Seasonal Challenges for a California Renewable-Energy-Driven Grid

Contact information:
Email: mabido@ucmerced.edu
Web: https://faculty.ucmerced.edu/skurtz/
GitHub: https://github.com/KurtzGroup
DOWNLOAD THE POSTER

Mahmoud Y. Abido*, Zabir Mahmud, Pedro Andrés Sánchez-Pérez, Sarah R. Kurtz

School of Engineering, University of California, Merced, 5200 Lake Rd, Merced, California

Background

Decarbonizing the electricity grid is a long-term target for a growing number of countries. The continuous development in the solar and wind electricity during the previous decades make them a reliable key sources of electricity especially if connected to a battery storage system.

Objective

- How can 100% renewable energy grid be achieved in California?
- When will be the resource adequacy challenge in a 100% renewable energy grid?
- What is the effect of different renewable energy scenarios on the required storage size?

Methods

A high-level energy balance approach [1] is used as in Eq. (1), in which a balance between the supply and demand is applied while considering an energy storage is connected to the grid.

$$\boldsymbol{Generation \pm Storage = Load + Surplus} \quad \textbf{Eq.(1)}$$

Data Analysis

The effect of the size of the solar buildout on the calculated state of charge is shown in Fig. 1. The historical thermal generation, nuclear generation and imports were replaced with additional solar. This six-year analysis clearly shows that for each year the time of the biggest challenge is around February. Similar calculations for 2015-2020 in Fig. 2, showed that the minimum state of charge in the reservoir is always observed during the winter. Fig. 3 shows the storage state of charge while scaling up the solar, onshore wind, offshore wind and a flat generation separately. The needed storage size is increased while adding onshore wind generation and decreased while adding offshore wind or flat generation. The minimum state of charge occurs in winter for all except flat generation. A similar conclusion can be extracted from Fig. 4 for more scenarios. Fig. 5 shows how the surplus electricity increases, and the storage size decreases with the annual generation as the solar generation is increased while having an almost fixed <10% losses due to the storage round trip efficiency.

