«EMR of a Partial Power Converter for Fuel Cell Vehicle»

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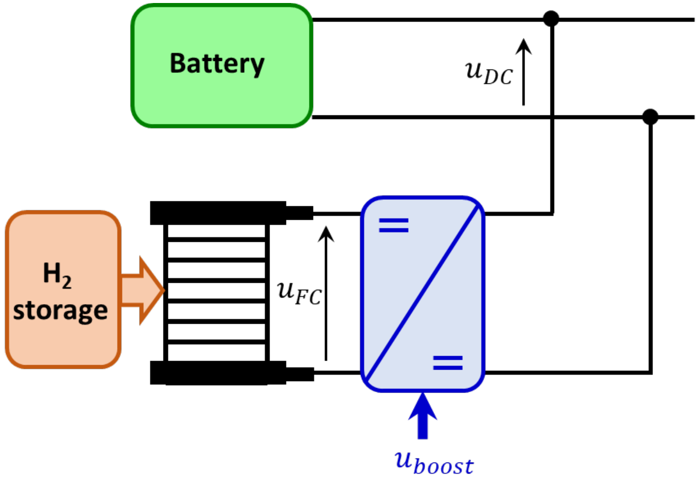
Based on A. Desreveaux et al. « EMR of a partial-power converter based FCEV » *IEEE-VPPC'24*, 2024

«Introduction»

Fuel Cell Electric Vehicle topology



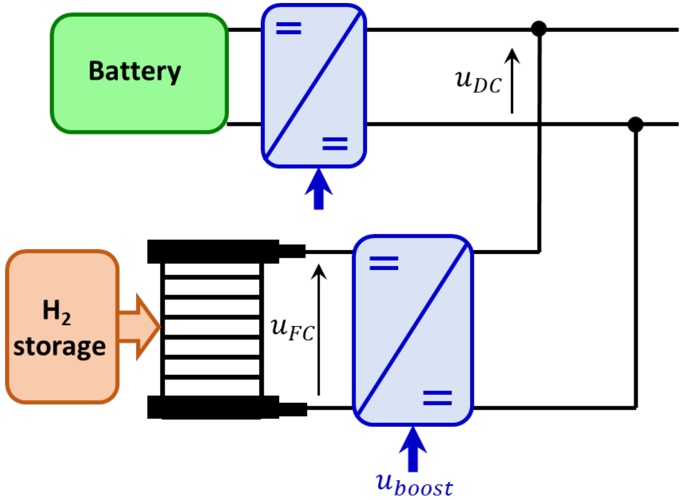
Semi-active topology

Currently in Stellantis or Renault FCEV...

The DC bus is maintained by the battery

Generally used in range extender/Plug-in

Peugeot FCEV



Full active topology

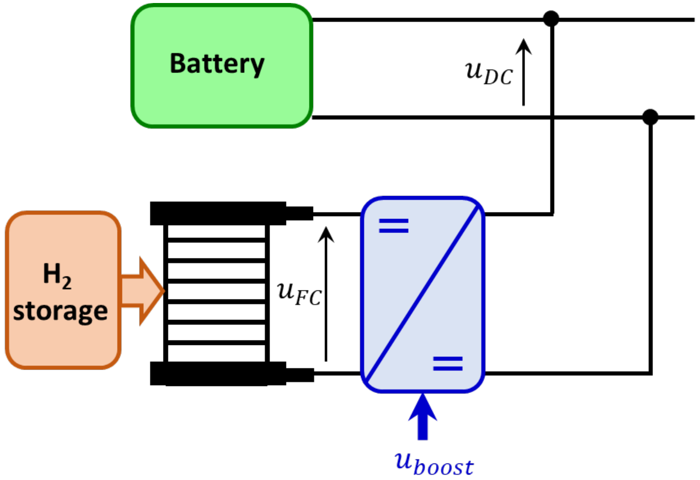
Currently in Toyota Mirai and Hyundai Nexo...

Independence of the DC bus and energy sources

High power Fuel cell

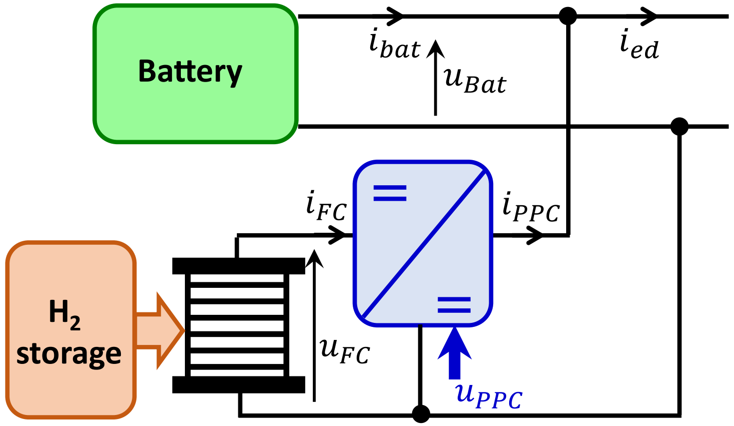
Toyota Mirai

New converter for semi-active topology



Boost converter

New topology



Partial power converter (PP converter)

