Appendix B

Method Description

Detailed Testing Approach

Deliverability testing at the detail used for power flow models requires examining a myriad of dispatch combinations and resultant transmission flows to determine whether such generation dispatch can be accommodated without overloading facilities under pre-contingency and contingency conditions. Each monitored element and contingency combination needs to be evaluated. For the testing reported here there were about 1.8 million combinations to evaluate for generation dispatch sensitivity. Such a calculation is only practical through the use of a linearized power flow model. Using the distribution factors (also called DFAX or generation shift factors) the impact on transmission loading for different dispatch combinations can be more quickly calculated. A linear power flow model cannot represent voltage changes under varying dispatch and flow conditions. Voltage limits computed elsewhere with non-linear power flow models are included in the linear model by interface limits.

Using a linear model the overall approach then is to identify generation dispatch patterns that would lead to overloaded transmission facilities[1]. Since the objective in deliverability analysis is to determine whether the aggregate of all generation can operate to their maximum output without causing overloads, the dispatch conditions to be considered are simultaneous maximum outputs. This is the fundamental idea behind this detailed power flow level deliverability analysis.

The process begins by finding the distribution factors of every generator on every monitored element / contingency pair ("monitored pair") in the network model. The first and essential decision is the source and sink of this distribution factor calculation. That is, when the output of a generator is increased, what is counteracting this increase? In many studies the counteraction is a decrease in other generation. For deliverability testing it is more appropriate to offset a source increase with a load increase, since maximum generation conditions are what is being tested. The downside of this generation-to-load shift assumption is that the load is artificially being increased to counteract the increased generation of the upstream generation being tested. This is usually not a problem when bottlenecks define a separation of large areas (for example, a key 345 kV line), but a load increasing action can lead to unrealistic overloads when the bottleneck is to a small load pocket (for example, through a transformer). The downside of the alternative generation-to-generation shift is that the downstream generation may be dominated by one generator, causing the results to be "lumpy". A small pocket may not have any generation located downstream to be shifted against.

The existing New York locational capacity requirements recognize transmission factors limiting generation delivery from the New York Rest-of-State (ROS, or NYISO zones A through I) to New York City (Zone J) and Long Island (Zone K). For this reason distribution factors for deliverability testing are calculated as:

- ROS generation to ROS load
- Zone J generation to Zone J load
- Zone K generation to Zone K load

[1] The sign of the DFAX determines whether generation or load is upstream or downstream relative to a particular monitored pair (monitored element – contingency combination).

To check whether the assumption of intra-zonal shift is distorting the identification and evaluation of bottlenecks the calculations were also performed for a NYCA-NYCA shift and compared to zonal shift results. This test will be discussed in more detail below.

Once distribution factors are calculated, the transmission loading effect of full capacity output of all generators within a close electrical proximity of each and every monitored element / contingency pair is easily computed. Close proximity is judged by a cutoff distribution factor of 4%. In line with the notion of testing transmission loadings under full output conditions, if there is no monitored pair overload when all generators are running at their maximum, the generators are considered to be deliverable.[2] The "universe" of generators and loads used to test for the impact on monitored pairs is the same as that used to define the shift factors; in other words, if the shift is defined from zone J generation to Zone J load, the impact of changing generators outside of zone J will not be considered in calculations. This is why the current software should only be used to study from and to shift systems that are one in the same.

If there is a transmission overload when all the generators in close proximity to a monitored pair are at their maximum output there is a deliverability concern. Depending on the sign of the distribution factors, increased generator output can aggravate a transmission overload (called "harmers" in the method description below) or relieve transmission loadings ("helpers"). Transmission can easily be overloaded if there a lot of harmer generation impact not offset by helper impact. This situation is often called a generator pocket.

Method Descriptions

Five deliverability calculation methods were developed and tested.

The initial test for all the methods is the same. All harmers and helpers are put to their maximum output and the monitored pair loading is calculated from the DFAX. If no overload occurs, then this combination does not need to be further considered. If an overload does occur, one of the methods described below are used to refine the deliverability question. In the initial test a particular monitored element may be overloaded for more than one contingency condition (including the normal or pre-contingent condition). These multiple instances are reviewed for the worst monitored element pair as judged by the maximum line flow for the same blend of harmer and helper generators.

