EMR'22
HES-SO Sion
June 2022

EMR'22 Summer School
"Energetic Macroscopic Representation"

«EMR-based simulation of DC railway electrical system with EV charging station»

Dr. Baoling GUO, Prof. Julien Pouget

HES-SO Valais Wallis

Hes·so VALAIS WALLIS
Haute Ecole d'Ingénierie
Hochschule für Ingenieurwissenschaften

EMR'22 Summer School
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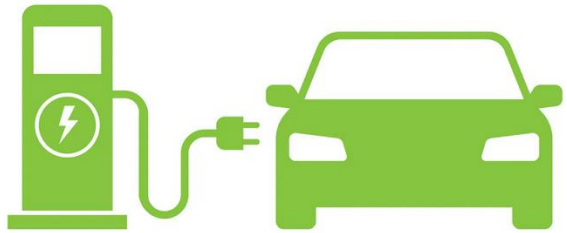
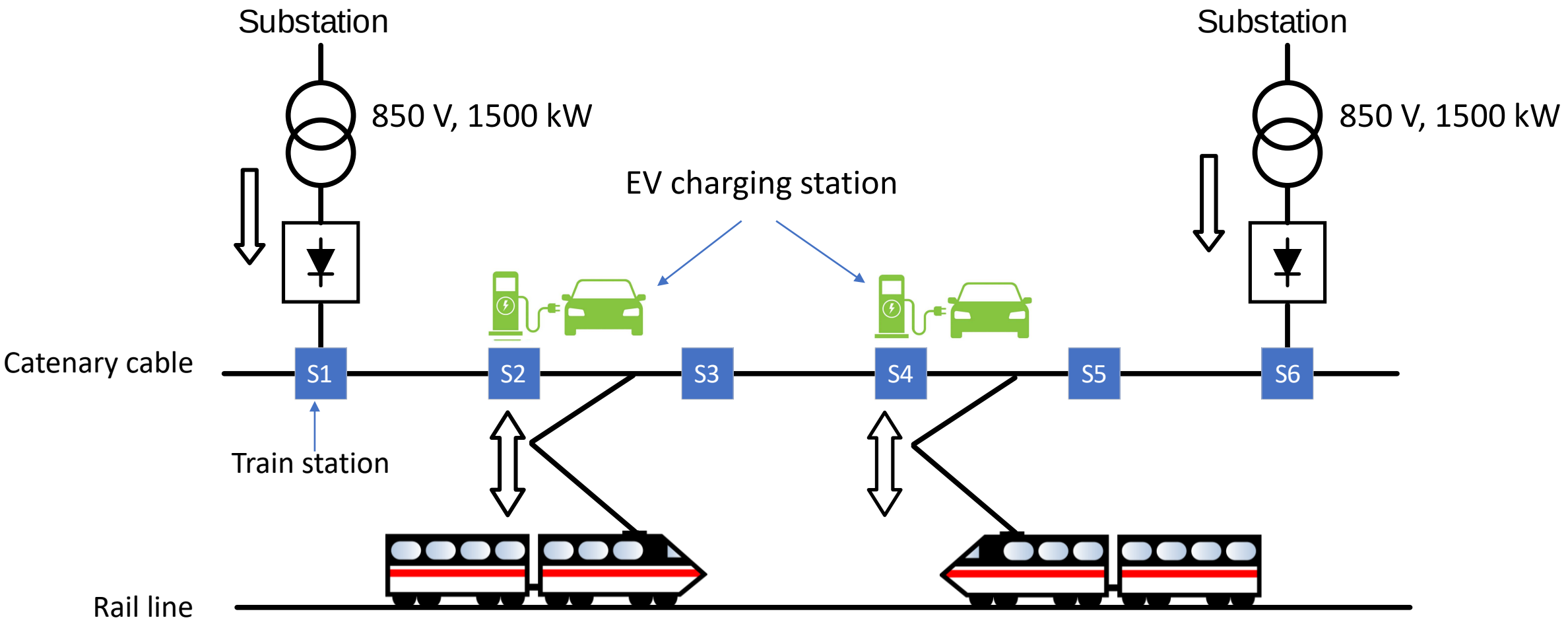
Content

