PV Pulling Ahead, but Why Pay Transmission Costs?

Bill Powers

Southern California Edison (SCE) and the Los Angeles Department of Water & Power (LADWP) recently announced plans to construct large remote photovoltaic (PV) arrays using First Solar thin-film technology. SCE has announced two projects totaling 550 megawatts in the Mojave Desert region of Southern California. The LADWP announced a 55-megawatt project in Imperial County, California. There is still a vast backlog of proposed concentrating solar projects in the Southwest. Yet, PV appears to be gaining momentum as the preferred technology for any solar application, whether remote or urban.

ALTERNATIVES COST MORE, USE WATER

Concentrating solar technologies, specifically solar trough, linear Fresnel, power tower, and dish Stirling, have a higher cost of energy (COE) than state-of-the-art PV. In terms of operating and planned projects, the predominant concentrating solar technology is solar trough. The estimated COE for the most recently constructed solar trough plant in the United States, Acciona's 64-megawatt Nevada One, built in 2007, is $0.15 to $0.17 a kilowatt-hour.[1]

The COE for state-of-the-art PV is in the range of $0.12 to $0.15 a kilowatt-hour. Solar trough has very high water consumption relative to conventional power plants on a megawatt-hour basis, at approximately 800 gallons a megawatt-hour.[2] The water consumption of a related solar trough technology, linear Fresnel, is even higher, at about 1,000 gallons a megawatt-hour. PV arrays use approximately 20 gallons a megawatt-hour for panel cleaning. The high water consumption of solar trough and linear Fresnel solar plants is a major impediment to the deployment of these types of solar plants, as the best solar resources are typically in regions with little water.

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By way of comparison, a water-cooled combined-cycle plant uses about 200 gallons a megawatt-hour. An air-cooled combined-cycle plant uses less than 20 gallons a megawatt-hour.

Air cooling can be used to dramatically reduce water consumption from solar trough plants, though use of air cooling adds cost and results in a substantial degradation in performance during hot, peak demand periods when the output is most needed. Power towers operate at higher steam temperature than solar trough or linear Fresnel solar plants. The higher steam temperature results in less performance loss when air cooling is used to condense low-pressure steam as it exhausts from the steam turbine.

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 DOI 10.1002/gas

One power tower developer, Brightsource, does incorporate air cooling into the standard plant design. Brightsource has yet to build a utility-scale project. For this reason, the cost and performance impacts of using air cooling have not been demonstrated in the field.

Remote renewable energy installations, whether concentrating solar or PV, require transmission lines to reach load centers. Transmission is expensive. The cost of any new transmission needed to move remote solar power to load centers must be included when comparing the cost of remote renewable energy resources and local solar alternatives. New transmission dedicated to transmitting solar power or wind power from remote locations to load centers in the Southwest would have a typical cost in the range of $0.06 a kilowatt-hour.[3] This cost is in addition to the COE for the renewable generation itself. Transmission losses during times of peak demand are in the range of 14 percent, with average losses in the range of 7 percent.[4] This cost is a given and must be attributed to any remote renewable power-generation resource.

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PV is the one proven renewable technology that can be deployed on a large scale at the point of use at the distribution level, avoiding the transmission cost and transmission losses associated with remote solar or wind resources.

UTILITIES GUARDING MONOPOLY STATUS

Why then are utilities generally not embracing low-cost urban PV as the lead card in a cost-effective and relatively noncontroversial greenhouse gas–reduction strategy? The answer appears to lie in the investor-owned utility business model, which is built upon utility ownership of electricity infrastructure. *Newsweek* effectively captured the essence of the situation in a recent article on the rapid growth in decentralized rooftop PV systems and the slow growth in large, centralized solar plants preferred by utilities:

> The disparity has utilities worried about loosing their grip on the country's energy industry, and the $130 billion residential electricity market. In some cases, utilities are actually taking direct steps to thwart rooftop solar. Two weeks ago in Colorado, the state's biggest utility, Xcel, tried passing a surcharge on homes and businesses using rooftop solar power. The public went ballistic, and with pressure from Democratic Gov. Bill Ritter, the proposal was eventually shelved. In early July, New Mexico's biggest utility, PNM, filed an official request to dramatically reduce incentives for businesses and homeowners to install solar panels, and is now fighting with state lawmakers over whether it has the right to exclusively own solar panels systems hooked up to its grid. During California's last legislative session, Southern California Edison, which serves 13 million residents, successfully lobbied against a bill that would have allowed the city of Palm Desert to pay solar users for the excess power they generate. (Phillips, M. [2009, August 25]. Taking a dim view of solar energy—Who could possibly be against homeowners using solar panels to power their homes? Utility companies. *Newsweek*, http://www.newsweek.com/id/213468)

When new transmission costs and line losses are considered, rooftop PV remains a more cost-effective value proposition.

