Lessons Learned in Wind Generation

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Lesson 1: Planning for Wind Generation for an 9 Year period-2002-2011

Transmission planning must include more than reliability considerations. Wind generation is primarily and energy resource and not a capacity resource that can be relied upon to deliver energy on at the time of peak or on demand. Wind energy is mainly produced at night and in the off peak seasons. The transmission required to deliver wind energy must be planned for state renewable policy compliance, economics and off peak delivery of energy as well as capacity. Wind generation is a social choice and not an economical decision. For Planning, wind is a given and the plans are to make the most of what is given according the MISO Guiding Principles and Conditions Precedent.

MISO's Guiding Principles

- Make the benefits of a competitive energy market available to all customers by proving access to the lowest possible electric energy costs.
- Provide a transmission infrastructure that safeguards local and regional reliability and supports interconnection wide reliability.
- Support state and federal renewable energy objectives by planning for access to all such resources, including wind, biomass and demand side management.
- Provide an appropriate cost allocation mechanism.
- Develop a transmission system scenario model and make it available to state and federal energy policy markets to provide context and inform their choices.

The transmission must meet a number of conditions precedents to construction to be approved

- A robust business case.
- Increased consensus on regional energy policies.
- A regional tariff matching who benefits with that pays.
- Cost recovery mechanisms to reduce financial risk.

In 2008, the National Renewable Energy Laboratory developed 10 minute wind energy models for the years 2004-2006 for the Eastern Interconnection that enabled wind to be modeled in a PROMOD production simulation model more accurately than ever before. The wind data allowed the evaluation of the Capacity Credit for wind and the reduction in variability due to geographic diversity of wind.

Decision makers have to be invited to the question and not just involved after an answer is proposed. Renewable Energy Zones were determined with the Organization of MISO States (regulators), Midwest Governors Association and MISO stakeholders using wind characteristics and economic interests. An

REZ is basically a substation that can collect about 750 MW of wind generation energy and have transmission connected to it to deliver the wind energy.   The blue ellipses are the REZs.

The Regional Generation Outlet Study developed some transmission plans that were used to make decisions about the general layout of a transmission system to deliver the 25,000 MW of wind Renewable Portfolio Standards for MISO.

Cost Allocation methodology was developed with the Organization of MISO States (CARP) and stakeholders.   Cost Allocation provided revenue for transmission lines that benefitted multiple areas.

A Multi Value tariff was developed that specified the functional and economic criteria that transmission must meet to qualify under the tariff

The Multi Value Study determined the first set of transmission lines of the A portfolio of 17 Multi Value Projects worth $5.2B were approved in 2011 by the MISO Board of Directors to deliver up to 21,000 MW of wind energy by the year 2021, provide congestion relief by improving energy market efficiency, avoid the cost of generation by raising the capacity credit of wind generation thus avoiding other generation construction and other values. The benefit to cost ratio of the transmission over 20 years is 1.8 to 1. The set of lines was approved as a group.

