EMR seminar
Lausanne
Sept. 2014

Seminar Sept. 2014
"Energetic Macroscopic Representation"

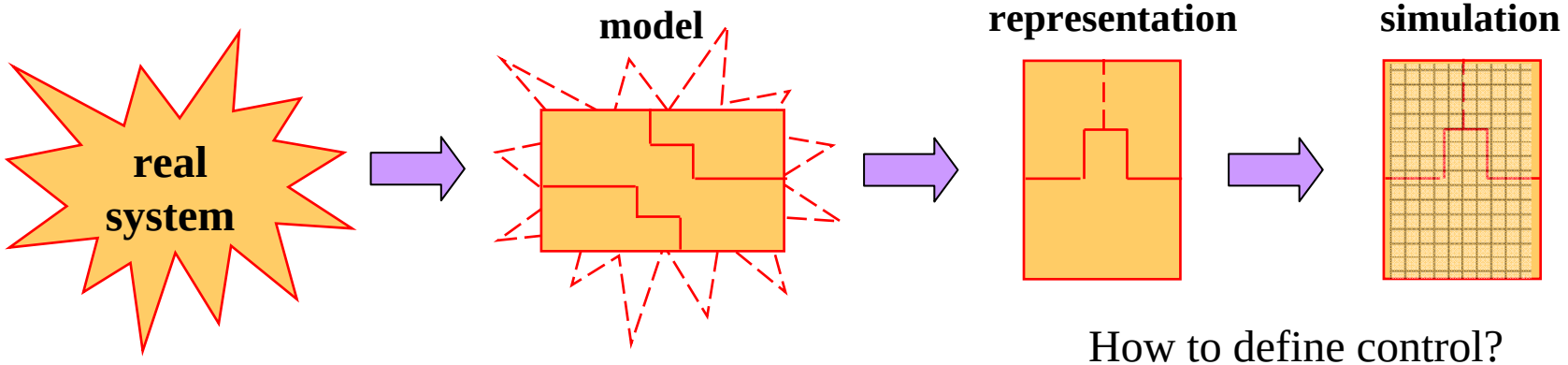
« EMR OF AN ELECTRIC VEHICLE »

Dr. W. Lhomme, Prof. A. Bouscayrol,
(L2EP, Université Lille1, France,)

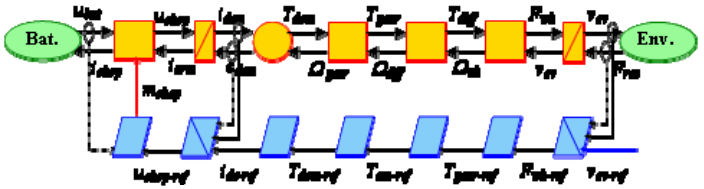
http://www.emrwebsite.org/

- Introduction -

Simulation is a key issue before working on a real system…



How to define control?



Tazzari Zero
of L2EP

$$J\frac{d}{dt}\Omega_{gear} = T_{dcm} - T_{gear} - f\Omega_{gear}$$

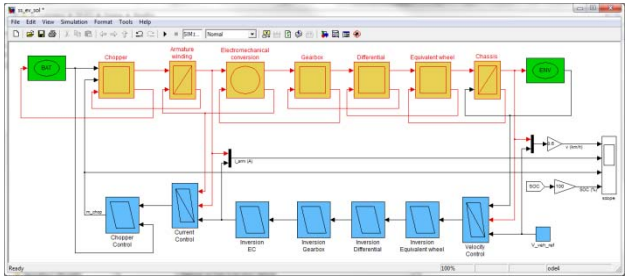
$$L_{arm}\frac{d}{dt}i_{dcm} = u_{chop} - e_{dcm} - R_{arm}i_{dcm}$$

$$\begin{cases} u_{chop} = m_{chop}\, V_{bat} \\ i_{chop} = m_{chop}\, i_{dcm} \end{cases} \quad \begin{cases} T_{dif} = k_{dif}\, T_{gear} \\ \Omega_{dif} = k_{dif}\, \Omega_{wh} \end{cases}$$

$$\begin{cases} T_{dcm} = k_{dcm} i_{dcm} \\ e_{dcm} = k_{dcm}\Omega_{gear} \end{cases} \quad \begin{cases} T_{gear} = k_{gear}\, T_{dcm} \\ \Omega_{gear} = k_{gear}\, \Omega_{diff} \end{cases}$$

$$M\frac{d}{dt}v_{ev} = F_{tot} - F_{res}$$

Which kind of model?



How to organize Simulation?

- Outline -

1. **Studied EV - Modelling**
2. **EMR of the EV**
3. **Control of the EV (objective)**
4. **More complex EVs**

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« STUDIED ELECTRIC VEHICLE - MODELLING STEP »

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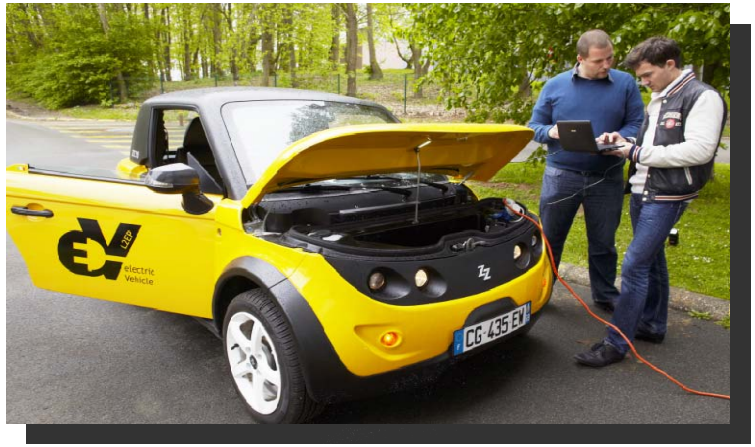
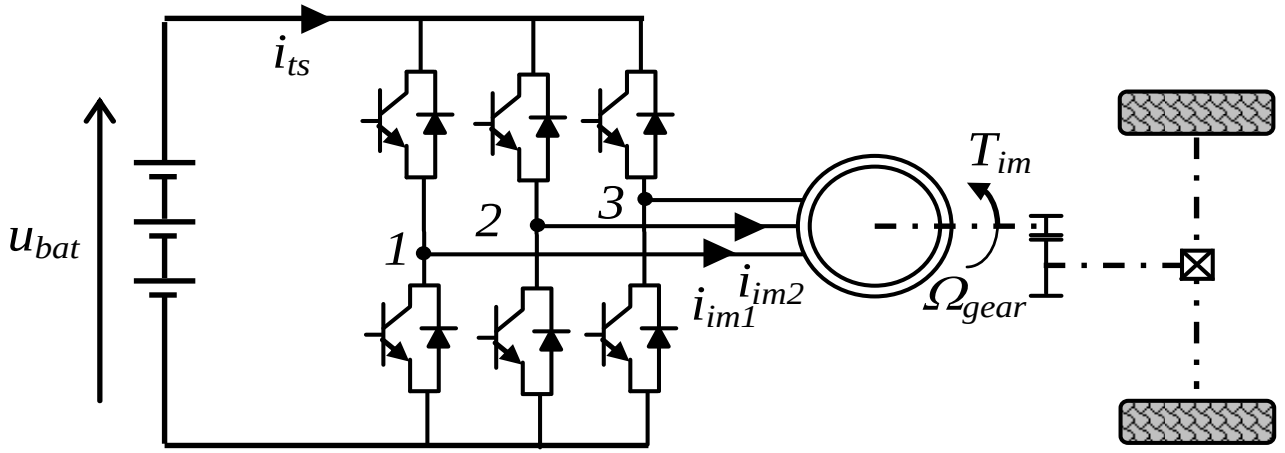
- Tazzari Zero EV -