Utility concern that rooftop PV owned by third parties may become the default renewable portfolio standard compliance strategy in the Southwest, given the difficulty the utilities have had in moving forward on concentrating solar projects, may be one factor in the recent trend toward more large, remote PV projects. However, when new transmission costs and line losses are considered, rooftop PV remains a more cost-effective value proposition. Resistance to the development of huge greenfield solar arrays on desert lands—whether PV or any other type of solar energy—and to the cost and environmental impacts of associated transmission may yet require utilities to ease their grip on electric power production and delivery as the pace of rooftop PV development accelerates.

NEED TO REDUCE WATER CONSUMPTION IN SOLAR THERMAL PLANTS

The U.S. Department of Energy (DOE) is engaged in an ongoing effort to evaluate and reduce water consumption in concentrating solar plants.[5] All operating solar thermal plants in the United States use evaporative water cooling. The use of water for power-plant cooling is increasingly controversial in the Southwest due to chronic water shortages.

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Evaporative water cooling is commonly used with fossil power plants, using a cooling tower, to reject the steam-cycle heat. A typical water-cooled coal plant or nuclear plant consumes 500 gallons of water per megawatt-hour of electricity generated. This is similar to the water consumption by a power tower. A water-cooled, combined-cycle natural gas plant consumes about 200 gallons a megawatt-hour. A water-cooled parabolic trough plant consumes about 800 gallons a megawatt-hour. Of this, 2 percent, approximately 20 gallons a megawatt-hour, is used for mirror washing.

Air cooling, in the form of an air-cooled condenser, is being used with increasing frequency in new fossil plants as an alternative to conventional evaporative cooling. The air-cooled condenser is similar in design to an automotive radiator. The primary advantage of the air-cooled condenser is that it dramatically reduces power-plant water usage, dropping it by 90 to 95 percent or more. An air-cooled combined-cycle plant consumes on the order of 10 to 20 gallons a megawatt-hour.

Numerous combined-cycle plants have been built in southern Nevada in recent years, and all of them use air-cooled condensers for cooling. The reason for this is the severe shortage of discretionary water supplies in southern Nevada.

The El Dorado 480-megawatt air-cooled combined-cycle plant owned by Sempra Generation is adjacent to the water-cooled 64-megawatt Nevada One solar plant that came online in June 2007. The Nevada One solar trough plant produces only a small fraction of the power output of the Sempra plant on an annual basis, approximately 5 percent,[6] yet consumes significantly more water than the combined-cycle plant.

Sempra Generation built a 10-megawatt PV array at the site of the El Dorado combined-cycle plant, using state-of-the-art First Solar thin-film PV. The PV plant came online in December 2008. Sempra Generation CEO Michael Allman states that the PV array produces the lowest-cost solar energy ever generated from anywhere in the world.[7] He also indicates that Sempra evaluated solar thermal technologies and determined that PV is a more cost-effective option.

TYPES OF CONCENTRATING SOLAR TECHNOLOGIES

There are four primary concentrating solar plant designs—solar trough, linear Fresnel, power tower, and dish/engine. All designs use a small amount of water for mirror washing. The first three of these technologies operate a steam cycle and require some water for steam makeup and, when they are water-cooled, require a substantial amount of water for heat rejection similar to water-cooled fossil and nuclear plants.

Currently, approximately 400 megawatts of solar trough power plants, including the 64-megawatt Nevada One plant, are in operation in the United States. In typical solar trough applications, oil flowing through the receiver tube is heated to about 750 degrees Fahrenheit and used to boil water to produce steam. The resulting steam is used in a conventional steam boiler plant Rankine power cycle and expanded through a turbine connected to an electric generator. The exhaust steam is cooled and condensed back to liquid water to be recirculated in the cycle. The condensers can be either water-cooled or air-cooled, or a hybrid combination.

The DOE reports that the use of air cooling on a solar trough plant reduces output approximately 18 percent during the hottest 1 percent of annual operating hours. The 18 percent reduction in output also represents power that is not available to meet critical peak demand.

