Technology Corridor

Redefining PV Capacity

Effective metrics give solar its due credit.

BY RICHARD PEREZ, *ET AL*

Photovoltaic (PV) power generation is an intermittent, non-dispatchable resource generally considered as energy-only with no capacity credit. However, there is ample evidence that solar energy reliably is available at peak demand time when loads are driven by day-time commercial air conditioning, and can contribute effectively to increasing the capacity available on a regional grid.

Several studies have shown that the availability of solar power plants often is high during times of peak electrical demand when peaks occur in summer and are driven by day-time commercial air conditioning. These peaks are intensified during heat waves, which are fueled by solar gain. Thus, the resource creating the demand also can be used to meet that demand and provide local grid decongestion. This relieves load pockets and transmission bottlenecks, providing the equivalent of firm peaking capacity, *i.e.,* effective capacity.

Effective capacity can be verified tangibly in the case of dispersed PV. For instance, the demand-response program run by the New York Independent System Operator (NYISO) is designed to provide the equivalent of peaking capacity via load curtailment and user-sited power generation. When dispersed PV generation is available, the program can be reduced substantially while maintaining the same degree of peak reduction effectiveness.[1] When the power grid is under stress due to high summer demand, high power transfers, and reaches the point of rolling blackouts, the PV resource generally is close to ideal. A case in point is the Aug. 14, 2003, Northeast blackout, which could have been prevented with less than 500 MW of PV dispersed over the entire northeastern United States, keeping all unattended failures from feeding into one another to the point of regional outage cascade.[2]

This non-traditional effective capacity credit can be quantified by: 1) identifying and comparing different metrics that have been proposed and sometimes used by the utility and renewable energy industries; 2) comparing these metrics through experimental case studies; and 3) reviewing the results of a consensus building effort involving the utility, solar and research industries.

Effective Capacity Metrics

Simple metrics can be estimated directly from the knowledge of load demand and power generation history (*see Figure 2*). These fall into four broad categories.

Metrics can be based on the concept of loss-of-load probability. Utilities used effective load-carrying capability to quantify the capacity of their power generation units before the strengthening of continental/regional interconnectivity. The methodology still was applied at Pacific Gas and Electric Co.[3] in the 1980s. As defined by Garver,[4] the effective load-carrying capability of a power plant represents its ability to increase the total generation capacity available on a local grid (*e.g.*, a contiguous utility's service territory) without increasing its loss-of-load probability. This is determined by calculating the loss-of-load probability of the considered generating resource (here PV) and comparing it to an ideal equivalent resource with a constant output.

An analysis of load-duration curves consists of two metrics. One is load-duration capacity, defined as the mean relative PV output for all loads greater than the utility's peak, minus the installed PV capacity. The other is demand-time interval matching, details of which are provided in technical reports.[5] Basically, the demand-time interval matching capacity over a given evaluation period represents the worst-case output of the PV system by subtracting the PV system output from the load, *i.e.*, the difference between the peak of the load duration curves with and without PV generation.

Load metrics quantifying the synergies between short term storage/load control and PV generation use solar load control capacity to answer a basic question: Given a certain amount of cumulative demand response available to a utility, how much more guaranteed load reduction is possible if PV is deployed? This also can be calculated on minimum buffer energy storage capacity, using minimum storage requirements,[6] rather than cumulative demand response.

Using predefined peak demand window metrics, the time-season window method calculates capacity credit across predefined hours, months, or seasons. It is cited often as the ERCOT method, named after the practice to assign capacity credit to wind generators operating in the ERCOT regional reliability council, a practice also used by the MAPP grid operator. There are several possible variations on the calculation. The ERCOT method predefines a peak demand time frame—*e.g.*, May through October and 10 a.m. to 6 p.m.—and defines capacity as the probability a minimum output is likely to occur (8 percent in the case of ERCOT).

