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

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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 facility 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).

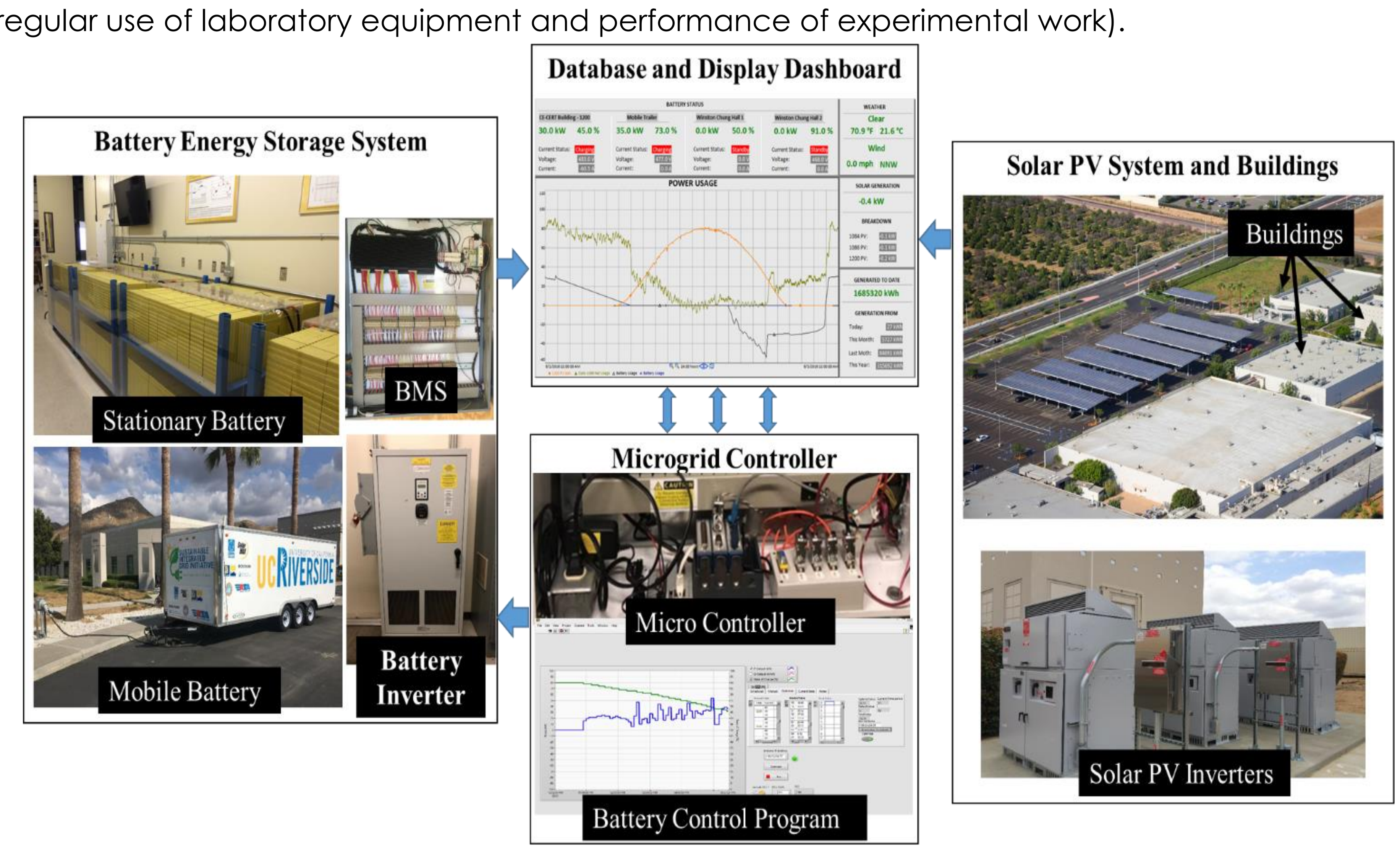

Figure 1. SIGI Microgrid System Architecture and Data Flow.

