Suggested Methodology for Competitive Path Assessment

Pivotal supplier analysis is central to competitive path assessment. It is a common feature of the MISO and PJM methodologies, although those ISOs have different methods of determining the relevant supply and demand for pivotal supplier analysis. They both use generation shift factors, but their choice of the slack for determination of generation shift factors is different. In general, and specifically in both cases of MISO and PJM, the choice of the slack for determining the shift factors is rather arbitrary and has a potentially important impact on the outcome of the pivotal supplier analysis. The methodology presented here attempts to address the pivotal supplier analysis without the need to designate a slack for the determination of the shift factors. In fact, the methodology proposed here does not even use the shift factors. This is advantageous, because the choice of shift factors will always be somewhat arbitrary, because the location of the INC (DEC) that matches the assumed DEC (INC) of a resource in question will depend on system conditions and economics. An additional advantage of the proposed method is that the method is comprehensive, in that it considers the interacting effect of all constraints at once. However, the proposed method does have its own limitations and drawbacks as explained later in this write-up; in particular, it may require an initial designation of a sequence of competitive path assessments, and the sequence may impact the analysis results.

The methodology for competitive path assessment (whether MISO’s, PJM’s or the one proposed here) starts by selecting one or more representative system conditions, load levels (and load distribution), and supply resources that would normally be available (not on forced or maintenance outage) under the assumed seasonal conditions. For a given set of load, network, and supply conditions, the question is whether there are pivotal suppliers in the sense that without their cooperative supply participation congestion will exist and cannot be resolved on the path in question (and thus some load would potentially be unserved in some local area). If there are such pivotal suppliers, the path in question is non-competitive under the given set of conditions. In the case of MISO the path is deemed competitive if there are no pivotal suppliers for the credible sets of load, system and supply conditions. In PJM the criterion is “no three jointly pivotal suppliers”. In CAISO the criterion contemplated at present is “no two jointly pivotal suppliers”.

The basic idea in the methodology proposed here is to take out all supply resources of a specific supplier (or 2 suppliers if two-jointly-pivotal-supplier analysis is desired) and determine if the remaining suppliers’ resources can be scheduled to meet the load subject to the transmission constraints, i.e., if a feasible solution exists with the remaining supply. This is done simultaneously for the entire system’s set of loads, resources, and transmission facilities. In case a feasible solution does exist, the supplier(s) in question are not pivotal for congestion relief on any path under the set of supply/demand/system conditions. Otherwise the supplier(s) in question are pivotal for congestion relief on the paths that cause solution infeasibility. To identify those paths and quantify the relative degree of infeasibility each cause, we define a “feasibility index” (FI) for each transmission constraint with respect to each supplier. To define the FI index, we modify the basic scheduling and market clearing by treating all transmission constraints as soft constraints with very high penalties (orders of magnitude higher than the highest bid price or the prevailing bid cap) for violating the constraint. Thus, instead of getting no
solution, we would get a “least cost” solution in which some transmission flows exceed the transmission (constraint) limit.

For a single supplier $i$ whose resources are removed, we define the Feasibility Index of Path $j$ with respect to Supplier $i$ (Fli)$ as follows:

Let

$$\text{Limit} (j) = \text{Transmission Limit on Path} j$$

$$\text{Flow} (i, j) = \text{Power Flow on Path} j \text{ without Supplier} i \text{’s Resources (with soft limits)}$$

Then

$$\text{FI} (i, j) = \frac{\text{Limit} (j) - \text{Flow} (i, j)}{\text{Limit} (j)}$$

If FI$(i,j)$ is negative, supplier $i$ is pivotal for congestion relief on Path $j$, and Path $j$ is not competitive. If FI$(i,j)$ is positive, supplier $i$ is not pivotal for congestion relief on Path $j$, but if FI$(i,j)$ is small, it is possible that the supplier $j$ could be jointly pivotal with another supplier $k$ with small feasibility index FI$(k,j)$ on the same path $j$. This provides for an easy selection of candidate suppliers for the two-jointly-pivotal-suppliers test if no single supplier is pivotal on Path $j$.

The following generic matrix demonstrates the single pivotal supplier test results for $n$ candidate paths.

<table>
<thead>
<tr>
<th>Paths $\Rightarrow$ Suppliers</th>
<th>P1</th>
<th>P2</th>
<th>.....</th>
<th>Pj</th>
<th>....</th>
<th>Pn</th>
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<tbody>
<tr>
<td>S1</td>
<td>FI(1,1)</td>
<td>FI(1,2)</td>
<td></td>
<td>FI(1,n)</td>
<td></td>
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<tr>
<td>S2</td>
<td>FI(2,1)</td>
<td>FI(2,2)</td>
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<td>FI(2,n)</td>
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<td>FI(i,j)</td>
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If a FI$(i,j)$ entry is negative for any $i$, Path $j$ is non-competitive. If all FI$(i,j)$ entries are positive for Path $j$, but some are small (below a designated threshold), then the test is repeated with the supply resources of both suppliers removed. In fact, we could adopt a Feasibility Margin (FM) such that if FI$(i,j)$ is below FM for any supplier $i$, Path $j$ is deemed non-competitive. To determine the appropriate level of FM (e.g., 0.05), we can use some historical analysis on the existing competitive internal control area paths (Path 15 and Path 26) to ensure the level of FM is not set too high.

