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Electronic Converters for the Fuel Cell Applications in Vehicle Driveline

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Introduction

- An alternative source of electrical energy has to be introduced!
- This could be hydrogen by the use of Fuel Cells

Electric vs. ICE vehicles

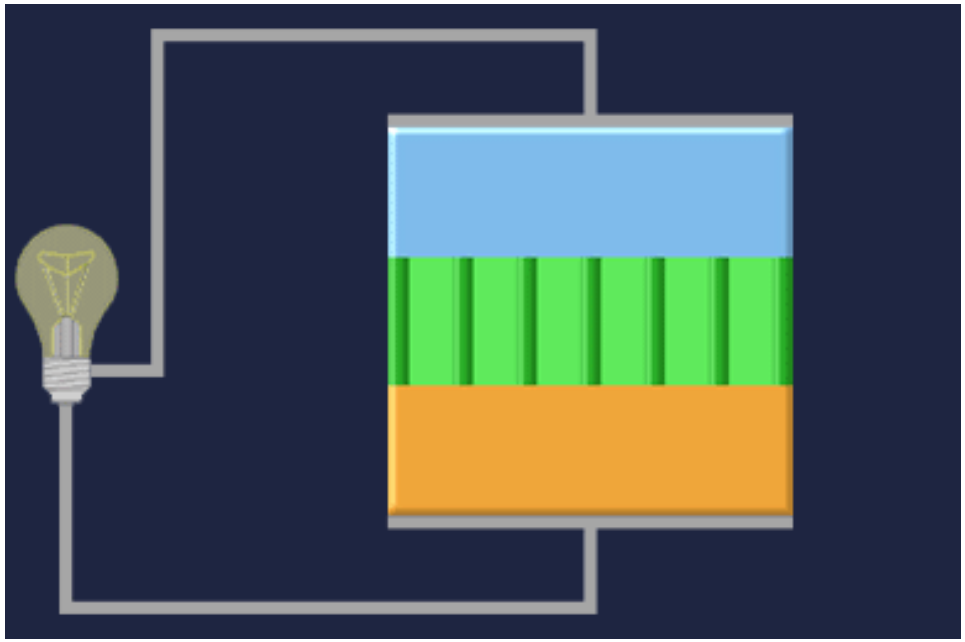
- Improved efficiency
  - ICE to wheels - around 15-20% on reference cycle
  - EV - battery to wheels - around 80% on reference cycle
- Reduced pollution
  - EV – no CO_2 emission.
- Main problem (key obstacle) - problem of electrical energy storage.

Problems of electrical energy storage

- Specific energy:
  - best currently available batteries (Li-ion) - not higher than 120-150 Wh/kg
  - gasoline - 11.8 kWh/kg
  - diesel - 13.3-13.7 kWh/kg
- Time of charging is long.
- Battery lifetime is still not long enough.

