1.1. Historic & Future Transmission Congestion

As part of the System & Resource Outlook, the NYISO develops estimates of historic and projected transmission system congestion. Transmission congestion limits the economic transfer of energy between generation resources and demand, creates inefficient generation commitment and dispatch, causes generation curtailment, and increases the cost of electricity when lower variable cost resources cannot be delivered to consumers. It is important to understand and quantify existing system resources, the expected buildout of renewable generation to comply with State mandates, other generation resources, and, as a result, the past, existing and projected transmission congestion patterns, including the identification of specific congested paths, impacting the New York Control Area.

The two metrics used to quantify the impact of specific congested transmission elements are demand congestion and constrained hour count. The demand congestion value of a transmission constraint represents the congestion component of the LBMP paid by NYCA load (sum of the total zonal loads) and is defined as the shadow price[1] of each constrained element multiplied by the load affected with consideration for zonal Generator Shift Factors (GSF). The formula used to calculate the demand congestion value of a transmission constraints is as follows:

$$\boldsymbol{Constraint\ Demand\ Congestion} = \sum_{Hour\ h}^{8760} \sum_{Zone\ i}^{Zone\ K} Shadow\ Price_{i,h} \times Zone\ GSF_{i,h} \times Zone\ Load_{i,h}$$

The constrained hour count metric represents the annual number of hours that a specific transmission constraint is active.

Historic actual transmission congestion metrics for constraints that were active in the NYISO's market are currently posted publicly on a quarterly basis to the NYISO website[2]. This data serves as the basis for the historic transmission congestion analysis. For the historic five year period, individual transmission constraints are compiled and reported in descending order according to

[1] Shadow price is a term used in economic theory to describe the monetary value of goods or services that are difficult to calculate and lack a clear market signal. In power markets where optimization engines determine security constrained economic dispatch, shadow prices are defined for transmission constraints and represent the production cost savings achieved by relaxing the constraint limit by 1 MW. Shadow prices are an indicator of the economic impact that binding transmission constraints have on a power market. For the demand congestion metric, by multiply the shadow price by zonal GSF and zonal load, the economic impact of transmission constraints can be separated into the impact on specific NYISO zones.

[2] See https://www.nyiso.com/ny-power-system-information-outlook/ > Congested Elements Report

their demand congestion value. The NYISO assesses and identifies transmission constraint groupings based on the individual rankings and proximity of congested elements.

Using the simulation results from each of the Reference Cases (Baseline, Contract, & Policy), the NYISO will compile, rank, and group the 20-year projected transmission constraints. Projected transmission congestion is then combined with congestion data from the historic analysis. The congested elements for the full twenty-five year period (both historic (5 years) and projected (20 years)) are ranked in descending order based on trends in the calculated present value of demand congestion for further assessment. The ranking is then adjusted to exclude any element when future system changes produce a significant declining trend in congestion over such congested element in later years of the study period. Likewise, elements with significant increasing trend in congestion could also be evaluated. The discount rate to be used for the present value analysis is the current weighted average cost of capital for the New York Transmission Owners.

The NYISO performs these computations for each System & Resource Outlook study and reviews them with the ESPWG.

1.2. Congestion Relief Analysis

The operational and economic impact of transmission congestion on the New York State Transmission System can be quantified through congestion relief analyses. With the projected potential future constraints and groupings initially identified for the Reference Case simulations, additional simulations will be performed to further analyze transmission paths as warranted. The NYISO will coordinate through ESPWG to identify the Reference Cases and specific constraints for study.

To perform the constraint relief analysis, selected individual or groups of congested elements are iteratively relieved independently by relaxing their respective limits. For each binding constraint that has been relaxed, the production cost model is re-run to produce results that reflect the system conditions that would occur were that transmission element not congested. By comparing this information with the associated Reference Case, the economic and operational impact of the constraint can be determined. The metrics used to evaluate the impact may include production cost, demand congestion, LBMP, and energy deliverability.

Another part of the constraint relief analysis will determine if any of the congested elements must be grouped with other elements, depending on whether new elements appear as limiting with significant congestion when a primary element is relieved.

1.3. Renewable Generation Pocket Formation

When specific areas of the New York State Transmission System contain one or more constrained transmission elements, preventing renewable energy resources from dispatching based on their availability, a renewable generation pocket exists. As part of the System & Resource Outlook, the NYISO will use the results from the future transmission congestion projection in the Reference Case(s) to identify, define, quantify, and visualize the potential renewable pockets formed. In consultation with the stakeholders via ESPWG, the NYISO will identify the Reference Case(s) simulation year(s) and the potential need for seasonal assessments for renewable pocket determination in each Outlook study.

