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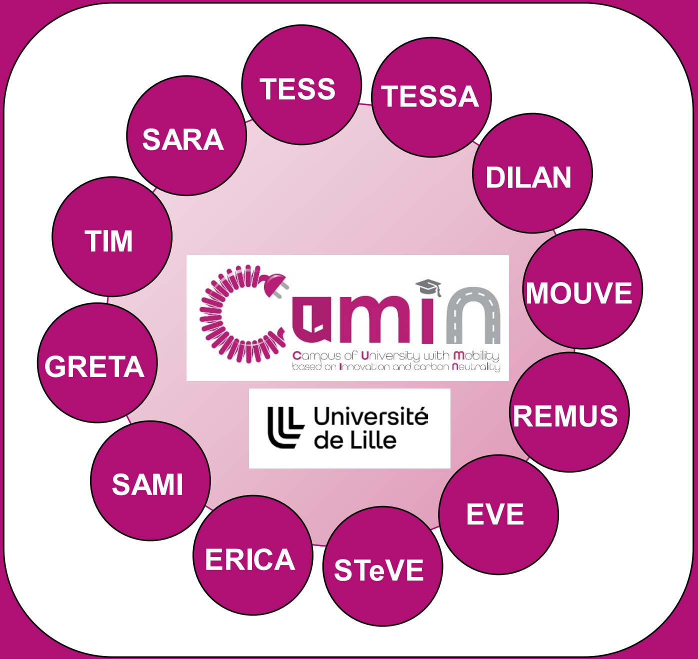

CUMIN - REMUS

Energy Consumption of the Subway

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Dr. Clément MAYET,
Prof. Alain BOUSCAYROL

L2EP, University of Lille, France

Erasmus+ | L2EP Laboratoire d'électrotechnique et d'électronique de puissance de Lille | Université de Lille

MEL MÉTROPOLE EUROPÉENNE DE LILLE

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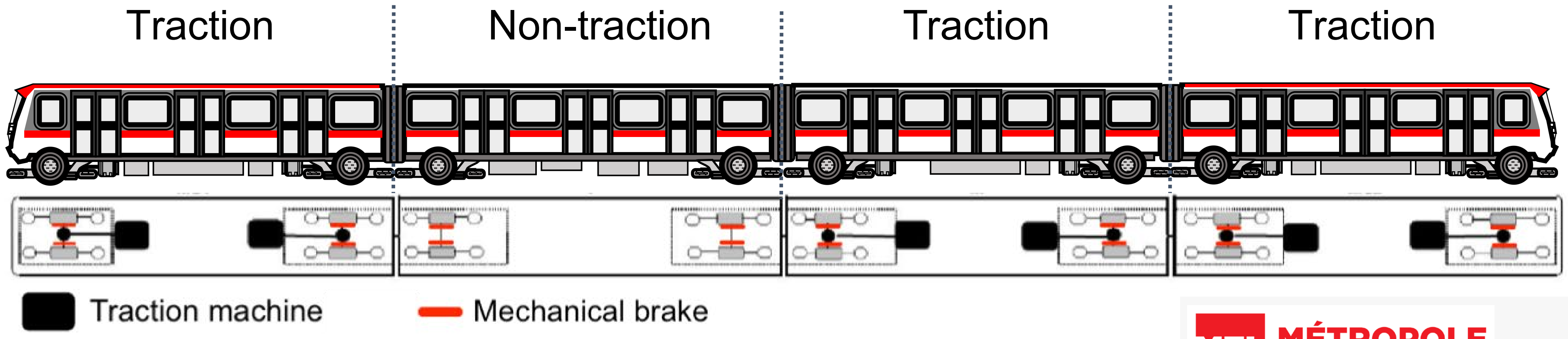
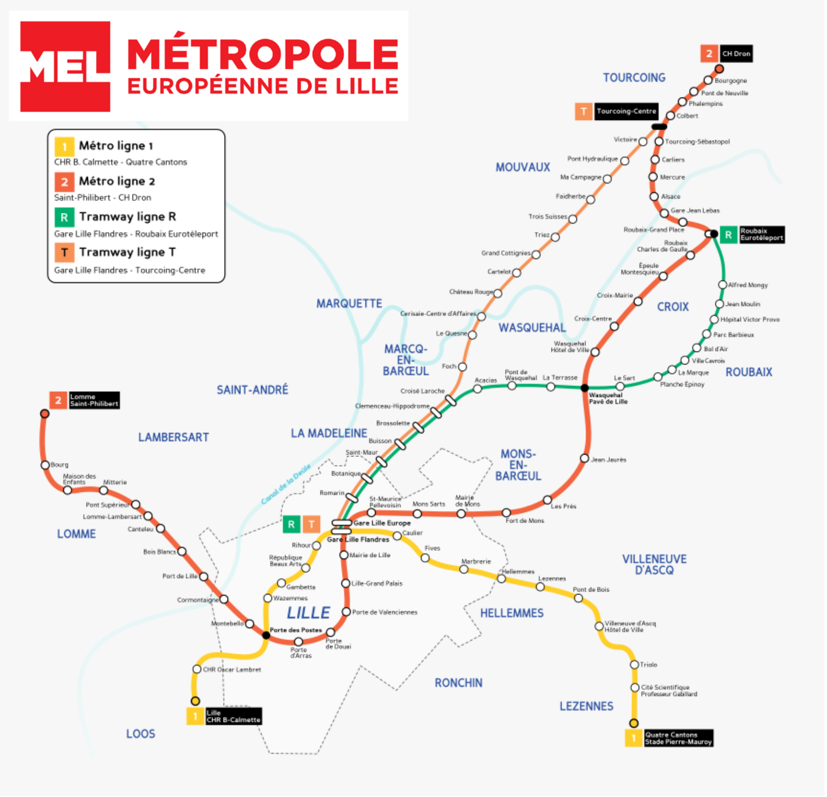
REMUS (**RE**ecovery of **M**etro braking energy for a s**US**tainable university)



