

EMR'23, Lille (France)

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«EMR-based hardware-in-the-loop for urban utility EV powered from supercapacitors»

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SIEMENS

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Introduction

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Building the EMR-RT model

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Comparative results & conclusions



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« Introduction »

Title of the presentation

- Introduction -

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EMR concept used for advanced research within funded projects

Replacement of Li Ion batteries with supercapacitors in urban EVs

Development of real-time EMR model

Philosophy of EMR-HIL testing



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« Building the EMR-RT model »

Title of the presentation

- Schematics and specifications -

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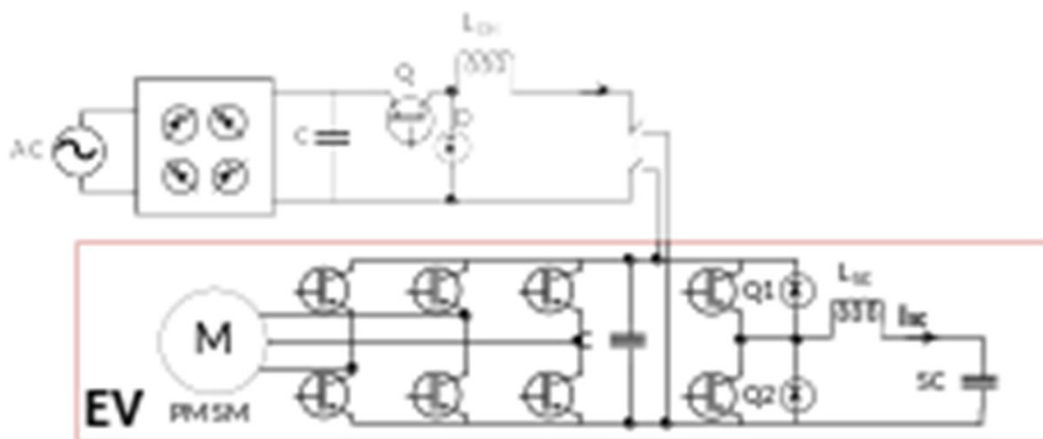


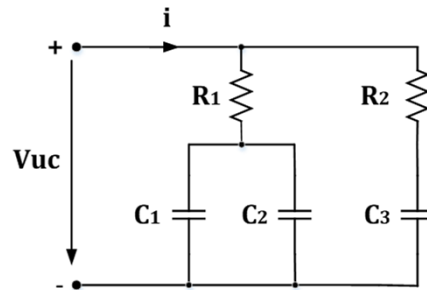
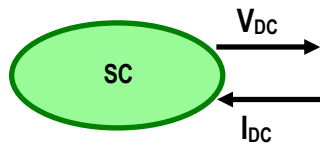
TABLE I. URBAN ELECTRIC VEHICLE SPECIFICATIONS

	Symbol	Value
Maximum mass	m	250 kg
Maximum speed	v	10 m/s
Wheel radius	R_w	12"
Maximum slope	α	15%
Rolling resistance	f	0.017
Frontal area	A	1.2 m ²
Aerodynamic coef.	C_s	0.36
Gear box ratio	gr	5
Wheel inertia	J	0.4 km ²

TABLE II. PMSM AND SUPERCAPACITORS RATINGS

PMSM		
	Symbol	Value
Rated power	P	2.5 kW
Maximum power	P_{max}	4 kW
Maximum torque	T_{max}	21 Nm
Rated speed	n_{rated}	2000 rpm
DC supply	V_{DC}	120 V
SUPERCAPACITORS BCAP3000		
Cell capacity	C	3000F
Cells in series		27
Series in paralel		2

