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Sept. 2013

Summer School EMR'13
"Energetic Macroscopic Representation"

« EMR OF AN AUTOMATIC SUBWAY FOR AN ENERGETIC STUDY »

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- Outline -

1. **Context and objective**

2. **Dynamical model of Val 208 subway**
   - EMR
   - Inversion Based Control
   - Validation

3. **Simplified model of Val 208 subway**
   - Quasi-static model
   - Static and constant velocity models
   - Comparison of the different models

4. **Conclusion & perspectives**

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« CONTEXT AND OBJECTIVE »

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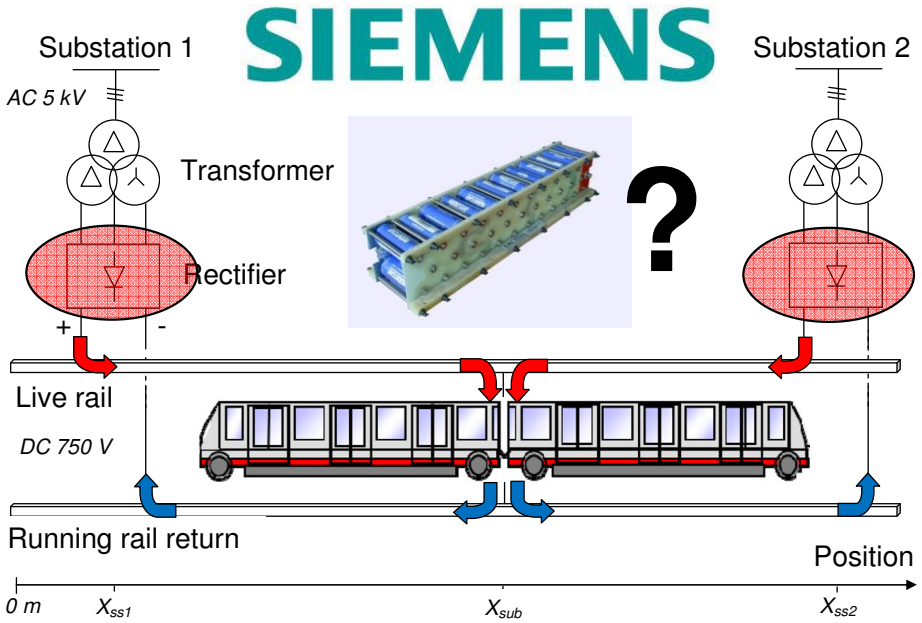
- Context and Objective -

