Is a Single Reasonable NE Market Feasible?
An Initial Analysis of Technology and Scalability

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Executive Summary

The Problem: Are the Platforms Scalable?

During the discussion on technology at the RTO mediation, a technical question was raised as to whether any of the ISO platforms have the potential to be scaled up to serve a regional market. Some participants stated serious reservations regarding whether running such a large regional market is even technically feasible. Obviously, this is a major issue, for if we can't proceed with scaling up major technical components, the exercise is doomed to failure.

Feasibility Screening Study

Nexant-Power Computer Applications (N-PCA, formerly Power Computer Applications) was retained to run some preliminary feasibility screens of these analytic tools based on a transmission and generation system configuration that was configured similarly to the entire northeast region of the county. The screens addressed some (**not all**) of the most important "technical engines" that support both the NY and PJM market systems. In particular N-PCA was asked to focus on the analytic elements of the most time critical applications, the real time market. This included the Optimal Power Flow/dispatch engines, and the engine for state estimation (i.e. developing the profile of what the overall electric system including generation and demand looks like).

Findings

As discussed more below, the results were very impressive. As shown in the summary table below, everything that needed to be solved could be solved on a regionally scaled program. Further, the running times were extremely impressive, even without considering simple hardware improvements that would be expected to reduce run times by 3 or 4

times. These findings clearly indicate that, for these solution engines, a regional market should be feasible. The numbers reported are from the first draft Nexant-PCA study and are offered at this time to allow their consideration within the mediation process. I will post any updating if necessary.

Function	Nexant/PCA Software	Overall Timing
State Estimation	GEN-SE	31 seconds
DC Security-Constrained Economic Dispatch	SCOPE	1.6 minutes (tracking); 3.8 minutes (cold start)
AC Security Analysis	SCOPE	1.8 minutes (contingency screening); 0.7 minutes (worst 200); 2.5 minutes total
DC 5-Period FTR Auction	SCOPE	75 minutes

Next Steps

The study did not address the feasibility of scaling a Security Constrained Unit Commitment (SCUC) day-ahead market engine since N-PCA does not have an SCUC model running. SCUC is not as time critical and my personal belief is that the SCUC will scale successfully. Discussions with others experimenting with larger SCUC configurations seem to support this, but obviously this is another necessary screening step and should be examined as soon as possible.

REPORT

Background

During the discussions on technology some comments were presented on whether or not any of the ISO platforms could be modified or scaled to serve as the basis for a regional model. Obviously this is a major issue. If we can't proceed with scaling up major technical components, the exercise is doomed to failure. This isn't necessarily a PJM or NY platform issue. As I said before, the systems are very similar, and while it is possible that there could be components of one ISO's approach that don't scale, while the other's

does, at least at this stage, I think more generic questions on scaling apply equally to both. An important first step, as we discussed in the straw work plan, is to establish some of the basic feasibility. However, it seemed that from some of the comments offered there was some pre-judgment on this issue implying that scaling wasn't possible. This ran counter to most of my personal knowledge and expectations, and I thought a bit of further investigation might be in order.

With this in mind I undertook a small effort on my own initiative to see if there were any fatal flaws in scaling up to a regional level some (**not all**) of the most important "technical engines" that support both the NY and PJM market systems. In particular I focused on the analytic elements of the most time critical applications, the real time market. This included the Optimal Power Flow (OPF)/dispatch engines, and the engine for state estimation (i.e. developing the profile of what the overall electric system including generation and demand looks like). If you have these elements solved in a sufficiently fast fashion, you have a feasible real time market.

There are similar analytic tasks for the day-ahead market, but these are less time critical, particularly so with one of the potential market applications structure versus the other. My belief is that this is a solvable problem in the day-ahead time frame, however I did not look at solution techniques for the day-ahead markets at this time.

To examine the feasibility of these analytic market components I retained the services of Nexant-Power Computer Applications (N-PCA, formerly Power Computer Applications) to run some preliminary feasibility screens of these analytic tools based on a transmission and generation system configuration that was representative of the entire northeast region of the county.