PEM (Proton Exchange Membrane) fuel cell

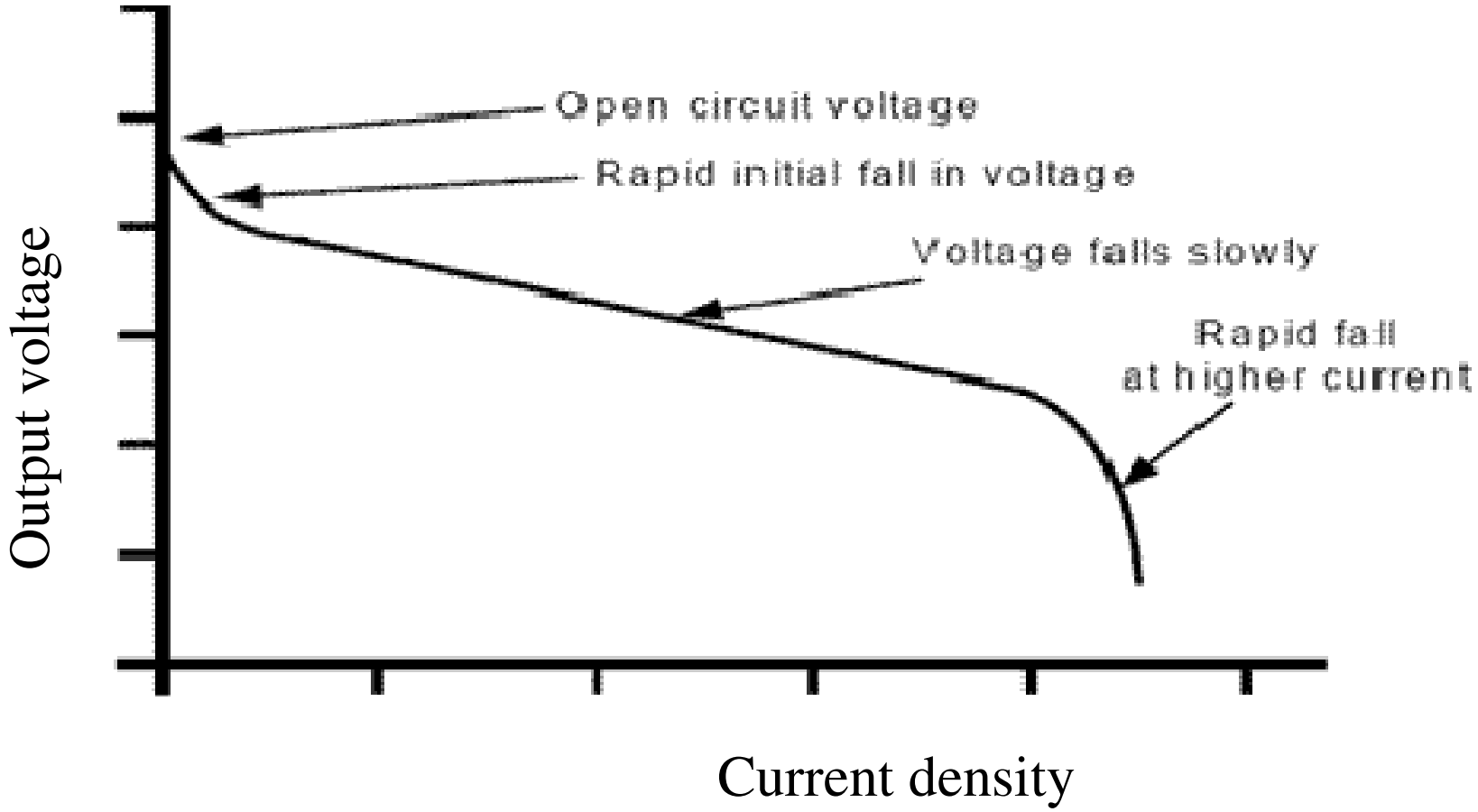
- Electrochemical device
- Uses Hydrogen as fuel
- Operates at low temperature
- High power density
- High modularity
- Used in:
  - mobile applications and
  - small-scale power generation



Fuel cell - problems

- Problems of a fuel cell power system without energy storage are:
  - fuel cells do not have electrical storage capability;
  - dynamics is slower without a battery;
  - output voltage fluctuates with loads.

PEM Fuel Cell - Voltage



HySYS Project

- HySYS Vehicles
- FC hybrid vehicle power architectures
- Electric motor control

HySYS - goals

- Goals:
  - Improvement of fuel cell system components for market readiness;
  - Improvement of electric drive train components (Synergies FC and ICE-hybrids) for market readiness;
  - Optimization of system architecture for low energy consumption, high performance, high durability and reliability;
  - Optimization of energy management;
  - Development of low cost components for mass production;
  - Validation of component and system performance on FC vehicles.
- Improved FC-system and e-drive components could be mass-produced and delivered by the suppliers to the automotive industry, providing competitive FC vehicles.
- The results of HySYS will be one step further towards the hydrogen economy and also a basis for future European research activities

HySYS (EU FP6)

- **Hybrid fuel cell vehicle**
- Companies:
  - CRF (Fiat, I), DC (D), PSA (F), Renault (F), VW (D), Volvo (S)
- Institutes:
  - AVL (AT) , TNO (NL), CNM (E), ENEA (I)
- OEMs:
  - Bosch (D), Continental Temic (D), Fischer (SME/D), Fumatech (D), Magna Steyr (AT), MicroChemical (SME/CH), Rivoira (I), Saft (F), Selin Sistemi (I), ATB (AT)
- Universities:
  - RWTH Aachen (ika + vka), EPFL (CH), University of Montpellier (F), University of Maribor (SLO), Fachhochschule Esslingen (D)
- Countries:
  - AT, CH, D, E, F, I, NL, S, SLO

