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Issues: Generation Capacity and Reliability
Witness: Robert M. Zavadil
Sponsoring Party: Grain Belt Express Clean Line LLC
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MISSOURI PUBLIC SERVICE COMMISSION

CASE NO. EA-2014-0207

DIRECT TESTIMONY OF

ROBERT M. ZAVADIL

ON BEHALF OF

GRAIN BELT EXPRESS CLEAN LINE, LLC

March 26, 2014

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I. WITNESS INTRODUCTION AND PURPOSE OF TESTIMONY

Q. Please state your name, present position and business address.

A. My name is Robert Zavadil, Executive Vice President and co-founder of EnerNex, LLC ("EnerNex"), whose primary business address is 620 Mabry Hood Road, Suite 300, Knoxville, Tennessee.

Q. What is the business of EnerNex?

A. EnerNex is a power system engineering consulting firm specializing in the analysis and application of electric power system equipment and technologies. EnerNex uses computer modeling and simulation tools to advise and serve clients, including electric transmission and distribution utilities, industrial end-users, generation project developers and operators, electrical equipment vendors, and research organizations.

Q. What are your duties and responsibilities as Executive Vice President at EnerNex?

A. I am responsible for developing and overseeing EnerNex's power system consulting business advising electric utilities, large industrial customers, power equipment vendors, research organizations, and project developers.

Q. Please describe your education and professional background.

A. I received a Bachelor of Science degree in electrical engineering (with highest honors) from South Dakota State University in 1982. I began my professional career in 1982 with Nebraska Public Power District as a technical support engineer in the Transmission and Distribution Engineering Division. In 1989 I joined Electrotek Concepts, a small consulting engineering company based in Knoxville, Tennessee. In 2003 I formed EnerNex with two partners. I have held a variety of positions at EnerNex and its sister company Dranetz-BMI. I have been a member of the Institute of Electrical and Electronic Engineers ("IEEE") for 32 years, and maintain registration in the Power and

Energy Society ("PES"), Power Electronics Society, and the Industrial Applications Society.

My career has centered on the application of various modeling, simulation, and other analytical techniques to a wide variety of power system engineering problems. I have extensive experience with new and emerging technologies for electric power generation, delivery, and utilization, including distributed generation and power electronics-based equipment. A copy of my curriculum vitae is attached as Schedule RMZ-1.

Q. Please describe your background in performing reliability benefit studies

A. I have been studying wind generation impacts on electric power systems for over 25 years. Over this time, I directed or contributed to approximately 20 different investigations into the effects of significant wind generation on power system operation and reliability. In several of these studies, the impact of wind generation on resource adequacy was a major topic of investigation.[1] I have also contributed substantially to the discussion of this topic in professional engineering circles. I have served as an officer of the IEEE Power and Energy Society's Wind and Solar Power Coordinating Committee since its establishment in 2006.

Q. What is the purpose of your direct testimony?

A. On behalf of Grain Belt Express Clean Line LLC ("Great Belt Express"), this testimony examines and measures the reliability impact of the Grain Belt Express transmission project ("Grain Belt Express Project" or "Project") on the State of Missouri. By applying

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[1] These include wind integration studies for Xcel Energy in Minnesota (2004) and Colorado (2005-2008, multiple studies), the Minnesota Public Utilities Commission (2006), the Nebraska Power Association (2009), the Eastern Wind Integration and Transmission Study for the U.S. Department of Energy through NREL(2010), and the PJM Interconnection (2013)

widely used techniques to assess resource adequacy, my testimony will demonstrate that the injection of wind energy via the Project improves the reliability of the Missouri bulk electric system.

II. <u>OVERVIEW OF LOSS OF LOAD EXPECTATION ("LOLE") ANALYSIS</u>

Q. Please define the reliability impact of the Project that is the subject of your testimony and analysis.

A. In order to maintain high levels of electric reliability, generating capacity must be available and able to produce power in sufficient quantities to meet the expected peak demand. This is often termed "resource adequacy." Because all generators experience forced outages or other times of unavailability, generation capacity must exceed expected peak load in order to maintain resource adequacy with a high level of certainty. The simplest measure of resource adequacy is the ratio of total generation capacity to expected peak load, sometimes termed the "planning" or "capacity" margin. However, a more rigorous assessment of resource adequacy is Loss of Load Expectation ("LOLE").

LOLE analysis calculates the probability that a set of generating units or other supply options is insufficient to meet an expected level of electric demand. A higher LOLE indicates a higher probability of loss of load, whereas a lower LOLE value indicates a lower probability of loss of load and improved reliability in the bulk electric system.

