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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**

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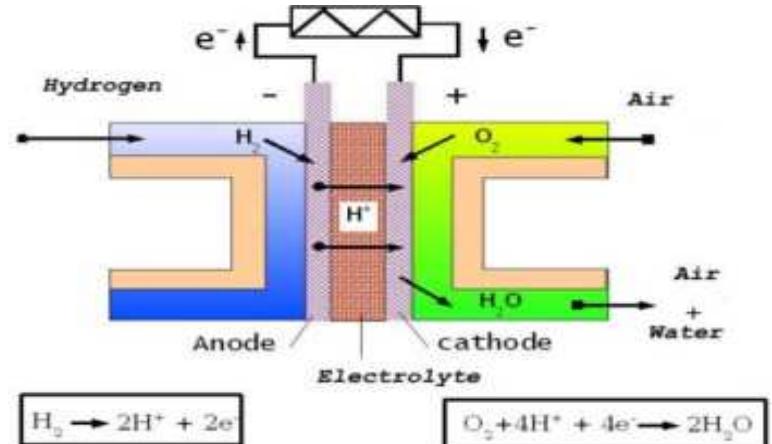


Introduction

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

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FCHEV Powertrains

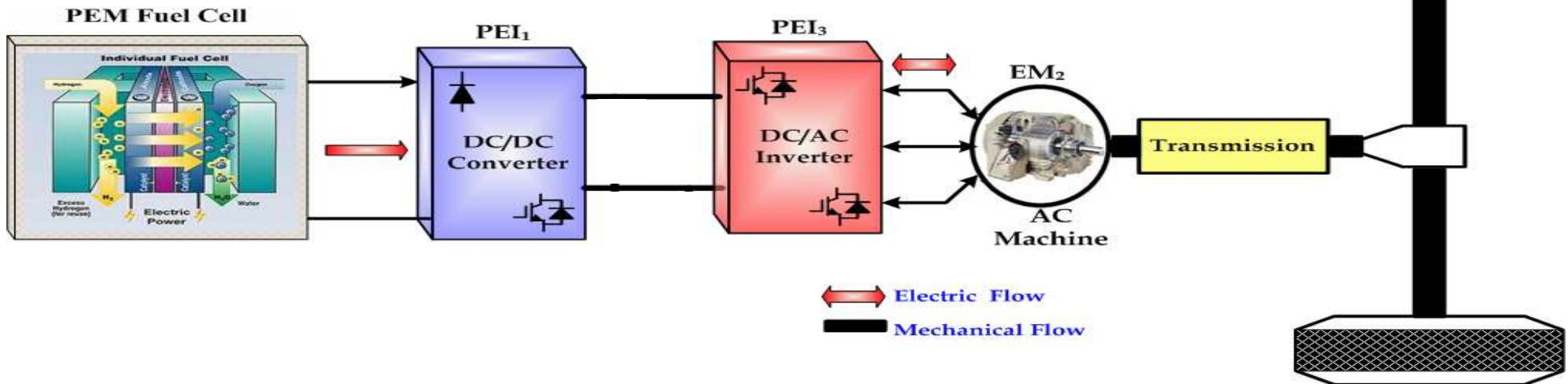
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1. FCEV

2. FC/BS HEV

3. FC/SC HEV

4. PFCHEV



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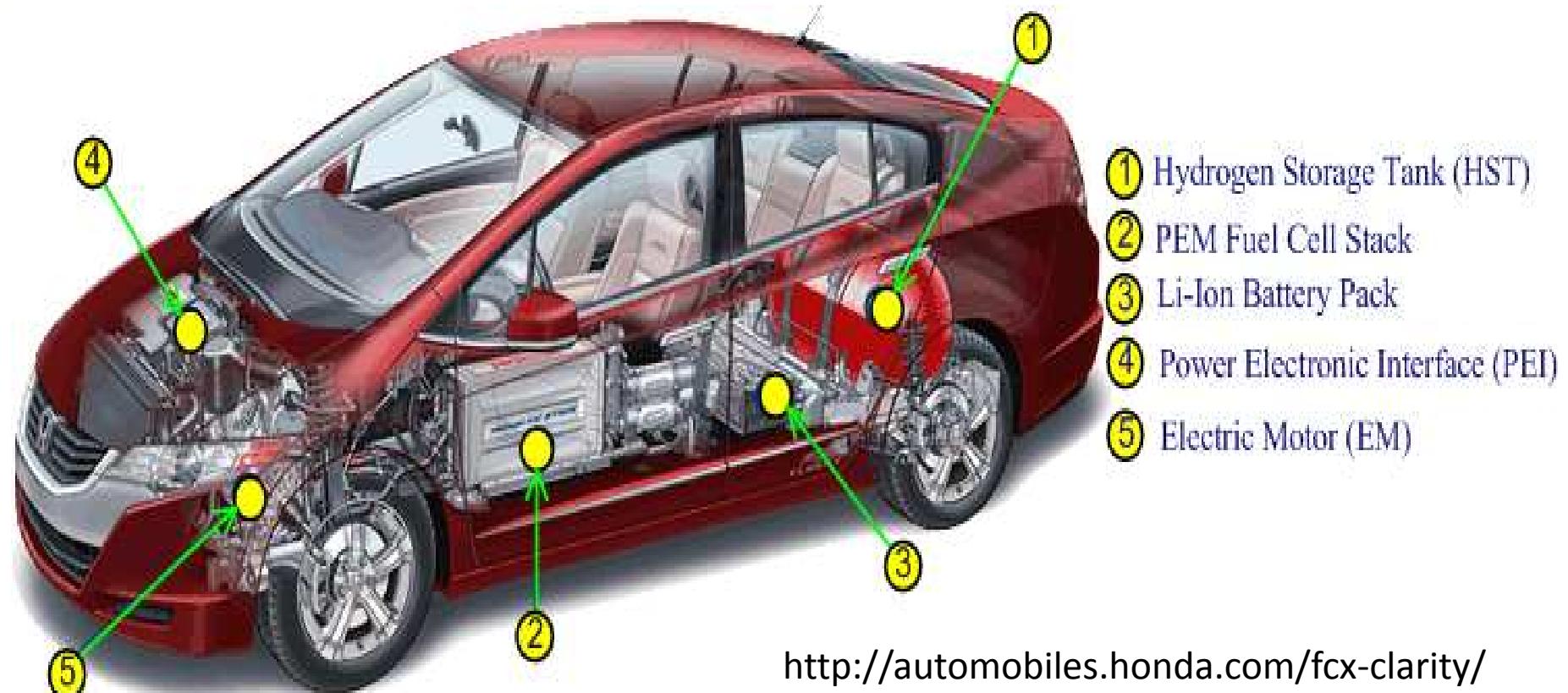
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FCHEV Powertrains