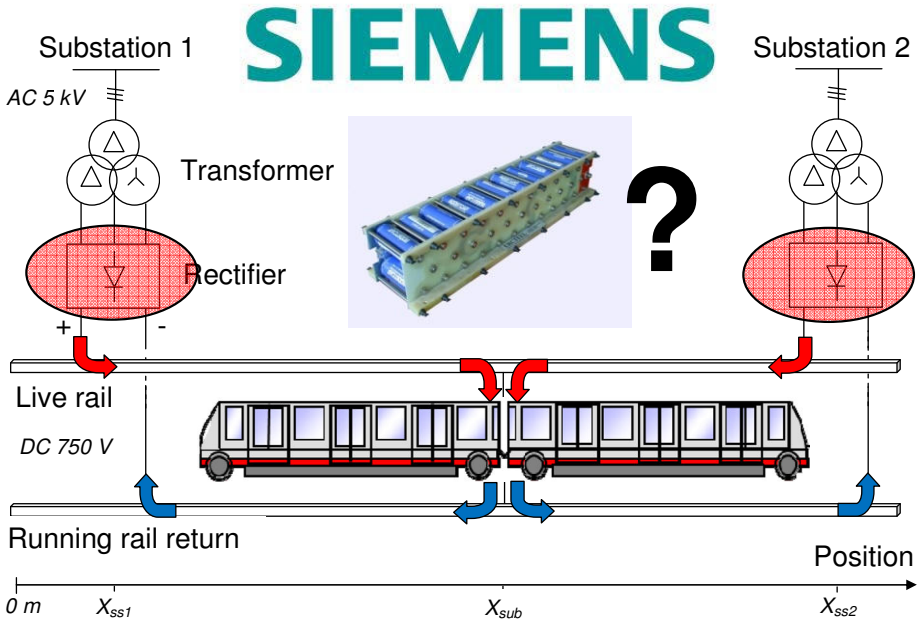


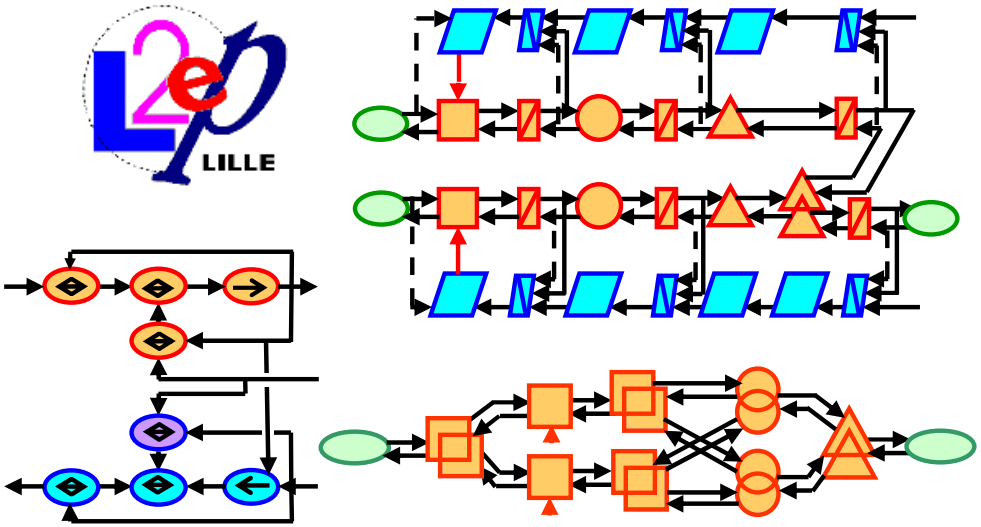
The energy consumption of subway lines has to be reduced

- ❑ Energetic Storage Systems (ESS)
- ❑ Reversible Substation
- ❑ Improved of the system control
- ❑ …

These new solutions increase the complexity of the system !

- Context and Objective -





The complexity of the system leads to more complex studies

- ❑ Simulation tools
- ❑ Modeling of the entire system (vehicles, substations, ESS, rails…)

