Comparison Between Two MPC Algorithms for Demand Charge Reduction in a Real-World Microgrid System

UCR Sustainable Integrated Grid Initiative (SIGI)

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Abstract

This paper describes an evaluation between two model predictive control (MPC) algorithms for microgrid energy management combined with solar production and battery energy storage for demand charge reduction in a real-world microgrid system. The first control algorithm is a constant threshold MPC (CT-MPC) that works well on a system with relatively stable solar generation and a well-known building load profile. CT-MPC can maintain the on-peak demand under a certain value during the entire on-peak rate period. The second control algorithm is an adjusting demand threshold MPC (ADT-MPC). ADT-MPC can better deal with unpredictable solar generation and/or changing building loads. The on-peak threshold under this algorithm is adjusted to the optimal value during the on-peak rate period. As expected, the CT-MPC algorithm performs well when coupled with accurate forecast models, while the ADT-MPC algorithm excels when forecasting is more unpredictable.

CT-MPC Algorithm and Experimental Results

1. Principles:
   - Change the BESS when there’s extra solar generation;
   - Calculate maximum average discharge power $p$ and $d$ to ensure that enough remaining battery capacity is available during the entire on-peak period;
   - Solve the optimization problem, and only use the first index of the result as the control demand;
   - A new peak-on-index $p_{dis}$.

2. Experimental Results

Fig. 4. Solar Generation and Building Load Experiment.

Fig. 5. Battery Operation and SOC Level.

Fig. 6. ADT-MPC Net Load Simulation Under a Cloudy Day on 6/9/2015.

Fig. 7. ADT-MPC Battery Operation and Storage Simulation Under a Cloudy Day on 6/9/2015.

Fig. 8. Net load comparison between ADT-MPC and CT-MPC on a Cloudy Day.

Fig. 9. Battery operation under ADT-MPC on a Cloudy Day.


MPC Principles

MPC models have a prediction horizon $M$ and a control horizon $H$. The detailed MPC principles can be applied as follows:

i. For each On-Peak rate period in a single day, the time intervals can be divided into $M$, where

$$M = \text{hours} \times 12 + 6$$

hours refers to the on-peak hours: in summer, $6$ (12:00-18:00) and in winter $4$ (17:00-21:00).

The duration for each interval is $5$ minutes. At electricity demand charges are calculated based on the $5$ minutes moving average by the utility company, the battery bank is programmed to start discharging $15$ minutes prior to the on-peak rate period start time, and stop discharging $15$ minutes past the end time.

ii. Set control horizon $H$ and prediction horizon $M$, and fetch the prediction model for solar generation and building load $p$ and $P_l$ respectively.

Additionally, fetch the electricity price $p_{charge}$ and set $disRate=0.4$.

Conclusion

From Fig. 8 it can be observed that CT-MPC will use the entire battery capacity to the lowest allowed SOC level (20%) to maintain the constant demand threshold, while the ADT-MPC algorithm adds a threshold of higher value to maintain the battery status between 20% and 30%. The ADТ-MPC was designed to provide the lowest load demand resulting in lower battery SOC. The ADT-MPC algorithm maintains a higher SOC reserve capacity and is likely to be more responsive to changing demand rates and energy fluctuations. The CT-MPC-MP is within control with accurate forecasts, while the ADT-MPC algorithm excels when forecasting is more unpredictable. The ADT-MPC algorithm has a larger area of applicability to a higher variability system, when comprehensive historical energy generation or building load profiles are lacking.