Supply model - Supercapacitors

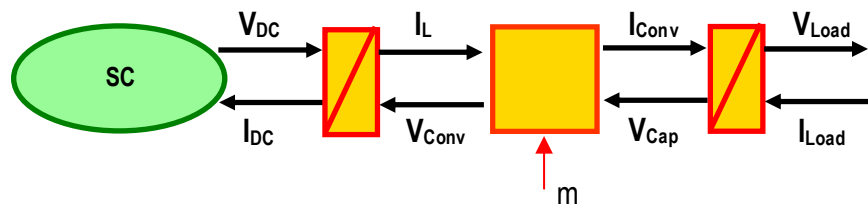


$$u_1 = R_1 \cdot i_1 + \frac{1}{C_1 + C_2} \int i_1 \cdot dt$$

$$u_2 = R_2 \cdot i_2 + \frac{1}{C_3} \int i_2 \cdot dt$$

$$i = i_1 + i_2$$

Supply model – bidirectional Buck-Boost converter



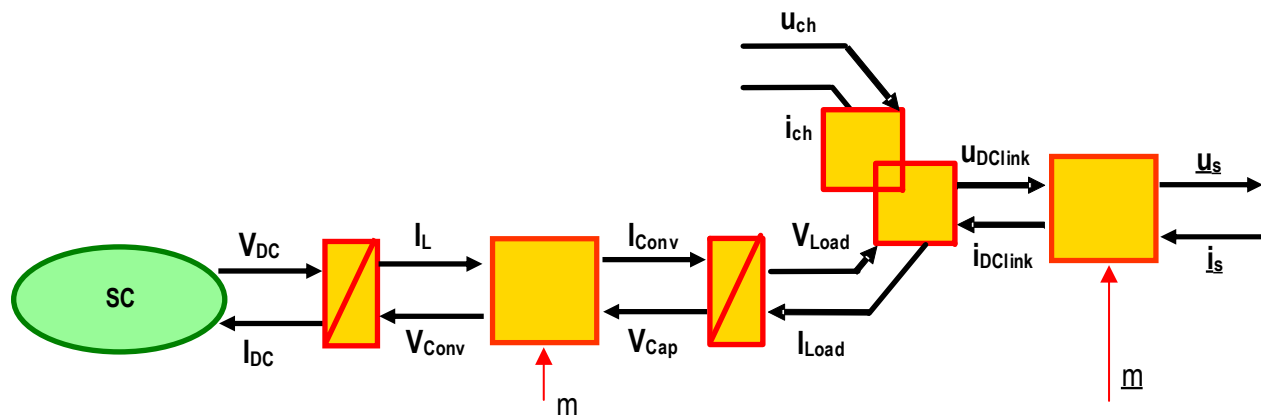
$$i_L = \int (u_{sc} - u_{conv} - R_L \cdot i_L) / L \cdot dt$$

