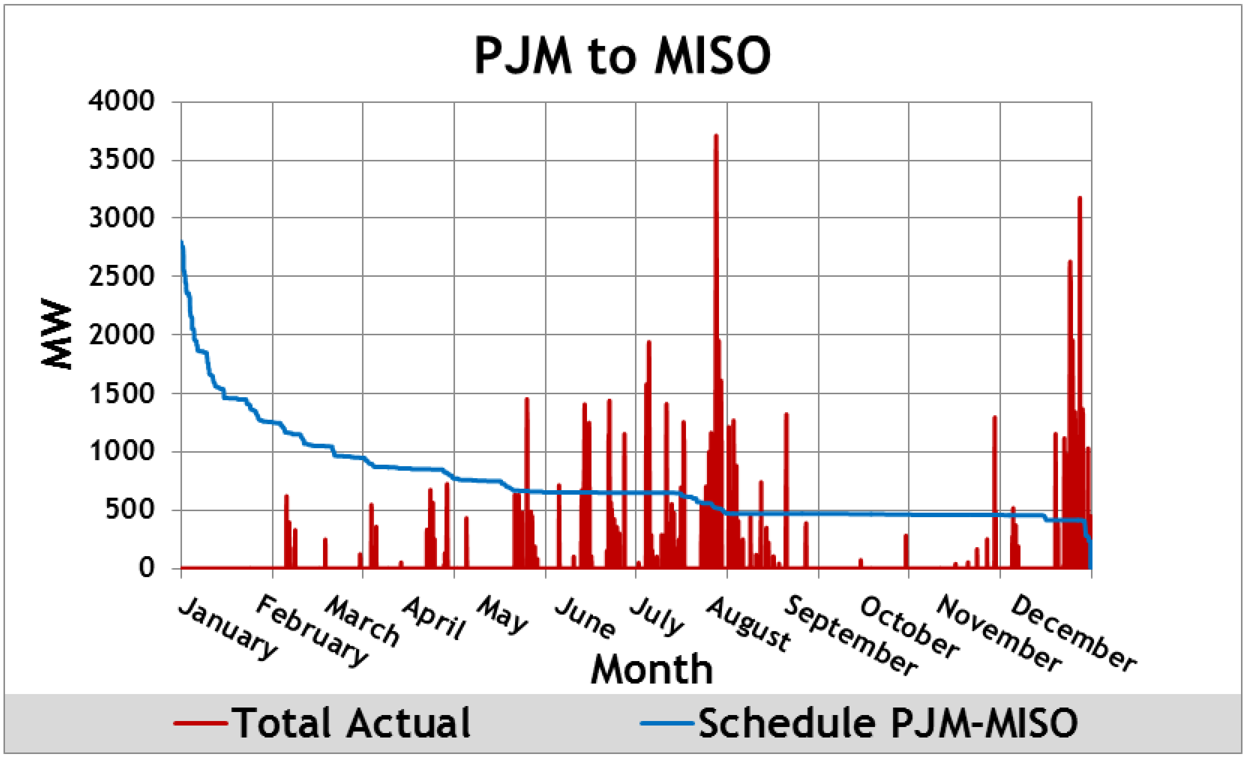


Figure 2.2l: Schedule Flow Duration Curve and Hourly Actual



2.3 TLR Metrics

The frequency and duration of TLR actions on particular flowgates were evaluated as a measure of constraints. Frequency indicates how often scheduled transactions were curtailed, and the duration indicates the length of time transactions were curtailed.

For PJM, the data were collected from the NERC website for the year 2015. These data on the NERC website were only available for the months January-July, 2015. Therefore the PJM TLR metrics only represent the curtailments during the first seven months of 2015. The data for interfaces SOCO→MISO, SOCO→TVA, and MISO→SPP were taken from the IDC database and are for the entirety of 2015.

The following data were used for the TLR metric calculations for interfaces and the sub-region:

1. Flowgate which was constrained so a TLR was issued.
2. Time duration of TLR
3. MWh curtailed for a TLR
4. Level (priority) of TLR (0-7)

The non-firm schedule curtailments were due to the TLRs at level 0 to 6, and the firm curtailments were considered at level 7.

The five most limiting flowgates were identified based on the TLR counts. The results from the TLR Metric for the pilot interfaces are provided in Table 2.3a and Table 2.3b.

