An Evaluation Study of Current and Future Fuel Cell Hybrid Electric Vehicles Powertrains

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Outline

• Introduction

• Fuel Cell Hybrid Powertrains

• Power Control Strategies and Comparative Study

• Conclusions
**Introduction**

**Fuel Cell Electric Vehicles (FCEVs)**

**>> Advantages**
1. Zero Emissions
2. High efficiency
3. Low Noise

**>> Disadvantages**
1. Low dynamic response (during starting & transient)
2. High cost and size
3. No ability to recover the braking energy

**Hybridization with High Power or/and High Energy**
FCHEV Powertrains

1. FCEV
2. FC/BS HEV
3. FC/SC HEV
4. PFCHEV
FCHEV Powertrains

Commercial Vehicle: Honda FCX Clarity Fuel Cell Electric Vehicle (FCEV)

http://automobiles.honda.com/fcx-clarity/
Advantages:
- High Efficiency
- High Reliability
- Low current/voltage ripples
- Small size
Power Control Strategies

- Control Strategy Based on Efficiency Map (CSEM)
- Control Strategy Based on PSO (CSPSO)

**PSO: Particle Swarm Optimization Algorithm**
Control Strategy Based on Efficiency Map (CSEM)

- $\text{SoC}_{\text{ESS}}(k) < \text{SoC}_{\text{init}}$, FC is operated at its point of maximum efficiency (called “On” point)

- $\text{SoC}_{\text{ESS}}(k) > \text{SoC}_{\text{init}}$, FC is turned off (called “Off” point)
Control Strategy Based on PSO (CSPSO)

\[ k_{fc}(t) = \frac{P_{fc}(t)}{P_{req}(t)} \]

\[ P_{fc,\text{opti}}(k) = k_{fc}(k) \cdot P_{req}(k) + k_{SOC}(k)(P_{fc,\text{max}} - P_{fc,\text{min}}) \left( \frac{SoC_{\text{ref}} - SoC(k)}{(SoC_{\text{max}} - SoC_{\text{min}})^2} \right) \]

\[ F(x) = \frac{1}{E_{\text{low,H2}}} \sum_{k=0}^{N} \frac{P_{fc,\text{opti}}(k)}{\eta(P_{fc,\text{opti}}(k))} \Delta T \]
Simulation Results & Comparative Study

Power sharing between sources

![Graph showing power sharing between sources](image)
Power sharing between sources

Simulation Results & Comparative Study

Battery SoC
Comparison of the total cost of the electric sources based driving cycles

- **FC/B HEV**
- **FC/SC HEV**
- **FC/B/SC HEV**

<table>
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<th>NEDC</th>
<th>FTP75</th>
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Comparison of the total mass of the electric sources based driving cycles

- FC/B HEV
- FC/SC HEV
- FC/B/SC HEV

Mass (kg)

NEDC

- 254.3
- 302.6

FTP75

- 249.4
- 297.8

Simulation Results & Comparative Study
Comparison of the total volume of the electric sources based driving cycles
Simulation Results & Comparative Study

The hydrogen improvement after using CSEM

![Graph showing the hydrogen improvement for FC/B HEV, FC/SC HEV, and FC/B/SC HEV under NEDC and FTP75 conditions.](image)
Simulation Results & Comparative Study

The hydrogen improvement after using CSPSO

- NEDC
  - FC/B HEV: 14.3%
  - FC/SC HEV: 19.2%
  - FC/B/SC HEV: 17.1%

- FTP75
  - FC/B HEV: 13.6%
  - FC/SC HEV: 20.8%
  - FC/B/SC HEV: 16.4%
Conclusions

• This paper has presented an evaluated study of different FCHEV powertrains from the point of view of the fuel economy, cost, mass and volume.

• FC/SC HEV has slightly higher fuel economy than the FC/B HEV and FC/B/SC HEV powertrains.

• FC/B HEV is smaller than the FC/SC HEV and FC/B/SC HEV powertrains.

• FC/B/SC HEV can improve the life cycle (LC) of the battery.
Thank you for your attention