$$u_{conv} = \int (i_L - i_{DC}) / C \cdot dt$$

$$u_{sc} = u_{conv} \cdot m$$

$$i_{conv} = i_L \cdot m$$

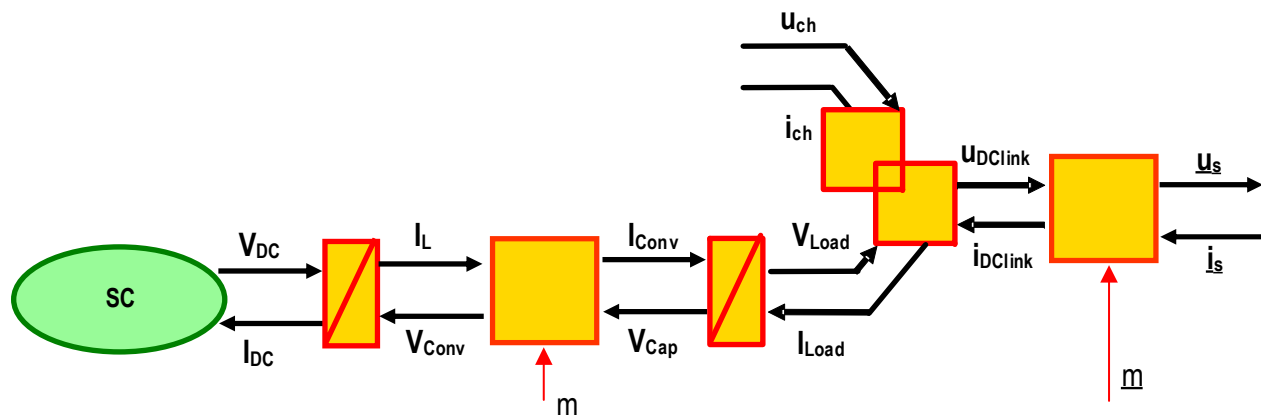
Supply model – 3-phase converter



$$u_{sA,B,C} = m_{A,B,C} \cdot V_{DC}$$

$$i_{DC} = m_A \cdot I_A + m_B \cdot I_B + m_C \cdot I_C$$

Supply model – the buck charger converter



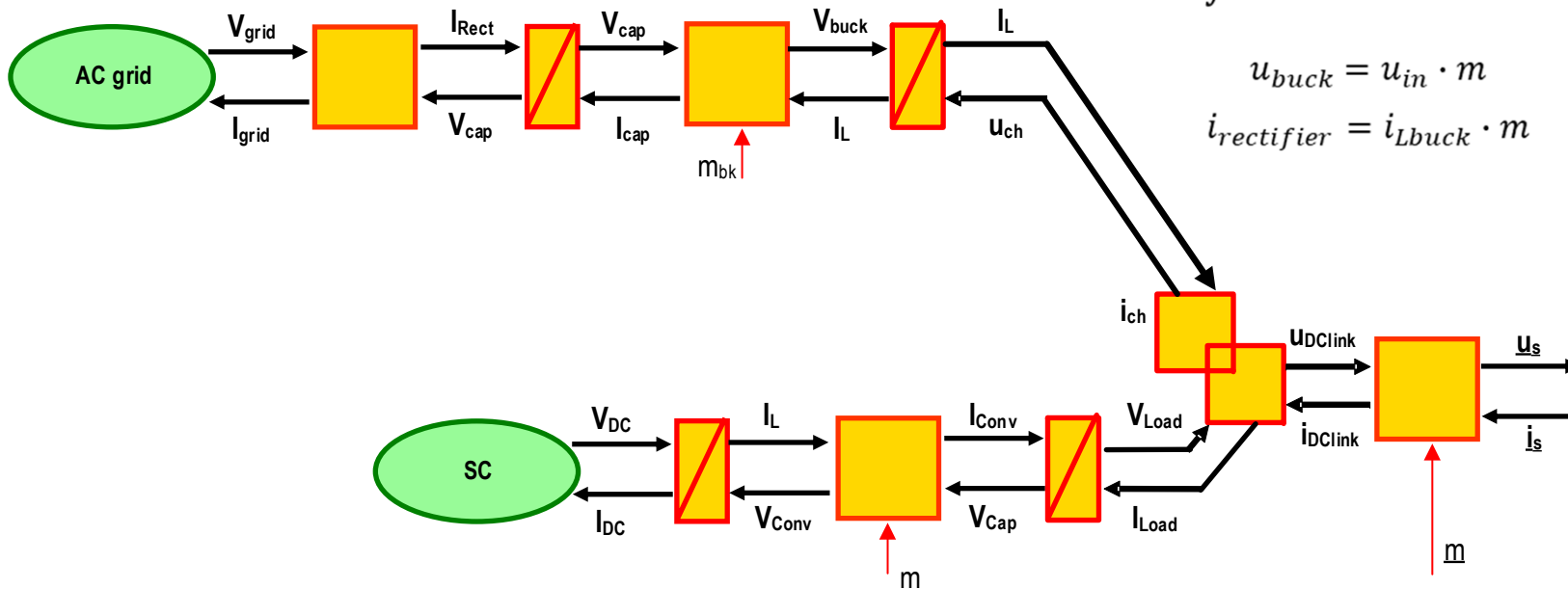
Supply model – the buck charger converter

$$i_{Lbuck} = \int (u_{Vdc} - u_{buck} - R_{Lbuck} \cdot i_{Lbuck}) / L_{buck} \cdot dt$$

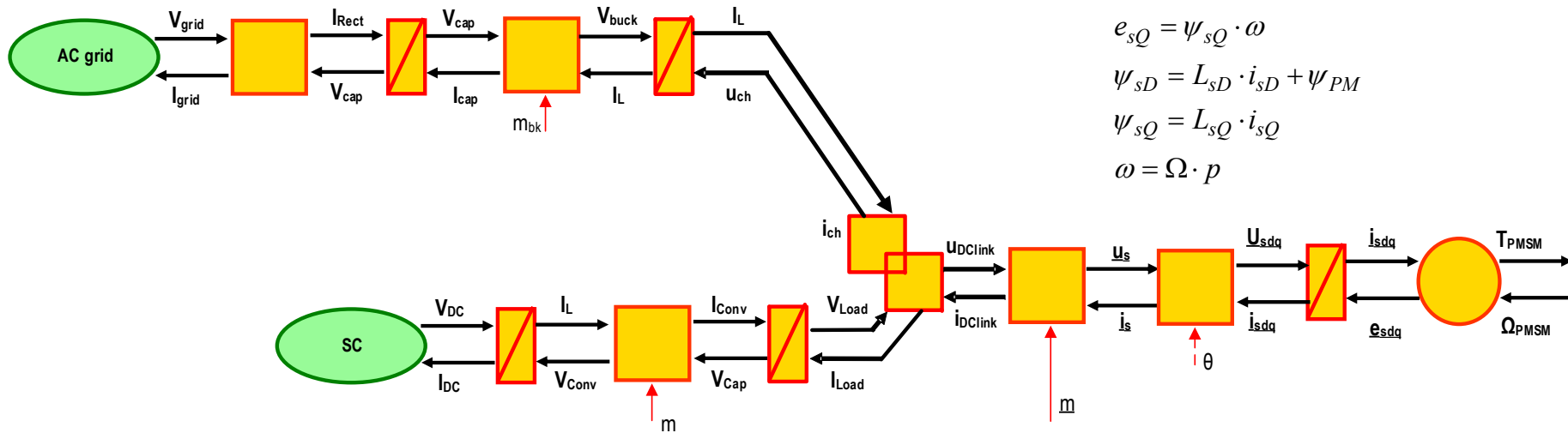
$$u_{in} = \int (i_{buck} - i_{rectifier}) / L_{in} \cdot dt$$