- Introduction
- Modeling of DC railway electrical microgrid
- Results analysis
- Conclusions & Perspectives

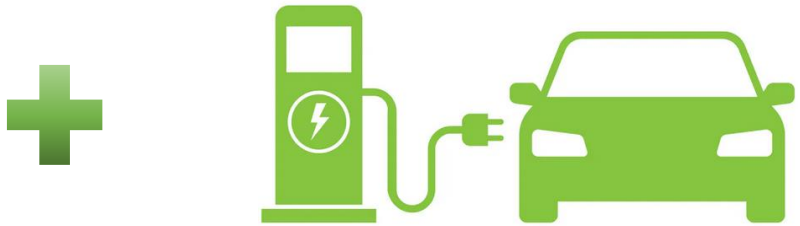


Introduction



Introduction

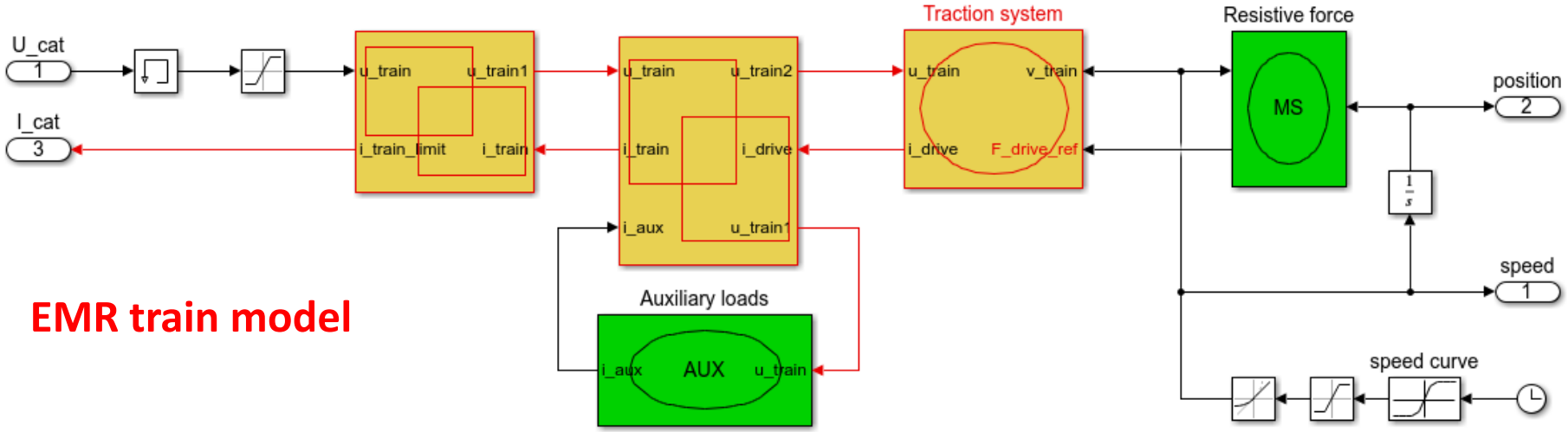
- Objectives
  - To stabilise high overvoltage variations by integrating wayside EV charging stations
  - To achieve a higher global efficiency by recuperating the braking power to charge EVs
  - To fully profit the DC railway electrical network



« EMR modeling»