Commonly used in FCEV application

FC voltage < DC bus (battery) voltage

High current in the converter → losses, ripples

New converter family (comes from PV systems, NASA) [Button 1996] [Agamy 2014]

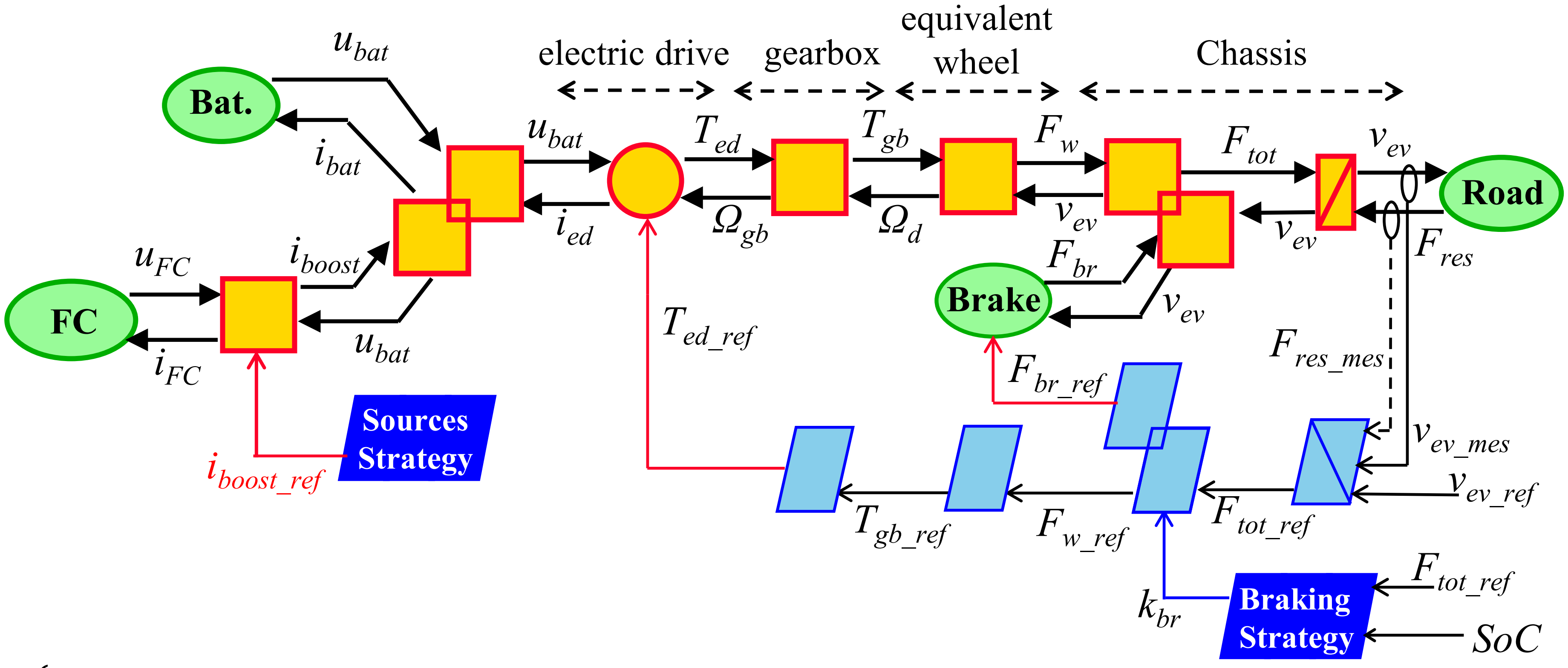
Reduction of the converter size
→ Expected losses and ripples reduction

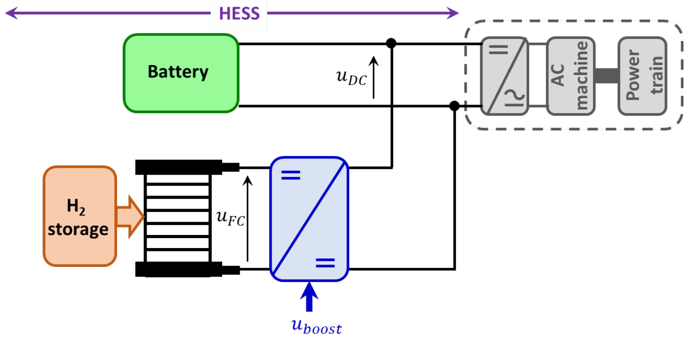
Objective : Evaluate the interest of this converter for an FCEV application