Requires modeling and representation tools

- ❑ Energetic Macroscopic Representation (EMR), Causal Ordering Graph (COG), (Bond-Graph)…

Realize an energetic simulation tool of a subway line !

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« DYNAMICAL MODEL OF VAL 208 SUBWAY »

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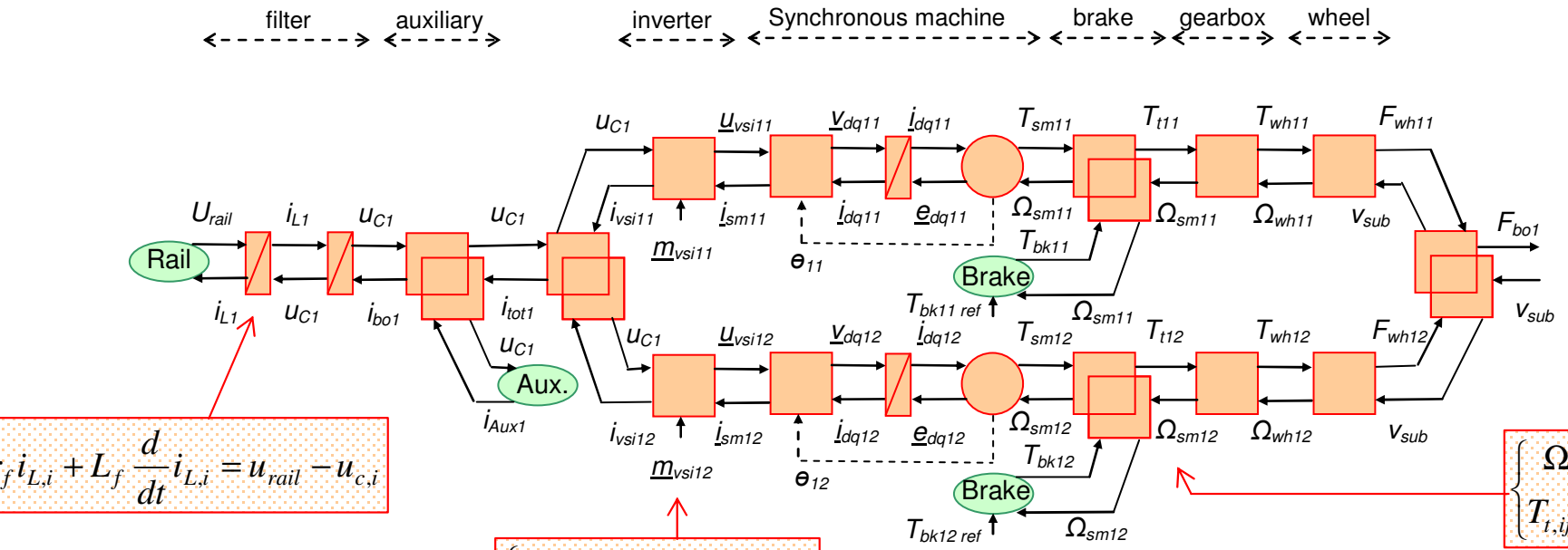
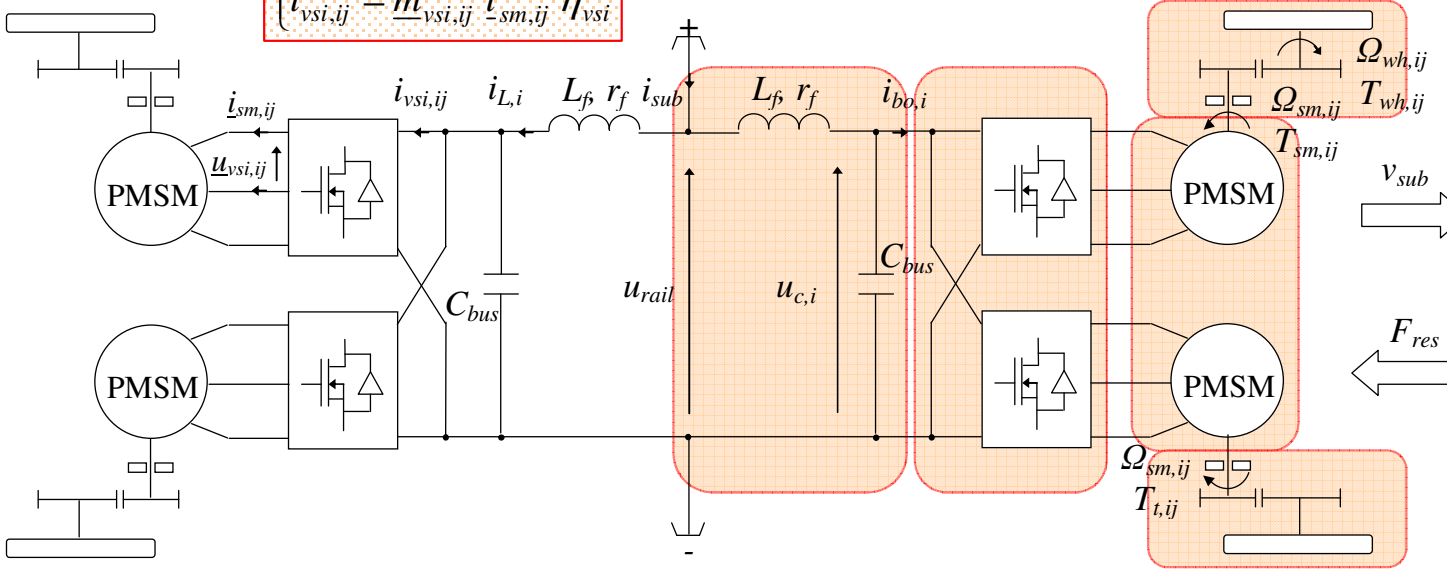
- EMR of Val 208 Subway -