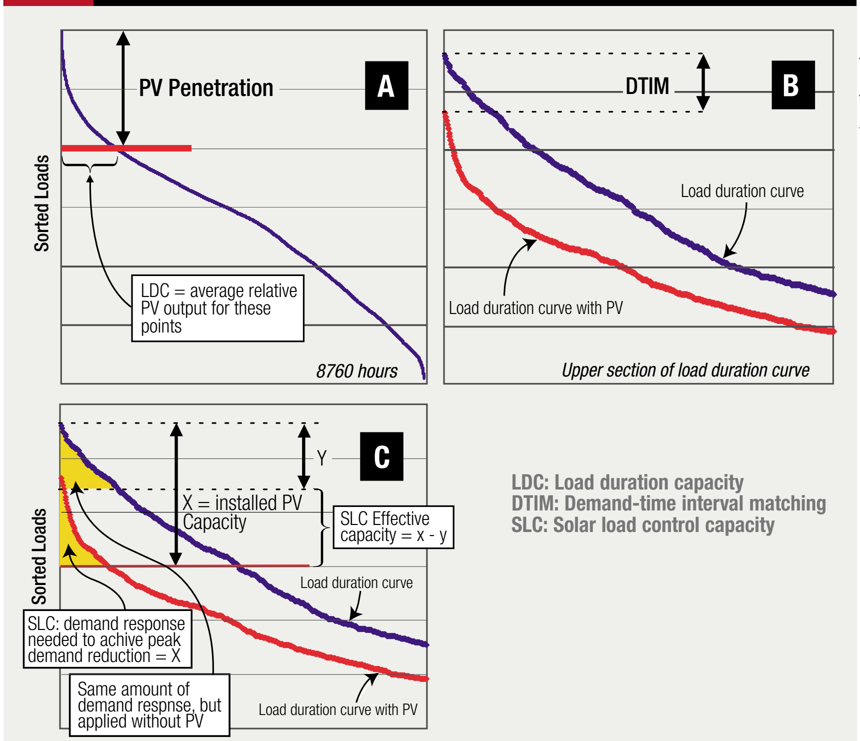
Capacity Drivers

The main driver of effective capacity is the relationship between load demand and PV supply. All of the above metrics can be calculated by analyzing concurrent time series of PV generation data and load data. In addition to the supply-demand relationship, there are two contextual items that also have relevance on effective capacity.

PV grid penetration represents the amount of PV installed on a given grid, quantified as the percentage ratio between the deployed PV peak output and the considered grid's peak. Because of its potential as a peak shaver, penetration is highly relevant to PV's capacity—the more PV penetrates a grid, the less it can be solely targeted to serve peak demand, and hence the less effective it becomes at providing capacity (*see Figure 3*). All the considered metrics account for the effect of penetration, except for the time-season window method, which only can provide a probability of availability in a given time window, independent of how much PV is deployed. In the three case studies cited, PV penetrations range up to 20 percent of peak loading.

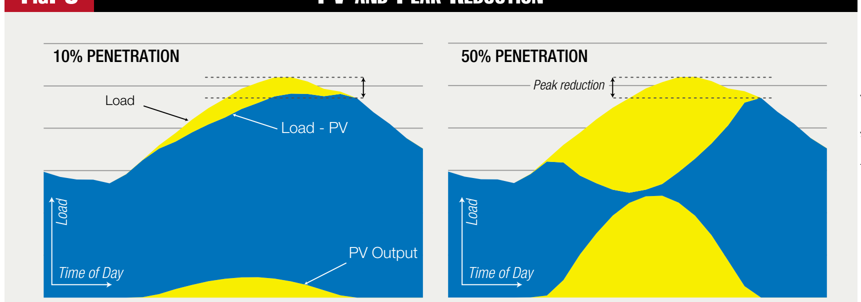
Time frequency also is relevant. But it is necessary only to look at an hourly frequency for load and PV generation data, not any sub-hourly variability. This is justified because: 1) dispersed PV generation tends to eliminate short term variability; and 2) very high frequency variability is an ancillary service issue rather than a capacity issue. In addition, some of these metrics methods absorb short-term fluctuations (in particular, minimum buffer energy storage and solar load control) and would lead to identical results regardless of the considered time frequency.

FIG. 2 COMPARING PV CAPACITY METRICS



Source: SUNY-University at Albany, Atmospheric Sciences Research Center

FIG. 3 PV AND PEAK REDUCTION



The more PV penetrates a grid, the less it can be targeted solely to serve peak demand, and hence the less effective it becoms at providing capacity.