$$u_{buck} = u_{in} \cdot m$$

$$i_{rectifier} = i_{Lbuck} \cdot m$$



The PMSM model



$$U_{sDQ} - e_{sDQ} - (i_{sDQ} \cdot R_s) = L_{DQ} \frac{d}{dt} (i_{sDQ})$$

$$T_{PMSM} = 3/2 \cdot p \cdot i_{sQ} (\psi_{PM} + (L_{sD} - L_{sQ}) \cdot i_{sD})$$

$$e_{sD} = -\psi_{sD} \cdot \omega$$

$$e_{sQ} = \psi_{sQ} \cdot \omega$$

$$\psi_{sD} = L_{sD} \cdot i_{sD} + \psi_{PM}$$

$$\psi_{sQ} = L_{sQ} \cdot i_{sQ}$$

$$\omega = \Omega \cdot p$$

The vehicle mechanics

$$F_{rez} = F_1 + F_2 + F_3$$

$$F_1 = acc \cdot M_{chass}$$

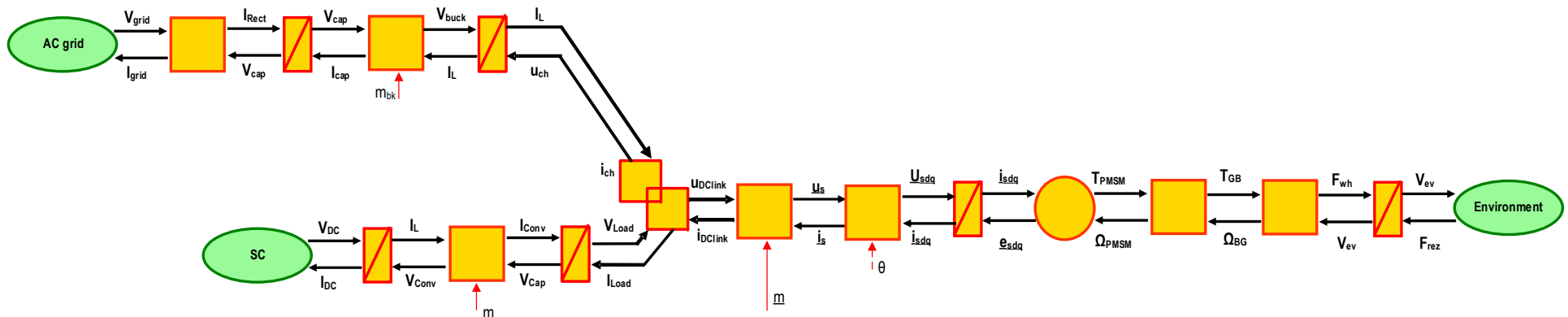
$$F_2 = \sin(\alpha) \cdot M_{chass} \cdot g + M_{chass} \cdot g \cdot \mu \cdot \cos(\alpha)$$

