«EMR & inversion-based control of a multi-stack Fuel cell system»

Prof. Loïc Boulon, Khalid Ettihir, Neigel Marx, Prof. Daniel Hissel
Université du Québec à Trois-Rivières
Hydrogen Research Institute
1. Introduction
   • Why FC system?

2. EMR of FC system
   • Representation
   • Experimental Validation

3. Multi-FC system
   • Why Multi-FC system?
   • Energy management & simulation results
   • EMR of a Multi-FC system
   • Experimental results

4. On-line identification for energy management
   • Why On-line identification
   • Experimental results
   • Integration into the EMR of the Multi-FC system
Introduction
For vehicular application
+ No local emission / Fast Refueling
- Cost & durability

Modeling & Simulation for
✓ Architecture design
✓ Energy management
✓ System performances
« EMR of a FC system »
• EMR of the FC stack (ancillaries are summarized into the source elements)

• Dynamics are highlighted

• Control input are on the source elements

• Strong interactions: a FC stack cannot be seen as a cartesian system
Inputs: measured values are imposed to the model
• Current steps
• Air flow variation
• (Constant H\textsubscript{2} flow)

Outputs: simulated values are compared to measurements
• H\textsubscript{2} input pressure
• Air input pressure
« Multi-FC system »
Several fuel cells for:

- Energetic performance improvement
- Faulty mode operation
- Modular design (scale cost reduction)

This work is focused on power sharing in order to increase the energetic efficiency.
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- Power Distribution -
Equi-distribution = same shape than 1 stack

- Optimisation-based is always the best distribution

- Daisy chain is not very relevant

- Main improvements are realized at low power (up to 10-15%)

- Moreover, the Operating Range (OR) is increased (FC are generally not used between $P=0$ and $P=P_{\text{max}}/3$)

Simulation results

- Efficiency vs Power curves

- Equi-distribution

- Optimisation based

- Daisy Chain
- EMR of a multi Fuel Cell System -

EMR provides requested current and distribution criterion from:
- SoC
- Powertrain requested power
- ...

FC EMR could be reduced to a simple multiphysics converter due to study assumptions.

Distribution criteria is given by a look-up table obtained with the optimization algorithm.
Experimental results are highly dependant of:

- The driving cycle
- The FCS sizing
- The vehicular energy management (power split between the FCS and the battery pack)

<table>
<thead>
<tr>
<th>Distribution Method</th>
<th>Consumption (kJ)</th>
<th>Relative value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equi-distribution</td>
<td>590.8 kJ</td>
<td>100 %</td>
</tr>
<tr>
<td>Optimal distribution</td>
<td>501.6 kJ</td>
<td>84.90 %</td>
</tr>
</tbody>
</table>
« On-line identification of FC system for global energy management »
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- Good operation point seeking -

Multiphysics behavior & ageing are difficult to model

but

Many energy management are model based…
The identified model fits with experimental results.

3 modules EM organisation

Experimental results show the method relevance.
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- Vectorial representation -

- to save space & to reach a more syntetic scheme: **vectorial representation**

- Just a representation: **No new assumptions**
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- Vectorial representation-

Energy Management is a complicated block…
Conclusion
EMR is useful in order to organize several works in same way

- Fuel Cell modeling
- Power sharing between the 4 fuel cell systems
- Best operating point tracking

How to organize the Energy Management block?
3 levels with strong interactions (the performances of each FCS should impact the vehicular energy management):

- Fuel Cell System (ancillaries)
- Multi Fuel Cell System (power sharing)
- Vehicular (power split)
« BIOGRAPHIES AND REFERENCES »
Prof. Loïc Boulon
Université du Québec à Trois-Rivières, Canada
Hydrogen Research Institute
PhD in Electrical Engineering at Univ. of Franche-Comté (2009)
Research topics: Energy Storage Subsystems, Fuel Cell Systems, Operation of vehicles in cold winter conditions


Loïc BOULON, Marie-Cécile PERA, Philippe DELARUE, Alain BOUSCAYROL, Daniel HISSEL, "Causal fuel cell system model suitable for transportation simulation applications", ASME Fuel Cell Science and Technology, Vol. 7, Iss. 1, 2010


« Appendix: new EMR pictograms »
No equation number in slides

borders of power elements = b pt

power vectors
(size b, full arrows)

signal vectors
(size b/2, empty arrows)
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- Control pictograms -

(same pictograms – same size - with or without oblique bar)

borders of control elements = b/2 pt

signal vectors (size b/2, empty arrows)

(support square a x a)
Source

borders of estimation elements = \( \frac{b}{2} \) pt

signal vectors
(size \( \frac{b}{2} \), empty arrows)
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- Example -