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PARABOLIC TROUGH POWER FOR THE CALIFORNIA COMPETITIVE MARKET

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ABSTRACT

California is about to complete its third year of a deregulated competitive wholesale power market. During the first two years of the competitive market, power prices averaged between 2 and 3¢/kWh. During 2000, electric supply to California was constrained a number of times causing maximum the price of power to peak over 100¢/kWh, and the average price of power to quadruple.

The power output from solar plants tends to coincide with the high power demand periods in California. This fact had been demonstrated by the solar electric generating stations (SEGS) located in the California Mojave Desert, which operate under specific contracts signed in the 1980's and early 1990's with the local utility. This paper, on the other hand, examines how new parabolic trough solar plants would have faired on the wholesale competitive power market during 1999 and 2000.

INTRODUCTION

During the last several years, the electric power sector in United States has been going through a significant restructuring in an effort to become more competitive (EIA, 2000). In some States, retail electricity customers can now choose their electricity company. New wholesale electricity trading markets, which were previously nonexistent, are now operating in many regions of the country. The number of independent power producers and power marketers competing in these new retail and wholesale power markets has increased substantially over the past few years. The power transmission system is being reorganized to allow fair access to it by all generators. However, the introduction of these new markets has been far from seamless. California, where retail competition was introduced in 1998, has recently had well-publicized problems. Electricity prices in some parts of the State have quadrupled and there have been supply interruptions as well.

Increasing prices and open access provided by the wholesale market could offer an opportunity for the reintroduction of large-scale solar power plant technologies. This paper assesses how new parabolic trough solar power plant technology would have performed in the wholesale California power market during 1999 and 2000.

THE CALIFORNIA POWER MARKET

On March 31, 1998, California's new deregulated power market began operation. The large power utilities in the state turned over control of their electric transmission facilities to the new Independent System Operator (ISO) to assure fair access to transmission by all generators. The new California Power Exchange (CalPX) opened to provide a competitive marketplace for the purchase and sale of electric generation.

The deregulation required electric utilities to split their business into generation, transmission, and distribution businesses. The utilities continue to own all of the transmission and distribution facilities, but the ISO controls all of the transmission facilities. Utilities provide all distribution services, but customers are allowed to choose their energy supplier. The utilities were required to sell off 50% of their generating facilities. In addition, utilities have to sell all their electric generation to the Power Exchange and purchase all power for their customers through the Power Exchange. The exception being that utilities are required to continue purchasing electricity from pre-existing must-take power contracts. These include the large nuclear plants and the qualifying facility (QFs) power contracts such as co-generators and renewable energy generators. Although the power from the must-take contracts is not sold on the competitive market, the power from these plants is scheduled through the CalPX.

The existing SEGS plants currently fall into this category. Their power is sold to the utilities under must-take power contracts and is not marketed on the competitive wholesale market.

1. California Power Exchange

California is in its third year of operation in the competitive power market. Approximately one third of California's generating capacity is currently marketed competitively on the CalPX. The remaining two-thirds of California's generation is on must-run contracts. When more power is needed than is available on the must-run contracts, as is generally the case, private generators sell power to the power exchange on a competitive basis. Although there are a number of various ancillary power services marketed on the CalPX, generation is commonly sold through a day-ahead competitive bidding process. The lowest bids are accepted up to the point that the demand for power is met. The final bid defines the market-clearing price, which is the price paid to all generators. For example, if the final bid accepted is for 3¢/kWh, then even the generators whose bids were below 3¢/kWh will receive this amount for the electricity generated.

2. The 1999 & 2000 Markets

During 1999, the CalPX operated much as it was designed. In general, 1999 was a good year for hydro-electric power, there was an excess of capacity available to feed into the market, and natural gas prices were relatively low. As a result, the market clearing price generally increased slightly as the demand for power increased. The average market-clearing price on the CalPX was 2.8¢/kWh for the day ahead market. However, the price varied throughout the day and seasonally as demand for power changed. The peak price paid during the year on the day ahead market occurred during the summer peak and was 23¢/kWh. A minimum price of 0¢/kWh occurred several times during May and June when there was excess hydroelectric capacity.