<http://automobiles.honda.com/fcx-clarity/>

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

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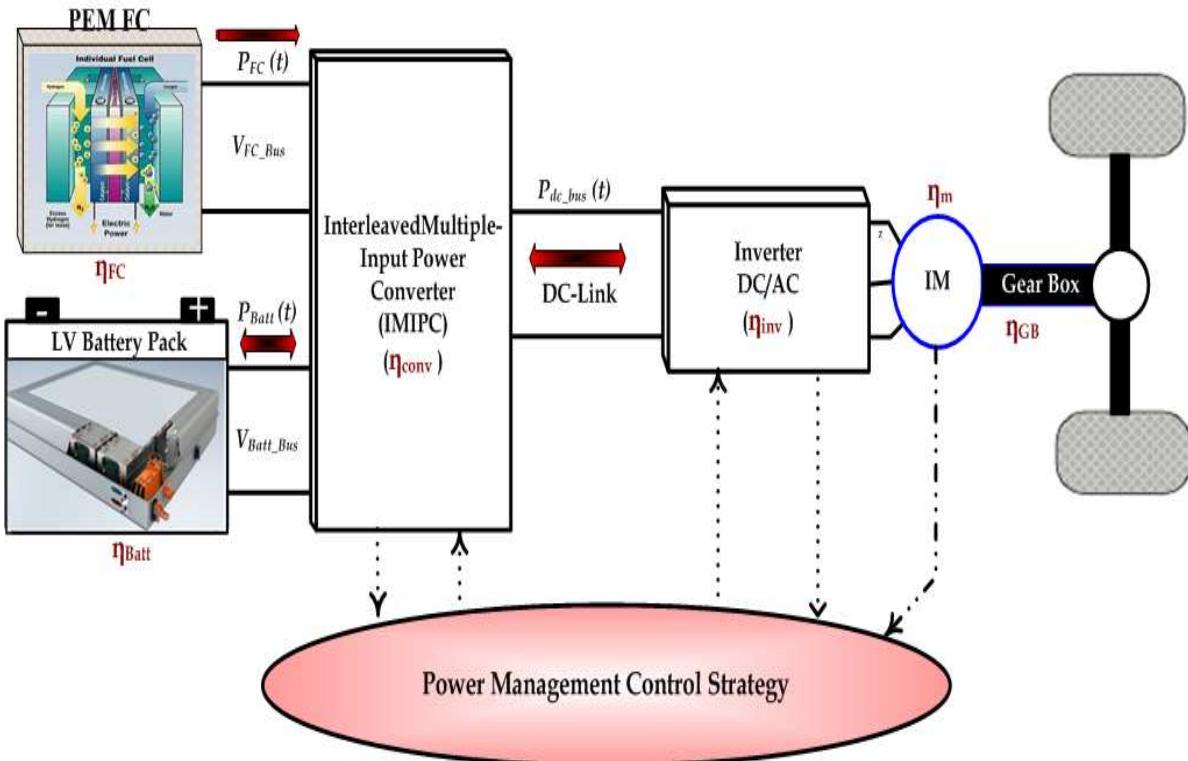


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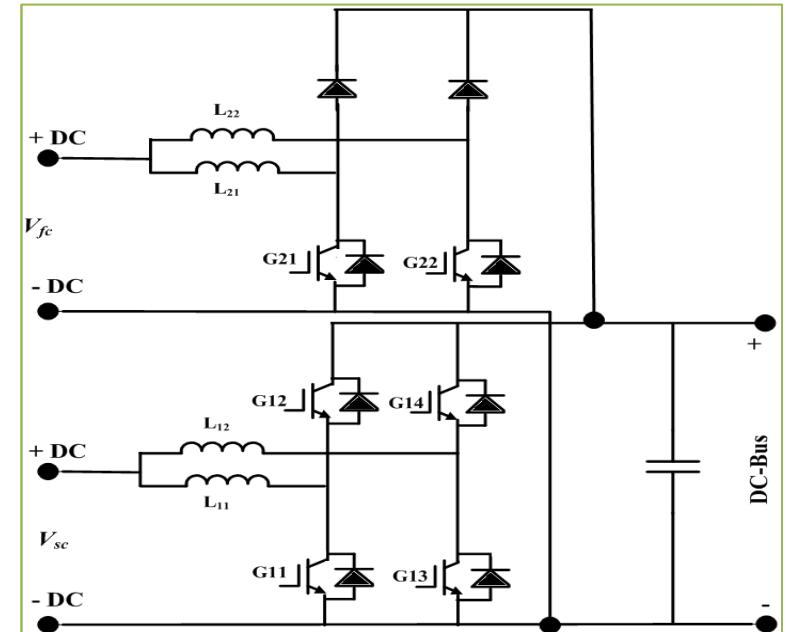