N-PCA is a world recognized vendor of analytic software in these areas. Their software is used extensively by a large number of the world's electric utilities and supports the internal "guts" of many of the large companies such as ABB, GE Harris, and Siemens AG that develop utility operations and energy management systems. For the NYISO they developed the TCC auction software, and they also developed similar FTR auction software that is used by PJM for auditing purposes. N-PCA is particularly well known for the computational speed and efficiency of their products in solving large-scale utility power flow problems. A summary of their qualifications is attached to the web posting.

It should be noted that this effort is just the first scratch on feasibility. While a negative finding here would suggest that we are going to face real problems, a positive finding that we can scale these models is a strong indication (though not dispositive) that we can run a regional market of the size of the entire NE.

Introduction

At the "100,000 foot" level, there are two gross areas of software applications that are used in each of the ISO structures. The first relates to external interfaces with market participants. This is like the market information system (MIS) in the NYISO, and some elements of the PJM eSuites. These tools address the flow of information in, out and between market participants, the ISO, billing functions, etc. For the most part you would not expect that these systems **today** would be able to handle a regional market. There simply isn't any reason for them to have been designed to do so. Similarly, you also won't worry too much about whether or not these systems could be scaled up to handle a regional market, as the functions are pretty basic. In a simpleminded sense these interface functions are similar to the telephone lines coming into a customer information or service center. If you double or triple the number of customers you expect to handle, it is likely that the number of phone lines currently in place won't handle the new demand. However, it also typically isn't a cause for worry regarding the ability to get more telephone lines installed to support this application. While getting more lines may take some work, and maybe even require a switch in technology, for the most part this would appear to be a manageable task. (Obviously these elements would be subject to scaling screens as part of work plan.)

The second aggregate area of software in the ISO structures relates to the technical engines that drive the market functions and related analyses. These would include the heuristic solution model for the SCUC, optimal power flow, dispatch models, state estimators and AC security analyses that support the system dispatch and pricing, and optimization software that support the FTR and TCC auctions. In these cases, it is not obvious that the software will scale up and allow us to solve these problems on a regional basis; or if the software will solve, that the solutions will be provided quickly enough to support some of the time critical market functions that require these results.

Again the analogy to a customer call center is good. While we can add telephone lines when customers double, if the customer service software being used now takes 30 minutes to run instead of 10 seconds, it won't be very useful to solving real time questions for people that are waiting on the telephone.

Thinking about the problem in this fashion, I asked PCA to specifically consider several of the technical engines that support major market functions, particularly the ones that are time critical. I asked that they look at solving optimal power flows (OPF's) for regional sized transmission systems and that they also evaluate the feasibility of solving the related question of system dispatch. . The OPF is the main technical "ingredient" for the ability solve for the dispatch of the system (both PJM and NY) and has to be solvable in near real time (e.g. less than 5 minutes if we wanted to go to a 5 minute real time market).

I also asked them to look at solving for state estimation for similarly sized systems. (State estimators basically provide a snapshot of the status of the electric system including the distribution of generation and load.) Again this is a near real time critical component. The availability of a "good" state estimator solution is very important. It is a key element in the PJM pricing structure, and a very desirable improvement for NY, which currently does not include state estimation results in their real time operations, but instead uses assumed distribution of load (in fact my conclusion would be that the presence of a state estimator would contribute significantly to securing the reliability concerns that NY has expressed).

I also had N-PCA conduct solutions for AC security analyses. These security analyses problems are again typically solved near real time, although my understanding is that these are solved on a slightly less frequent basis (e.g. I think PJM does this every 15 minutes, and I am not sure of the NY time step). Again this is a critical requirement for the reliable function of the real time market and associated operations.

I also asked N-PCA to look at solving a multi-period (5 period) FTR/TCC auction for a similarly sized problem. While this isn't a time critical application (the auction could take place over days or weeks), I consider this a very important market element and wanted to be assured of the initial feasibility of scaling this market to the regional level.