Table 2.3a: TLR Metrics for Pilot Interfaces

Interface	Firm			Non-Firm		
	TLR Duration (Hours)	TLR MWh	TLR Count	TLR Duration (Hours)	TLR MWh	TLR Count
PJM→MISO	0	0	0	0	0	0
SOCO→MISO	0	0	0	4.8	190.0	9
SOCO→TVA	0	0	0	4.1	12.4	8
MISO→SPP	0	0	0	2	8.0	2

Table 2.3b: Top Five Limiting Flowgates (Count Based) for Pilot Interfaces

Interfaces	Firm			Non-Firm		
	Flowgate	Count	MWh	Flowgate	Count	MWh
PJM→MISO	None	0	0	None	0	0.0
SOCO→MISO	None	0	0	Volunteer - Phipps Bend 500 kV FLO Jefferson - Rockport 765 kV	9	190.0
SOCO→TVA	None	0	0	Widows Creek 500/161 bank flow Browns Ferry-Maury 500 kV	8	12.4
MISO→SPP	None	0	0	Monroe-Bayshore345kV floAllenJct-Monroe-Milan345kV	2	8.0

This study also developed TLR metrics for the PJM sub-region and identified 5 most limiting TLR flowgates based on the TRL counts. The results from TLR Metric for the pilot interfaces are provided in Table 2.3c to Table 2.3d.

Table 2.3c: TLR metrics for PJM sub-region

Sub-region	Firm			Non-Firm		
	TLR Duration (Hours)	TLR MWh	TLR Count	TLR Duration (Hours)	TLR MWh	TLR Count
PJM	0	0	0	253.6	59804	23

Table 2.3d: Top Five Limiting Flowgates (Count Based) for PJM Sub-region

Sub-region	Firm			Non-Firm		
	Flowgate	Count	MWh	Flowgate	Count	MWh
PJM	None	0	0	310 - Person-Halifax 230 kV line l/o Wake-Heritage 500 kV	8	39218.4
				20793 - Greenville-Everetts 230 kV l/O Bath County-Valley 500 kV Line	4	3045.1
				20817 - Greenville-Everetts 230 kV l/o Edgecombe-Rocky Mount 230 kV	3	1926.3
				1704 - Person-Halifax 230 kV line	2	6419.3
				1707 - WAKE-CARSON 500	1	4985.6

2.4 Market Metrics Based on Market Flow

Transmission congestion in a market is managed mostly by market re-dispatch instead of relying on a TLR procedure to alleviate congestion. The market operator will call for market re-dispatch by binding a constraint in the market when there are one or more potential or actual operating security limit violations.

When the binding constraint is on Jointly Controlled Market (JCM) flowgates, market re-dispatch and settlement are managed using the coordination agreement between the RTOs. The coordination agreement allocates the firm market Flow Entitlements for each RTO. This firm Flow Entitlement for the RTOs are calculated based on historical usage of the JCM. MTM payments are calculated between coordinated RTOs based on over or under use of each RTO's Firm market Flow Entitlements. JCM flowgates are used for the MTM settlements by coordinated RTOs. The coordinated non-monitoring RTO pays for the generation re-dispatch if that RTO has exceeded its firm Flow Entitlements. The market flow impact above the historical use can be used as an indicator of congestion similar to TLR metrics.

PJM provided the hourly data for binding constraints including binding constraint name, flowgate information, and the associated congestion cost associated for the year 2015. Market flow metrics were developed that identify the five most JCM flowgates by their binding count and congestion cost. In discussions with PJM, PJM suggested identification of the JCM flowgates that are owned by PJM for these market flow metrics. The total market congest cost for the whole year of 2015 was not provided by PJM, therefore the percentage based on the total cost for each constraint was not calculated.

Correlation of the MTM congestion to sub-regional interfaces is not straightforward from the data provided; therefore, more investigation is needed to develop interface congestion metrics. However, metrics developed from market flow may be a substitute and could be used as an indicator of the interface congestion issues. It was agreed that correlation of the MTM congestion will be limited to the metric developed from market flow impacts as discussed above.

This study developed Market flow metrics for PJM and identified the five most limiting JCM flowgates based on the market binding counts. The results from the Market flow metrics for the PJM sub-region are provided in Table 2.4a and Table 2.4b.

Table 2.4a: Five Most Limiting PJM Owned JCM based on Binding Constraint Count due to the Market Flow Impacts

Binding Constraints Ranking	Binding Constraints Name	Market Binding Hour count	% of Binding hours for the month
1	156 CHER345 KV TR83	822	48.30%
2	107 DIXO138 KV 10714	182	10.69%
3	945 CRET345 KV CRE-STJ1	119	6.99%
4	155 NELS138 KV TR82	110	6.46%
5	155 NELS345 KV 15503	68	4.00%

Table 2.4b: Five Most Limiting PJM Owned JCM Based on RT Congestion Cost Due to Market Flow Impacts

Binding constraints Ranking	Binding constraints Name	Congestion cost
1	156 CHER345 KV TR83	$69,615,305.18
2	20 BRAID345 KV 2001	$20,464,410.58
3	107 DIXO138 KV 10714	$15,255,985.02
4	6 BYRON 345 KV 0622	$6,746,386.90
5	122 BELV138 KV 12205 1	$6,175,063.95

2.5 Interface Data Analysis Summary

The following graphs compare data such as TTC, ATC, reservation, and actual and schedule flow for the whole year for all the pilot study interfaces. For PJM-MISO, two graphs were generated as PJM has both firm and non-firm TTC.

