Decarbonizing Railway Operations and Prime Movers

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Outline of Presentation

– Environmental Impact of Diesel Prime Movers
– Emissions Reduction Record of Canadian Railways
  • Locomotive Emissions Monitoring Data
  • Emissions Reduction Tactics: - Current and Foreseen
– Railway Electrification – Overhead Catenary & Third-Rail
– Application Studies of Carbon-free Hydrogen Fuel Cell – Battery Powering for:
  • Self-propelled Heavy-Rail Commuter Railcars
  • Industrial Switcher Locomotive
  • Mainline Heavy-Rail Commuter Train Locomotive
– Plus: Highlight the 10-year € 50 million contract awarded to Hydrogenics by Alstom France for 200 HFCs for hydrogen-fuelled FCEMU Commuter Railcars to be deployed in Germany
Environmental Impact of Diesel Prime Movers as Railway Motive Power *

- **Canadian Railway Motive Power Fleet:**
  - Mainline Freight Locomotives - 2,000 }
  - Yard, Road Switching Locos - 840 }
  - Passenger Locomotives - 230 } **Total: 3,070**

- **Annual Diesel Fuel Consumption (litres):**
  - Freight operations - 1.9 billion }
  - Passenger (VIA + Commuter) 100 million } **Total: 2 billion**

- **Annual Diesel Exhaust Emissions (tonnes):**
  - Greenhouse Gases - 6.0 million
  - NOx, HC, CO, PM, SOx - 102 thousand

* Source – Railway Association of Canada ‘Locomotive Emissions Monitoring Program - 2013’
Railway Fuel Efficiency

- Newest locomotives can haul one tonne of freight 200 km on one litre of fuel,
- GHG emissions intensity (kg of CO$_2$/1000 revenue tonne-km) reduced by 39.5% since 1990,
- Train fuel efficiency 5 times that of trucks,
- Strategically, moving freight by rail instead of by truck lowers GHG emissions by 75%.
Emissions Reduction Tactics in Current Railway Operations

- Crew Education and Awareness
- Locomotive and Car Equipment Initiatives
- Emerging Technologies
- Operational Related Initiatives
- Infrastructure Related Initiatives
- Government Programs for Research and Development
Railway Electrification Options (to avoid fossil fuel emissions)

- **Overhead Catenary Energized from Grid:**
  - Conventional Technological Arrangement for Mainline Freight (ex BC Rail), Heavy Rail Commuter (AMT Montreal) and Light Rail Commuter Systems (LRT in Calgary, Edmonton, Kitchener, Ottawa)

- **Third Rail Energized from Grid:**
  - Vancouver Skytrain, Montreal Metro, Toronto Subway

- **Disruptive Technologies:**
  - Inductive Power Transfer / Battery Storage (Grid Energized)
  - Hydrogen Fuel Cell / Buffer Battery Modules (H₂ gas fuelled)
Hydrogen Fuel Cells (HFC) with Battery Buffers as Railway Prime Movers

• Permit Electrification of Railcars **avoiding:**
  – Polluting Emissions, Noise and Vibration
  – Expensive Overhead Catenary Infrastructure
  – Track Access Operating Limitations
  – Mechanical Complexity of Diesel Power Pack
  – Continuous Idling when Train Stopped
  – Use of Carbon-based Fossil Fuels.

• Permit capture, storage and regeneration of braking energy inherent in frequent stop-and-go commuter train operations.
Hydrogen Fuel Cells (HFC) with Battery Buffers as Railway Prime Movers (cont’d)

• **Avoid draw on peak-hour grid load** by using otherwise wasted electrical energy generated during off-peak hours to produce hydrogen gas (by electrolysis of water), which is then compressed and stored for delivery to railcar.

• **Site-specific application studies** needed to determine comparative overall $/kW-hr of a hydrogen energy infrastructure vs. conventional catenary electrical system.
Railway Hydrogen Fuelling System Chain

- Hydrogen Gas Cylinders
- Fuel Cell Power Modules + Power Conversion Component
- Braking Energy Regeneration Equipment

HySTAT Electrolyser

Wind, PV, Hydro or Nuclear Electricity

GHG Free H₂ Gas
5 D’s of the Innovation Cycle for New Transportation Technology*

**DEFINITION**

> **DESIGN**

> **DEVELOPMENT**

> **DEMONSTRATION**

> **DEPLOYMENT**

plus need **Determination, Defending, Dollars**

* Modus operandi of TELLIGENCE Group
Definition Study of HFC *UP Express* Toronto’s Union Station – Pearson Airport Shuttle
Hydrogenics Fuel Cell Power Module Proposed for Electric UP Express

HyPM™ HD 180

198 kW

Dimensions L x W x H: 1582 x 1085 x 690
Mass: < 720 kg
Volume: < 1122 L
Hydrogenics HD 180 HFC Performance Data
Tier 4 Diesel-powered *UP Express* deployed in time for 2015 Pan-Am Games
Post Pan-American Games *UP Express*: DMU to EMU Conversion