Modeling of DC railway electrical microgrid

- Modeling of the train traction system

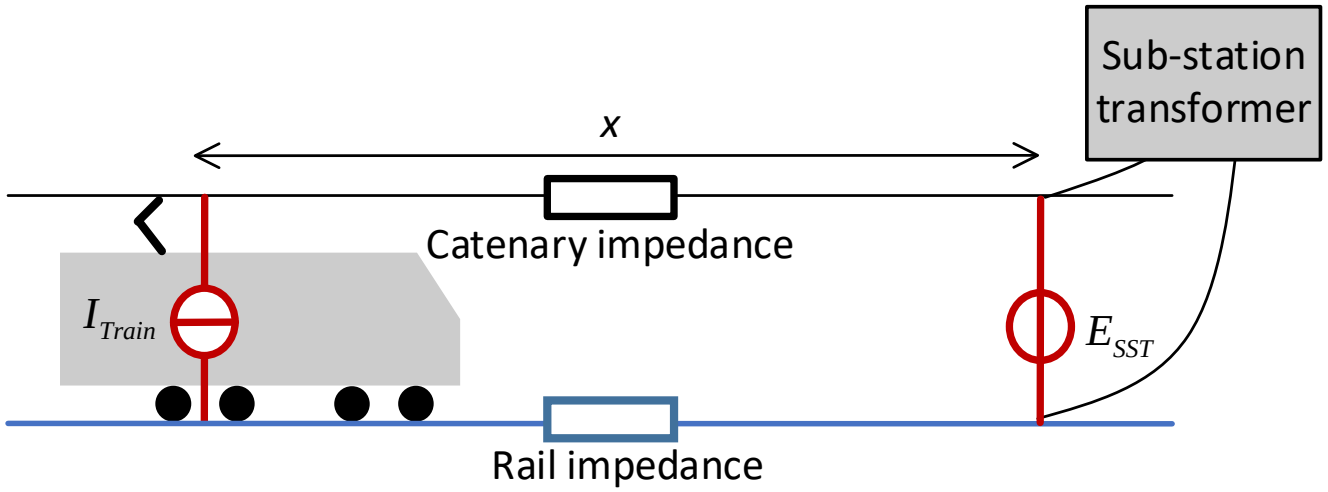


EMR train model

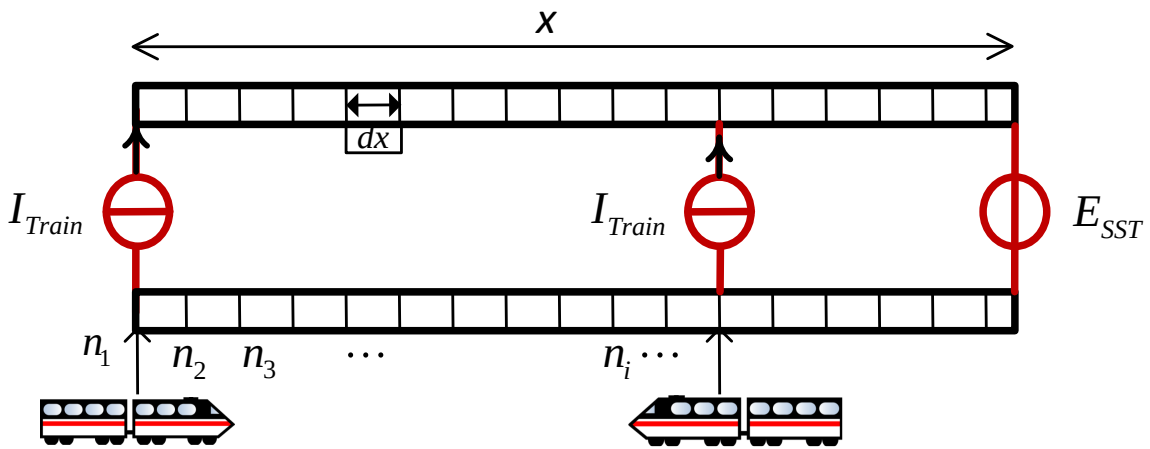
[1] J. Pouget, B. Guo, L. Bossoney, J. Coppex, D. Roggo and C. Ellert, "Energetic simulation of DC railway micro-grid interconnecting with PV solar panels, EV charger infrastructures and electrical railway network," *2020 IEEE Vehicle Power and Propulsion Conference (VPPC)*, 2020, pp. 1-7.