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Advantages:

- **High Efficiency**
- **High Reliability**
- **Low current/voltage ripples**
- **Small size**

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Power Control Strategies

Power Control Strategies

**Control Strategy Based on
Efficiency Map (CSEM)**

**Control Strategy Based
on PSO (CSPSO)**

PSO: Particle Swarm Optimization Algorithm

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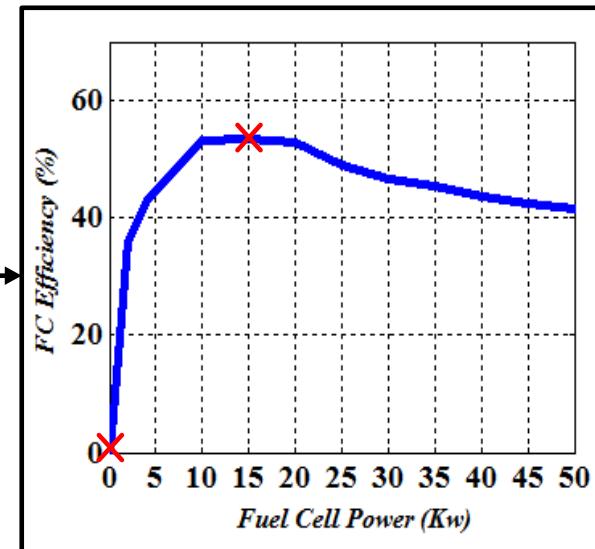
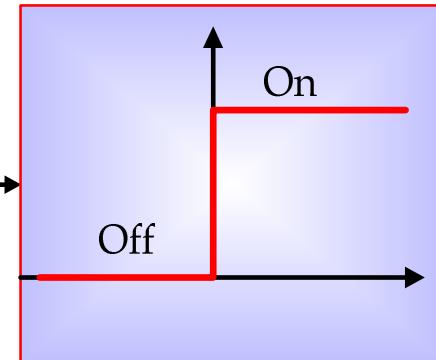
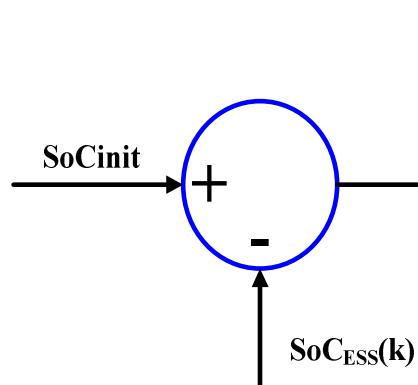


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Control Strategy Based on Efficiency Map (CSEM)



- $SoC_{ESS}(k) < SoC_{init}$, FC is operated at its point of maximum efficiency (called “On” point)
- $SoC_{ESS}(k) > SoC_{init}$, FC is turned off (called “Off” point)

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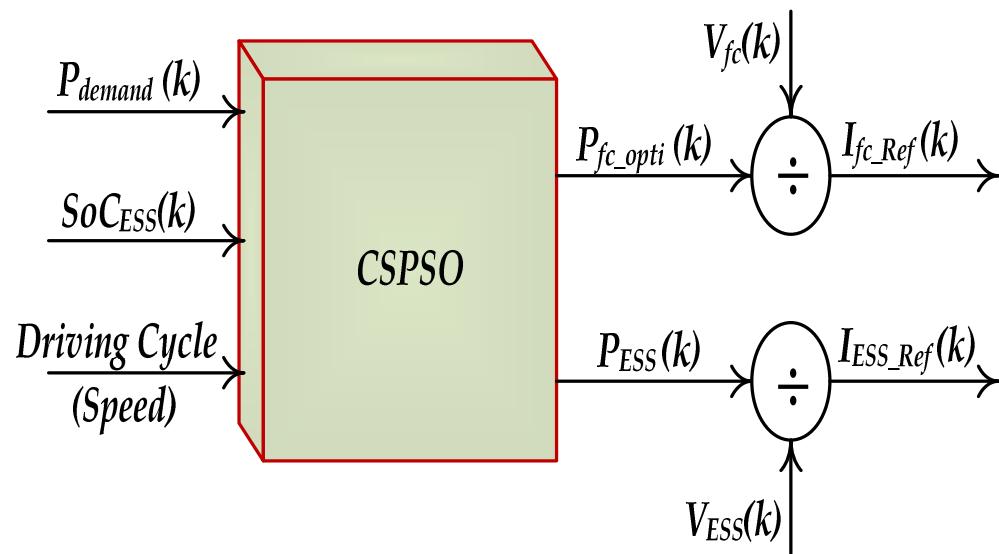


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Control Strategy Based on PSO (CSPSO)



$$k_{fc}(t) = P_{fc}(t)/P_{req}(t)$$

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

$$F(x) = \frac{1}{E_{low,H2}} \sum_{k=0}^N \frac{P_{fc,opti}(k)}{\eta(P_{fc,opti}(k))} \Delta T$$

