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QUANTIFYING RELIABILITY BENEFITS OF PROPOSED GRAIN BELT EXPRESS HVDC TERMINAL IN MISSOURI

OBJECTIVE

The purpose of this analysis is to quantify the reliability benefits of the proposed Grain Belt Express HVDC transmission project ("Grain Belt Express Project" or "Project") which will deliver 500 megawatts ("MW") of power to the state of Missouri.

APPROACH

The North American Electric Reliability Corporation ("NERC") definition of reliability for the Bulk Electric System (BES) is based on two principles. The first is operational reliability, which is achieved by always operating the BES in a state where it is able to recover from and continue functioning after defined disturbances such as the loss of generators or transmission lines. The second principle is adequacy, defined as the ability to meet the aggregate power and energy demands of electric consumers. A key component of adequacy is the availability of generating capacity sufficient to meet the expected peak demand, also known as resource adequacy.

Since generation equipment is subject to failures and must be periodically removed from service for maintenance, achieving specific adequacy levels requires the availability of generation capacity in excess of peak loads. And, because "perfect" reliability (practically defined as some infinitesimally small probability that available generation capacity would not be adequate to meet peak demand) is not economically feasible, generation capacity is planned to meet some value that exceeds expected peak load. Resource Adequacy is sometimes simply gauged as the ratio of maximum generation capacity to expected peak load, expressed as "planning" or "capacity" margin.

A more rigorous assessment of adequacy incorporates a probabilistic target, or Loss of Load Expectation (LOLE). A LOLE analysis calculates the probability that a given set of generating units or other supply options (such as demand-side resources and firm capacity purchase contracts) would be insufficient to meet an expected level of electric demand. Primary inputs to the calculation of LOLE are peak electric demand or annual demand profiles, the inventory of generating units and their seasonal capacity ratings along with 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.

Wind generation is primarily considered an energy source, but there has been significant research over the past three decades into exploring its influence on bulk system reliability and resource adequacy. The National Renewable Energy Laboratory (NREL) has been especially active in this area. Through the integration studies performed over the past decade, some consensus techniques have emerged on the analytical approach for calculating the capacity value of a variable renewable energy resource, such as wind. The approach used in this study, which is described here, is based on those consensus techniques, and utilizes the concept of "Effective Load Carrying Capability" or ELCC.

ELCC measures the increase in load that can be met at the target reliability level, expressed as LOLE, by the addition of a new supply resource to the portfolio. In this study, a case with the expected LOLE considering all Missouri electric demand and supply resources serving this demand was calculated (base case), and then compared with a case where the LOLE considering the addition of the Grain Belt Express Project hourly wind injection was calculated. The increase in load, measured in MW, that can be met with the same target reliability as the base case is attributed to the addition of the wind energy injection.

LOLE studies are routinely performed as part of the long term electric power system planning process. Due to the critical role that the high voltage transmission system plays in maintaining system reliability, LOLE and other reliability-focused studies are performed on a regional, rather than state, basis. The purpose of the study described here, however, is to evaluate only the Missouri electric demand and supply resources, since the jurisdiction over resource adequacy is not part of the NERC charter.

Consequently, this study takes a view of Missouri as an electric island and gauges the impact of the Grain Belt Express Project wind injection on the adequacy of the supply portfolio for Missouri electric loads.

For purposes of this calculation, the profile of hourly load within the Missouri state borders was not treated probabilistically. Instead, sequential Multi-Area Reliability Simulations ("MARS") were run for scaled load profiles derived from 0.90 or 90% up to 110% of the original load level. This approach allows the LOLE for each case to be aggregated into a curve (see Figures 1 and Figure 2 below), with peak hourly load on the horizontal axis and LOLE (in days/year) on the horizontal axis. This method of presentation shows the relationship of varying reliability targets and changes in peak load. It should be noted that the scaling process involves all hours of the annual profile, not just the peak hour.

This presentation of the results is also important when applied to variable renewable energy, such as wind, since it allows the effects of the renewable energy injection to be calculated by comparing two cases: 1) a case without renewable energy injection, and 2) a case where renewable energy delivery to the system is defined each hour of the study year. The distance between the two plotted curves (in MW) at the target reliability level (generally taken as 0.1 days/year or 1 day in 10 years) is the ELCC of the wind energy injection.

Input data for the study and the General Electric ("GE") MARS cases were derived primarily from the Ventyx Powerbase data. Hourly load and generating unit data were extracted for defined operating areas within the state of Missouri. Peak load and load energy levels represented forecast calendar year 2019 conditions.

