Proposal for Capacity Credits
for Variable Output Electric Power Generators in Michigan

Michigan Wind Working Group
Subcommittee on Capacity Credits
Michigan Renewable Energy Program

March 2005

DRAFT – Not for Citation or Quotation

Introduction

The Capacity Need Forum (CNF) established by the Michigan Public Service Commission in Case No. U-14231 has been charged with the task of developing forecasts of Michigan electric power supply and demand, and analyzing different scenarios for what resource options might be used to meet future demands. Recent resource assessments of Michigan's wind energy potential have strongly suggested that Michigan has ample wind resources to make a significant contribution towards meeting Michigan's future electric power demands. Part of the modeling task for the CNF, however, is to assess the contributions that wind energy (or other variable output sources of electric power such as solar or hydroelectric generators) is capable of making. The purpose of this paper is to propose analytical methods that can be used to evaluate the capacity contributions that might be provided by variable output electric power generators, and recommend that those methods be used by the CNF in its modeling efforts.

What is a capacity credit and how is it used?

There is no absolute guarantee that capacity from any electric power generator will be available whenever it is needed. Because of this fact, utilities have historically been responsible for maintaining a suitable reserve margin of excess capacity sufficient to meet demands, even under the possible contingency that any specific generation or transmission resource might be unavailable at a time when it is needed to provide resources to the utility system. Utilities have used a planning reserve margin, usually expressed as a percentage of incremental capacity, such as 12 to 15 percent, when deciding whether and when to undertake system expansion. This planning reserve takes account of the probability of the failure of generation during critical system periods.

Because all generators have forced outage rates that exceed zero, the calculation of *effective capacity* can provide a robust measure of the likely capacity that any generator can deliver during peak periods or other times of high-risk to the electric utility system. The most robust and mathematically consistent measure of capacity value is effective load carrying capability (ELCC), which takes all of these considerations into account. ELCC calculations can be used in the planning process to determine any generator's contribution to planning reserves, subject to the reliability goals of the system operator, utility, or public utility regulators. Capacity value, as determined by ELCC, can also be used to calculate the appropriate level of payments to entities that provide capacity to help meet system reliability goals. Examples of the use of capacity value include:

- PJM has adopted a simplified approach to calculating capacity value for wind generators, using the capacity factor (ratio of average generation to peak capability) during a defined period when the system is at high risk. PJM has indicated that it may corroborate this method with a full ELCC study in the future. In the meantime, PJM translates the capacity value into a capacity payment to generators (currently about $1/MWh). See http://www.pjm.com/contributions/pjm-manuals/pdf/m21v03.pdf.

- The Mid-Continent Area Power Pool (MAPP) uses a monthly metric to calculate the capacity contribution of all generators in the region, and has a specific approach to calculating the capacity contribution of wind generators. MAPP employs this data in monthly adequacy assessments, to determine the expected match between load and resources. See http://www.mapp.org/assets/Reliability%20Handbook/discarded/s3_AccSub.doc, pp. 22-24.

- The California Energy Commission has adopted ELCC as the capacity metric of record to help load serving entities to determine the least-cost and best-fit generation to meet reliability and adequacy goals. The ELCC approach, or a simplification, is applied to all renewable generators to help determine the ranking of bids from these generators. These calculations are used in setting long term supply contracts. See http://www.energy.ca.gov/reports/2004-02-05_500-03-108C.PDF.

- PacifiCorp, in its recent Integrated Resource Plan, utilized ELCC to determine the capacity value of wind, and thus help determine the quantity of other generation that would be required to meet system adequacy targets.

- A recently-completed study for the New York State Energy Research Development Authority (NYSERDA), performed by GE Power Systems Consulting, used ELCC to determine the adequacy contribution of wind generators as part of New York's Renewable Portfolio Standard.

Why are capacity credits important?

Capacity from any generator is not guaranteed to be available at the precise times when it might be most needed. Every generator has some risk of failure, at any given time, and all generators require some down-time for maintenance and repairs. Some generators are more likely to fail than others. Generators that contribute significant reliability have more value (that is, they help more to reduce the risk of an outage), compared to generators that don't contribute as significantly to reliability.

Establishing an appropriate capacity credit for each generator is a means of measuring the relative contribution to reliability that each generator provides to the utility system, in the context of overall system reliability.