Tazzari Zero characteristics

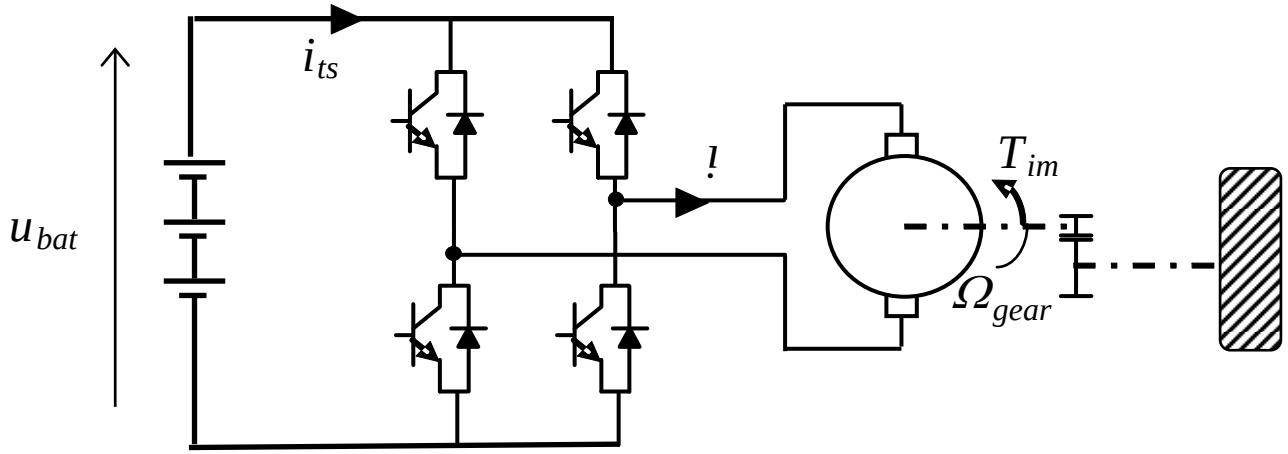
- 15 kW induction machine
- 80V 160Ah LiFePO4 battery
- 542 kg (empty mass)
- Maximum speed: 85km/h

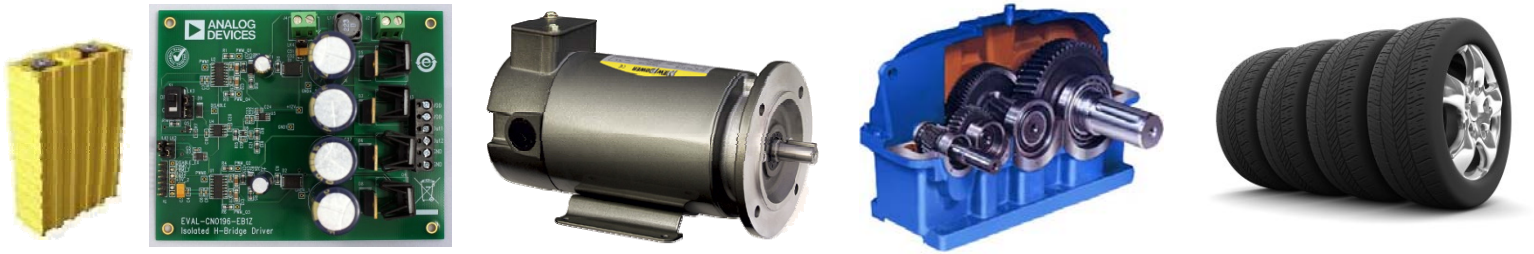


Objective:
control of the traction system

Simplifications:

- a permanent magnet DC machine is considered in a first step
- an equivalent wheel is considered (no curve)





Battery:

• *RE* model

$$V_{bat}(t) = E(t) + Ri_{chop}(\mathrm{t})$$

Chopper:

• ideal power switches

• average modelling

$$\begin{cases} u_{chop}(t) = m_{\mathrm{chop}}(t)\, V_{bat}(t) \\ i_{chop}(t) = m_{\mathrm{chop}}(t)\, i_{dcm}(t) \end{cases}$$

DC Machine:

• no magntic saturation, permanent magnets

Armature winding

$$L_{arm}\frac{d}{dt}i_{dcm}(t) = u_{chop}(t) - e_{dcm}(t) - R_{arm}i_{dcm}(t)$$

Electromagnetic conversion (PM)

$$\begin{cases} T_{dcm}(t) = k_{dcm}i_{dcm}(t) \\ e_{dcm}(t) = k_{dcm}\Omega_1(t) \end{cases}$$

Rotation shaft

$$J\frac{d}{dt}\Omega_1(t) = T_{dcm}(t) - T_1(t) - f\Omega_1(t)$$

Gearbox:

• no losses

$$\begin{cases} T_2(t) = k_{gear}\ T_1(t) \\ \Omega_1(t) = k_{gear}\ \Omega_2(t) \end{cases}$$

Wheel:

• no slip

$$\begin{cases} F_{wh}(t) = \dfrac{1}{R_{wh}} T_2(t) \\ \Omega_2(t) = \dfrac{1}{R_{wh}} v_{ev}(t) \end{cases}$$

Chassis:

$$M \frac{d}{dt} v_{ev}(t) = F_{wh}(t) - F_{res}(t)$$

Environment:

$$F_{res}(t) = F_0 + a\, v_{ev}(t) + b v_{ev}^2(t) + Mg \sin\alpha(t)$$

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« EMR OF THE EV - MODEL ORGANIZATION »