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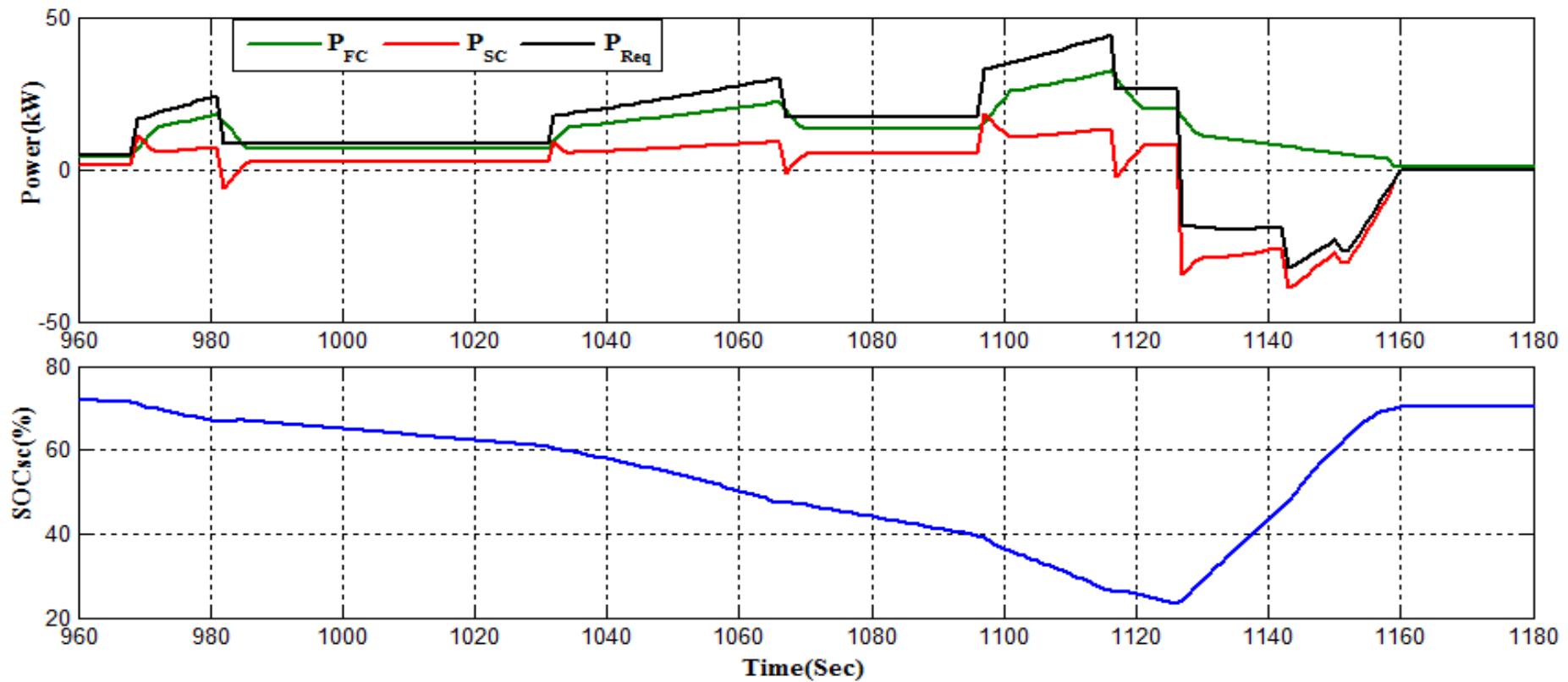
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Simulation Results & Comparative Study

