PROPOSED METHODOLOGY FOR HISTORICAL TRANSMISSION CONGESTION ANALYSIS ON EASTERN INTERCONNECTION FOR YEAR 2015 v6.0

PREPARED FOR LAWRENCE BERKELEY NATIONAL LABORATORY

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Revision History

Version	Date	Comments	Author(s)
0.1	12/15/2015	Initial Draft	OATI
1.0	12/29/2015	Approved for DOE review	OATI
1.1	01/18/2016	DOE comments included for Industry Advisers review	OATI
2.0	01/20/2016	Approved for DOE review	OATI
3.0	01/25/2016	Additional comments for DOE review	OATI
4.0	07/15/2016	Updated based on Industry Advisers comments	OATI
4.1	08/25/2016	Clarifications based on meeting with Industry Advisers on 8/24/2016	OATI
5.0	09/09/2016	Fully Approved	OATI
5.1	05/11/2018	Graph Updates	OATI

1. Terms and Acronyms

Term, Acronym, or Concept	Description
AFC	Available Flowgate Capability
ATC	Available Transfer Capability
BA	Balancing Authority
DAM	Day-Ahead Market
DOE	Department of Energy
EIPC	Eastern Interconnection Planning Collaborative
ERCOT	Electric Reliability Council of Texas
IDC	Interchange Distribution Calculator
IDCWG	Interchange Distribution Calculator Working Group
ISO	Independent System Operator
ISONE	Independent System Operator New England
JCM	Jointly Controlled Market
LBNL	Lawrence Berkeley National Laboratory
LMP	Locational Marginal Price
MISO	Midcontinent Independent System Operator
MW	Megawatt
NERC	North American Electric Reliability Corporation
NYISO	New York Independent System Operator
OASIS	Open Access Same-Time Information System
OATI	Open Access Technology International, Inc.
OSL	Operating Security Limits
PJM	Pennsylvania-New Jersey-Maryland Interconnection
RT	Real-Time
RTO	Regional Transmission Operator
SOCO	Southern Company Services, Inc.
SPP	Southwest Power Pool, Inc.
TLR	Transmission Loading Relief
TRU	Transmission Reservation Utilization
TSR	Transmission Service Request or Reservation
TTC	Total Transmission Capability
TVA	Tennessee Valley Authority
VACAR	Virginia-Carolinas area
WAPA	Western Area Power Administration
WECC	Western Electricity Coordinating Council

2. Introduction

The DOE, through LBNL, issued a contract to OATI to develop a methodology for transmission congestion analysis for the Eastern Interconnection. OATI was also asked to perform an historical data analysis using information from OASIS and transmission operators to identify transmission system constraints that limit the market and non-market operation and Real-Time transfer of energy from generating sources to the load centers.

Phase 1 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 according to the sub-regions within the Eastern Interconnection that had been defined by the EIPC for the years 2011, 2012, and 2013. DOE received several comments during review of the Phase 1 report from industry experts and it also identified a need for congestion analysis considering reservation, schedule curtailment, and market data.

Phase 2 of this project will perform a congestion analysis using data from the Eastern Interconnection electricity markets OASIS nodes, and the IDC for year 2015. The Phase 2 congestion analysis will address the concerns raised by industry experts in the Phase 1 study.

Phase 2 work will be performed in two parts:

- Part 1: Development of Congestion methodology working with industry experts and the DOE.
- Part 2a: Pilot congestion analysis for selected interfaces working with industry experts and DOE.
- Part 2b: Congestion analysis for remaining interfaces and report development.

As a component of Part 1 of the Phase 2 work, OATI has developed a draft methodology for congestion analysis and presented version 3.0 of proposed methodology to DOE and industry experts for their review and comments. A web seminar was held on 02/19/2016 to review the version 3.0 of the draft proposal with industry experts. Subsequently, several series of meeting 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, incorporates 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. This final draft of the methodology document, version 5.0 incorporates comments from the August 24, 2016 web seminar. This document summarizes the

proposed congestion analysis methodology and the various congestion metrics and data requirements necessary to complete the analysis. It also summarizes the proposed findings that the methodology will reveal.

Table 2-1 provides a summary of the items to be measured in this report and the proposed findings that will result from the process followed and the data collected. OASIS metrics provide information regarding restrictions faced by the Transmission Customers during the reservation process. It highlights the limitations faced by the Transmission Customers in securing the transmission service up to the hour-ahead of operation and the MW usage of reservations on an interface. TLR metrics provide information regarding restrictions faced by the Transmission Customers when these transmission reservations are scheduled. TLR metrics will also identify transmission elements that are overloaded or exceeded OSL during the actual operation of the system and required curtailment of energy schedules. Market metrics identify the market congestion due to significant binding constraints that resulted during RT market operation. All three classification of metrics, OASIS Reservations, Energy Schedules, and Market Data will be useful in visualizing congestion in the Eastern Interconnection. In addition, the correlation of the three classifications to interface impacts reveals an additional level of visualization and summarization of congestion.

Table 2-1: Summary of Metrics and Proposed Findings

Metrics/Item Measure	Data	Proposed Findings
OASIS ATC, Reservations	Reservations, ATC, and AFC.	Limitations faced by the Transmission Customers during the transmission reservations process. Report total count of negative ATC/AFC and reservations exceed a percentage of TTC. Top five most limiting flowgates will be reported. This will identify congestion during the reservation time.
TLR Energy Schedule Impacts	Energy Schedules, Actual Flows, TLRs including total number of Hours, Level, and MW curtailed.	Limitations due to curtailment of schedules and other operating issues. Report total TLR counts and MWs. Report top five most limiting constraints for each sub-region and rank them based on yearly count by Firm and Non-Firm curtailments. This identifies congestions from schedules and operation issues.

Metrics/Item Measure	Data	Proposed Findings
Market Impacts	RT binding constraints, shadow price, and Actual Flows.	Limitations due to market flow and market operational issues for Market sub-regions. Report number of binding constraints, counts, and congestion costs. Report top five binding constraints based on yearly count and congestion cost. This identifies congestions during the market operation.
Interface Correlations	OASIS metrics and TLR metrics.	Summarization of each interface based on the OASIS and TLR. This will summarize congestion on an interface.

The metrics identified above will be developed only if such metrics are applicable for a sub-region and also data are available for the year 2015. More detailed discussions of metric development for each sub-region can be found in Section 4.

It should be noted that this study will primarily focus on inter-regional congestion rather than internal sub-regional congestions as internal and local sub-regional congestion is not in the study scope. Furthermore, sub-regions/RTOs regularly perform internal congestion analysis for their regions and there is no need to duplicate those efforts. Therefore, this study will mainly be to address congestion between sub-regions and only a limited flowgate analysis and market binding constraint analysis will be performed to identify internal congestion within the sub-regions.

The centralized markets use the LMP prices for the indicating value of generation at a given node or zone. However, LMP prices do not directly reflect where the congestion causation is located within the market. Markets also calculate the congestion cost to establish the value of network congestion. This congestion cost is associated with a binding constraint, such as flow gates. Identification of binding constraints and congestion costs resulting from binding constraints will be used to measure the congestion. The study will also develop congestion metrics based on the market flow impacts for MISO, PJM, and SPP where the market is managed using coordinated agreement and settlement between these RTOs.

This study plans to use the RT market conditions for calculating various metrics. The study does not plan to use the DAM results due the following two reasons:

- The RT market results reflect the final congestion that happened on the network.

- The DAMs have a lot of virtual bidding that does not materialize, and as a result, can show non-realistic congestion on the system. Therefore, this project plans to use the RT market data analysis to identify the congestion on the interfaces due the RT market.

Preliminary study results will be provided to sub-regions to seek their comment and ensure that study results adds to or complements sub-regional study results. In the case of conflicting study results, OATI and DOE will discuss it first with the entities, and if there is no resolution, offer them opportunities to comment formally on the findings in the final study.

Part 2 of the congestion analysis work is expected to start immediately after finalizing the congestion analysis methodology with DOE and industry experts. Prior to Part 2b work, congestion analysis will be performed as a pilot project to verify the proposed methodology on three or four interfaces selected by DOE and industry experts.

This final draft of the methodology document, version 5.0, incorporates changes and comments agreed with these industry experts and sub-region. The following tables for OASIS, TLR, and Market metrics summarizes the mutual agreement between OATI and industry advisors and resulted in OATI modifying the original methodology document, version 3.0, to version 5.0 to incorporate the industry advisors suggestions and concerns.

Table 2-2: OASIS Metrics

Entity	Reservation Metrics	ATC Metrics	AFC Metrics	Comments
NYISO	NO	YES	YES	No reservation data is available. NYISO will provide internal interfaces can be used as proxy flowgates to generate AFC metrics. ATC metrics will be calculated using TTC-Limits as suggested by NYISO.
ISONE	NO	NO	NO	No reservation data is available. No proxy flowgates therefore no AFC metrics will be generated. Schedules are created up to the TTC on the interfaces, therefore, OATI suggests to continue from last study based on schedule count above 100% of TTC.
SOCO	YES	YES	NO	OATI will add ATC metrics based on TTC-net tag schedules for Firm and Non-firm. If ATC is zero, additional metrics such as percentage of firm/non-firm utilization and capacity available will be developed. SOCO is an ATC based sub-region, no AFC metrics will be developed.
FRCC	YES	YES	NO	Reservation and ATC metrics will remain the same as the original proposed methodology, version 3.0. Since FRCC is an ATC based sub-region, no AFC metrics will be developed.