To define a renewable generation pocket, the NYISO will first identify the specific renewable generators that experience curtailment throughout the study period being analyzed. Where needed, a seasonal analysis well be conducted to account for factors specific to certain resource technologies. The GE-MAPS generation shift factor report (YRGSF) will be used to identify the specific transmission constraints directly contributing to the curtailment of renewable generation resources. This can include multiple lines and multiple impacted generators from each congested transmission line. The NYISO will qualitatively and, if warranted by the degree of the constraint, quantitatively collect transmission constraints causing curtailed generation and other electrically similar transmission paths into a grouping to form a renewable generation pocket. The NYISO will report specific transmission paths comprising each renewable generation pocket. Additionally, the NYISO will produce a graphical representation of the identified renewable pockets plotted on a New York State map.

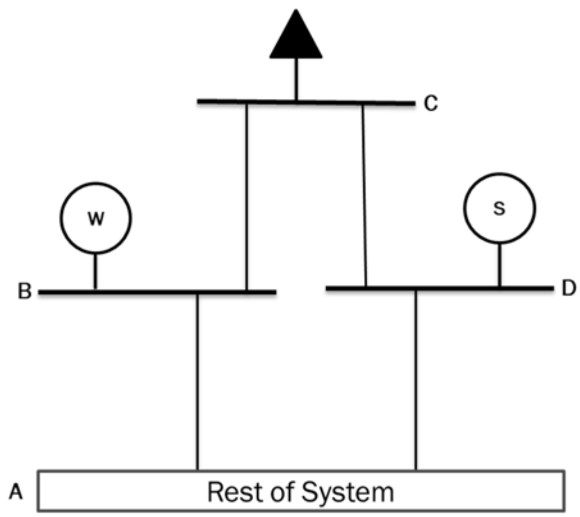
1.4. Energy Deliverability Analysis

The NYISO will evaluate the relationship between transmission congestion and the operation of resources throughout the system utilizing an energy deliverability metric. This metric will consider potential seasonal factors and account for the respective fuel availability of each Resource type, including wind, solar, and water, and quantify the energy projected to be produced by such Resource considering the impact of applicable local, statewide, and interregional transmission constraints as compared to the total amount of energy it would otherwise produce absent transmission constraints. The formulation used to determine energy deliverability for each resource on the system is as follows:

$$Energy\ Deliverability\ (\%) = \frac{Energy\ Production}{Energy\ Production\ Capability}\ x\ 100$$

Data from production cost simulations will be used to quantify the collective impact of resources on energy deliverability at locations on the system that are identified as being constrained. Generation shift factors, which quantify the incremental impact of generation on the flow of transmission facilities, will be used to identify groupings of generators with similar energy deliverability impacts. Information on the collective impact of transmission congestion on resource groupings will be provided.

Shown below is an illustrative example system with a load, wind generator, and solar generator interconnected by four transmission lines and 3 buses. The example network is assumed to connect to a larger bulk power system.



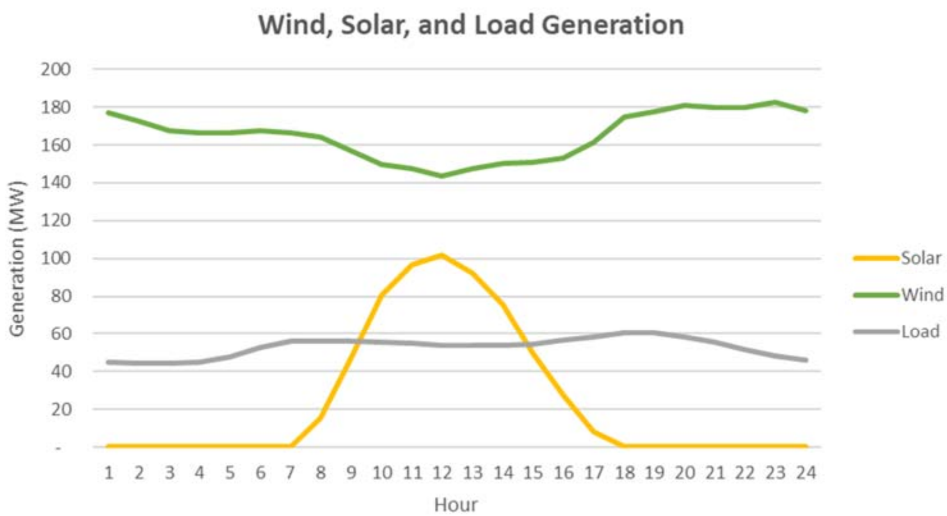
Parameter	Value
Wind "W" Capacity	500 MW
Solar "S" Capacity	250 MW
Load	100 MW
Line Limits	100 MW

