Autonomous fuel cell railway vehicles

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Contents

- Brief background on potential UK rail market of autonomous traction systems in future railways
- Overview of railway traction systems
- Fuel cell battery hybrid analysis – including control strategy
- Results
- Summary
Scope for novel forms of traction

- Total of about 2000 vehicles in UK are low/medium power diesel multiple units
- Pacers will be out of service by 2018 (ish) Other Diesel Multiple Units (150, 158 and 165) due to retire between 2020 and 2030
- Novel forms of traction may be applied to those routes where electrification is not cost effective, and are lightly used
- Small market
- Uncertain diesel fuel future
<table>
<thead>
<tr>
<th>Country</th>
<th>Non-electrified routes (1000 km)</th>
<th>Electrified routes (1000 km)</th>
<th>Total route (1000 km)</th>
<th>Electrified route (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Great Britain</td>
<td>11.50</td>
<td>5.20</td>
<td>16.70</td>
<td>31.1</td>
</tr>
<tr>
<td>Northern Ireland</td>
<td>0.30</td>
<td>—</td>
<td>0.30</td>
<td>—</td>
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<tr>
<td>Austria</td>
<td>2.20</td>
<td>3.44</td>
<td>5.64</td>
<td>61.0</td>
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<td>Belgium</td>
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<td>2.71</td>
<td>3.47</td>
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<td>Denmark</td>
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<td>Finland</td>
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<td>France</td>
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<td>Germany</td>
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<td>18.02</td>
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<td>Greece</td>
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<td>Irish Republic</td>
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<td>0.05</td>
<td>1.97</td>
<td>2.5</td>
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<td>10.63</td>
<td>16.11</td>
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<td>0.27</td>
<td>95.0</td>
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<td>0.90</td>
<td>2.81</td>
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<td>Spain</td>
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<td>12.32</td>
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<td>4.01</td>
<td>61.3</td>
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<td>Switzerland</td>
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<td>3.15</td>
<td>3.16</td>
<td>99.7</td>
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</table>
Typical railway applications for fuel cells

<table>
<thead>
<tr>
<th>Target powered equipment</th>
<th>Benefits</th>
<th>Requirements</th>
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</thead>
<tbody>
<tr>
<td>Auxiliary power units on DMUs</td>
<td>Reduction in noise and reduced emissions in confined boarding locations</td>
<td>20–30 kW of continuous power</td>
</tr>
<tr>
<td>Light rail and tram schemes</td>
<td>Possible reduction in infrastructure costs and improved aesthetics</td>
<td>100–200 kW of variable power</td>
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<tr>
<td>DMU for suburban services</td>
<td>Reduced noise and emissions and increased efficiency</td>
<td>200–500 kW of variable power and large energy storage devices for recoverable energy</td>
</tr>
</tbody>
</table>

- Also note stationary applications
  - UPS
  - Stations
  - Signalling systems
Options for alternative traction power

- Energy storage
  - On board – hybrids and EMUs
  - Wayside
- Other prime movers
  - Fuel cell
Options for energy storage 1

- Onboard storage
  - Diesel electric multiple units
  - Diesel multiple units
  - Locomotives
  - Shunting locomotives
  - Electric multiple units
Options for energy storage 2

- Wayside storage (fixed installations)
  - DC railways
    - Load levelling
    - Regeneration capture and reuse
  - AC railways – not such an important issue
Conventional DEMU

- Diesel engine
- G
- V<sub>DC</sub>
- Inverter
- Brake chopper
- Brake resistor bank
Hybrid DEMU

Diesel engine → G → V_{DC} → M

Inverter

DC/DC converter

Energy storage device
Fuel Cell Vehicle Modelling

- Snow Hill Line
- Stratford Upon Avon to Birmingham Moore Street (and back)
- Class 150 (two car)
- 374kW of power at wheels (max)
Measured vs Simulated Journey

- Blue line: Measured
- Green line: Simulated
- Red line: Line speed

**Axes:**
- Y-axis: Speed (m/s)
- X-axis: Displacement (m)
Hybrid Drivetrain Model
Supervisory Control Strategies

- **Load Levelling Control Strategy**
  - Primary power for propulsion is supplied by the fuel cell system.
  - Battery pack is used to supplement the peak power demand and absorb braking energy.

- **Trickle Charge Control Strategy**
  - Battery pack provides the primary power for the vehicle propulsion while absorbing the braking energy.
  - Fuel cell stack operates at its optimum efficiency point when the hybrid energy drive is accelerating, maintaining vehicle speed or stationary (e.g., idling at station).
  - When decelerating fuel cell stack is switched off.
Fuel cell train results (80km Journey)

- Pure fuel cell:
  - 38 kg Hydrogen

- Fuel cell hybrid:
  - 27 kg Hydrogen

- Pure diesel
  - 102 litres

- Hybrid diesel
  - 82 litres
Summary

- Energy storage and novel forms of traction (Fuel Cells) are being seriously considered for some parts of the railway – for traction, APU and Lineside.
- Much of the technology, skills and techniques already exist within the industry to deploy this technology.
- Prototype trials are expensive and are often quite expensive.
- Rail vehicles have a very long life – issue over replacing diesel stock in 2020 – 2030.
- Local emissions – a driver for change.
- Noise issues important too.