THE EFFECTS OF INTEGRATING WIND POWER ON TRANSMISSION SYSTEM PLANNING, RELIABILITY, AND OPERATIONS

Report on Phase 1:

Preliminary Overall Reliability Assessment

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New York has the potential to generate a significant share of its electrical energy requirements through the use of indigenous renewable resources such as the wind. Emerging green retail markets and renewable portfolio standard initiatives in New York and elsewhere suggest that the pace of wind development will be increasing in the near term. For instance, preliminary analyses conducted by the NYS Department of Public Service in Case No. 03-E-0188 Proceeding on Motion of the Commission Regarding a Retail Renewable Portfolio Standard (RPS) predict the eventual addition of as much as 3000 MW of wind generation in response to a New York RPS. In addition, the neighboring states of Massachusetts, Connecticut and New Jersey have already enacted RPS standards that encourage regional wind power development.

Industry experience and studies indicate that large-scale wind generation can have unique impacts on power system operations. While these impacts may be relatively small at low penetration levels, at the significant penetration levels possible in New York physical system reinforcements and special bulk power system planning and operating practices may be required. In acknowledgment of these unique characteristics and the emerging market for wind generation, the New York Independent System Operator (NYISO) and the New York State Energy Research and Development Authority (NYSERDA) jointly commissioned a two-phased Reliability Assessment to produce an empirical analysis that will assist the NYISO in evaluating the reliability implications of increased wind generation.

The draft results of the first phase of this Reliability Assessment were presented to an audience of NYISO market participants and parties to the New York RPS Proceeding, and written comments were invited and received from over a dozen parties. After consideration of these comments selected corrections and changes were incorporated into the final Phase 1 Preliminary Overall Reliability Assessment that follows. Many of the comments received pertained to the scope of further analyses and these comments are being reserved for consideration and incorporation into the final detailed system performance evaluation called for in Phase 2 of the Reliability Assessment.

The results of the Phase 1 Assessment presented in the following report assume the immediate inclusion of a relatively large amount of wind generation in the New York State bulk power system. In reality the pace of development would be slower, with market and operating experience increasing with each development cycle, and with reasoned and timely system planning and operating practices being applied in response.

To be sure, as with any new project proposed in New York, NYISO Staff will review every project's System Reliability Impact Study and must first be satisfied that all applicable reliability issues relevant to the New York Control Area have been addressed before recommending the project for approval. Furthermore, all new projects are recommended for approval with the understanding that they will be operated in

accordance with NYISO operating procedures and limits through its day ahead Security Constrained Unit Commitment (SCUC) and real time Security Constrained Dispatch (SCD) protocols.

The following Phase 1 Preliminary Overall Reliability Assessment provides a preliminary but reasoned empirical basis upon which the NYISO can address reliability implications of increased wind generation. More detailed system performance analyses are planned under Phase 2, which will provide further instruction on the need to add to or modify existing NYISO procedures and guidelines, and when and how such changes should be applied through time.

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2. EXECUTIVE SUMMARY

2.1 OVERVIEW

NYSERDA and NYISO commissioned this study to evaluate the impact of large-scale wind generation on the planning, operation, and reliability of the New York State Bulk Power System (NYSBPS). The study is being conducted in two phases:

- Phase 1: Preliminary Overall Reliability Assessment
- Phase 2: System Performance Evaluation

Phase 1 has been completed and results are summarized in this report.

2.2 DATA ON NY STATE WIND RESOURCES

AWS Scientific, Inc., provided two critical data sets that enabled much of the analysis conducted during Phase 1.

- **Potential Wind Generation Capacity**. A total of 101 prospective wind generation sites in NY State were identified, with a total generation capacity of 10,026 MW. Data for each site included total wind generation output in MW, capacity factor, and the nearest existing transmission substations.
- **Hourly Wind Profiles**. For each of the 101 prospective sites, this data included statistically derived hourly power output in MW for a full calendar year.

Figure 2.1 shows geographic distribution of the potential wind sites with respect to the eleven zones within the New York Control Area (NYCA).