Entity	Reservation Metrics	ATC Metrics	AFC Metrics	Comments
NWPP*	NO	NO	NO	The interfaces between the Eastern Interconnection and WECC will not be included in this study.
RMPA*	NO	NO	NO	The interfaces between the Eastern Interconnection and WECC will not be included in this study.
AZ_NM_SNV*	NO	NO	NO	The interfaces between the Eastern Interconnection and WECC will not be included in this study.
ERCOT*	NO	NO	NO	The interfaces between the Eastern Interconnection and ERCOT will not be included in this study.
MISO	YES	YES	YES	OATI will proceed with the original proposed methodology, version 3.0, to generate these metrics.
PJM	YES	YES	YES	Additional AFC/ATC metrics will be developed using 18 months, 6 months, and last posted values Reservation and AFC metrics using top 10-20 limited flowgates will remain the same as stated in the original methodology, version 3.0.
SPP	YES	YES	YES	OATI will proceed with the original proposed methodology, version 3.0, to generate these metrics.
TVA	YES	YES	YES	OATI will proceed with the original proposed methodology, version 3.0, to generate these metrics.
VACAR	YES	YES	YES	OATI will proceed with the original proposed methodology, version 3.0, to generate these metrics.
Non RTO Midwest	YES	YES	YES	OATI will proceed with the original proposed methodology, version 3.0, to generate these metrics.
MAPP US	YES	YES	YES	OATI will proceed with the original proposed methodology, version 3.0, to generate these metrics.
HQ*	YES	YES	YES	The interfaces between the Eastern Interconnection and Canadian sub-regions will not be included in this study.
IESO*	YES	YES	YES	Data will be collected from concerned entity or MISO/MAPP OATI OASIS.
Maritime*	YES	YES	YES	Data will be collected from concerned entity or ISONE OATI OASIS if applicable.
MH-SPC*	YES	YES	YES	Data will be collected from concerned entity or MISO/MAPP OATI OASIS.

*sub-region metrics will not be included in this study

Table 2-3: Market Metrics

Entity	Sub-Region Market Metrics	Market Flow Metrics	Comments
MISO, SPP, PJM	YES	YES	Market data will be collected from MISO, SPP, and PJM. No interface correlation for the Market to Market analysis. Will develop seasonal and yearly market metrics and identify binding constraints. Market flow metrics will identify binding constraints that are JCM flowgate. Market metrics will use the RT binding constraint, RT market flow, RT shadow price, RT Congestion Cost, and JCM flowgates to get the constraint count and rank top 5.
NYISO	YES	NO	No market flow metrics will be developed because NYISO does not have the Market to Market settlement. Will request sub-regional market data from NYISO. No interface correlation for the Market to Market analysis will be performed. Will develop seasonal and yearly market metrics and identify binding constraints. Market metrics will also use the RT binding constraint, RT shadow price, and RT Congestion Cost to get the constraint count and rank top 5. OATI also recommended a pilot investigation of market metrics methodology based on LMP price differential posted by NYISO for the NYISO-PJM interface working with NYISO for potential consideration for future DOE studies.
ISONE	YES	NO	No market flow metrics will be developed because ISONE does not have the Market to Market settlement. Will request sub-regional market data from ISONE. No interface correlation for the Market to Market analysis will be performed. Will develop seasonal and yearly market metrics and identify binding constraints. Market metrics will also use the RT binding constraint, RT shadow price, and RT Congestion Cost to get the constraint count and rank top 5.

More details of these methodology changes are provided in Section 3 of this methodology document.

2.1 Pilot Study

Based on discussions with the industry advisors, the following sub-region and interfaces are recommended for the Pilot study.

Sub-region: PJM

Interfaces: SOCO-MISO, SOCO-TVA, PJM-MISO, MISO-SPP, and NYISO-PJM*

PJM has agreed to participate in the pilot study and has suggested to include the PJM-MISO interface and PJM sub-region. SOCO has agreed to participate in the pilot study and has suggested to include the SOCO-MISO and SOCO-TVA interfaces. MISO has agreed to include MISO-SPP interface for the pilot project.

The NYISO-PJM interface study will be limited to investigation of market metrics based on LMP price differential posted by NYISO for the NYISO-PJM interface working with NYISO.

2.2 Study Schedule

Phase 2 work will be performed in two parts:

- Pilot congestion analysis for selected interfaces working with industry experts and DOE.
- Congestion analysis for remaining interfaces and report development. These schedules are contingent on OATI receiving data from sub-regions on time.

  Pilot study start – 09/05/2016
  Draft report to Pilot sub-regions for review – 10/30/2016
  Final report for Pilot study - 12/15/2016
  Congestion analysis for remaining interfaces - 11/30/2016
  Draft report to Sub-regions for review – 02/15/2017
  Final report - 03/30/2017

3. Phase 2 Congestion Analysis Methodology Development and Approach

Congestion occurs on the nation's electric transmission grids when there is not sufficient transmission capacity to reserve transmission service or schedule all desired electricity transfers. Transmission congestion occurs in two stages. The first stage is when customer reserves transmission service. The second stage is when customer schedules the energy in RT operation. A historical congestion analysis and congestion measurements are very useful for identifying where and how much congestion exists and how it impacts the electricity markets and electric grid operation.

In order to develop a congestion analysis methodology for the Phase 2 study, OATI reviewed two previous DOE study reports performed by OATI.

3.1 DOE Study for Year 2009

The DOE 2009 Study used public data including OASIS reservation metrics and AFC, IDC e-Tag schedules and TLR data, Market LMP, and shadow prices to correlate the limitations identified by OASIS, Market, and IDC data. Lack of naming standards made it difficult to correlate data from these three different sources. Another goal of the study was to present the results on an electronic geographic map to facilitate further analysis. This proved to be a challenge as the geographic locational data was not readily available for the study. No comparison was done against actual flow since this data was not publicly available. The study also did not use the schedule (e-Tag) data for interface (BA to BA) schedules.

3.2 DOE Study for Year 2010 through 2013

The DOE 2010 Study used non-public data in IDC tag schedules and actual flows to identify transmission system constraints within the Eastern Interconnection and between the sub-regions defined by the EIPC in its study report. The OATI report provided hourly scheduled and actual flows among sub-regions, as well as the utilization metrics that were developed to summarize these flows.

There was no study performed for 2014.

3.3 Study Findings and Concerns

DOE study for the year 2009 tried to align with EIPC study configuration for the sub-regions. However, sub-regions modeled within RTO by the EIPC study do not represent how the system

is scheduled and operated; therefore, any estimation of scheduled and actual flows does not represent the usage as expected by the EIPC study. In addition, there have been changes to the BA and Market footprints since the EIPC study was performed.

The schedules are the expected flows on the interfaces before RT; however, the actual flows are based on the RT power flows. The schedules and actuals are not expected to match due to loop flows, inadvertent interchange, dynamic schedules, and pseudo ties.

The 2010-2013 OATI Historical Analysis Study did not include OASIS metrics, market analysis, and TLR analysis as included in the 2009 DOE Study. These additional metrics could add valuable information in addition to the loading curves done for actual and scheduled flows included in the 2010 Study.

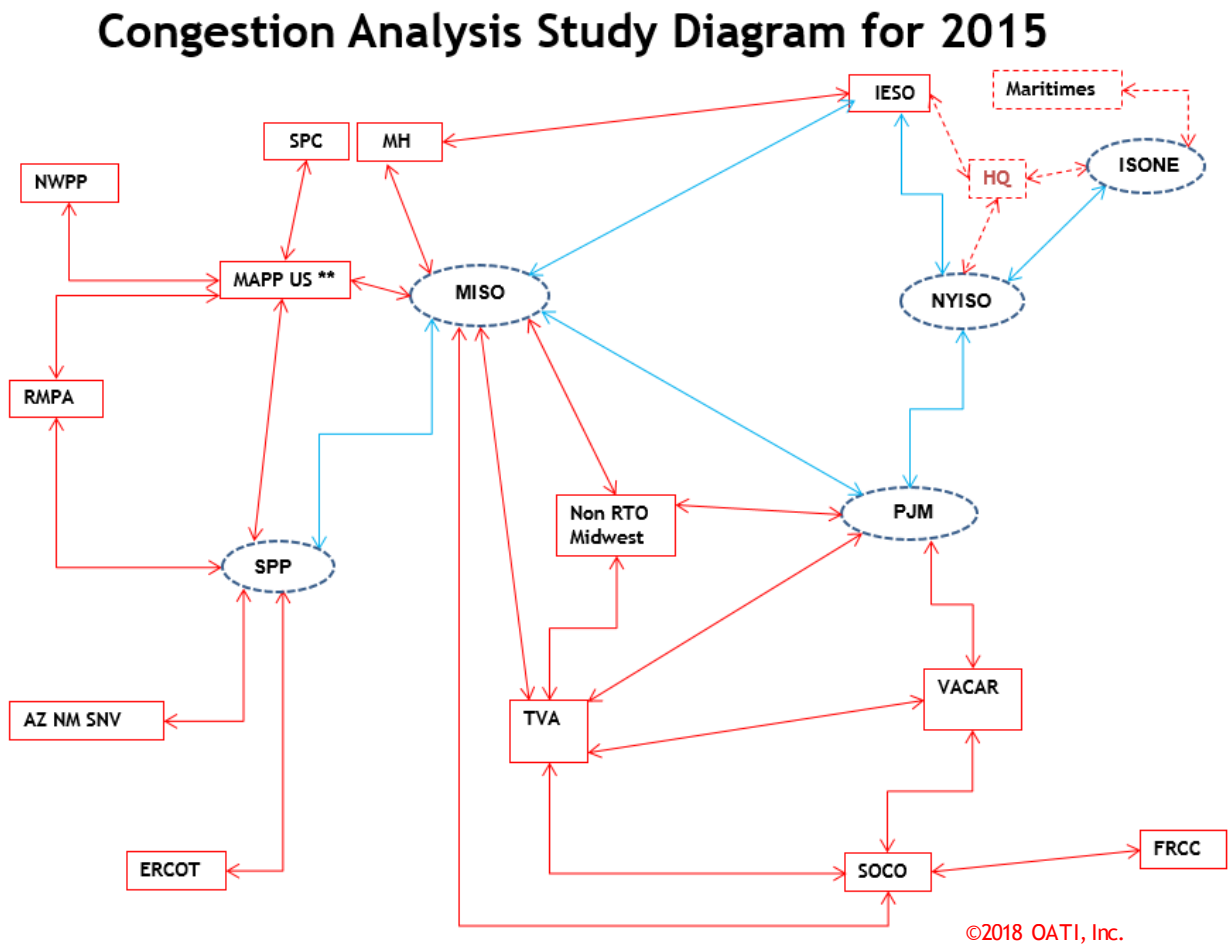
3.4 Study Approach for Phase 2 Congestion Analysis

OATI worked with the DOE and industry experts, especially ISO/RTO staff, for validation of the analysis approach and for collection of data from selected transmission operators needed for this analysis. The purpose of the study is to identify transmission system limitations in both market and non-markets for the year 2015.

