Solar Energy and Capacity Value

Solar Energy Can Provide Valuable Capacity to Utilities and Power System Operators

Solar photovoltaic (PV) systems and concentrating solar power (CSP) systems without integrated thermal energy storage (TES) are variable, renewable energy resources with output that depends on the time of day, season, and weather patterns. These resources are unlike traditional dispatchable generators that can be controlled to respond to variations in demand. An important benefit of all generators is capacity value—their ability to reliably meet demand. Generator outages—caused by mechanical failures, planned maintenance, or lack of real-time generating resources (especially for renewables)—may leave a power system with insufficient capacity to meet load. Because variable energy sources are not as controllable as conventional power plants, analysis is needed to evaluate their capacity-related benefits, which are not always readily apparent.

Calculating Capacity Value

The capacity value of a renewable generator is calculated by one of several methods. Detailed reliability-based metrics are widely accepted by utilities and system planners. These methods use statistical approaches to determine the ability of a generation resource to maintain a reliable system and meet demand. An alternative approach is to use approximation techniques, such as examining the output of a renewable generator during periods of highest risk of not meeting load. These are typically hours of high demand—often late afternoons in summer, when the demand for air-conditioning places utility systems under greatest stress. Examining solar output during these periods can provide insight into the potential of different solar generators to add reliable capacity.

Coincidence of Solar Energy With Electricity Demand Patterns

Although detailed analysis is needed to quantify solar capacity value, examining patterns of electricity demand and solar generation can provide some indication of the ability of solar energy to contribute to meeting peak demand. Figure 1 shows the demand for electricity on a hot summer day in Colorado in 2006. It also shows simulated solar output for a scenario in which solar satisfies 1% of total demand and the corresponding solar generation during that time. In this figure, net load is the normal load minus the contribution from wind and solar, or the load that needs to be met with conventional generators. Both PV systems (and CSP systems without storage) provide significant generation during the hours of peak demand (typically 4 to 6 p.m.) and provide capacity value to the system. In the western United States, the capacity value of PV plants can be in the range of 50% to 80% of their alternating current (AC) rating, with the higher values representing systems that use active tracking to orient the PV modules toward the sun. The capacity value of CSP plants without storage can be similar to that of PV plants. This means that a 100-MW (AC rated) solar plant can potentially provide the same level of reliability as a 50-MW to 80-MW conventional plant, depending on type and location.

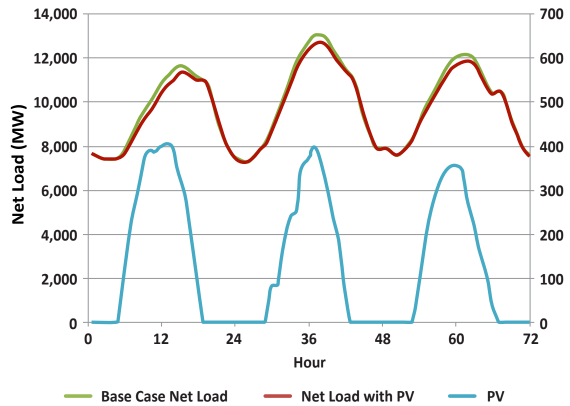

Figure 1. Coincidence of solar energy with peak demand

Impact of Solar at High Penetrations

The capacity value of solar generation is dependent on the coincidence of sunlight with demand patterns. A challenge occurs when increased solar generation on the grid

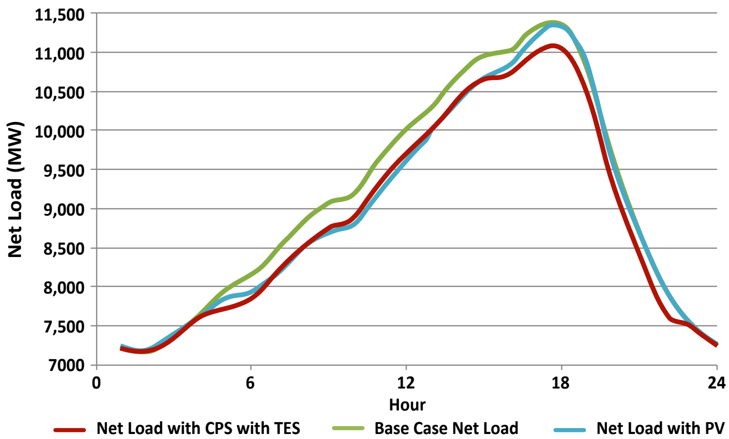

Figure 2. Changes in solar capacity value at high penetration

actually changes the net load patterns. As solar is added to the grid, it reduces the net demand for electricity in the middle part of the day and shifts the time of greatest need to the evening. This is illustrated in Figure 2, which demonstrates the change in demand that results when solar provides 10% of the system demand for electricity. It shows the new net demand for energy, which peaks at 7 p.m., at a time when PV generation has dropped significantly and no longer provides significant capacity value. At high penetrations of solar, new techniques will be needed to maintain high capacity values for solar generation technologies. One approach is to deploy TES in CSP plants. These plants can shift generation to the evening and continue to provide reliable capacity to utilities and system operators. Figure 2 demonstrates how CSP with TES can be dispatched to provide energy during peak demand periods in the evening and provide high capacity value.

Associated Publications

S. H. Madaeni, R. Sioshansi, and P. Denholm. (2012). *Comparison of Capacity Value Methods for Photovoltaics in the Western United States.* NREL/TP-6A20-54704. Golden, CO: National Renewable Energy Laboratory. Accessed January 2013: www.nrel.gov/docs/fy12osti/54704.pdf.

S. H. Madaeni, R. Sioshansi, and P. Denholm. (2011). *Capacity Value of Concentrating Solar Power Plants.* NREL/TP-6A20-51253. Golden, CO: National Renewable Energy Laboratory. Accessed January 2013: www.nrel.gov/docs/fy11osti/51253.pdf.

More Information

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Defining Capacity-Related Terms

Capacity generally refers to the maximum output (generation) of a power plant. Capacity is typically measured in a kilowatt (kW), megawatt (MW), or gigawatt (GW) rating. Rated capacity may also be referred to as "nameplate capacity" or "peak capacity." This may be further distinguished as the "net capacity" of the plant after plant parasitic loads have been considered, which are subtracted from "gross capacity."

Capacity from PV systems may be measured by either their AC or DC capacity. PV modules produce direct current (DC) voltage. This DC electricity is converted into alternating current (AC). As a result, PV power plants have both a DC rating (corresponding to the output of the modules) and an AC rating, which is always lower than the DC rating because of losses associated with converting DC to AC. AC rating better corresponds to traditional power plant ratings. CSP plants are rated by their net AC capacity in the same manner as conventional power plants.

Capacity factor is a measure of how much energy is produced by a plant compared with its maximum output. It is measured as a percentage, generally by dividing the total energy produced during some period of time by the amount of energy the plant would have produced if it ran at full output during that time.

Capacity value refers to the contribution of a power plant to reliably meet demand. The capacity value (or capacity credit) is measured either in terms of physical capacity (kW, MW, or GW) or the fraction of its nameplate capacity (%). Thus, a plant with a nameplate capacity of 150 MW could have a capacity value of 75 MW or 50%. Solar plants can be designed and operated to increase their capacity value or energy output.

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