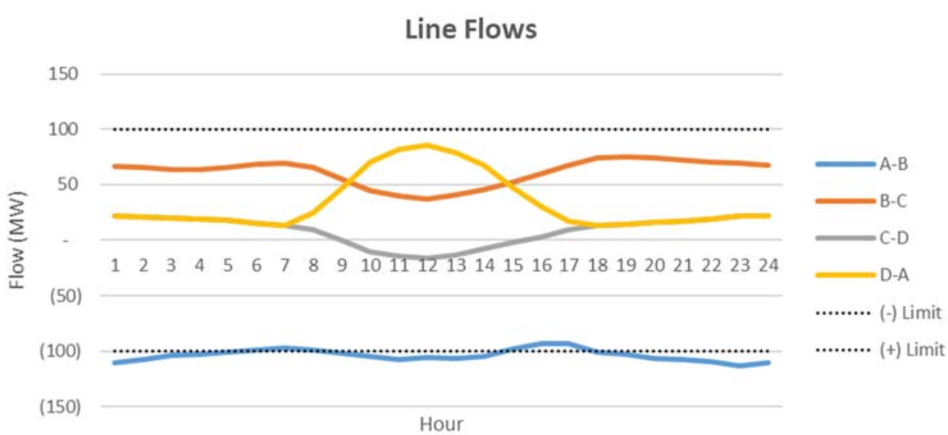
Transmission line flows on the example system are dictated by the electrical impedances of the transmission lines, which are assumed to be equal in this example. In this example, assuming that bus "A" acts as the reference point, if the wind generator at bus "B" produced 1 MW, 0.75 MW would flow on line "B-A" and 0.25 MW would flow on lines "B-C", "C-D", and "D-A". The full set of relationships between generators and the transmission system can be captured through a generation shift factor matrix. The GSF matrix for this example system is show below:

GSF Matrix	A-B	B-C	C-D	D-A
Wind	-0.75	0.25	0.25	0.25
Solar	-0.25	-0.25	-0.25	0.75
Load	0.5	0.5	-0.5	-0.5

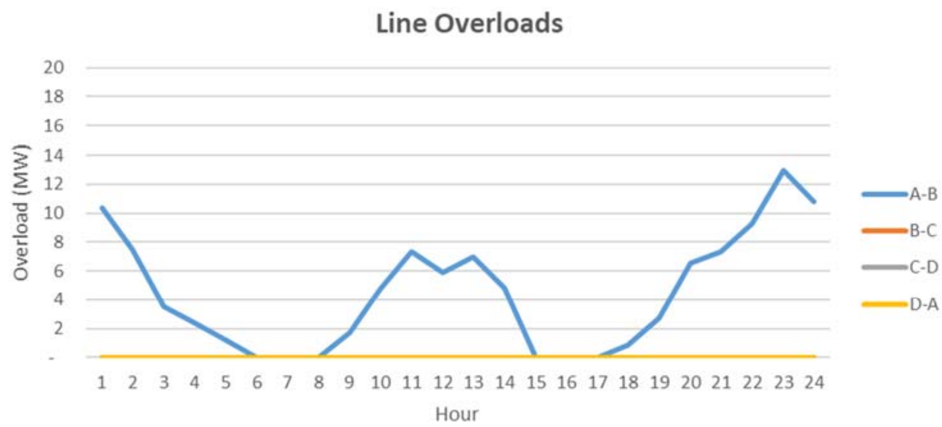
Note that GSF values must be between the values of 0 and 1, positive or negative, depending on the defined direction of the transmission line.

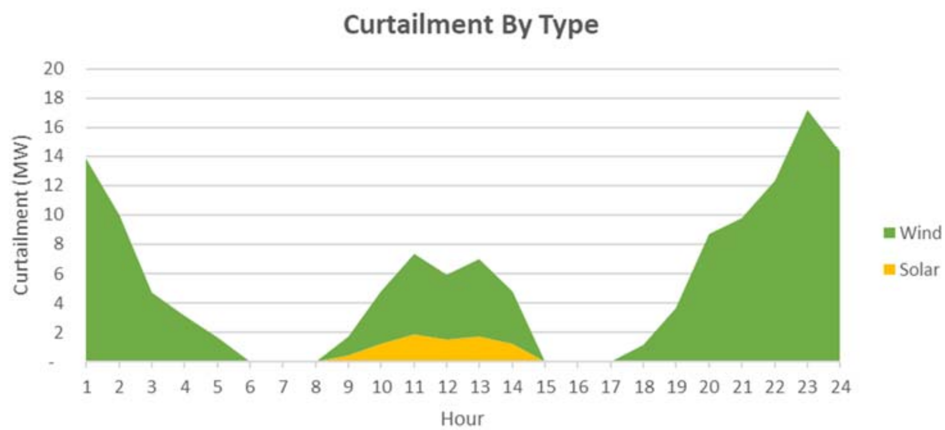
With the example system defined, a representative day of generator and load dispatch values can be applied to evaluate the transmission flows compared to their limits. This allows transmission constraints and generator curtailments to be identified. The charts below show an example 24 hour period of generator dispatch and transmission line flows.





