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

Dr. Mircea Ruba*, Dragan Zuber, Dr.Călin Husar*****

* Technical University of Cluj Napoca

** Typhoon HIL, Novi Sad, Serbia

*** Siemens Industry Software, Romania

TECHNICAL UNIVERSITY OF CLUJ-NAPOCA ROMANIA

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- Outline -

« 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

« Building the EMR-RT model »

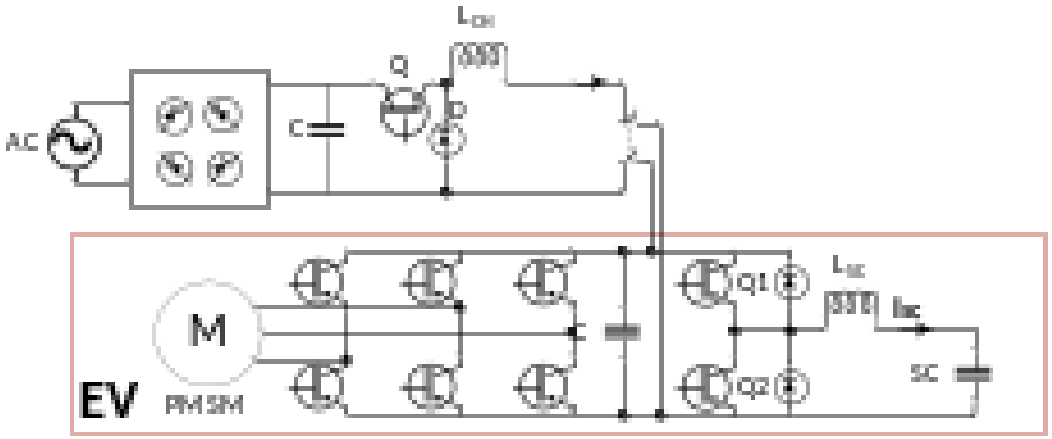


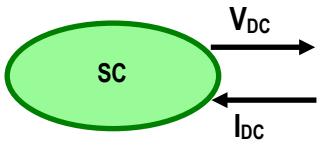
TABLE I. URBAN ELECTRIC VEHICLE SPECIFICATIONS

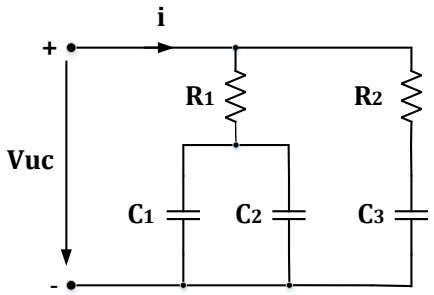
	Symbol	Value
Maximum mass	m	250 kg
Maximum speed	v	10 m/s
Wheel radius	Rw	12"
Maximum slope	α	15%
Rolling resistance	f	0.017
Frontal area	A	1.2 m^2
Aerodynamic coef.	Cs	0.36
Gear box ratio	gr	5
Wheel inertia	J	0.4 km^2

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_{nom}	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