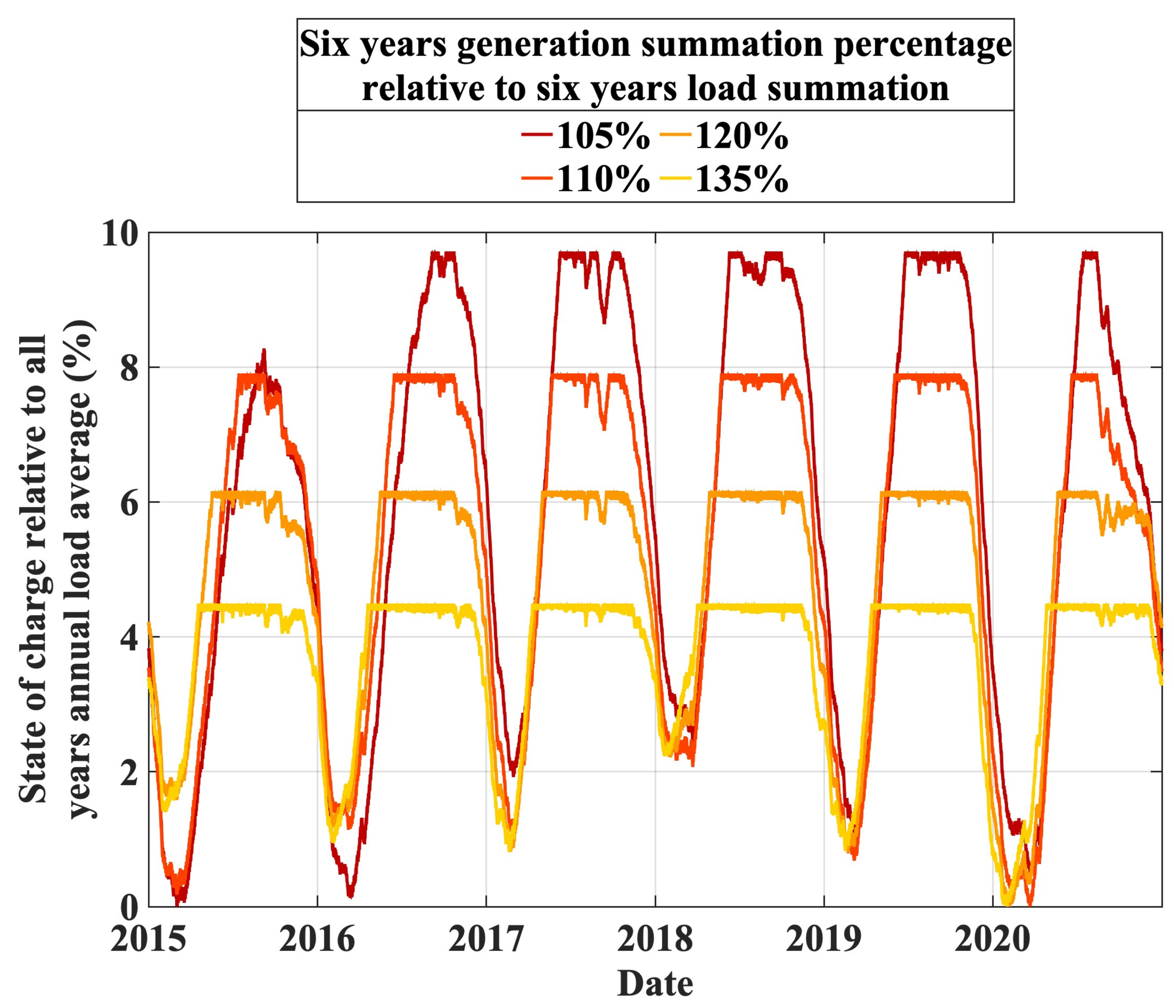

Fig. 1: Calculated storage state of charge using 2015 - 2020 generation and load data.