Q. How does an LOLE analysis measure the reliability impacts of wind generation?

A. An LOLE analysis can incorporate meteorological data and wind generators' ability to generate during peak load hours. Hourly wind generation data are an input into the LOLE model. The techniques for the LOLE analysis of wind generation have been developed in part by the National Renewable Energy Laboratory ("NREL"). Several integration studies performed over the past decade, including those previously mentioned studies for the Minnesota Public Utilities Commission and the Eastern Wind Integration and Transmission Study ("EWITS"), have established some consensus techniques for the LOLE analysis of wind generation, and they form the basis of my analysis of the Grain Belt Express Project.

Closely related to LOLE is Effective Load Carrying Capability or ("ELCC"). ELCC measures the increase in load that can be served by the addition of a new supply resource to the portfolio. An ELCC calculation solves for the increase in load that can be accommodated while maintaining the same reliability level, expressed as a fixed LOLE. ELCC allows the ready comparison of wind generation's reliability contribution compared to that of other generation technologies.

III. STUDY METHODOLOGY AND INPUTS

Q. Please provide an overview of the study methodology for the study you performed.

A. In this study I first calculated the expected LOLE considering all Missouri electric demand and supply resources in the State. I then recalculated the LOLE considering the addition of the Project's hourly wind injection. The resulting LOLE reduction is one important measure of the reliability benefit of the Project. Finally, I calculated the increase in load, measured in megawatts ("MW") that the Project can support while maintaining the original level of reliability. This increase in load is the ELCC of the wind energy injection of the Grain Belt Express Project.

Q. Are the LOLE study and the methodology you describe in this testimony generally accepted in the electric industry as measures of reliability?

A. Yes, LOLE studies are routinely performed as part of long-term electric power system planning. They are a standard industry technique to assess the resource adequacy of the bulk electric system used by various regional reliability coordinators like Southwest Power Pool and Midcontinent Independent System Operator, and many utilities throughout the United States. The methodology employed in this analysis conforms to the accepted industry approach for measuring the probability of a supply resource shortfall.

Q. What software did you do to perform your LOLE and ELCC calculations?

A. I used the Multi-Area Reliability Simulation ("MARS") software developed and maintained by General Electric ("GE") Energy Consulting. MARS is a widely used model for LOLE and ELCC calculation. I have used MARS on several prior engagements including Xcel Energy in Minnesota and Colorado, the Minnesota Public Utilities Commission, and the EWITS. The GE MARS program employs a full sequential Monte Carlo simulation of available generation capacity and a chronological hourly simulation of the electric system. Such widely accepted simulations employ a broad class of computational algorithms that are used to calculate the probability of an event. In each hour, MARS compares the hourly load demand in each area to the total available generation in the area, which has been adjusted to account for planned maintenance and randomly occurring forced outages and, in the case of wind energy, meteorological conditions and the resulting wind energy output.

Q. What was the geographic scope of your analysis?

A. LOLE and other reliability studies are sometimes performed on a regional, rather than a state basis. The purpose of the study here, however, is to evaluate the contribution of the Grain Belt Express Project to Missouri supply resources. Therefore, I limited the scope of my analysis to the State of Missouri since this is the region of most concern to the Missouri Public Service Commission. This study takes a view of Missouri in isolation and gauges the impact of the Project's wind injection on the adequacy of the supply portfolio to meet Missouri electric loads.

Q. What are the primary inputs to an LOLE analysis?

A. The primary inputs to the LOLE calculation are peak electric demand or annual demand profiles, the inventory of generating units, generators' seasonal capacity ratings, and generators' scheduled maintenance periods. Other key parameters for generating units are their mechanical reliability expectations, including the probability of a failure or forced outage, and the average time to repair and restore the unit to service. For wind generation units, the hourly profile of generation, based on wind speeds and adjusted for any appropriate losses, is incorporated into the model.

Generator and load data for the study was derived primarily from the Ventyx Powerbase data set. This is a widely used data set also used by witness Gary Moland in his direct testimony on behalf of Grain Belt Express. I have used this same database for some of my prior engagements to perform LOLE analysis. From the Ventyx database, hourly load and generating unit data were extracted for Missouri. Peak load and load energy levels represented forecast calendar year 2019 conditions. Generating unit forced outage information extracted from the Ventyx Powerbase data was derived from the NERC Generator Availability Data System ("GADS").[2]

In addition to the generators in the Ventyx database, I added generation capacity to the model so that the base case LOLE value was the industry-standard one day in ten

[2] NERC's GADS Services group manages the Generating Availability Data System. This unique series of databases is used to collect, record, and retrieve operating information for improving the performance of electric generating equipment. It also provides assistance to those researching the vast amounts of information on power plant availability stored in its database. The information is used to support equipment reliability and availability analyses, and decision-making by GADS data users.

years (0.1 day per year, or 2.4 hours/year). This modification is justified since the objective of this study is to calculate the reliability of the Project, not to assess the baseline sufficiency of Missouri generating resources. Between now and 2019, if it is necessary for Missouri to add generation to compensate for coal plant retirements or load growth, it is safe to assume that this generation will be added. Further, this additional generation may reflect the fact that some Missouri load serving entities have contracts with out-of-state generation, which are used to serve their load and meet reliability targets but are not included in the Ventyx database.