→ Comparison of the two semi-active topologies

«2. Energetic Macroscopic Representation of FCEVs»

EMR of the boost converter based FCEV





$$\begin{cases} i_{boost} = i_{boost\_ref} \\ i_{FC} = \dfrac{i_{boost} u_{bat}}{u_{FC}} \end{cases}$$

$$i_{bat} = i_{ed} - i_{boost}$$

$$\begin{cases} T_{gb} = k_{gb} T_{ed} \\ \Omega_{gb} = k_{gb} \Omega_{wh} \end{cases}$$

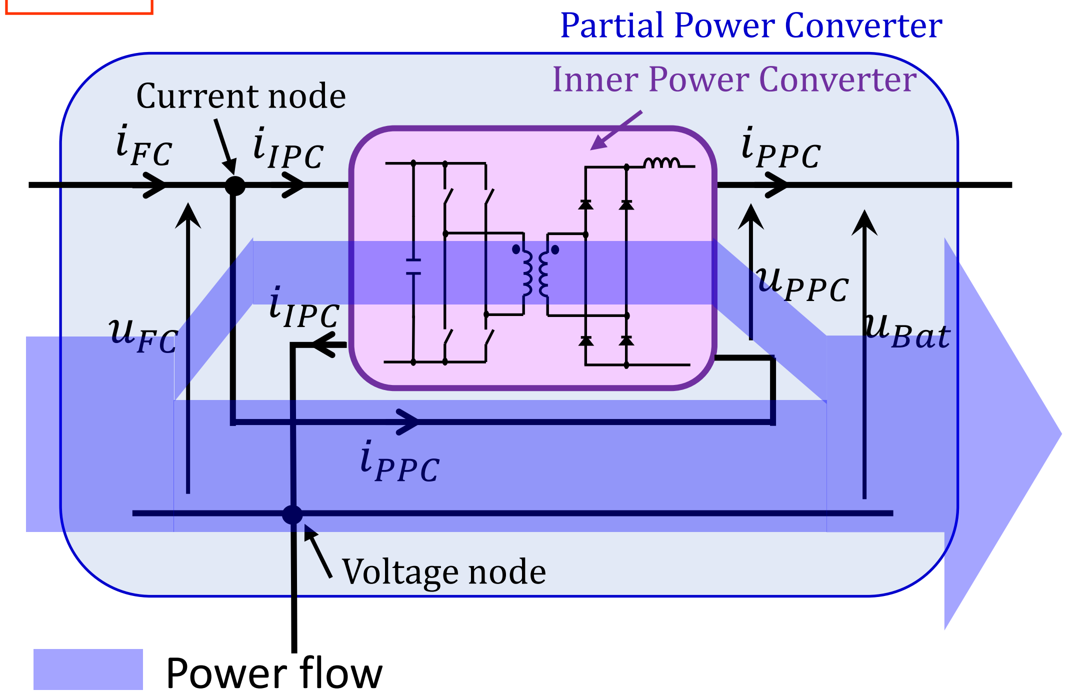
$$\begin{cases} F_{wh} = {}^{1}/_{R_{wh}} T_{gb} \\ \Omega_{wh} = {}^{1}/_{R_{wh}} v_{ev} \end{cases}$$