New Rolling Stock (**NMR** - Nouveau Matériel Roulant)
- Metro Line N°1 of Lille
- manufactured by Alstom



Objective: develop simulation and test potential new energy management strategy.

Outline

1. Subway Simulation
2. New Energy Management
3. Simulation Results
4. Conclusions & Perspectives

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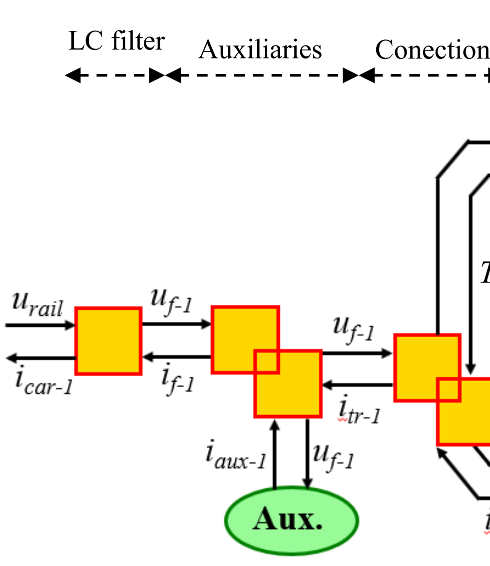
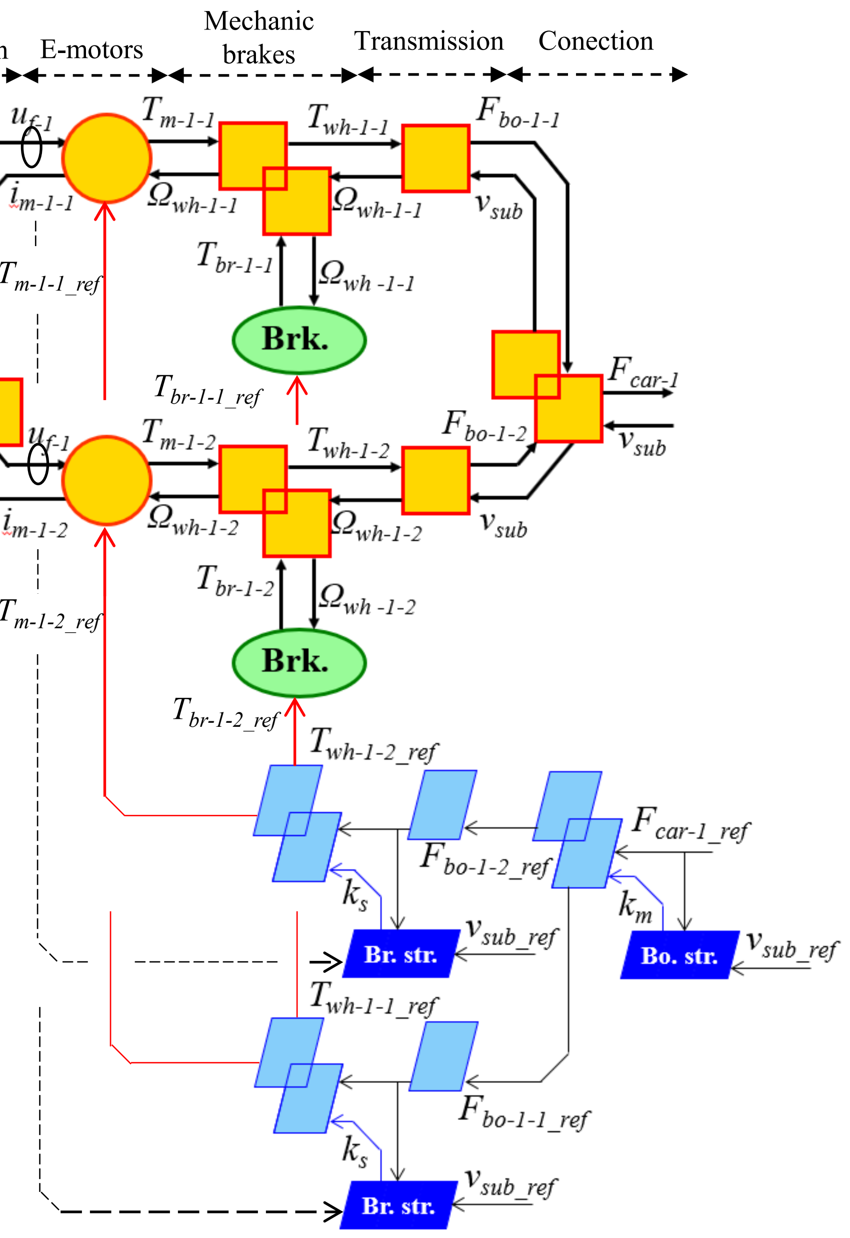
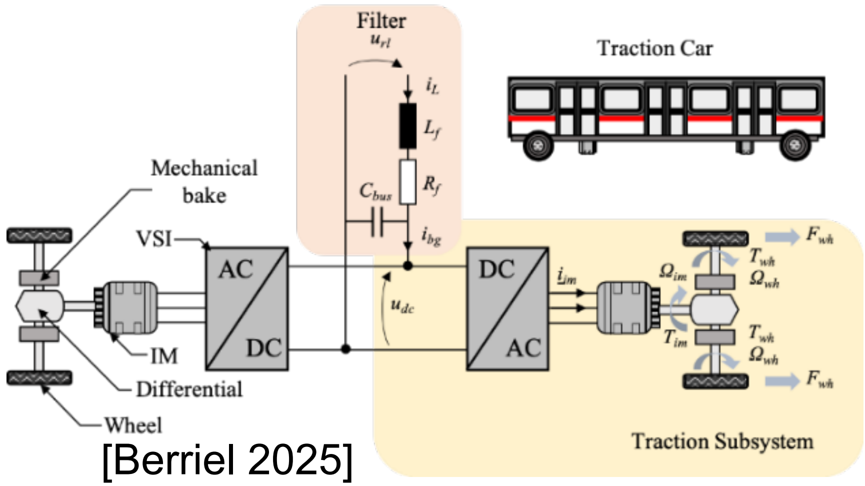
Subway Simulation

