A Decision Support Framework for Grid-Aware Electric Bus Charge Scheduling

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In collaboration with Philip Pugliese, Chattanooga Area Regional Transportation Authority
**Electric Bus Charge Scheduling**

**Motivation:** minimize energy cost of electric transit services while ensuring the extra power demand does **not overload the power grid**

**Problem:** schedule bus charging at chargers located along route

**Constraints:**
- EVs increase grid demand: avoid grid overloading and failures
- Energy prices fluctuate: avoid over-spending on energy

Must maintain level of service => avoid delays or running out of charge
Decision Support Framework

Simulation
Replicates the transit system to estimate the impact of potential charging schedules

Traffic Simulator
Models travel times and battery discharge under varying traffic conditions

- OpenStreetMaps
  - Roadway Network
  - Transit Schedules
- Simulation of Urban MOBility
  - Micro traffic simulator
  - Built in EV bus models

Grid Impact Model
Captures the impact charging actions have on the power grid

- Line losses
- Power phase balancing
- Etc.

Case study’s feeder network

Decision Agent
Evaluates potential charging schedules by estimating their long-term effects

Monte Carlo Tree Search
- Represents control process as game tree
- Asymmetrically grows tree, balancing exploration and exploitation
- Estimates values of actions using surrogate models
- Online algorithm; no training needed (unlike reinforcement learning). Adaptable to dynamic environments

Reward Function

\[ r_c = -e + \beta g - \varphi n_f \]

- energy costs ($e$)
- power grid impact ($g$)
- Number of failed buses ($n_f$)
- Tradeoff parameter ($\beta$)

State updates, Estimated rewards

Charging actions to evaluate

Experimental Setup

- 5 EV bus routes in Richland, WA
- 2 chargers placed at major bus stations
- Compared our framework to greedy policy: charge bus when it stops at a charger if SOC under prescribed threshold

Example of a route with two chargers

Results

Example of a route with two chargers

Effect of Reward-Tradeoff Parameter on Energy Cost

<table>
<thead>
<tr>
<th>Reward-Tradeoff Parameter ($\beta$)</th>
<th>Energy Costs per day ($) (lower is better)</th>
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<tr>
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<tr>
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<td>4</td>
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Effect of Reward-Tradeoff Parameter on Power Grid Score

<table>
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</tbody>
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Our Approach | Baseline
---|---
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Tradeoff parameter ($\beta$) allows customization to a particular city’s needs

Energy cost savings of up to 10% while decreasing power grid strain
Conclusions/Recommendations

• EV buses introduce power grid demand => charge scheduling must be grid-aware
• A decision support framework underpinned by traffic and power grid simulations is an effective and adaptive management system
• This exploratory analysis shows that such a framework can improve both grid impacts and energy costs to run a bus system for a midsized city
• It motivates continued work, including
  – Examining how to optimally place chargers along routes
  – Testing framework generalizability to other sized cities
  – Integrating with route scheduling
  – Possible extensions: paratransit, rideshare, delivery fleets

Next Steps: collaboration with Chattanooga city to integrate with route scheduling and paratransit services

*Images courtesy of the Chattanooga Area Regional Transportation Authority (CARTA)