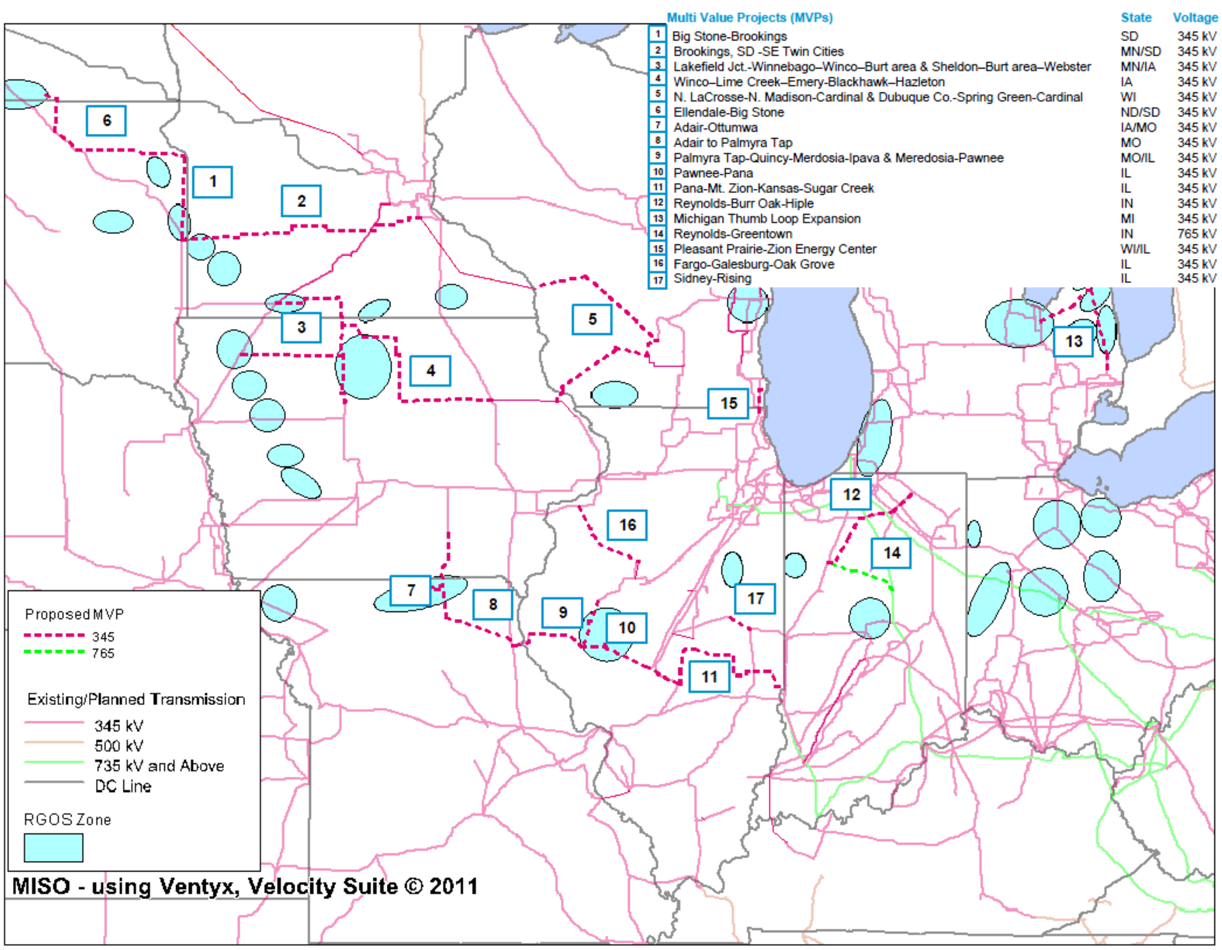

Figure 1: Multi Value Project Portfolio of transmission lines

Resource Policy

Lesson 2: Decision makers have to be invited to the question and not just involved after an answer is proposed.

- The Midwest Governors Association, the Organization of MISO States (state regulators), MISO stakeholders and staff worked together to choose Renewable Energy Zones to locate the 345 kV substations. Those substations collect wind generation and deliver it over a network of primarily 345 kV lines to the load.
  Total cost of energy delivered and the economic benefits of wind generation development to the local economy were considered. More than one-third of the cost of a wind generator installation is estimated to be delivered to the state economies during the wind generator's first year of operation. The social choice of choosing wind extends to the choice of obtaining the economic benefits from wind generation construction.

Interconnection Queue Procedures

Lesson 3: Robust Interconnection Queue procedures are needed to add order and obtain processing efficiency for studying and interconnecting proposed generation. These procedures should align with the overall development of the generation project and should facilitate transmission access for projects that are ready to be built. The free market system does not produce the lowest cost of energy to the customer without some rules and order.