$$F_3 = (V_{ev} + V_{wind}) \cdot C_d \cdot \delta \cdot A_f \cdot 0.5$$

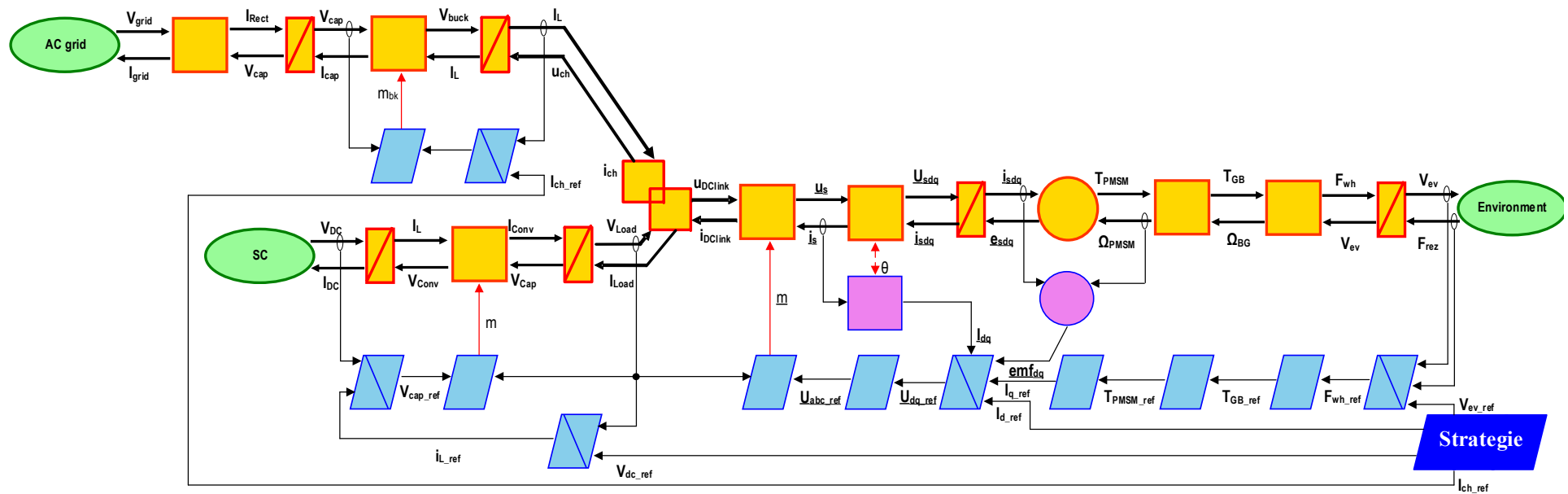
$$T_{Gb} = T_{PMSM} \cdot G_b$$

$$F_{wh} = \frac{1}{R_{wh}} T_{Gb}$$

$$V_{ev} = \int (F_{wh} - F_{rez}) dt \cdot M_{chass}$$



The Control scheme

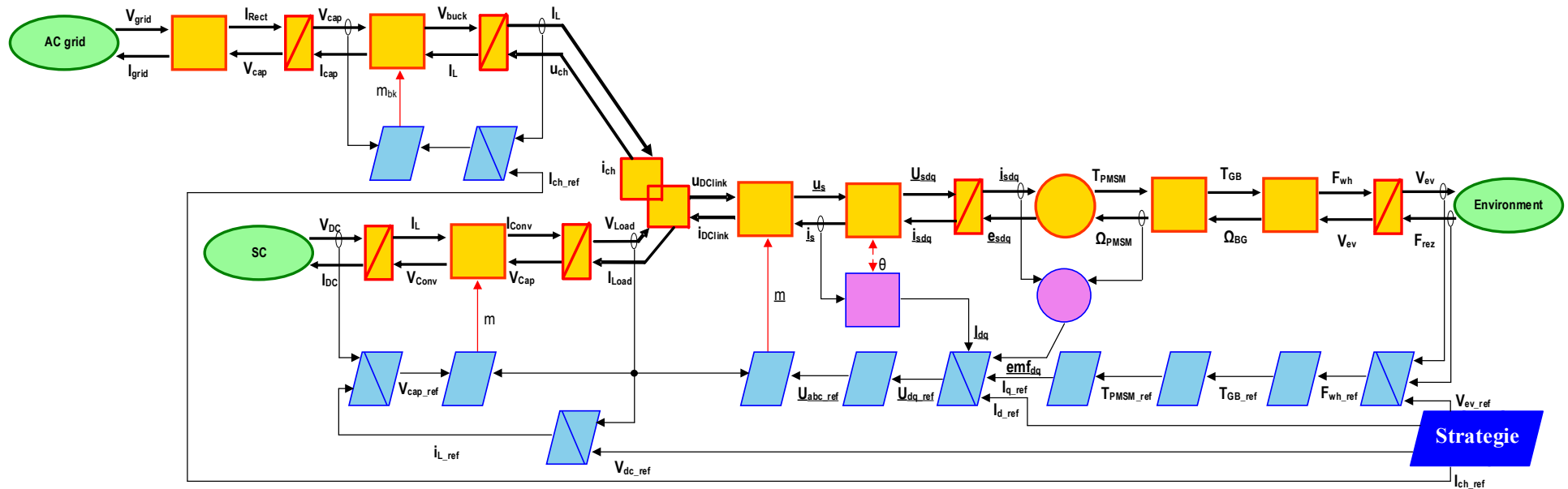




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«Comparative results»

