USEA GLOBAL WORKSHOP ON LOW CARBON POWER SECTOR DEVELOPMENT

Washington D.C.

INTEGRATING LARGE SCALE VARIABLE RENEWABLE RESOURCES in New England

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ISO new england

Disclaimer

- All views and opinions expressed in this presentation are strictly those of the presenter and do not necessarily reflect the views of ISO New England.

Special Appreciation

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ISO New England Overview

A Little Bit of Regional History

- After the 1965 Northeast blackout, there was a need seen for regional effort to manage daily electricity load and ensure stable supply
- 1971, New England Power Pool (NEPOOL) created:
  - Integrated utilities and municipal systems
  - Established central dispatch system
  - Enhanced New England system's reliability
- 1996, FERC Order 888
  - Deregulated portions of the market
  - Change in NEPOOL role
  - ISO New England created

About ISO New England

- **Not-for-profit corporation created in 1997 to oversee New England's restructured electric power system**
  - Independent of companies doing business in the market
  - Regulated by the Federal Energy Regulatory Commission (FERC)

- **470 Employees**
  - Headquartered in Holyoke, MA
  - Largely power system engineers, economists and computer scientists

ISO New England's Major Responsibilities

Operating the Power System

- Balance electricity supply and demand every minute of the day by centrally dispatching the generation and flow of electricity across the region's transmission lines

Power System Planning

- Ensure the development of a reliable and efficient power system to meet current and future electricity needs

Oversee Wholesale Electricity Markets

- Develop and administer the region's marketplace through which wholesale electricity is bought and sold

ISO New England's Responsibilities Are Defined and Guided by Rules and Standards

FERC
FEDERAL ENERGY REGULATORY COMMISSION

Defines ISO's authority and the services it provides. ISO responsibilities are guided by rules approved or mandated by FERC.

NERC coordinates its activities with eight regional entities. NPCC develops, implements, and enforces criteria for the design and operation of the interconnected power systems in the Northeast.

Rules and standards give industry certainty of purpose and provide clear goals for maintaining reliable electricity service at competitive prices.

NERC
NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION

Develops and ensures compliance with mandatory standards for planning and operating power systems in North America. Can levy fines of $1,000 to $1 million per day for violations.

Develops and follows procedures to meet the numerous, stringent reliability standards.