OATI proposes a study approach that combines data analysis and methodology from 2009 and 2010 studies. The study will use OASIS reservation metrics and ATCs, IDC tag schedules, TLR data, transmission congestion constraint shadow prices, and actual flows to identify transmission system constraints between the sub-regions. Each ISO/RTO will be considered as a single sub-region at higher level. However, the study will also seek to identify constraints within the ISO/RTO Market footprints. Also, the study will redefine the Phase 1 DOE study sub-regions as to better align with 2015 RTO and market membership and alignment.

The study will focus on all interfaces between the sub-regions highlighted in the Figure 3-1 diagram. This diagram was reviewed with industry advisers and sub-regions and updated based on their input. The study will not address any internal interfaces except selected flowgate analysis and market analysis to capture internal congestion.

Figure 3-1: Sub-Regions and Interfaces for Study



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

4. Proposed Congestion Methodology and Congestion Metrics Development

This section provides an overview of the congestion metrics to understand how transmission is managed in the Eastern Interconnection. It discusses the temporal relationship among the elements, the differences in practices among Eastern Interconnection Transmission Operators in the way the elements are implemented, the data that are available to calculate metrics (which quantify aspects of these practices), and finally, the interpretation and significance of the metrics in understanding congestion in the Eastern Interconnection. The study also correlates any limitations identified by these metrics, wherever possible.

The three core operational elements that will be examined for congestion metrics development are: OASIS Transmission Reservations, Transmission Schedules and TLRs, and RT Market Operations.

OATI will collect OASIS, IDC, and market data and store the data in a database, to calculate a set of metrics to identify the congestion. The data collection and analysis process will be conducted independently for the OASIS, Market, and IDC data.

Interfaces between the Eastern Interconnection, WECC, and ERCOT will not be included in this study. Therefore, no metrics will be developed for these interfaces and sub-regions.

4.1 OASIS Transmission Reservations

OASIS metrics provide information regarding restrictions faced by the Transmission Customers during the reservation process. These metrics highlight the limitations faced by the Transmission Customers in securing the transmission service up to the hour ahead of operation. However, it was pointed out by industry advisors, these limitations alone may not be an indicator of congestion since system is typically planned only to accommodate current and future confirmed firm transmission service and transmission will be planned and expanded as needed based on new TSRs from customers. The OASIS reservations only provide the capacity of reservations and not the actual energy schedule. Therefore, the amount of transmission reservations in some cases may be larger than the scheduled energy.

The OASIS metrics will use the posted ATC and/or AFC, TTC, and reservations.

The following table describes the transmission reservation metrics being proposed for the study.

Table 4-1: Congestion Metrics for OASIS Reservation Data

Item Measured	Process	Metrics	Ranking/ Threshold
Firm Reservations on interfaces	Directional Hourly confirmed reservations	Total count above threshold	75% of TTC 90% of TTC
Firm plus non-firm Reservations on interfaces	Directional Hourly confirmed reservations	Total count above threshold	75% of TTC 90% of TTC

The total MW reservation (firm and non-firm) on each interface direction for each hour will be calculated. In calculating the reservations data, care will be taken to use only the reservations that were sinking into the transmission provider's BA to avoid any double-counting of the reservations. A count will be generated for each interface when total reservation exceeds the TTC threshold. Two thresholds will be used to quantify and visualize congestion on an interface.

It should be noted that the OASIS Reservation metrics are not applicable to NYISO and ISONE, therefore, no Reservation metrics will be developed for these two sub-regions. Certain provisions of the Pro forma tariff regarding transmission service do not apply to ISONE and NYISO does not require transmission reservations on its OASIS.

Based on SOCO request, OATI reviewed the TSR metrics posted on the OASIS and found that posted metrics may not be that useful since the posted TSR metrics for approvals/refusals combine both firm and non-firm and not specific to an interface. It was suggested that future DOE study should consider including certain additional reservation related metrics for each interface. Based on this request, the study will generate metrics based on the approvals/refusals of TSRs on sub-regional interfaces for firm and non-firm transmission service separately.

- Total Firm TSR refusal count/MW.
- Total Firm TSR approval/confirmation count/MW.

The following table describes the AFC metrics being proposed for the study.

Table 4-2: Congestion Metrics for OASIS AFC Data

Item Measured	Process	Metrics	Flowgate Ranking/Threshold
Posted Daily Firm AFC if applicable Posted hourly Non-firm AFC if applicable	Zero AFC count	Total number for the year	Report top five most limiting flowgates for each sub-region

An AFC value of zero indicates that there was no transmission capability available for that period. Firm AFC metrics will use daily AFC values and non-firm AFC metrics will use hourly Non-firm AFC values. The AFC metrics will calculate total number of hours where AFC was zero during the year.

This study will only focus on the 10 to 20 most limiting flowgates from each sub-region recommended by sub-region advisors. Each sub-region advisors will select most limiting flowgates for the congestion analysis based on the following historical data.

- Negative AFC flowgates that limits transactions on internal or external interfaces.
- Negative AFC flowgates that limits transactions on internal or external interfaces based on current scenario analyzer results.
- Most TLR called flowgates.
- Most congested flowgates in the Market operation.

The flowgates will be ranked based on total number of zero AFC count for each sub-region and the top five most limiting flowgates for each sub-region identified.

Based on discussions with PJM, they will provide flowgates data for the AFC metrics. PJM was also concerned regarding the interpretation of the daily or last zero AFC values which are not indicators of transmission congestion since firm AFC may be available during planning horizon and which was used up by customers prior to the operating horizon. Therefore, OATI is recommending to add additional AFC metrics for 18 months prior to the study horizon, six months prior to the study horizon, and the last posted AFC values if data are available for the interface.

Based on discussions with NYISO, there are four or more internal congestion interfaces within NYISO which could be use as proxy flowgates. NYISO has agreed to provide these proxy flowgates

and AFC values are calculated subtracting actual flow from the scheduling limit (TTC) for these proxy flowgates. Therefore, OATI will generate the AFC metrics using these proxy flowgates.

Based on discussions, ISONE has indicated that proxy flowgates are not applicable to them, so therefore, no AFC metrics will be developed for ISONE.

Based on discussions with SOCO, the AFC metrics are not applicable for SOCO sub-region. SOCO is an ATC based sub-region. They do not calculate AFCs therefore no AFC metrics will be developed for SOCO.

Based on the discussions with MISO and SPP, these Sub-regions have agreed to provide top 10-20 most limiting flowgates data for the AFC metrics. OATI will use these flowgates and generate the AFC metrics in the final report.

Any Sub-regions that provides proxy flowgates, OATI will include these proxy flowgates in the congestion report as limiting proxy flowgates for the sub-regions.

Also, any Sub-regions that identify 10 to 20 most limiting flowgates for the AFC analysis, OATI will include these will generate AFC metrics for Sub-regions and identify the five most limiting flowgate based on the AFC metrics.

The following table describes the ATC metrics being proposed for the study.

Table 4-3: Congestion Metrics for OASIS ATC Data

Item Measured	Process	Metrics	Ranking/Threshold
Posted Daily Firm ATC for interfaces if applicable. Posted hourly Non-firm ATC for interfaces if applicable.	Zero ATC count	Total number for the year	Report each sub-region interface

ATC value of zero indicates that there was no ATC available for that period. Firm ATC metrics will use Daily ATC values and Non-Firm ATC metrics will use Hourly Non-Firm ATC values. The ATC metrics will calculate total number of hours where ATC was zero during the year.

Effective ATC will be utilized if data is available on the OASIS.

Based on discussions with PJM, there is concern with the usefulness and accuracy of the Daily ATC metrics. The last posted ATC value may not indicate congestion. PJM was also concerned

regarding the interpretation of the daily or last zero ATC values which are not indicators of transmission congestion since firm ATC may be available during planning horizon and available ATC was utilized by the customers prior to the operating horizon. Therefore, OATI is recommending to add additional ATC metrics for 18 months prior to the study horizon, 6 months prior to the study horizon, and the last posted ATC values if data is available for the interface. OATI will clearly document PJM concerns regarding the daily ATC values as stated above in the final report.

There was some concern raised at the IDCWG meeting by VACAR region with use of last posted value for the ATC metric since some VACAR members like Duke Energy posts zero ATCs when the window for the transmission service is closed in accordance with their business practices. OATI will work with VACAR region to address these types of data issues due to regional differences.

Based on discussions with ISONE, the schedules are created up to the TTC on the interfaces. Therefore, generating these zero ATC metrics are not relevant and not meaningful to capture congestion on ISONE interfaces since the ATC is always equal to the TTC. OATI is suggesting to add additional ATC metrics based on schedule count above the 100% of the TTC, similar to the last study. ISONE would need to provide the hourly TTC and actual flow data.

Based on discussions with NYISO, no ATC metrics will be developed since the data are not available. NYISO has suggested to OATI to calculate ATC metrics utilizing the Limit (TTC) minus the Flows for their external interfaces. Therefore, OATI will calculate these ATC metrics utilizing the Limit (TTC) minus the Flows for NYISO external interfaces.

Based on the discussions with SOCO, OATI is adding an additional ATC metric calculation based on the TTC minus the after-the-fact tags (TTC-tag schedules), similar to the last study. The ATC metrics will be developed based on the TTC-tag schedules. For special cases where SOCO's TTC-tag schedules are zero then additional metrics will be developed including percentage of firm utilization (net firm schedule/TTC), capacity available (100% of net firm utilization), and non-firm utilization (net non-firm schedule/TTC).

4.2 TLR Metrics

Transmission Schedules and TLR IDC data will provide information on the flowgates that are overloaded or exceeded OSL during the actual operation of the system and that required curtailment of energy schedules. The collected data will include measurements of how often

and for how many hours a flowgate has been overloaded and curtailments have been made. The following table describes the metrics that will be developed and analyzed for the IDC data.