Energetic Macroscopic Representation and Control



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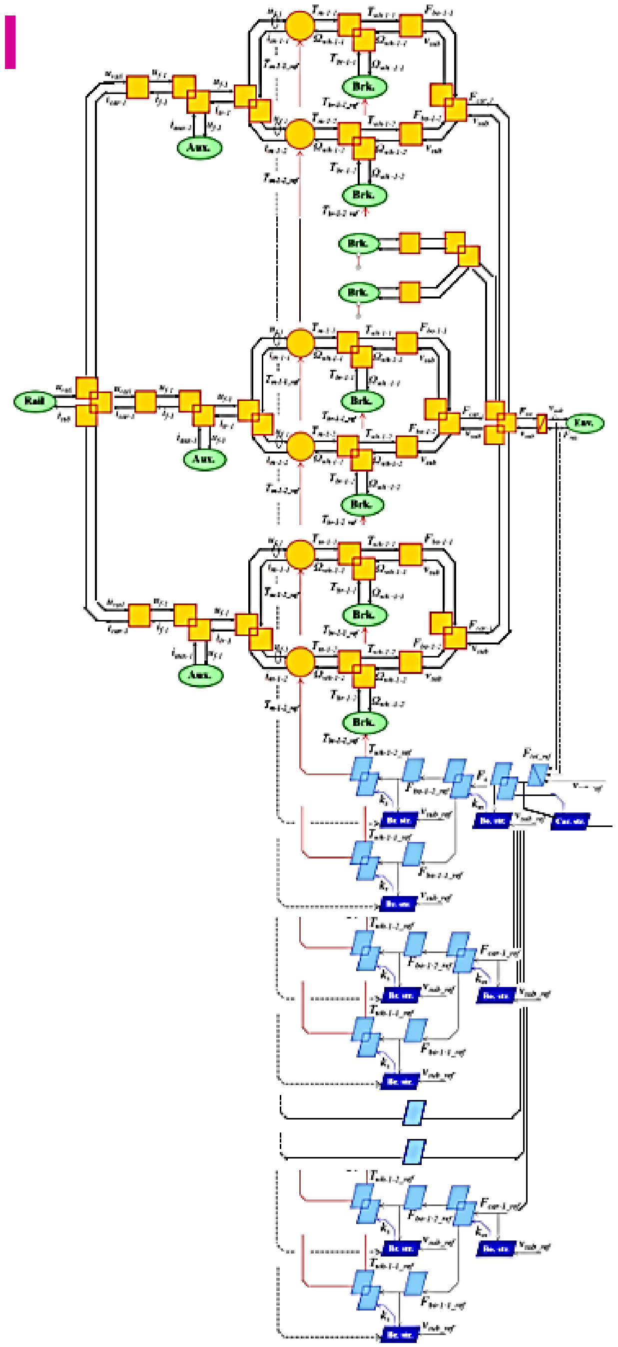
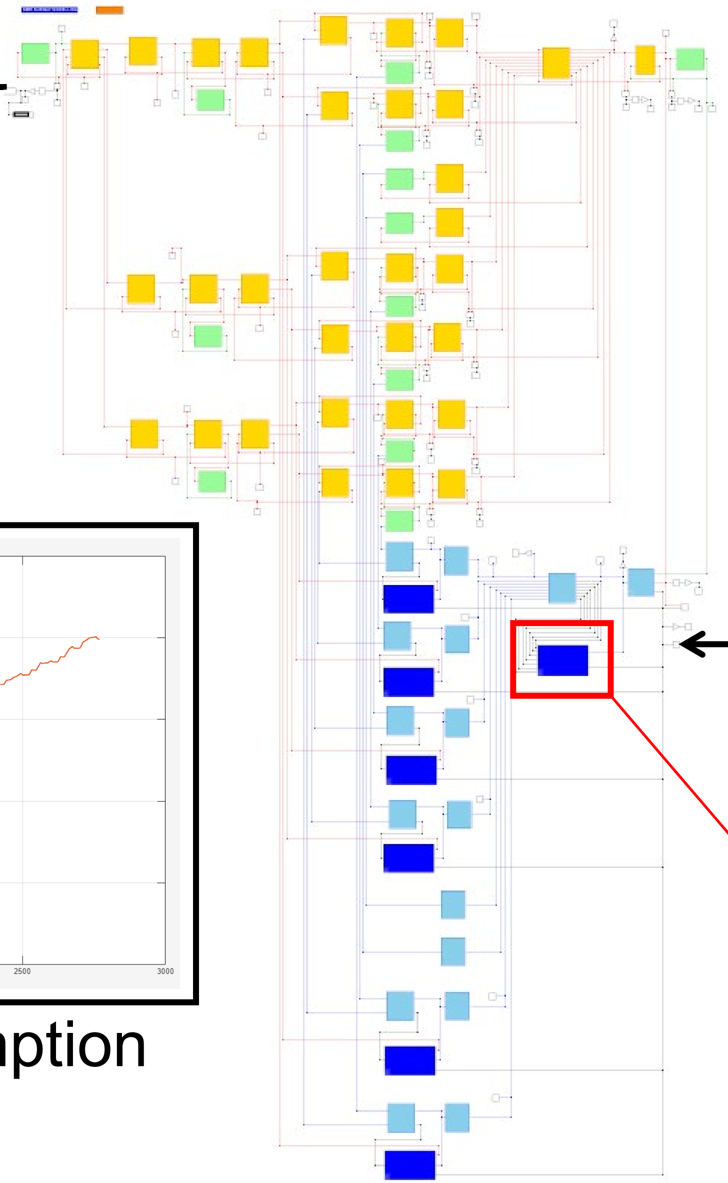
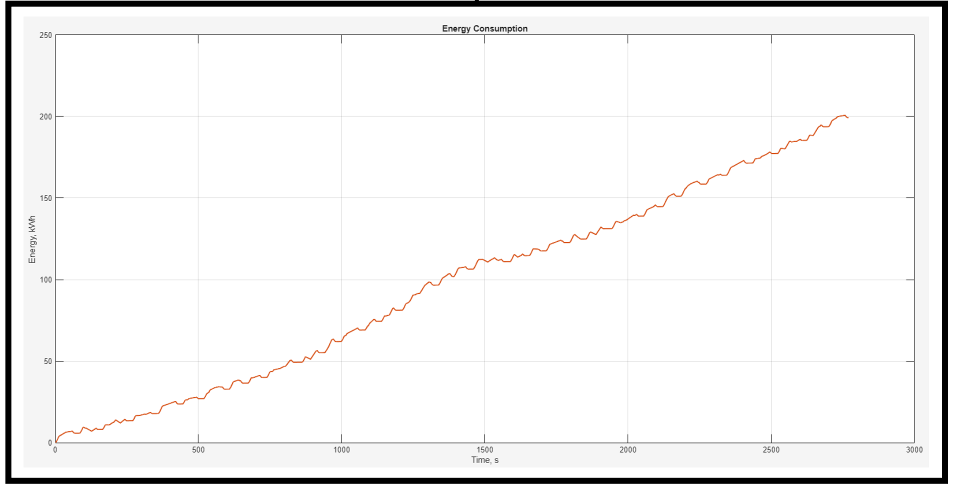


