Modeling and Simulation of NYC MTA Electric Bus

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Introduction

- MTA operates over 5,800 buses, which consume 46 million gallons of fuel annually

- MTA has incorporated hybrid-electric buses (Orion VII) into their fleet and have already benefited from a reduction in fuel consumption

- Some issues associated with hybrid buses: complexity, cost, often only marginal benefits compared to diesel powered buses

- This study aims to characterize the performance of an all-electric bus platform on a NYC route
Objectives

- Build vehicle and electric powertrain models
- Incorporate auxiliary systems models
- Simulate M42 route driving cycle
- Identify range and recharging needs
- Optimize bus and powertrain components for maximum range
Vehicle and Powertrain Model in GT-Suite

Vehicle, motor and braking controls

Powertrain

Environment
Vehicle Body Model

- Vehicle body includes:
  - Parts of drivetrain (driveshaft, differential)
  - Body
  - Axles
  - Wheels, tires
  - Brakes

- Communicates with powertrain, environment and control submodels
Brake Energy Recuperation Submodel

- Brake energy recuperation submodel includes control logic for recharging the battery under braking.

- Communicates with powertrain and brakes in body.
## Sample Simulation Inputs

<table>
<thead>
<tr>
<th>Part</th>
<th>Field</th>
<th>Attribute</th>
<th>Unit</th>
<th>Object Value</th>
<th>Justification</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Body</strong></td>
<td>Vehicle</td>
<td>Vehicle Mass</td>
<td>lbs</td>
<td>29730</td>
<td>Penn State – Orion VII</td>
</tr>
<tr>
<td></td>
<td>Aerodynamics</td>
<td>Drag Coefficient</td>
<td>-</td>
<td>0.6</td>
<td>Assumption</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Frontal Area</td>
<td>m²</td>
<td>10.4516</td>
<td>Orion VII – General Info</td>
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<tr>
<td></td>
<td>Axles/Geometry</td>
<td>Vehicle Wheelbase</td>
<td>m</td>
<td>7.264</td>
<td>Orion VII – General Info</td>
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<tr>
<td><strong>Differential</strong></td>
<td>Main</td>
<td>Final Drive Ratio</td>
<td>-</td>
<td>7.60</td>
<td>Gear Ratio Optimization</td>
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<tr>
<td></td>
<td>Main</td>
<td>Efficiency</td>
<td>-</td>
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<tr>
<td><strong>Tire</strong></td>
<td>Tire</td>
<td>Number of Tires on Front Axle</td>
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<td>Given</td>
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<tr>
<td></td>
<td></td>
<td>Number of Tires on Rear Axle</td>
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<td>Given</td>
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<tr>
<td></td>
<td></td>
<td>Rolling Resistance</td>
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<tr>
<td></td>
<td></td>
<td>Rolling Radius</td>
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<td>Orion 7 – General Info Goodyear – Bus Tires for Transit Application</td>
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<tr>
<td><strong>Auxiliary Load</strong></td>
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<td>AuxLoad</td>
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<tr>
<td><strong>Battery</strong></td>
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<td>Battery Temperature</td>
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<td>SAFT</td>
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<tr>
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<td>SOC Model</td>
<td>Battery Capacity</td>
<td>Ah</td>
<td>156</td>
<td>SAFT</td>
</tr>
<tr>
<td></td>
<td>SOC Model</td>
<td>Open Circuit Voltage Map</td>
<td>V</td>
<td>XYZ Map</td>
<td>SAFT</td>
</tr>
<tr>
<td><strong>Case Setup</strong></td>
<td>Main</td>
<td>Target</td>
<td>kph</td>
<td>MTA_M42</td>
<td>HVH410-150mm-DOM-625Vdc-425A-70C-20&amp;30LPM: Efficiency_Table</td>
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<tr>
<td></td>
<td>Main</td>
<td>Target Speed</td>
<td>kph</td>
<td>MTA_M42-1</td>
<td>HVH410-150mm-DOM-625Vdc-425A-70C-20&amp;30LPM: Efficiency_Table</td>
</tr>
<tr>
<td><strong>Motor</strong></td>
<td>Motor</td>
<td>Electromechanical Conversion Efficiency</td>
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<td>XYZ Map</td>
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<tr>
<td></td>
<td>Power Control</td>
<td>Maximum Brake Torque</td>
<td>N-m</td>
<td>EM1MaxTorqueCurve</td>
<td>HVH410-150mm-DOM-625Vdc-425A-70C-20&amp;30LPM: 1_S_Generating</td>
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</tr>
</tbody>
</table>
Electric Motor

- Electric motors supplied by Remy International
- Permanent magnet or induction
- 425 A max current
- 6000 rev/min max motor speed
- 300 kW peak power
- 1270 N-m peak torque
Batteries

- Battery stack supplied by SAFT
- Lithium iron phosphate cell (Li-FePO₄)

<table>
<thead>
<tr>
<th>Battery (kWh)</th>
<th>Low SOC (%)</th>
<th>SAFT (hours)</th>
<th>GT Simulation (hours)</th>
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<tbody>
<tr>
<td>99</td>
<td>8.9</td>
<td>4.283</td>
<td>4.094</td>
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<td>198</td>
<td>14.2</td>
<td>8.572</td>
<td>7.798</td>
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</table>
Vehicle Performance

- MTA requires that their buses can accelerate at 0.07g, or 0.687 m/s²

- Simulation can help us identify which gear ratios meet this requirement

- Minimize the battery depletion

- Maximize electric motor efficiency
Summary and Future Work

- Electric buses can be accurately modeled using GT-Suite and inputs from experimental measurements.

- Bus can operate for at least 2.5 hours without recharging (based on minimum battery capacity).
  - Results agree with SAFT’s preliminary calculations.

- Future work:
  - Improving the fidelity of auxiliary systems submodels:
    - HVAC system
    - Air compressor (e.g. kneeling, air brakes)
    - Steering Pump
  - Optimize powertrain configurations for different routes.
Thank you!