2.5.1 Interface Data Summary by Interface

Figure 2.5.1a: Interface Data Comparison Summary for SOCO→TVA 2015

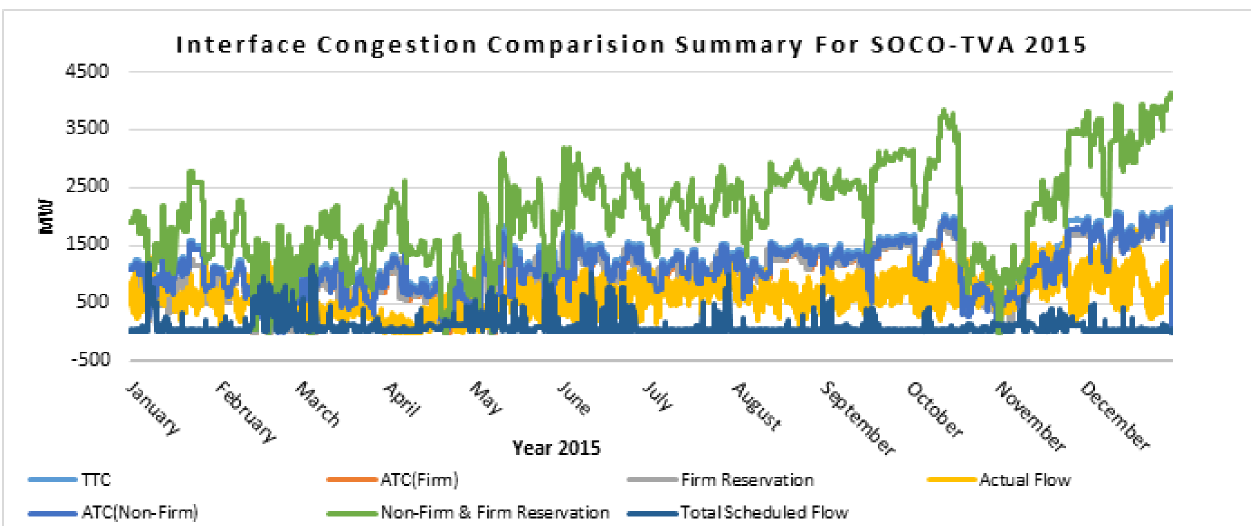


Figure 2.5.1b: Interface Data Comparison