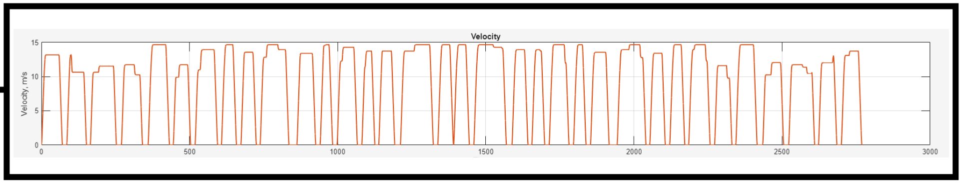
Subway Simulation





Output: energy consumption

Input: driving cycle



Focus on energy management strategy

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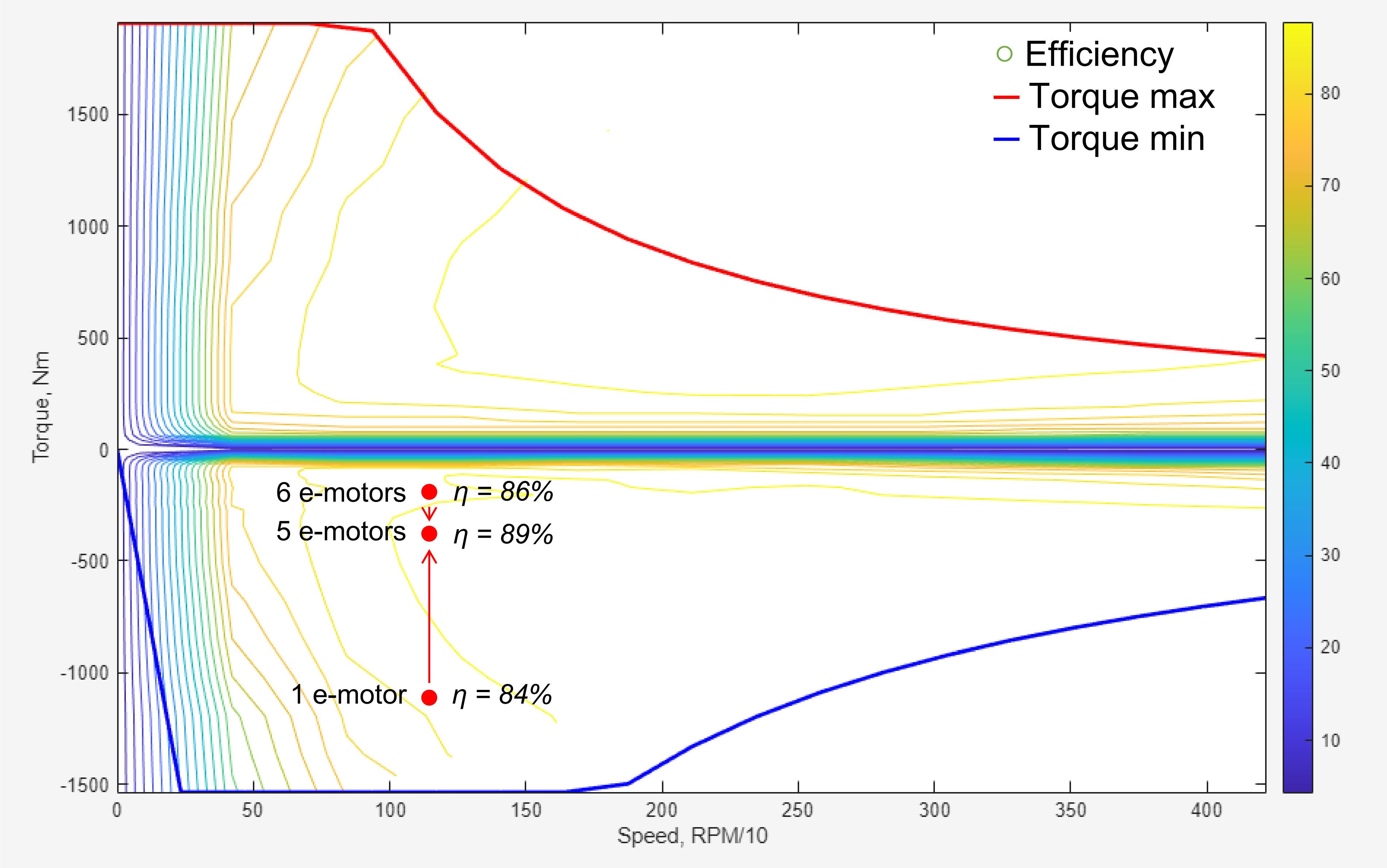
New Energy Management