The simulation program



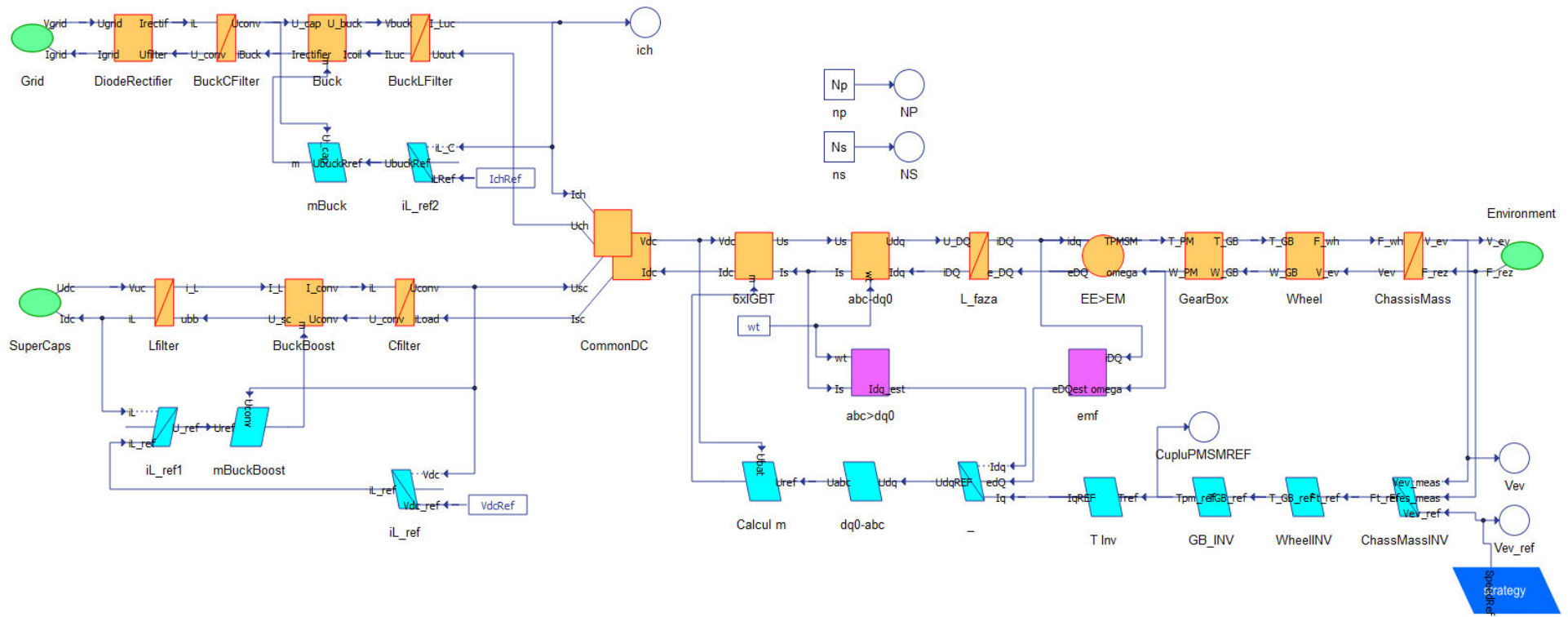
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- Typhoon Setup