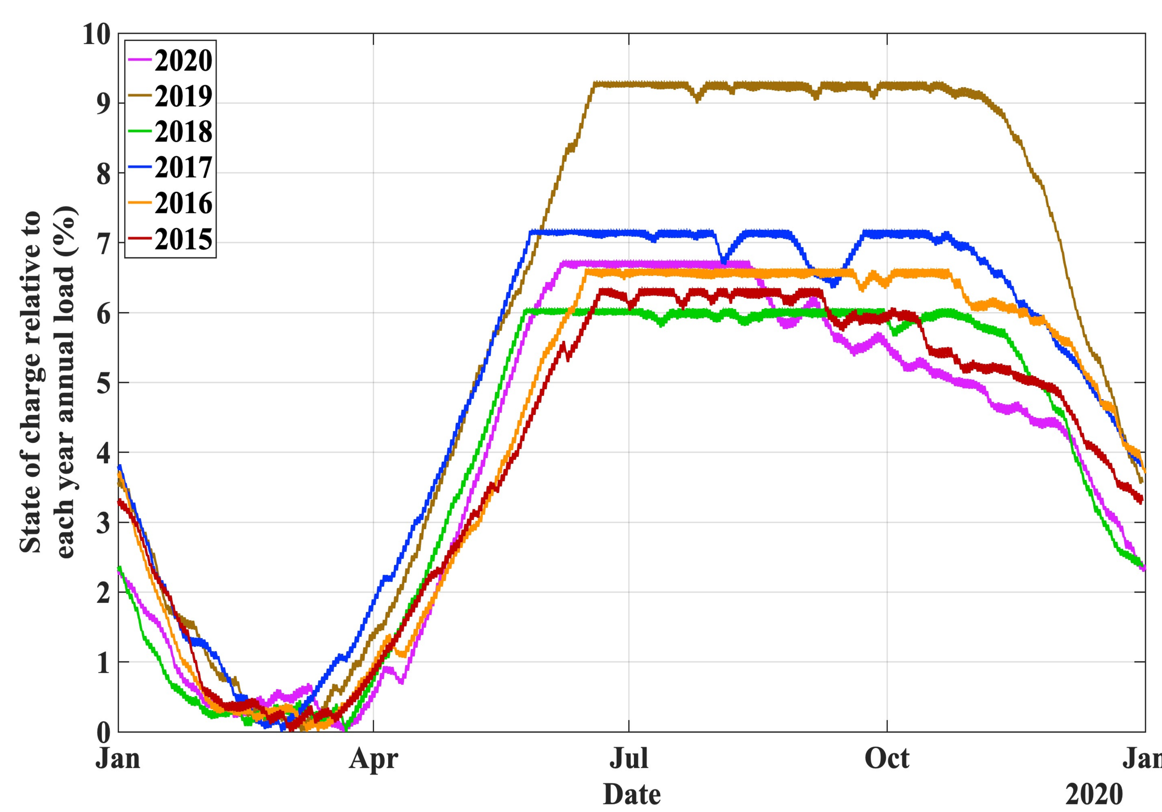

Fig. 2. Calculated storage state of charge using data from 2015-2020, showing only the total annual generation = 110% of annual load case for each year.

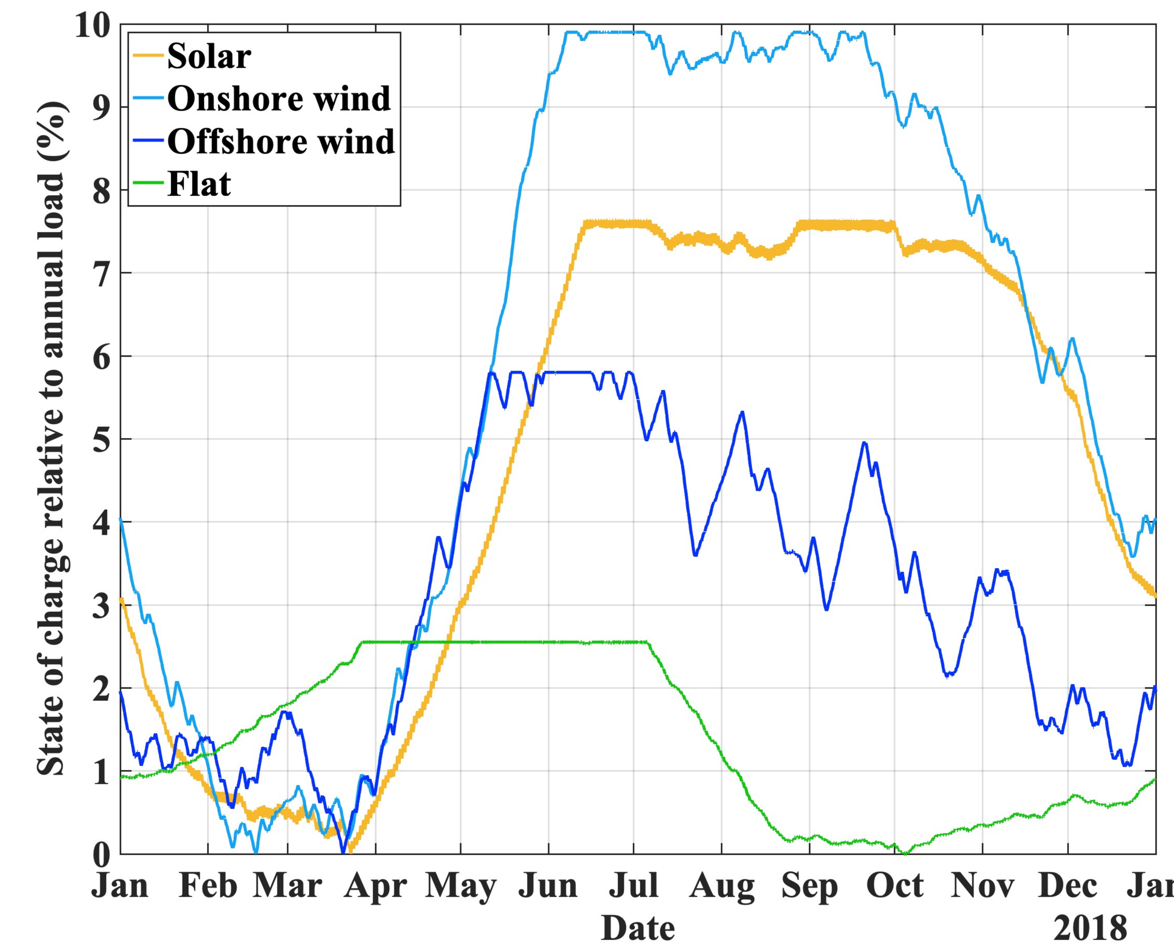

Fig. 3. Calculated storage state of charge using 2018 generation and load data with thermal, nuclear, and imports replaced with electricity generation from a single technology (as indicated) to deliver total generation equal to 105% of the annual load.