MISO has 10,000 MW of wind registered in the energy market that has been designated for connection through the Generation Interconnection Queue study processes. Most of the wind generation has been connected to existing transmission that required modest transmission upgrades. The lower cost options have been used, so the next level of interconnections requires higher costs, more cooperation through cost allocation of transmission and improved Queue processes.

Operation and market practices integrate wind generation more economically.

Lesson 4: Large Balancing Areas ease the integration of wind.

- MISO consolidated 26 balancing areas operating prior to formation of the energy market into one balancing area after the energy market was formed. Having one control area shifts the responsibility of smaller balancing areas with relative high levels of wind generation compared to load to the larger single balancing area with a relatively low level of wind generation compared to load.

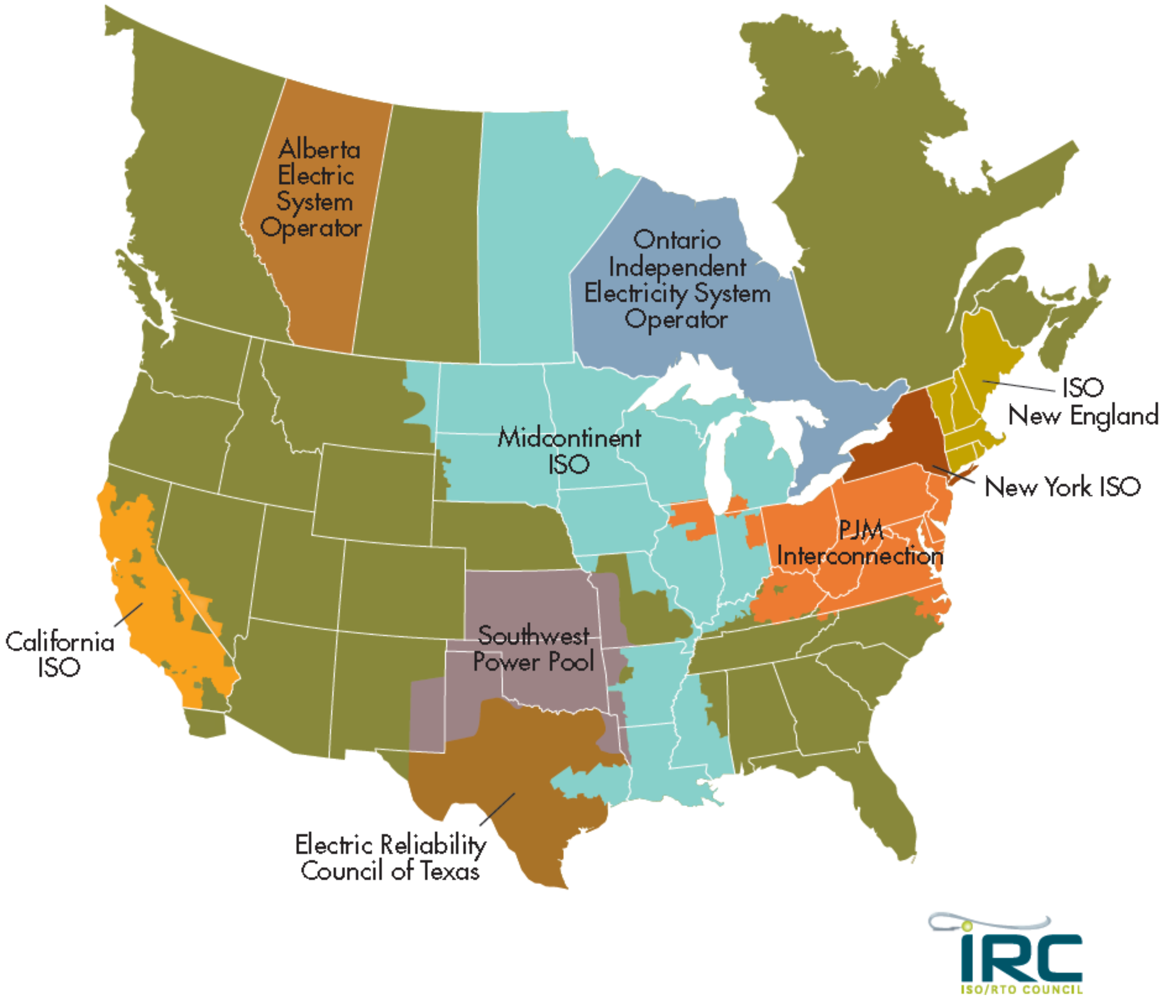

Figure 2: RTO/ISO Map

Lesson 5: Shorter dispatch periods reduce problems in integrating wind

Before the energy markets were established in MISO, the time between changing the dispatch on the power system was one hour. The energy markets operate on a five-minute period. Shorter dispatch times reduce the error of forecasting wind generation and load.

Lesson 6: Geographical Diversity reduces wind and load variations to improve the wind product, but transmission is required.

Wind has about a 30% variability when viewed in low concentrations in a small area.

The variability of wind generation is greatest when the wind generation level is about 45% of rated.

MISO has 12,000 MW of wind generation on a 130,000 MW load in the footprint. Wind variability over a large geographic area is reduced by a factor of 3 when larger amounts of wind are spread over a large geographic area. The Capacity Credit for wind increases with geographic diversity of wind locations. MISO has not added spinning reserves for the wind generation on the MISO system.

MISO wind Capacity Credit is 13%. Capacity Credit displaces about 1,500 MW of other types of generation and adds value for wind generation.

The correlation of wind energy is low over a 600+ mile footprint which is another indicator of the value of geographic diversity.

