SOLAR POWER

Using Photovoltaics to Preserve California's Electricity Capacity Reserves

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The California Power Authority (CPA) is committed to increasing the use of renewable energy supplies—such as photovoltaics and wind—as a *hedge* against price fluctuations of electricity and natural gas.

The CPA wants to own and operate an adequate supply of reserve generation that:

- Can be deployed quickly in response to severe summer peak loads, unexpected loss of base and intermediate generation units, and failure of critical transmission facilities.
- Will minimize the reliance on spot market purchases during periods when the State is most vulnerable to price gouging from private generators.

High-efficiency, low-emission natural gas generators play a role in providing this reserve. Dispatching power from new plants owned and operated by the State will reduce the need to run older, highly polluting "peaker" plants for longer periods of time, and will provide a superior cost and environmental solution than retrofitting older plants.

However, photovoltaics (PV)—or solar electricity—has great value as a source of firm, reliable power during extreme peak loads. But this value has not been made clear and has been drastically underestimated by most energy planners.

Substantial evidence from well-attested studies using actual solar and system load data verify the following: an excellent correlation exists between the available solar resource and the periods when California relies most on an adequate power supply.

Using well-documented planning methods, we can demonstrate that PV can:

- Provide dependable summer peak capacity in California
- Reduce the run-time of existing high-polluting peaker plants
- Reduce the number of new gas generation plants needed
- Improve the reserve capacities of the transmission and distribution (T&D) system
- Operate in conjunction with energy efficiency measures, reducing system peak load more than either could alone
- Further reduce total power plant emissions
- Provide a valuable energy option if natural gas prices fluctuate.

Solar Power is an Intermittent Resource

The output of a PV power plant depends entirely on the amount of sun shining on the solar cells. Sunny California has a very high availability of the solar resource, making it one of the most attractive regions in the country to install PV generating systems.

The amount of energy generated varies both during the day and by season. When the sun is brightest, the generating output is greatest. Likewise, a cloud drifting across the sun on an otherwise clear day will reduce the output by 50% or more, with the power ramping back up just as quickly when the cloud passes. After the sun sets, no solar power is generated. Seasonally, the summer’s long daylight hours and sun high in the sky offer the greatest solar output.

Because the output is not "controllable," solar power, like wind power, is considered an intermittent resource. Therefore, the notion of flipping on a PV plant during a power crisis like one would a gas plant *seems* entirely illogical—but it's *not*.

Solar Power is a Dependable Peaking Resource

California's inadequate generation reserve is mostly a problem during the summer, specifically during heat waves. During these periods, the sun is consistently unobstructed and even the early morning skies are powerfully bright.

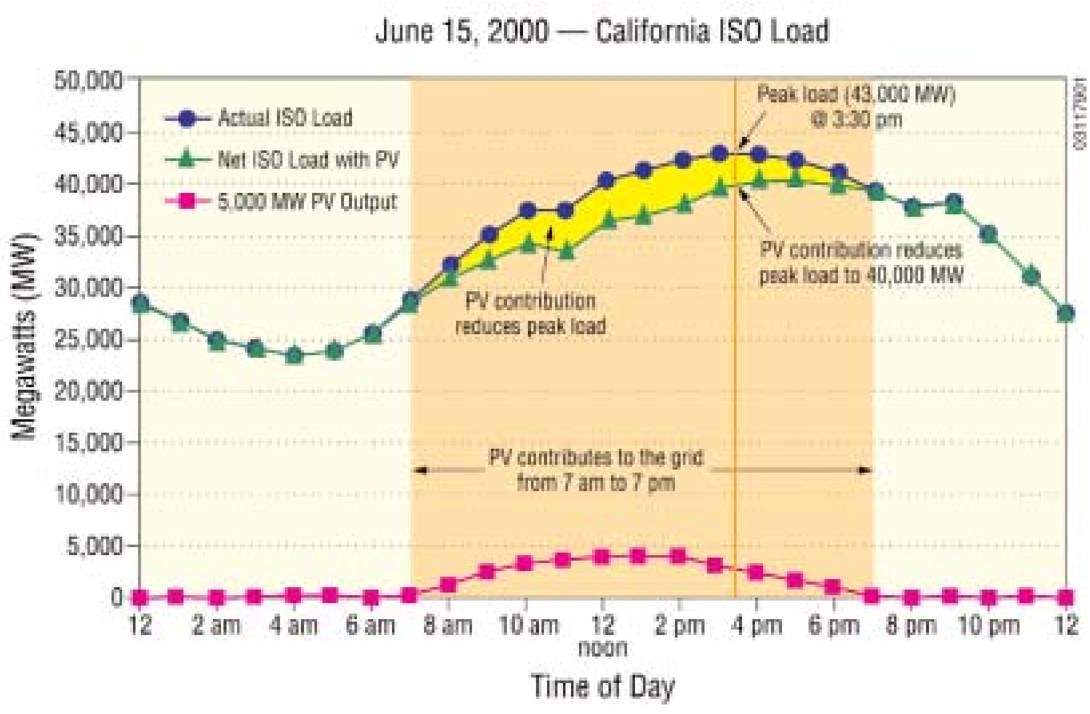
So although power from a single PV plant on a cloudy April day might not be highly predictable, nor will it be most needed then. In contrast, the June 2000 California heat wave is one of many examples when available reserve capacity was limited, California energy prices topped out at over $600/MWh, and the State's solar resource was fully dependable [1].

The following figure shows the actual California independent system operator (ISO) load on June 15, 2000. The chart also shows the solar energy output from an actual California PV plant on the same day, scaled to 5,000 MW, to demonstrate its impact on the ISO load shape.