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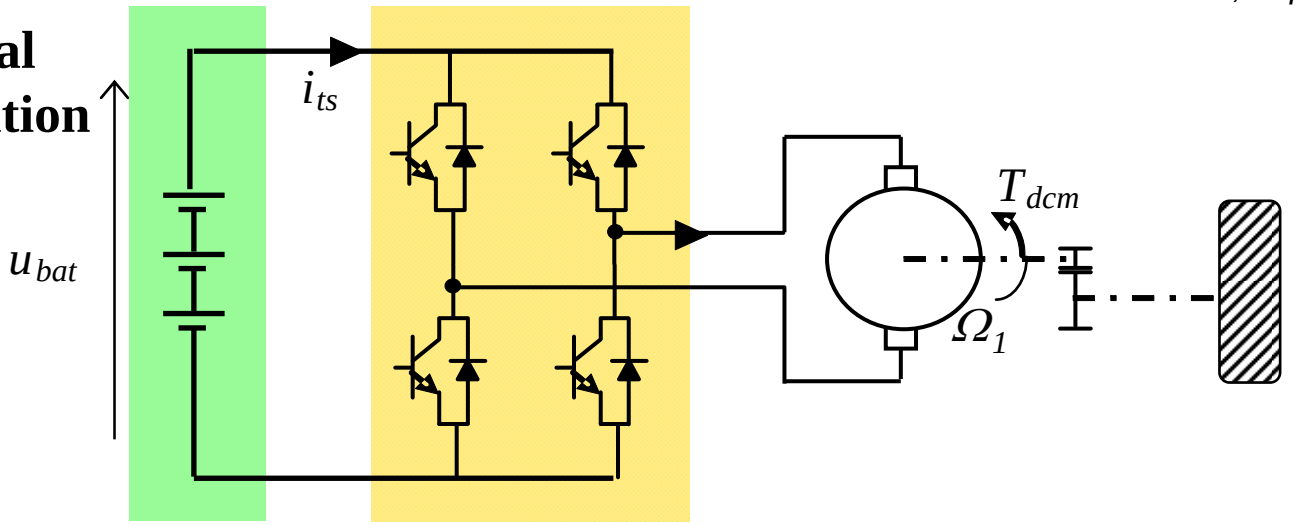
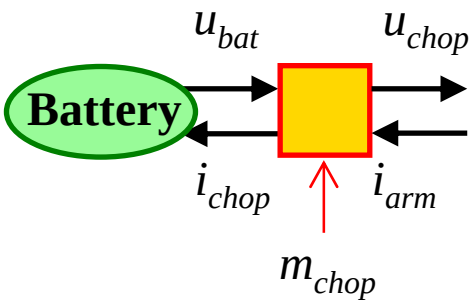
Structural Representation

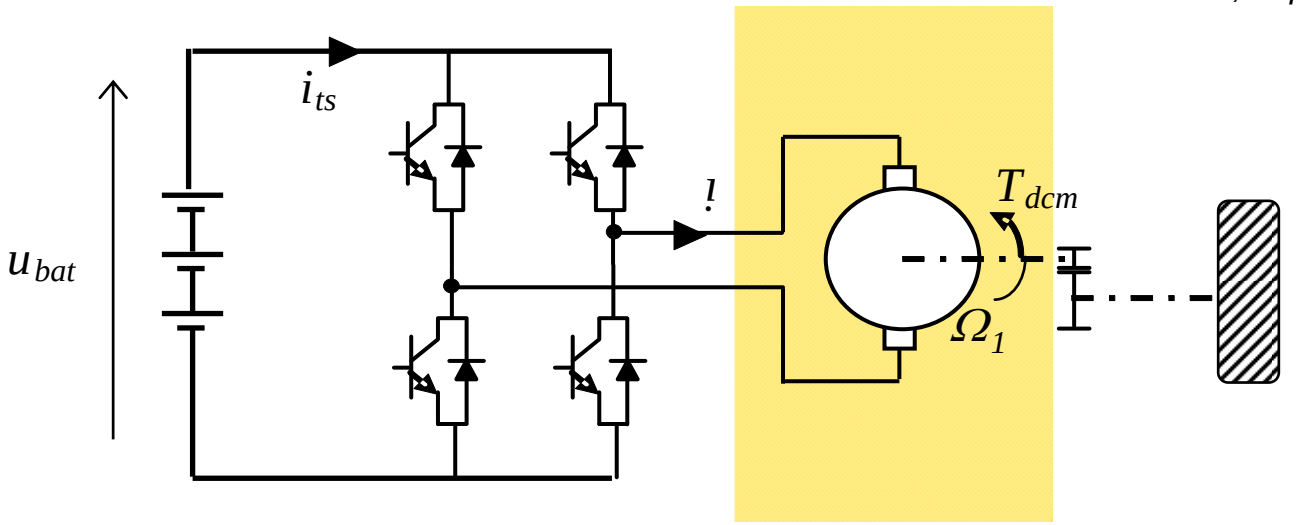


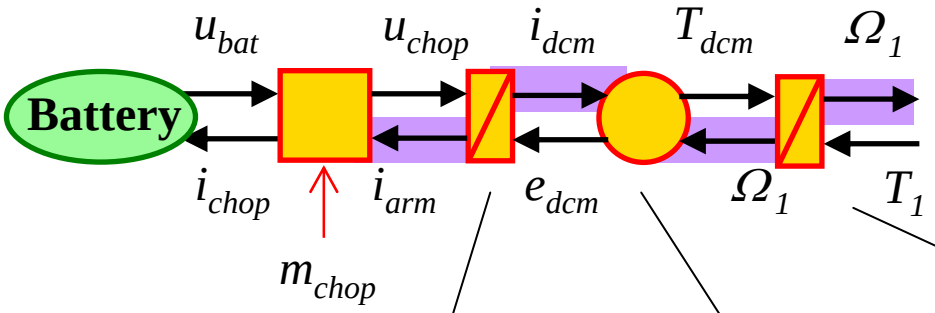
Functional Description



$$\begin{cases} u_{chop} = m_{chop} V_{bat} \\ i_{chop} = m_{chop} i_{arm} \end{cases}$$