II. Real-time Battery Control Scheme

A. Off-Peak Control

1. **Operation period**
   - 23:00 – 08:00 (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 bp_i to keep $Pnet_i < offSch$;
   - Calculate the average charge power pca_i;
   - Update $\Delta soc_i = (pca_i - bp_i) \cdot \Delta t + \Delta soc_{i-1}$
   - Increase $offSch$ 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);
   - Discharge the BESS to keep $Pnet_i < midSch$, and maintain the $SOC > 80\%$ for the first mid-peak period (Summer);
   - Uniformly discharge the BESS left from the on-peak rate 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 $onSch$ (Winter)
   - To adjust onlline the $onSch$ when the building load or solar generation are both unpredictable (Summer)

3. Control Principles [2]
   - Constant Threshold Model Predictive Control for Winter rate period;
   - Adjust Demand Threshold Model Predictive Control for Summer rate period.

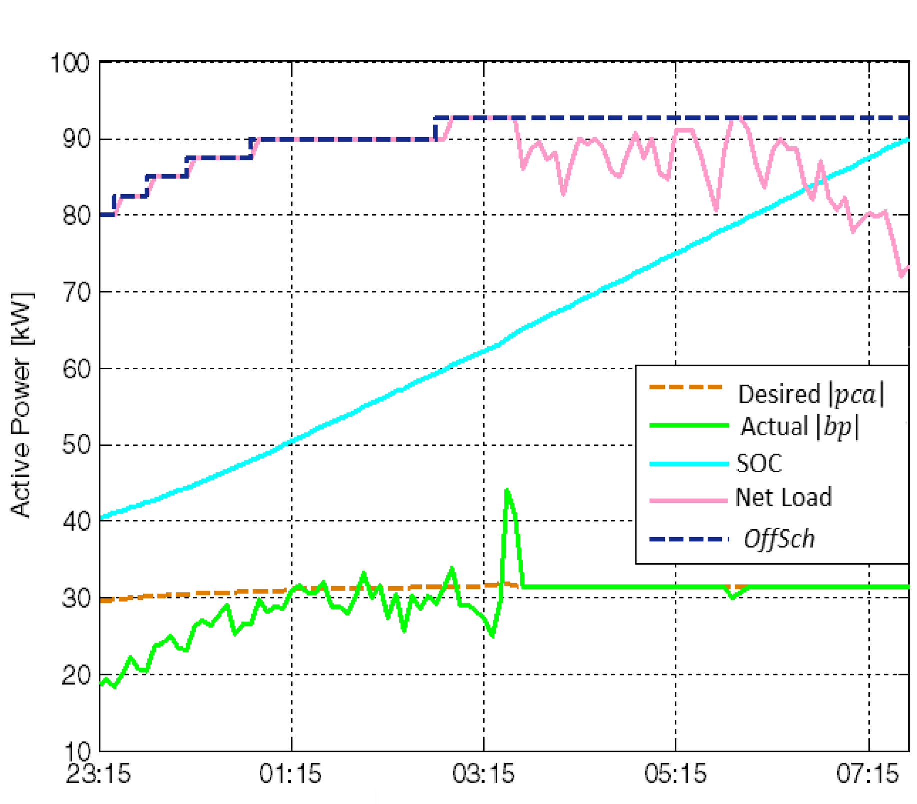

Figure 2. Off-Peak Simulation under a High Off-Peak Load Day.