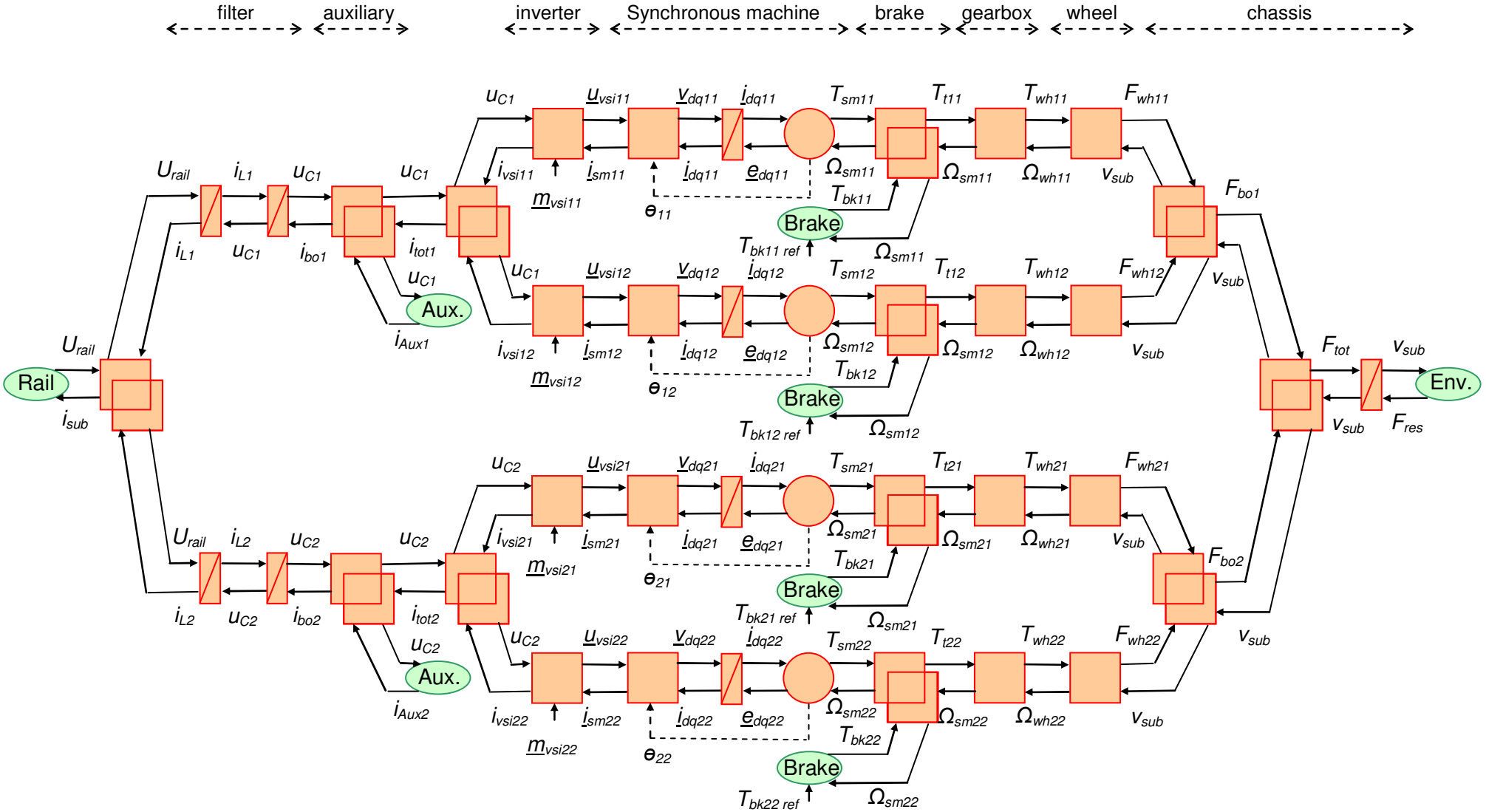
$$r_f i_{L,i} + L_f \frac{d}{dt} i_{L,i} = u_{rail} - u_{c,i}$$