Power sharing between sources



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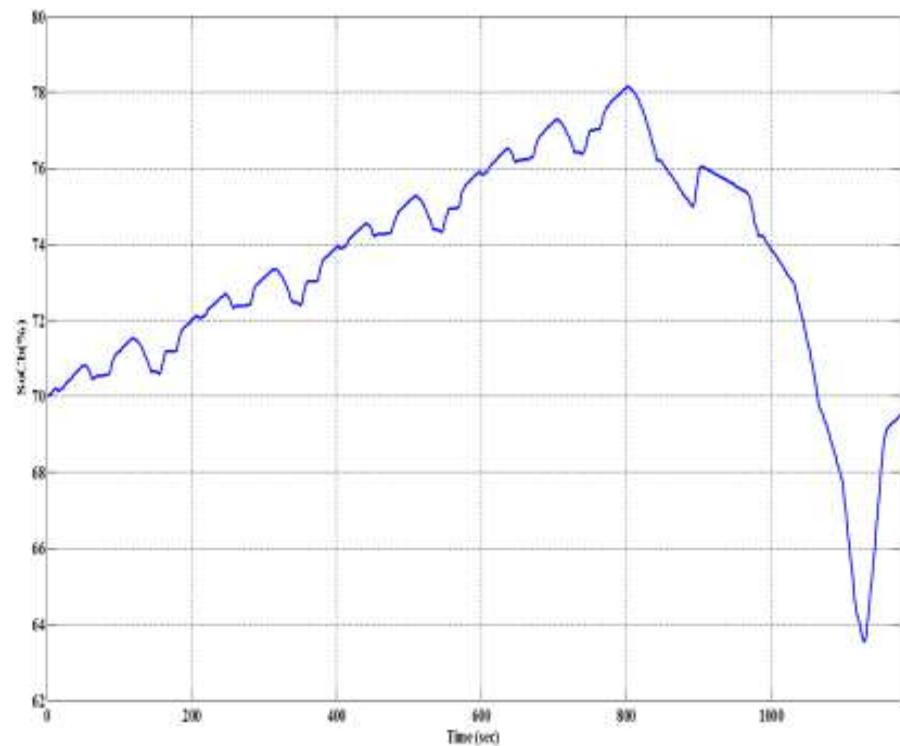
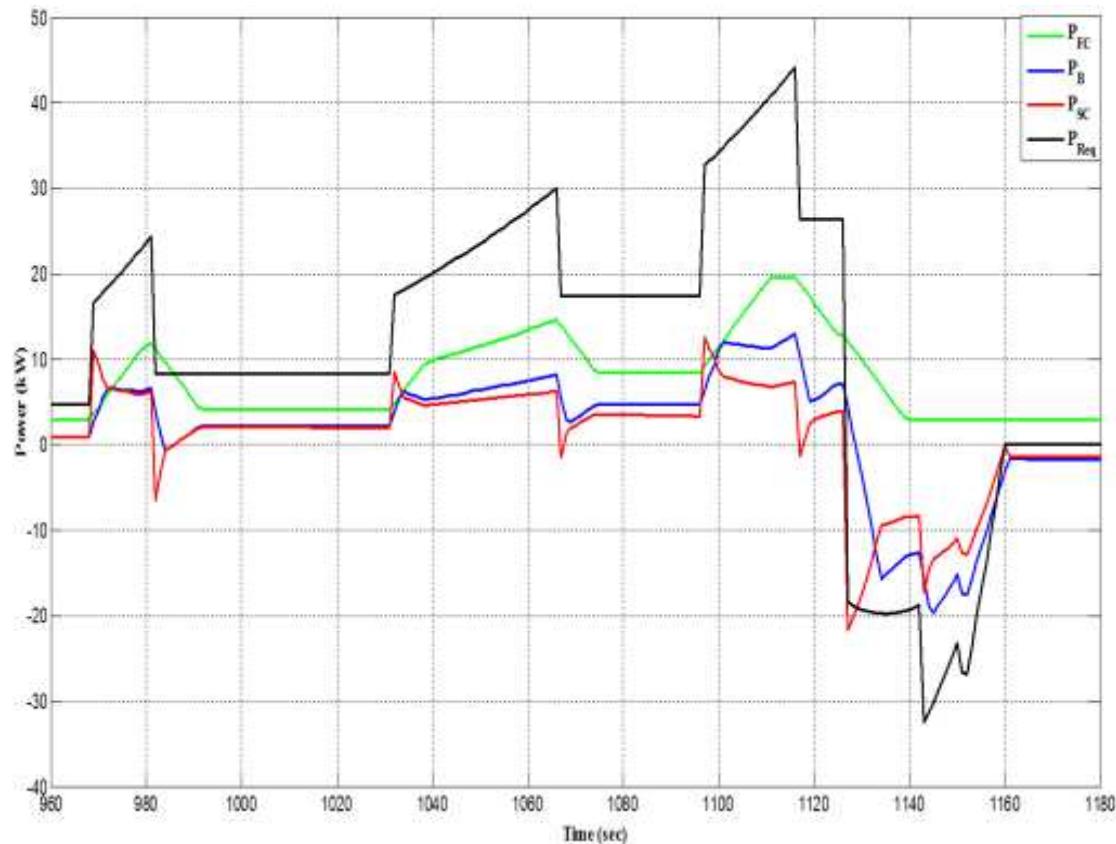
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Simulation Results & Comparative Study

Power sharing between sources



Battery SoC

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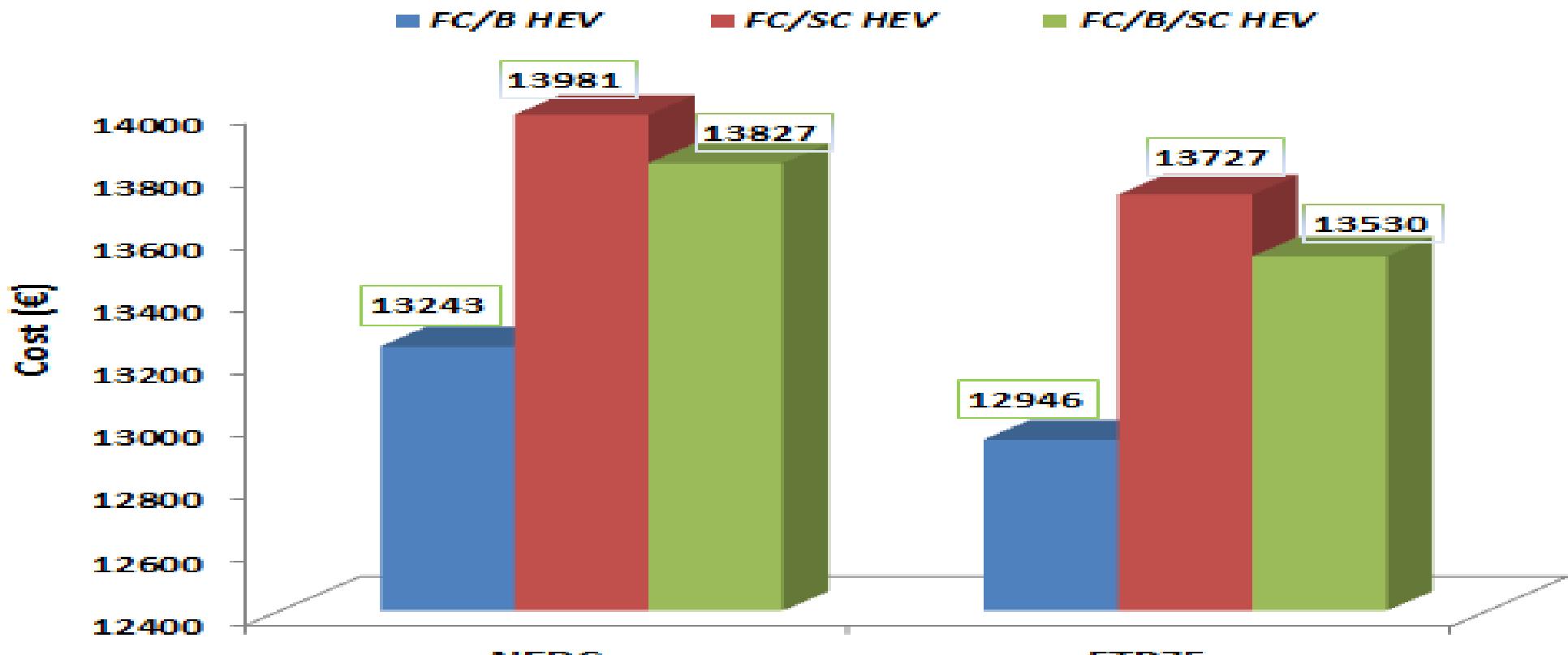
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Simulation Results & Comparative Study