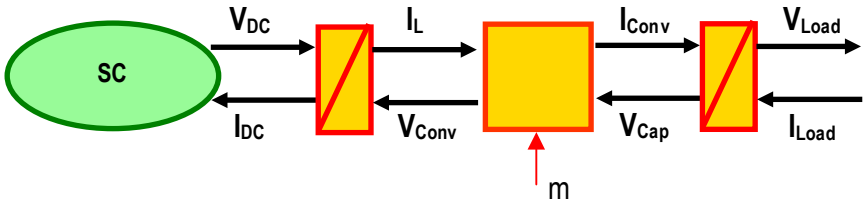


$$u_1 = R_1 \cdot i_1 + \frac{1}{C_1 + C_2} \int i_1 \cdot dt$$

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

$$i = i_1 + i_2$$

Supply model – bidirectional Buck-Boost converter



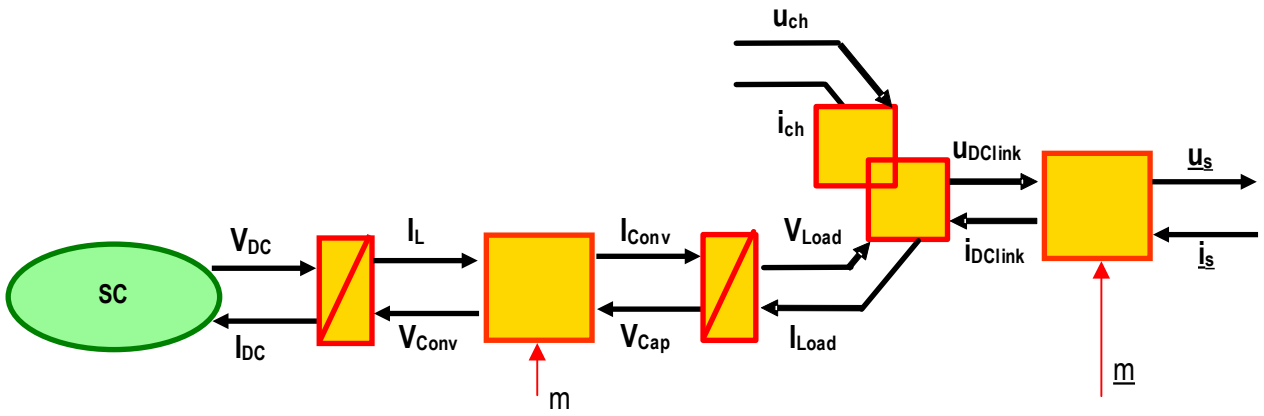
$$i_L = \int (u_{sc} - u_{conv} - R_L \cdot i_L)/L \cdot dt$$

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

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

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

Supply model – 3-phase converter



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

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

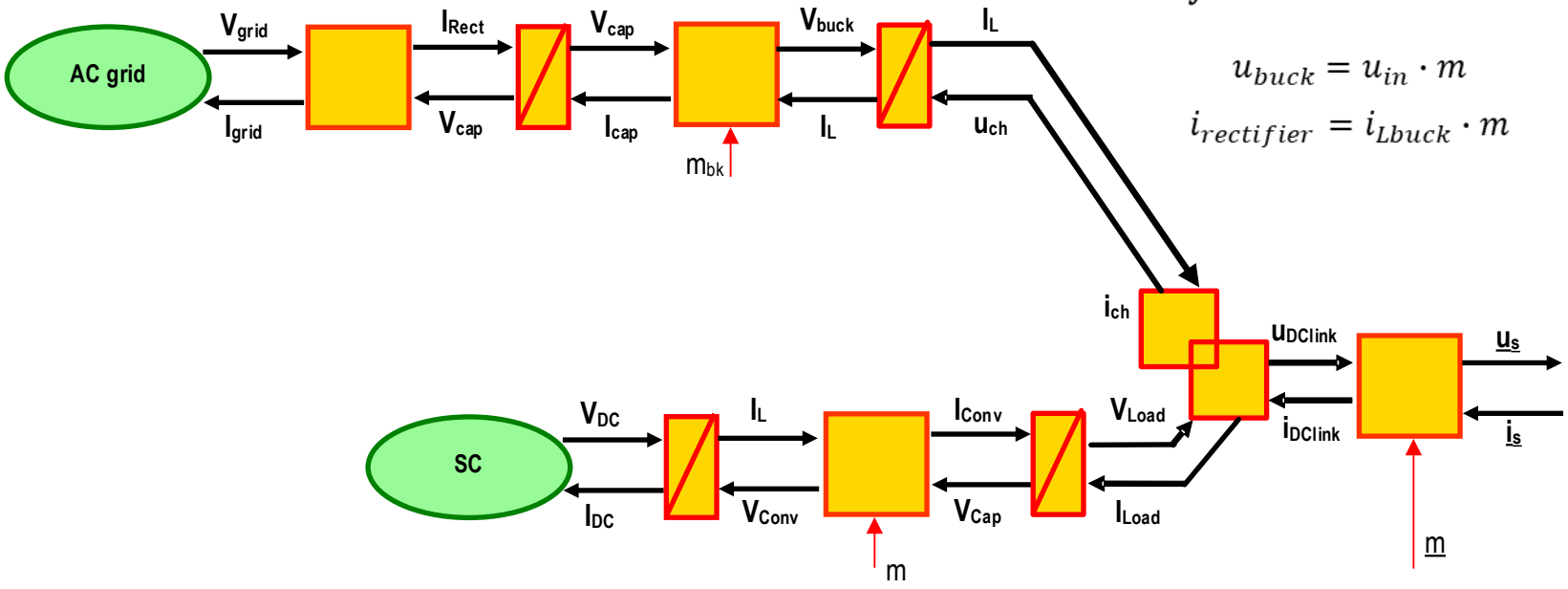
Supply model – the buck charger converter