$$\begin{cases} \underline{u}_{vsi,ij} = \underline{m}_{vsi,ij}\, u_{c,i} \\ i_{vsi,ij} = \underline{m}^{t}_{vsi,ij}\, \underline{i}_{sm,ij}\, \eta^{k}_{vsi} \end{cases}$$

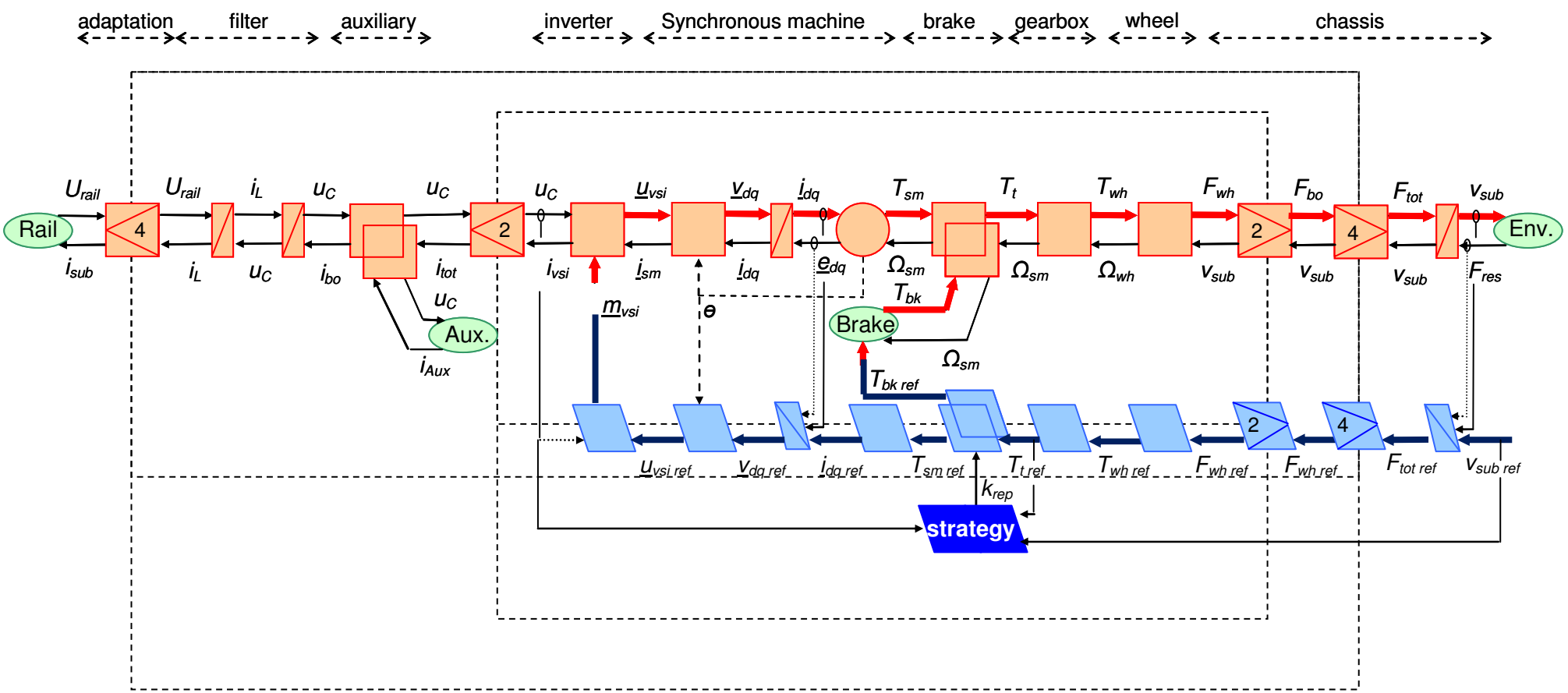
$$\begin{cases} \Omega_{sm,ij} \text{ common} \\ T_{t,ij} = T_{sm,ij} + T_{bk,ij} \end{cases}$$