An installed dependable PV capacity of 5,000 MW reduces the peak load for that day by about 3000 MW—thereby cutting in half the number of equivalently sized gas peakers needed to ensure capacity reserve. Although this example pertains to a single day, it illustrates how PV systems typically perform in California during summer heat waves.

The measure of how PV will perform more generally as a reliable source of peak energy is called the *effective load carrying capability* (ELCC).

ELCC is defined as "the ability of a power generator—whether PV or conventional—to effectively contribute to a utility's capacity, or system output, to meet its load. Therefore, ELCC for a PV system represents PV's ability to provide power to the utility *when it is needed*. It is the *capacity credit* of the PV power plant." [2] The PV capacity credit applies directly to California's reserve needs because it illustrates the potential of PV to reliably meet peak energy requirements.



Several studies document this PV capacity credit at various locations throughout the United States using actual utility load data [2-4]. Among their conclusions is that high PV ELCC or PV capacity credit is associated not only with high solar resource, but also with regions characterized by:

- Intense summer heat waves
- High daytime commercial demand
- Small electric-heating demand.

The annual *average* ELCC estimated for PV plants distributed across California is 64% of the PV system rating. This value easily exceeds 80% for periods when the load is driven by the sun, as in California's summer peaks. For example, a PV system rated at 5 MW could *reliably* be considered a summer peaking power source of 4 MW (=0.80 x 5).

This is important to meeting California's energy reserve needs because even though solar output can't be controlled in the traditional way, it naturally responds to the environmental conditions that create the peak loads in the first place. The statistical methods documented in these studies can easily be applied to the California ISO's historic load data—to demonstrate PV's contribution to peak generation capacity and its ability to offset new fossil-fuel-based peaking plants.

PV Provides Capacity Reserve Benefits to T&D Systems

As with generation supply, California's T&D delivery systems are most stressed and vulnerable to failure during summer peak days. Locating PV systems within the distribution system—as opposed to locating larger gas plants at remote locations on the transmission system—reduces the amount of power that needs to be transmitted through the T&D lines and substations during these crucial periods. This means that the same reserve capacity that PV provides for California's generation supply simultaneously benefits California's overburdened T&D systems.

The PV ELCC concept has been applied to peak load periods on targeted T&D substations and lines, using substation demand information from numerous locations within a utility's service territory. PV generators located in areas with high PV capacity credits will help to relieve overloads on the T&D facilities, while reducing the need for costly T&D expansions.

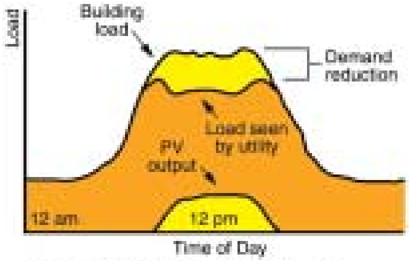
For example, one study identified PG&E planning areas totaling more than 8,000 MW of distribution capacity that had PV ELCC values exceeding 60% [5]. Results at the *distribution* level are determined by the customer load mix and energy consumption patterns. For example, distribution systems dominated by *commercial* customers have the highest PV capacity credit because PV generates best during the same 8:00 a.m. to 5:00 p.m. hours of demand for commercial lighting and air conditioning. However, distribution systems dominated by *residential* customers have a lower PV capacity credit because residential air-conditioning demand is greatest in the late afternoon. The credit in such areas, though, can be improved by using tracking systems and systems installed on southwest-facing residential rooftops.

PV and Energy Efficiency Work Together

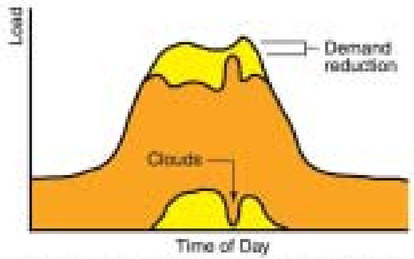
The ELCC of PV at very localized levels—such as on a single commercial building—can be improved further by controlling the building's HVAC system to react to changes in solar output. The "solar load controller" concept mitigates the *localized* uncertainty of solar power and guarantees a specific reduction in a customer's peak demand [6].

As illustrated in the following figure, the concept is very simple. The building HVAC is controlled to raise the temperature setting by 1 or 2 degrees Centigrade when a cloud passes across the sun. The shading limits the PV output, but also slows the rise of the building's internal temperature. Days with consistent cloud cover require less air-conditioning load to begin with.

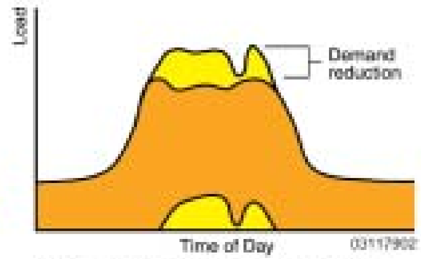
Devices such as the solar load controller coordinate renewable energy and efficiency measures to provide true dispatchable capacity and can raise the ELCC of a PV plant from less than 80% to 100% at the local level. The end



The correlation is high between commercial load (building) demand and solar availability. So PV provides power when needed, thus displacing peak energy and **reducing demand.**



The correlation between PV output and load demand is normally high. But localized demand reduction may be hindered by occasional clouds.



The **Solar Load Controller (SLC)** reduces the load when needed by acting on end-use settings or scheduling. Because of the naturally high correlation between PV and load, the **end-use inconvenience is minimal** compared to the demand reduction enhancement.

result is to reduce the system load more effectively than could be provided by either the PV system or the efficiency measures alone.

PV is Part of the Peaking Power Supply

California is in an excellent position to demonstrate the dependable peaking power of PV generation as it implements new renewable capacity over the next 5 years. The CPA should recognize PV's significant role as a summer peaking resource and actively incorporate PV when planning California's peaking reserve portfolio.

Acknowledgements

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