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

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

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

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



The PMSM model

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

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

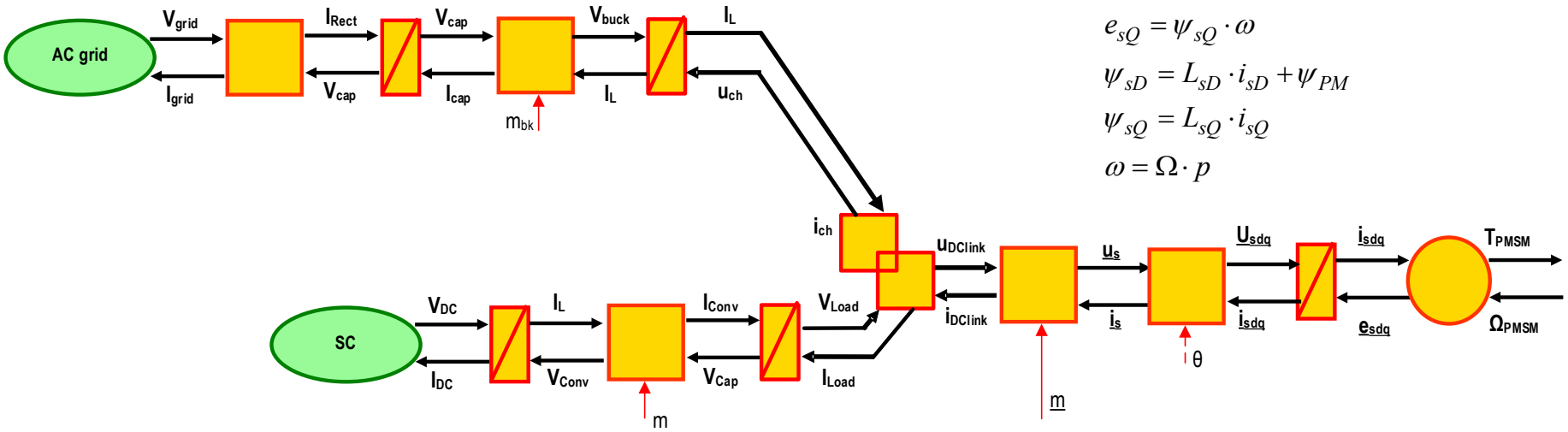
$$e_{sD} = -\psi_{sD} \cdot \omega$$

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

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

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

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



The vehicle mechanics

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

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

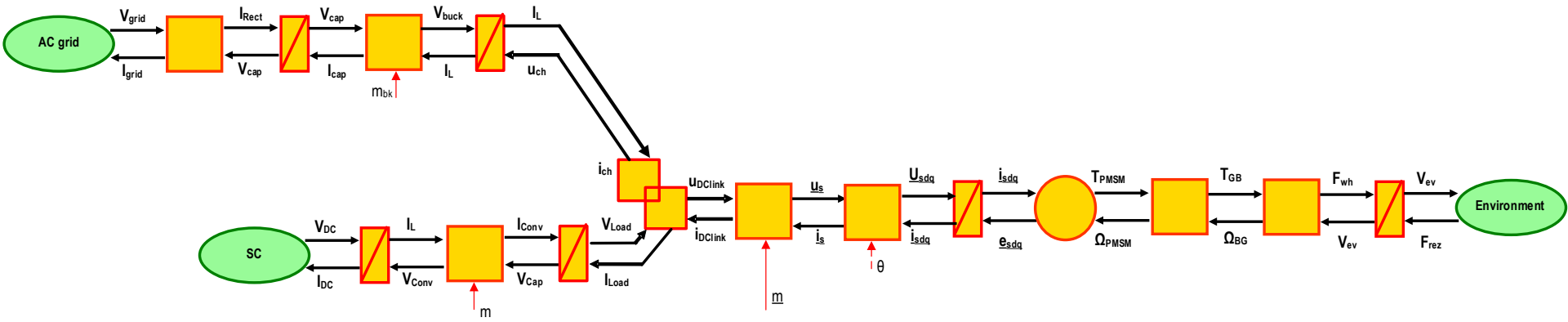
$$F_2 = \sin(\alpha) \cdot M_{chass} \cdot g + M_{chass} \cdot g \cdot \mu \cdot \cos(\alpha)$$