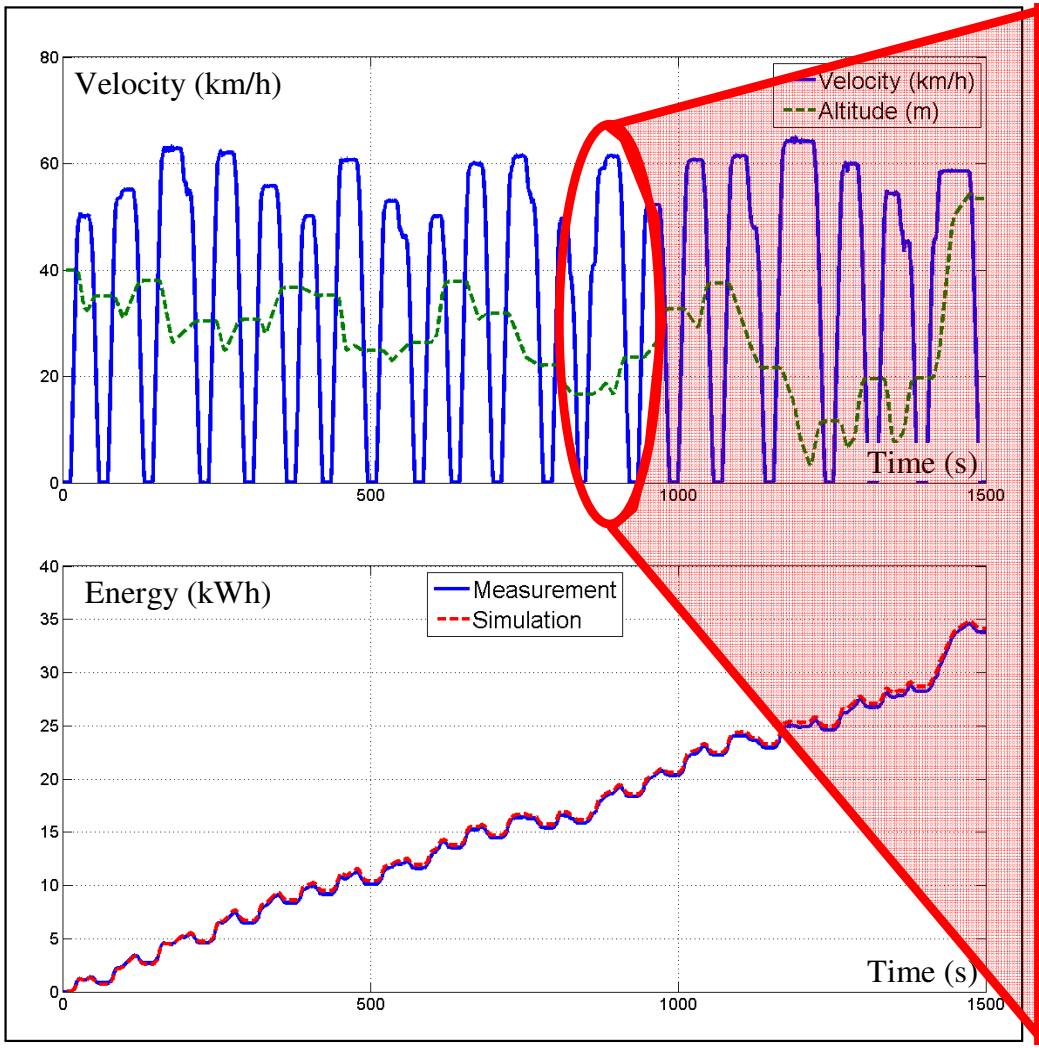
- EMR of Val 208 Subway -

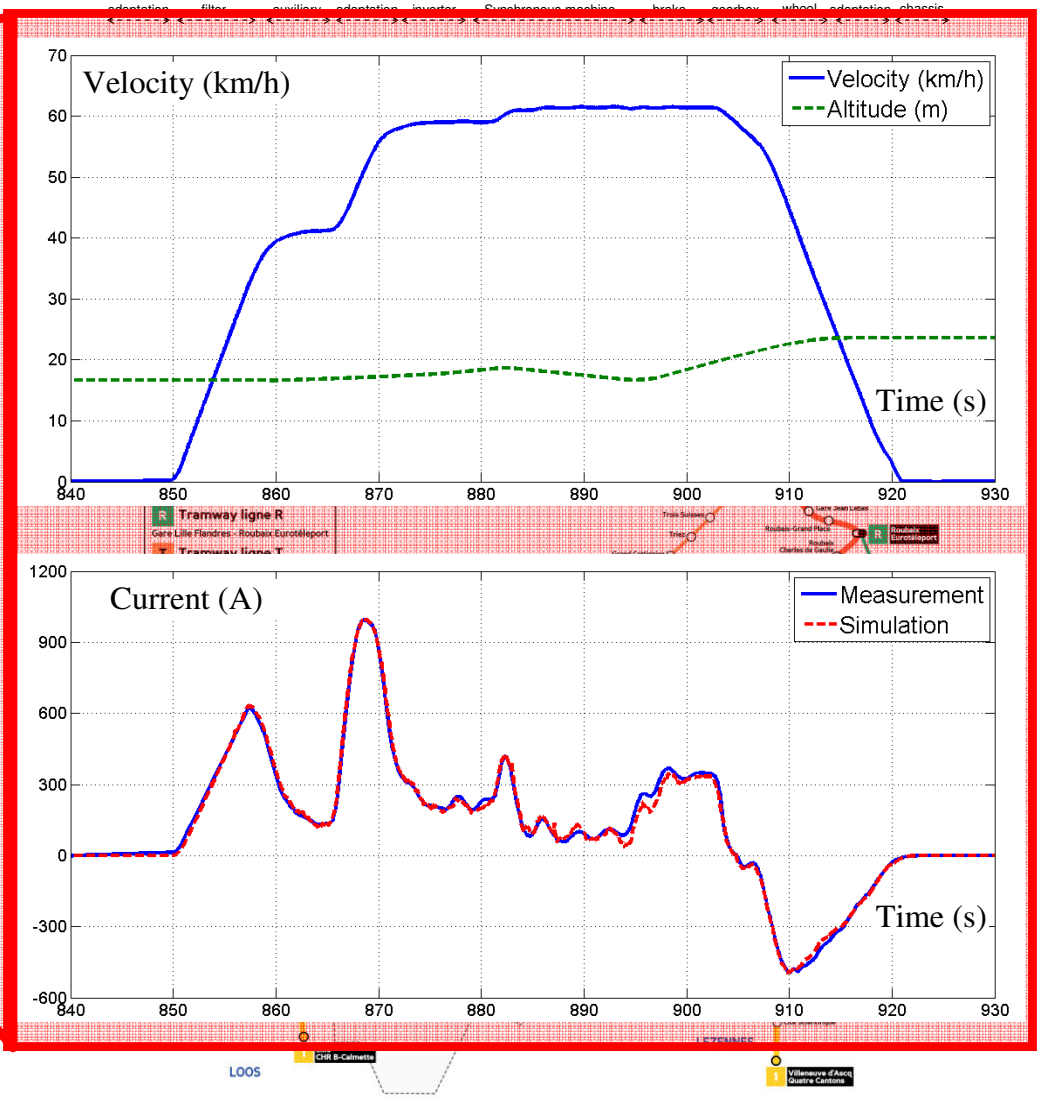


- IBC of Val 208 Subway -



- Validation of Val 208 model -





Energetic error of about 3 %, but very long simulation time (185 s)…

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« SIMPLIFIED MODELS OF VAL 208 SUBWAY »