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The Typhoon HIL Schematics



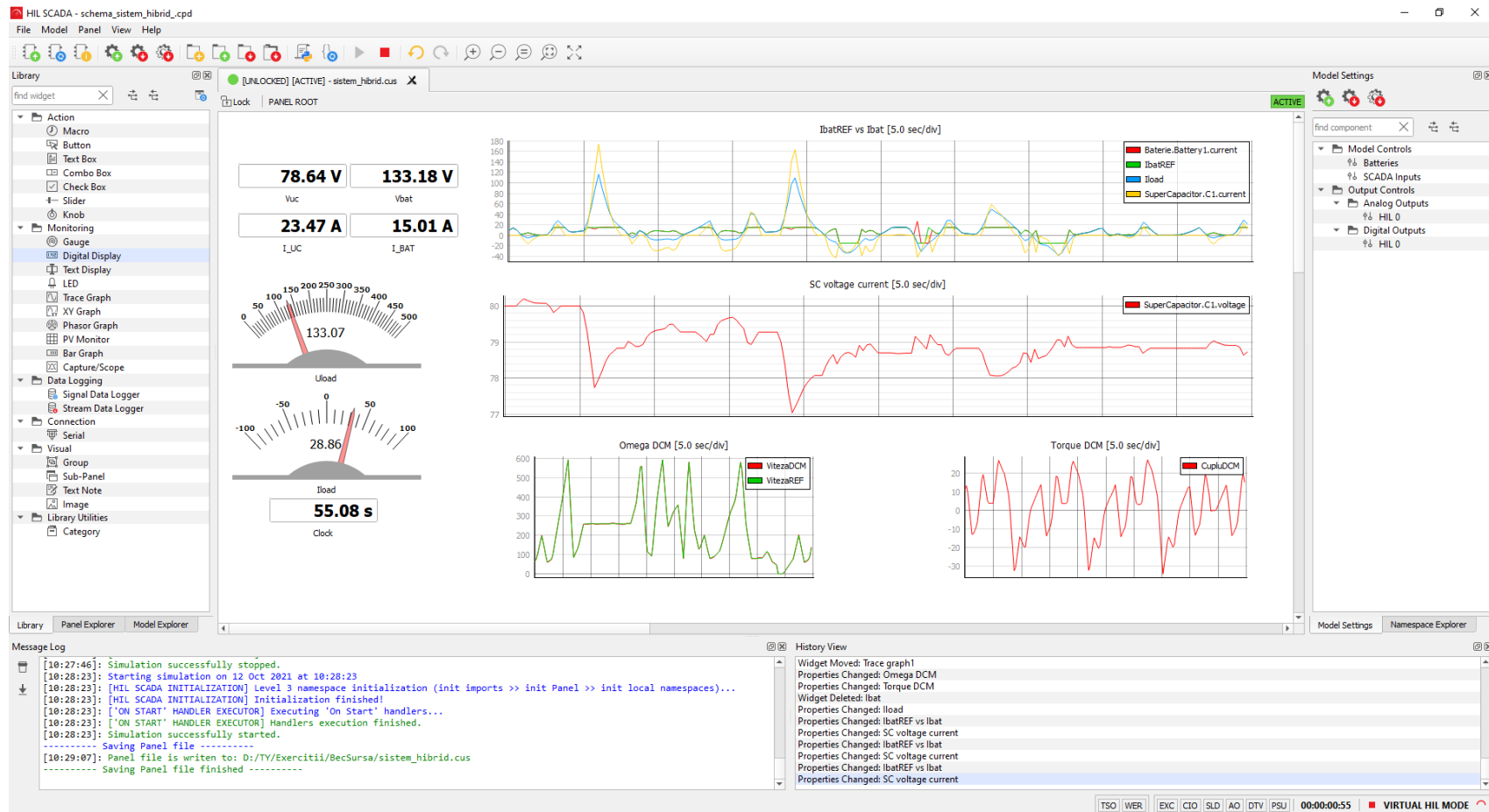
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- Typhoon Setup