The following table describes the TLR metrics proposed for the study.

Table 4-4: Congestion Metrics for IDC Data

Item Measured	Process	Metrics - Per Flowgate and Total for Sub-Region	Flowgate Ranking/Threshold
TLR Hourly Firm and Non-firm	Number of TLRs issued	Total number of TLRs for Year	Ranked based on Yearly count. Report top five limiting flowgate for each sub-region
Duration of TLR	Number of hours a flowgate is in TLR	Total number of hours in TLR for Year	Ranked based on Yearly count. Report top five limiting flowgate for each sub-region
Magnitude of TLR	Total MWhs curtailed by TLR on a flowgate	MWhs curtailed for the Year	Ranked based on Yearly count. Report top five limiting flowgate for each sub-region

To focus only on significant TLRs, constraints will be ranked based on number of occurrence, number of hours and total MW cut for each month. The following two sets of TLR counts and MW curtailment will be developed.

- TLR count for TLR level > 0 and TLR level = 3 - This metrics will provide non-firm TLR counts and MW curtailments.
- TLR count for TLR level = 5 or higher - This metrics will provide firm TLR counts and MW curtailments.

The industry advisers requested OATI to report firm and non-firm TLR counts separately since non-firm curtailment is not likely an indicator of transmission congestion.

This study will also develop transmission utilization metrics U90 using the schedule and actual flow for the study year 2015.

Based on the discussion with NYISO and ISONE, TLR metrics are not applicable for their regions. However, OATI will report TLR metrics for all sub-regions including NYISO and ISONE if TLR curtailments impacting these sub-regions are found based on the IDC data analysis.

Based on the discussion with PJM, TLR metrics may not be applicable to them. PJM pointed out that not many TLRs are called on their interfaces as the work with MISO market to relieve

congestion. However, OATI will report TLR metrics for all sub-regions including PJM if TLR curtailments impacting these sub-region are found based on the IDC data analysis.

4.3 RT Market Operations

For each market, binding constraints and shadow price are collected for the development of market metrics. A metric will be developed only for RT operation to reduce amount of data required for the market congestion analysis. No day-ahead market congestion will be used in the metrics.

The shadow price of a transmission constraint on an interface is a direct indicator of congestion on that interface. The shadow price of a constraint is a measure of incremental change in operating cost as a result of an incremental change in the constraint limit. Generally, a higher magnitude of the shadow price indicates a higher level of congestion.

To focus only on significant binding constraints, constraints will be ranked based on a number of occurrence, a number of hours, and total congestion cost for the year.

OATI discussed the draft market methodology with PJM, MISO, SPP, NYISO, and ISONE.

Based on the discussion with market regions, correlation of the Market to Market congestion to sub-regional interface is not straight forward from the sample data provided by the market and therefore, it was agreed that correlation of the Market congestion to interface will not be performed. OATI worked with PJM and recommended congestion metric for all market sub-regions as described in Section 4.3.1.

OATI worked with PJM for developing market flow metrics based on the Market to Market settlement data with MISO. The methodology for the market flow metrics are described in Section 4.3.2. These market flow metrics are only applicable to MISO, PJM, and SPP.

ISONE informed OATI that with respect to ISONE sub-region congestion, the 2015 reports are not yet available but the 2014 Internal Market Monitor and External Market Monitor reports concluded that there was limited internal congestion within ISONE. With the transmission construction that has occurred over the last few years ISONE does not expect any different observation for 2015 and therefore, ISONE is not recommending any additional sub-region congestion analysis for their sub-region.

OATI recommends development of market metrics identified in Section 4.3.1 for both ISONE and NYISO. OATI also recommended a pilot investigation of market metrics methodology based on LMP price differential posted by NYISO for the NYISO-PJM interface working with NYISO for potential consideration for future DOE studies.

4.3.1 Sub-Regional Market Congestion Metric

Using the hourly RT binding constraints, shadow price, and congestion costs provided by sub-regions, OATI will develop following congestion metrics for each market sub-region.

- Average shadow price.
- Percentage of Congestion Cost to Total Market Cost.

These metrics will be developed for monthly, seasonal, and yearly. However, sub-regions suggested that final report should only include the seasonal and yearly metrics to avoid short-term congestion from operating issues such as outages.

Table 4-5: Sub-Region Metric Seasonal (based on RT market)

	Average Shadow Price	%(Congestion Cost/Total Market Cost)
Sub-Region	$XX	YY.YY

The study will also identify five most limiting constraints based on total hourly binding count and congestion cost. The entities will be requested to provide RT binding constraint, RT market flow, RT market value, and RT congestion cost for the sub-region. PJM suggested to consolidate the same monitor element even though the binding constraint may have different contingencies. Using RT binding constraints occurrence in the study interval, they will be sorted to list the top 5 binding constraints for all flowgates including the JCM flowgates. Similarly, using congestion cost for a particular constraint in the study interval, they will be sorted to list the top 5 binding constraints.

Table 3-6: Five Most Limiting Constraints for Sub-Region based on Binding Constraint Count (Based on RT Market)

Binding constraints Ranking	Binding Constraints Name	Market Binding Hour Count	% of Binding Hours for the Season
1	Constraint 1	XX	YY.YY
2	Constraint 2	XX	YY.YY
3	Constraint 3	XX	YY.YY

Binding constraints Ranking	Binding Constraints Name	Market Binding Hour Count	% of Binding Hours for the Season
4	Constraint 4	XX	YY.YY
5	Constraint 5	XX	YY.YY

For each sub-region, the binding constraints will be ranked based on their hourly count and five most limiting constraints will be identified.

Table 4-7: Five Most Limiting Constraints for Sub-Region based on Congestion Cost (Based on RT Market)

Binding Constraints Ranking	Binding Constraints Name	Congestion Cost	% of Congestion Cost (Based on Total Regional Congestion Cost)
1	Constraint 1	$ XX	YY.YY
2	Constraint 2	$ XX	YY.YY
3	Constraint 3	$ XX	YY.YY
4	Constraint 4	$ XX	YY.YY
5	Constraint 5	$ XX	YY.YY

For each sub-region, the binding constraints will be ranked based on their congestion cost and five most limiting constraints will be identified.

4.3.2 Congestion Metrics based on Market Flow

The congestion on the interface between the markets is managed using the coordination agreement between the RTOs. The agreement provides for each RTO to control their entitlement to use each Jointly Controlled Flowgate (JCF), including Day-Ahead (DA) adjustments to the entitlements. When such a flowgate binds, the flow is controlled by re-dispatch of the most efficient generation control between the two RTOs, to control for all market flows, parallel flows, and inadvertent uses of the flowgate. Congestion on Market to Market coordinated flowgates is, therefore, handled by re-dispatching generation within the RTO instead of relying on Loading Relief TLR procedure to alleviate congestion. The total flow impact due to all causes can be used as indicator of congestion similar to TLR metrics for the market.

Market to Market settlement will provide hourly RT Market to Market binding constraints and congestion payments/credits. OATI will develop following seasonal and yearly congestion metrics due to the market flow impacts for each sub-region.

- Average shadow price for the market flow JCM flowgates.

- Will identify five most limiting JCM for each sub-region due to market flow impact.

The following is an example of the market flow metrics for the PJM sub-region. In this example, during an hour a PJM flowgate is constrained and binding in PJM, then market flow impact is identified if binding constraint is a Market to Market JCM flowgate.

Table 4-8: Average Shadow Price (Only included PJM Owned JCM flowgates)

	Average Shadow Price for the Binding Constraints
PJM and MISO Market flow impact to PJM Market	$ XX

The study will also identify five most limiting constraints (JCM flowgates only) based on total hourly binding count and congestion cost. The market sub-regions will be requested to provide RT JCM binding constraint, RT market flow, RT market value, and RT congestion cost for the sub-region. PJM suggested to consolidate the same monitor element even though the binding constraint may have different contingencies. Using RT JCM binding constraints (occurrence in the study interval), they will be sorted to list the top 5 binding constraints based on hourly binding count. Similarly, using the congestion cost based on the RT congestion cost for each JCM binding constraint will be sorted to list the top 5 binding constraints. It should be noted that JCM settlement credit will not be used for this analysis.

Table 4-9: 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
1	Constraint 1	XX	YY.YY
2	Constraint 2	XX	YY.YY
3	Constraint 3	XX	YY.YY
4	Constraint 4	XX	YY.YY
5	Constraint 5	XX	YY.YY

Table 4-10: Five most limiting PJM owned JCM based on RT congestion cost due to Market flow impacts

Binding Constraints Ranking	Binding Constraints Name	Congestion Cost	% of Congestion Cost (based on Total RT Congestion Cost)
1	Constraint 1	$ XX	YY.YY
2	Constraint 2	$ XX	YY.YY
3	Constraint 3	$ XX	YY.YY

Binding Constraints Ranking	Binding Constraints Name	Congestion Cost	% of Congestion Cost (based on Total RT Congestion Cost)
4	Constraint 4	$ XX	YY.YY
5	Constraint 5	$ XX	YY.YY

For each sub-region, the JCM owned sub-region will be ranked based on RT congestion cost and five most limiting JCM will be identified.

4.4 Market Metrics Correlation to Interfaces

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

However, the correlation of TLR curtailment to interface will be performed as shown in Section 4.5.

4.5 TLR Metrics Correlation to Interfaces

The following table describes proposed methodology for the study for correlating TLR curtailments to interfaces. The correlation of TLR curtailments to interfaces will help to visualize RT congestion on interfaces.

Table 4-11: Correlation of TLR Metrics to Interfaces

Item Measured	Process	Metrics	Flowgate Ranking/Threshold
TLR Hourly Firm and Non-firm	Sum number of hours an interface is impacted by TLR	Total number of hours for the Year	Ranked based on yearly count. Report top five most limiting flowgate/constrains for each interface.
TLR Hourly Firm and Non-firm	Total MW curtailed on the interface	Total MW for the Year	Ranked based on yearly count. Report top five most limiting flowgate/constraints for each interface.