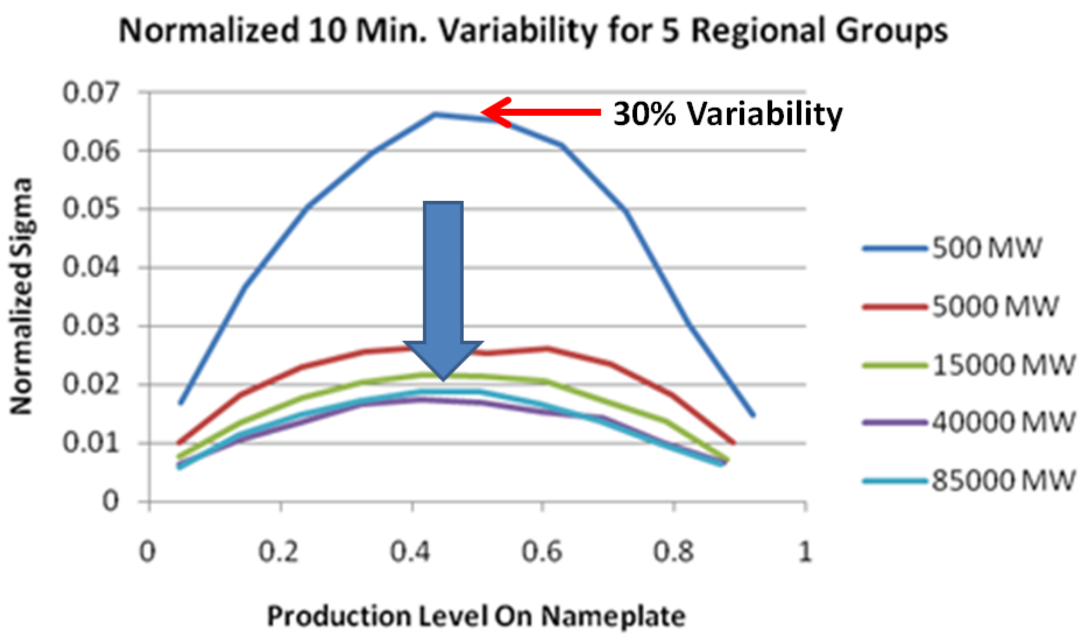

Figure 3: Variability of Wind from NREL EWITS Report

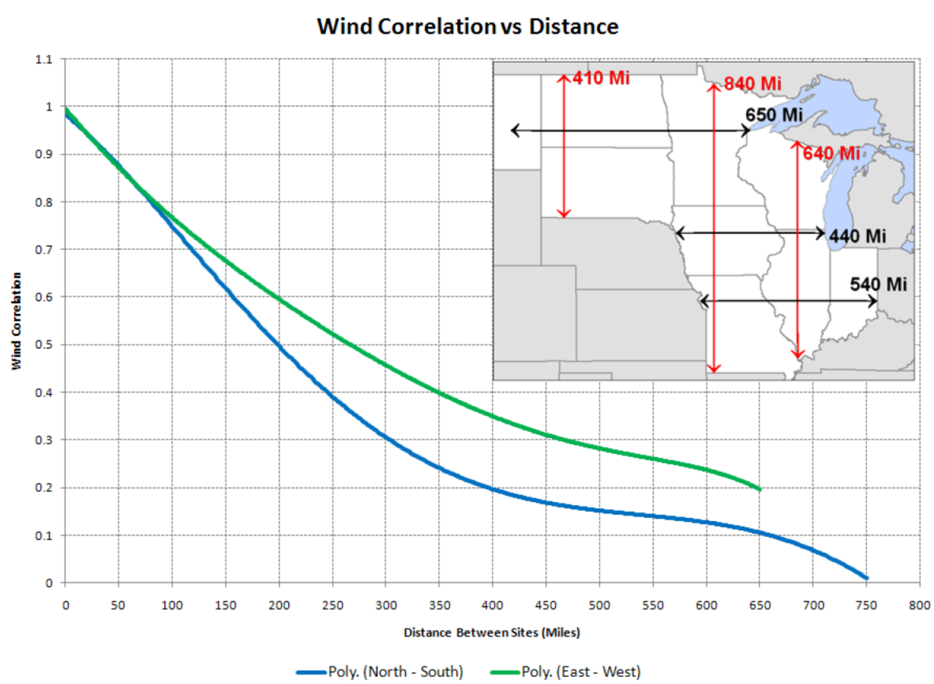

Figure 4: Correlation of Wind Energy versus Distance

MISO is positioned to exchange geographic diversity of wind energy with most of the major wind locations in the middle of the U.S. as shown on the 600 mile diameter circle on the map below.