**Discussion Potential Limitations and Drawback:**

The method proposed here does have its own limitations and drawbacks. To see this, let’s assume that without imposing Path $j$’s limit the flows are feasible for all other paths considered (FI$(i,k) >= 0$ for all $k$ not equal to $j$). Now if adding Path $j$’s limit renders the system infeasible, the infeasibility may show up on a different path (FI$(i,j) =$>0, but FI$(i,k) < 0$ for some $k$ not equal to $j$). Which path shows an infeasibility will depend on...
the relative effectiveness of constraint violations in minimizing the optimization objective function (the optimization will pick a path or several paths to make infeasible in order to minimize the degree of infeasibility). The important thing is that an infeasibility shows up somewhere in the system when path \( j \) is imposed, but the infeasibility will not necessarily show up on that path.

**Example Illustrating the Method’s Limitations and Drawback:**

A simple example on a three node network illustrates the above concern. Let three areas A,B,C be connected by three lines with equal reactance (all designated competitive): A-B, B-C, and C-D. Each line has capacity 1000 MW. Imagine that there is no generation at C, that A has load 5000 MW and generation capacity of 5000 MW, and B has lots of excess generation. Imagine that supplier X at A has capacity 1400 MW. Remove its capacity, and the system is feasible (generate 3600 MW at A, and export 1400 MW from B, flow on A-B is –933 MW, which is feasible).

Now imagine that there is a transmission constraint within A that divides A into two subareas A1 and A2 (as shown in the above diagram). The four areas are now connected as follows: A1 radially to A2 (via line A1-A2); A2 to B and C (via lines A-B and A-C, respectively), and B to C (via B-C). All of A’s load is at A2 (5000 MW); X’s 1400 MW is at capacity is at A2; and the rest of A’s capacity (3600 MW) is at A1. Further, assume that the A1-A2 flow limit is 3000 MW. Imposing the A1-A2 path limit and taking out X’s capacity makes the system infeasible (3000 MW can flow from A1 to A2 and 1500 MW can flow from B to A2 via paths B-A2 and B-C-A2, totaling 4500 MW, compared to the 5000 MW of load at A2). Solving the least cost model proposed above (minimizing the infeasibilities) would result in \( F(X,A1-A2) = 0 \) (flow of 3000 MW, limit of 3000 MW) and \( F(X,B-A2) = (1000-1333)/1000 = -0.333 \). (This is because the minimum infeasibility is achieved by increasing B’s generation exports by 500 MW [from 1500 MW to 2000 MW] resulting in 333 MW more flow over B-A2 than is feasible [1333 MW vs the 1000 MW limit], not by increasing A1’s generation from 3000 to 3500 MW, as the
latter results in 500 MW of infeasible flow [3500 MW over A1-A2 rather than the 3000 MW limit].

So imposing A1-A2 has resulted in an infeasibility, and X is pivotal. Accordingly, path A1-A2’s limit results in a noncompetitive situation, but the optimization model would actually identify a different path as “noncompetitive” (since the infeasibility shows up on B-A2).

**Concluding Remarks**

The above drawback and limitation need not necessarily mean that the proposed method should be abandoned as flawed. It could still be maintained as a potential candidate if we adopt a sequencing of competitive path designations: Let the set of already competitive paths be defined as set CP (i.e., FP(k,i) >= 0 for all k in CP and all i). Now consider a path j not in CP; if adding path j to the constraint set results in FP(k,i) < 0 (or, more generally, less than FM) for any combination of k and i, then path j would be designated noncompetitive. That is, set {CP,j} is noncompetitive as a whole, and we “blame” j for this.

The remaining drawback of this procedure is that the order effects the outcome. An arbitrary choice of what order to add paths to the constraint set could change the conclusions. For instance, if CP = {B-A2, B-C, C-A2}, X is not pivotal (no FP < 0). Then adding k=A1-A2 to CP would result in FP(X,B-A2)<0 (see above), and A1-A2 would be designated the uncompetitive path. If, on the other hand, CP = {A1-A2, B-C, C-A2}, X is not pivotal (no FP < 0). Then adding k=B-A2 to CP would result in FP(X,B-A2)<0, and B-A2 would be designated the uncompetitive constraint. Which constraint is “uncompetitive” depended on the order that paths were added. The only unarbitrary conclusion is that {A1-A2, B-A2, B-C, C-A2} results in X being pivotal, but that any subset of three paths would not result in X being pivotal.

Using this procedure would require further discussion and exploration. The initial designation of competitive paths (the existing inter-zonal interfaces) may not be too controversial, but the sequencing of other potential candidates would involve discretion.