- EMR of the EV -



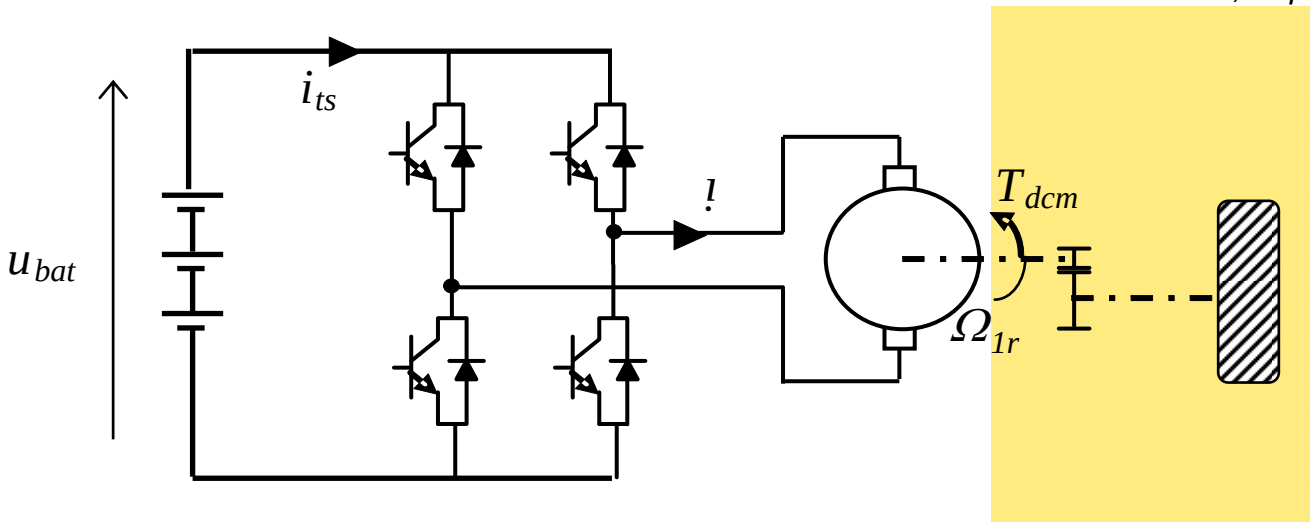


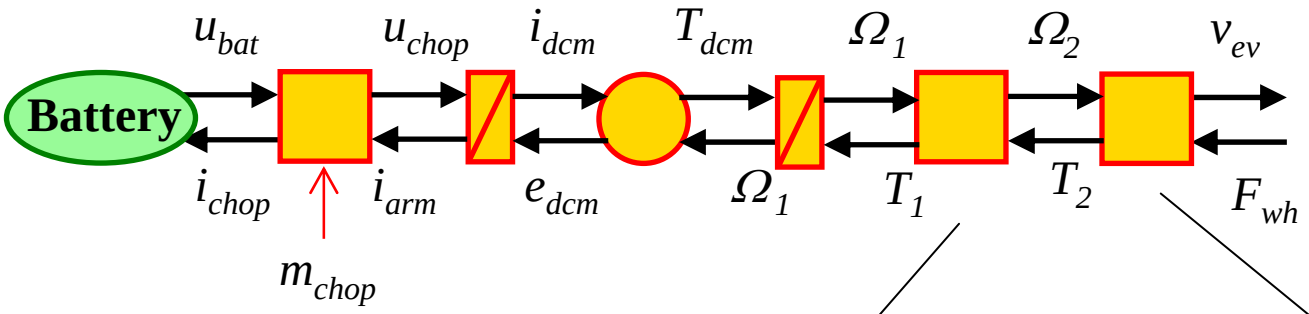
$$L_{arm}\frac{d}{dt}i_{dcm} = u_{chop} - e_{dcm} - R_{arm}i_{dcm}$$

$$\begin{cases} T_{dcm} = k_{dcm}i_{dcm} \\ e_{dcm} = k_{dcm}\Omega_1 \end{cases}$$

$$J\frac{d}{dt}\Omega_1 = T_{dcm} - T_1 - f\Omega_1$$

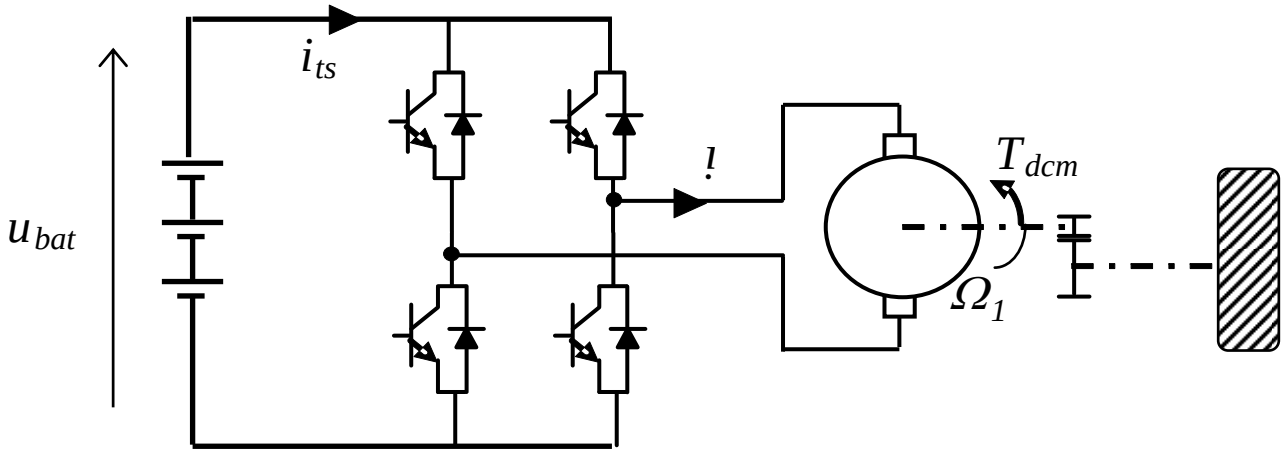
- EMR of the EV -

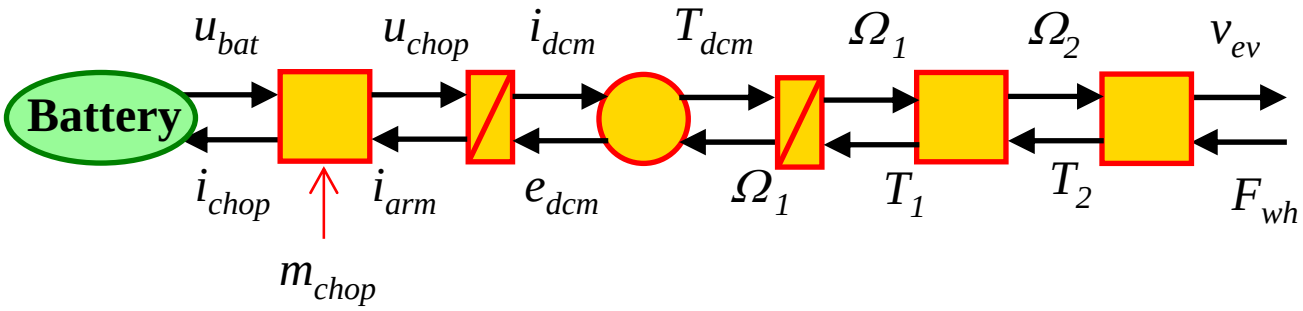


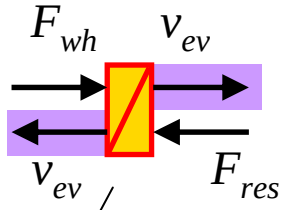


$$\begin{cases} T_2 = k_{gear}\ T_2 \\ \Omega_1 = k_{gear}\ \Omega_2 \end{cases}$$