The hourly profile of wind injection representing the Project facility in Missouri was developed by Clean Line Energy Partners LLC ("Clean Line") from measurement data and numerical weather simulations.

Generating unit forced outage information extracted from the Ventyx Powerbase data was derived from the NERC Generator Availability Data System ("GADS") system.

The cases defined for this study included a base or benchmark consisting of forecast hourly profiles for electric load within the state of Missouri and resources serving Missouri load, as taken from the Ventyx Powerbase dataset, and a second set of cases including hourly wind injection from the Project tap located in Missouri. The initial case in this set utilized an annual hourly profile of wind delivery, provided by Clean Line, developed from measurement data and representative of calendar year 2013. An additional eight (8) cases were generated by shifting this profile by one or more weeks either forward or backward in time. Each of these cases was executed with the GE MARS program to develop a set of numerical results and curves from which annual ELCC is calculated for each case.

Adjusting the wind profile via time shifting is a technique that has been used in previous integration studies 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 – and high levels of wind generation. Marked inter-annual variation in annual ELCC for wind generation resources has been observed in several of the previous major integration studies that used up to only three years of annual data.

RESULTS

Results from the initial GE MARS case showed that the LOLE for the forecast peak load was in excess of 0.7 days/year. This was, in all likelihood, entirely a consequence of the assumptions used to frame the computation for this study. While all supply resources designated to Missouri operating areas in the Ventyx Powerbase data were included in the calculation, this does not necessarily reflect the entirety of the capacity available to Missouri utilities. Firm capacity contracts with neighboring utilities outside of Missouri, for example, are a common mechanism for supplementing capacity needs.

To account for the other sources of capacity not represented by the portfolio of Missouri generating resources in the Ventyx Powerbase data, the initial case was modified by adding additional capacity until the LOLE for the annual case was the industry-standard of 1 day in 10 years (0.1 day per year, or 2.4 hours/year). This modification is well justified since the primary objective of this study is to calculate the ELCC of the new – Project wind energy – resource, rather than to support a commentary on the sufficiency of Missouri generating resources.

Additionally, the ELCC of an incremental resource can be dependent on the starting LOLE of the system being examined. If the system is short of capacity – meaning that the LOLE is higher than the target of 0.1 days per year – the capacity value of the new resource will tend to be amplified. Conversely, if the LOLE is already very low, the capacity benefit from additional resources will be small. In the wind integration studies mentioned above, the standard approach has been to adjust the LOLE of the underlying system so as not to overstate or discount the capacity value of the wind resources being studied.

The quantitative results from the study show that the Grain Belt Express Project wind energy injection in Missouri would have the capacity benefit of a single-medium sized natural gas power plant. For the nine (9) scenarios of wind constructed for the study, the annual ELCC averaged 165 MW, with a low annual value of 28 MW and a high value of 450 MW. The 33% average capacity benefit (capacity value divided by the nameplate rating of the Grain Belt

Express Project tap) is consistent with what has been calculated for high quality wind resources in previous studies. Similarly, the reduction in LOLE from the assumed baseline is 0.023 days/year, or a 23% reduction from the assumed baseline of 0.1 days/year. The complete set of ELCC and LOLE results for each of the nine (9) scenarios is provided in Table 1 below.