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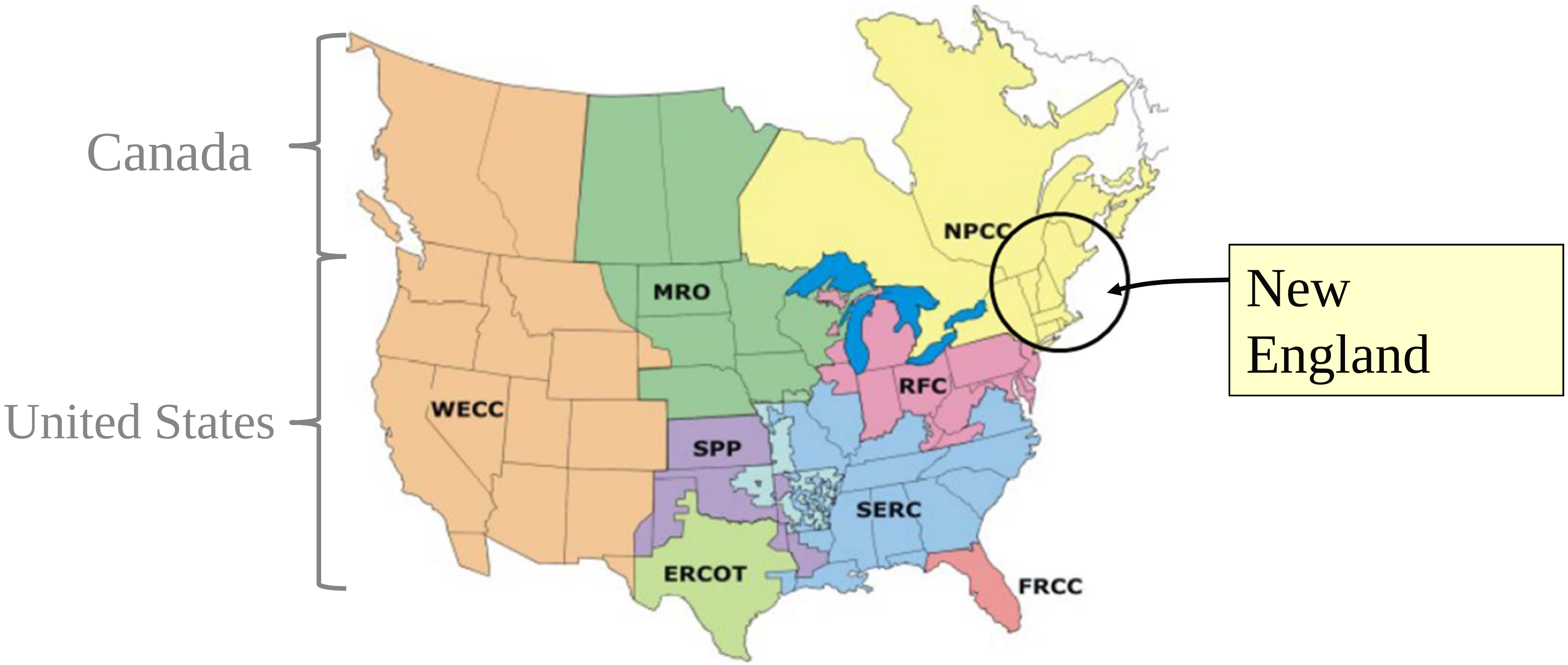
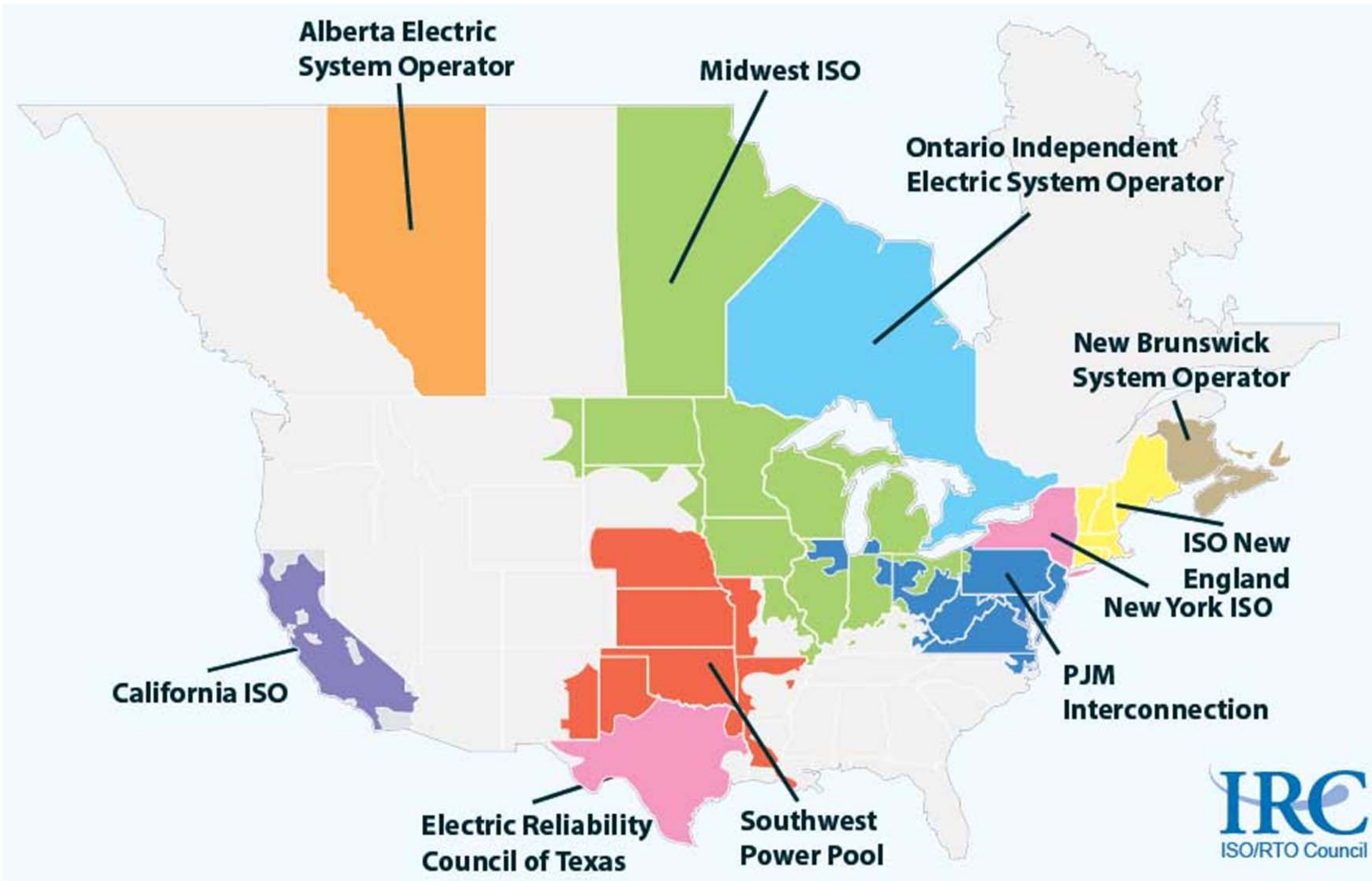
New England is in the North East