Modeling of DC railway electrical microgrid

- Modeling of electrical network with moving train loads



$$\Delta U(x) = I_{Train} \cdot x \cdot \left(\frac{\rho_C}{S_C} + \frac{\rho_R}{S_R} \right)$$

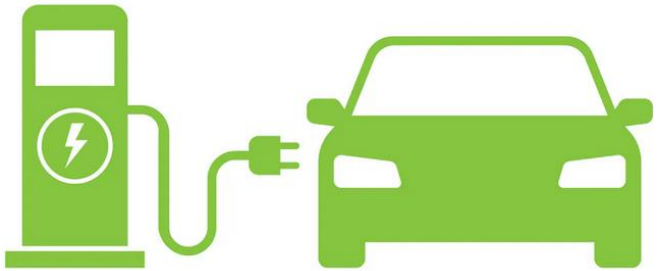


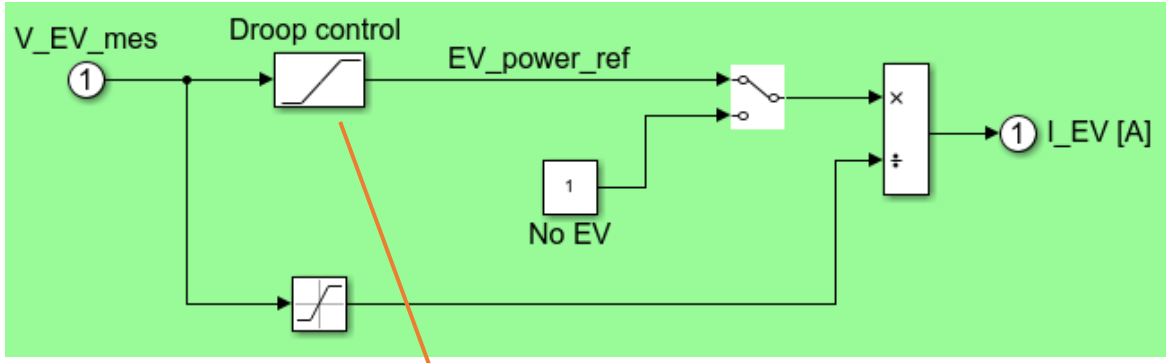
$$dU(x) = I_{Train} \cdot dx \cdot \left(\frac{\rho_C}{S_C} + \frac{\rho_R}{S_R} \right)$$

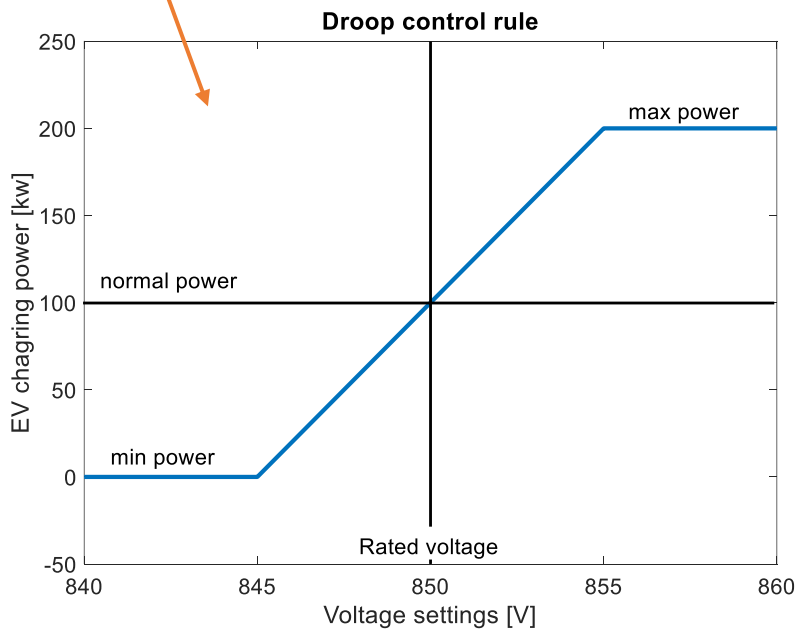
Modified Nodal Analysis (MNA)