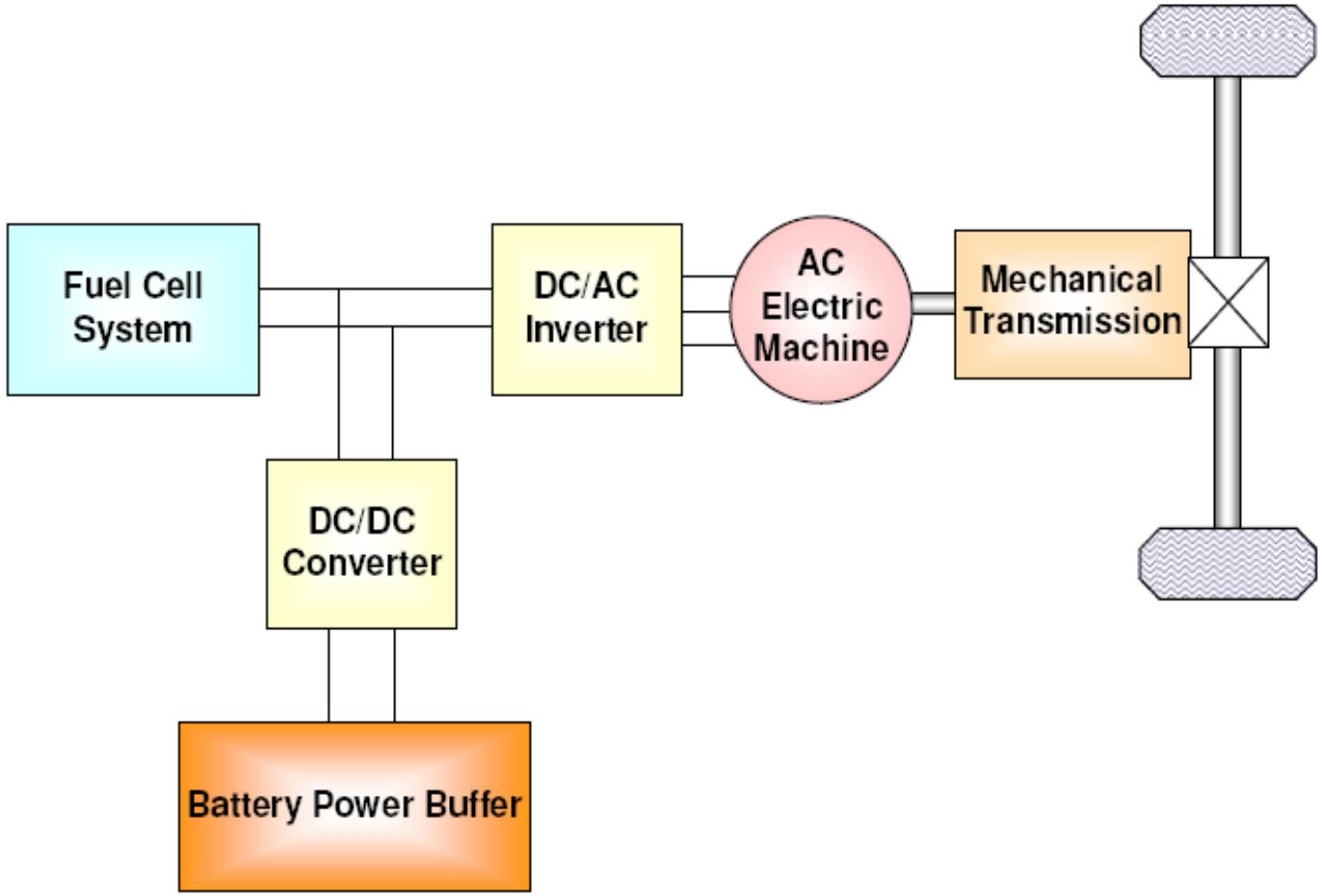
HySYS Vehicles

- Two evaluation vehicles will be designed by:
  - Daimler Chrysler (DC) and
  - PSA Peugeot Citroen (PSA).
- Testing under operation conditions.
- Same maximal velocity and range.
- Installed power is different.
- DC vehicle:
  - high power fuel cell as the main energy source.
- PSA vehicle has
  - high power battery,
  - low power fuel cell as a range extender.
- Components are the same in order to reduce the development and manufacturing costs.

FC hybrid vehicle power architectures

- Architecture with:
  - Battery sided DC/DC converter
  - FC sided DC/DC converter
- Advantages and disadvantages