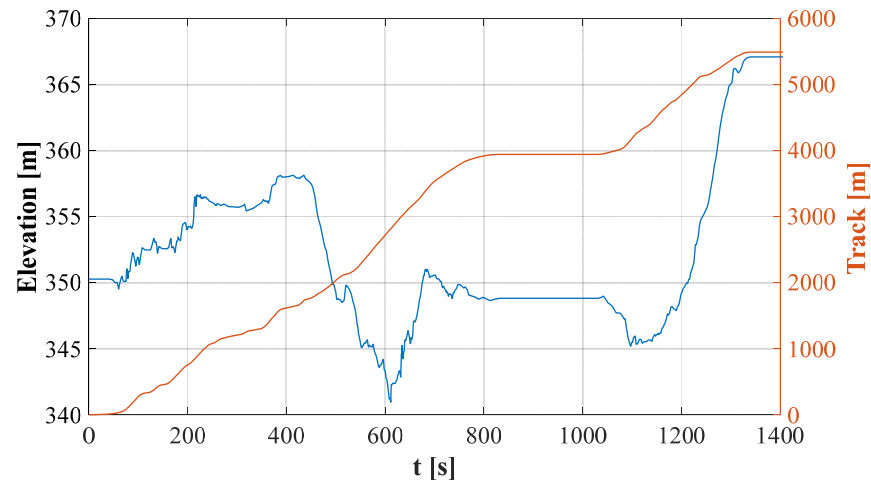
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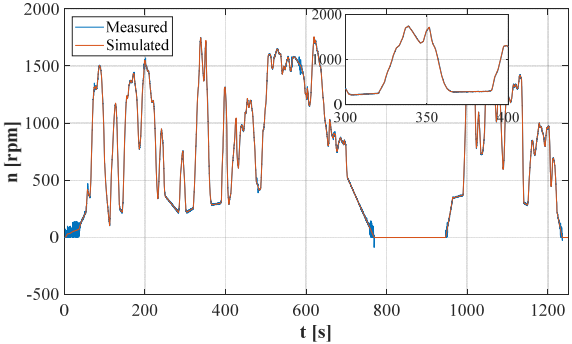
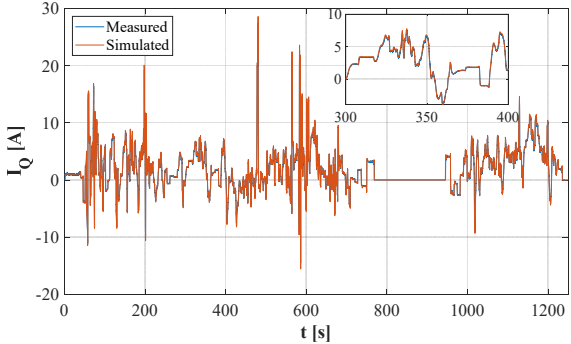
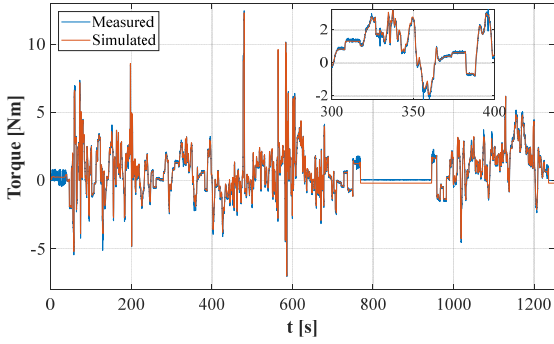
The Typhoon HIL SCADA



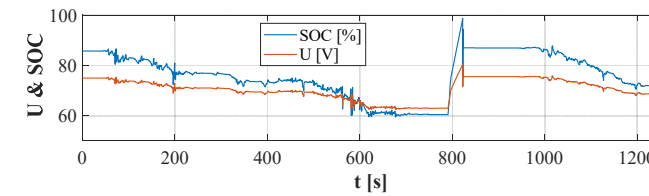
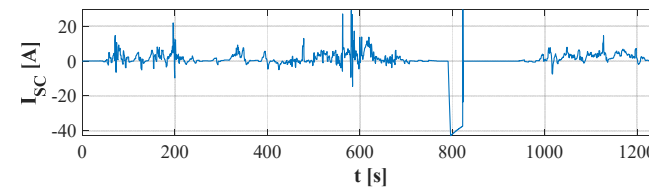
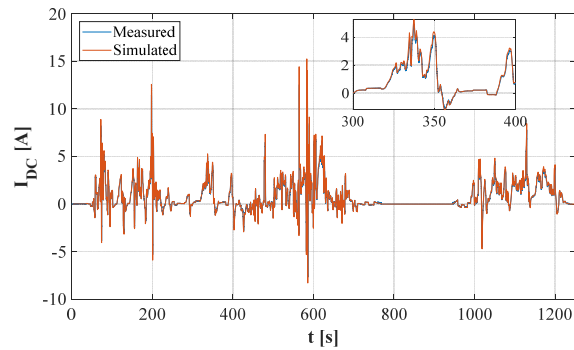
The proposed roadmap from Cluj Napoca, Romania



The comparison of the PMSM data



The supply data





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« Conclusions »

The EMR philosophy is a lucrative tool for HIL analysis

Using EMR, the transition to/from HIL is very simple

The results prove that the SC can replace batteries in urban vehicles

Typhoon HIL already developed EMR libraries



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« Thank you for your attention! »