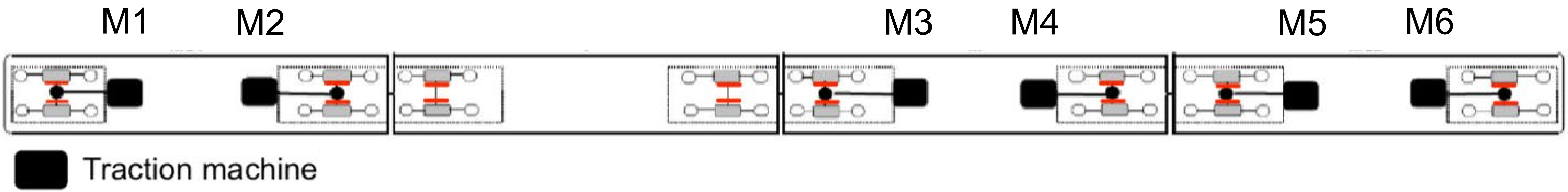
Efficiency Map of the E-motor

Same rotational speed,
6 e-motors = 14% of losses,
5 e-motors = 11% of losses

interest to stop some e-motors



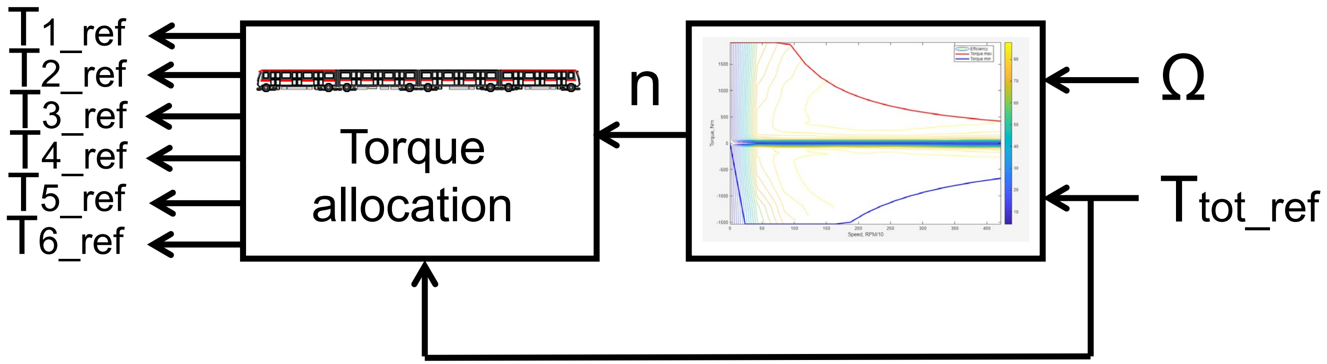
New Energy Management



Actual energy management: all 6 e-motors is activated all the time.

	Number of each motor					
Count of active e-motors (n)	**1**	**2**	**3**	**4**	**5**	**6**
1			X			
2	X				X	
3		X		X	X	
4	X	X		X		X
5	X	X	X	X		X
6	X	X	X	X	X	X

New EMS:



Uniform load distribution extends the lifetime of joint parts.