Summary for SOCO→MISO 2015

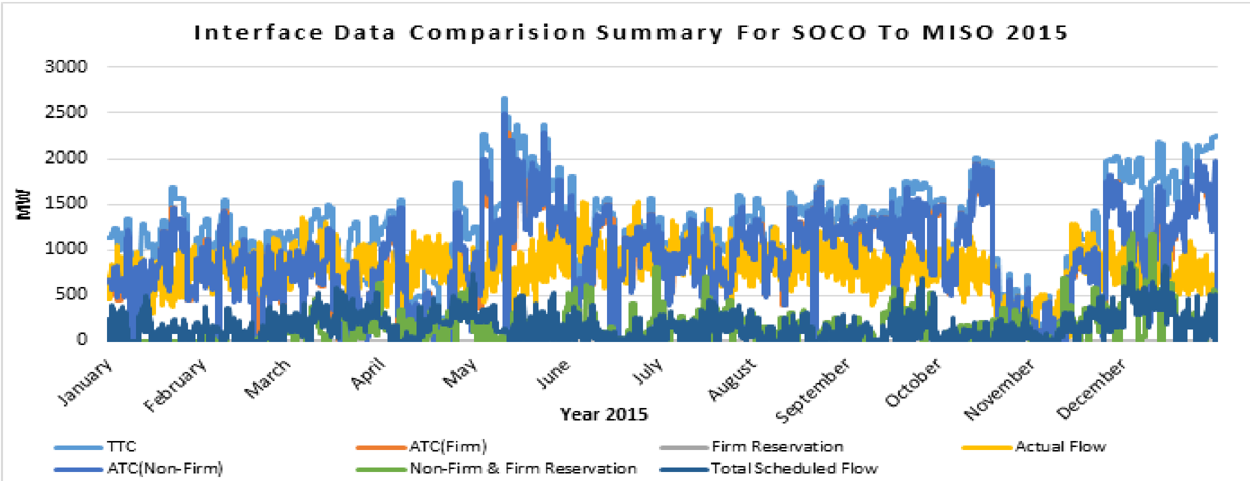


Figure 2.5.1c: Interface Data Comparison Summary for MISO→SPP 2015

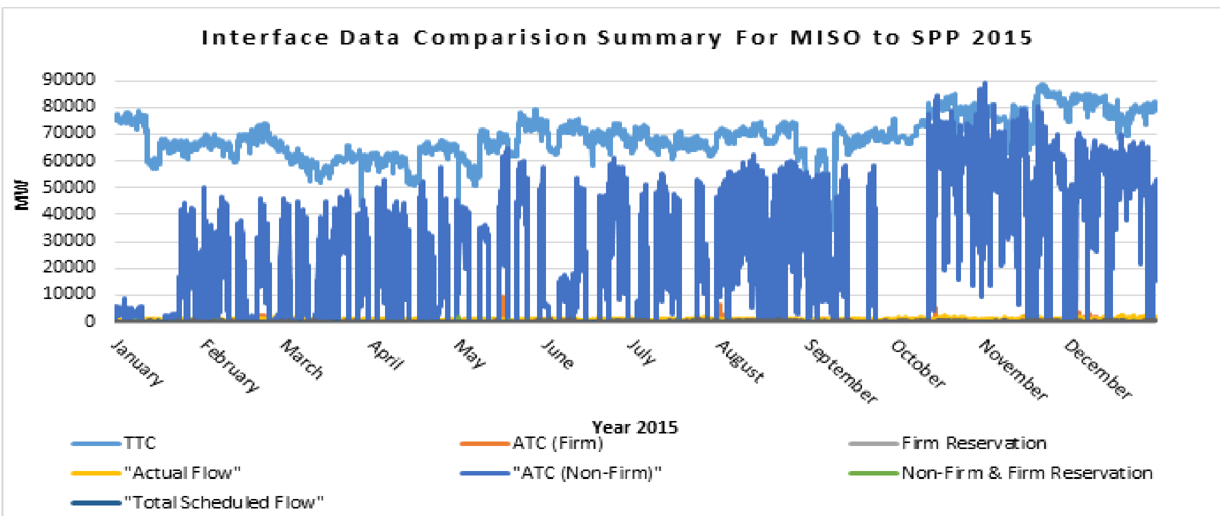