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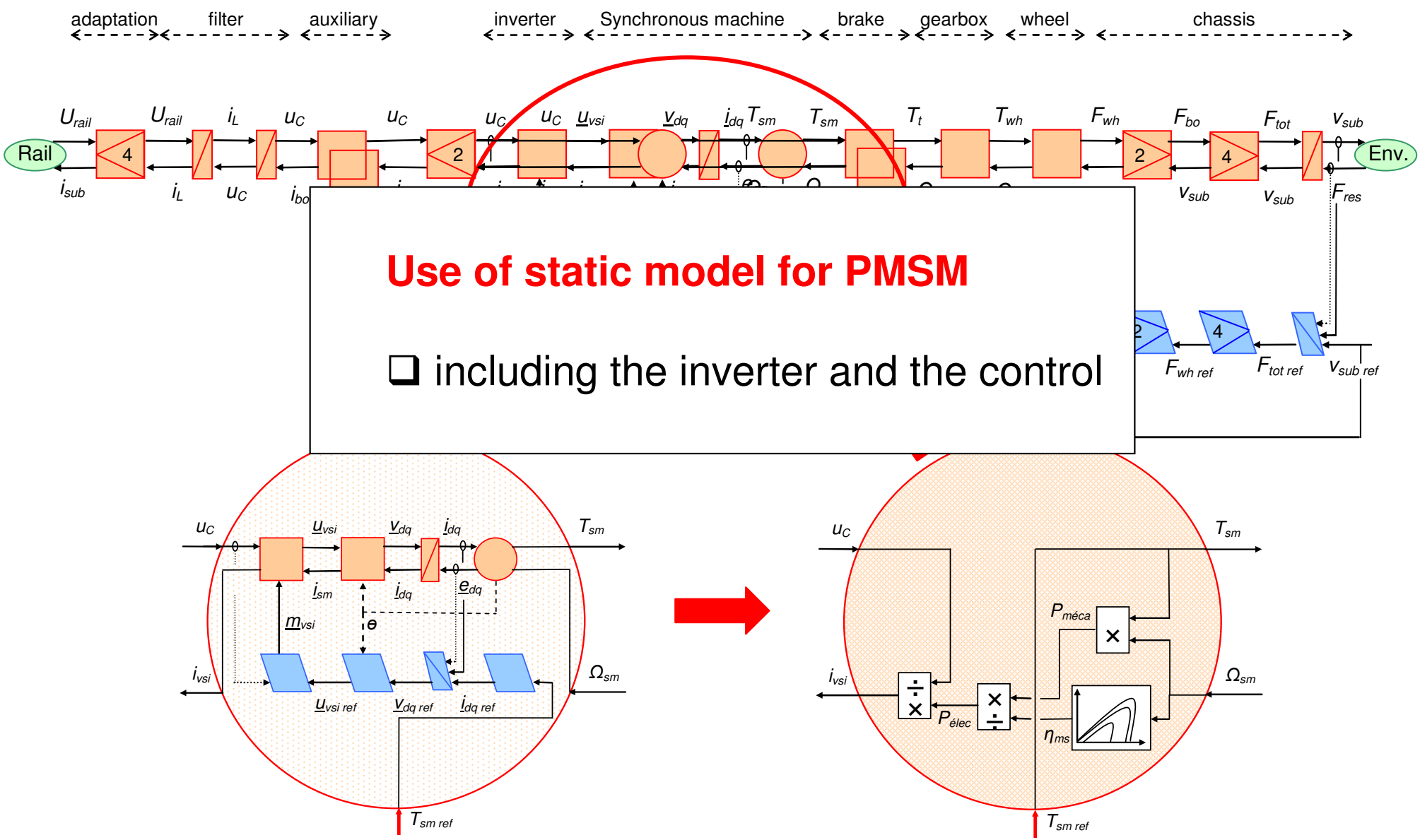
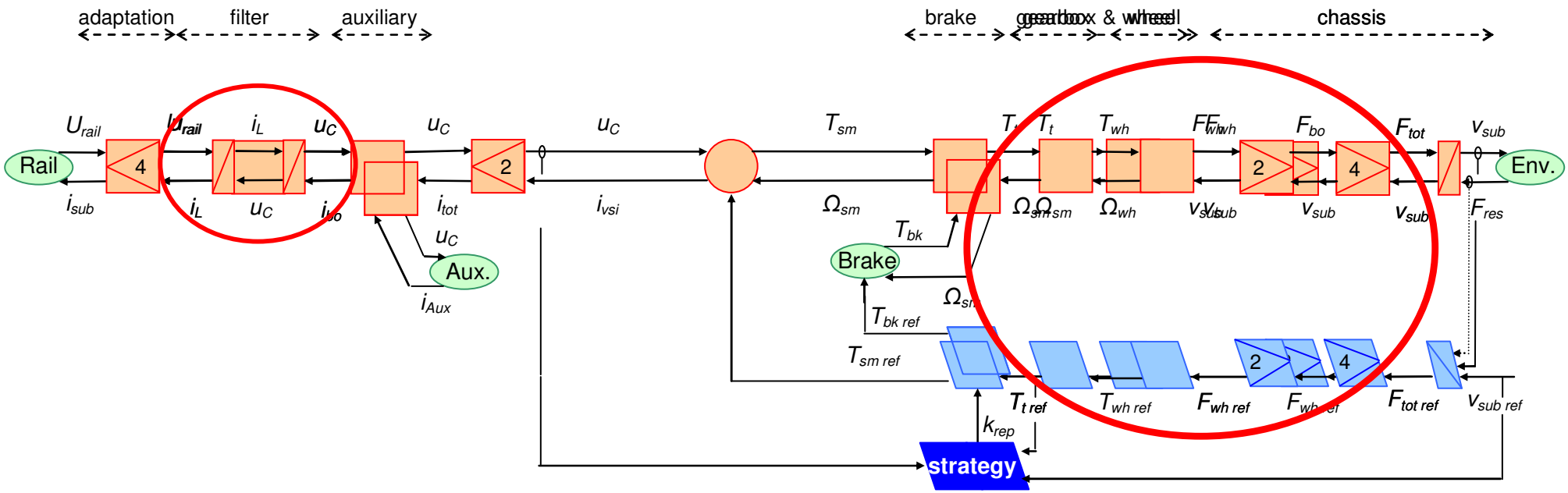
- Quasi-static model -