Source: Source: SUNY-University at Albany, Atmospheric Sciences Research Center

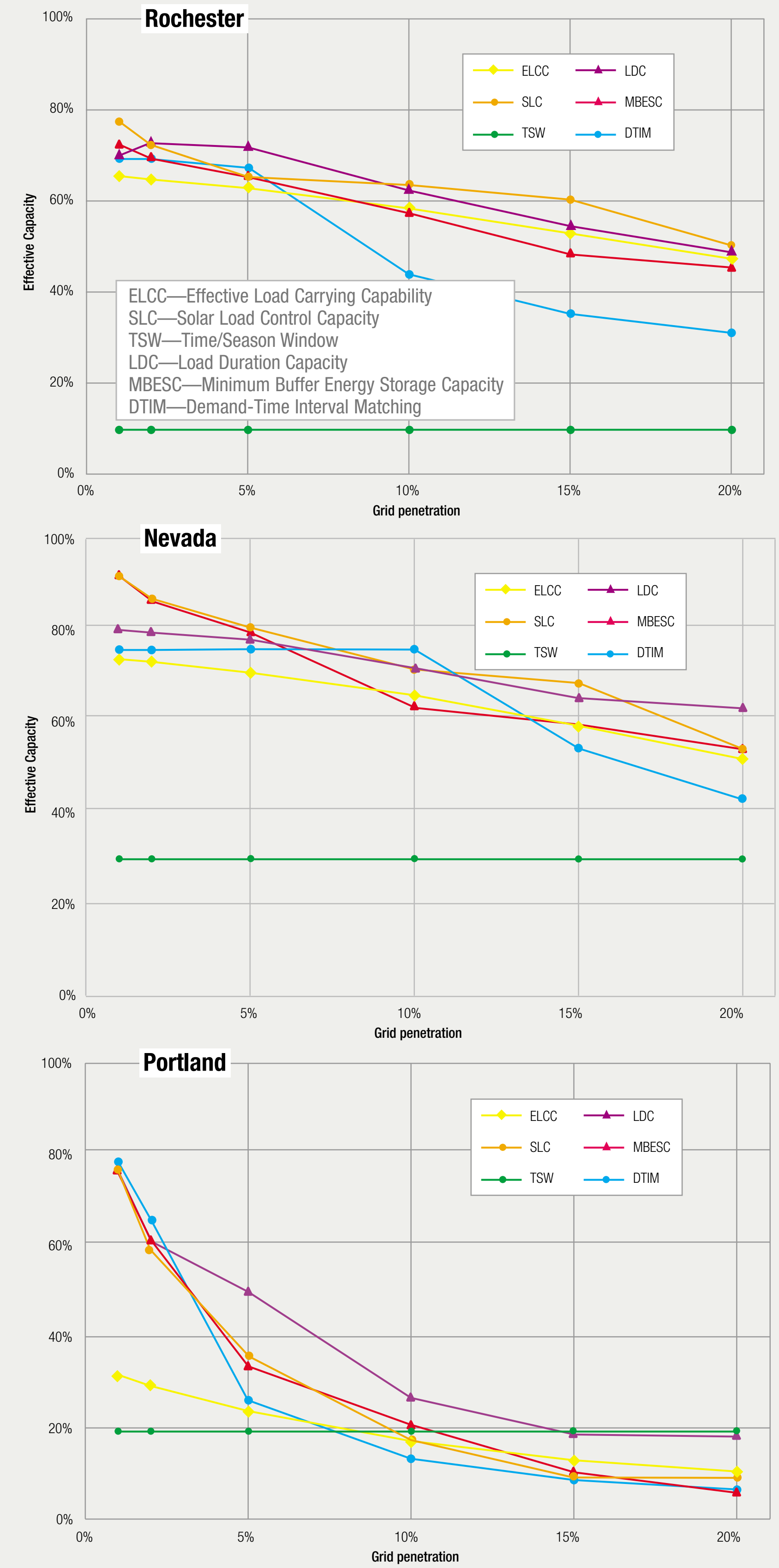
Three Case Studies

Following is an analysis of the hourly PV-load relationship and extracted capacity metrics for three distinct utilities: Nevada Power (NP), Portland General (PG) and Rochester Gas and Electric (RG&E) (*see Figure 4*).