- New England is in the North Eastern United States
- Part of Northeast Power Coordinating Council (NPCC)
- NPCC is one of eight NERC Reliability Regions



Existing ISO/RTO Configurations



Source: ISO/RTO Council

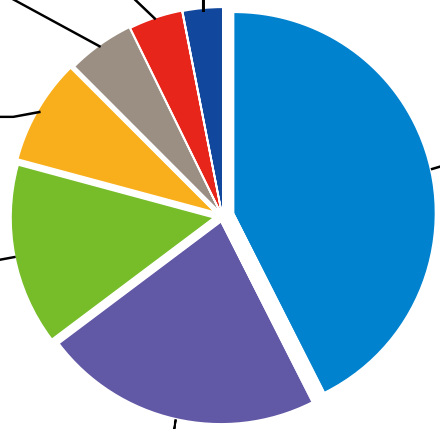
New England's Electric Power Grid

A tightly integrated regional power system

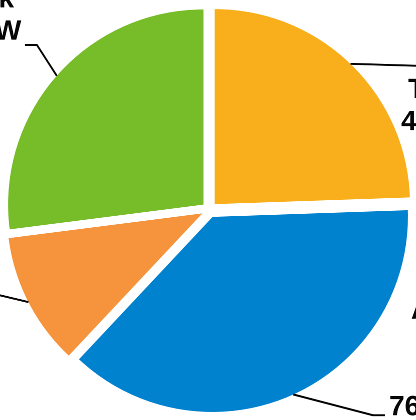
- 6.5 million households and businesses; population 14 million
- More than 300 generators
- Over 8,000 miles of high-voltage transmission lines
- 13 interconnections to electricity systems in New York and Canada
- Approx. 32,000 megawatts of total supply and 2,035 megawatts of demand resources
- All-time peak demand of 28,130 megawatts, set on August 2, 2006
- More than 450 participants in the marketplace
- $5-11 billion annual energy market value