Architecture with Battery sided DC/DC converter



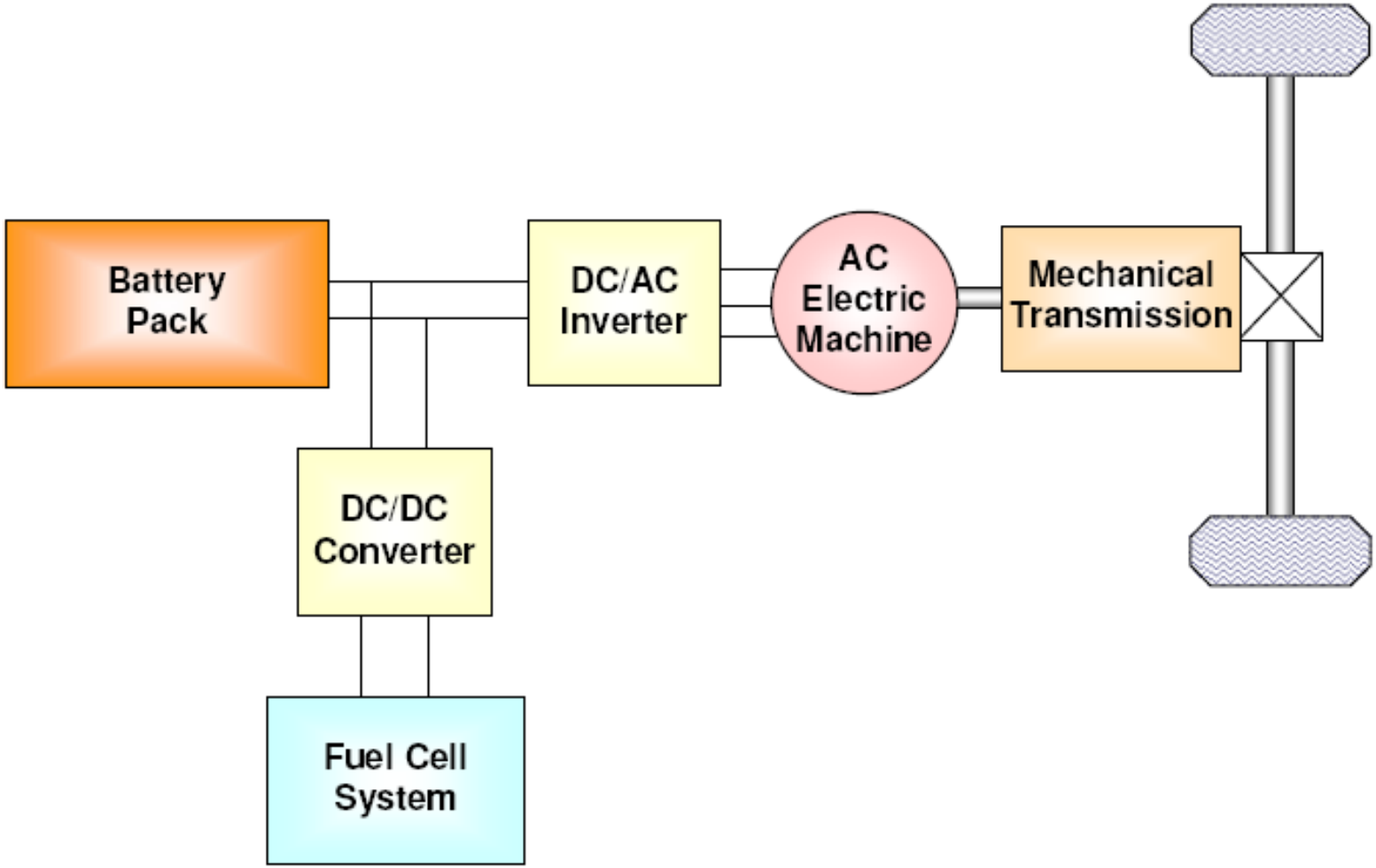
Architecture with Battery sided DC/DC converter

- Primary source of electric energy: **Fuel cell**
- Supporting power buffer: **battery** (applied in the transient conditions).
- Bidirectional:
  - DC/AC converter for the electric machine and
  - DC/DC converter for the battery power buffer.

Architecture with Battery sided DC/DC converter

- Advantages:
  - DC/DC converter for the fuel cell system is not required,
  - increased power efficiency.
- Disadvantages:
  - Voltage of the fuel cell is not conditioned by a power converter
  - voltage on the DC/AC inverter DC-link is changing in a relatively wide range

Architecture with FC sided DC/DC converter



Architecture with FC sided DC/DC converter

- Low number of cells in the fuel cell stack:
  - voltage can be increased by the use of boost converter, thereby reducing the current
- Unidirectional:
  - Fuel Cell DC/DC converter.
- Bidirectional:
  - DC/AC converter for the electric machine .

Architecture with FC sided DC/DC converter

- Advantages:
  - Battery does not require a designated power converter.
  - Low production costs.
- Disadvantages:
  - Less practical for the power conditioning,
  - Convenient for the limited performance vehicles.

Electric motor control

- Interior permanent magnet synchronous motor (IPMSM)
- Non-linear system
- Effects, which complicate the model:
  - saturation,
  - cross saturation,
  - cogging torque, and
  - presence of higher harmonics in the rotor flux

Electric motor control – Torque ripple

- Torque ripple is an important issue.
- Fixed speed transmissions (without the use of conventional gearbox clutch)!
- drivability problems due to the presence of low frequency harmonics at low speed should be avoided.
- Maximal torque has to be obtained with the minimal stator current – use of **reluctance torque**.
- Hill-holding operation of vehicle is an important issue.

Conclusions

- Demands for the:
  - driving comfort,
  - precision and
  - reliability.
- More complex systems:
  - power architecture with battery and fuel cell sided converters should be used
    - can satisfy the power conditioning and transfer requirements.
    - a relatively constant DC voltage.

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