Modeling of DC railway electrical microgrid

- Modeling of the EV V1G charging system



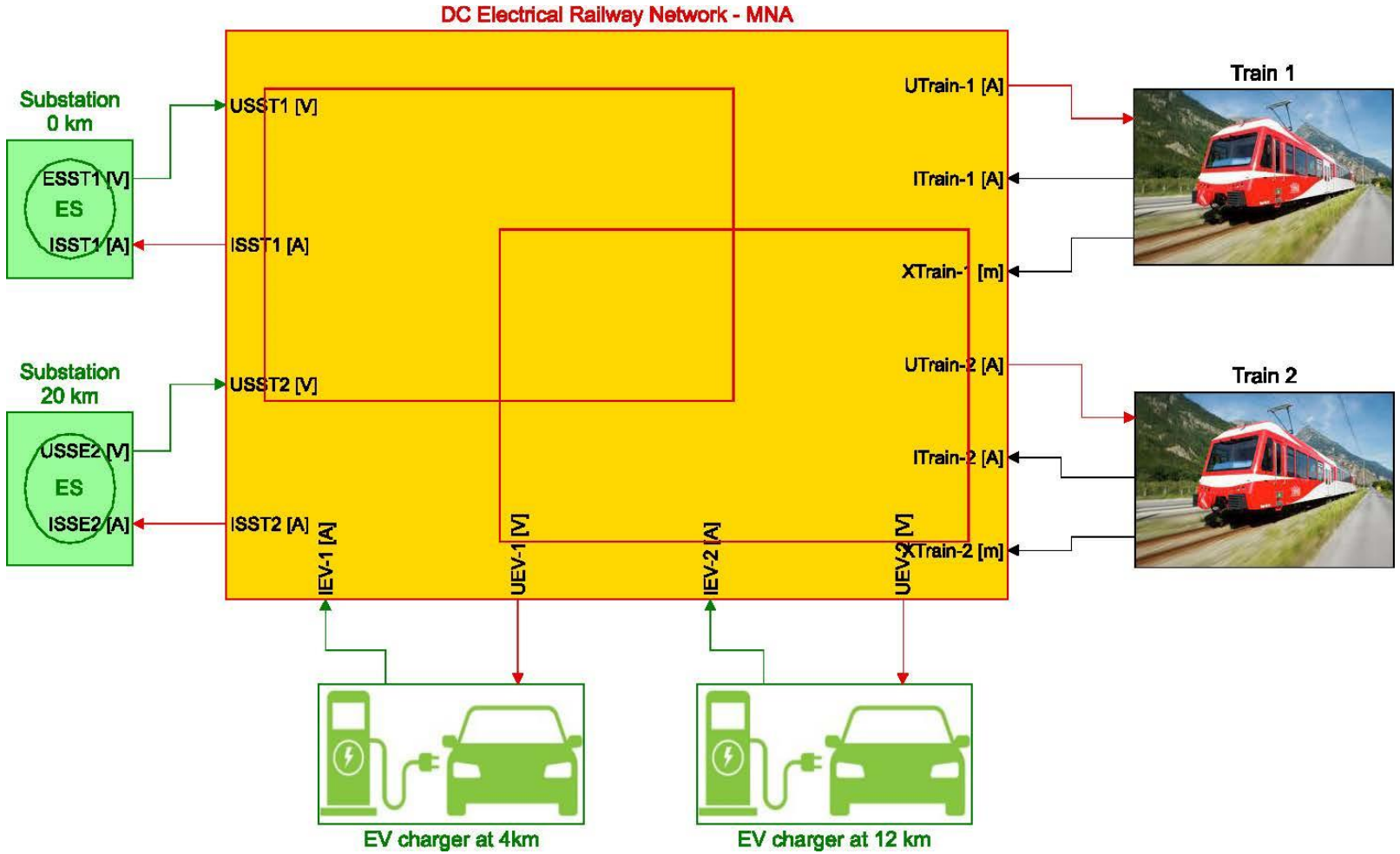




[2] Guo, Baoling, Julien Pouget, Bossoney Luc, Mauro Carpita, Thomas Meier, and Jean-Paul Maye. Catenary overvoltage stabilization of DC railway electrical system by integrating EV charging stations. In ICHQP 2022 – The 20th International Conference on Harmonics and Quality of Power.