For each hour, schedule curtailment due to TLR will be collected for each interface and total TLR count and curtailed MW will be calculated.

The industry advisers requested OATI to report firm and non-firm TLR counts separately since non-firm curtailment is not likely an indicator of transmission congestion.

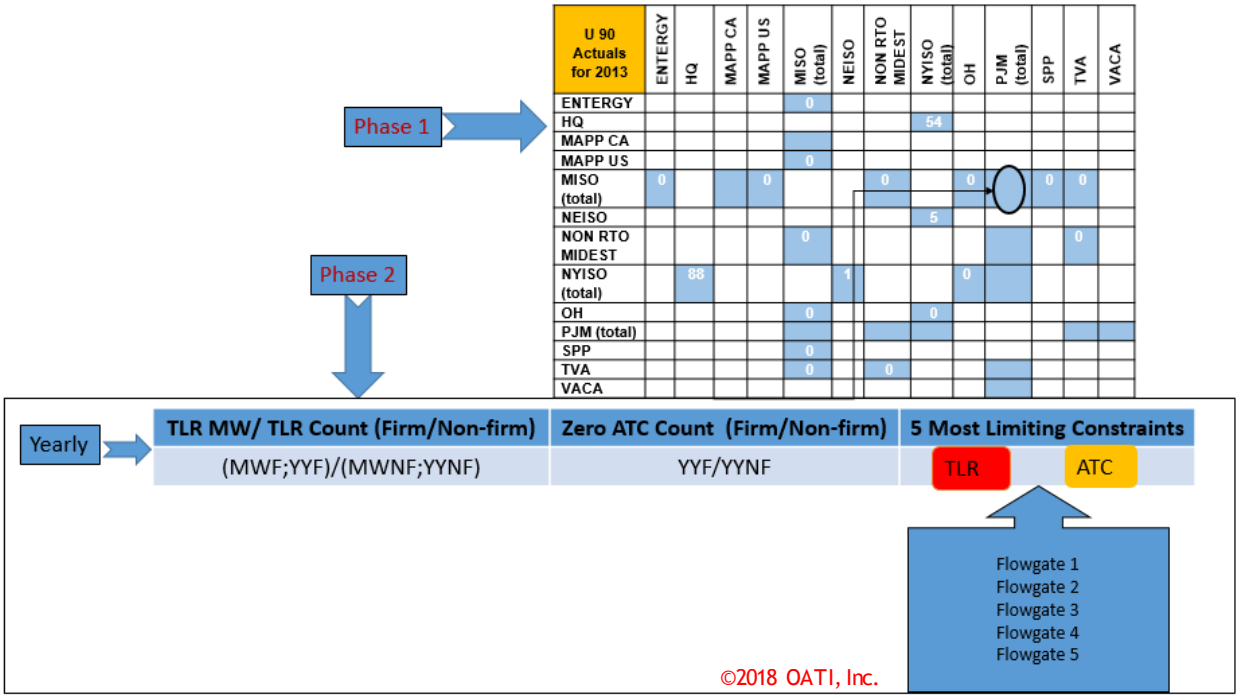
4.6 Congestion Analysis Summary Metrics

The study will summarize congestion for each interface based on Phase 1 actual flow metrics and Phase 2 metrics including OASIS, TLR, and Market metrics.

4.6.1 Congestion Analysis Summary for Eastern Interconnection

The following figure is a template that summarizes the congestion analysis combining Phase 1 and Phase 2 results for the interfaces.

Figure 4-1: Congestion Analysis Summary for Eastern Interconnection



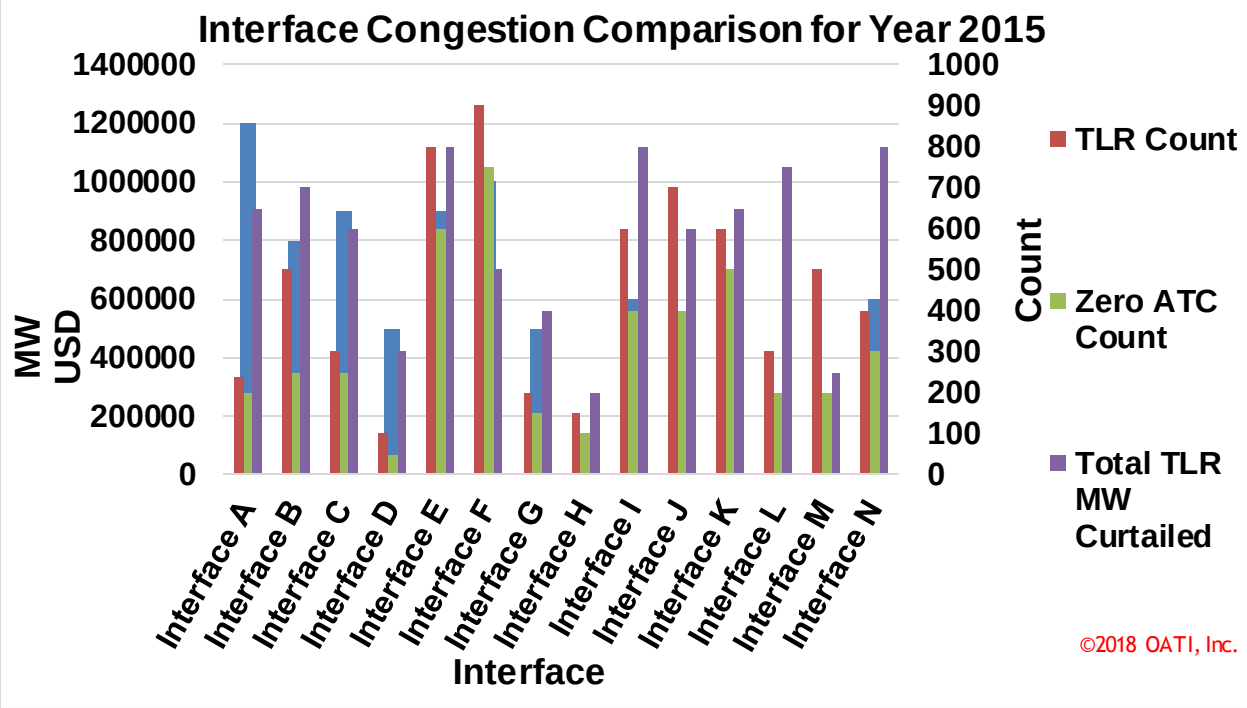
The transmission utilization metrics U90 was developed as part of the Phase 1 study work and it indicates number of times actual flow on an interface exceeded 90% of flow limit. It should be noted that U90 metrics from the Phase 1 provide limited information with respect to congestion on an interface. In the Phase 1 study, the U90 metric was not populated for many of the interfaces due to unavailability of data. The U90 count is zero for the majority of interfaces where U90 metrics were calculated. A U90 count of zero means that RT flows on these interfaces never exceeded 90% of the TTC. This information alone is not enough to confirm whether congestion exists on an interface. In order to visualize and quantify congestion

on an interface the following Phase 2, congestion metrics must be examined along with actual flows:

- Zero ATC count.
- TLR count and total TLR curtailment.
- Potential congestion cost paid.

A graph such as the one shown below will be used to compare congestion on all interfaces considering the different factors indicated above.

Figure 4-2: Template for Interface Congestion Comparison for Year 2015



The following table will provide top five most limiting flowgates for each interface due to ATC and TLR.

Table 4-12A: Top Five Most Limiting Flowgates for an Interface and Limitations Summary

	Top five Flowgates	
Interfaces	ATC	TLR
A	Flowgate 1	
	Flowgate 2	
	Flowgate 3	
	Flowgate 4	
	Flowgate 5	
B		

	Top five Flowgates	
Interfaces	ATC	TLR
C		

The above table of the five most limiting flowgates due to TLR and ATC will help to identify the cause and location of the major constraints associated with each of these interfaces.

The following table will provide top five most limiting flowgates for each sub-region due to ATC/AFC, TLR, and Market limitations.

Table 4-12B: Top Five Limiting Flowgates for Sub-Region with Limitation

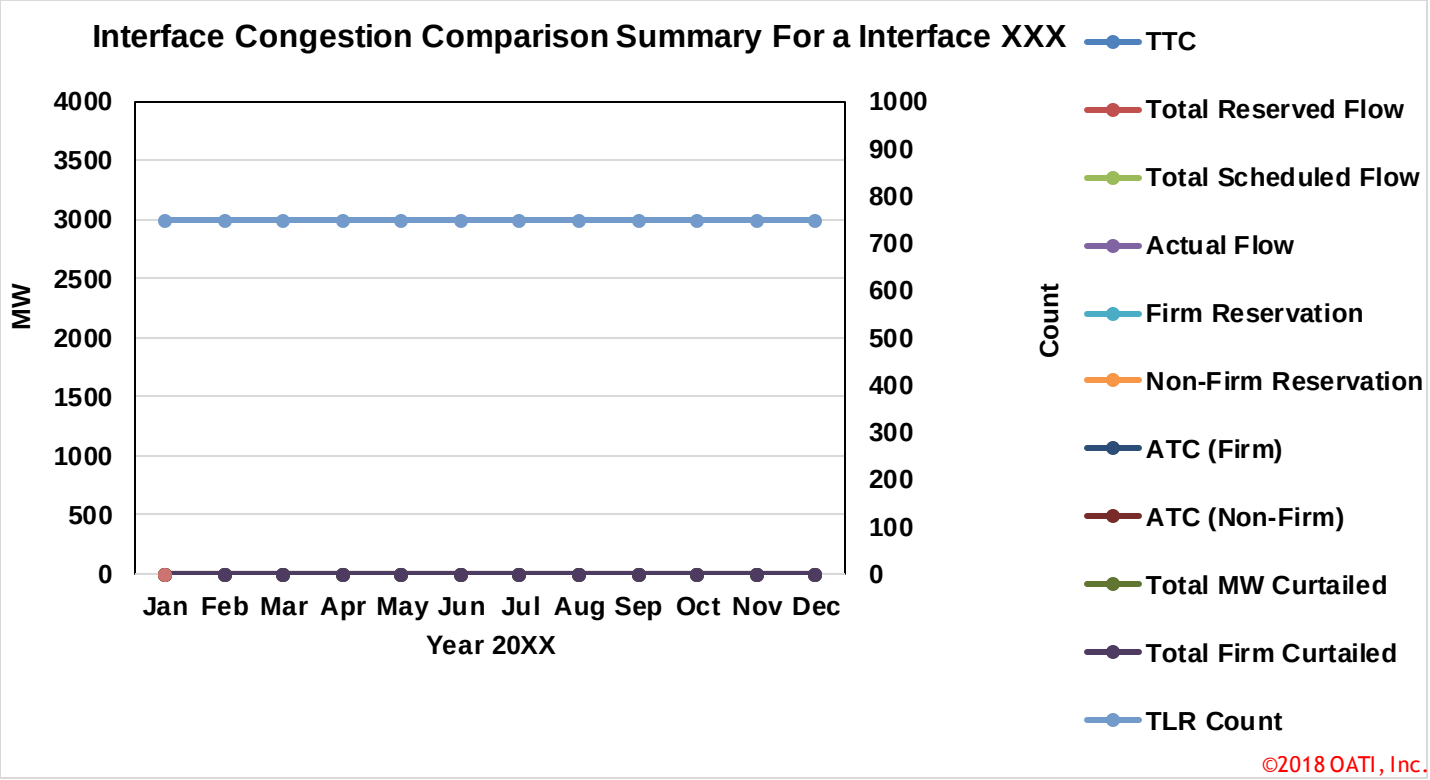
	Top Five Flowgates		
Sub-Region	ATC	TLR	Market
A	Flowgate 1		
	Flowgate 2		
	Flowgate 3		
	Flowgate 4		
	Flowgate 5		
B			
C			