ISO New England Control Room

2011 Summer: Installed Generation and Demand Resources Capacity



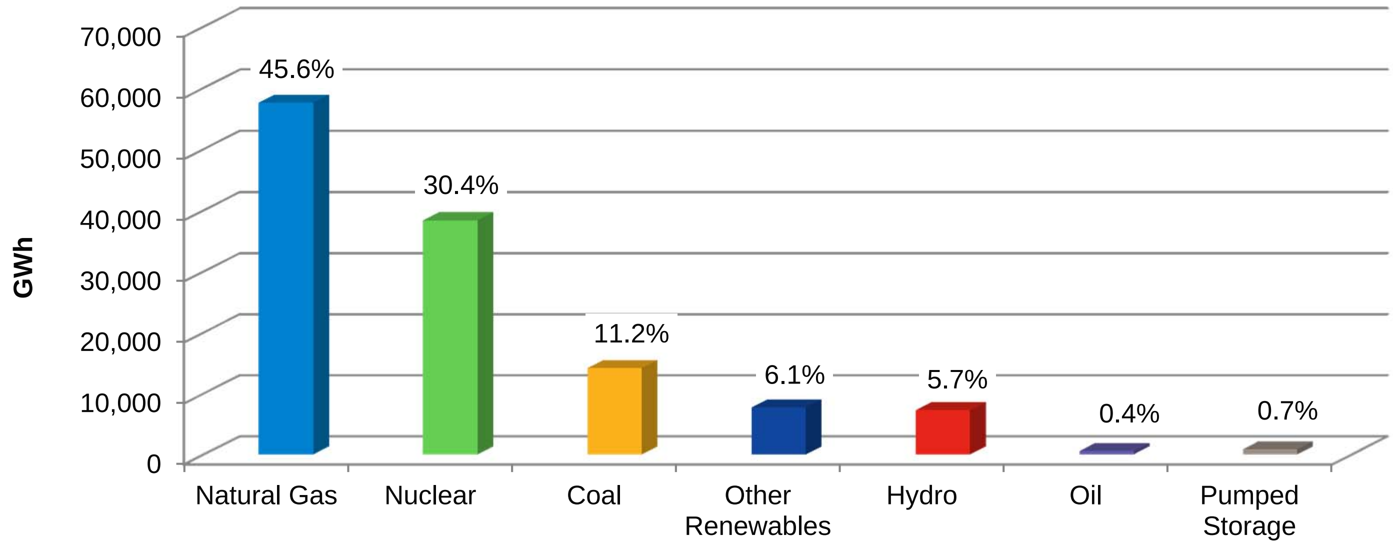
Generation Total = 32,037 MW



Demand Resources Total = 2,035 MW

- Values do not include external resources, such as purchases, and sales.
- The “Other Renewables” category includes landfill gas, other biomass gas, refuse (municipal solid waste), wood and wood-waste solids, wind, and tire-derived fuels.
- Demand Resources values are based on 2011 Summer Capacity Supply Obligations from the 2011 CELT

2010 Generator Energy Production by Fuel Type



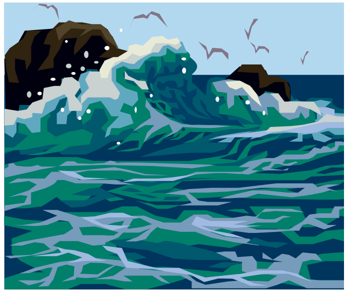
- The “Other Renewables” category includes landfill gas, other biomass gas, refuse (municipal solid waste), wood and wood-waste solids, wind, and tire-derived fuels.

What are renewable resources and renewable generation resources?

Definition of Renewable resource

"A **renewable resource** is a natural resource with the ability of being replaced through biological or other natural processes and replenished with the passage of time. Renewable resources are part of our natural environment and form our eco-system."*

- Renewable resources are replenished through biogeochemical and physical cycles.
- Non-renewable resources do not replenish themselves, or, as in the case of fossil fuels, do so only at a very slow rate.



* Based on Wikipedia

Renewable Generation Resource

Renewable generation resources are generating units that produce electricity using renewable resources. Examples of renewable generation resources are the generating units that use solar, wind, tides, waves, biomass, or geo-thermal as fuel to produce electricity.

Integrating Renewable Generation Resource

Addition of renewable generation resources to the grid is not a problem, if the energy production of the generating units **is predictable** (with reasonable accuracy) **and can be controlled**.

The problem is associated with a large amount of generation from the renewable resources that are **variable and non (or semi)-dispatchable**.

– Not close to load presents additional problems

Many Variable (Wind) Renewable Generation Resources in the Horizon*

New Generation Projection - By Operating Type and Fuel Type

	Total		Baseload		Intermediate		Peaker		Wind Turbine	
Fuel Type	No. of Projects	Capacity (MW)	No. of Projects	Capacity (MW)	No. of Projects	Capacity (MW)	No. of Projects	Capacity (MW)	No. of Projects	Capacity (MW)
Biomass/Wood Waste	9	313	9	313	0	0	0	0	0	0
Coal	1	36	1	36	0	0	0	0	0	0
Hydro	8	114	0	0	7	39	1	75	0	0
Landfill Gas	1	28	1	28	0	0	0	0	0	0
Natural Gas	3	135	1	9	2	126	0	0	0	0
Natural Gas/Oil	8	2,147	0	0	7	2,017	1	130	0	0
Nuclear Uprates	1	13	1	13	0	0	0	0	0	0
Oil	2	43	0	0	0	0	2	43	0	0
Solar	3	16	0	0	0	0	3	16	0	0
Wind	33	2,277	0	0	0	0	0	0	33	2,277
Total	69	5,122	13	399	16	2,182	7	264	33	2,277

* Based on December 1, 2011 Interconnection Request Queue.

Why are there so many MWs of Wind Resources in the Horizon?