Modeling of DC railway electrical microgrid

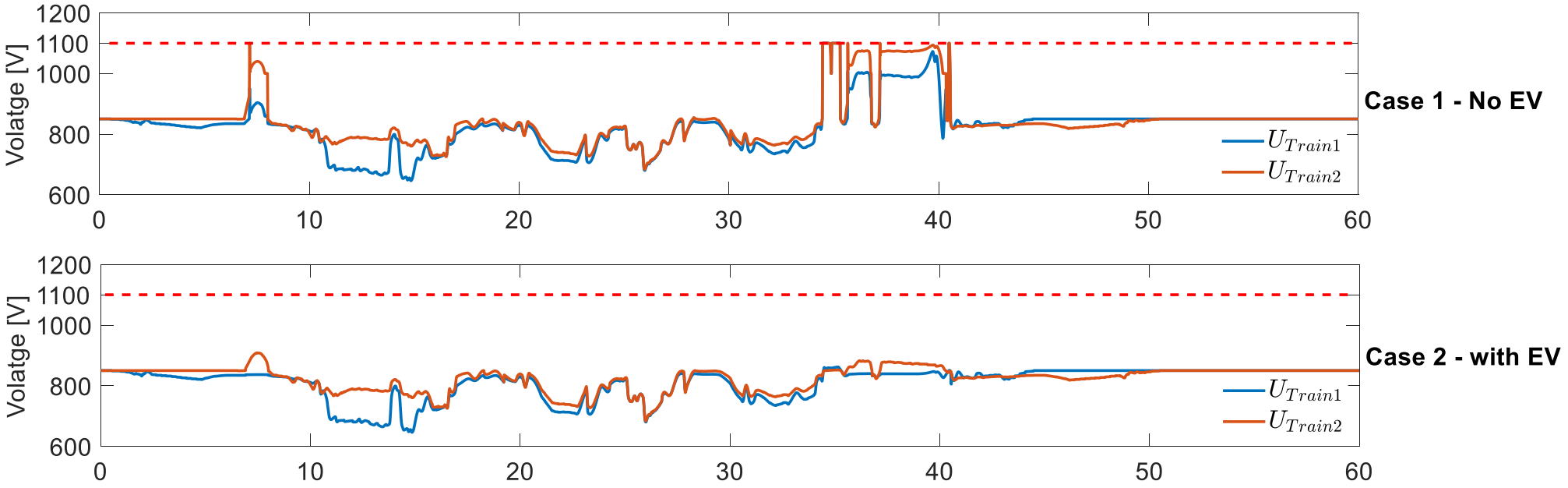
- EMR simulation model with Matlab/Simulink



«Results analysis»