NP is a metropolitan utility in an arid western state, endowed with a considerable solar resource and a large commercial air conditioning demand. NP is summer-peaking by a wide margin (with a summer-to-winter peak ratio approaching 2). RG&E serves a medium-sized industrial city in upstate New York, where cloudy conditions are frequent. It also peaks in summer, driven by daytime industrial and commercial air conditioning but much less than NP (summer-to-winter peak ratio = 1.3). Finally PG serves the city of Portland, Ore. and vicinity. It was a winter-peaking utility until recent years, but is now becoming marginally summer peaking due to increased air conditioning use and a general climatic trend to

FIG. 4 **UTILITY PV CREDIT METRICS**

Comparing capacity credit metrics and the impact of grid penetration for three utilities.



Source: Source: SUNY-University at Albany, Atmospheric Sciences Research Cente

warmer summers.

Using experimental load data for each utility for year 2003, site-time coincident PV outputs were generated via simulation of satellite-derived irradiance data.[7] Stationary flat-plate PV installations were optimized for mid-afternoon production (30 degrees tilt and south-west orientation).

Upon comparing these sets of metrics, the most striking observation is that all the metrics that account for PV penetration provide comparable measures of capacity. Only the time-season window leads to different results. With no dependence on penetration, the time-season window is unreflective of any load-PV relationship. This underestimation is understandable because within an arbitrarily predefined peak time window, there are many occurrences when the load is small and when reliance on PV output is not critical. It is thus arguable that the time-season window is not an appropriate measure of PV capacity credit, no more than the capacity factor should be a measure of capacity credit.

Selecting between the other metrics is not a critical choice, because they provide comparable results. By bundling minimal control/storage with generation, both solar load control and minimum buffer energy storage metrics eliminate the notion of risk associated with a non-dispatchable resource, introducing the notion of firm power delivery (100 percent reliability). The effective load-carrying metric is a slightly more conservative measure of capacity. Demand time interval matching shows more discontinuity than the others when plotted against penetration, because it is based on one single critical data point at the top of the load duration curve, and this point may shift significantly depending on the size of PV relative to the grid it serves.

Reaching Consensus

There are two opposite viewpoints regarding PV capacity credit. In gen- »

eral, utilities consider PV to be an intermittent, energy-only source of electricity, while the solar industry regards it as a demonstrably reliable peaking resource. Presentations and arguments for each viewpoint were exchanged at the PV Capacity Workshop during the Solar Power 2007 conference[8] for a mix of utility, government and solar industry representatives.

After discussing issues directly and indirectly related to measuring capacity credit—the monetary value of capacity, emergency planning, capacity planning, ancillary services, the cost of PV, planning for future penetration of PV, the question of ownership, what happens at very high penetration levels—the workshop focused on capacity calculation methodology, ending with a straw poll on metric appropriateness and preferences.

Effective load-carrying capacity was the preferred method overall, followed by the solar load control and minimum buffer energy storage metrics (combined because of their operational similarity). There was a clear distinction, however, between utility and solar industry preferences, with utilities preferring the more familiar effective load-carrying capacity, while the solar industry preferred the methodologies exploiting control-storage synergies and eliminating the notion of risk associated with non-dispatchable PV generation.

This choice is consistent with agreed-upon methodology for other non-dispatchable resources. For example, the utility-wind industry[9] relationship shows a fair degree of acceptance for effective load-carrying capacity.

Appropriate capacity credits for PV might determine whether PV power generation will continue to be considered an energy-only resource. But research demonstrates that metrics can quantify the effective capacity of PV, providing the information utilities need to integrate significantly more solar energy into their resource portfolios. »

