Field Implementation of a Real-time Battery Control Scheme for a Microgrid at the University of California, Riverside

Yun Xue1,2, Michael Todd2, Sadrul Ula2, and Alfredo A. Martinez-Morales2
1 Department of Electrical and Computer Engineering.
2 Bourns College of Engineering Center for Environmental Research and Technology University of California, Riverside, California 92521 (allmart@cert.ucr.edu)

I. Introduction (Background)
In 2014, the University of California, Riverside launched the Sustainable Integrated Grid Initiative (SIGI), one of the largest renewable energy initiatives of its kind in the state [1]. SIGI is comprised of 500 kW of solar PV generation, 100 kW/500 kWh stationary battery energy storage system (BESS), 100 kW/500 kWh mobile BESS (installed in a trailer), and three faculty buildings. The work presented here is focused on a real-time battery control scheme that is carried out on a sub portion of the SIGI microgrid system. Namely, the control scheme is implemented using 100 kW of solar PV generation, 100 kW/500 kWh of stationary battery energy storage, and one research laboratory building with highly variable loads (due to the irregular use of laboratory equipment and performance of experimental work).

II. Real-time Battery Control Scheme

A. Off-Peak Control
1. Operation period
   - 23:00 – 06:00 (Summer) or 22:00 – 08:00 (Winter) on week days;
   - Weekends and U.S. Holidays.
2. Objective
   - To charge the BESS to 90% SOC;
   - To maintain a low off-peak demand value.
3. Control principles
   - Charge the BESS at \( \eta_p \) to keep \( P_{net} \leq \eta_f \) when \( \Delta t \):
     - Calculate the average active power \( \mu_i \);
     - Update \( \Delta SOC = (P_{in} - P_{out}) \cdot \Delta t + \Delta SOC_{i-1} \)
     - Increase \( \eta_f \) by 2.5 kW when \( \Delta SOC < -0.5 \).

B. Mid-Peak Control
1. Operation period
   - 08:00 – 12:00 and 18:00 – 23:00 (Summer) or 08:00 – 17:00 (Winter) on week days.
2. Objective
   - To maintain the predetermined mid-peak demand:
     - To efficiently utilize the battery capacity.
3. Control principles
   - Monitor the microgrid system in a passive mode (Winter):
     - Charge the BESS when \( P_{net} < 0 \) and maintain the \( SOC > 80\% \) of the first mid-peak period (Summer):
     - Uniformly discharge the BESS left from the on-peak period for the second mid-peak period (Summer).

C. On-Peak Control
1. Operation Period
   - 12:00 – 18:00 (Summer) and 17:00 – 21:00 (Winter) on week days.
2. Objective
   - To maintain a stable predetermined active power (Winter):
     - To adjust online the \( SOC \) when the building load or solar generation are both unpredictable (Summer).
   - Constant Threshold Model Predictive Control for Winter rate period;
   - Adjust Demand Threshold Model Predictive Control for Summer rate period.

III. Real-time Battery Control Scheme Experiment

Fig. 4 shows the results form an experiment carried out on a regular working Tuesday. Due to the sufficient solar generation in the mid-day, the BESS was capable of maintaining minimal power import (near 0 kW) from the grid. For each rate period, the net demand was tightly kept below the scheduled demand values, and the BESS was fully utilized during the operation.

IV. System Cost Efficiency

- System 1 – the building with the solar PV system and the BESS under the proposed control scheme.
- System 2 – the building with the solar PV system and the BESS under scheduled operation – constant charge/discharge power.
- System 3 – the building with solar PV system only.
- System 4 – the building without solar or BESS.

V. Conclusion

Via the implementation of different control strategies based on a time-of-use rate schedule, the proposed control scheme can maintain load demands for different rate periods daily, while efficiently utilizing the capacity of the battery and prolonging the lifetime of the battery system. Operating the BESS in the proposed real-time control scheme can achieve significant electricity cost reductions under the time-of-use rate schedule.

Reference

Acknowledgements
The study and demonstration is funded in part by the South Coast Air Quality Management District.