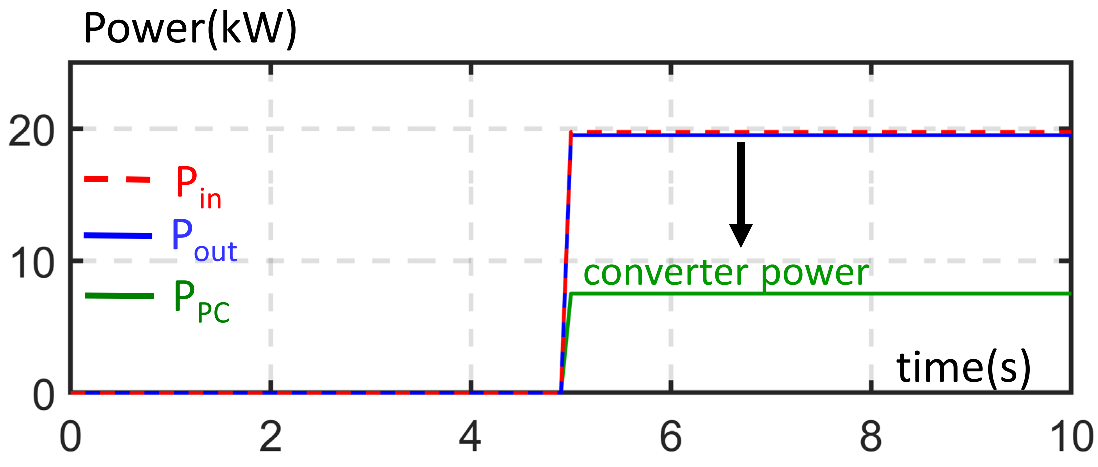
$$F_{tot} = F_{wh} + F_{br}$$

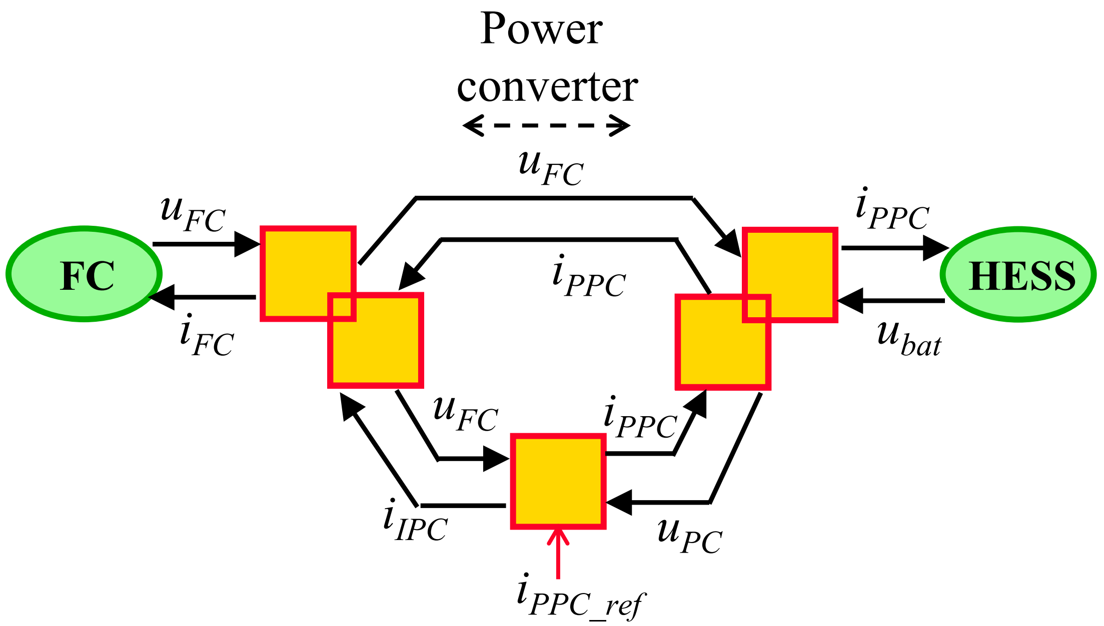
$$v_{ev} = \frac{1}{M} \int (F_{tot} - F_{res}) dt$$

