System Integration of China’s First Hydrail Locomotive

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the Eighth International Hydrail Conference
Ryerson University – Centre for Urban Energy, Toronto, Canada, 2013.06.11~12
Contents

I. Overview of SWJTU and NEEC
II. Opportunity for Hydrail
III. China’s First Hydrail Locomotive
IV. Future Work

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Contents

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II Opportunity for Hydrail
III China’s First Hydrail Locomotive
IV Future Work

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I. Overview of SWJTU and NEEC

- Founded in 1896, Southwest Jiaotong University (SWJTU) was originally named Imperial Chinese Railway College;

- SWJTU was born for rail transportation. So many China's FIRSTs in rail transportation were from SWJTU:
  - The first independently designed and constructed Beijing-Zhangjiakou Railway;
  - The first electrified railway ---- Baoji-Chengdu railway;
  - The first internal combustion locomotive;
  - The first electric locomotive;
  - The first manned superconducting trial maglev;
  - ....
  - The first fuel cell locomotive
I. Overview of SWJTU and NEEC

- NEEC - National Rail Transit Electrification and Automation Engineering Technique Research Center, was founded in 2009;

- The key role of NEEC is to bridge the newest research achievements in rail transit electrification and automation area to industry;

- There is a development center, an industrialization center and 6 companies in NEEC.
I. Overview of SWJTU and NEEC

- Main research platforms in NEEC:
  - High speed railway supervisory control and data acquisition system (SCADA)
  - High speed railway traction power substation automation system

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I. Overview of SWJTU and NEEC

- Main research platforms in NEEC:
  - High speed railway train operation simulation and driver training system
  - Co-phasal traction power supply system for electrified railway

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I. Overview of SWJTU and NEEC

- Main research platforms in NEEC:

  Fuel cell and hybrid power driving research
II. Opportunity of Hydrail

Air pollution

Car emission

Iceberg melted

Energy crisis, climate changing and environment protection call for clean energy
II. Opportunity of Hydrail

- Fuel cell rail vehicles vs fuel cell buses and cars:
  - Duty cycles of rail vehicles are far less flexible and better for fuel cell performance;
  - Hydrogen delivery infrastructures for fixed rail transportation lines are less;
  - Investment of rail transportation is huge enough to absorb high cost of fuel cell power systems;
  - Passenger carrying capacity is much greater and operation cost is lower.
II. Opportunity of Hydrail

• Application of fuel cells in hydrail includes switcher locos and rail transportation vehicles:

• Switcher locomotive:
  - Most of the switcher locos are powered by diesel engines, with low efficiency and high air pollution;
  - Advantages of fuel cell locos include clean, high efficiency and fuel economy;
  - Challenges include high power requirement, high cost and the market acceptance.
II. Opportunity of Hydrail

- Rail transportation vehicles:
  - Catenary of present rail transportation vehicles destroys modern city scenery greatly;
  - Catenary-free light rail vehicles (LRV) or trams based on fast charging develop fast these years;
  - Fuel cell powered LRV or trams will cut down investment of transportation line construction.
II. Opportunity of Hydrail

Construction investment comparison of a fuel cell LRV line and a catenary LRV line:

- 20km LRV line, with 40 LRVs in operation;
- Investment of catenary based traction power system exceeds $60 million*;
- According to present price, 300kW fuel cell system costs $1.5 million, cost of 40 LRVs increases $60 million;
- 3000Nm³/h methane reforming hydrogen production plant cost less than $6 million;
- Investment hydrail LRV line is near to that of catenary based LRV line, less than catenary-free LRV line.

* According to Chinese price with 1:6.5 exchange rate between USD and RMB
II. Opportunity of Hydrail

- Operation cost comparison of a fuel cell LRV line and a catenary LRV line:
  - Average power requirement of 40 LRVs in operation is about 5000 kW;
  - Electricity for rail traction is about ￥0.75 /kWh, operation cost for catenary LRV line is $577 /h;
  - Cost of hydrogen from methane steam reforming is ￥0.8~1.5/Nm³, take an average value, operation cost for a fuel cell LRV line is $553 /h;
  - Operation cost of a hydrail LRV line is also near to that of catenary based LRV line.
Contents

I Overview of SWJTU and NEEC

II Opportunity for Hydrail

III China’s First Hydrail Locomotive

IV Future Work
III. China’s First Hydrail Locomotive

China’s first fuel cell locomotive – “Blue Sky” developed by NEEC ran successfully on Jan 24, 2013.

<table>
<thead>
<tr>
<th>Factor</th>
<th>Value</th>
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<tbody>
<tr>
<td>Fuel cell type</td>
<td>PEMFC</td>
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<tr>
<td>Fuel cell power</td>
<td>150 kW</td>
</tr>
<tr>
<td>H₂ storage</td>
<td>High pressure</td>
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<tr>
<td>Pressure</td>
<td>35 MPa</td>
</tr>
<tr>
<td>H₂ weight</td>
<td>23 kg</td>
</tr>
<tr>
<td>Loco weight</td>
<td>45 tons</td>
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<tr>
<td>Transmission</td>
<td>DC-AC</td>
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<tr>
<td>Dimensions</td>
<td>13.5m × 2.6m × 3.6m</td>
</tr>
<tr>
<td>Design speed</td>
<td>65 km/h</td>
</tr>
</tbody>
</table>
III. China’s First Hydrail Locomotive

- The idea of developing China’s first fuel cell locomotive was initialized in 2007;
- Financing of the hydrail loco development is totally raised by NEEC;
- The investment ratio is as following.

Hardware investment

- Loco body: 48.6%
- Hydrogen vessels: 16.7%
- HD-6 system: 25.7%
- Balance of plant: 9%

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Fuel cell system schematics

III. China’s First Hydrail Locomotive

Hydrogen Delivery Subsystem

Air Delivery Subsystem

Cooling Subsystem

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III. China’s First Hydrail Locomotive

- Partners of the locomotive development

Loco bodywork development

Fuel cell system integration with SWJTU

Provide 150kW HD-6 fuel cell

Provide 35MPa H₂ storage system

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III. China’s First Hydrail Locomotive

Fuel cell system

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III. China’s First Hydrail Locomotive

Fuel cell system

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System layout of the hydrail locomotive

III. China’s First Hydrail Locomotive

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III. China’s First Hydrail Locomotive

System layout of the hydrail locomotive
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II  Opportunity for Hydrail

III  China’s First Hydrail Locomotive

IV  Future Work
IV. Future Work

- Unsolved problems:
  - Surge behavior of the turbo air compressor under low rotation speed;
  - Heat management optimization;
  - Power control to meet the real-time requirement;
  - System components and layout optimization;
  - Noise control.
IV. Future Work

Future work:

- Step I: Solve the problems of the present prototype locomotive and optimize layout and control design;
- Step II: Conduct fuel cell / battery hybrid power traction reconstruction on the prototype locomotive;
- Step III: Design and construct an hybrid LRV and conduct real operation tests;
- Step IV: Industrialize fuel cell hybrid LRV.
We would like to cooperate with industries and academia for research and development in:

- Lower cost and longer life time fuel cell technologies;
- Higher capacities hydrogen storages technologies;
- System integration technologies.
Thank you for your attention!

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