Figure 2.5.1d: Interface Firm Data Comparison Summary for PJM→MISO 2015

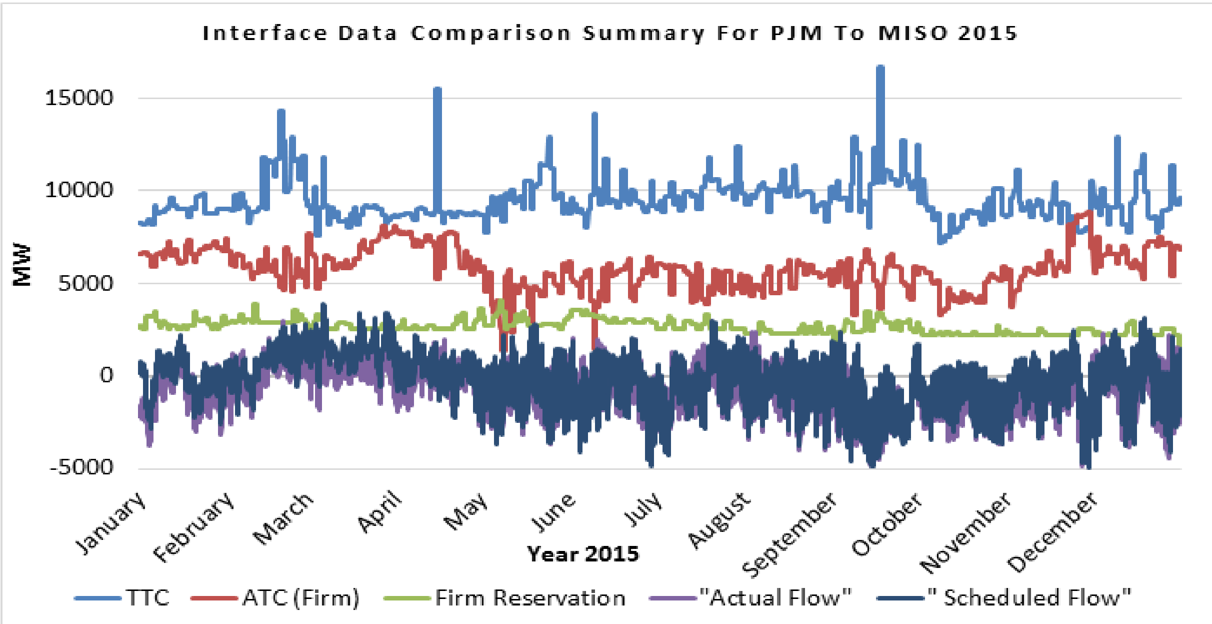
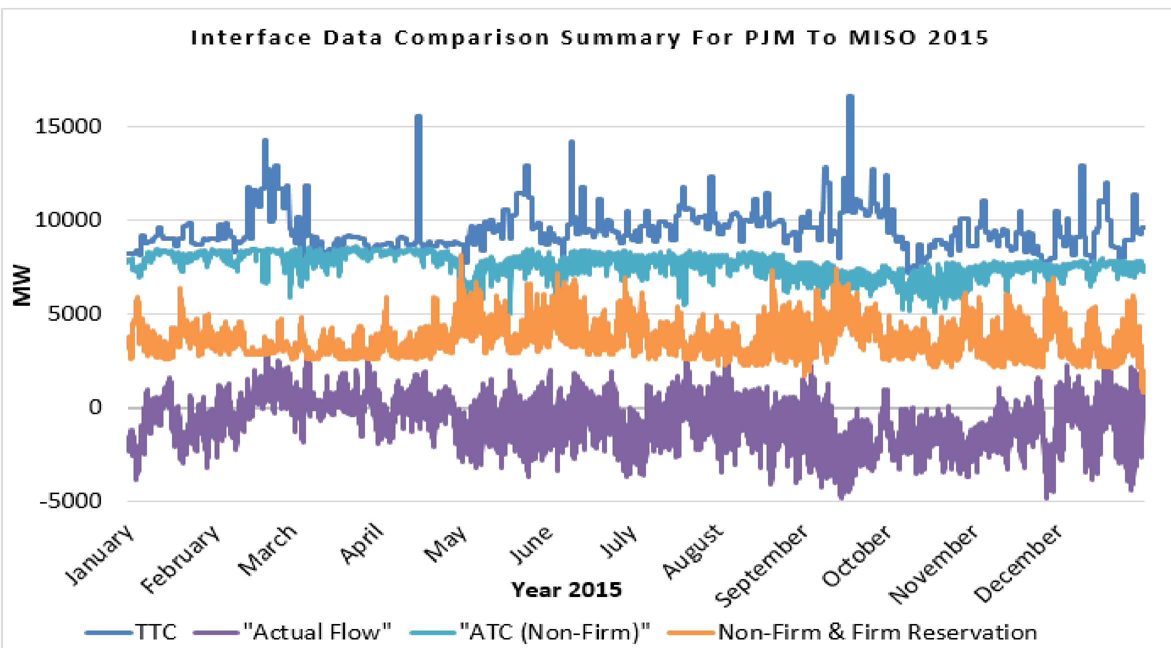
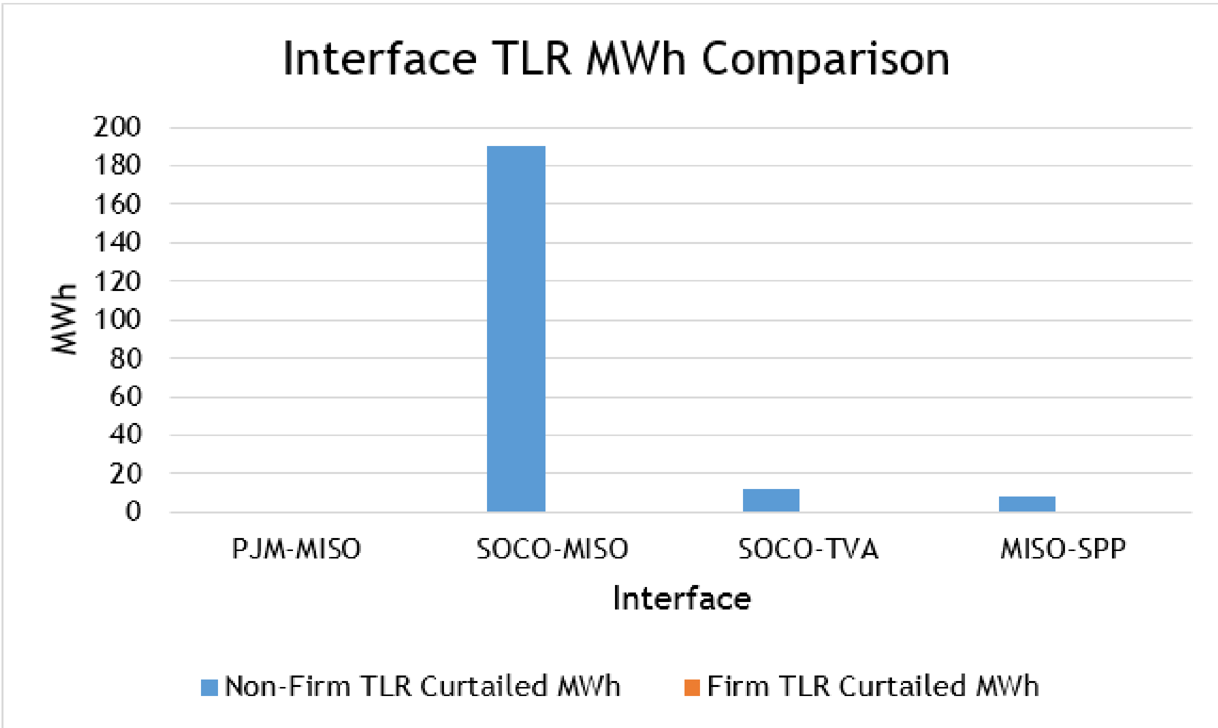