During 2000, the power exchange has been plagued by a different environment. Hydro-electric output was reduced due to a poor snow pack. The supply of natural gas was constrained by problems with pipelines and gas supply not keeping up with growing demand. Natural gas prices began the year at $2.80/MMBtu. By December, natural gas spot markets has peaked at over $50/MMBtu. In addition, as the utility generation power plants were sold off to non-utility generators, utilities lost control of when plants were shut down for scheduled outages. As a result, a number of generators shut down for scheduled outages in June when CalPX rates were historically at the lowest point of the year because of excess hydro-electric capacity. However, because 2000 was a poor hydro year, demand for power during June remained high. With several large generators down for maintenance outages, and a large nuclear plant out of service for a forced outage, California found itself short of electricity supply. Prices on the power exchange went up to new highs until they were limited by the 75¢/kWh maximum. The maximums were later reduced to 50¢/kWh and later to 25¢/kWh. However, California continued to find itself in short supply throughout much of the remainder of 2000. Ironically, the price caps in California caused part of the problem, because California generators could sell power to the Pacific Northwest or the Southwest for more that the price caps in California allowed. Power shortages occurred even during November and December when there is normally a significant excess of capacity. High gas prices and CalPX rate caps made it more expensive to generate power that the power exchange would pay for power. In December, the price cap of 25¢/kWh was raised to 150¢/kWh. This helped ease the constrained supply in the state. During 2000, the average price of power was 11.1¢/kWh, nearly four times that of 1999. The minimum price was again 0¢/kWh during the hydro spill in the spring. However, the peak price paid was 150¢/kWh.

Figure 1 shows the price paid for power versus the system load for all hours during 1999 and 2000. The 1999 data shows a fairly linear relationship between the system load and price of power. The scatter for the most part accounts for seasonal variations and natural gas pricing. Although, 1999 worked well from the consumer standpoint, many generators had a difficult time covering expenses due to low market prices for power (CEC, 1999).

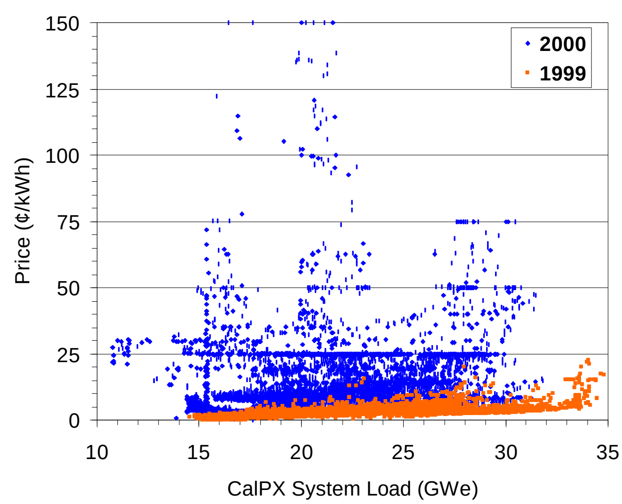

Fig. 1: California Power Exchange Day Ahead Pricing

The year 2000 data in Fig. 1 shows a much more erratic power environment with very high prices even at low system loads. The price caps at 25¢, 50¢, 75¢, and 150¢/kWh can also be observed in the Figure. The competitive market did not perform as expected in a supply-limited environment. The high prices during 2000 have caused many problems for the state including bringing the large investor owned utilities to the verge of bankruptcy. The utilities cannot raise prices to consumers, but must pay the high prices charged on the power exchange. Clearly, the California market is still in a state of transition. 2001 will bring additional changes to the California power market.

3. Solar Power for the California Market

The power output from solar plants tends to coincide with the peak power demand periods in California. This fact had been demonstrated by the five parabolic trough solar electric generating stations (SEGS) located at Kramer Junction in the California Mojave Desert. These plants have demonstrated in excess of 100% of their rated capacity during the Southern California Edison summer peak demand period (noon to 6 pm) for each summer month during the last 11 years (Cohen et. al., 1999).

Figure 2 shows the California average hourly system load for three months based on data from 1999. The figure has data for the month of April, August, and December. August represents the month with the highest load due to the high afternoon air conditioning loads. December has an evening peak due to evening lighting and electric heating loads. April is one of the lowest demand months due to a lack of high heating or cooling loads. The peak demand for power is about 50% higher in August than in April. All months clearly show increased demand for power during the day and into the evening. Solar plants are well suited to meet the daytime peak and with thermal storage are able to meet evening peak loads as well.