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



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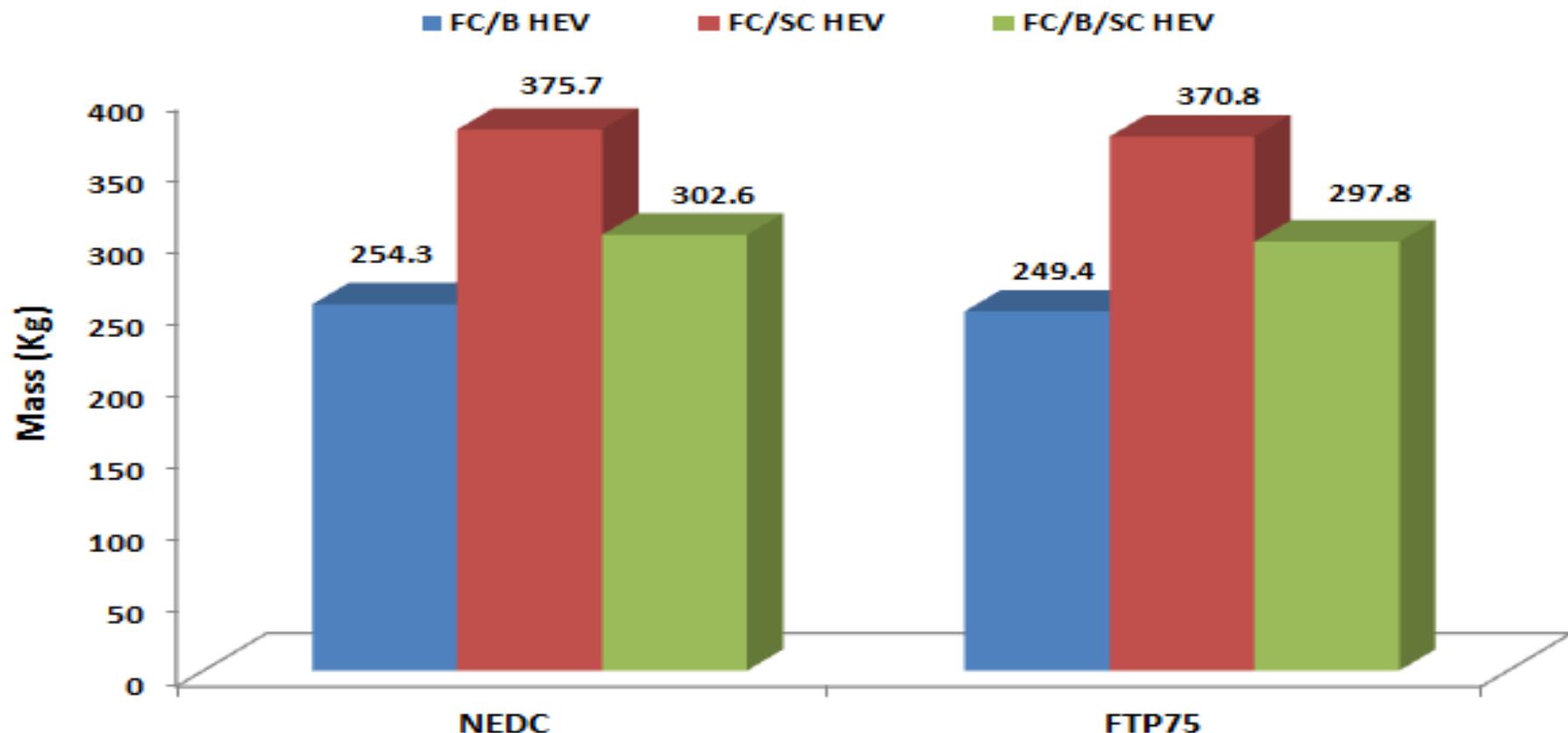


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Simulation Results & Comparative Study