Qualities of Good Approaches for Modeling Capacity Contributions

A good methodology for analyzing the capacity contributions of various electric generation resources will be equitable in the way that all generators are treated. A good method will ensure horizontal equity; meaning two generators with like reliability properties will be treated in like manner and will receive like capacity contribution scores. It will also ensure vertical equity; meaning a generator with higher reliability and therefore a greater ability to deliver on peak and at times of greatest system risk will receive a higher capacity contribution score compared to generators that are less able to consistently deliver. A good method should also be based on accepted electric utility system reliability theory and modeling practices.

The following table summarizes the properties of the ELCC metric. As can be seen in the table, this metric excels in all aspects, except that it is not usually considered to be very simple or transparent. However, it should be noted that ELCC is a consistent metric, and its methods of calculation explicitly and accurately evaluate a large number of important factors related to system reliability.

Table 1: Qualities of ELCC Metric

Quality of Metric | Does ELCC Possess that Quality (Yes or No)?	
Is method based on generally accepted reliability theory and utility modeling practices?	Y
Does method reflect the risk reduction contribution of any generator?	Y
Does method capture system load shape in analysis?	Y
Does method reflect generator delivery pattern relative to load shape?	Y
Is method mathematically consistent?	Y
Is method horizontally consistent (that is, two generators with like reliability characteristics will receive like capacity value scores)?	Y
Is method vertically consistent (that is, generators with higher reliability and availability receive higher scores, compared to generators with lower reliability and availability)?	Y
Are results from using the method independent of the order in which various generators are evaluated?	Y
Is method data driven (as opposed to speculative)?	Y
Is method transparent (meaning …)?	N
Is method simple (meaning …)?	N

If, in the interest of simplification, a method other than ELCC is employed, care must be taken to ensure there will not be an accompanying significant loss of accuracy, nor the introduction of arbitrary bias. The benefit of using ELCC is that a large number of important system characteristics are explicitly accounted for. Although simplified methods can be useful (for example, calculating the capacity factor of a generator over a specified time period corresponding to high-risk or peak-load periods), these simple calculations inherently ignore factors like load shape, capacity of other units that are available during specific high-risk or high-load periods (that is, units that are not out for maintenance or repairs at the time), outage rates of other units, or seasonal hydropower flows or constraints.

If the capacity value (in MW) is used as part of a payment or market mechanism, it can be relatively easy to structure a payment using ELCC or another similar capacity metric. In the case of ELCC, which is an annual metric, an annual capacity price, expressed in $/kW-year, can be used to determine appropriate payments. Payments are typically based on the cost of a benchmark generator, chosen for modeling in the region. In the recent past, the benchmark units have often been natural gas fired combustion turbines, but in principle any appropriate unit can be used.

For example, if the capacity price of the benchmark unit is $75/kW-year, and a 100 MW (100,000 kW) wind plant has a 30% ELCC (as percent of rated capacity), the annual capacity payment would be $2,250,000 ($75/kW-year * 100,000 kW * 30% = $2,250,000). The wind plan will produce an estimated 262,800,000 kWh per year (100,000 kW * 8760 hours/year * 30% = 262,800,000 kWh/year). The capacity payment would be spread across the annual energy. This equates to $0.008562/kWh ($2,250,000 / 262,800,000 kWh = $0.008562/kWh). Or, if the capacity price would be developed for a benchmark base-load unit, with an estimated cost of $300/kW-year, then the capacity payment would equate to about $0.03425/kWh.

What is the MREP/WWG Recommendation for Analyzing Wind Energy Capacity Credits in the Context of the Capacity Need Forum?

The basic recommendation of the MREP/WWG is to use ELCC methods for calculating the appropriate capacity credits for variable output electric generators being evaluated for their potential contributions to Michigan's future capacity needs. MREP/WWG proposes the following approach:

1. Use meteorological data to estimate wind power density for each hour of the year. Use meteorological data that is representative of the three areas of Michigan that are being analyzed for the CNF (SE Michigan, Lower Peninsula outside of SE Michigan, and Upper Peninsula), incorporating data from multiple measurement locations in each area, in order to model the typical variations in wind power associated with typical Michigan weather patterns. Use multiple years of meteorological data so that the hourly estimates are based on average wind power density.

2. Given the data on wind power density identified in step 1, convert into estimated wind power production, based on a prototypical wind generator. For now, use GE 1.5 MW or Vestas 1.6 MW wind generators as prototypes.

