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Capacity value of wind power - summary

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The capacity value of a generator is the contribution that a given generator makes to generation system adequacy. Due to the variable and stochastic nature of wind, the modeling of wind generation in the same manner as conventional generation for capacity value calculations is inappropriate. In this paper a short summary of the issue is given. This summary is largely based on IEA task 25 activities and the output of an IEEE task force. A preferred method for calculating capacity value along with approximate methods for the calculation are also described with their limitations outlined.

Index Terms—capacity value, capacity credit, wind power generation, Loss of Load, ELCC, LOLE, LOLP

I. INTRODUCTION

Power system reliability is divided into two basic aspects, system security and system adequacy. A system is secure if it can withstand a loss (or potentially multiple losses) of key power supply components such as generators or transmission links. Generation system adequacy refers to the issue of whether there is sufficient installed capacity to meet the electric load [1]. This adequacy is achieved with a combination of different generators that may have significantly different characteristics. Capacity value (or capacity credit) can be defined as the amount of additional load that can be served due to the addition of the generator, while maintaining the existing levels of reliability. Effective load carrying capability (ELCC) is the metric used to denote the capacity value. The metrics that are used for adequacy evaluation include the loss of load expectation (LOLE) and the loss of load probability (LOLP).

The topic of capacity value of wind power has been attracting attention in recent times with many recent publications [2-6]. The rest of this summary briefly describes a preferred method for capacity value calculation, data needs, characteristics and approximations.

II. CAPACITY VALUE CALCULATION

Conventional generation units are modeled by their respective capacities and forced outage rates (FOR). Each generator capacity and FOR is convolved via an iterative method to produce the analytical reliability model (capacity outage probability table (COPT)) of the power system. The COPT is a table of capacity levels and their associated probabilities [1]. The cumulative probabilities give the LOLP for each possible available generation state. Wind power cannot be adequately modeled by its capacity and FOR as wind availability is more a matter of resource availability than mechanical availability. This leads to a different treatment of wind generation and the preferred method is given below [7].

The COPT of the power system is used in conjunction with the hourly load time series to compute the LOLE

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without the presence of the wind plant. The time series for the wind plant power output is treated as negative load and is combined with the load time series, resulting in a load time series net of wind power. In the same manner as above LOLE is calculated. It will now be lower (and therefore better) than the original LOLE. The load data is then increased across all hours using an iterative process, and the LOLE recalculated at each step until the original LOLE is reached. The increase in the load is the ELCC or capacity value of the wind plant.

III. DATA AND CHARACTERISTICS

The input data employed in the calculation is crucial - if sufficient data of the required quality is not available, the resulting answer cannot be relied upon. The method requires:

- Load time series for the period of investigation (multi-year of at least hourly resolution is preferable [4])
- Wind power time series for the same period as loads
- A complete inventory of conventional generation units' capacity, forced outage rates and maintenance schedules

The length of the period of investigation required to provide a robust answer is dependent on a number of factors including the size of the system, load curve and penetration of wind power on the system [4]. An important characteristic of wind power is its spatial diversity. This means that the capacity value increases relatively with larger region sizes [2].

The reliability level can have a large impact on the capacity value of both conventional power and wind power [5]. When the reliability level, is lower, and LOLE higher, there is relatively more value in any added capacity than in cases where LOLE is very low. The relationship between the wind and the load is a key factor to be captured by the calculation method. The correlation between wind and load is site dependent. In some areas there is a diurnal and/or seasonal wind pattern. Therefore, it is critical to use hourly wind and load data from the same year so that the underlying relationship between wind and load is implicitly captured in the modeling.

IV. APPROXIMATE METHODOLOGIES

With modern computing power the preferred method is not overly time-consuming for moderately sized systems; Approximation methods must therefore be justified on grounds of ease of coding or lack of data. The preferred method contains approximations also but as it utilizes the datasets which capture the full relationship between load and wind it provides the best assessment of wind's capacity value.

An alternative risk calculation to the preferred method is the multi-state approach, which utilises a probabilistic representation of the wind plant [8]. Similarly to

conventional units with de-rated states, the wind plant is modeled with partial capacity outage states each of which has an associated probability. To evaluate the LOLP at a given time, the wind generation is included in a COPT calculation in the same manner as a multi-state conventional unit. The ELCC calculation then proceeds as described in the preferred method, except using the modified calculation.

Garver proposed a simplified, approximate graphical approach to calculating the ELCC of an additional generator [9]. This has been an important method but has been superseded by advances in computing power.

Loss of load probability at time of annual peak demand is used as a proxy for system risk in some regions [10, 11]. Probability distributions are required for the demand and available wind capacity at time of annual peak (the distribution for available conventional capacity is derived via a COPT calculation, as in the ELCC calculation method). The main criticisms of an annual peak calculation are that it does not explicitly consider loss of load at other times of the year, and that it is difficult to obtain appropriate probability distributions for the wind resource at annual peak, and also for the peak load.

There has been considerable interest in using capacity factors (average output) calculated over suitable peak periods to estimate the capacity value of wind. Some of these approximations are reasonably accurate [12]. Although capacity factor approximations may be useful as quick screening methods (for instance, a higher capacity factor would usually imply a higher capacity value on the same system), they do not capture the short term or annual variability of wind power, or the correlation of wind availability with demand.

The z-statistic method [13] is based on taking the difference between available resources and load over peak demand hours (surplus availability) as a random variable with an associated probability distribution. The z-statistic for that distribution (mean divided by standard deviation) is taken as the primary system adequacy metric. The incremental load carrying capability for an added power plant is taken to be the load addition that keeps the z-statistic constant.

V. CONCLUSIONS

When estimating capacity value of wind power, the employment of time synchronized load and wind power output data that captures their correlation is vital. Representation of wind as a two state probability model or assessment of wind's capacity factor at peak times is inadequate. Factors such as the correlation between different wind sites and with the load, the geographical area and the target reliability level have a considerable impact on the capacity value.

The accuracy of approximation methods is varied. While some may be useful given limited data, it is important to be clear about the approximations being made. Analysis showing the comparison of the method to some of the approximate methods illustrate that diverse methods and wind resources lead to a wide range of values for the capacity value of wind power [6]

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