N-PCA does not have a SCUC model running so we did not evaluate this engine. The SCUC is the main tool for the day-ahead market. While the OPF results are related to the function of the SCUC heuristics used by PJM and NY, the results from the regional modeling of the OPF are not sufficient on their own to come to any "first screen" conclusions. My personal belief is that the SCUC (which is not as highly time critical) will scale successfully. Discussions with others experimenting with larger SCUC configurations seem to support this, but obviously this is another necessary screening step and should be examined as soon as possible.

Finally, I also asked N-PCA to comment on the ability of their tools to be usefully integrated into new or existing market structures. The ability of others to use these tools is an important issue, as the results are based on their state of the art software tools. To be useful generically these types of fast solving engines have to be able to fit in modularly with other applications and structures such as the overall PJM and NY market models. My understanding from the N-PCA comments is that the type of interface that they have developed allows these results to be seen as generic, (i.e. this type of software solution could be incorporated into existing structures if desired.)

This is not a surprising result as these tools have been designed to integrate into the larger systems of the full function integration vendors that N-PCA supports (GE Harris,

Siemens AG, ABB and others). Further, although the N-PCA software is not used by ESCA, the main PJM integration vendor, the PCA products were also designed to be easily integrated into third party systems with compatible data modeling, like the ESCA proprietary systems. Thus while nothing is exactly plug and play, it is reasonable to assume that all of these types of results are available to each of the ISO systems that are currently in use.

A short statement of the N-PCA work scope is included at the end.

As discussed more below, the results were very impressive. Basically everything that needed to be solved could be solved on a regionally scaled program. Further, the running times were extremely impressive. These running times and overall results clearly indicate that for these solution engines, a regional market should be feasible.

Hardware Considerations

It is also important to consider the following results in the context of the hardware that was used. Basically N-PCA ran their models on a Dell 1.4 GHZ Pentium desktop computer with only 256 M memory. This is pretty much home office, off the shelf equipment, and costs about $12-1500. That is, this is nothing special. There are major improvements in hardware that are readily available that would significantly accelerate the excellent results seen below. For example, there are workstations with faster speed, much larger cache, huge "swap out" spaces on their hard discs, and general architecture that is better designed for this type of computational application. Further, the specifics of the OPF computations are amenable to distributed (not parallel) processing. This means that if you use multiple processors you can cut computational time significantly. (E.g. with a four processor system you might see the OPF run times to decrease by 2 or 4 depending on the binding contingencies.) There is commercially available software for this type of distributed processing for OPF problems, including some developed by N-PCA. I see no reason why in an ISO/RTO commercial environment with state of the art hardware you couldn't expect reductions in the some of the following run times (e.g. OPF's) by a factor of 3-5 or more, with significant reductions in the other areas.

Results

The full Nexant-PCA report is attached to the posted version of this report on the RTO website. I have excerpted from the report in the text below as well as included some additional comments of my own to clarify the problems being considered. The following are highlights.

1) **Regional Configuration.**

N-PCA assembled a regional scale database to use in evaluating the system. They started from the NERC Multi-Regional Modeling Working Group (MMWG) 2002 summer peak case. This case was used as the starting point for the studies described in their report. This case models the Atlantic coast, Midwest and southern portions of the Continental United States. It does not include the ERCOT and WSCC systems. The MMWG network comprises 37,696 buses, 5,893 generators, 37,148 transmission lines and 12,412 transformers.

Starting from this base, N-PCA established a subset of busses that included the entire northeast region plus all adjacent areas that were needed for a reasonable electric transmission representation of the region. In order to create a realistic model of the proposed Northeast RTO, the MMWG case was reduced to create an equivalent network, using the Nexant/PCA network reduction software MODELEX. The following areas were retained intact in the reduced network: New England, New York, PJM, PJM West, Ontario and Virginia. An electrically equivalent reduced system was formed of the remaining areas. The entire resulting system has the following characteristics:

- 10,500 buses
- 2,267 generators
- 6,480 loads
- 1,750 shunts
- 9,177 transmission lines
- 6,074 transformers

The subset of the system representing the potential northeast RTO was about 7,000 busses, and 1390 generators. To give a sense of scale, PJM represents about 50-55% of the total load in the region. PJM includes about 2200 busses, 560 generators and about 1200 transmission contingencies modeled by the ISO. I believe that this is a very reasonable first cut at a regional representation, and certainly a fair basis for this type of initial screen. From an operational perspective I think this captures the type of contingency structure that people would require in a regional model.