**Step 1: DMU Tier 4 Diesel Parts Removal**
**Step 2: Retrofit Electrical Parts for EMU Version**

**Question:** Catenary or Hydrogen Fuel Cell Powering?
Definition Study of Powering TractivePower Industrial Switcher Locomotive as HFC (TP56 Diesel Unit No.1 Assembled in Squamish, B.C.)
TP56 Body is Half of a Scrapped SD40-2 Freight Locomotive
TP56 Shunting Hopper Cars at Grain Elevator, Cloverdale, B.C.
# Hybrid HFC – Battery Buffer Options for TractivePower TP56 Industrial Switcher

## Hybrid-1

<table>
<thead>
<tr>
<th>ID</th>
<th>Device Name</th>
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</thead>
<tbody>
<tr>
<td>A</td>
<td>Fuel Cell 90kW</td>
</tr>
<tr>
<td>B</td>
<td>DC-DC Booster (400-600V) + Battery (24KWh/75Ah/150Cells)</td>
</tr>
<tr>
<td>C</td>
<td>Cooling (120kW Heat Removal)</td>
</tr>
<tr>
<td>D</td>
<td>H2 Tank (W205 QTY=12 x5kg)</td>
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</tbody>
</table>

*Booster, 300-400V, 100-75A, 30kW Rating
**Kokam XALT 53Ah, 1x String 105 Cells

## Hybrid-2

<table>
<thead>
<tr>
<th>ID</th>
<th>Device Name</th>
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</thead>
<tbody>
<tr>
<td>A</td>
<td>Fuel Cell 30kW+DCDC*+Battery**</td>
</tr>
<tr>
<td>B</td>
<td>Cooling (40kW Heat Removal)</td>
</tr>
<tr>
<td>C</td>
<td>Fuel Cell 30kW+DCDC*+Battery**</td>
</tr>
<tr>
<td>D</td>
<td>Cooling (40kW Heat Removal)</td>
</tr>
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<td>E</td>
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*Booster, 300-400V, 100-75A, 30kW Rating
**Kokam XALT 53Ah, 1x String 105 Cells
2014-09-24 Alstom to develop a new emission-free passenger trains in Germany

- LOI to purchase 40 fuel cell-powered regional trains signed by 4 German States
- Commercial service on regional lines in Germany by 2020
- Train Platform: Alstom Coradia LINT
- Powertrain to combine hydrogen fuel cells, batteries and energy storage systems to replace diesel powerpack
- Equivalent performance to electric multiple-units
- Two prototype trains to be in operation by the end of 2018 for revenue service trials
2014-11-12: Fuel cell drives to replace diesel railcars – National Innovation Programme hits the rails

- 7.9 million euros, the Federal Ministry for Transport and Digital Infrastructure (BMVI) is supporting the development of a new generation of rail vehicles with fuel cell drives from the company Alstom.
- Alternative to conventional diesel railcars, being regionally deployed for services on non-electrified lines.
- Development and manufacture at Alstom’s competence centre for regional trains in Salzgitter, Germany.
- First prototypes are to go into test service operation by the end of 2016.
- Trains with fuel cell drives will then go into regular passenger service in four German states:
  - Lower Saxony
  - North Rhine-Westphalia
  - Baden-Württemberg
  - Hesse (Rhine-Main Region)
2015-05-27: Hydrogenics and Alstom Transport Sign Agreement to Develop and Commercialize Hydrogen-Powered Commuter Trains in Europe

- Hydrogenics selected by Alstom following rigorous technical review process
- Valued at over €50 million, including the supply of at least 200 engine systems along with service and maintenance support over a 10 year period
- Fuel cell systems based on Hydrogenics Heavy-Duty HD series fuel cell power modules
- First units to be delivered to Alstom Salzgitter, Germany in 2016 following prototype work in 2015
Fuel Cell Electric Multiple Units announced by NRW for 2018

10 FCEMU (ALSTOM CORADIA LINT) to be operated in Ruhr area plus 30 in three other regions in Germany

Technical data (first design values):
- 540 kW propulsion power
- 2 x 200 kW fuel cell power
- \( H_2 \) : 2 x 90 kg @ 350 bar
- Battery: 2 x 120 kWh
- 600 km range

Total hydrogen demand of NRW fleet: 2,000 kg/day

Feasibility Study on \( H_2 \) refueling station initiated
HFC Powering Study of Heavy Rail Commuter Locomotive

- Hydrogen Storage
- Heat Removal Unit
- Power Buffer Storage
- Drive and Controller
- Fuel Cell
- Drive and Controller
Speed Profile of GO Transit Burlington – Toronto – Oshawa Commuter Line

- 18 Station Stops; 101.5 km; 1 hour 37 minutes
Candidate HFC Powered Demonstration: Commuter Coach-Yard Shunter based on TractivePower TP56 Industrial Switcher
Candidate for HFC Commuter Demo:
Using Former GO Transit EMD F59PH
Grateful for Suggestions of Candidate Railway HFC Powering Applications

Thank you

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