Comparison of the total mass of the electric sources based driving cycles



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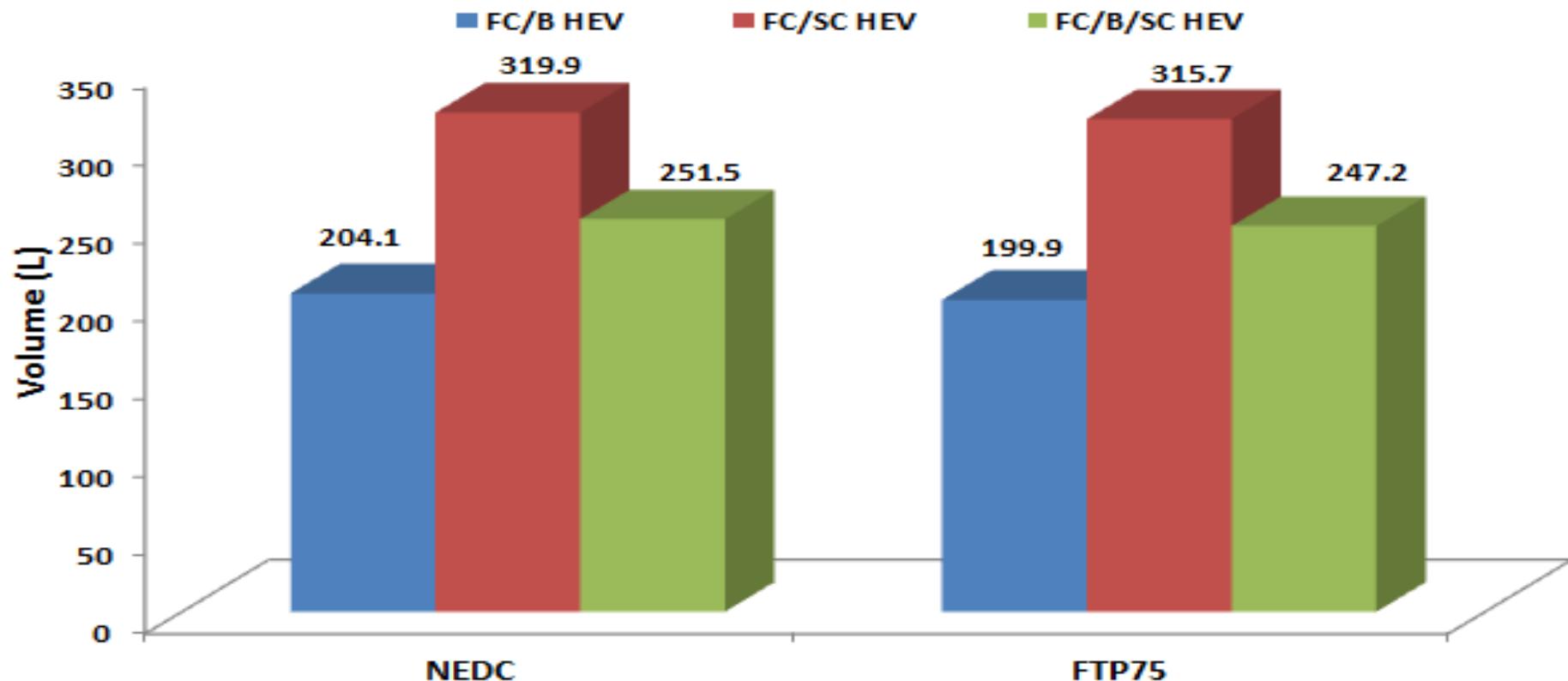


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Simulation Results & Comparative Study

Comparison of the total volume of the electric sources based driving cycles



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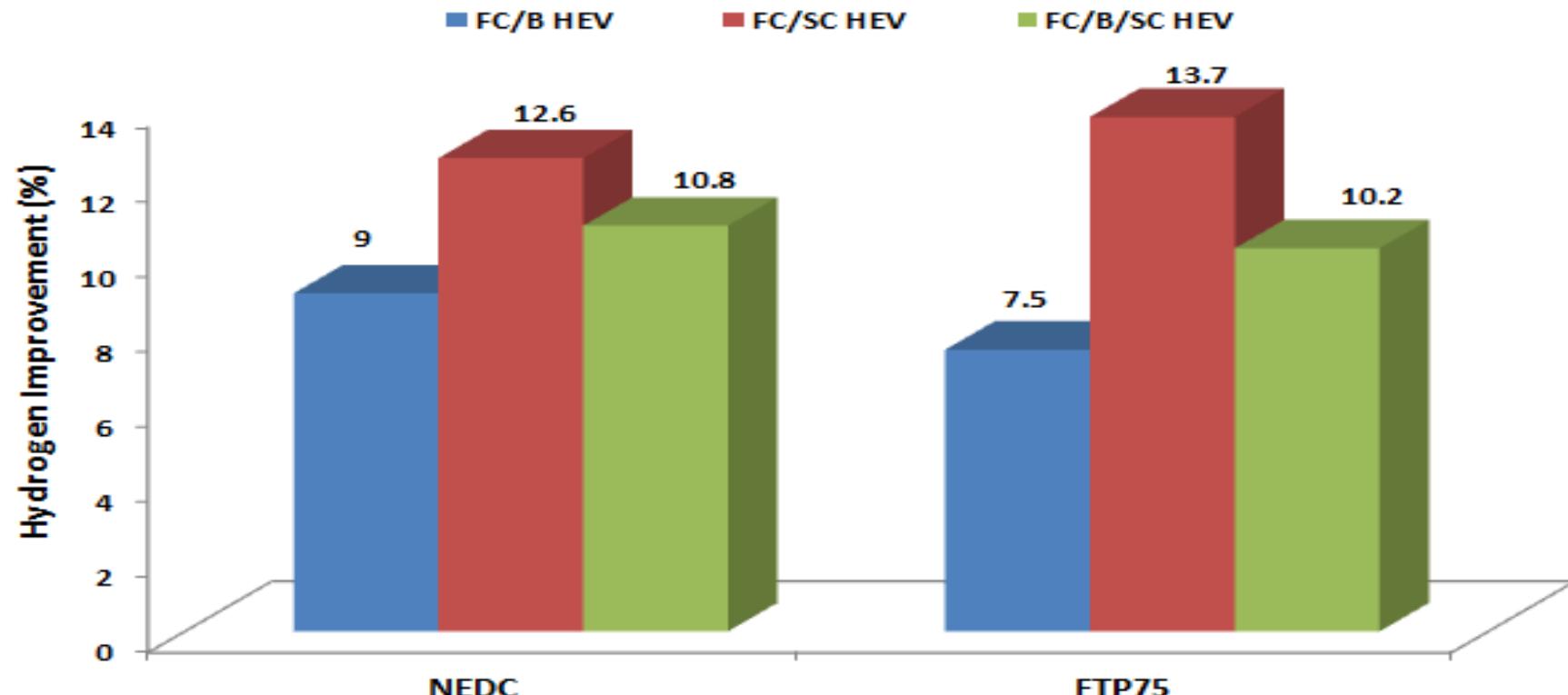
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Simulation Results & Comparative Study