$$\begin{cases} T_2 = R_{wh} F_{wh} \\ v_{ev} = R_{wh} \Omega_2 \end{cases}$$

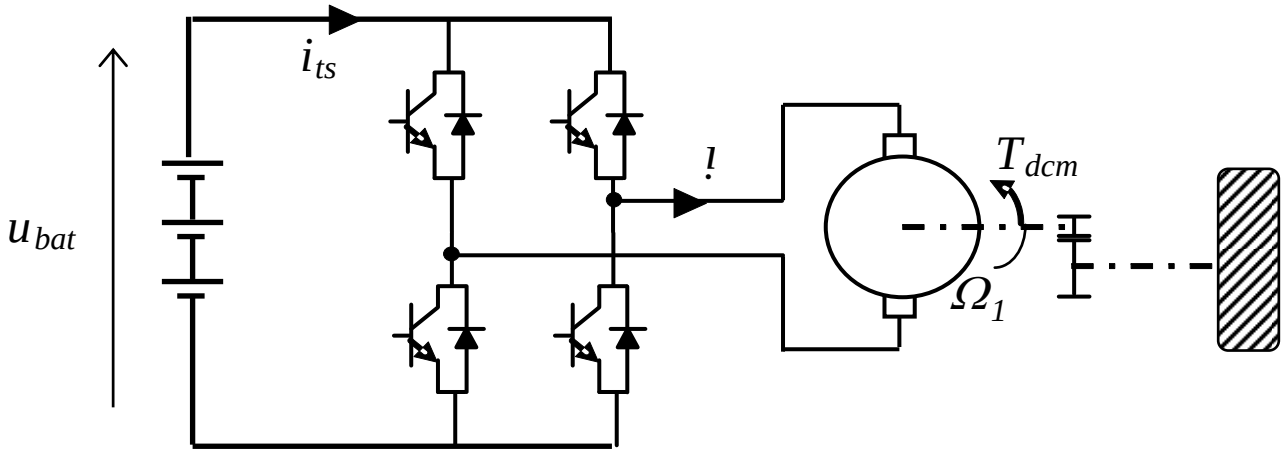


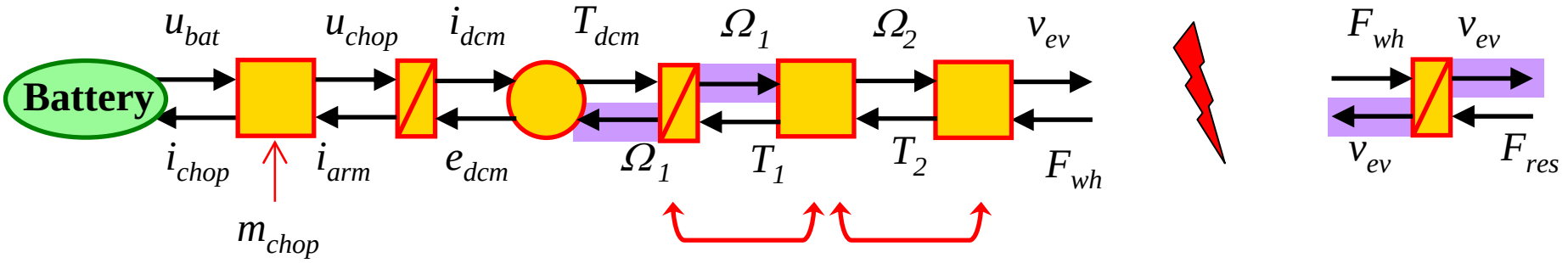




$$M \frac{d}{dt} v_{ev} = F_{tot} - F_{res}$$

- EMR of the EV -

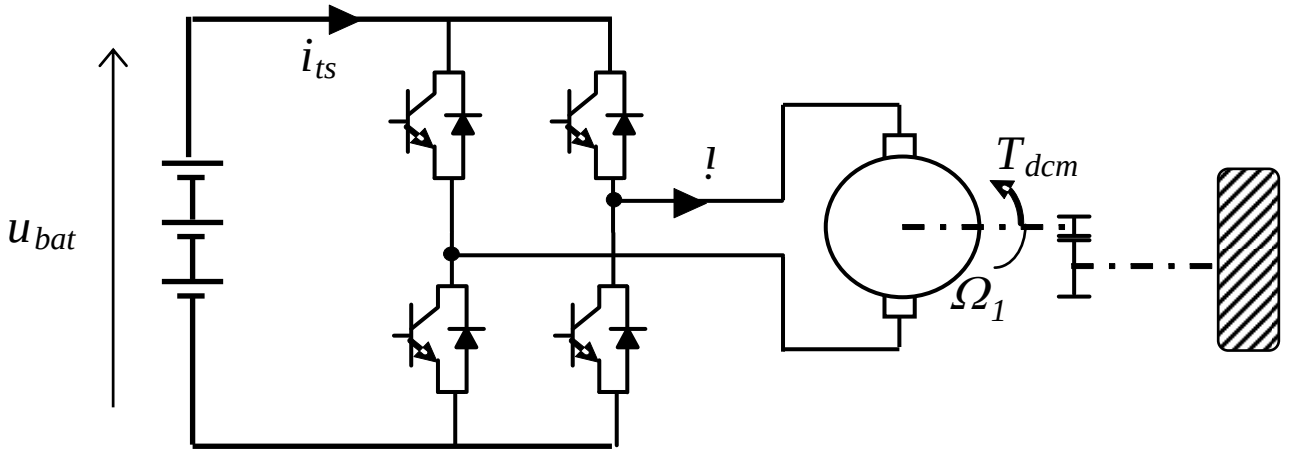


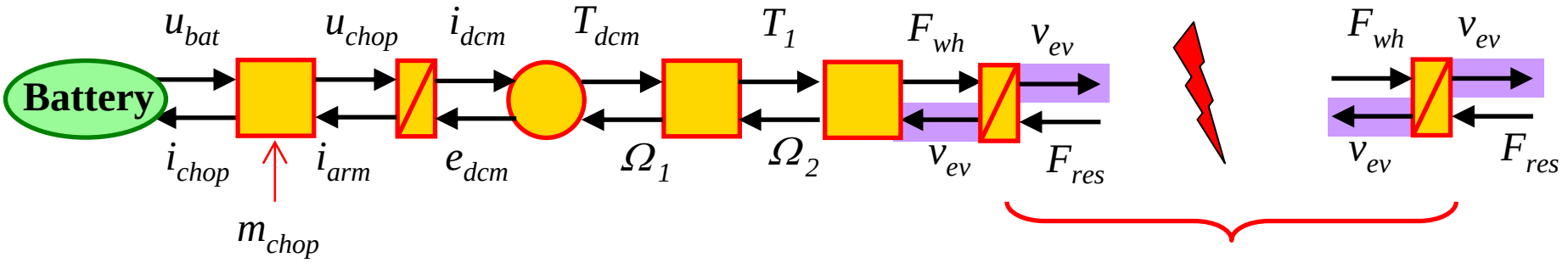


Conflict of association:

Ω_1 and v_{ev} state variables but $v_{ev} = R_{wh} k_{gear}\ \Omega_1$

- EMR of the EV -





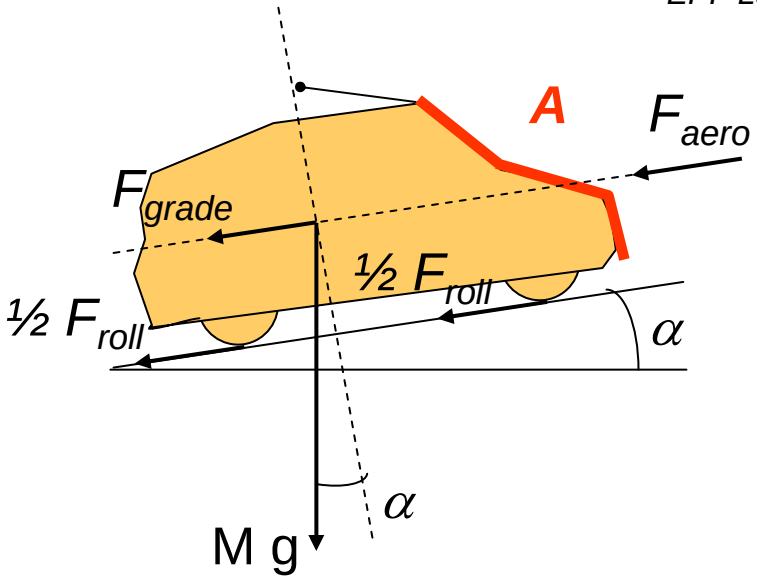
merging

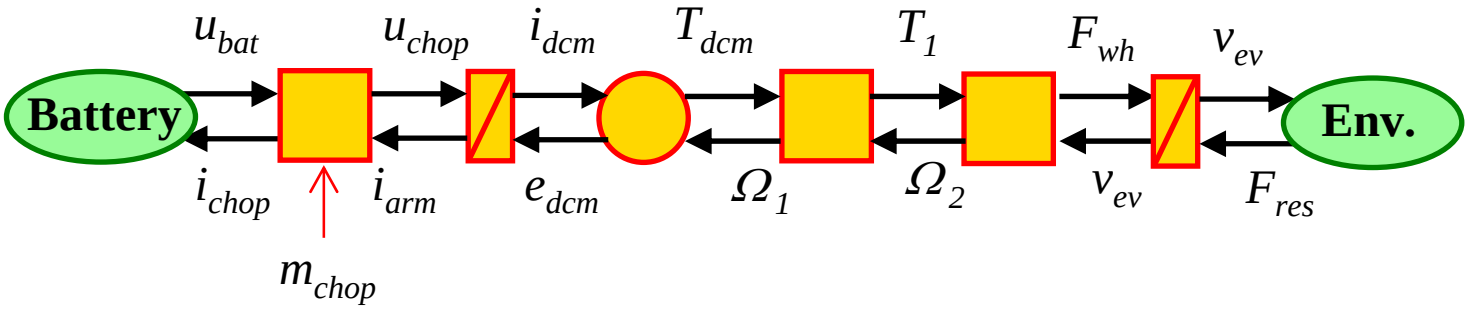
Conflict of association:
a unique state variable is required!

$$M_{eq}\frac{d}{dt}v_{ev} = F_{tot} - F_{res} - \frac{k_{gear}^2}{R_{wh}^2} f$$

$$M_{eq} = M + \frac{k_{gear}^2}{R_{wh}^2} J_{shaft}$$

- EMR of the EV -





$$F_{res} = k_{roll} Mg \cos\alpha + \frac{1}{2}\rho_{air} A C_x v_{ev}^2 + Mg \sin\alpha$$