Linear Fresnel is in essence a subcategory of solar trough. Tracking mirrors focus on a fixed

 DOI 10.1002/gas / © 2009 Wiley Periodicals, Inc.

receiving tube where water is boiled directly, producing saturated steam at about 535 degrees Fahrenheit, which powers the steam cycle. Linear Fresnel has lower efficiency than solar trough, though it is expected to cost less due to a simpler design. Today there are no operating linear Fresnel power plants in the United States. As a result of the lower cycle efficiency, linear Fresnel is projected to have a higher cooling water requirement than solar trough.

Power towers use tracking mirrors, called heliostats, to reflect solar energy on a receiver located on a centrally located tower. The solar energy is absorbed by the working fluid, either pressurized water or molten salt, flowing through the receiver. Power towers operate at significantly higher temperatures than solar trough or linear Fresnel. As a result, the performance of the power tower is less affected by the use of air cooling. DOE reports a 6 percent reduction in output for power towers during the hottest 1 percent of annual operating hours.

As noted, one power tower developer, Brightsource, incorporates air cooling in the standard plant design. Some studies have found that this technology has potential for lower costs than solar trough or linear Fresnel collectors, but this is only for large plant sizes. No utility-scale power tower plants have yet been built in the United States.

The dish/engine concept uses a field of individual parabolic-shaped dish reflectors that each focus sunlight onto an engine/generator that used the Stirling thermodynamic cycle to directly produce electricity without producing steam. Unlike solar trough or linear Fresnel plants, dish/engine arrays can be installed on uneven land. There are six 25-kilowatt prototype dish/engine prototype units at Sandia National Laboratory. An ongoing challenge with this technology has been maintaining an effective seal on the hydrogen working fluid. The dish/engine is air-cooled and requires water only for periodic cleaning of the reflecting surfaces.

PV WINNING THE RACE

PV seems to be edging ahead of concentrating solar technologies for remote centralized solar applications. The move to PV for remote arrays appears to be an effort by utilities to regain some control over the development of solar energy, which has rapidly expanded principally in the form of distributed rooftop PV owned by third parties. It is unclear whether this effort will be successful.

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Remote centralized renewable energy projects face a number of similar hurdles—competing uses for large tracts of undeveloped desert land, the high cost of new transmission, the difficulty in siting new transmission, and the line losses associated with moving remote renewable energy to load centers. Locating the PV in the urban core is the least-cost solution and eliminates the negative aspects of remote development. Even the switch to PV for remote centralized solar plants by utilities may not substantially alter the dynamic that favors distributed rooftop PV over the remote alternative.

NOTES

1. Peltier, R. (2007, December). Nevada Solar One, Boulder City, Nevada. *Power,* http://www.powermag.com/issues/cover_stories/Nevada-Solar-One-Boulder-City-Nevada_230.html.
2. U.S. Department of Energy (U.S. DOE). (2009, July 16). Concentrating solar power commercial application study: Reducing water consumption of concentrating solar power electricity generation. Report to Congress, http://www.nrel.gov/csp/pdfs/csp_water_study.pdf.
3. California Public Utilities Commission Application A.06-08-010, SDG&E Phase I Opening Brief, Exhibit 142, p. 50. The total revenue requirement for a proposed 1,000-megawatt Sunrise Powerlink transmission line Southern Route is $149.8 million a year over a 58-year cost recovery period. Assume that the capacity factor of 1,000 megawatts of solar trough resources interconnected to the transmission line is 0.29, per the August 2008 Renewable Energy Transmission Initiative Phase 1A final report (www.reti.org). Under this scenario, the transmission line transmits 1,000 MW x 8,760 hr/yr x 0.29 = 2,540,400 MWh/yr. Cost of transmission = ($149,800,000/yr)/(2,540,400 MWh/yr) = $59/MWh ($0.059/kWh).
4. D. Kondoleon, transmission program manager, California Energy Commission, e-mail communication, January 30, 2008.
5. See note 2.
6. This assumes the solar plant operates at a 29 percent capacity factor and the combined-cycle plant operates at a 70 percent capacity factor.
7. Wan, U. (2009, April 22). Sempra wants 300 MW plus of solar in Arizona. *GreenTechMedia*, www.greentechmedia.com/articles/read/sempra-wants-300-megawatts-plus-of-solar-in-arizona-6074/.