2) **System Dispatch and OPF**

In order to run the real time dispatch, the MMWG test system data was augmented with generator cost curves, single line contingencies and a monitored facilities list. Generator cost curves were created based on the units' MW capacity. The contingency list included all single line outages of lines greater than or equal to 138 kV and the monitored facilities list included all branches from 115 kV to 765 kV in the proposed RTO network.

The portion of the system being dispatched included:

- 1,390 generators
- 2,204 contingency cases
- 4,634 monitored transmission facilities
- Over 10 million monitored flow constraints (2205 x 4634)

To solve this type of system in what is referred to as a "tracking mode" e.g. moving from a previously existing solved state to the next increment of dispatch, the program solved in 1.6 minutes. From a "cold start", which basically is the same as saying you dispatch the system from an unrelated configuration, the run times were 3.6 minutes. Again, given the hardware and computational limitations this was very impressive.

3) **State estimator run times.**

Moving from the optimal power flow results and the system dispatch, a reduced set of information was used to examine the ability of the state estimator to function at this scale. A set of measurements was randomly created from the test system. It comprised flow measurements on 80% of branches, measurements of loads/generators on 40% of the internal buses and measurements of voltage on 40% of internal buses, leading to a measurement redundancy [ratio of number of measurements to number of buses] of 1.48. Gaussian noise and errors were superimposed on the results of the power flow. This noise was added to present the estimator with a more difficult problem to solve. There were also missing data elements. It took 7 seconds to solve the internal system, which represented the entire northeast RTO system. It took an additional 24 seconds to solve the entire representation.

4) AC security analyses run times.

The set of contingencies and monitored facilities defined in the dispatch section was used for the AC contingency analysis also:

- 4,634 monitored transmission facilities
- 2,204 contingency cases

The full AC security analysis solution using fast screening (ranking all 2,204 contingencies) took 2.5 minutes. This included 1.8 minutes for the fast contingency screening (serving as an approximate selection of worst cases) and 0.7 minutes for the full AC solution of the worst 200 contingencies.

5) FTR/TCC Action run times.

A five period FTR auction was run on the internal northeast regional system. About 3300 bids were examined, with the system transmission topology slightly changed from each period to the next. This was to allow for the likely changes that would occur in a "real" system and to present a more difficult problem to solve. The software was able to solve for the best feasible bid results in 75 minutes, with significant data handling and processing tasks. This again is very impressive for an application that isn't time critical. Currently in the NY structure each period TCC auction is structured over multiple days. The software used by N-PCA in this example was created to be the NYISO end state, and has been accepted by NY. This exercise demonstrates that not only will the NYISO TCC auctions be accelerated when they are conducted in this more sophisticated multi-period structure, but that the NY solution is applicable to the region as a whole.

SUMMARY TABLE OF COMPUTATIONAL RESULTS

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Summary of Nexant-PCA Work Scope

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CONFIDENTIAL QUOTATION
TO
Roy Shanker
August 16, 2001

Nexant/PCA is pleased to provide this quotation for consulting services to Roy Shanker.

1. Description of Work

   - Nexant/PCA will develop a reasonable network model of the proposed Northeast RTO (NE, NY, PJM) and use Nexant/PCA's software for obtaining feasibility checks and timings. The work entails:
     - Reducing an existing NERC MMWG case of the eastern interconnection using the MODELEX program.
     - Creating a list of 2500 single line contingencies.
     - Generating fictitious bid curves for 1500 generators.
     - Running a state estimation of the case using the GEN-SE package
     - Running a real-time DC dispatch on the case using the SCOPE package
     - Running an AC contingency analysis on the case using the SCOPE package
     - Modifying the case to create 5 1-year period cases and creating FTR bids
     - Running the multi-period FTR auction on the above using the SCOPE package
     - Writing a report detailing the process, size of system and execution times. The report will also contain a description of the software's Application Program Interface (API) and comment on the API's usability in any programming environment.