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

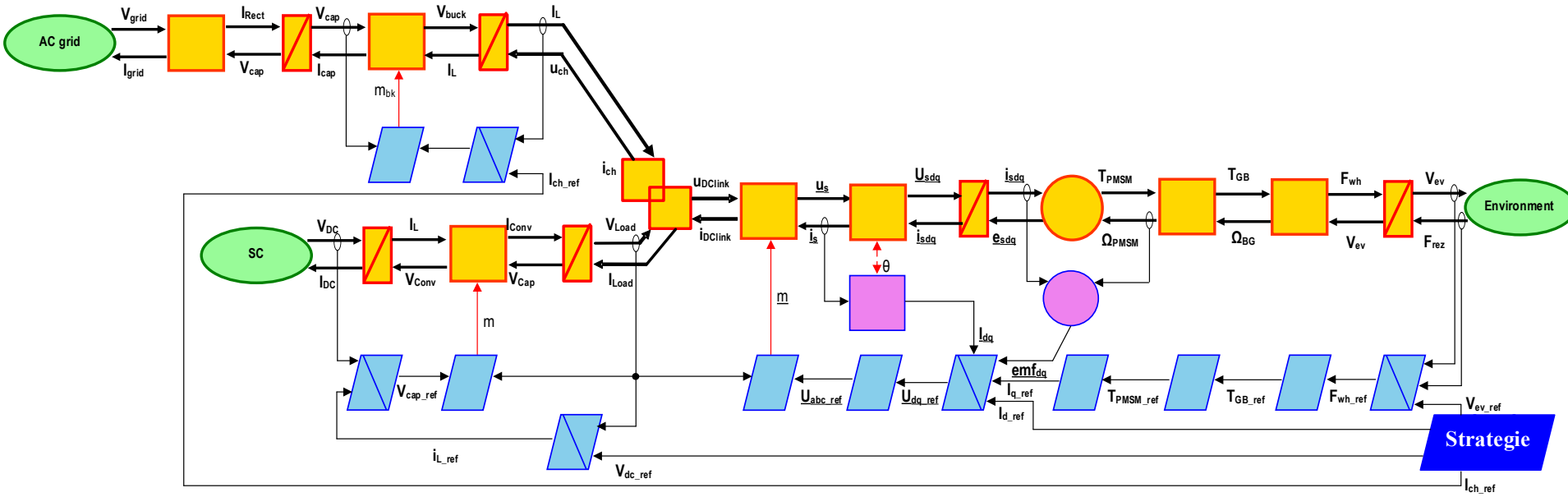
$$T_{Gb} = T_{PMSM} \cdot Gb$$

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