Figure 2.5.1e: Interface Non-Firm Data Comparison Summary for PJM→MISO 2015



2.6 Interface TLR MWh Comparison

Figure 2.6: Interface Non-Firm Data Comparison Summary for PJM→MISO 2015



3. Summary

This pilot historical transmission congestion study calculated the metrics developed in the study methodology to analyze transmission constraints. The study also proved the efficacy of or adjusted the methodology based on the results discussion with the pilot study participants.

The OASIS data, IDC data, and Market data from the year 2015 were used for the analysis. The congestion metrics developed by the study methodology were calculated in this study. All metrics calculations used hourly data as the basic input. Some metrics represent the yearly count of a specific occurrence. For example, Zero ATC metrics provide a yearly count of hours where an interface is fully subscribed or the ATC is equal to or less than zero. The study also identified the top five limiting flowgates due to ATC and AFC limitations, TLR calls, and Market congestion. The study also captured historical transmission system limitations starting from the time of making reservations to transfer energy to RT scheduling and operation by using data available from each stage of the energy transfer process.

The following are the metric developed as part of this study.

- Transmission Service Request (TSR) Count for 2015
- Transmission Reservation Utilization for 2015
- Zero ATC Count for 2015
- Zero AFC Count for PJM and top 5 limiting flowgate for 2015
- Schedule Utilization and Actual flow count for 2015
- Transmission Loading Relief (TLR) Count and MWH Curtailed for 2015
- Top Five Most Limiting Flowgates for pilot interface due to zero ATC and TLR calls
- Top Five most limiting flowgate for PJM Sub-region due to TLR calls
- Top Five Most Limiting PJM Owned JCM based on Binding Constraint Count due to the Market Flow Impacts
- Top Five Most Limiting PJM Owned JCM Based on RT Congestion Cost Due to Market Flow Impacts

The results from each of the above metrics are summarized below.

The OASIS metrics described in Table 3a counted the number of firm and non-firm TSRs that were confirmed or refused on the given interface.

Table 3a: Transmission Service Request (TSR) Count

Interface	Firm Confirmed TSR Count	Firm Refused TSR Count	Firm % Refusal	Non-Firm Confirmed TSR Count	Non-Firm Refused TSR Count	Non-Firm % Refusal
PJM→MISO	323	26	7.45	10748	10	0.09
SOCO→MISO	986	53	5.11	254	19	6.96
SOCO→TVA	141	30	9.97	153	4	2.76
MISO→SPP	33	9	21.43	984	444	31.09

The OASIS metrics described in Table 3b counted the number of instances when total firm or non-firm reservation on a given interface were greater than 75% or 90% of the interface TTC.

Table 3b: Transmission Reservation Utilization (TRU) Count

Interface	Firm TRU75 Count	Non-Firm TRU75 Count	Firm TRU90 Count	Non-Firm TRU90 Count
PJM→MISO	0	167	0	10
SOCO→MISO	136	138	63	63
SOCO→TVA	5816	8490	2865	8365
MISO→SPP	0	0	0	0

The OASIS metrics described in Table 3c provide the total yearly count of zero ATCs on each of the pilot interfaces.

Table 3c: Zero ATC Count

Interface	Firm Zero ATC Count	Non-Firm Zero ATC Count
PJM-MISO	0	0
SOCO-MISO	233	207
SOCO-TVA	144	22
MISO-SPP	8563	3067

Table 3d provides the five most limiting flowgates for the PJM sub-region based on zero AFC count.