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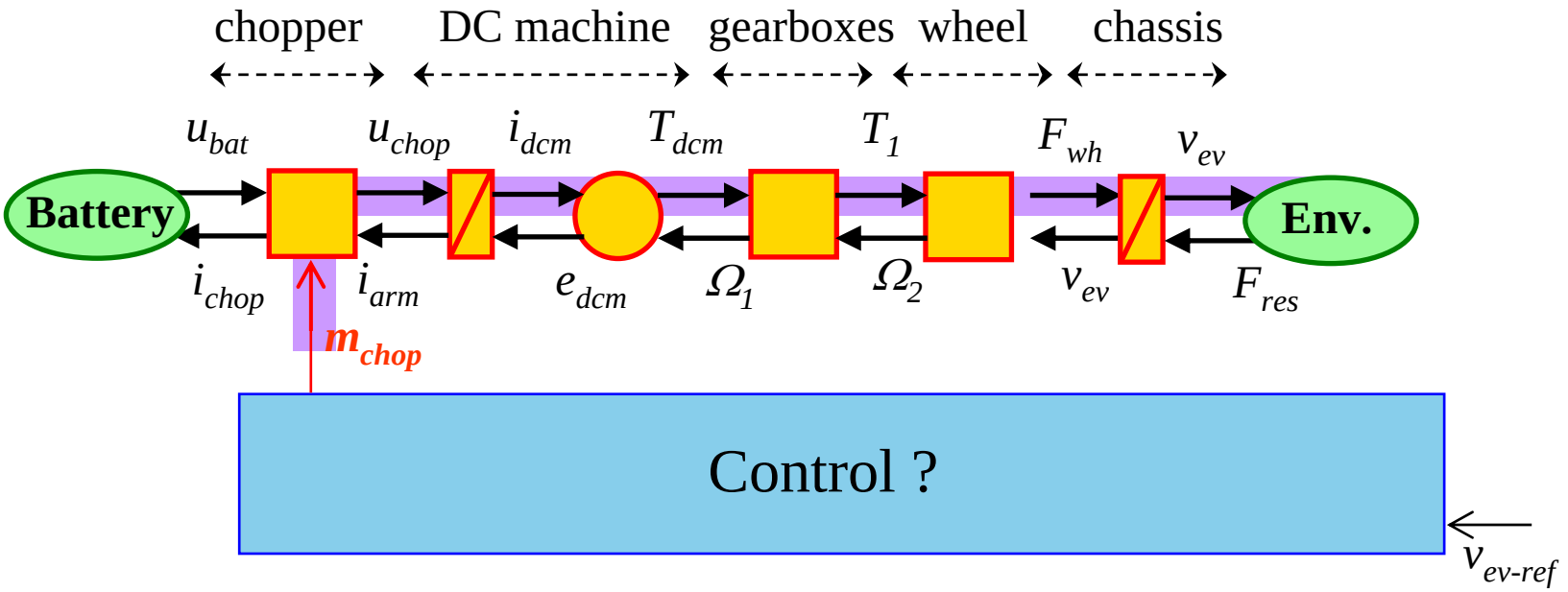
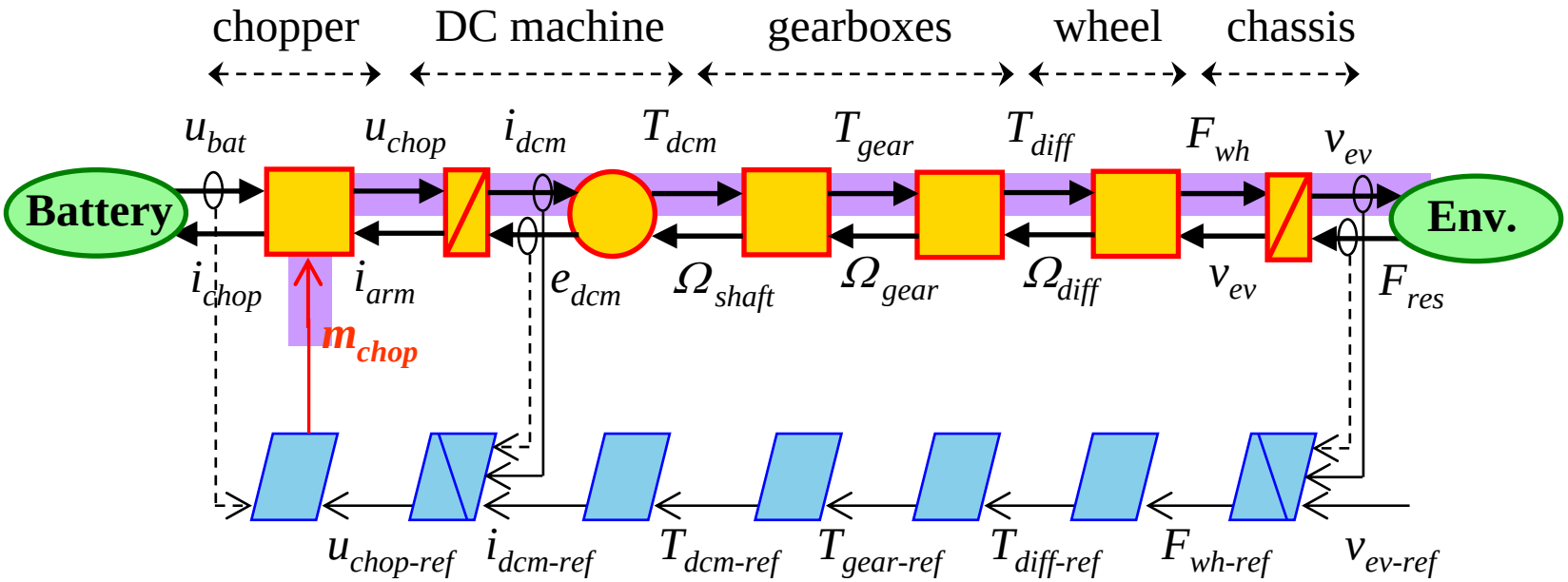
- Tuning path -



Objective: control the EV velocity

Tuning variable: modulation ratio of the DC-DC converter

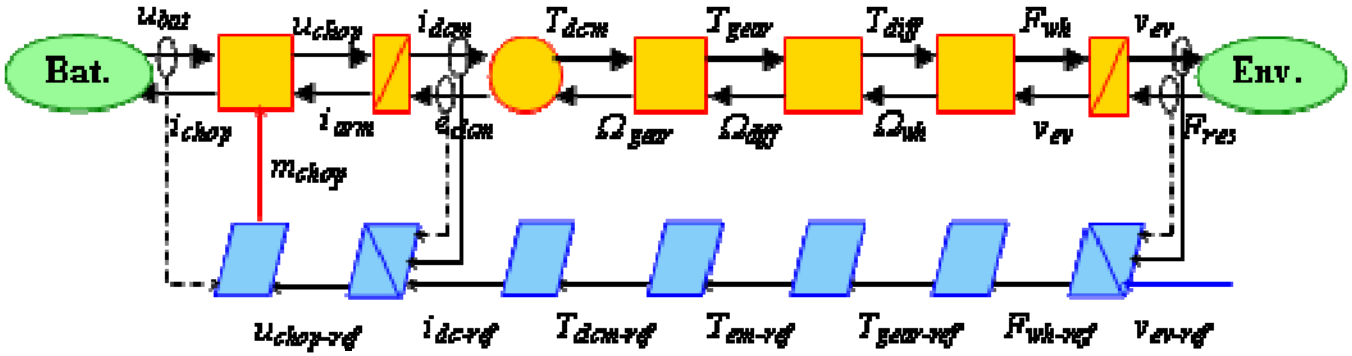
- Maximum Control Structure -

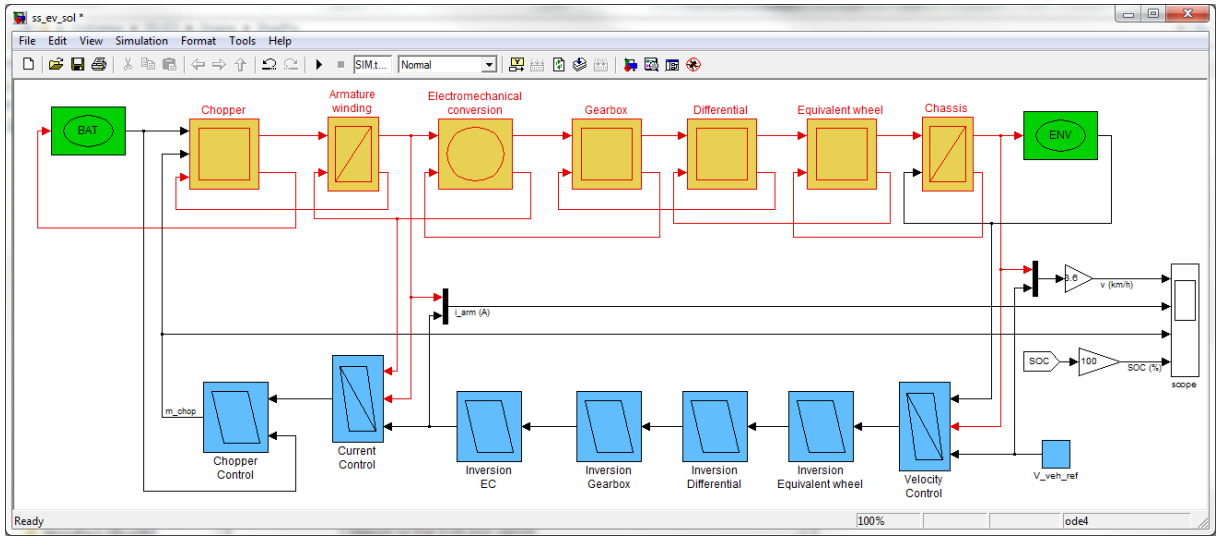


Maximum Control Structure:

- inversion of each element step-by-step
- all variables are assume measurable

- Simulation -



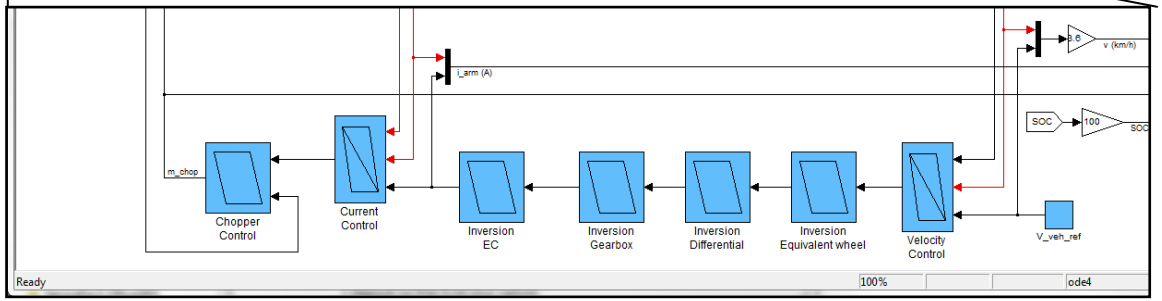


Matlab-Simulink ©, using the EMR library

- Implementation on the real vehicle -

Electronic Control Unit

sensors



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« More Complex Electric Vehicles »

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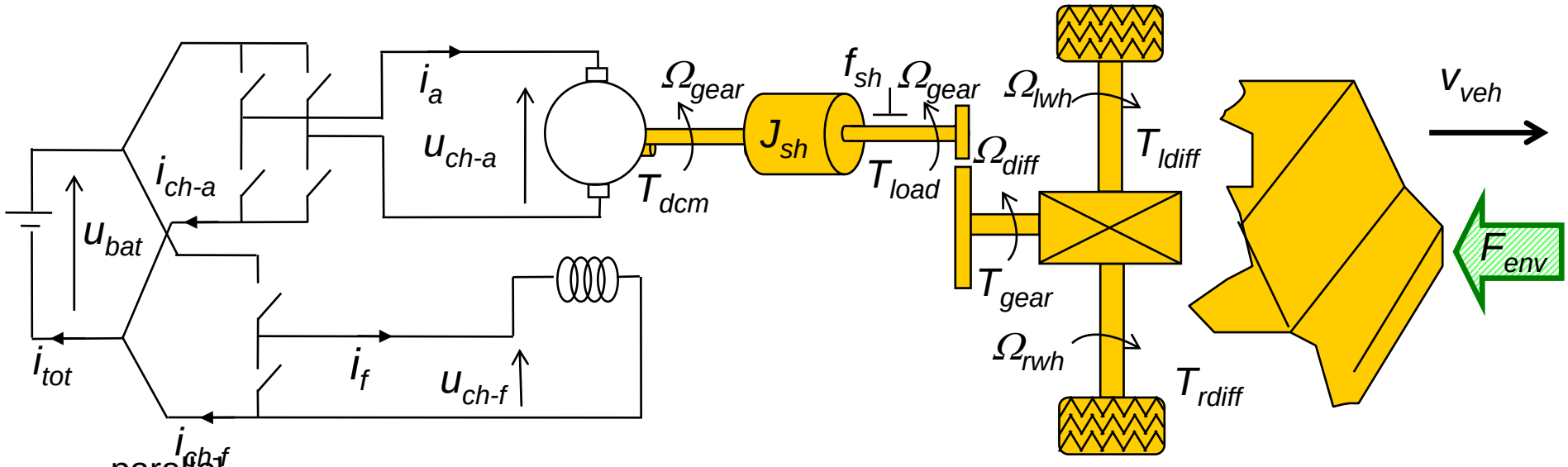
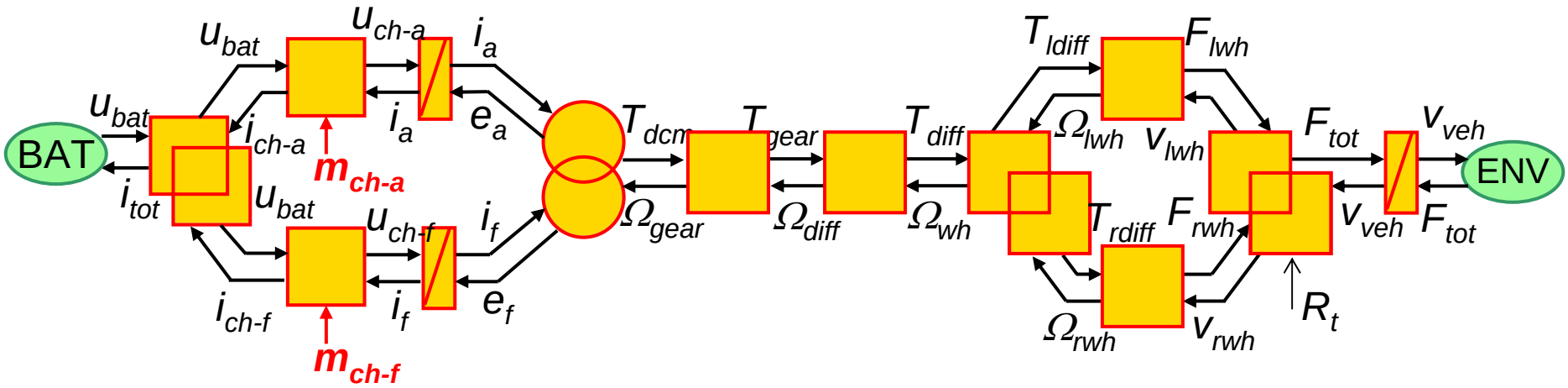
- EV with a field-winding DC machine -



parallel connection | choppers | DC machine | gearbox | differential | wheels | chassis



« REFERENCES »

- References -

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- EV with a field-winding DC machine -