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

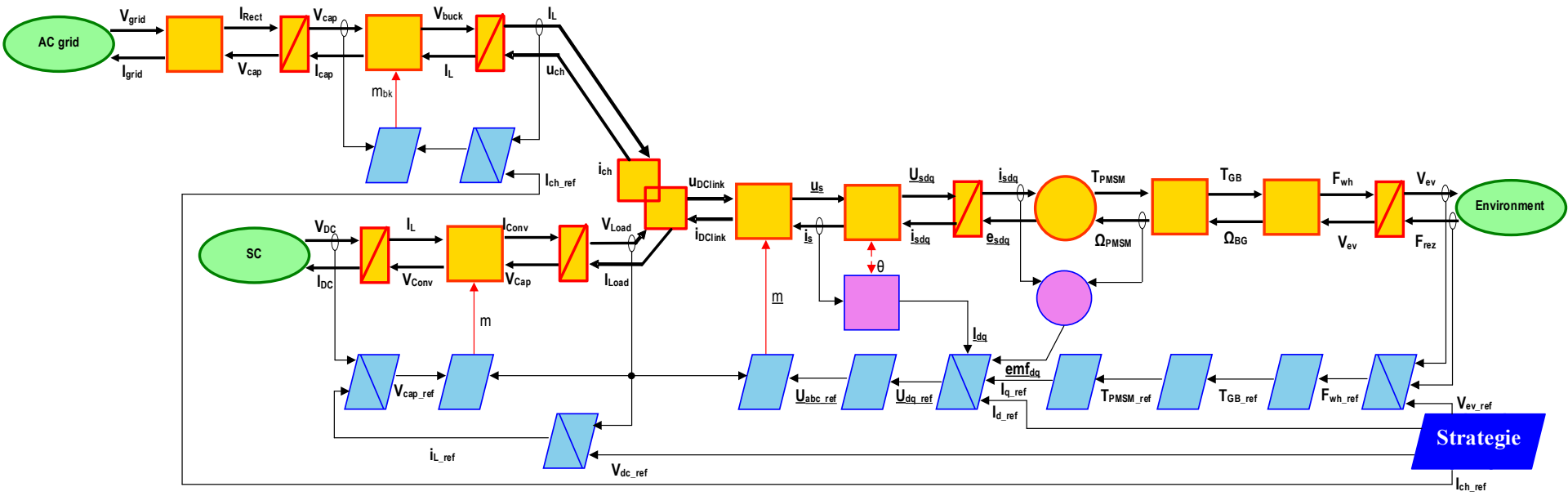


The Control scheme

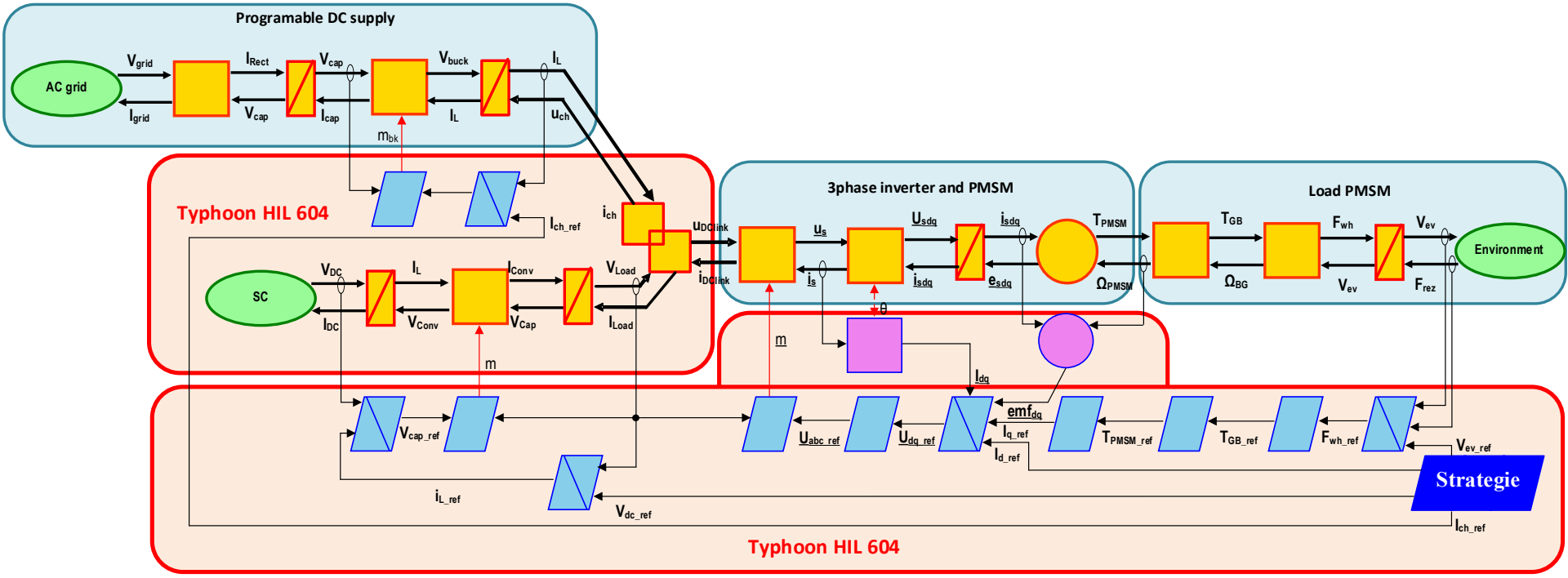


«Comparative results»