Potential Wind Generation by Zone	
Zone A	4016 MW
Zone B	515 MW
Zone C	922 MW
Zone D	433 MW
Zone E	2683 MW
Zone F	703 MW
Zone G	154 MW
Zone H	0 MW
Zone I	0 MW
Zone J	0 MW
Zone K	600 MW
Total	10026 MW

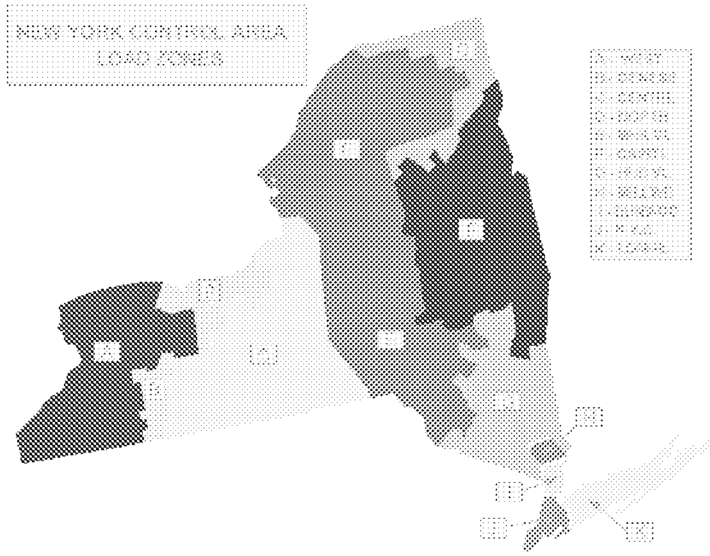

Figure 2.1. New York Control Area Load Zones, and Potential Wind Generation

AWS Scientific also provided technical reports relating to wind generation, including

- Wind Generation Technical Characteristics for the NYSERDA Wind Impacts Study
- Overview of Wind Energy Generation Forecasting

These reports are presently in draft form, and will be released in February 2004.

2.3 WORLD EXPERIENCE WITH WIND

Several regions of the world that have integrated substantial penetration of wind resources were evaluated with the objective of identifying lessons learned and best practices applicable to New York State. Some of those regions are listed in Table 2.1.

Table 2.1 Example systems with high penetration of wind resources

	Peak Load	Installed Wind	Penetration
Eltra (Denmark)	3.8 GW	2.3.GW	62%
Germany	78 GW	12 GW	15%
Spain	33 GW	4.8 GW	15%
PNM (New Mexico)	1.5 GW	0.2 GW	14%
ERCOT (Texas)	63 GW	1.9 GW	3%

2.3.1 Emerging Best Practices on Interconnection Requirements

New York State should adopt some of the requirements that have grown out of the experiences of other systems. Specifically, New York State should require all new wind farms to have the following features:

1. Voltage regulation at the Point-of-Interconnection, with a guaranteed power factor range.
2. Low voltage ride-through.
3. A specified level of monitoring, metering, and event recording.
4. Power curtailment capability.

These features are implemented in wind farms around the world, and are proven technology. The following features are emerging in response to system needs. They are in early development, and should be required by New York State in the future as they become available.

5. Ability to set power ramp rates
6. Governor functions
7. Reserve functions
8. Zero-power voltage regulation

New York State may also wish to consider a minimum wind farm size, on the order of 5 to 10 MW, below which the local transmission operator may waive some or all of these requirements on a case-by-case basis.

2.3.2 Centralized Forecasting

For secure operation of the power system, it is essential that the system operator have wind power production forecast information for all wind facilities. Forecasts of the hourly production for each individual wind farm are required, at least, for day-ahead planning, and may be valuable for short-term operations decisions as well. The combined forecasts will tend to reduce the operational importance of small local errors in wind generation predictions for individual facilities. With central collection of forecasts, major weather events and the problems they might cause can be anticipated at the system operator level. Regardless of whether responsibility for forecasting power production resides with individual wind facilities or a centralized system, a center to collect, distribute, archive and possibly enhance forecast information should be established for New York State.