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Simulation Results

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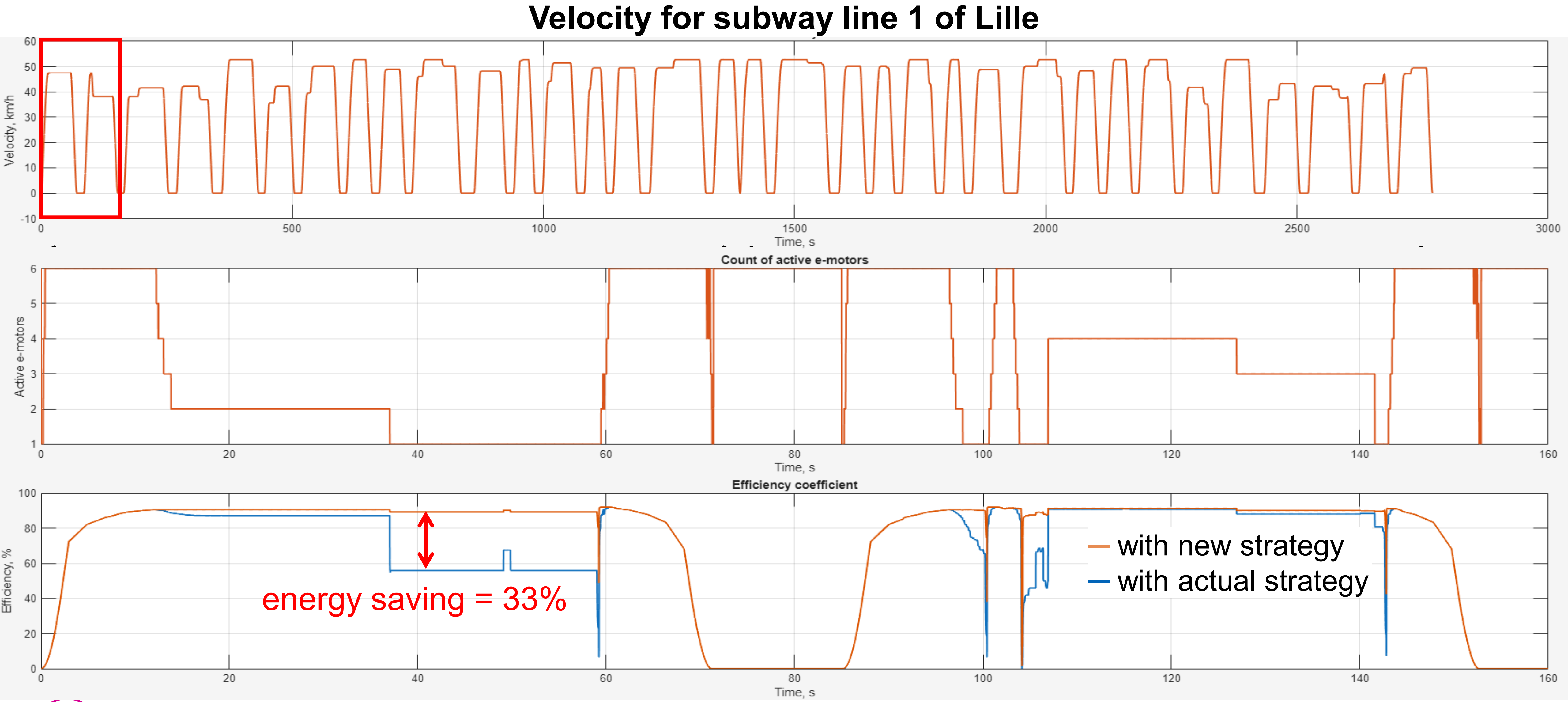
Simulation Results



3.3% (6.8 kWh) of energy saving for both direction.

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Conclusions & Perspectives

Conclusions & Perspectives

Conclusions

1. Simple new energy management: 3.3% energy saving.
2. Number of e-motors activated: 1, 2 or 6 most of the time.
3. Distribution of uniform load (not presented): extend the life time of joint parts.

Perspectives

1. More advanced energy management to save more energy.
2. Application to other metro lines (impact of distance).
3. Experimental validation.

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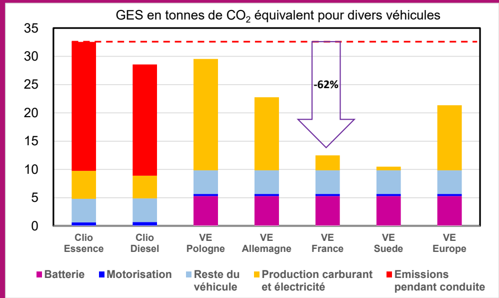