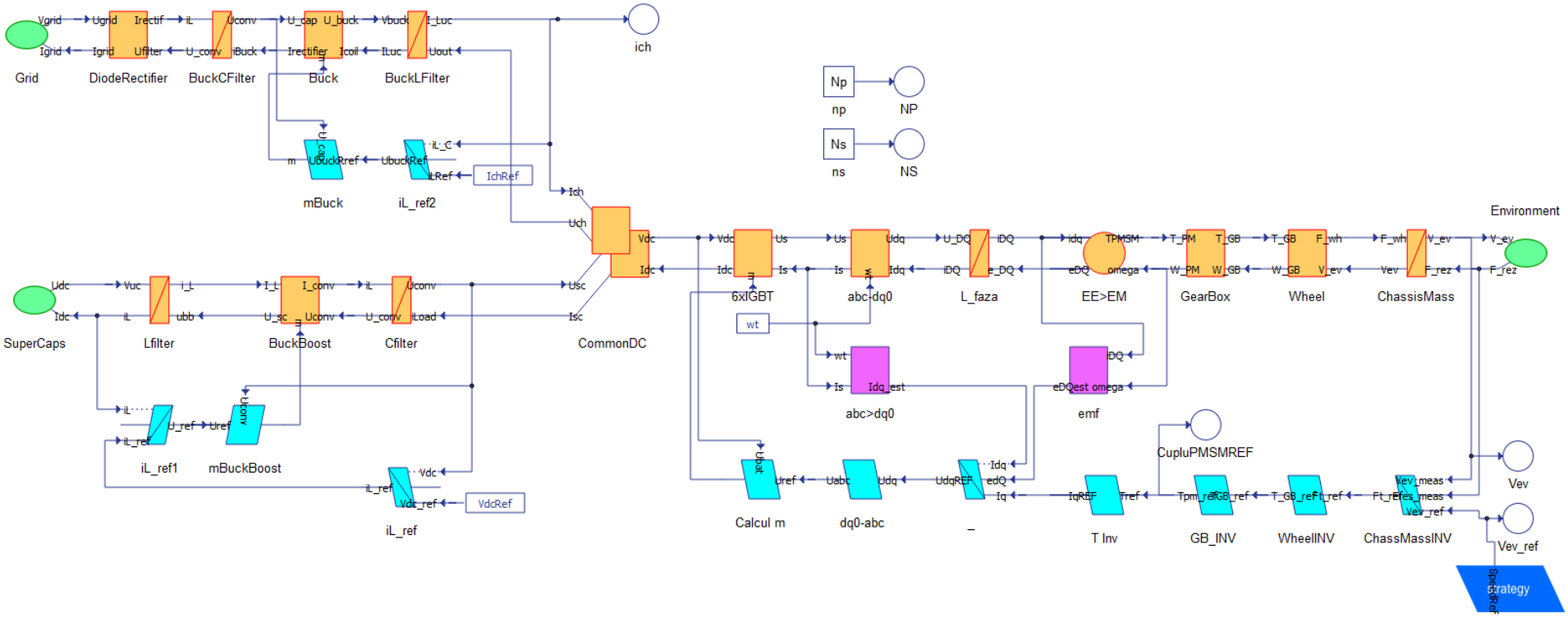
The simulation program



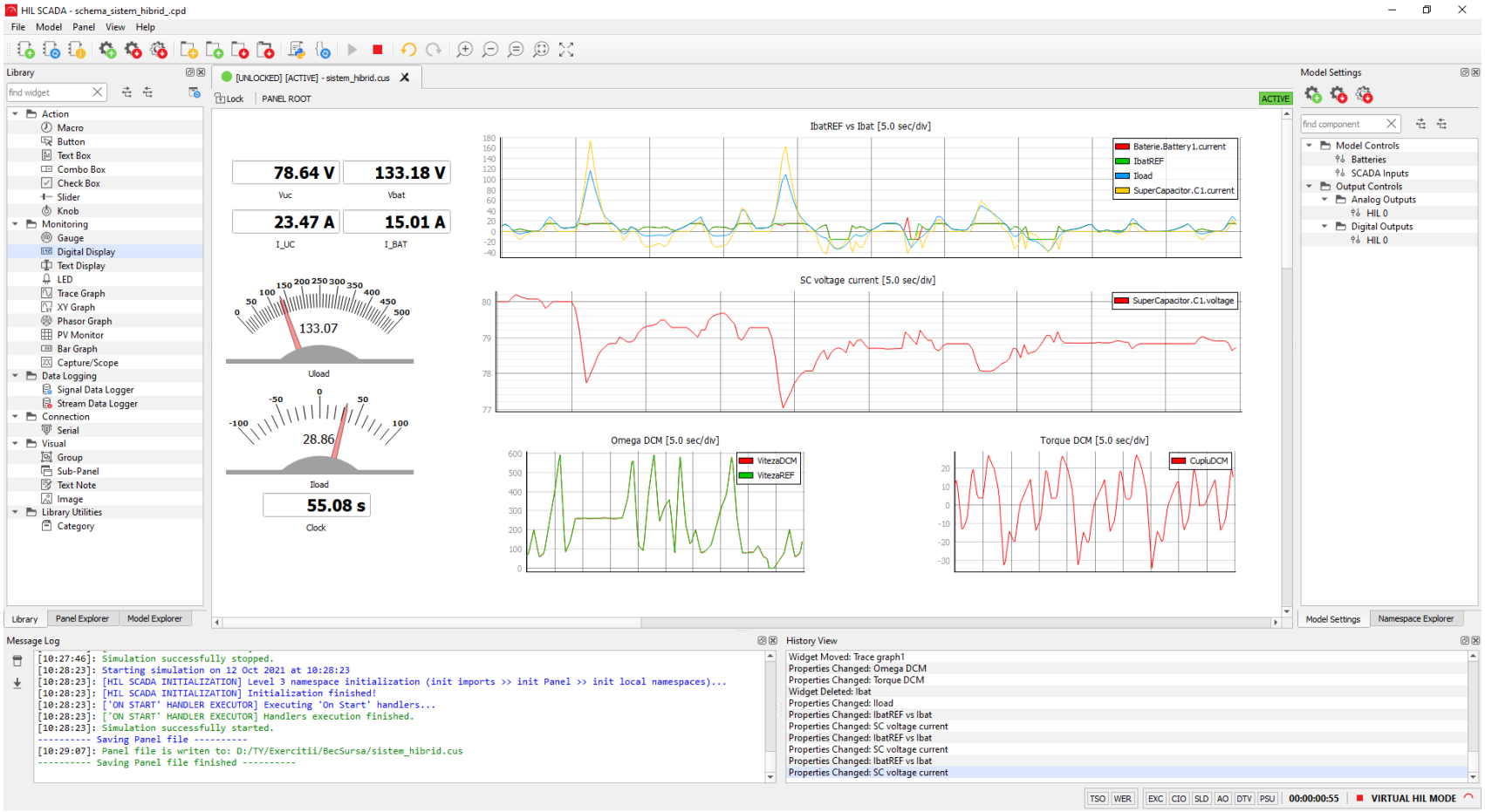
The HIL setup



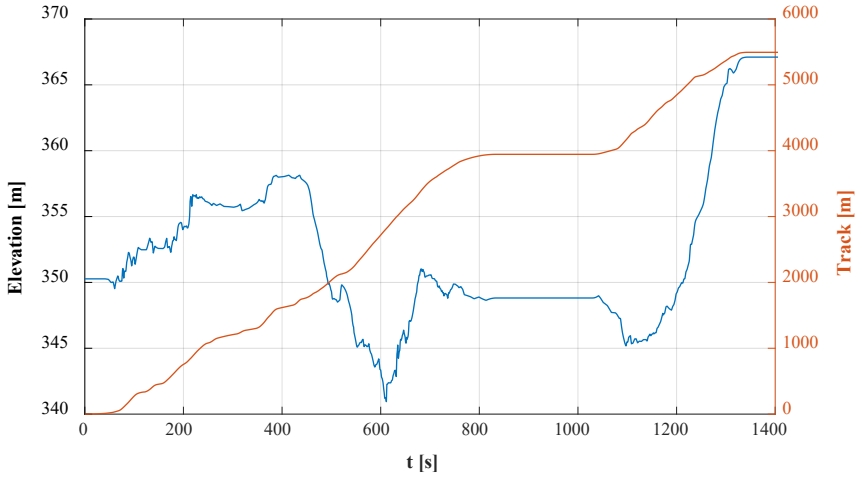
The Typhoon HIL Schematics



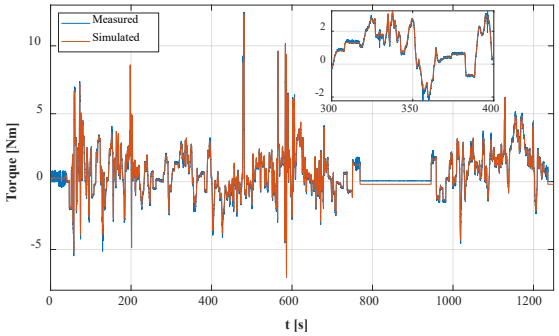