The above table of the five most limiting flowgates due to TLR, ATC, and Market limitations will help to identify the cause and location of the major constraints associated with each sub-region.

4.6.2 Congestion Analysis Summary by Interfaces

The following is a graph template that summarizes the congestion comparison for an interface. The template is based on fictitious data to illustrate various metrics that will be included in this summary graph. Similar graphs will be developed for each interface in the eastern Interconnection.

Figure 4-3: Congestion Comparison Summary for an Interface



* -- Only available for marked interface.

The table below will provide the five most limiting flowgates due to AFC and TLR for an interface.

Table 4-13: Top Five Limiting Flowgates for the Interface

AFC	TLR
Flowgate XX	

The following congestion summary table will provide yearly totals for various congestion metrics.

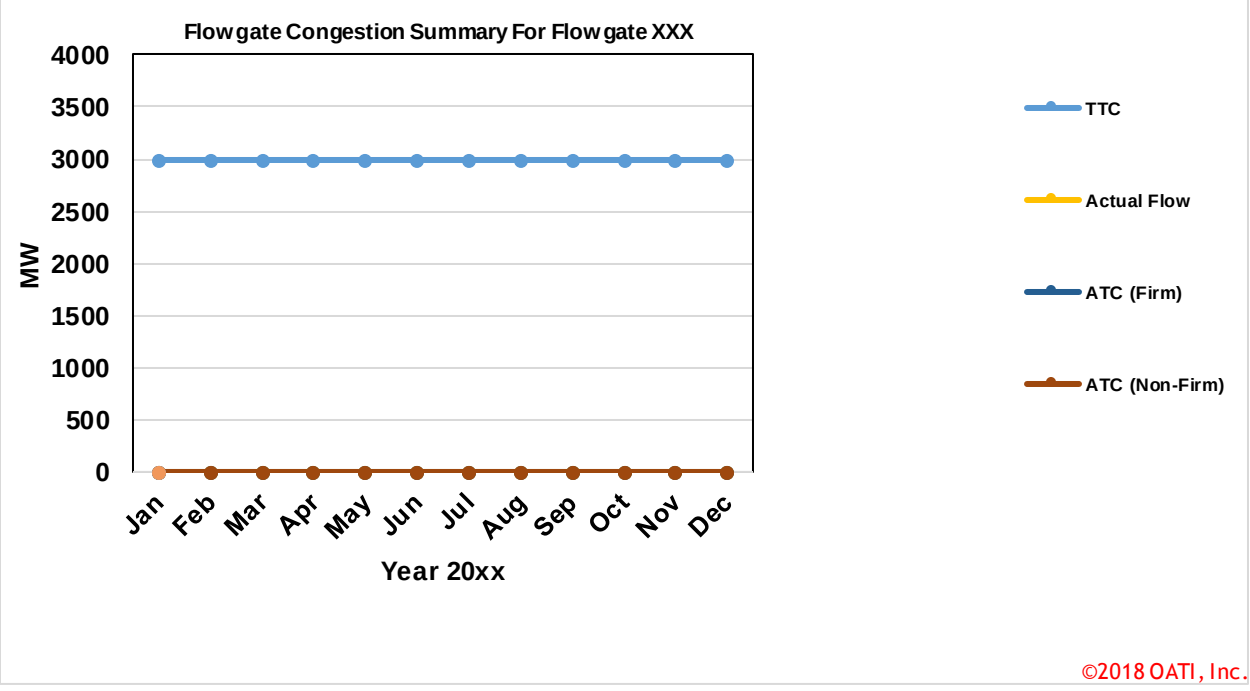
Table 4-14: Yearly Congestion Summary Table for the Interface

Total TLR Count	
Total Zero ATC Count	
Total Number of Flowgate Constrained by TLR	
Total Number of Flowgate Constrained by Market	
Total Number of Flowgate Constrained AFC	

4.6.3 Congestion Analysis Summary by Flowgate

The following is a graph template that summarizes the congestion summary for a Flowgate. The graph provided below is based on fictitious data to illustrate the methodology and template development. Similar graphs will be developed for most limiting five flowgates in each sub-region.

Figure 4-4: Congestion Analysis Summary for a Flowgate



The following congestion summary table will provide yearly totals for various congestion metrics for the flowgate.

Table 4-15: Yearly Congestion Summary Table for the Flowgate

Total TLR Count	
Total Zero ATC Count	
Binding Constraint Count	
Total Congestion Cost	

4.7 Congestion Analysis Additional Graph and Metrics Templates

The following are templates of additional graphs and metrics that will be generated as part of this study.

4.7.1 Template for OASIS Reservation

A TRU metric from OASIS reservation data will be developed. A TRU 90 count of zero means that RT flows on these interfaces never exceeded above 90% of the TTC. The following table provides the total yearly count of TRU 90 for an interface.

Table 4-16: Transmission Reservation Utilization Count Based on 90% of TTC (TRU 90) Metrics Template for Interfaces

Total Yearly TRU 90 Count	HQ	MH-SPC	MAPP US	MISO	ISONE	NON RTO MIDEST	NYISO	IESO	PJM	SPP	TVA	VACAR	FRCC	SOCO
HQ														
MH-SPC														
MAPP US														
MISO														
ISONE														
NON RTO MIDEST														
NYISO														
IESO														
PJM														

Total Yearly TRU 90 Count	HQ	MH-SPC	MAPP US	MISO	ISONE	NON RTO MIDEST	NYISO	IESO	PJM	SPP	TVA	VACAR	FRCC	SOCO
SPP														
TVA														
VACAR														
FRCC														
SOCO														

Similarly, there will be an additional table created for transmission reservation utilization metrics for 75% of the TTC (TRU 75).

4.7.2 Template for OASIS ATC Data

A metric will be reported for a total zero ATC count on an interface. These metrics are based upon yearly totals.

The following table will provide yearly zero ATC count on an interface.

Table 4-17: Template for OASIS Yearly ATC Zero Count for Interfaces

Zero ATC Count	HQ	MH-SPC	MAPP US	MISO	ISONE	NON RTO MIDEST	NYISO	IESO	PJM	SPP	TVA	VACAR	FRCC	SOCO
HQ														
MH-SPC														
MAPP US														
MISO														
ISONE														
NON RTO MIDEST														
NYISO														
IESO														
PJM														
SPP														
TVA														
VACAR														
FRCC														
SOCO														

The above table will be generated for both firm and non-firm ATC.

A metric will be reported for schedules above 100% of the TTC on an interface. These metrics are based upon yearly totals.

The following table will provide yearly total schedules above 100% of the TTC on an interface.

Table 4-18: Schedule Count Above 100% of the TTC

Schedule Count above 100% of TTC for 2015Schedule count above 100% of TTC for 2015	HQ	MH-SPC	MAPP US	MISO	ISONE	NON RTO MIDEST	NYISO	IESO	PJM	SPP	TVA	VACAR	FRCC	SOCO
HQ														
MH-SPC														
MAPP US														
MISO														
ISONE														
NON RTO MIDEST														
NYISO														
IESO														
PJM														
SPP														
TVA														
VACAR														
FRCC														
SOCO														

The following graph will provide comparison of zero ATC count on interfaces. This comparison graph table will be generated for both firm and non-firm ATC.

Figure 4-5: Template for Comparison of Zero ATC Count for Various Interfaces

The following comparison graph provide yearly count of zero ATCs for all interfaces.