- Wind generation is emissions free
  - can help to meet New England States' Renewable Portfolio Standard targets
- Wind energy can dampen fuel cost uncertainty
- Wind energy improves fuel diversity
- Wind generation is price competitive with other new resources
- Wind generation, itself, is quick to build

Stetson, ME

Kibby, ME

Lillegrund (Sweden)

HOW IS WIND DIFFERENT?

FROM A POWER SYSTEM OPERATOR'S POINT OF VIEW

Wind is Novel for Large Scale Generation

- Small unit size (in MW)
  - Distributed Generation ~ 5MW – a handful of turbines
  - Windfarm up to say 1,000 MW – tens to hundreds of turbines
- Variable and somewhat unpredictable generation
  - Semi-dispatchable (at best): down, not up (caveat)
  - Doesn't usually correlate well with use pattern
  - Forecast accuracy improves as time horizon shrinks
- Locationally constrained
  - Can't ship the wind in
  - Often best resources are distant from load centers
- Young technology
  - Evolving grid-awareness/support
  - Power electronics (on most machines) make them very flexible

Integration Challenges: Operational

The variable and uncertainty of wind output over:

- Seconds to minutes
  - Affects regulation to maintain system frequency and voltage
- Minutes to hours
  - Affects load following and balancing to match demand with generation
- One hour to day ahead intervals
  - Affects unit commitment and scheduling to ensure economic dispatch

Integration Challenges: Operational (cont.)

- Minimum generation issues
  - e.g., spill wind to maintain system security
- Congestion management
  - e.g. ,spill wind to maintain thermal limits
- Coordination with other Balancing Areas
  - Share the variability (and reduce overall variability)

Impact on Reserves

- Spinning reserve
  - Usually no effect – requirement typically based on large generators/tie-lines
  - Unless loss of wind (or forecast error) exceeds 2nd largest contingency
- Non-spin reserve
  - High wind cutout can cause loss of generation on the order of approximately 25% wind plant output per hour
  - Wind variability may increase non-spin reserve requirements

Challenges: Markets & Planning

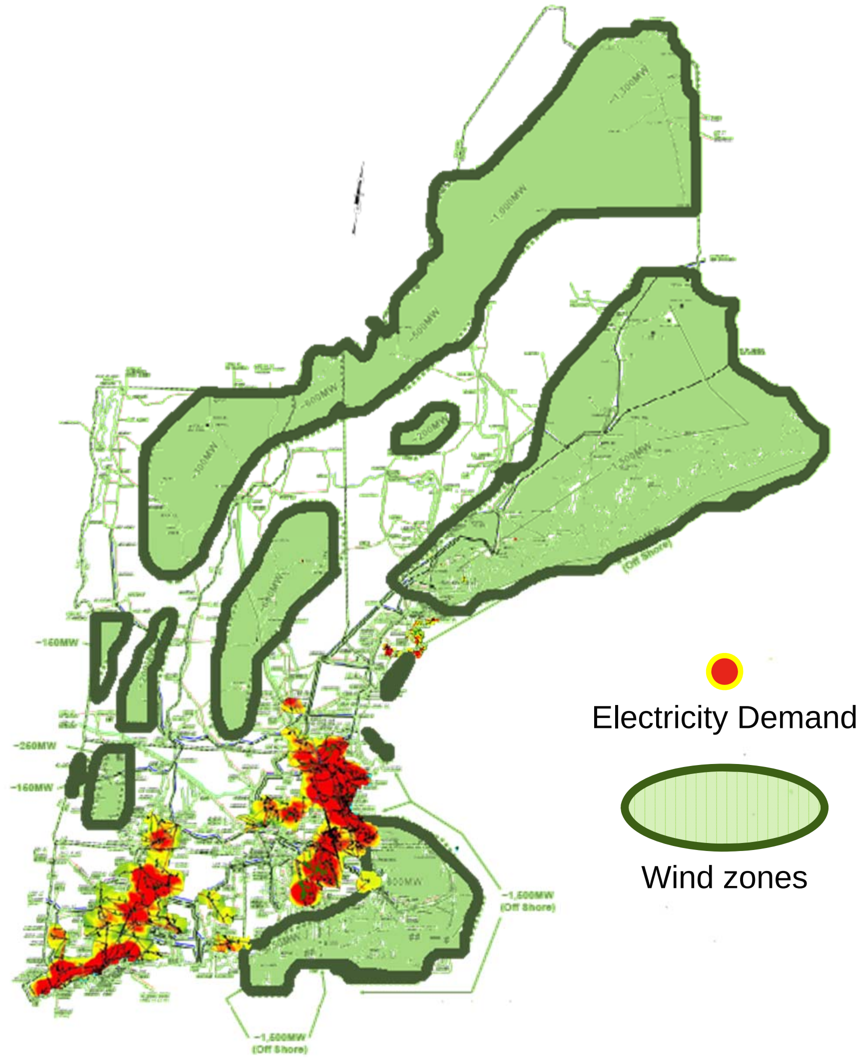
- Markets

Over–commitment	Under–commitment
Inefficient use of resources May depress LMPs May raise uplift	Can increase price volatility