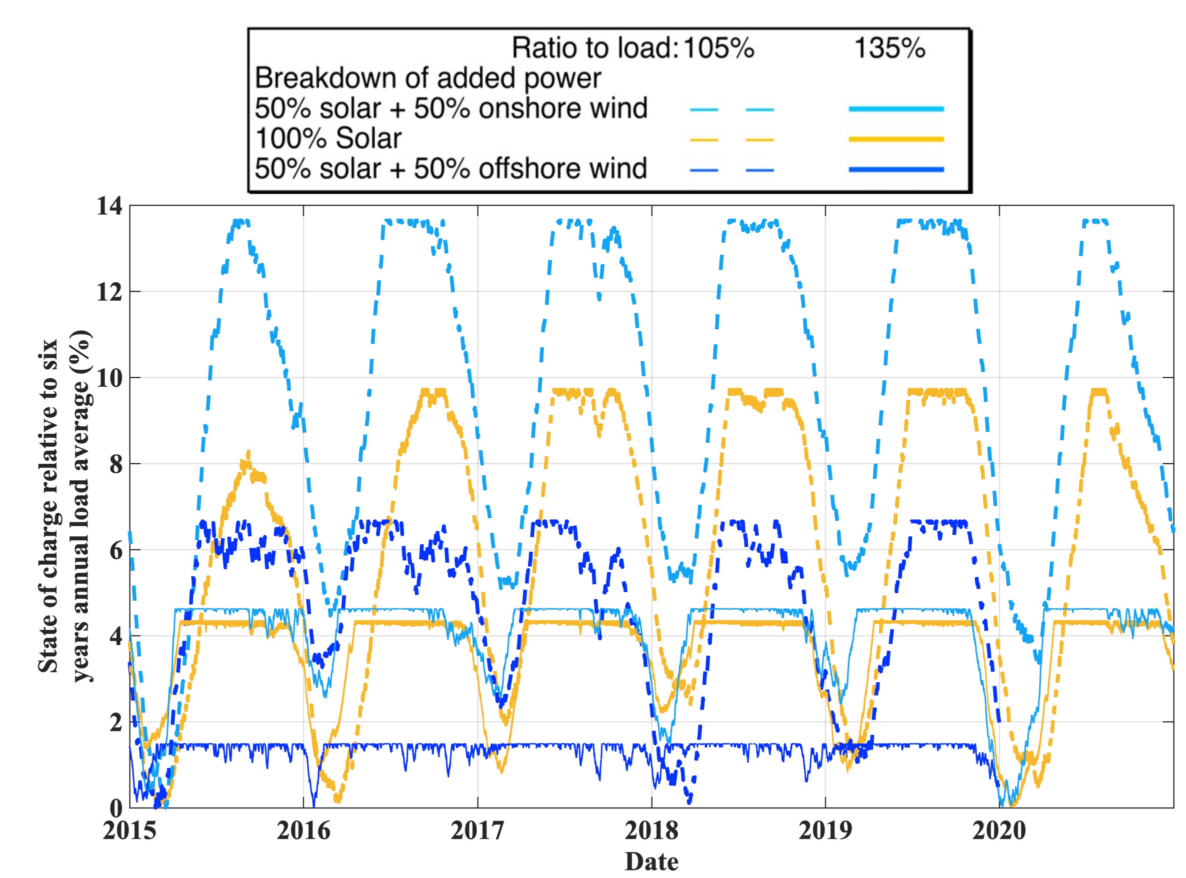

Fig. 4. Calculated state of charge for stored energy using renewables generation and load data for years 2015-2020 adding additional solar and wind generation as indicated in the legend to replace thermal, nuclear and imports. Offshore wind speed data were not available for 2020.

