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Modeling and optimal control of energy storage devices for a Lithium-ion battery-photovoltaic hybrid system

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The intermittent nature of many renewable power sources inhibits their implementation in the electric grid. [1] Consumers demand an uninterrupted power supply and the unpredictable nature of renewables means that only a portion of the electric grid's energy portfolio can come from these sources. However adding an energy storage device to renewable power sources can stabilize the source's intermittency.

A coupled system can supply a constant level of power to the grid (below the system's peak generation rating) by storing part of the energy created during peak generation hours and releasing that energy during periods of low or no power generation (see figure 1).

Our study utilizes a model of a photovoltaic solar cell coupled with a Lithium-ion battery. The system charges the battery anytime power generation exceeds the goal constant output and discharges the battery when the solar power output falls below the goal output. This protocol will control the system with the goal of generating the highest constant power output while still protecting the battery from degradation. Stabilizing the power source inevitably leads to sub-optimal charging and discharging patterns for the Li-ion battery and additionally can lead to intermittent cycling (small depth of discharge or small charging percentages). Our control strategy will seek to optimize both systems for single cycle and lifetime results.

The hybrid system will involve an electrochemical and transport based Li-ion battery model [2-5] and a 1-D continuum model of a p-n homojunction silicon solar cell [6-7] that were both validated independently. The two models are combined and solved as a single system with current, voltage, and power dependent on both systems. The hybrid system will utilize solar insolation data from various locations to understand real-world charging patterns.

We will investigate ideal system power outputs and find the most favorable battery capacity for individual systems. Lifetime studies of the Li-ion battery will be conducted by including capacity fade mechanisms within the battery model. Capacity fade can be largely determined through the charge-discharge pattern forced on the battery. In addition, we will look at scaling of the combined system to account for larger solar arrays and large battery stacks.

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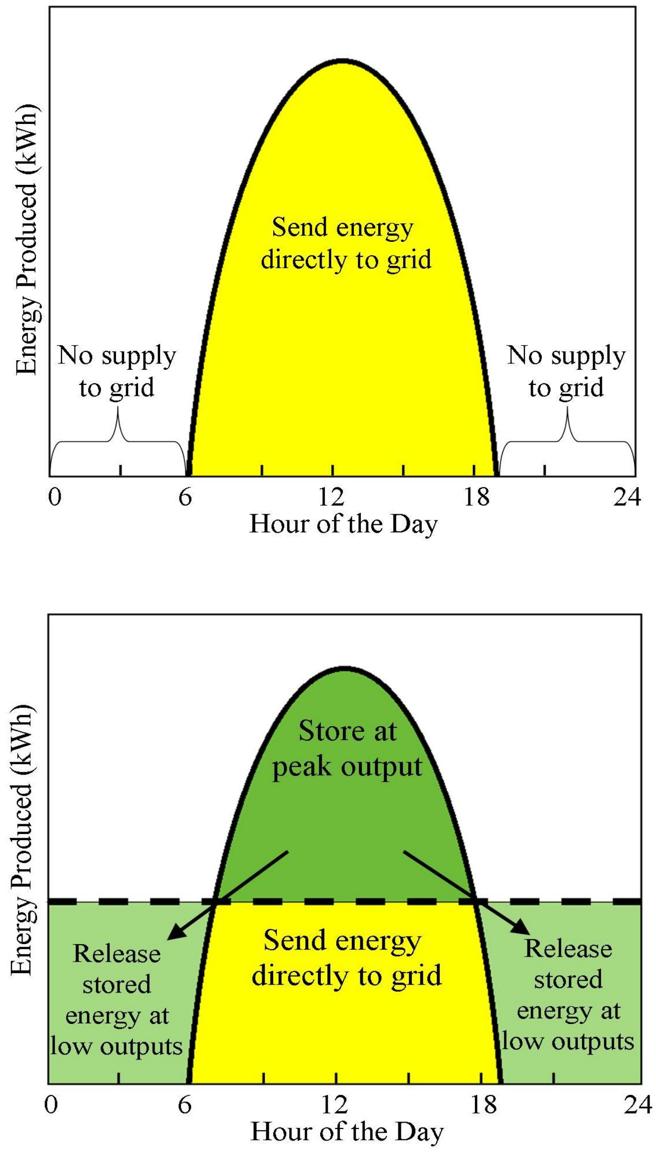

Figure 1: (Top) Without energy storage, generation is intermittent. (Bottom) With energy storage source become effectively a constant generator.

References

[1] Gopstein, A. M. Energy Storage & the Grid-From Characteristics to Impact. Proceedings of the IEEE Vol. 100 no.2: 311-316 (2012)
[2]Santhanagopan, S., et al. Review of models for predicting the cycling performance of lithium ion batteries. J. of Power Sources. 156:620-628 (2006)
[3] M. Doyle, et al. Modeling of Galvanostatic Charge and Discharge of the Lithium Polymer Insertion Cell. J. of the Electro. Society, vol. 140: 1526-1533, (1993)
[4] T. F. Fuller, et al. Simulation and optimization of the dual lithium ion insertion cell. Journal of the Electrochemical Society, vol. 141: 1 (1994)
[5] P. W. C. Northrop, et al., Coordinate Transformation, Orthogonal Collocation, Model Reformulation and Simulation of Electrochemical-Thermal Behavior of Lithium-Ion Battery Stacks Journal of the Electrochemical Society, vol. 158: A1461 (2011)
[6] Fonash, S. J. Solar Cell Device Physics (E-Version). Academic Press (Elsevier) Boston, MA. (2010)
[7] Basore, P.A. Numerical Modeling of textured Silicon Solar cells Using PC-1D. IEEE Transactions on Electron devices. Vol, 37 No. 2. (February 1990)