$$F_{res} = F_{roll} + F_{aero} + F_{slope}$$

EMR of a partial power converter





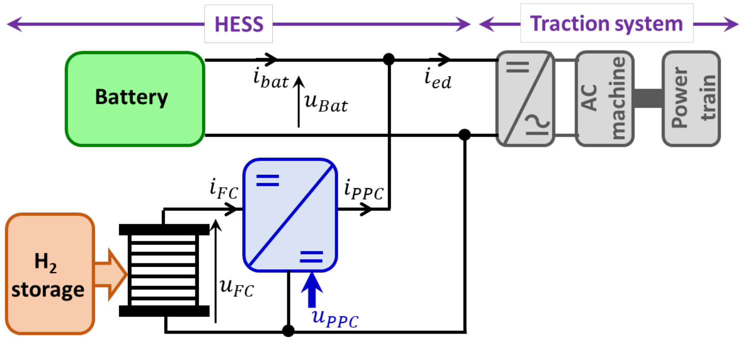


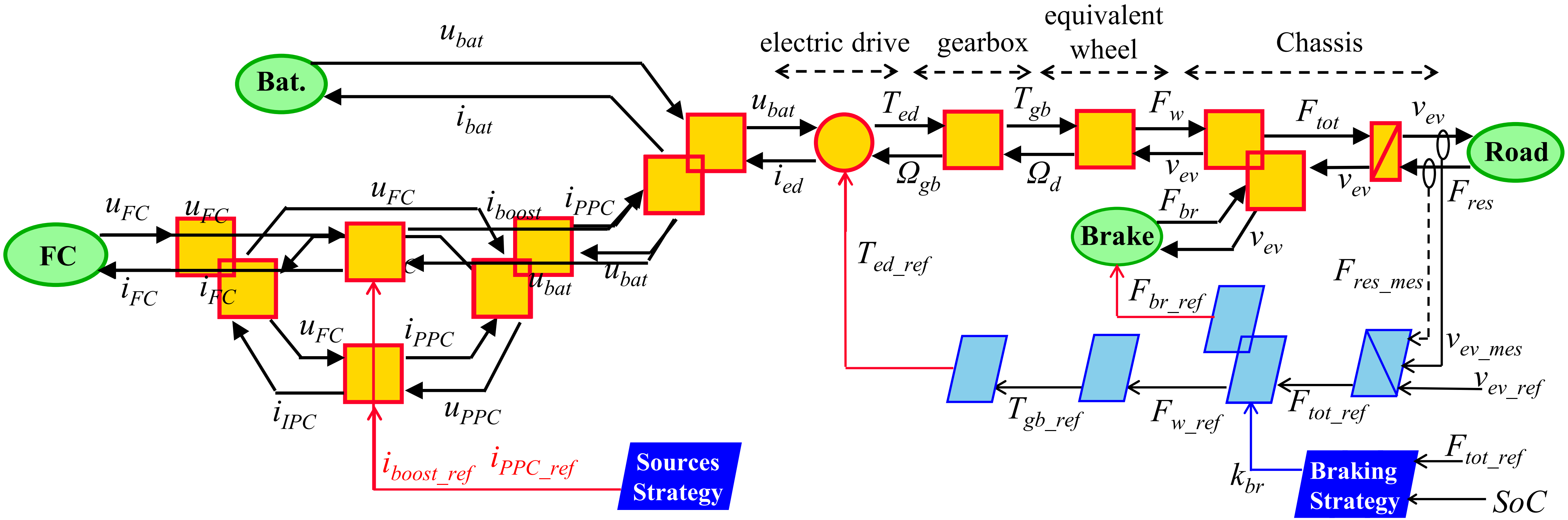
$$i_{FC} = i_{PPC} + i_{IPC}$$

$$\begin{cases} i_{PPC} = i_{PPC\_ref} \\ i_{FC} = \dfrac{i_{PPC} u_{PC}}{u_{FC} \eta_{PC}} \end{cases}$$

$$u_{bat} = u_{FC} + u_{PC}$$

EMR of a Partial Power Converter for Fuel Cell Vehicle





«3. Comparison of semi-active topologies for FCEVs»

EMR of a Partial Power Converter for Fuel Cell Vehicle

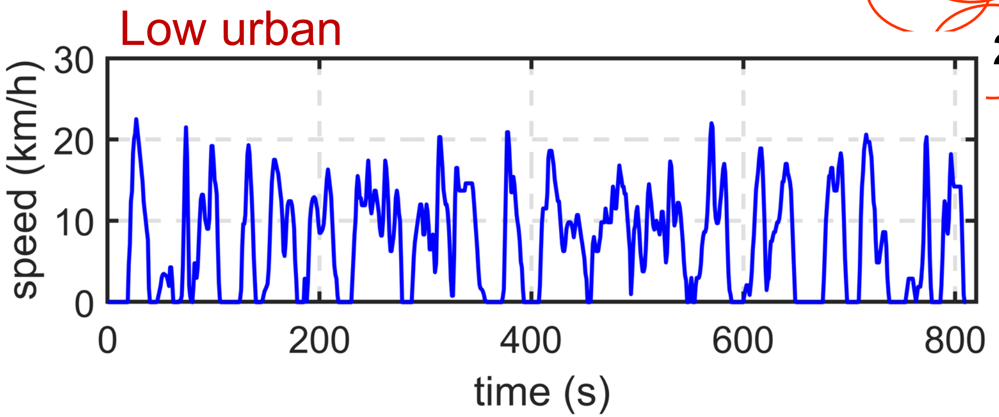
Create a range-extender fuel cell vehicle based on the Peugeot 208 (not real application)

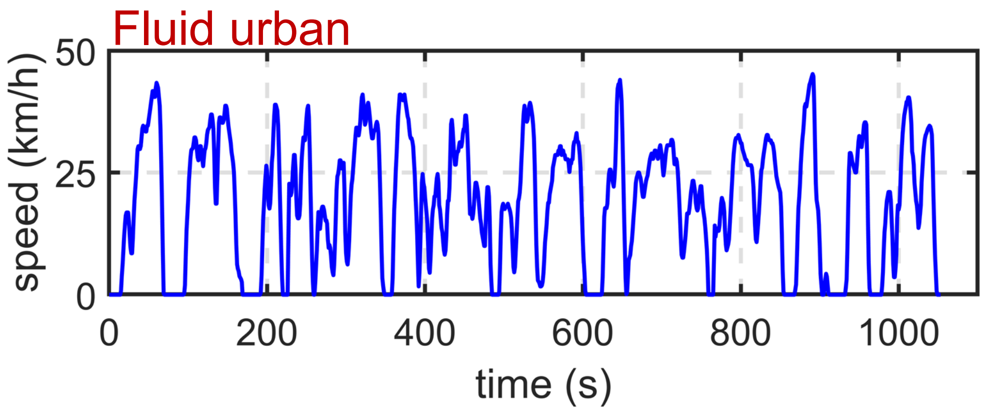
Characteristics	
Battery	Li-ion NMC 50 kWh
Electric Machine	100 kW
Weight	1600 kg
Autonomy (WLTC)	340 km
Fuel cell (not existing in the real vehicle)	35 kW – 300 cells