The hydrogen improvement after using CSEM



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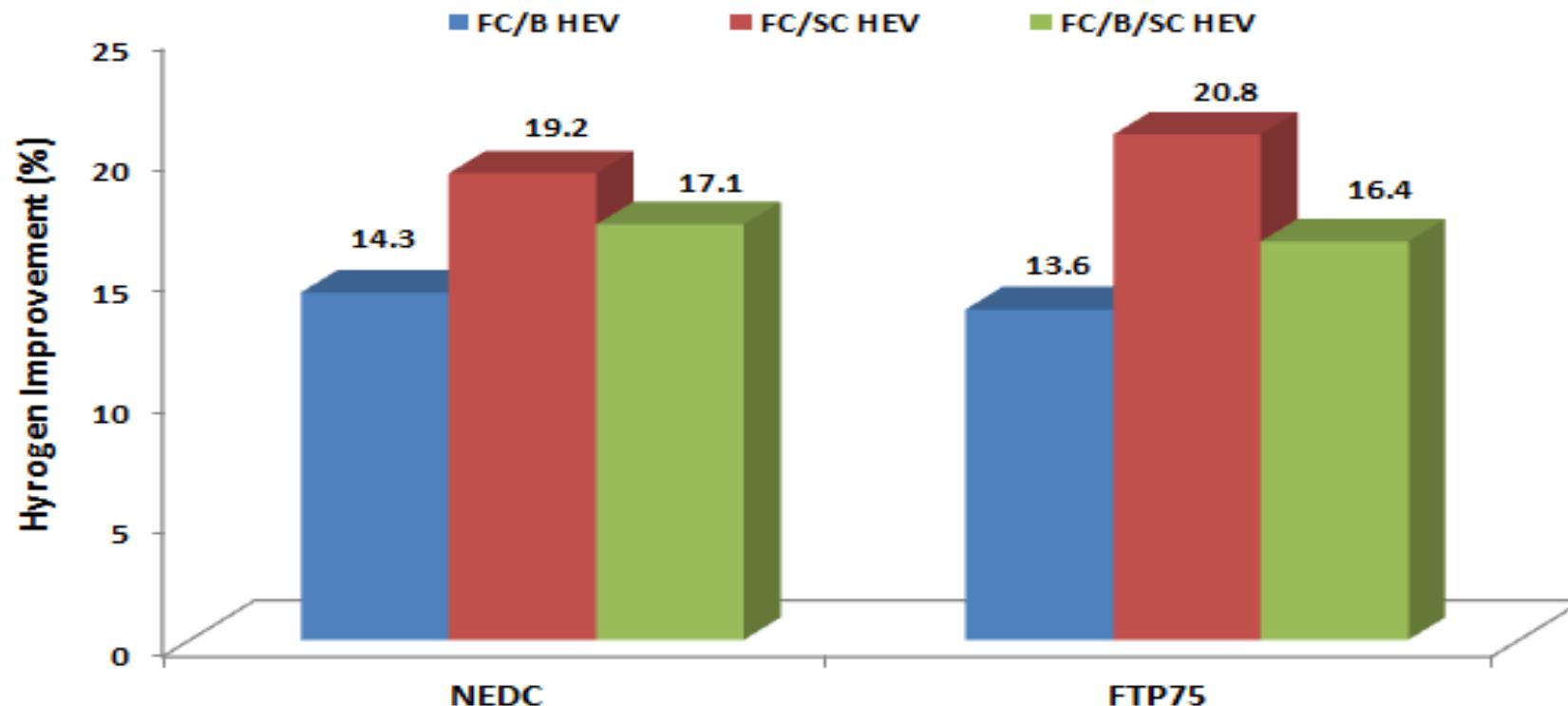
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Simulation Results & Comparative Study

The hydrogen improvement after using CSPSO



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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.

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