2.3.3 Evolution of Technology and Procedures

New York must recognize that both wind technology and practices are maturing quickly. The regulating and operating entities must maintain institutional flexibility that allows the adoption of new procedures. System operators have learned how wind generation affects the particular characteristics of their systems.

The amount of wind generation in New York is expected to increase over a number of years. New York should begin documentation of operating experience now. Gathering experience in the near term, while wind penetration is low, will increase confidence for future operation with higher levels of penetration. Having wind projects come on-line will help determine how best to integrate significant wind generation in future years.

2.3.4 Operations Impacts

The largest impact of wind generation on New York State system operations is expected to be on load following reserves and unit commitment. Impact on regulation is not expected to be substantial. The addition of wind generation increases the net load variability. The preliminary analysis shows that the addition of 3300 MW of wind generation will increase the net New York system load variability by about 6% (from 920 MW to 975 MW). This increase in variability is not expected to create significant operating problems, but it is expected to impact scheduling, load following and unit commitment. At this level of penetration, any rapid drop in production from the wind farms is not expected to impact the existing 10-minute operating reserve requirement (1200 MW) for the state. This preliminary analysis provides insight into the expected level of hour-to-hour variability that might accompany wind generation. It does not provide the detail necessary to make an assessment of the expected impact on hourly and daily operations. In Phase 2, the variability of selected sites will be investigated further, including consideration of intra-hour, diurnal, monthly and seasonal impacts.

Critical objectives for the next phase of this project include developing a better understanding of New York State requirements and practices with respect to:

- Load following and regulation, and the impact of wind generation variability.
- Unit commitment, and the impact of wind forecasting accuracy.

2.3.5 Penetration Limits

World experience indicates that New York State should be able to integrate wind generation to a level of at least 10% of the system peak load – a total of about 3300 MW of wind turbine-generators. The experiences of the example systems provide a good foundation on which to make this preliminary assessment. At this level of penetration, there should be no substantial operational limits or problems, provided New York adopts wind farm requirements and operations practices as described above.

Some other systems have experienced unexpectedly rapid increases in wind penetration. New York State should be able to accommodate any rate of wind generation additions at least up to this level of penetration without substantial operational limits or problems.

2.4 FATAL FLAW POWERFLOW ANALYSIS

The survey of world experience with wind generation indicated that New York State should be able to accommodate at least 10% penetration. The primary objective of the fatal flaw power flow analysis was to determine whether the existing New York State transmission system could accommodate this level of wind generation. Specifically, the goal was to determine the maximum power output at each of the 101 prospective wind generation sites in various regions of New York State with the existing transmission system infrastructure. The analysis focused solely on the thermal impact of the prospective wind generation on the transmission network. No transmission reinforcements were evaluated.

The local contingency analysis restricted the maximum amount of wind generation at each site such that pre- and post-contingency branch loadings were within thermal rating criteria, given the existing transmission system. The results show that of the approximately 10,000 MW of prospective wind generation, the transmission system can accommodate about 5,800 MW under 80% peak load system conditions, and about 6,100 MW under light load (44% of peak) conditions.

Existing generation was redispatched to compensate for the addition of new wind generation in each zone. The majority of generation available for redispatch in Zones B and C (Areas 2 and 3) was nuclear generation. If the nuclear plants are treated as both must-run and non-dispatchable, then the maximum wind generation under 80% peak load conditions would be reduced to about

5,100 MW. Similarly, the maximum wind generation under light load conditions would be reduced to about 4,900 MW.

In general, the preliminary transmission system analysis showed that the impact of the additional wind generation was mixed. It improved thermal performance in response to some outages and reduced it in response to others. Additional analysis would be required to determine the relative impact due to each wind generation project and the associated redispatch, as well as any mitigation requirements.

In summary, although some local sites may be restricted, the fatal flaw powerflow analysis did not preclude the system from reaching the 10% level of penetration discussed above.