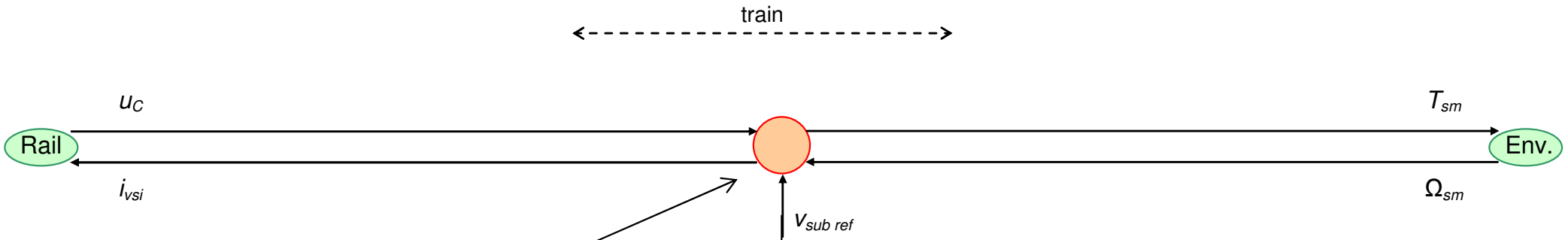


- Quasi-static model -



- Use of static model for the filter and the PMSM
- Merging of some elements
- Just the main dynamic is considered

- Static and constant velocity models -



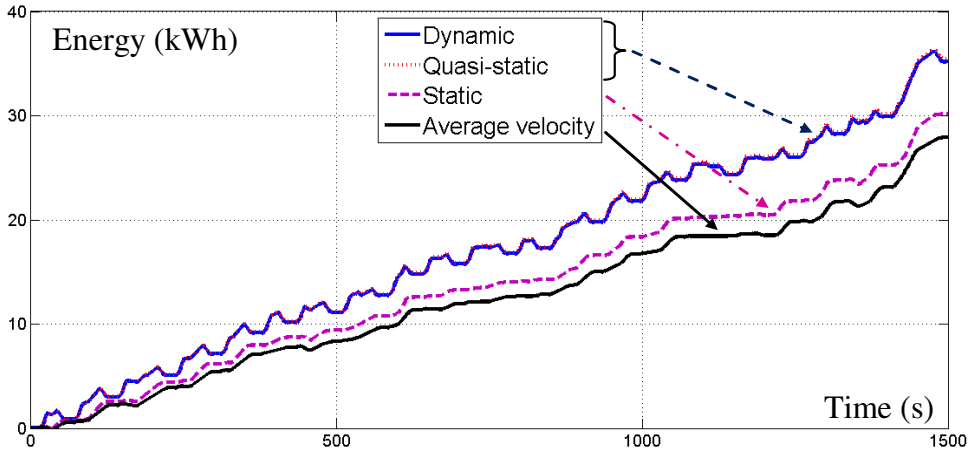
$$i_{sub} = \frac{v_{sub} F_{res}}{\eta_{sub}^{k} u_{rail}} \quad \text{with} \quad k = \begin{cases} -1 & \text{when } v_{sub} F_{\text{res}} < 0 \\ 1 & \text{when } v_{sub} F_{\text{res}} > 0 \end{cases}$$

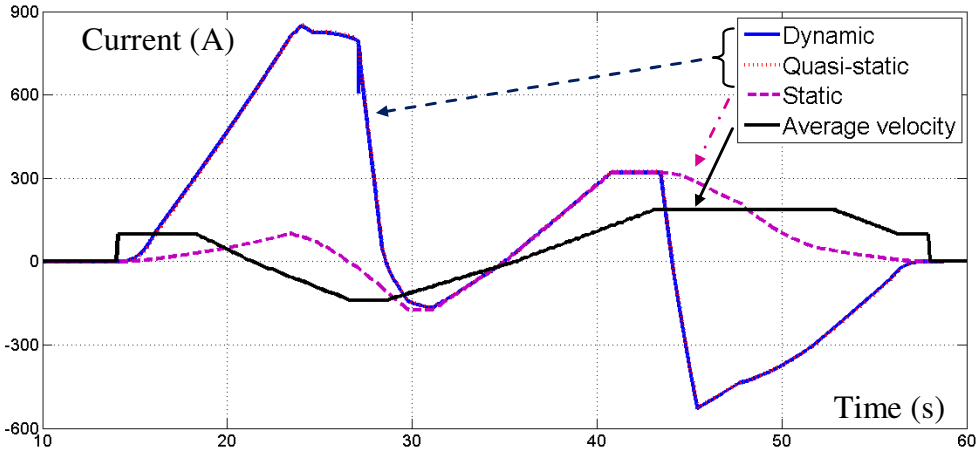
Static and constant velocity models

- ❑ None dynamics are considered
- ❑ These models are sometime used to compare different electrical topology

- Comparison of the different models -

MODELS	STEP TIME	COMPUTATION TIME	ΔW
Dynamical	1 ms	185 s	0 %
Quasi-static	50 ms	1.92 s	0.77 %
Static	100 ms	0.25 s	14.16 %
Constant velocity	100 ms	0.23 s	20.54 %





The quasi-static model seems the most suitable for an energetic study.

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« CONCLUSION & PERSPECTIVE »

Conclusion

- ❑ Description of Val 208 subway using EMR
- ❑ Validation of the model
- ❑ Deduction of different simplified models from the dynamical model
- ❑ Determination of an appropriate model for an energetic study

Perspective

- ❑ Introduce this model in the simulation tool of the subway line
- ❑ Test new electrical structure (ESS, RSS…) and new energy management.

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« BIOGRAPHIES AND REFERENCES »

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