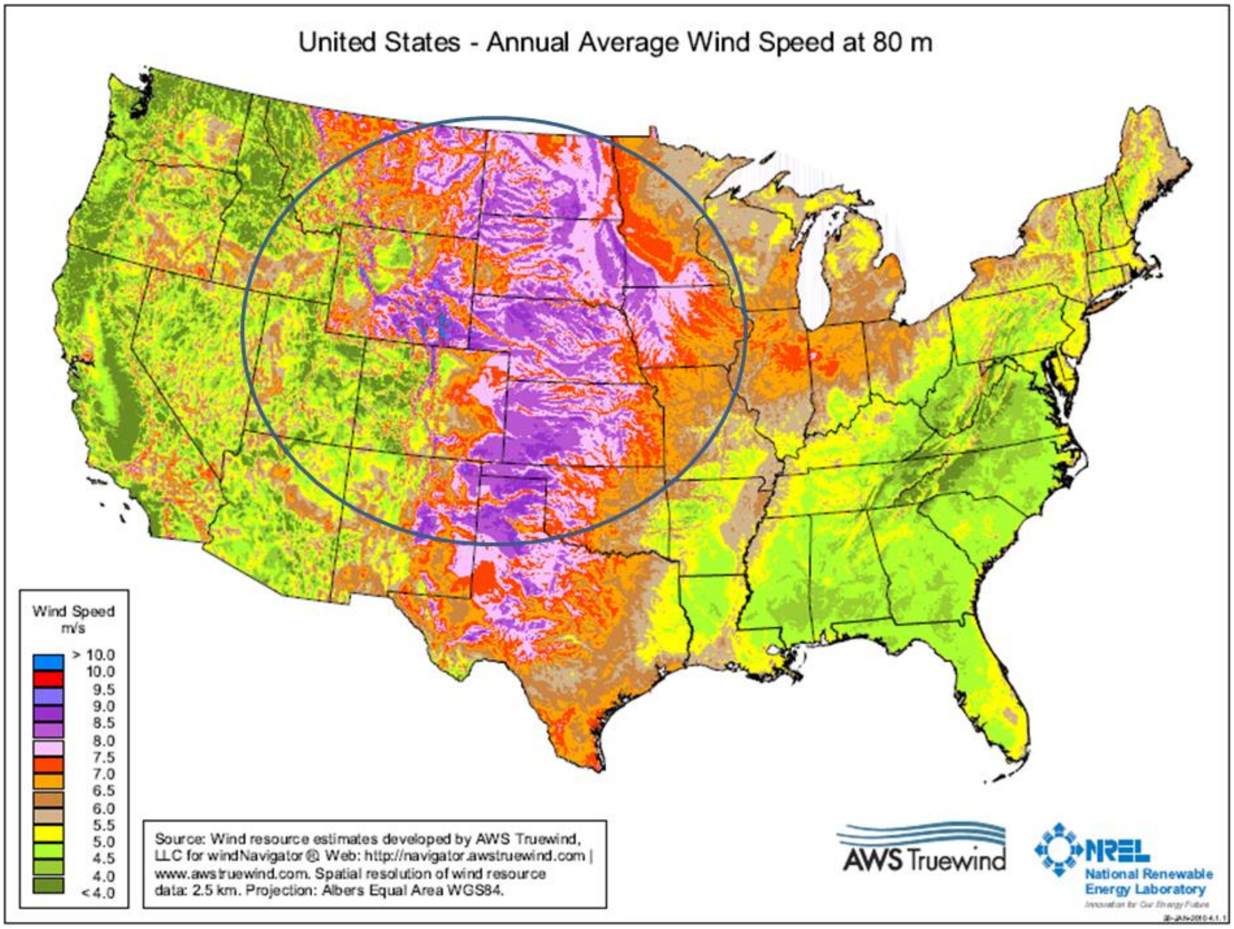

Figure 5: U.S. Wind Map

Lesson 7: Transmission does not need to be constructed to deliver 100 percent of rated wind output.

- MISO has a 6 percent wind curtailment on energy.
- Full wind output does not exceed 80 percent of the connected wind output.

Lesson 8: Ensembles of wind forecasts are necessary.

- Wind forecasts using different methods produce different times and magnitude that a ramping event may occur. The timing is the more significant error for the system to respond. The different forecasts may be better for certain conditions than others. The dispersion of forecasts may require that more reserves be on line to handle the uncertainty which may occur.

Lesson 9: Local economic development and job creation off shore and local wind will limit wind development in the high plains.

Storage

Lesson 10: There are existing storage capabilities on the existing MHEB system that the Manitoba Hydro Wind Synergy Study showed reduced the curtailment of wind generation in MISO.

HVDC

Lesson 10: Voltage Source Converter HVDC systems can be ordered now for 600 kV and 2,400 MW. The rating is an economical size to capture wind, load, frequency response diversity between MISO and its neighbors. The benefits from the reduction in other types of generation expansion and fuel use may be sufficient to pay for the HVDC Network to collect and exchange capacity diversity as well as energy diversity products.

HVDC can cherry pick the highest value market products to pay for the lines and exclude loop flow energy that does not pay for the transmission.