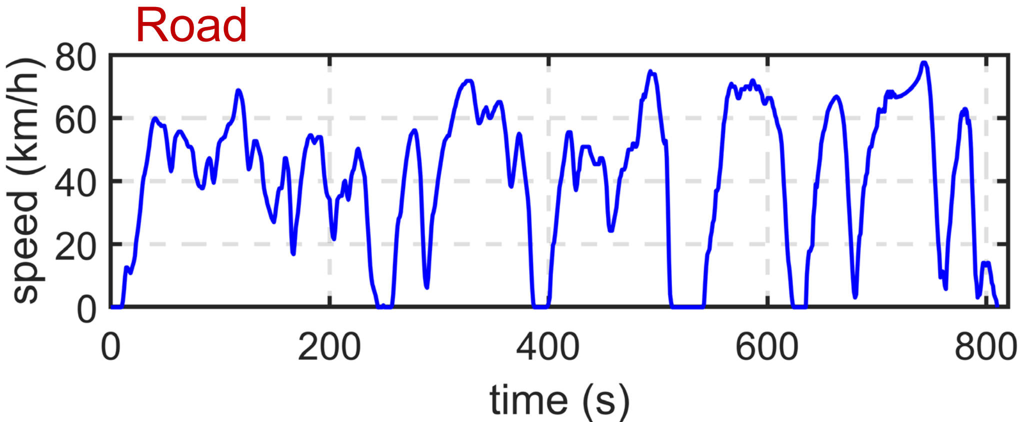
10 driving cycles: from low urban driving conditions to highway

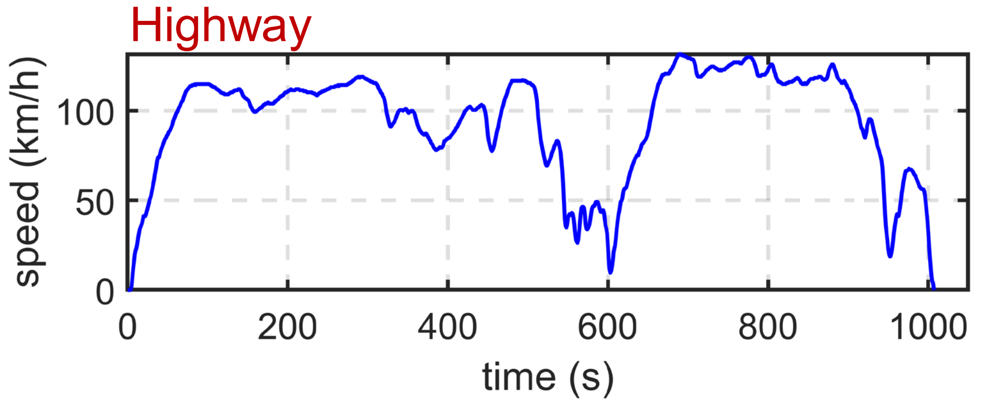
We choose 4 different driving cycles :

- Low urban
- Fluid urban
- Road
- Highway









Fair comparison between the two converters:

Energy Management for the two simulations:

same low-pass filtering strategy

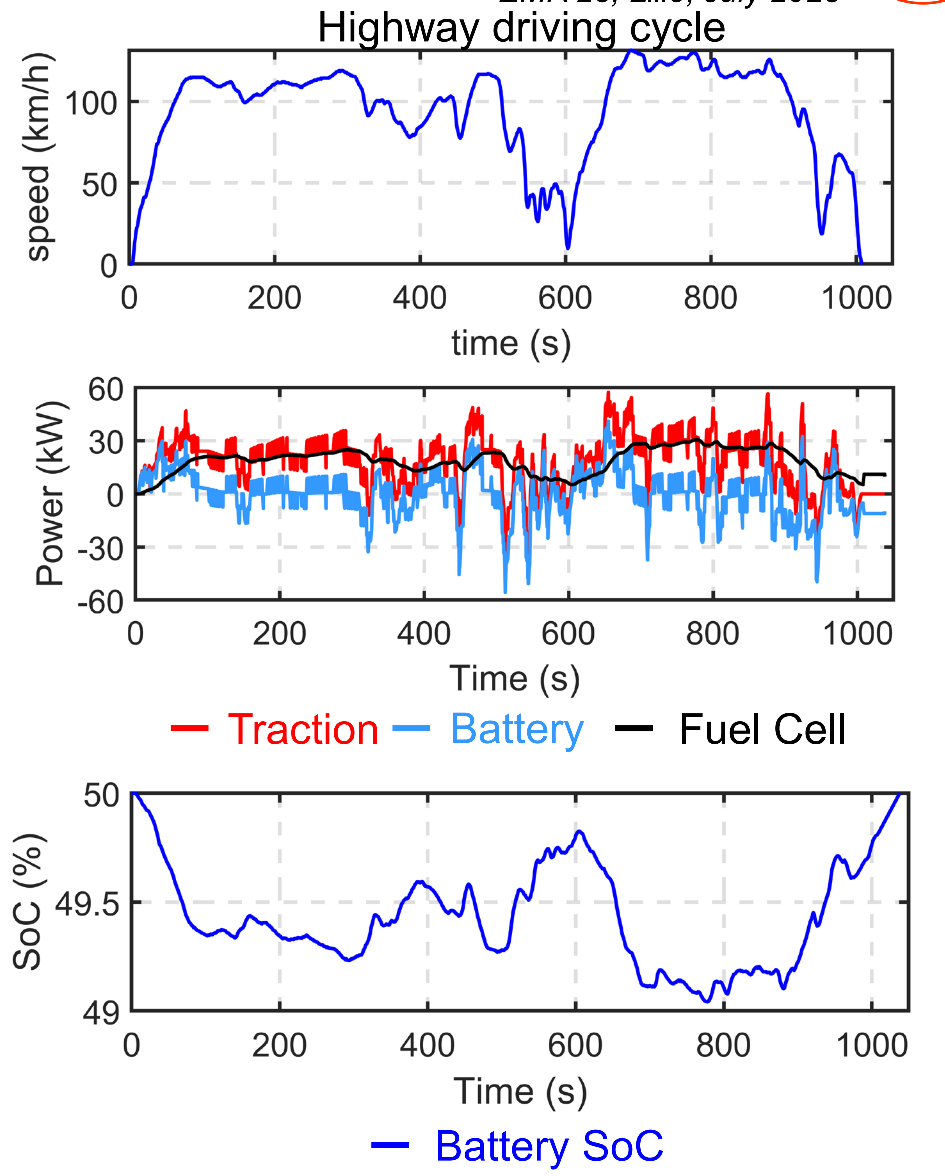
Battery State of Charge: start at 50 % and end at 50 %
→ Charging the battery at the fuel cell maximum efficiency at the end of the cycle

First hypothesis on converters:

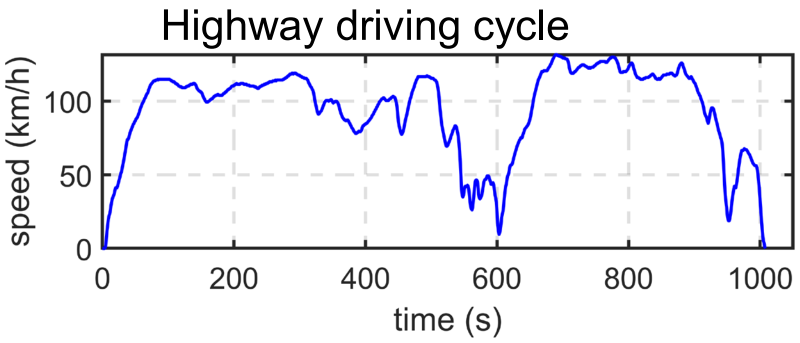
comparison with a static efficiency

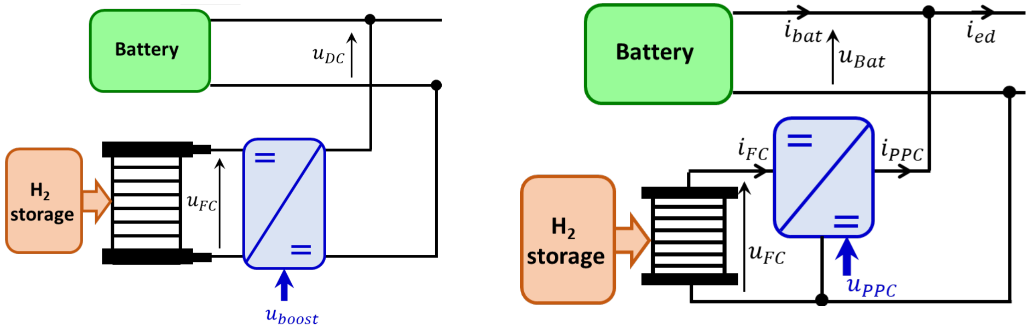
PPC converter efficiency: 95 %

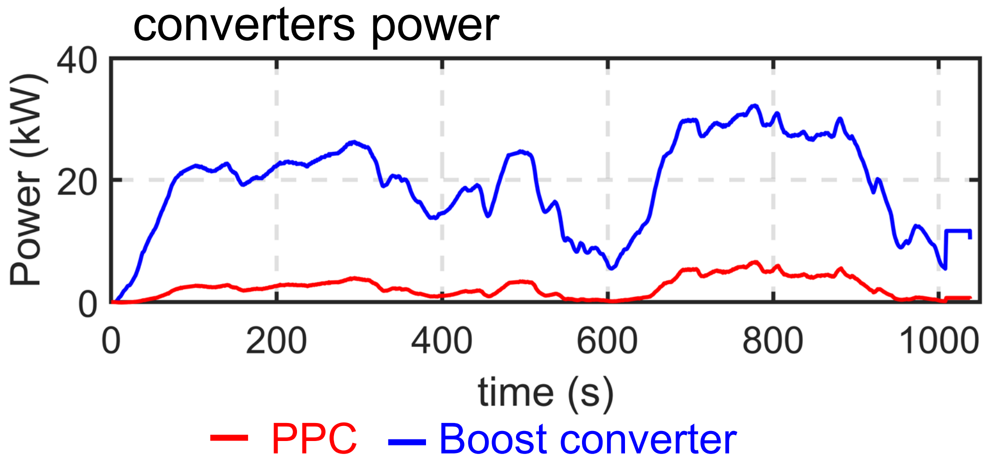
Boost converter efficiency: 95 %

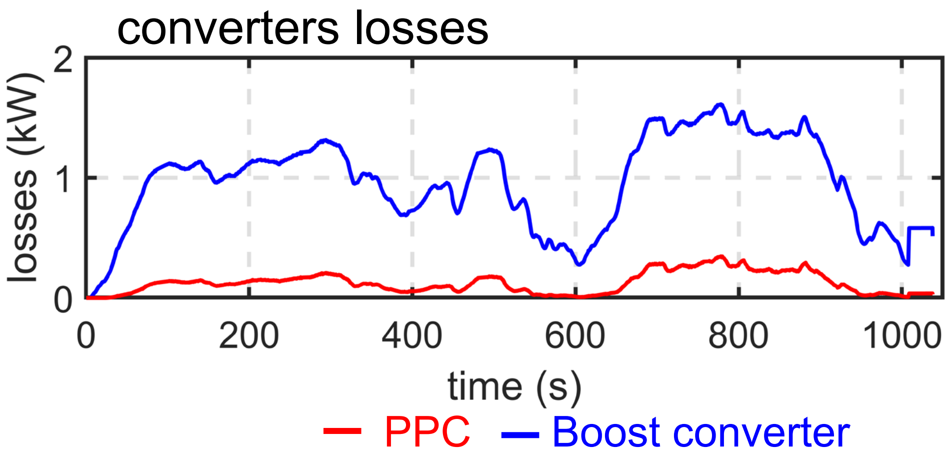


Detailed result for highway driving cycle









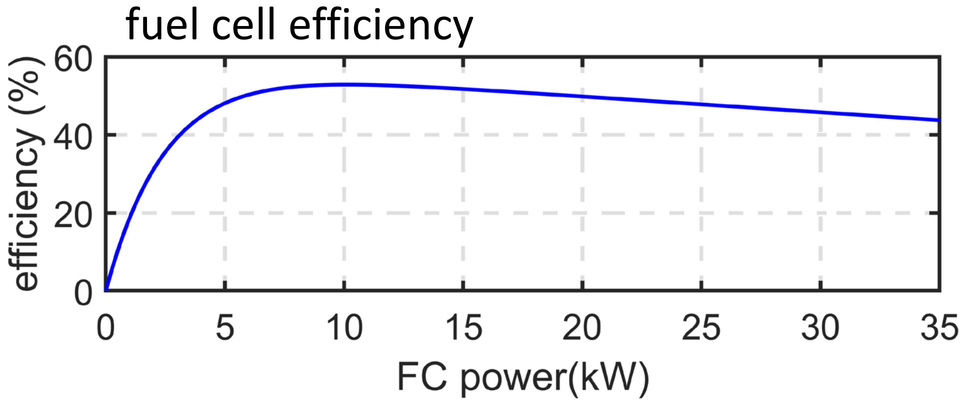
PPC convert less power than boost converter

PPC have less losses than boost converter

Results for different driving cycles

Less power in PPC → less power provided by fuel cell

Fuel cell efficiency depends on its power



Fuel cell energy consumption (kWh)

	Low Urban	**Free Urban**	**Road**	**Highway**
Boost converter	1.199	2.109	2.820	11.45
PPC	1.188	2.067	2.727	10.97
Difference (%)	0.92	1.95	3.29	4.19

For all driving cycles, PPC has a better efficiency

Variation in differences due to fuel cell efficiency

Conclusions:

Introduction of PPC for FC application in vehicles

EMR use to realize a fair comparison with boost converter

First results using Inrets driving cycles shows improvement in energy consumption for the FCEV

Perspectives:

- Better losses comparison by considering converters wide operating range
- PPC current is reduced → current ripple may decrease; fuel cell lifespan should be better?
- Limited temperature rise in PPC → expected reduction in the cooling system.

« Biographies and references »

- First Authors -

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Thanks for your attention !