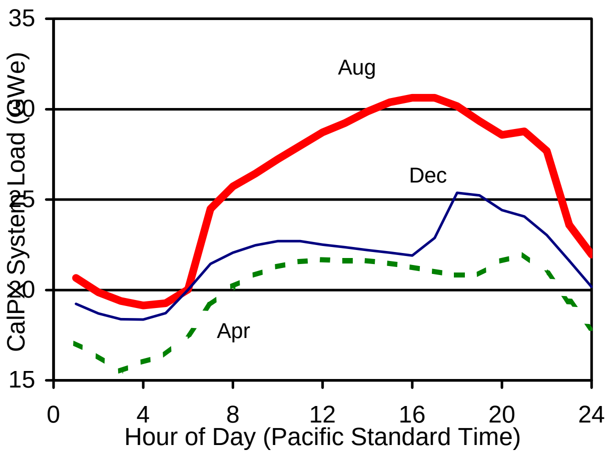

Fig. 2: California 1999 Average Hourly System Load

In addition, since the price paid for power increases with system load, a solar plant that generates power to meet peak loads will receive, on average, a higher price for power than the average price paid. Is the added value of peaking power sufficiently attractive to encourage the development of new trough power plants? The remainder of this paper evaluates how well parabolic trough power plants would have performed in the California competitive market during 1999 and 2000.

ANALSYSIS

Because the actual SEGS plants are hybrid plants that burn some natural gas during part of the year and are operated on a must-take contract with different scheduling requirements, the actual output from the SEGS plants cannot be used for this analysis. Instead, the authors have chosen to use a computer model to simulate the output from parabolic trough power plant based on an operating strategy optimized for the actual CalPX loads and rate structures.

An hourly performance simulation computer model has been developed by the authors to model the expected performance from a parabolic trough power plant. Validation runs between the model and the existing parabolic trough plants show the model to reproduce the actual performance from the plants within about 10% on a daily basis and 2% on an annual basis.

The analysis looks at three configurations of parabolic trough plants.

- Solar w/o Storage: A parabolic trough solar plant with no thermal storage. This plant produces power whenever there is sufficient solar radiation to produce power. This plant will have an annual capacity factor of approximately 25%.

- Solar w/Storage: This is a parabolic trough plant with thermal storage that allows solar power to be dispatched to higher demand periods. This plant has the same size solar field and produces approximately the same amount of power as the first case.

- 2x Solar w/Storage: This is a solar plant with a solar field twice as large as the first two cases and increased thermal storage. This plant will produce about twice as much power on an annual basis as the first two cases.

The analysis modeled the solar electric production for each solar plant configuration using actual solar radiation data collected at the Kramer Junction SEGS plants during 1999 and 2000. The California hourly system load and the market clearing prices were downloaded from the CalPX website (CalPX, 2000).

RESULTS

The electric output from the three modeled parabolic trough solar power plants configurations were compared to the actual CalPX system loads. Figure 3 shows the hourly output from the three solar plant configurations compared with the CalPX system load for a typical summer day. There is generally a good match between the power output from the solar plant without thermal storage and the CalPX peak system load. The addition of thermal storage allows the solar electricity to be shifted to better match the peak system load. The plant with the enlarged solar field is able to meet a larger portion of the peak load.

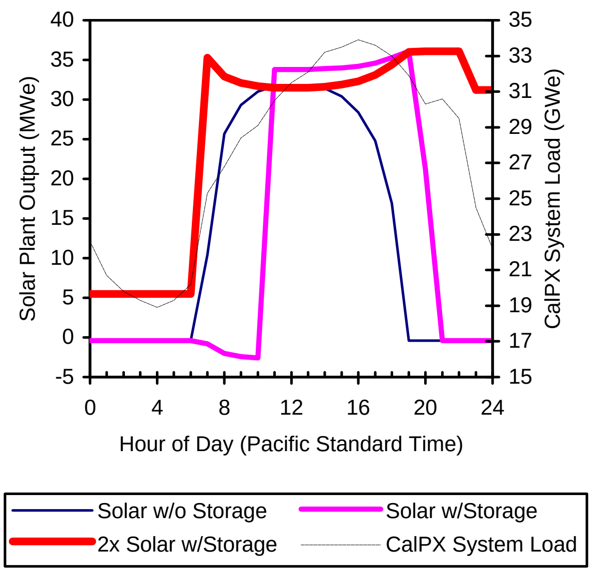

Figure 3: Solar Output for 3 Solar Plant Configurations Compared to CalPX System Load (July 1, 1999).