A refinement to the deliverability assessment adjusts the assumed magnitude of the harmers and helpers to represent probabilistic factors. Five different methods of refining the basic deliverability test have been developed.

[2] It is tempting to define the shift as being from 4% impact region generators to other generators outside the "4% circle" around the monitored pair. It often happens that there is not sufficient generation outside the "4% circle" to counteract the generation increase.

Method 1: Derated Unit Outputs

This method puts all harmers and helpers within a 4% DFAX impact range for each monitored pair to the maximum MW output, derated by the regional EFORd percentage. The generation change is incremental from that output defined in the power flow case. This adjustment recognizes the average derated unit output, but not the uncertainties of generator availability and load uncertainty.

The incremental impact of harmer and helper output is calculated using the ROS, zone J, or zone K generation-to-load distribution factors (as appropriate to the study region). This means that the increased generator output is counteracted by a change of load in that region.

The incremental harmer and helper generator impact is added to the initial power flow case flow on the monitored pair. If this resultant flow is greater than the rating, the "headroom" is then negative, and this is classified as a deliverability problem.

This method is the simplest in concept but it does not consider the probabilistic nature of generation supply.

Method 2: PJM-Like Method

This method is similar to the PJM deliverability test. First, the harmers and helpers within a 4% DFAX impact range are identified for each monitored element pair. The full un-derated helper impact on the monitored pair is summed and its effect applied to unload the monitored pair under consideration. The incremental impact on the monitored pair is calculated using the ROS, zone J, or zone K generation (as appropriate to the study region) to load distribution factors. This means that the increased generator output is counteracted by a change of load in that region.

The harmer side generators are sorted in impact order. (PJM sorts in MW maximum capability order). Using the EFORd for that region the cumulative availability of the generators is calculated in the impact order of the harmer generators. For all generators with a cumulative availability more than 20%, the full not-derated incremental MW impact is summed and its effect applied to load the monitored pair under consideration. Otherwise 85% of the full un-derated harmer impact is summed for all other harmer generation with more than a 4% DFAX impact. The incremental impact of is calculated using the ROS, zone J, or zone K generation to load distribution factors (as appropriate to the study region). This means that the increased generator output is counteracted by a change of load in that region.

The incremental harmer and helper generator impact is added to the initial power flow case flow on the monitored pair. If this resultant flow is greater than the rating, the headroom is negative, and this is classified as a deliverability problem.

The approach and factors used are those chosen by PJM. They are meant to test whether the full output of generators "close to" the monitored pair can be simultaneously run, with a recognition that not all generation will be available simultaneously.

The advantage of this method is its acceptance at another ISO. The formulation is quite complex and not intuitive, with results dependent on several subjectively chosen factors (the 80/20 rule for example). Treatment of probabilistic factors is indirect.

Method 3: Load Adjustment as Uncertainty Proxy

This method makes an adjustment to recognize the generator unavailability and load uncertainty. From MARS studies it was found that there is a “free flow” reserve requirement (no transmission constraints) of 15.9% for New York State. This is the percent of additional generation that needs to be available to maintain a one-in-ten LOLE considering the effect of generator derates, unavailability, and other uncertainties, but assuming no transmission limitations.

To represent the 15.9% of extra generation needed to maintain reliability, the load on the harmer side within the 4% impact range was increased by this percentage. Essentially this is increasing the generation-to-load DFAX calculation to be sure that the harmer side load has sufficient reserve to react to uncertainties. No load adjustment is made on the helper side.

After increasing harmer side load, the harmer and helper incremental impact on the monitored element pair within a 4% impact range is calculated and summed using the full un-derated generator maximum MW and the ROS, zone J, or zone K generation-to-load distribution factors (as appropriate to the study region). This means that the increased generator output is counteracted by a change of load in that region.

The incremental harmer and helper generator impact is added to the initial power flow case flow on the monitored pair. If this resultant flow is greater than the rating, the headroom is negative, and this is classified as a deliverability problem.

This method is a more direct consideration of probabilistic factors, but is approximated by the unbalanced effect on the harmer side of each monitored pair. The use of generation-to-load shift factors for the entire study area causes some monitored pair flow reversals from the pattern usually expected.

Method 4 Upstream and Downstream Gen-Load Matching

This method has a distinct difference than methods 1, 2, and 3 in that the delivery of generation to load on the upstream (harmer) and downstream (helper) side is explicitly matched.