The hourly profile of wind injection representing the Grain Belt Express Project's converter station facility in Missouri is based on modeled hourly generation from western Kansas sites. The data source is the EWITS, led by NREL. The hourly profiles are based on numerical weather models developed by AWS Truepower, LLC, a leading meteorology consulting firm, and the National Weather Service. In my experience, EWITS is an appropriate and reliable data source for hourly wind generation profiles in ELCC analysis.

IV. <u>STUDY RESULTS</u>

Q. What cases were developed for the LOLE study?

A. The cases defined for this study included a base or benchmark consisting of forecast hourly profiles for electric load within Missouri and the resources serving Missouri load. This base case did not include the Grain Belt Express Project or its wind energy injection into Missouri.

A second set of cases include hourly wind injection from the Project's converter station or tap located in Missouri. The initial case in this set utilized the hourly wind profile described above. To account for inter-annual meteorological variations that could affect the correlation between periods of high electric demand (which are more likely to stress the electric power system in terms of supply resource availability and adequacy), an additional eight cases were generated by shifting this profile by one or more weeks either forward or backward in time, for a total of nine cases. Each of these cases was executed with the GE MARS program to develop a set of numerical results from which annual LOLE values are calculated.

By comparing the base case LOLE to the LOLE with the Project, I measured the LOLE improvement from the Project. Similarly, by adding load to the "with Project" case until the LOLE returns to the base case value, I measured the ELCC contribution of the Project's injection in Missouri

Q. What are the expected reliability benefits provided by the Project and the wind energy it will deliver to Missouri?

A. The addition of wind energy from the Project reduces the LOLE in all of the scenarios analyzed. The average reduction in LOLE is 23%, or a reduction of 0.023 days/year from the assumed baseline of 0.1 days/year. In terms of firm capacity, the results of the cases show an annual ELCC that ranges from a low of 28 MW to a high of 450 MW, which is an average of 165 MW over the nine individual scenarios. The 33% average capacity benefit (capacity value divided by the nameplate rating of the Project's tap) is consistent with what has been calculated for high-quality wind resources in previous studies. In other words, the Grain Belt Express Project's wind energy injection in Missouri would have approximately the same reliability benefit of a single medium-sized natural gas power plant.

A copy of my study is attached as Schedule RMZ-2.

Q. Based on the results of your LOLE study, what is your conclusion as to whether installation of the Grain Belt Express Project and the wind generating facilities that will be connected to it in western Kansas will increase the reliability of electric service in Missouri?

A. Wind energy injection from the Grain Belt Express Project into Missouri will positively impact resource adequacy and electric reliability in the state, based on reduced LOLE metrics from the addition of the Project.

Q. Does this conclude your direct testimony?

A. Yes, it does.

BEFORE THE PUBLIC SERVICE COMMISSION
OF THE STATE OF MISSOURI

In the Matter of the Application of Grain Belt Express Clean Line LLC for a Certificate of Convenience and Necessity Authorizing it to Construct, Own, Control, Manage, Operate and Maintain a High Voltage, Direct Current Transmission Line and an Associated Converter Station Providing an Interconnection on the Maywood 345 kV Transmission Line	)))))))	Case No. EA-2014-0207

AFFIDAVIT OF ROBERT M. ZAVADIL

STATE OF Tennessee)
) **ss**
COUNTY OF Knox)

Robert M. Zavadil, being first duly sworn on his oath, states:

1. My name is Robert M. Zavadil, Executive Vice President and co-founder of EnerNex, LLC.

2. Attached hereto and made a part hereof for all purposes is my Direct Testimony on behalf of Grain Belt Express Clean Line LLC consisting of 9 pages, having been prepared in written form for introduction into evidence in the above-captioned docket.

3. I have knowledge of the matters set forth therein. I hereby swear and affirm that my answers contained in the attached testimony to the questions therein propounded, including any attachments thereto, are true and accurate to the best of my knowledge, information and belief.

Robert M. Zavadil

Subscribed and sworn before me this 25 day of March, 2014.

Notary Public

PATTI D LIVESEY STATE OF TENNESSEE NOTARY PUBLIC COUNTY OF KNOX

My commission expires: 12-26-2017

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