The charts show the interaction between the transmission system and the varying dispatch patterns of these generators.. For the "A-B" transmission line, it can be noted that the flow exceeds the line limit of 100 MW. As a result, absent upgrades, the generators contributing to the line limit violation must be curtailed to reduce the flows to fall within operating limits. The charts below quantify line "A-B" overload levels and the required curtailment levels of the wind and solar generators where the current infrastructure would be sufficient to keep the transmission system within its limits.





Note that, for this example system, if only one of the technology types is producing energy at the time of line overloads, the amount of curtailment necessary to remedy line overloads will exceed the overload amount. This is due to a particular generators shift factor relationship to the overloaded line. The interrelationship between the specific unit or units operating in a given period and the required level of curtailment to bring the system within criteria will be captured.

Using the 24-hour period from this example, the energy deliverability metric can be calculated for each of the technology types. The table below shows the potential energy, curtailed energy, actual energy, and energy deliverability metrics relevant to this example.

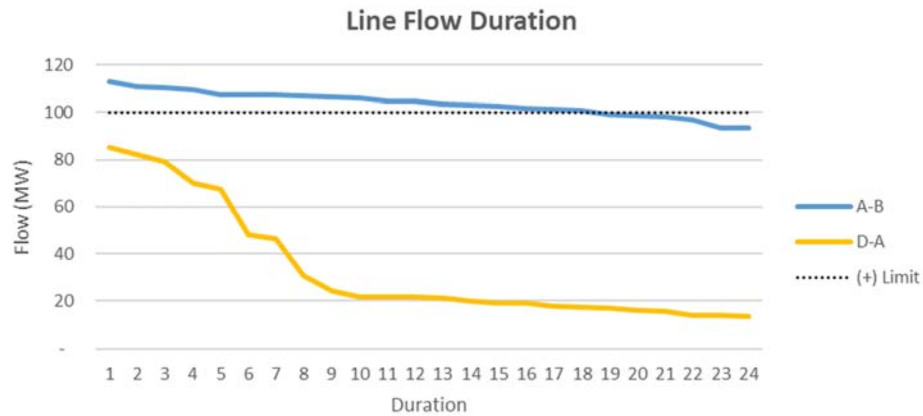
Energy (MWh)	Potential	Curtailment	Actual	Energy Deliverability (%)
Solar	595	8	587	99%
Wind	3,963	124	3,839	97%

The potential energy metric shows the total amount of energy that each resource could produce absent transmission constraints. The actual energy metric projects the energy each resource will produce considering the curtailed energy metric, which will be impacted by applicable local, control area-wide, and interregional transmission constraints. Where warranted, seasonal impacts will be quantified.

Where applicable, the energy deliverability metric may also include quantification of the collective impact of Resources at locations on the system that are identified as being constrained, in whole or in part. For example, if the sample system presented were identified as a renewable pocket, these metrics can be calculated and presented to produce the overall impact on the resources taken together. The table below shows the calculation for a renewable generation pocket encapsulating the example system.

Energy (MWh)	Potential	Curtailment	Actual	Energy Deliverability (%)
Pocket	4,558	132	4,426	97%

Where available, resource areas that have been identified will also include such additional information resulting from the study analysis concerning capability remaining on the transmission system to support energy deliverability. The metric may be expressed as a percentage of such total amount of energy or as the amount of curtailed energy. As an example, the hourly flows for line “A-B” and “D-A” can be quantified and compared to the line limit to determine the capability of the line to support additional flows. A duration curve for both of these lines during the sample time period is shown below.



In the chart, the area below each curve represents the energy transferred throughout the day over the line. The area above the curve but below the line limit represents the unused capability of the line to transact energy, sometimes known as energy headroom. Any area below a curve but above the line limit represents the transmission line overload, which results in curtailed energy. Calculation of this quantity requires simulations from the congestion relief analysis. These values are quantified in the table below. While it is not possible to calculate the energy headroom on each line on the system, the NYISO will collaborate with stakeholders to identify a subset of lines that should be considered based on the NYISO's expertise and experience and will provide the associated energy headroom information respectively.

Energy (MWh)	Max Flow	Actual Flow	Overload	Headroom	Headroom (%)
Line A-B	2,400	2,487	107	20	1%
Line D-A	2,400	803	0	1,597	67%

As part of the analysis, results from simulations may be analyzed to identify electrical, geographic, and/or temporal patterns in energy deliverability.