Table 3d: Zero AFC count for PJM and Top Five Limiting Flowgates

PJM	Firm		Non-Firm	
	Flowgate	Count	Flowgate	Count
Top 5 limiting flowgate	LORETTO-WILTON 345 (FLO) DRESDEN-PONTIAC 345 + XFMR	2496	Kyger Creek-SPORNAEP ck2 345 (flo) SPORNAEP-Kyger Creek ck1 345	176
	155 Nelson 345/138kV TR82 l/o Byron-LeeCo 345kV	2424	17714-Hegewisch 138 l/o Burnham-Sheffield 345	103

PJM	Firm		Non-Firm	
	Flowgate	Count	Flowgate	Count
	Breed-Wheatland 345 (flo) Jefferson-Rockport 765	2160	Breed-Wheatland 345 (flo) Jefferson-Rockport 765	88
	124 Maryland-11902 138kV l/o Byron-LeeCo 345kV	2064	155 Nelson 345/138kV TR82 l/o Byron-LeeCo 345kV	55
	BROKAW-80PONTIAC 345 (FLO) BLUE MOUND-80PONTIAC 345	1176	Kyger Creek-SPORNAEP ckt2 345	50

The Schedule and Actual flow metrics described in Table 3e counted the number of instances when schedule flow total or actual flow on a pilot interface was greater than 75% or 90% of the interface TTC. The last column of this table also provides the total count of when schedule flow was above interface TTC.

Table 3e: Schedule Utilization and Actual Flow Count

Interface	U 75 Schedule Count	U 75 Actual Count	U 90 Schedule Count	U 90 Actual Count	Schedule Count above TTC
PJM→MISO	0	0	0	0	0
SOCO→MISO	82	3116	2	1884	2
SOCO→TVA	153	2194	89	1243	75
MISO→SPP	0	0	0	0	0

Table 3f provides the yearly TLR duration, MWh curtailed, and TLR count called for by the pilot interface.

Table 3f: Transmission Loading Relief (TLR) Count and MWH Curtailed

Interface	Firm TLR Duration (Hours)	Firm TLR MWh	Firm TLR Count	Non-Firm TLR Duration (Hours)	Non-Firm TLR MWh	Non-Firm TLR Count
PJM→MISO	0	0	0	0.0	0.0	0
SOCO→MISO	0	0	0	4.8	190.0	9
SOCO→TVA	0	0	0	4.1	12.4	8
MISO→SPP	0	0	0	2.0	8.0	2

Table 3g provides the five most limiting flowgates on the pilot interfaces for firm and non-firm due to zero ATC and TLR calls.

Table 3g: Top Five Most Limiting Flowgates for Pilot Interface Due to Zero ATC and TLR Calls

Interfaces	Limiting ATC Flowgates	Limiting TLR Flowgates
PJM→MISO (Firm)	Loretto-Wilton 345 (Flo) Dresden-Pontiac 345 + Xfmr	None
	155 Nelson 345/138kV TR82 l/o Byron-LeeCo 345kV	
	Breed-Wheatland 345 (flo) Jefferson-Rockport 765	
	124 Maryland-11902 138kV l/o Byron-LeeCo 345kV	
	Brokaw-80 Pontiac 345 (Flo) Blue Mound-80 Pontiac 345	
PJM→MISO (Non-Firm)	Kyger Creek-Spornaep ck2 345 (flo) Spornaep-Kyger Creek ck1 345	None
	17714-Hegewisch 138 l/o Burnham-Sheffield 345	
	Breed-Wheatland 345 (flo) Jefferson-Rockport 765	
	155 Nelson 345/138kV TR82 l/o Byron-LeeCo 345kV	
	Kyger Creek-Spornaep ckt2 345	
SOCO→MISO (Firm)	None	None
SOCO→MISO (Non-Firm)	NONE	Volunteer - Phipps Bend 500 kV FLO Jefferson - Rockport 765 kV
SOCO→TVA (Firm)	None	NONE
SOCO→TVA (Non-Firm)	None	Widows Creek 500/161 bank flow Browns Ferry-Maury 500 kV
MISO→SPP (Firm)	RUERUSANOFSM; 446.00	NONE
	RUSDARANOFTS; 396.00	
	WELLYDWELNWT; 1059.00	
	NDEX; 2150.00	
	FTCAL_S; 803.00	
MISO→SPP (Non-Firm)	RUSDARANOFTS; 396.00	Monroe-Bayshore345kV floAllenJct-Monroe-Milan345kV
	TRU5C7OSIMSI; 217.00	
	TH_HILMTGY-O; 608.00	
	ASHCRALYDVAL; 278.00	
	PLSZIOARCZIO; 1526.00	

Table 3h provides the five most limiting flowgates for the PJM sub-region due to firm and non-firm TLR calls.