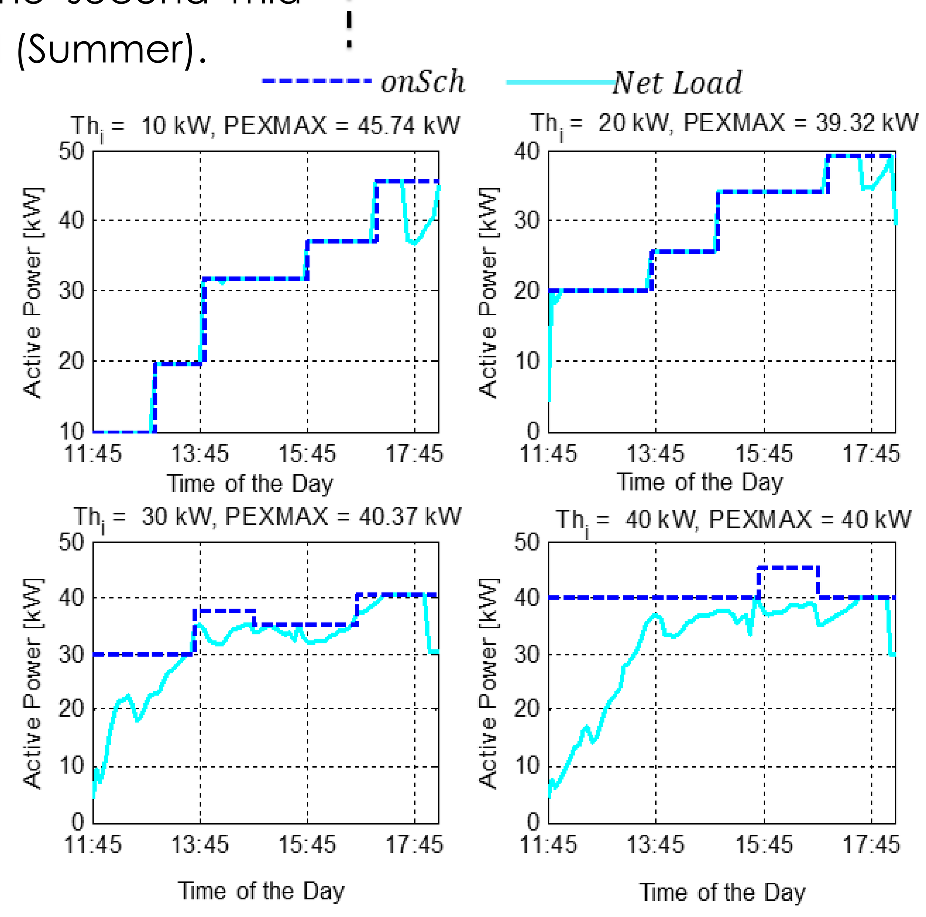

Figure 3. On-Peak Operation (Summer) Simulation for Different Choice of Initial $onSch$.

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.

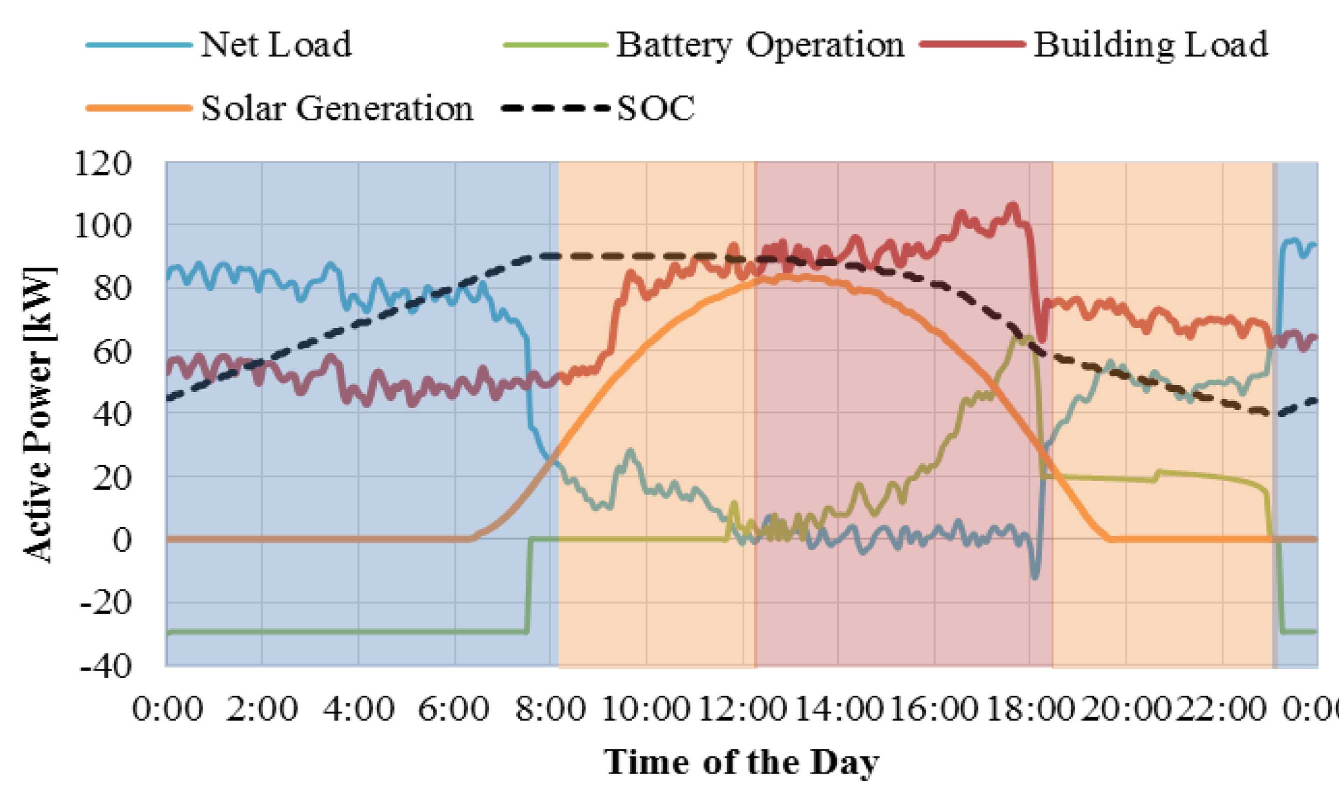

Figure 4. One-day Experiment with Operational Control for Three Different Rate Periods.