2.5 RELIABILITY ANALYSIS

This analysis examined the impact of progressively increasing levels of wind turbine additions on the interconnected reliability of the New York Control Area (NYCA) as measured by Loss of Load Expectation, LOLE. While their average capacity factors were about 30% the capacity values based on their intermittent generation characteristics ranged from 3% to 12% of the nameplate ratings for most of the sites. The exception was the offshore site in Long Island, which showed a 23% capacity factor during those hours when the loads exceeded 90% of the system peak load.

Wind turbines demonstrate definite seasonal and diurnal output characteristics and the existing UCAP calculations should be modified to reflect that fact. Wind generation patterns within New York State demonstrate much lower levels of output in the summertime (Figure 2.2), and within the day they tend to peak in the morning, with afternoon and evening outputs roughly half of the morning levels (Figure 2.3). This provides little reliability value to a system that typically experiences its greatest need for capacity in late afternoon and early evening in the summer. A modification of the UCAP calculations based on the expected capacity factor during peak intervals provides UCAP values much more in line with actual reliability impacts.

Due to the current generation and transmission configuration within New York, additional capacity added west of the Central East Interface provides only a fraction of the reliability value as compared to capacity added downstate. Since location is not a factor when evaluating the UCAP of conventional generation it should not be used to penalize wind. However, it is

something that needs to be kept in mind since 85% of the potential sites identified in this analysis fall west of this interface.

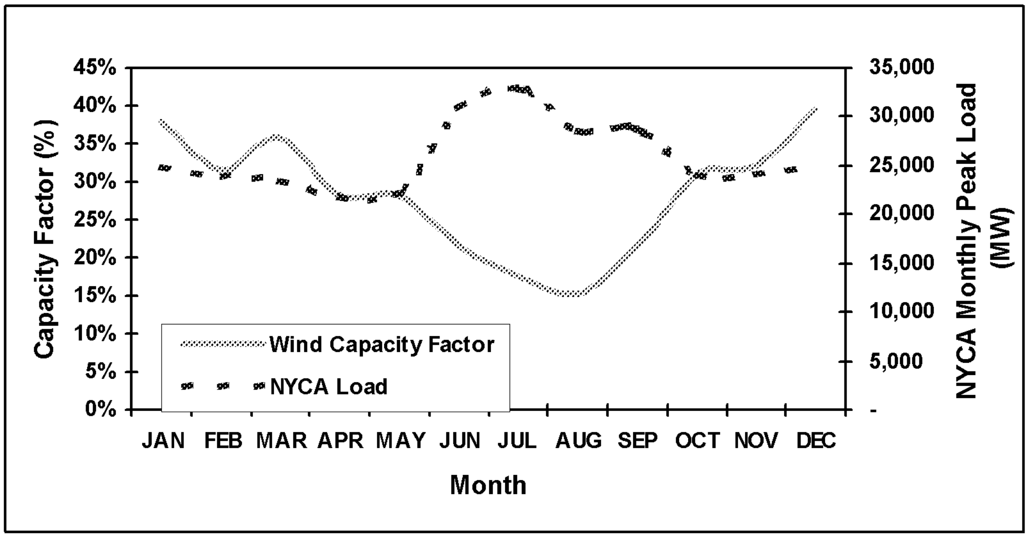

Figure 2.2 Average monthly capacity factor for all 101 wind sites and NYCA monthly peak load