3. For each 100 MW of wind generators, estimate the output under the wind conditions identified in the meteorological data, for each hour of the year.

4. As a benchmark for analysis, and as a simple method to calculate a proxy for ELCC, the CNF can identify the 10% of the hours of the year that are of most concern on the system, from a reliability standpoint.

5. For each 100 MW of wind generators, report the average output of the wind generators during those 10% of the hours of the year. That average production, expressed as a percent of nameplate capacity, is a capacity credit proxy, and a point of reference for the more detailed study described below.

   Later, this proxy – developed as a result of completing steps 1 through 5 – can be compared to the ELCC. Over time, if the proxy turns out to be a very close approximation of ELCC, then future capacity planning exercises could utilize this simplification, at least for preliminary investigations.

6. In order to calculate ELCC, the CNF Integration Committee will be asked to do one or more runs of the production simulation computer model of Michigan's electric power system(s), which holds the system at the same annual risk level, modeled with and without the addition of a proposed wind energy component.

   The annual risk level is typically expressed in terms of a loss of load probability (LOLP), or sometimes called loss of load expectation (LOLE), such as a risk of having an outage due to an insufficient availability of capacity to meet loads no more than one day every 10 years (representing about four nines reliability, or 99.99%).

7. First, the model is run without the wind energy component and without a benchmark unit power plant. The benchmark unit is the type of power plant that would be likely to be used to meet future needs in place of the wind energy component being modeled. The model is run in order to identify the maximum loads that can be served each hour, without the wind component and without the benchmark unit power plant, while achieving the LOLP goal (typically, not more than 1 day of outage in 10 years of operation).

8. The next step is to add the wind component, which includes hourly estimates of the wind power production (from step 3), and rerun the model, noting the change in annual reliability. Within reason, the quantity of wind capacity to be modeled can be expanded or contracted as necessary to reflect the generation capacity of the benchmark unit. (This analysis will be called the "wind case" for modeling purposes.)

9. Then, the wind power production modeled in step 8 is removed from the model, and replaced with the benchmark unit. Capacity of the benchmark unit is gradually, incrementally increased until the annual reliability of the system incorporating the benchmark unit matches the reliability of the wind case.

10. The capacity of benchmark unit that was added in order to match the reliability of the wind case is the ELCC of the wind plant.

The ELCC for a conventional power plant unit is predicated on the unit's forced outage rate (FOR). That rate represents the expected percentage of time when utility system operators might call for the plant to be available, but because of accidents or operating problems, the unit cannot produce power at that time. The critically important quality of the benchmark unit for purposes of this modeling is the unit's forced outage rate.

For wind generators, experience has shown that the outage rate due to operational problems is very low. Modern wind generators are available to operate as much as 98% of the time, which means that they are ready to make electricity when the wind blows, nearly all the time. Some downtime is expected, for planned maintenance, and actual operating experience is used to continuously update availability data for each wind generator manufacturer and model. The purpose of the ELCC modeling is to analyze the similarities between wind energy production and the capacity available from a conventional power plant, which might typically have a much larger FOR compared to a wind resource. For example, the FOR for a typical coal burning power plant being modeled for future use in Michigan would be on the order of 8%, and for a natural gas single-cycle combustion turbine unit, 4%.

Moving Beyond System Modeling to a Performance-Based Capacity Credit for Variable Production Power Generators in Michigan

The above explanation identifies methods that are proposed for use in the modeling of wind energy ELCC for Michigan, based on average wind power data and the predicted operation of wind generators in unspecified locations in Michigan. This section of this paper describes a plan for extending the calculation methods to be used for the purpose of identifying the appropriate ELCC to be used to properly compensate wind generators for their actual performance in Michigan.

The general idea of the approach recommended by the WWG is to gradually replace the meteorological data with actual operational data from wind generators. Each generator owner would select the generator or group of generators to be modeled, and would provide metered data that identifies the output of each generator group for each hour of the year.

The capacity planning production model runs would be completed as described above, but each year the oldest year of meteorological data will be replaced by one year of actual performance data, until eventually the meteorological data will all be replaced by actual output data (say, over a period of three or four years). For these purposes, it is appropriate to model the utility system for a specific Michigan utility company or companies that are purchasing the output from the wind generators in question, rather than using the more general regional model described above.

The capacity value, and thus the capacity payment, would be adjusted each year based on a rolling average of the previous 3 or 4 years. In this way, payments will reflect the capacity actually provided by the wind plants.