Estimating the Capacity Value of Concentrating Solar Power Plants with Thermal Energy Storage: A Case Study of the Southwestern United States

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***Abstract*—We estimate the capacity value of concentrating solar power (CSP) plants with thermal energy storage (TES) in the southwestern U.S. Our results show that incorporating TES in CSP plants significantly increases their capacity value. While CSP plants without TES have capacity values ranging between 60% and 86% of maximum capacity, plants with TES can have capacity values between 79% and 92%. We demonstrate the effect of location and configuration on the operation and capacity value of CSP plants. We also show that using a capacity payment mechanism can increase the capacity value of CSP, since the capacity value of CSP is highly sensitive to operational decisions and energy prices are not a perfect indicator of scarcity of supply.**

***Index Terms*—Capacity value, equivalent conventional power, concentrating solar power**

II. Introduction

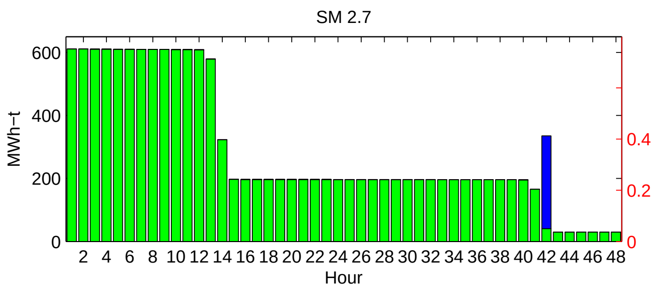
RESOURCE adequacy is an important issue with which power system planners contend [1]. Renewables provide an alternative to traditional sources of capacity and energy. Some renewables pose capacity planning challenges, however, due to variable and uncertain real-time output [2]–[6]. Thus accurate capacity value estimates of such resources are vital for long-term planning purposes.

Due to excellent solar resource availability, the southwestern U.S. has great potential for concentrating solar power (CSP)

B. Capacity Factor-Based Approximation Method

Although reliability-based methods, such as ECP, provide robust capacity value estimates, they require detailed system data. They can also be computationally expensive, since LOLPs must be iteratively recalculated until achieving condition (26). This is less of an issue today, however, with computational resources currently available [35]. As such, approximation techniques have been developed. One such class of techniques, which we call capacity factor-based approximations, consider the capacity factor of a generator over a subset of hours during which the system faces a high risk of a shortage—for instance hours with high loads or LOLPs.[1] A generator's capacity factor is defined as its average output during a set of hours divided by its maximum capacity. A number of studies apply capacity factor-based approximations to wind [3], [36], [37] and photovoltaic solar [38], comparing them with reliability-based methods to assess their accuracy. Madaeni *et al*. [7] compare the accuracy of applying different capacity factor-based approximations as opposed to reliability-based methods to CSP plants without TES. They approximate the capacity value of CSP as the average capacity factor during the 10 and 100 hours of each year with the highest loads and LOLPs, where the LOLPs of the base system without the CSP plant added are used. We refer to these as the top-load and -LOLP methods. They also examine a method, which we refer to as the LOLP-weighted method, which uses a weighted average capacity factor during the highest-load hours, with the LOLPs used as weights. They show that the LOLP-weighted method provides thegayanst-3.-304.073(T)-3.29355(h)-5F260.96r a

in TES, yielding the higher capacity value. Similarly, a larger TES system can affect the operation of a plant, for instance allowing it to startup during a high-priced hour due to more stored energy being available. This reduces the amount of stored energy available in subsequent hours, which can reduce the plant's capacity value.



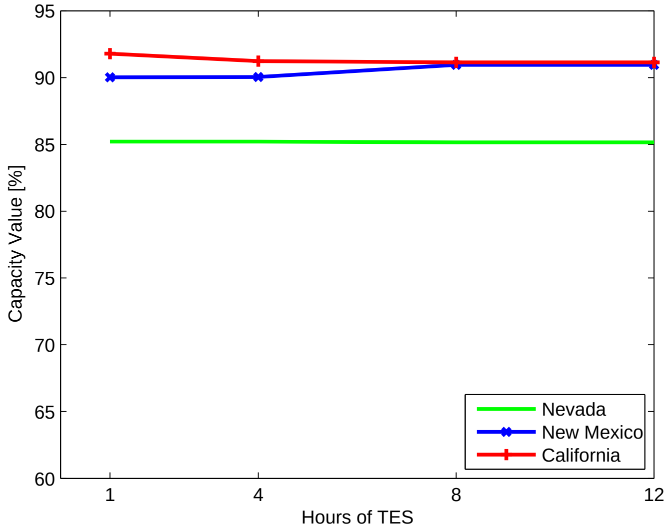


Fig. 6. Average annual LOLP-weighted approximation for CSP plants with SM of 1.5 at the three locations when a capacity payment is inc

While our analysis is limited to locations within the WECC,

[39] R. Sioshansi, P. Denholm, T. Jenkin, and J. Weiss, "Estimating the value of electricity storage in PJM: Arbitrage and some welfare effects," *Energy Economics*, vol. 31, pp. 269–277, March 2009.