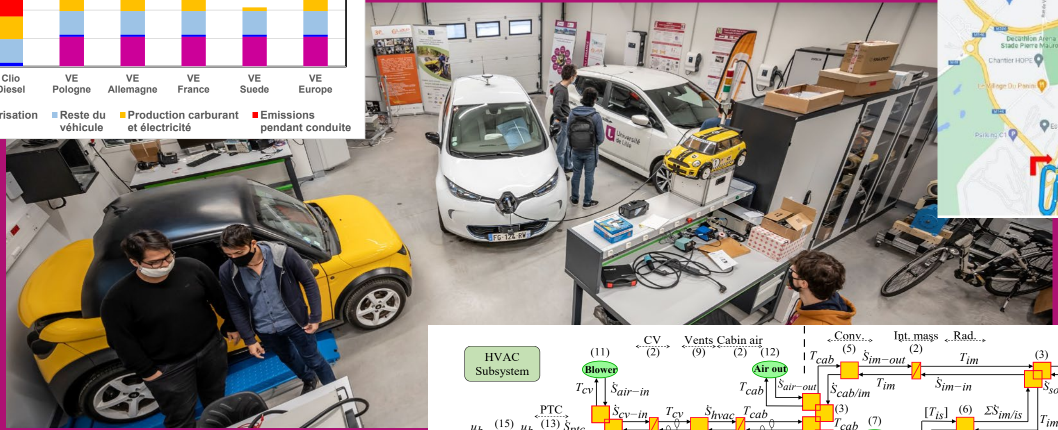

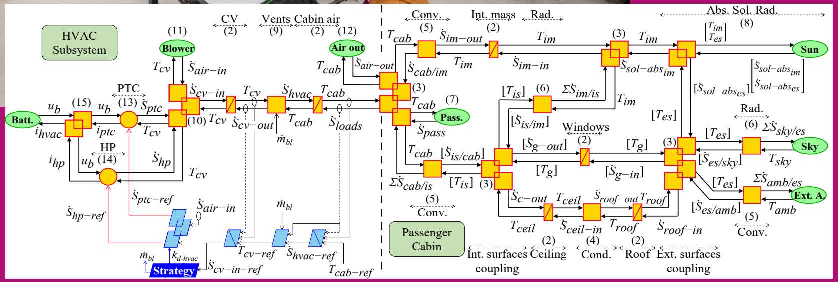

Our university as an exciting living lab towards eco-cities through an innovative transdisciplinary framework !

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Joint Force Calculation

$$C_i = F_{1i} - \frac{n}{m} F_{tot}$$

C_i – force on the joint

F_{1i} – driving force before joint

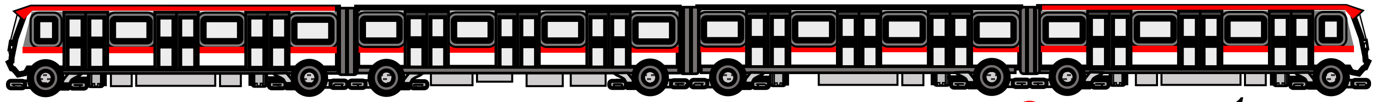
n – cars before joint

m – total number of cars

$$C_1 = \left(\frac{1}{2} - \frac{1}{4}\right) F_{tot} = 0.25\ F_{tot}$$

$$C_2 = \left(\frac{1}{2} - \frac{2}{4}\right) F_{tot} = 0$$

$$C_3 = \left(\frac{1}{2} + \frac{1}{4} - \frac{3}{4}\right) F_{tot} = 0$$



Active drives	F_1/F_{tot}	F_2/F_{tot}	F_3/F_{tot}	F_4/F_{tot}	C_1/F_{tot}	C_2/F_{tot}	C_3/F_{tot}
	1	0	0	0	0.75	0.5	0.25
	0	0	1	0	-0.25	-0.5	0.25
1	0	0	0	1	-0.25	-0.5	-0.75
	1	0	0	0	0.75	0.5	0.25
	0	0	1	0	-0.25	-0.5	0.25
	0	0	0	1	-0.25	-0.5	-0.75
	1/2	0	1/2	0	0.25	0	0.25
	0	0	1/2	1/2	-0.25	-0.5	-0.25
2	1/2	0	0	1/2	0.25	0	-0.25
	2/3	0	1/3	0	0.42	0.17	0.25
	2/3	0	0	1/3	0.42	0.17	-0.08
	1/3	0	2/3	0	0.08	-0.17	0.25
	0	0	2/3	1/3	-0.25	-0.50	-0.08
	1/3	0	0	2/3	0.08	-0.17	-0.42
	0	0	1/3	2/3	-0.25	-0.50	-0.42
3	1/3	0	1/3	1/3	0.08	-0.17	-0.08
	1/2	0	1/4	1/4	0.25	0.00	0.00
	1/4	0	1/2	1/4	0.00	-0.25	0.00
	1/4	0	1/4	1/2	0.00	-0.25	-0.25
	1/2	0	1/2	0	0.25	0.00	0.25
	0	0	1/2	1/2	-0.25	-0.50	-0.25
4	1/2	0	0	1/2	0.25	0.00	-0.25
	2/5	0	2/5	1/5	0.15	-0.10	0.05
	1/5	0	2/5	2/5	-0.05	-0.30	-0.15
5	2/5	0	1/5	2/5	0.15	-0.10	-0.15
6	1/3	0	1/3	1/3	0.08	-0.17	-0.08