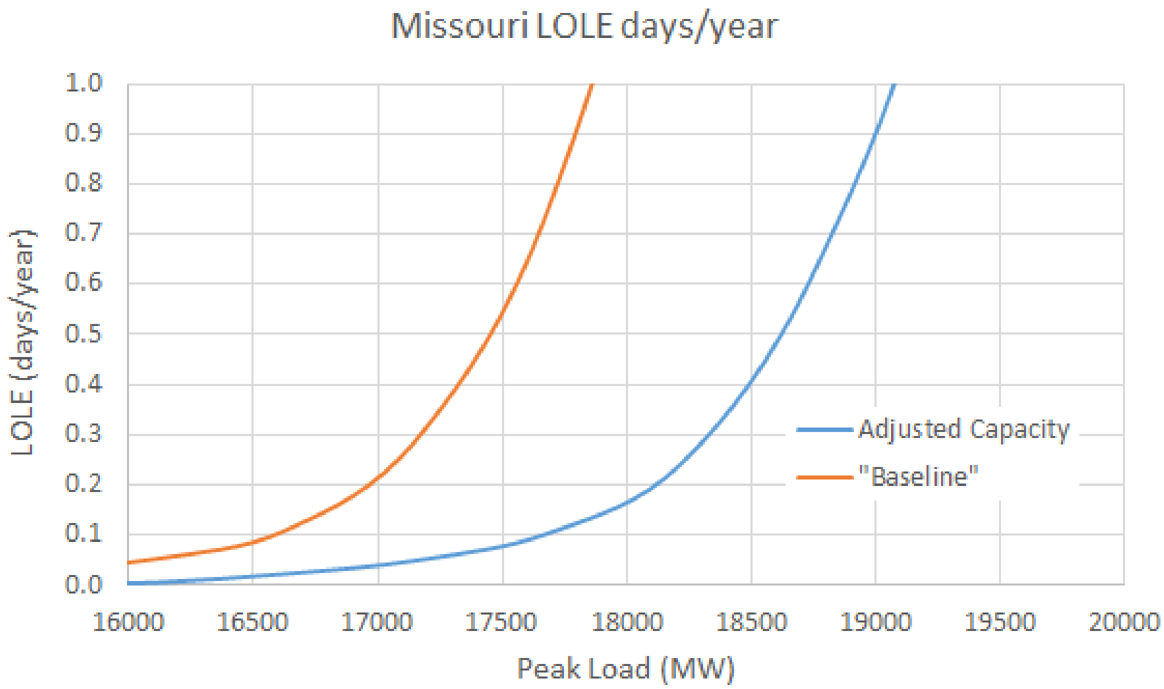

Figure 1: LOLE as a function of peak load level for "baseline" case (Missouri generating unit data extracted from Ventyx Powerbase) and modified case (to establish no-wind LOLE at 0.1 days/year).

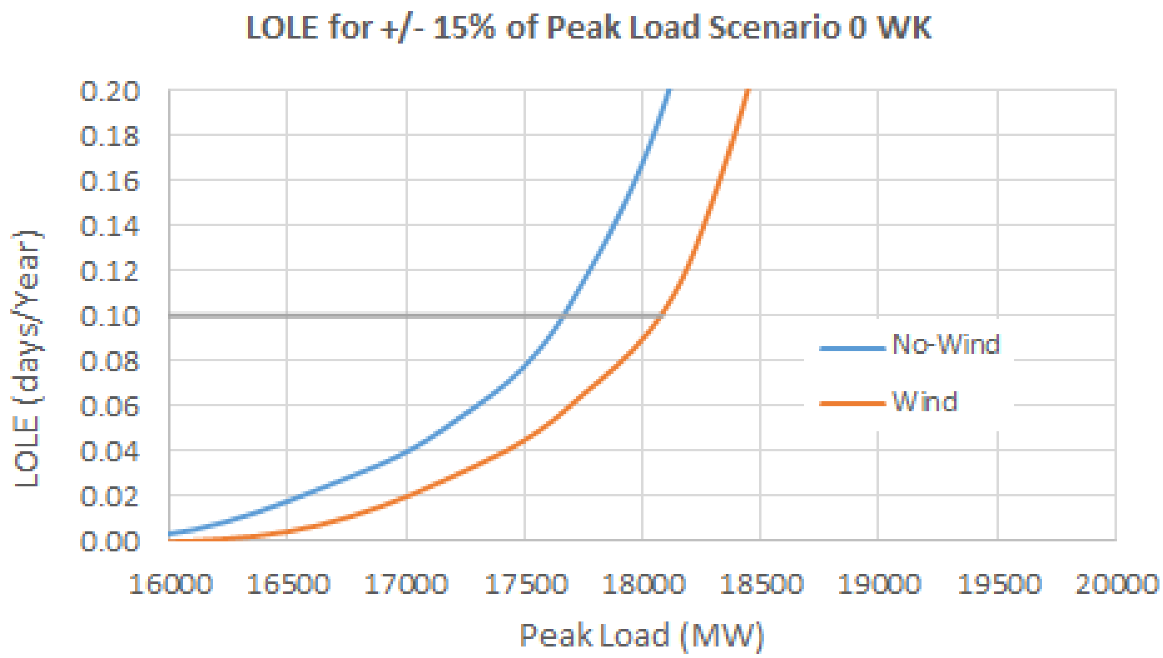

Figure 2: Illustration of ELCC calculation for one of nine wind cases analyzed with GE MARS

Table 1: Annual and Average ELCC values (in MW) and Reduction in LOLE for GBX Wind Energy Delivery to Missouri

Profile Time Shift	-4 Wk	-3 Wk	-2 Wk	-1 Wk	0 Wk	+1 Wk	"+2 Wk	+ 3 Wk	+4 Wk	**Average**
ELCC	210	79	28	450	419	260	109	75	60	**165**
LOLE Reduction	0.027	0.012	0.005	0.050	0.045	0.033	0.015	0.012	0.010	**0.023**

Analysis/Conclusions

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