  – Real-time vs. Day-ahead
  – Do we need to increase operating reserve requirements?
  – What are the effects of increased reserve requirements?
  – What are the effects of virtual bids?
- Planning
  – The real problem: forecasting the wind = forecasting the weather
    - Great amount of uncertainty relating to wind generation
      – Therefore, what to assume relating to its capacity and energy contributions?

The Challenge: Connecting Wind Energy to Load Centers

- Region’s population and electricity demand are substantially concentrated in southern New England
- Potential wind resources do not substantially overlap high population and high energy demand areas
- Therefore, new “backbone” transmission will be required to connect potential wind resources to load centers in New England



How ISO New England has addressed the Challenges

Short & Recent History of Wind at ISO-NE

- Scenario Analysis 2007:
  - Queue wind (780MW)
  - Plus approx. 5*¼*(5.4GW,8.9GW) =6.9GW, 10.9GW
- Levitan Phase I 2007
  - AWST wind map (2003): 50m hub onshore, 100m hub offshore
    - Onshore: class 3+, pop density<=Hull, 40MW min size
    - Offshore: class 4+, depth<=60m, min 3NM to shore, 200MW min
- Levitan Phase II 2008
  - Refined results of Phase I (transmission proximity)
    - Onshore/Offshore Nameplate Potential: 174GW/26.5GW
- Governor’s Blueprint Study (2010)
  - Conceptual Transmission Overlays for Wind integration
- The New England Wind Integration Study (2010)…

What is the New England Wind Integration Study (NEWIS) Study?

- ISO-NE needed a New England-focused analysis
- New England Wind Integration Study
  - Performed over two years (2008-2010)
  - Is a comprehensive wind integration study
    - Includes models of: windy neighbors, offshore, market system
  - Highlights operational effects of large-scale wind integration
  - Uses statistical and simulation analysis
    - Based on 3 years of historical data, develops
      - Highly detailed load dataset
      - Highly detailed and realistic representation of windpower
  - Includes trending to predict incremental effects
  - Learns from each iteration of simulation and analysis

NEWIS – Additional Objectives

- **Develop interconnection requirements**
  - Grid support functions
  - “Best practices” capacity value determination for wind power
    - Both for the entire region and for incremental wind power
  - Data/telemetry requirements
  - Wind forecasting
- **Show longer-term issues**
  - Capacity factors
  - Reliability effects of wind (LOLE, ELCC)
- **Several levels of review**
  - Stakeholder feedback
  - Internal ISO-NE review
  - Independent Technical Review Committee (TRC) of recognized experts

The NEWIS Scope of Work

- Wind Integration Survey
- Interconnection Requirements for Wind
- Build New England Wind Resource Area (NEWRA) models
- Scenario Development/Analysis: wind buildouts:
  - Partial queue
  - Full Queue
  - And various layout alternatives for:
    - 14% of Annual Energy
    - 20% of Annual Energy
- Scenario Simulation

The NEWIS Team

- Team GE
  - GE Energy and Systems Engineering
    - NYSERDA (‘04, ‘05) through to CAISO (’07) and WSIS (’10)
  - EnerNex
    - Minnesota (‘04) through to EWITS (‘09)
  - AWS Truepower
    - NYSERDA through to EWITS
- Technical Review Committee
  - J. Charles Smith: UWIG, AWEA
  - Michael Milligan, Brendan Kirby: National Energy Labs
  - Mike Jacobs: Developers/Transmission
  - Utama Abdulwahid: UMass Wind Energy Center
  - Warren Lasher: ERCOT

Recommended Changes to ISO-NE Operating Rules and Practices

Ten Minute Non-Spinning Reserve (TMNSR):

- A mechanism for securing this capacity as additional TMNSR during periods of volatile wind generation may need to be developed.
- Should investigate the use of TMOR instead of and/or in combination with TMNSR

Wind Forecast:

- Day-ahead wind forecast should be included in the ISO-NE economic day-ahead security constrained unit commitment and reserve adequacy analysis.
- Production simulation results show that the benefit of including forecasted wind generation in the day-ahead unit commitment increases with wind penetration

Recommended Changes to ISO-NE Operating Rules and Practices (cont.)

