On-Campus Activities in Electric Power Systems

John Orr, Alex Emanuel
Tanek Zhang
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Undergraduate Power Program

- Student interest in power is growing rapidly
- ECE 3500, *Introduction to Contemporary Electric Power Systems*: 80 students in Spring, 2013 (Orr)
- ECE 3501, *Electrical Energy Conversion*: 38 students in Fall, 2013 (Emanuel)
- ECE 3503, *Power Electronics*: 53 students in Fall, 2013 (Emanuel)
Awards, Outreach

- 11 WPI recipients of the IEEE PES Scholarship Plus Initiative
- 7 student members of the National Grid Engineering Ambassadors Program
Graduate On-Campus Power Program

• At least 15 on-campus graduate students studying Power Systems
• ECE 523 *Power Electronics*: 28 students in Fall, 2013 (Thompson)
• Many on-campus students enrolled in CPE Power courses
• Substantial demand for thesis topics in power
Current Research Activities

• Energy Storage on the Distribution Grid; Alex Emanuel, John Orr; Sponsors: Premium Power, National Grid, US Dept. of Energy

• In Mechanical Engineering: Yan Wang received the 2013 Catalyst Award from the Massachusetts Clean Energy Center for his work on Flow Batteries

• In Chemical Engineering: Research on Fuel Cells and production of Hydrogen
The Economic Benefits of Battery Energy Storage System (BESS) in Electric Distribution System

Advisors: Prof. Alexander E. Emanuel, Prof. John A. Orr

Presented by: Tanek Zhang
September 25, 2013
Background: Electric Power System
Goal:
Evaluate BESS Economic Benefits

Scope: Three BESS Applications

• Energy Purchase Shifting
• Distribution Feeder Deferral
• Outage Avoidance
Application 1: Energy Purchase Shifting

Differential Cost of Energy\[\text{DCE} = K_{WD} - K_{WC} \ (\$)\]
Result: Energy Purchase Shifting

DCE vs. $W_{BCh}/W_T$, round trip efficiency $\eta_B$ as parameter. 24 hour Load Curve Type I, $P_{max}/S_L=0.70 \text{ W/VA}$, $P_{min}/S_L =0.60 \text{ W/VA}$, $P_{Bmax}/S_L=0.05 \text{ W/VA}$, $T_B = 5.0 \text{h}$, $S_L=10 \text{ MVA}$, $W_T = 160.8 \text{MW} \text{h}$, marginal cost curve C.
Application 2: Distribution Feeder Deferral

Load History with three BESS Installation.
Result: Distribution Feeder Deferral

NPV vs. ra\%, “l” is parameter. P_B=0.5 MW, T_B=6h. CL=3000 cycles, \eta_B=60\%. 
Application 3: Outage Avoidance

Annual Load Variation

Notice the Outages occur at end of June and beginning of July
Application 3: Outage Avoidance

Annual Load Variation

Notice the Outages occur at end of June and beginning of July
## Result: Outage Avoidance

### Avoided Outage Reparation Costs (Thursday)

<table>
<thead>
<tr>
<th>Feeder Type</th>
<th>Resid. 50% ($)</th>
<th>Small Com./Ind 25% ($)</th>
<th>Large Com./Ind. 25% ($)</th>
<th>DCE ($)</th>
<th>TOTAL ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional</td>
<td>28,353</td>
<td>479,036</td>
<td>173,053</td>
<td>3,000</td>
<td>683,442</td>
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<td>Smart I</td>
<td>227</td>
<td>3,832</td>
<td>1,384</td>
<td>3,000</td>
<td>8,443</td>
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<tr>
<td>Smart II</td>
<td>454</td>
<td>--</td>
<td>--</td>
<td>3,000</td>
<td>3,454</td>
</tr>
</tbody>
</table>
Conclusion

A BESS with high round-trip efficiency and long life span can be beneficial by combining three applications: energy purchase shifting, feeder installation deferral as well as outage avoidance.

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Power Flow Modeling Environment

• Goal: Develop and implement a user-friendly modeling environment to determine the electrical and economic performance of feeder-based energy storage systems with distributed generation

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Power Flow Modeling Environment

- Continuous calculation over time
  - Vs. conventional “snapshots”
- Electrical and economic calculations
- User input data for load/generation profiles and LMP
- User input settings for all other blocks
- BESS algorithm customizable

Feeder Components
Example Block User Settings

Function Block Parameters: Renewable Generation

- Renewable Generation (mask)
  A renewable source that makes use of a yearly or seasonal average data from historical generation data.

- Parameters
  - Connected
  - Renewable Type: Solar
  - Region: Northeast
  - Multiplier: 1
  - Season: Summer
  - PF Compensation

Function Block Parameters: Battery Storage

- Subsystem (mask)

- Parameters
  - Connected
  - Number of Units (Batteries): 1
  - Initial Charge of System (MWh): 0
  - Battery Efficiency per Unit (Round Trip in Decimal Form): 0.9
  - Battery Size per Battery (MWh): 2.5
  - Max. Rate per Battery (MW): 0.5
  - Max. Rate per Battery (MVAR): 0.5
  - LMP Charge Limit (Low): 38
  - LMP Discharge Limit (High): 53
Algorithm Application - Dynamic Programming

![Graphs showing LMP and Demand over 24 hours]

2 MWh
1.5 MWh
1 MWh
0.5 MWh
0 MWh

Rate of Change

Time (hrs)
Dynamic Programming Example

70% Efficiency
3MWh Capacity
$72 Savings
Renewable Energy Smoothing Example

Output from Solar

Output from BESS

Net Site Power

Battery Charge
Thank You!

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