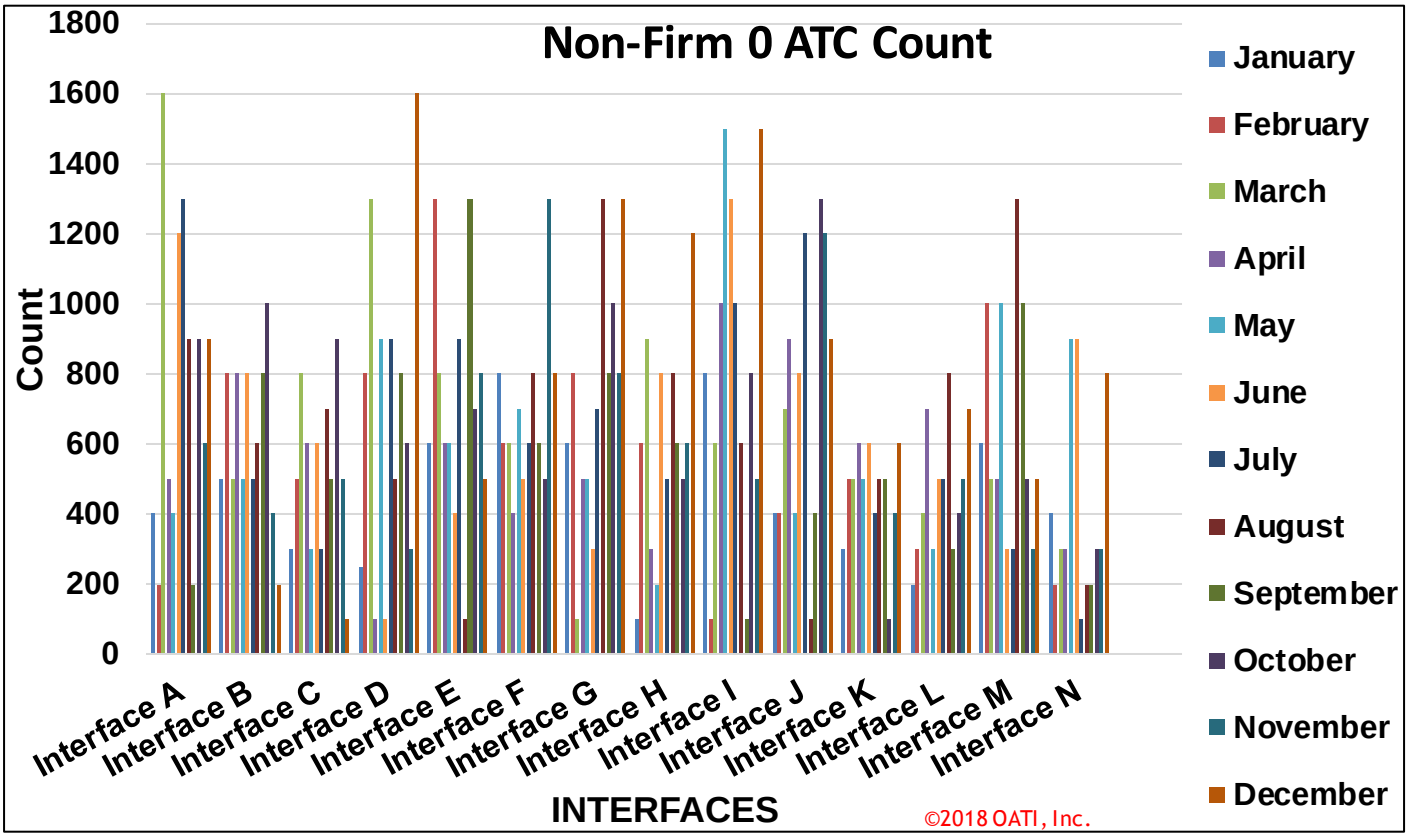
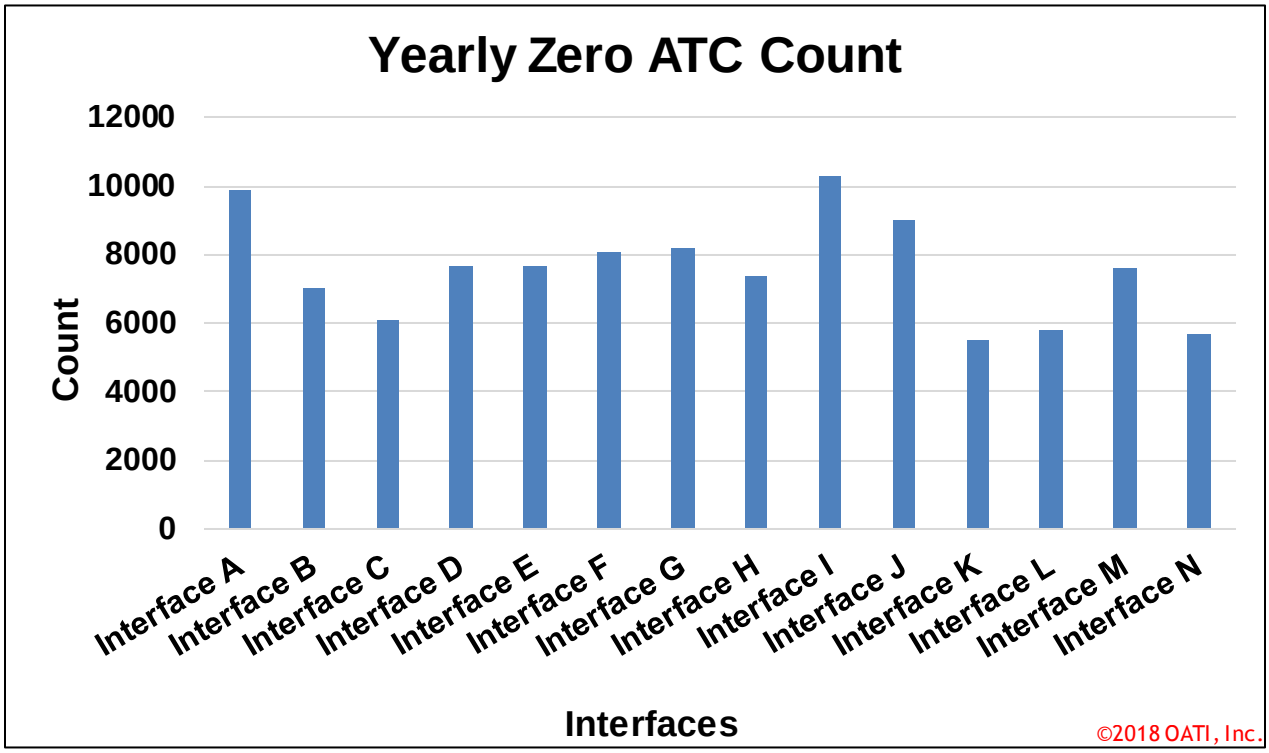


Figure 4-6: Template for Yearly Zero ATC Count



4.7.3 Template for IDC Data

TLR metrics will be developed from IDC data. The following table will provide yearly TLR count on an interface.

Table 4-19: Template for TLR Count by Interface

Yearly TLR Count	HQ	MH-SPC	MAPP US	MISO	ISONE	NON RTO MIDEST	NYISO	IESO	PJM	SPP	TVA	VACAR	FRCC	SOCO
HQ														
MH-SPC														
MAPP US														
MISO														
ISONE														
NON RTO MIDEST														
NYISO														
IESO														
PJM														

Yearly TLR Count	HQ	MH-SPC	MAPP US	MISO	ISONE	NON RTO MIDEST	NYISO	IESO	PJM	SPP	TVA	VACAR	FRCC	SOCO
SPP														
TVA														
VACAR														
FRCC														
SOCO														

The above table will be generated for both firm and non-firm count of TLRs issued in a year.

In addition, above table will be regenerated for yearly TLR MW curtailment for the interfaces.

4.7.4 Template for Market Data

A Market metrics will be developed from Market data.

4.7.4.1. Templates for Sub-region Market Data

Table 4-20: Template for Sub-Regional Market Congestion Metric for Shadow price (Seasonal and Yearly)

	Average Shadow Price or Weighted Average of Shadow Price	%(Congestion Cost/Total Market Cost)
Sub-Region	$ XX	YY.YY

Table 4-21: Five Most Limiting Constraints for Sub-Region based on Binding Constraint Count (Seasonal and Yearly)

Binding Constraints Ranking	Binding Constraints Name	Market Binding Hour Count	% of Binding hours
1	Constraint 1	XX	YY.YY
2	Constraint 2	XX	YY.YY
3	Constraint 3	XX	YY.YY
4	Constraint 4	XX	YY.YY
5	Constraint 5	XX	YY.YY

Table 4-22: Five Most Limiting Constraints for Sub-Region based on Congestion Cost (Seasonal and Yearly)

Binding Constraints Ranking	Binding Constraints Name	Congestion Cost	% of Congestion Cost (Based on Total Regional Congestion Cost)
1	Constraint 1	$ XX	YY.YY
2	Constraint 2	$ XX	YY.YY
3	Constraint 3	$ XX	YY.YY
4	Constraint 4	$ XX	YY.YY
5	Constraint 5	$ XX	YY.YY

4.7.4.2. Templates for Market-to-Market Data

The following is an example of the market flow metrics for PJM sub-region. In this example, during an hour a PJM flowgate is constrained and binding in PJM, then market flow impact is identified if binding constraint is a Market to Market JCM flowgate.

Table 4-23: Average Shadow Price (Only Included PJM Owned JCM Flowgates)

	Weighted Average Shadow Price for the Binding Constraints
PJM and MISO Market Flow Impact to PJM Market	$XX

Table 4-24: 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
1	Constraint 1	XX	YY.YY
2	Constraint 2	XX	YY.YY
3	Constraint 3	XX	YY.YY
4	Constraint 4	XX	YY.YY
5	Constraint 5	XX	YY.YY

Table 4-25: Five Most Limiting PJM Owned JCM based on RT Congestion Cost due to Market Flow Impacts

Binding Constraints Ranking	Binding Constraints Name	Congestion Cost	% of Congestion cost (based on total RT congestion cost)
1	Constraint 1	$ XX	YY.YY
2	Constraint 2	$ XX	YY.YY
3	Constraint 3	$ XX	YY.YY
4	Constraint 4	$ XX	YY.YY
5	Constraint 5	$ XX	YY.YY

5. Data Needs and Requirements

Data will be collected from publicly available data sites. In some cases, where the historical data is not directly available on the OASIS, the OASIS operator will be contacted to provide the data in an electronic format. Table 5-1 provides a summary of the data that is required for the Phase 2 congestion study:

Table 5-1: OASIS Data Requirements for the Phase 2 Study

Data Type	Data needs
Flowgate AFCs	Both daily firm and hourly non-firm. Maximum 10 to 20 most limiting flowgate will be considered for each sub-region as recommended by industry advisors.
Effective ATC and Limiting Constraint (Flowgate)	For all sub-regional interfaces.