Wind Forecast (cont.):

- If wind forecasts are not included in unit commitment
    - Conventional generation will be overcommitted
        - Operating costs will be increased, LMPs will be depressed
        - Will be surplus spinning reserve
        - Excessive wind generation curtailment
  - Current practices for publishing the load forecast should be followed for publishing the wind forecast, subject to confidentiality requirements
- Intra-day wind forecasting should be performed in order to reduce dispatch inefficiencies and provide for situational awareness

Technical Requirements for Interconnection of Wind Generation

Task 2 report, “Technical Requirements for Wind Generation Interconnection and Integration,”

- Includes a set of recommendations for interconnecting and integrating wind generation into the ISO-NE power grid
- These recommendations were re-examined after the NEWIS scenario analysis was completed and no changes were warranted
- Scenario analysis reinforces the need to implement those recommendations
- Implementation of the Task 2 report recommendations is essential for the reliable and efficient integration of large-scale windpower for New England

Technical Requirements for Interconnection of Wind Generation

A few of the most significant Task 2 recommendations related to the areas of:

- Active Power Control
  - Wind plants must have the capability to accept real-time power schedule commands from the ISO
- AGC Capability
  - Encourage the capability to accept AGC signals
- Centralized Wind Forecast
  - ISO-NE should implement a centralized wind power forecasting system

Technical Requirements for Interconnection of Wind Generation (cont.)

A few of the most significant Task 2 recommendations related to the areas of:

- Communications
  - Wind plants should have the same level of human operator control and supervision as similar sized conventional plants
  - Wind plants should have automated control/monitoring functions, including communications with ISO-NE, to implement operator commands (active/reactive power schedules, voltage schedules, etc.) and provide ISO-NE necessary data to support wind forecasting functions

Future Work

Transmission system overlay refinement

- Assumed transfer capability from transmission overlays shown to have adequate capacity for considered scenarios
- ISO-NE should consider conducting planning study to develop more refined transmission expansion for wind integration

Sub-hourly performance during challenging periods

- More in-depth investigation of dynamic performance of the system under conditions of high stress using additional simulation tools
  - Coincident high penetration
  - High variability

Future Work (cont.)

Sub-hourly performance during challenging periods (cont.)

- Both long-term dynamic simulations and fine time resolution quasi-static time simulations could give insight on:
  - Frequency
  - Area Control Error (ACE)
  - Control Performance Standard (CPS)
  - Other performance measures
  - Incremental maneuvering duties imposed on incumbent generation

Future Work

Impacts of Cycling and Maneuvering on Thermal Units

- Understanding the impacts and the quantification of cost associated with:
  - Starting and stopping of units
  - Static impacts on heat rates
  - Dynamic impacts on Emissions
  - Quantification of
    - Expected cycling duty
    - Ability of thermal generators to respond
    - Further Investigation of impact on
      - O&M, Emissions, Heat rate, and Loss of life

Future Work (cont.)

Economic Viability and Resource Retirements

- Investigation of revenue impacts and their implications for long-term viability of marginal assets that make up a majority of the flexible resources in ISO-NE’s fleet
- Investigation of possible resource retirement from
  - Reduced energy sales and revenues
  - Efficacy of possible market structures for maintaining the necessary resources for system reliability

Demand Response

- Investigation into the efficacy and limitations of various demand-side options for adding system flexibility and define direction and policy to pursue

What Is ISO-NE working on with regard to wind right now?

- Wind Power Forecasting
  - RFP awarded for a suite of wind power forecasting products
  - Wind Plant Data Requirements
    - Static Data (e.g. power curves, turbine locations, etc.)
    - Real-time Data (e.g. wind speeds, directions, etc.)
- Strategic Analysis
  - Refining the required transmission system
- Integrating wind/wind power forecast into:
  - Control Room situational awareness: displays and alarms
  - Commitment: make efficient use of available resources
  - Dispatch: automate congestion management
  - Publishing: help markets to operate efficiently

Questions and Discussion