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.

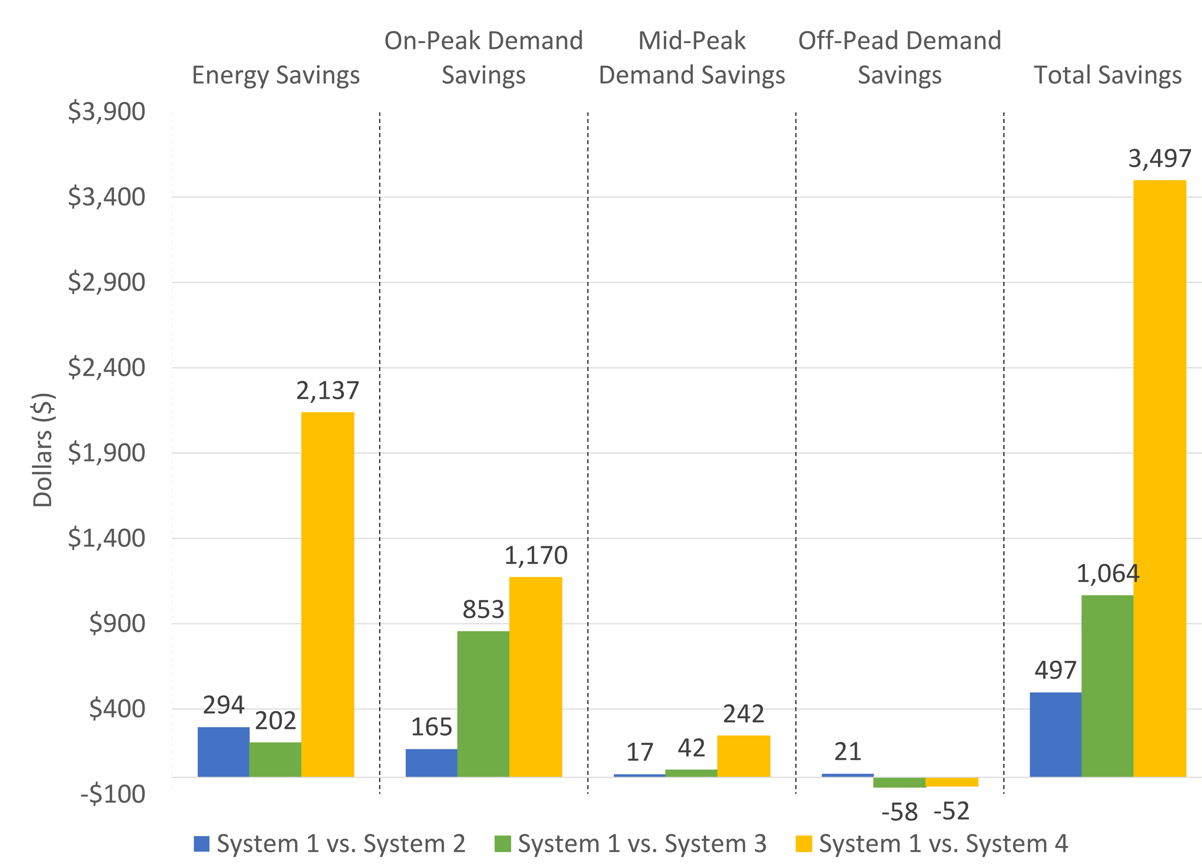

Figure 5. Additional Cost Savings Comparison Over Two Months for Different System Architectures.

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

[1] SIGI highlights - https://www.cert.ucr.edu/newgrid/

[2] X. Yun, M. Todd, S. Ula, M. J. Barth and A. A. Martinez-Morales, "A Comparison Between Two MPC Algorithms for Demand Charge Reduction in a Real-World Microgrid System," in 43rd IEEE Photovoltaic Specialists Conference, Portland, 2016.

Acknowledgements

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