Energy Management Strategy and Solar Energy Utilization in Oversized Solar Array and Grid-tied Photovoltaic Systems

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ABSTRACT— A decrease in solar module cost has led to the array over-sizing issue, causing inverter to clip off solar power when energy production exceeds the inverter rating. A battery management strategy is introduced to utilize wasted energy from the inverter clipping effect. The bifacial PV system was used as a testbed. The battery was configured to be charged during the clipping period to alleviate the clipping loss and discharged during peak demand to reduce grid consumption. The result shows that 8.5% of daily DC energy is clipped but can be utilized using the proposed battery management strategy, leading to 12.9% reduction of daily grid import.

I. INTRODUCTION

Photovoltaic (PV) technology is one of the most promising options for reducing atmospheric CO_2 [1]. PV systems reduce electric grid consumption while providing more long-term revenue for system owners. A factor of 10 decrease in PV module cost over the past decade has led to the practice of over-sizing the PV DC power relative to the inverter AC rating. This leads to lower energy costs over time but also to inverter clipping when solar energy production is high. In this work, the battery management strategy has been introduced to mitigate the impact of inverter clipping loss in an over-sized PV system.

II. EXPERIMENTAL SETUP

We performed an experiment with 5-kW fixed-tilt bifacial solar array powering to a 3.8-kW grid-connected inverter, 10 kWh Li-ion battery, and Electric Vehicle (EV) charging station to represent a residential-scale PV system. The full system configuration has been installed at the Institute of Energy Conversion (IEC) as shown in Fig.1. The battery management was done through the inverter customer interface.

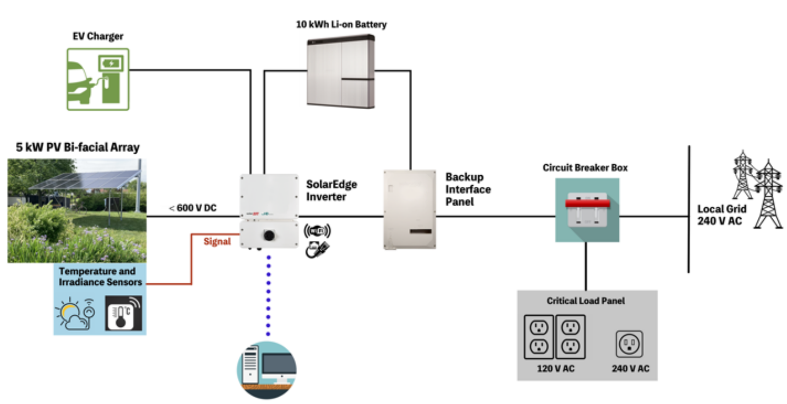
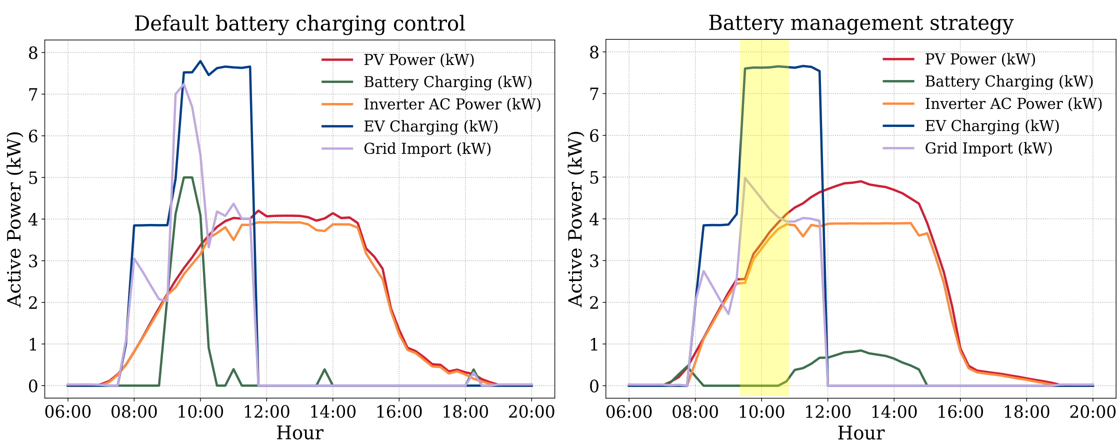


Fig.1 A high level diagram of IEC bifacial photovoltaic system.

III. RESULTS AND DISCUSSION

The key finding is that under clear sunny skies, the array produced almost 5 kW, yet the AC energy output was limited at the inverter capacity, resulting in roughly 1.1 kW DC power was wasted as a clipping loss. The clipping loss potentially occurs in summer on sunny days from 10:30 am – 2:30 pm, while winter has less clipping which will still be seen only on a very sunny day [2]. To utilize the excess PV energy, the battery control was configured to store the DC energy during clipping period and discharge it to the EV or other critical loads during high consumption period to minimize the grid import. This reduces the electricity expenses and supports the electric grid during the peak time. The results of battery control test indicated that the proposed strategy helps mitigating the energy waste in a residential scale PV system. In comparison to the default battery control, 8.5% of daily PV energy is clipped which can be utilized by charging to the battery with the proposed strategy as shown in Fig.2b. Yellow areas in the plots highlight the benefit of battery control which helps reducing 28.7% of the grid import from 9:00 – 10:15, resulting in 12.9% reduction of the total grid import. Other elaborate details will be discussed at the conference.



(a) (b)

Fig.2 A comparison between (a) the default battery charging control and (b) the battery management strategy.

IV. CONCLUSION

The battery management strategy demonstrated in this work showed that the battery can alleviate solar energy waste by charging it during the clipping period and discharging it during the peak demand. This strategy provides benefits of mitigation of the grid consumption, peak load shaving, and overall CO2 emissions which are environmentally and economically profitable to the electric utility and PV system owners. Our future works include weather forecast and real time battery control via Modbus communication and machine learning.

REFERENCES

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