The first step is to use the generation-to-load distribution factors to identify what generation and load is situated on the upstream (harmer) and downstream (helper) side of each monitored pair (no 4% distribution factor cutoff is used).

The load on the upstream side of the monitored pair is increased by 15.9% to represent generation derates, unavailability, and load uncertainty. DFAX for all upstream generation to upstream load are calculated. Generation on the upstream side of the monitored pair is then dispatched against upstream load pro rata to generation available upstream using these DFAX until all of the (adjusted) load is supplied.The generator output is increased proportional to unit size, not an incremental increase from the power flow case as in methods 1, 2, and 3. This will result in some flow on the monitored pair under study.

The same procedure as the upstream side of the monitored pair is performed for the downstream side. Again, this will result in some flow on the monitored pair under study. The action of PAR's, loop flow from areas external to New York, and losses are then calculated as an additional resultant flow on the monitored pair. This will be called non-dispatchable flow.

If there is excess generation on the upstream side of the monitored pair, the DFAX of this surplus generation (no 4% DFAX cutoff) is calculated with respect to downstream generation. The intent is to displace downstream generation with upstream generation up to the full MW capability of the upstream generation. The monitored pair impact of shifting all excess upstream generation to downstream generation is then calculated.

The monitored pair flow caused by upstream generation serving (adjusted) upstream load, downstream generation serving (adjusted) downstream load, non-dispatchable flow, and the flow from excess upstream generation displacing downstream generation are summed. If this resultant flow is greater than the rating, the headroom is negative, and this is classified as a deliverability problem.

Method 5: Only Transfer as Much as is Needed

This method changes the method 4 approach to test whether there is sufficient transmission capability to serve the load on the downstream side not servable by downstream generation, that is, where the downstream load exceeds downstream generation. This calculation is similar to the zonal resource and transfer capability balancing that is performed by the NYISO today. In place of predefined zones however, the load/generation/ transfer capability balancing is performed relative to each monitored element pair.

In this calculation, only the amount of upstream generation needed to make up for a downstream generation deficit if transferred. New DFAX shifting upstream generation to downstream load are calculated and used for the shift. The impact of this "only needed" upstream generation on the monitored pair is calculated and added to the flow from by upstream generation serving (adjusted) upstream load, downstream generation serving (adjusted) downstream load and non-dispatchable flow. If this resultant flow is greater than the rating, the headroom is negative, and this is classified as a deliverability problem.

This method uses varying generation-to-load shifts particular to the upstream and downstream regions, reducing the potential for results anomalies caused by shift assumptions. Handling of probabilistic factors are similar to Method 3.

Since the initial power flows due to power flow case dispatch assumptions are not used, this method is not affected by initial power flow case assumptions as much as other methods.

Results from this method may be peculiar in load pockets, where transmission loadings are influenced by PAR's, or if the study region is dependent on imports to meet load.

The table below summarizes the differences between the deliverability calculation methods.

Method	Harmer (Upstream) Side Adjustments	Shift Used To Counter Increased Harmer Gen	Helper (Downstream) Side Adjustments	Shift Used To Counter Increased Helper Gen
1	Reduction by Zonal Average EFORd	Zonal Available Generation (Pmax-Pgen) to Zonal Load	Reduction by Zonal Average EFORd	Zonal Available Generation (Pmax- Pgen) to Zonal Load
2	100% of largest impact generator MW above cumulative 20% unavailability. 85% of impact thereafter	Zonal Available Generation (Pmax-Pgen) to Zonal Load	None	Zonal Available Generation (Pmax- Pgen) to Zonal Load
3	Load increased 15.9% to represent gen and load uncertainties	Zonal Available Generation (Pmax-Pgen) to Zonal Load	None	Zonal Available Generation (Pmax- Pgen) to Zonal Load
4	Load increased 15.9% to represent gen and load uncertainties	Upstream Gen to Upstream load. *Excess* Upstream gen to Downstream gen	Load increased 15.9% to represent gen and load uncertainties	Downstream Gen to Downstream Load
5	Load increased 15.9% to represent gen and load uncertainties	Upstream Gen to Upstream load. *Needed* Upstream gen to Downstream	Load increased 15.9% to represent gen and load uncertainties	Downstream Gen to Downstream Load