Solar Morphology

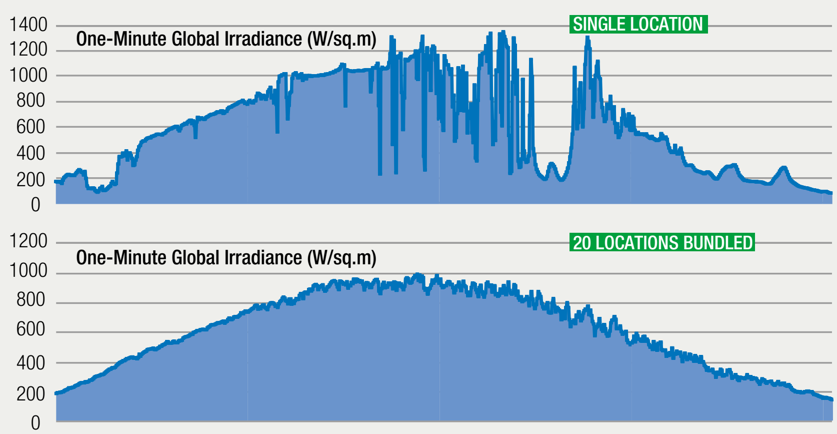
Solar Power Generation: There are two basic categories of solar energy technologies: Those that are end-use specific, such as space heating or domestic hot water production, and those that produce electricity. The two leading electricity generating technologies are concentrating solar power (CSP) and photovoltaics (PV). Whereas CSP operation follows the traditional utility model of centralized generation, the PV resource, because of its modular nature can be highly decentralized. The equivalent of a large power plant can consist of numerous multiple-size installations dispersed over a utility or substation service area.

The Solar Resource: The solar resource is abundant and could supply all of the planet's energy requirements many times over. However it is locally intermittent due to weather, and daily and seasonal cycles. Daily and seasonal cycles are precisely predictable, but weather-driven intermittencies are less so; these fluctuations may span from a few seconds (a passing cloud) up to several days (a passing weather system). However, short-term fluctuations can be reduced considerably in practice by bundling individual PV plants, much like the bundling of individual utility customers tends to smooth electrical demand (*see Figure 1*).

Capacity Factor: The average output of a power plant in relation to its rating is its capacity factor. Because solar plants only operate during daytime hours and are affected by weather, their capacity factor is low, typically ranging from 15 percent to 25 percent in the United States. As a measure of average energy output, it is only loosely related to the issue of PV capacity credit.

Capacity Credit: A plant's capability to generate power on demand and contribute to the generating capacity available on a regional power grid determines its capacity credit. The capacity credit of a power plant generally is assessed at a fraction of its rated output, accounting for the plant's forced outage rate. Because of intermittency, solar power plants cannot guarantee output on demand and carry no capacity credit in this traditional sense, unless operated with built-in backup or storage.–***RP***

FIG. 1 REGIONAL DISPERSION AND RELIABILITY



Source: USDOE's ARM network

Comparing the solar irradiance at one location on a single partly cloudy day (top) to that of 20 locations dispersed over approximately 100 square miles illustrates how system-wide distribution greatly reduces variability in solar energy.

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ENDNOTES

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Risk Management Forum

(Cont. from p. 31)

Longer term it becomes a significant issue for us, in terms of development and acquisition of new facilities.

The volatility in the economy makes projecting what will happen six to 12 years from now more difficult. Building a power plant has a multi-year lead time. What we do in the resource-planning group is look at different areas of the economy, try to understand the drivers as best we can and understand the scenarios. Our resource planning group takes that and develops options in resource acquisition, planning what steps we'll take to accommodate load, higher or lower than what we're projecting. Having those options in our planning process allows us to make sure we're not trapped and acquiring too much or too little of the supply resource.

Fortnightly: What do you see as the most important political and regulatory risks facing Xcel? How are you positioning to address them?

Dybalski: I think the biggest risks we see for regulation are related to climate change and overall energy policy. This is true at the federal and state levels. We've expected this for some time, so for instance we've taken steps to add considerable amounts of wind generation to our mix.

The risk isn't necessarily the need to reduce CO_2 and things like that, but the way it's done and the potential that regulations could change. We could go down one direction—for example to meet a renewable portfolio standard that calls for X percent of wind generation—and three or four years into it the regulations could change out from under us. That potentially changes what investments we have to make, and that could change the whole cost structure, which would affect our customers.

From a financial hedging perspective, that would be difficult to manage. Realistically, the volumes and costs are too large. You can trade CO_2 credits and those kinds of things, but [financial hedging isn't possible] for the magnitude of political risks that we're talking about. It goes to the regulatory and political arena to manage these risks.

We have a vice president of environmental policy whose role is to work with regulatory bodies, legislators and political parties to ensure we have a seat at the table, and policies are developed that we understand. We're pretty certain there's going to be regulation and limits on CO_2. That's fine, we can deal with that once we know what those regulations are and we know they're unlikely to have material changes through time.

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