Table 3h: Top five most limiting flowgate for PJM Sub-region due to TLR calls

Sub-region	Firm				Non-firm			
	Limiting TLR Flowgates	Count	Duration (Hours)	MWh	Limiting TLR Flowgates	Count	Duration (Hours)	MWh
PJM	None	0	0	0	310 - Person-Halifax 230 kV line l/o Wake-Heritage 500 kV	8	146.2	39218.4
					20793 - Greenville-Everetts 230 kV l/O Bath County-Valley 500 kV Line	4	46.0	3045.1
					20817 - Greenville-Everetts 230kV l/o Edgecombe-Rocky Mount 230kV	3	28.4	1926.3
					1704 - Person-Halifax 230 kV line	2	15.8	6419.3
					1707 - WAKE-CARSON 500	1	9.0	4985.6

Table 3i provides the top five binding JCM constraint in PJM based on the market binding count.

Table 3i: Top Five Most Limiting PJM Owned JCM based on Binding Constraint Count due to the Market Flow Impacts

Binding Constraints Ranking	Binding Constraints Name	Market Binding Hour count	% of Binding hours for the month
1	156 CHER345 KV TR83	822	48.30%
2	107 DIXO138 KV 10714	182	10.69%
3	945 CRET345 KV CRE-STJ1	119	6.99%
4	155 NELS138 KV TR82	110	6.46%
5	155 NELS345 KV 15503	68	4.00%

Table 3j provides the top five binding JCM constraint in PJM based on the congestion cost.

Table 3j: Top Five Most Limiting PJM Owned JCM Based on RT Congestion Cost Due to Market Flow Impacts

Binding constraints Ranking	Binding constraints Name	Congestion cost
1	156 CHER345 KV TR83	$69,615,305
2	20 BRAID345 KV 2001	$20,464,410
3	107 DIXO138 KV 10714	$15,255,985
4	6 BYRON 345 KV 0622	$6,746,386

Binding constraints Ranking	Binding constraints Name	Congestion cost
5	122 BELV138 KV 12205 1	$6,175,063

This study had challenges in developing the methodology due to differences in sub-regional business practices and data availability. Therefore, significant coordination and meetings were required with industry participants. It took longer than the expected time to collect the required data, receive proper authorization to use the data, review the methodology, and study the results with industry experts. The industry experts provided great insight and input into the process, but it took several meetings to reach a consensus and finalize the methodology and study results. The next step is to complete this congestion analysis for the remaining sub-regions and interfaces within the Eastern Interconnection.

Appendix B

Interface	POR	POD
MISO-SPP	MISO	WR
MISO-SPP	MISO	WFEC
MISO-SPP	MISO	SPS
MISO-SPP	MISO	SPA
MISO-SPP	MISO	SECI
MISO-SPP	MISO	OPPD
MISO-SPP	MISO	OKGE
MISO-SPP	MISO	NPPD
MISO-SPP	MISO	MPS
MISO-SPP	MISO	MOWR
MISO-SPP	MISO	LES
MISO-SPP	MISO	KCPL
MISO-SPP	MISO	KACY
MISO-SPP	MISO	GRDA
MISO-SPP	MISO	EDE
MISO-SPP	MISO	CSWS
MISO-SPP	MISO	WAUE
PJM-MISO	PJM	MECS
PJM-MISO	PJM	ALTE
PJM-MISO	PJM	ALTW
PJM-MISO	PJM	MEC
PJM-MISO	PJM	WEC
PJM-MISO	PJM	NIPS
PJM-MISO	PJM	AMIL
PJM-MISO	PJM	IPL
PJM-MISO	PJM	CIN
SOCO-TVA	SOCO	TVA
SOCO-TVA	AEC	TVA
SOCO-MISO	SOCO	MISO
SOCO-MISO	AEC	MISO

Interface	Actual Flow Tie lines	
MISO-SPP	MISO	ALTW
MISO-SPP	MISO	DPC
MISO-SPP	MISO	GRE
MISO-SPP	MISO	MDU
MISO-SPP	MISO	MEC
MISO-SPP	MISO	NSP
MISO-SPP	MISO	OTP
MISO-SPP	MISO	AMIL
MISO-SPP	MISO	KCPL
MISO-SPP	MISO	MPS
MISO-SPP	MISO	WR
MISO-SPP	MISO	CSWS
MISO-SPP	MISO	EDE
MISO-SPP	MISO	OKGE
MISO-SPP	MISO	SPS
MISO-SPP	MISO	LES
MISO-SPP	MISO	NPPD
MISO-SPP	MISO	OPPD
PJM-MISO	PJM	ALTE
PJM-MISO	PJM	ALTW
PJM-MISO	PJM	MEC
PJM-MISO	PJM	WEC
PJM-MISO	PJM	NIPS
PJM-MISO	PJM	AMIL
PJM-MISO	PJM	IPL
PJM-MISO	PJM	CIN
PJM-MISO	PJM	MECS
SOCO-TVA	SOCO	TVA
SOCO-MISO	SOCO	ENTERGY
SOCO-MISO	SOCO	SMEPA