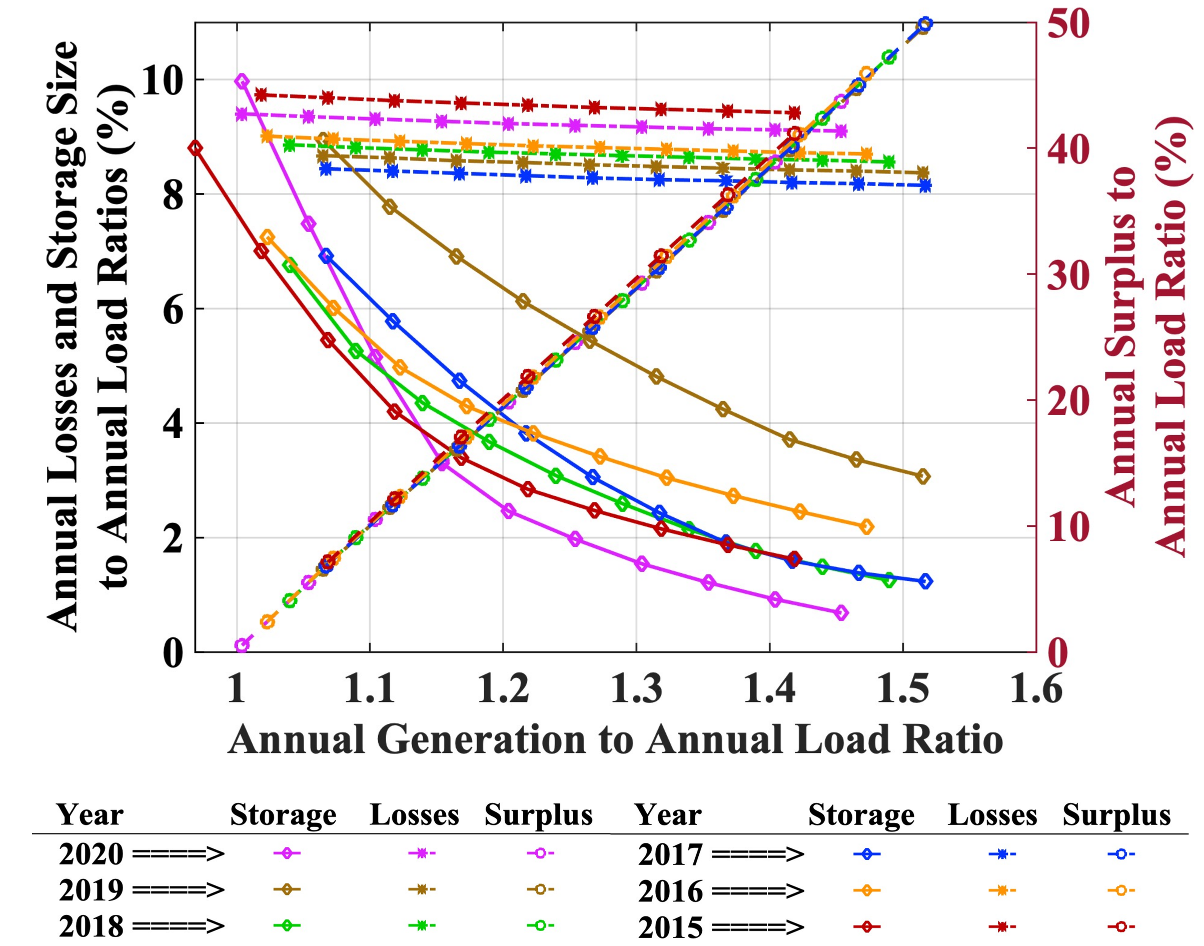

Fig. 5. Storage needed to meet minimal resource adequacy and the losses due to storage round-trip efficiency (left axis) and associated surplus electricity (right axis) as a function of solar build out.

Conclusions

We find that the resource adequacy will be most challenged for a renewable-electricity-driven grid around sunrise during January, February, or March, depending on the amount of solar generation that is built. The seasonal storage needed to balance supply and demand may be cut in half by building 30% more electricity generating capacity.

References

[1] Abido, M. Y. et al., 2021. Seasonal Challenges for a Zero-Carbon Grid. Miami-Fort Lauderdale, FL, s.n.

Acknowledgments

This document was prepared as a result of work sponsored by the California Energy Commission. This report has not been approved or disapproved by the Energy Commission nor has the Energy Commission passed upon the accuracy of the information in this report.