The Typhoon HIL SCADA

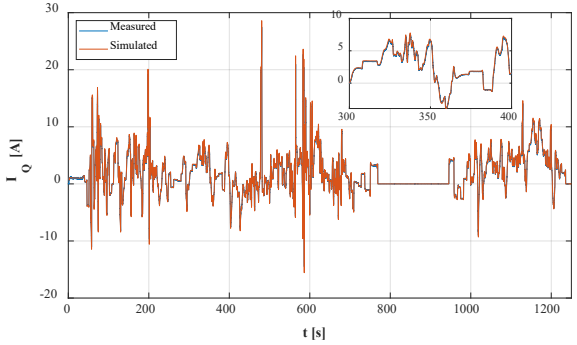


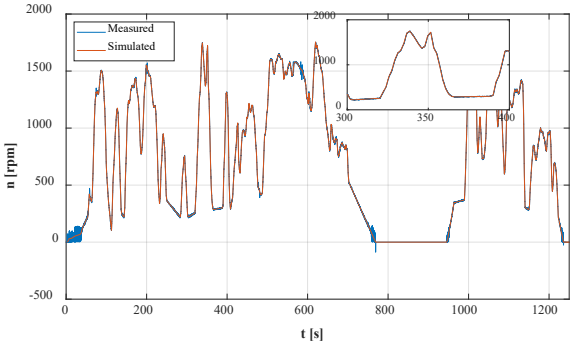
The proposed roadmap from Cluj Napoca, Romania



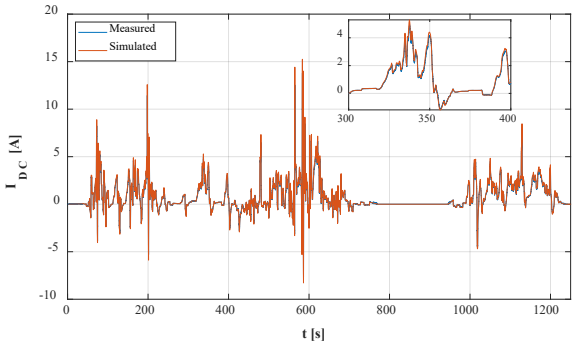
The comparison of the PMSM data

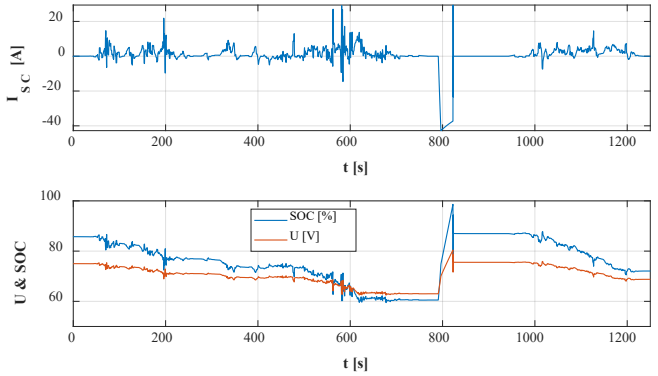






The supply data





« Conclusions»

- 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

«REFERENCES »

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« Thank you for your attention! »