Summer is typically when the output from a solar plant best matches the peak demand of the electric power system in California. How well does the solar plant output meet the peak power demand during the remainder of the year? To answer this question we evaluated the solar plant output for every day during a year and compared it to the CalPX system load. Figure 4 shows the average solar capacity factor during each hour of the day, where hour 1 represents the highest hour of power demand during the day and 24 represents the lowest power demand during the day. Although the solar plant appears to do a good job of meeting the peak power demand during the summer, Figure 4 shows that without thermal storage the solar plant only meets the peak load about a 35% of the time. It should be noted that the solar plant produces virtually no power during the 9 hours of the day with the lowest demand for power. The addition of thermal storage clearly helps the solar plant meet a greater portion of the daily peak demand hours. Increasing the solar plant size helps to further increase the plants ability to generate during the peak load hours of the day. This plant achieves 100% rated output during the highest hour of demand and more than 80% output during the 4 highest load hours of the day. This clearly demonstrates how a parabolic trough plant with thermal storage can clearly be used to meet daily peak power demands.

It should be noted that this analysis assumed no forced or scheduled plant outages during the year. Although this is not completely realistic, the existing plants typically have availabilities well in excess of 90% on an annual basis and even higher when just considering the summer peak period.

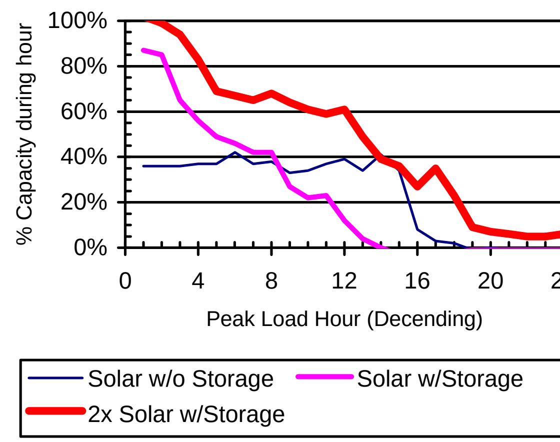

Figure 4: Solar Output During Daily Peak Load Hours

It should be noted that the analysis used average monthly loads for the dispatch strategy in the model. This was done to simplify the analysis. In actual practice, operators would adjust their dispatch strategies on a daily basis to better meet the actual hourly loads. As a result solar plants in real practice would likely outperform the results indicated by the model.

Using the market clearing prices from the CalPX web site we calculated the average price of power paid during 1999 and 2000. We also calculated the price paid for the power from our solar plants with and without thermal storage, which are shown in Table 1.

TABLE 1 CALPX MARKET CLEARING PRICES

	1999		2000	
	¢/kWh	% Inc.	¢/kWh	% Inc.
Average Price	2.83		11.11	
Price For Solar	3.32	17%	12.03	8%
Solar with Storage	3.78	33%	14.31	29%

A number of conclusions can be drawn from Table 1. First, the dramatic increase in prices during 2000 is apparent. The average price of power during 2000 was nearly four times the price paid in 1999. Second, the average price paid for solar power is higher that the average price of power because solar power in general is produced during high demand high value periods of the day. Third, because thermal storage shifts more solar generation to higher revenue periods, the average price paid to a solar plant with thermal storage is higher yet. Although not shown in the table, the solar plant with the enlarged solar field actually generates a lower average price of power than the other storage case because on average a greater percentage of power is generated during lower value periods.

CONCLUSIONS

The analysis presented here shows that parabolic trough solar power plants can be effectively used to help meet California's peak power loads. Parabolic trough plants with thermal storage (or hybridized as in the case of the SEGS plants) can be dispatched to effectively meet the daily high power demand periods throughout the year.

During 2000 a parabolic trough plant with thermal storage would have been paid an average price of 14¢/kWh for power generated. This price is sufficient to support the development of new parabolic trough power plants. However, it is unlikely that that the California market will sustain such high prices into the future.

Conventional wisdom has been that competitive markets are a disadvantage for renewable power technologies, because they tend to drive towards least cost power. However, the California market clearly shows that the competitive market pricing increases value of solar power because of the good correlation between solar energy and California's high power demand periods.

Deregulation is creating new opportunities for large-scale solar power technologies that did not exist a few years ago. Clearly the California market is still in a state of transition, however, if 2000 is an indication of energy markets of the future, Solar technologies could once again become highly valued resource options for diversifying energy portfolios in the U.S. Southwest.

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