Table 5-2 provides a summary of the data that will be collected and/or provided by the ISO/RTO for Phase 2 study:

Table 5-2: OASIS Interface Data Collection

Interface	Metrics			Data Source
	Reservations	ATC	TTC	
ISONE - NYISO	No	No	YES	ISONE
ISONE - HQ	No	No	YES	ISONE
HQ-ISONE	No	No	YES	ISONE
NYISO-ISONE	No	Yes	Yes	NYISO website
NYISO-PJM	No	Yes	Yes	NYISO website
PJM-NYISO	No	Yes	Yes	PJM
NYISO-OH	No	Yes	Yes	NYISO website
OH-NYISO	No	Yes	Yes	NYISO website
NYISO-HQ	No	Yes	Yes	NYISO website
HQ-NYISO	No	Yes	Yes	NYISO website
MISO-PJM	YES	YES	YES	MISO
PJM-MISO	YES	YES	YES	PJM
Non RTO Midwest-MISO	YES	YES	YES	LGEE
MISO-Non RTO Midwest	YES	YES	YES	MISO
TVA-MISO	YES	YES	YES	TVA
MISO-TVA	YES	YES	YES	MISO
MISO-SOCO	YES	YES	YES	MISO
SOCO-MISO	YES	YES	YES	SOCO
MISO-SPP	YES	YES	YES	MISO

Interface	Metrics			Data Source
	Reservations	ATC	TTC	
MISO-MH_SPC	YES	YES	YES	MISO
MH_SPC-MISO	YES	YES	YES	MH_SPC
MISO-MAPP US	YES	YES	YES	MISO
MAPP US-MISO	YES	YES	YES	MAPP US
MISO-IESO	YES	YES	YES	MISO
IESO-MISO	YES	YES	YES	MISO
MISO-PJM	YES	YES	YES	MISO
PJM-MISO	YES	YES	YES	PJM
Non RTO Midwest-PJM	YES	YES	YES	LGEE
PJM-Non RTO Midwest	YES	YES	YES	PJM
TVA-PJM	YES	YES	YES	TVA
PJM-TVA	YES	YES	YES	PJM
PJM-NYISO	YES	YES	YES	PJM
NYISO-PJM	YES	YES	YES	NYISO
PJM-VACAR	YES	YES	YES	PJM
VACAR-PJM	YES	YES	YES	VACAR
MISO-SOCO	YES	YES	YES	MISO
SOCO-MISO	YES	YES	YES	SOCO
TVA-SOCO	YES	YES	YES	TVA
SOCO-TVA	YES	YES	YES	SOCO
VACAR-SOCO	YES	YES	YES	VACAR
SOCO-FRCC	YES	YES	YES	SOCO
FRCC-SOCO	YES	YES	YES	FRCC
SPP-MISO	YES	YES	YES	SPP
SPP-MAPP US	YES	YES	YES	SPP
MAPP US-SPP	YES	YES	YES	MAPP US
SPP-ERCOT	NO	NO	NO	N/A
ERCOT-SPP	NO	NO	NO	N/A
SPP-AZ NM SNV	NO	NO	NO	N/A
AZ NM SNV -SPP	NO	NO	NO	N/A
SPP-RMPA	NO	NO	NO	N/A
RMPA -SPP	NO	NO	NO	N/A

Table 5-3: OASIS Flowgate Data Collection

Sub-Region	AFC Metrics	Data Source	Comment
ISONE	No	None	

Sub-Region	AFC Metrics	Data Source	Comment
NYISO	YES	NYISO	OATI will include Proxy flowgate, provided by NYISO.
MISO	YES	MISO	MISO to provide limiting flowgates.
PJM	YES	PJM	PJM to provide limiting flowgates.
SOCO	NO	NA	ATC based Transmission Provider.
SPP	YES	SPP	SPP to provide limiting flowgates.
Non RTO Midwest	YES	Non RTO Midwest	
IESO	NO	NA	
TVA	YES	TVA	
VACAR	YES	VACAR	
FRCC	NO	NA	ATC based Transmission Provider.

5.1 Market Data Collection

Data will be collected from market operators.

Table 5-4 provides a summary of the data that is required for the Phase 2 congestion study:

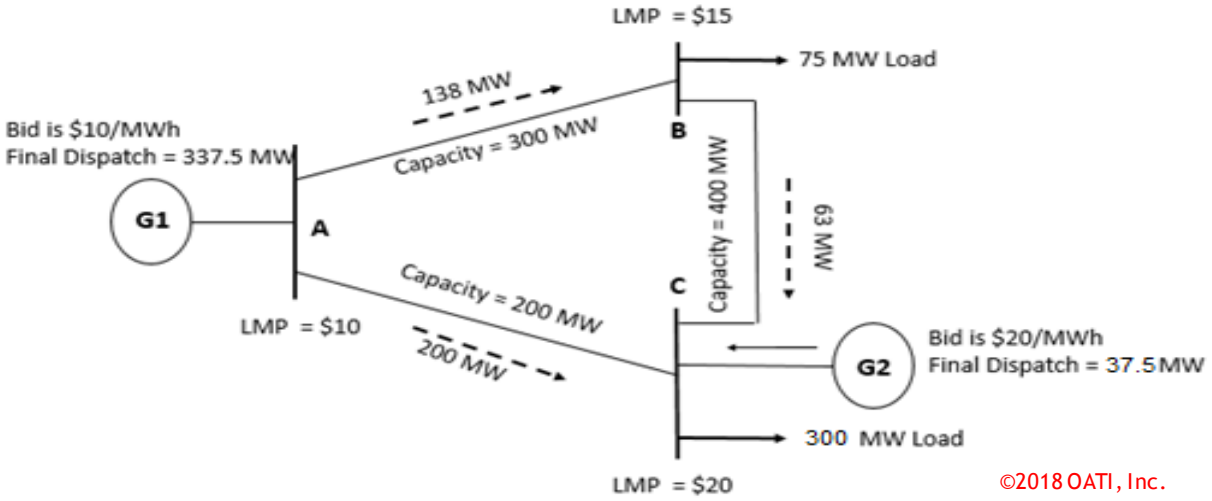
Table 5-4: Market Data Requirements for the Phase 2 Study

Data Type	Data Needs
RT-Binding Constraints, Market to Market Binding Constraints, RT market flow, monitor name, RT congestion cost, total market cost (energy + congestion), and Shadow Prices.	Hourly

5.1.1 Market Data Definition and Data Need for the DOE 2016 Historical Congestion Analysis

The following example provides a three bus market LMP calculation to illustrate shadow price congestion cost calculation.

This three bus LMP example is taken from CAISO's LMP educational class document. http://www.caiso.com/docs/2004/02/13/200402131607358643.pdf



The above example shows a single binding constraint AC with line limit of 200 MW.

Shadow Price Calculation

If total capacity of line AC were to increase by 1 MW to supply 1 MW load increase at C, then

1.) Reduction in higher priced unit of G2 (change of -1.5 MW)

2.) Increase in lower priced unit of G1 (change of +1.5 MW)

Change in total system cost = -1.5 MW * $20/MWh+1.5 MW * $10/MWh
= -$15/h

Shadow price = (-$15/h)/ (200 MW – 201 MW) = +$15/MWh ..... (1)

1) Congestion cost from binding constraint AC

Congestion cost = shadow price of AC * flow on AC

Total Congestion Cost = $15/MWh * 200 MW = $ 3000 ..... (2)

2) Total System Congestion Cost (Calculation 1)

Total Market Charges

1.) At Load Bus B = $15 * 75 MW = $ 1125

2.) At Load Bus C = $20 * 300 MW = $ 6000

Total Market Charges (cost) = $(1125+6000) = $ 7125 ..... (3)

Note: it should include load charges and bilateral transaction charges

Generation Credits

1.) At Bus A = $10 * 337.5 MW = $ 3375

2.) At Bus C = $20 * 37.5 MW = $ 750

Total = $ (3375 + 750) = $4125

Total system congestion cost = $ (4125 - 7125) = -$3000 ..... (4)

It should be noted that with single binding constraint, system congestion cost (4) is same as the Congestion cost from binding constraint AC (2)

3) Total System Congestion Cost (Calculation 2)

Congestion Rent

1.) Congestion rent on AB
= 137.5MW * $ (15-10) = $687.5

2.) Congestion rent on AC = 200 MW * $ (20-10) = $2000

3.) Congestion rent on BC = 62.5 MW * $ (20-15) = $312.5

Total Congestion Rent (Congest cost) = $ 3000 …… (5)

It should be noted that with single binding constraint, system congestion cost (5) is same as the Congestion cost from binding constraint AC (2).

The following table provides a summary of the data that will be collected and/or provided by the RTO/or market operators for the Phase 2 study:

Table 5-5: Data Collection

Market Data	Data Collected	Comments
MISO	RT Binding Constraints, Market to Market Binding Constraints, RT market flow, monitor name, RT congestion cost, total market cost (energy + congestion), and Shadow Prices.	Data will be collected from MISO.
PJM	RT Binding Constraints, Market to Market Binding Constraints, RT market flow, monitor name, RT congestion cost, total market cost (energy + congestion), and Shadow Prices.	Data will be collected from PJM.
NYISO	RT Binding Constraint, shadow price, hour, congestion cost, total market cost (energy + congestion).	Data will be collected from NYISO.
ISONE	RT Binding Constraint, shadow price, hour, total congestion cost due to binding constraint, total market cost (energy + congestion).	Data will be collected from ISONE.
SPP	RT Binding Constraints, Market to Market Binding Constraints, RT market flow, monitor name, RT congestion cost, total market cost (energy + congestion), and Shadow Prices.	Data will be collected from SPP.

5.2 IDC Data Collection

Table 5-6 provides a summary of the data that is required from NERC IDC for the Phase 2 study:

Table 5-6: IDC Data Requirements for the Phase 2 Study

Data Type	Data Needs
Schedules/Tags.	Complete tag data.
TLR data.	Flowgate, curtailed schedules including tag information (source and sinks).
Actual flows on TLR Flowgate.	Hourly.

5.3 Actual Flow Data

Each BA and Market Operator will be contacted to collect the actual flow on BA to BA ties and possibly some of the most commonly curtailed Flowgates.