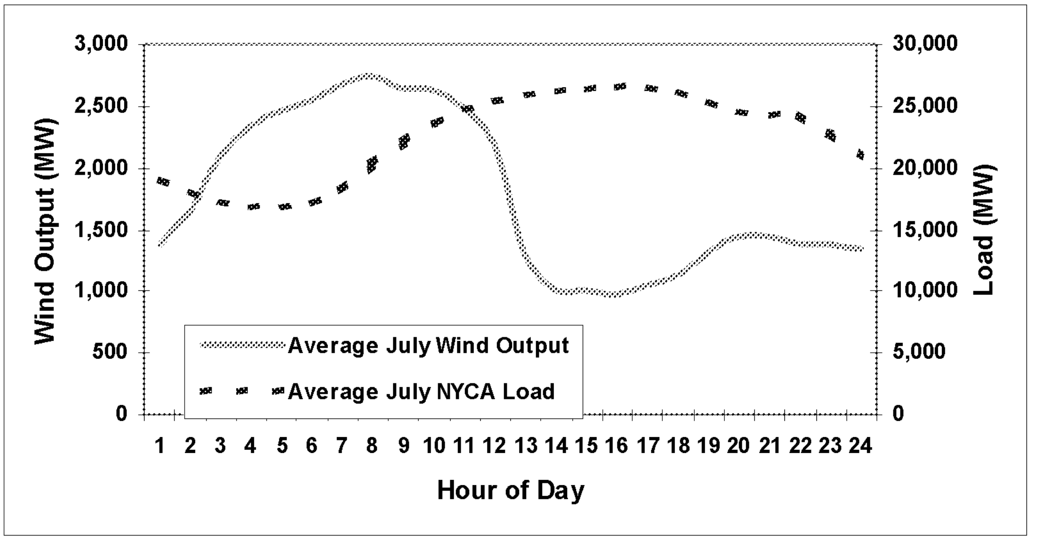

Figure 2.3 Average hourly output for all 101 wind sites and NYCA average load for July

Although it may provide minimal benefit, the addition of wind generation, in and of itself, will not cause the reliability of the system, as measured by LOLE, to degrade. However, if existing, marginally operating, thermal generation is retired, or if expected new generation is deferred or cancelled as a result of wind additions then system reliability will be negatively impacted,

although the NPCC minimum reliability threshold of 0.1 days/year LOLE will always be maintained. Phase 2 of this study will examine more of the operational impacts of wind generation, including the impact on spinning reserve, unit commitment and the change in cycling duty and capacity factors of thermal generation.

2.6 NEW YORK STATE PLANNING AND OPERATING PRACTICES

This review of the reliability rules for the planning and operation of the NYSBPS shows that, in general, the rules as written do not need to be modified to account for the presence of significant wind generation in the state. However, some of the procedures and the planning and performance criteria definitions referenced in the rules may have to be examined and possibly modified. Specifically, the following procedures may need to be modified:

- Calculation of operating reserves, regulation and load following requirements in the presence of wind generation
- Calculation of unforced capacity value of wind generation
- Consideration of wind generation in transmission planning
- Test requirements for the Dependable Maximum Net Capacity (DMNC) measurement of wind generation
- Operating procedures for operation with impending severe weather conditions

From an operational standpoint, it is not essential to update any of these procedures immediately in order to proceed with the integration of new wind generation projects in the State. However, all of these procedures will need to be updated before significant wind penetration levels are achieved.

Some procedures may need to be updated sooner than others in order to facilitate the planning of the system. For instance, the procedure for calculating the UCAP for wind generators will need to be updated before capacity credits can be issued to wind generators. This will also be critical to wind developers, as capacity payments are a factor in determining the economic feasibility of prospective wind projects. Also, operating procedures with severe weather conditions and the rules for calculating operating reserves, regulation and load following requirements will need to be updated.

This is a preliminary review that will be revisited in Phase 2, where the evaluation will be made in light of the complete findings of the study.

2.7 CONCLUSIONS

The results of this preliminary assessment indicate that New York State should be able to integrate wind generation distributed across the NYCA to a level of at least 10% of the system peak load (a total of about 3300 MW of wind turbine-generators) without significant adverse impacts on the planning, operations, and reliability of the bulk power system, provided that appropriate wind farm requirements and operations practices are adopted when needed. This conclusion is based on the experience of other systems with significant penetration of wind resources, and is further supported by the results of the fatal flaw power flow analysis and the reliability analysis of the NYSBPS.

Phase 2 of this study will evaluate the impact of wind generation on planning and operation of the NYSBPS in more detail, and refine the conclusions from this preliminary assessment.