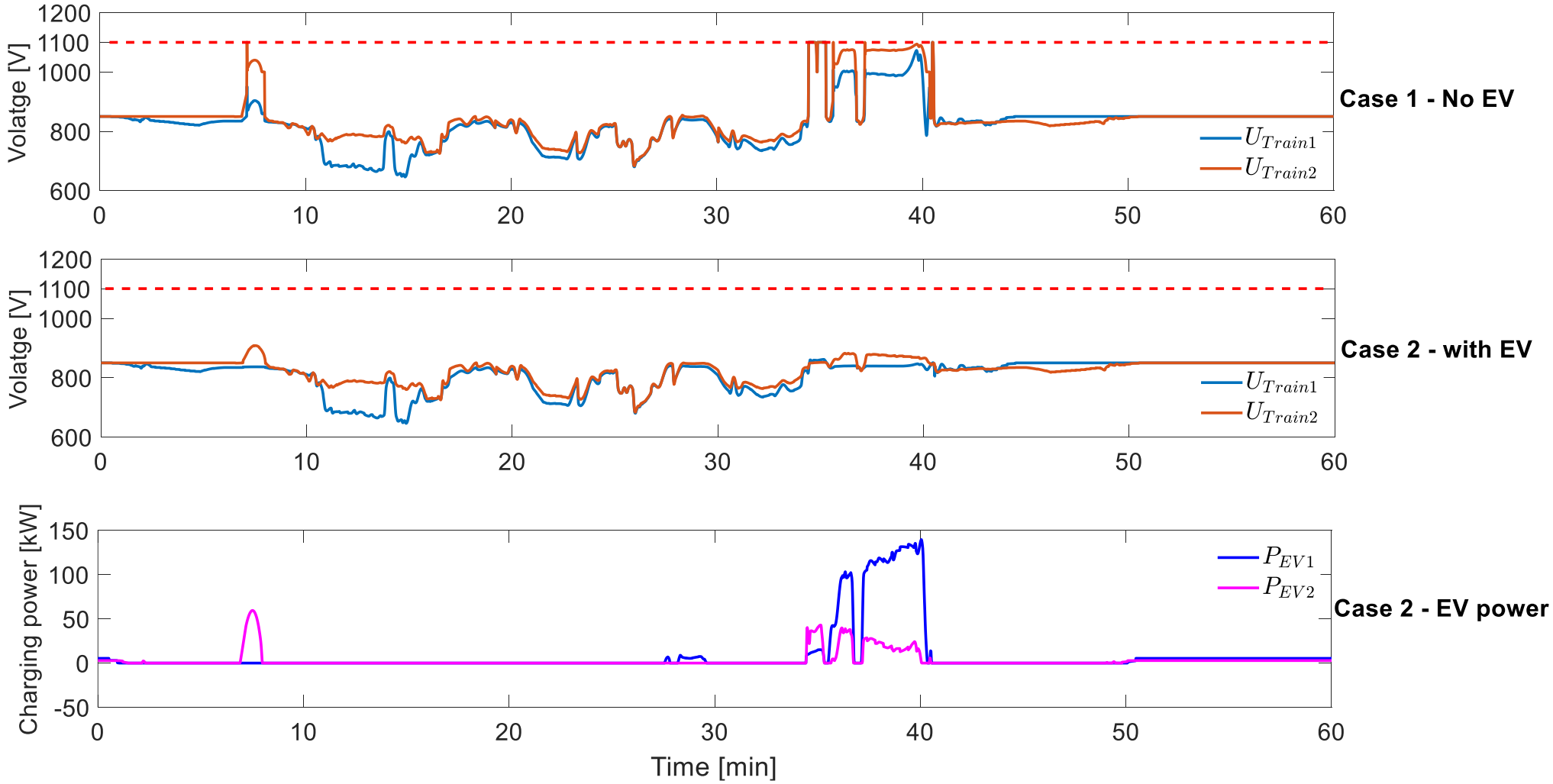
Results analysis

- Voltage profiles comparison for two cases with and without EV



Results analysis

- Voltage profiles comparison for two cases with and without EV



Results analysis

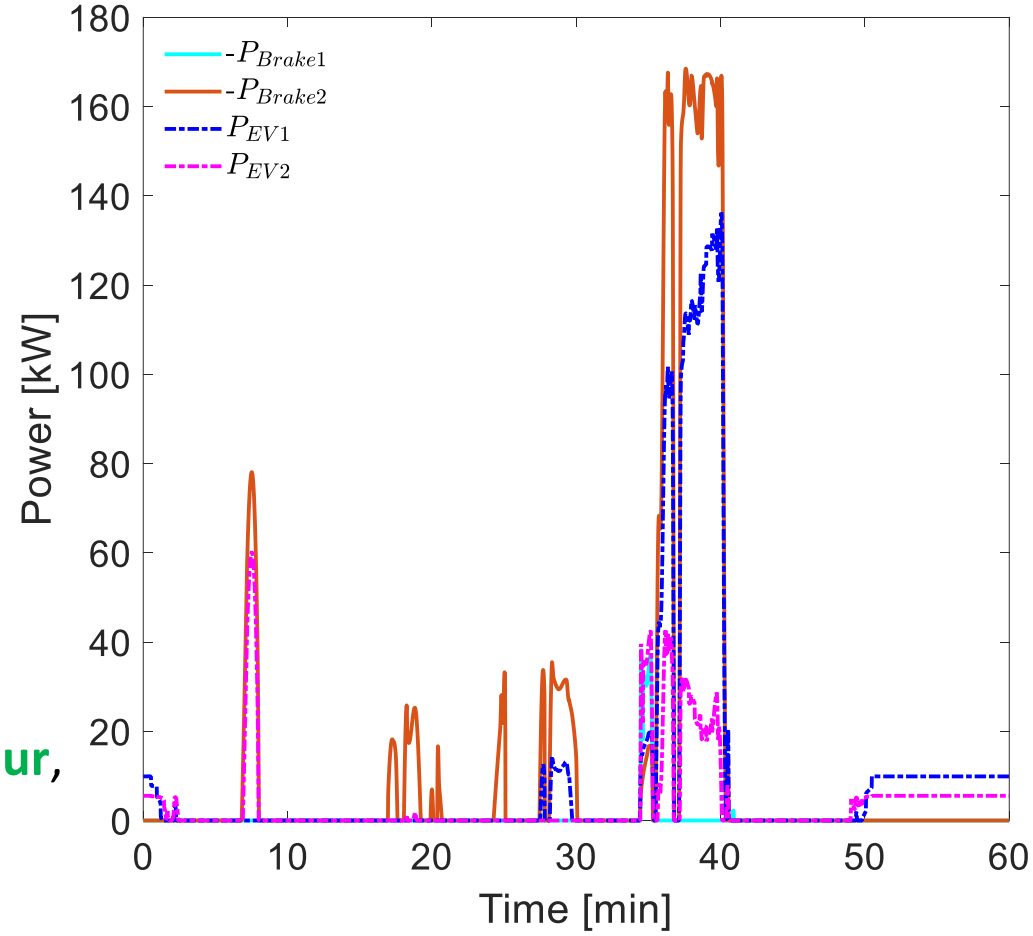
- Braking power recuperated for charging EV

(kWh)	E_{EV1}	E_{EV1}	E_{SST1}	E_{SST2}	$E_{\_brake\_total}$
No EV(*)	0	0	60.44	65.12	8.54
With EV	9.19	3.16	64.34	68.78	8.54

$E_{brake\text{-}EV} = E_{EV1} + E_{EV2} - (E_{SST1} + E_{SST2} - E^*_{SST1} - E^*_{SST2}) = 4.79kWh$

Braking energy used to charge EV reaches around **4.79kWh per hour**,

Recuperation rate of braking power increase more than **50%.**



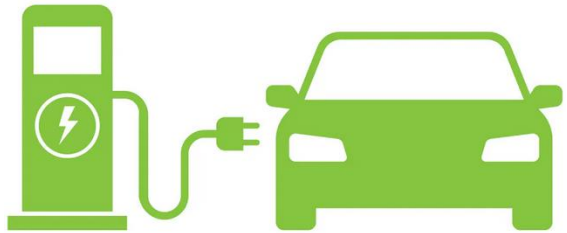
«Conclusions & Perspectives»

Conclusions & Perspectives

- Conclusions
  - The overvoltage variations are stabilized by the proposed V1G solution with droop control.
  - The braking power is used to charge the wayside EV, achieving a higher global efficiency.
- Perspectives
  - The energy transfer is assumed to be unidirectional from DC traction network to EV battery for V1G, the solution can stabilize overvoltages but cannot deal with the voltage drops. Vehicle-to-Grid (V2G) concept has been popular, V2G solution will be studied to address the above issues in next step.
  - The EV users charging behaviors will be studied to ensure the feasibility of the proposed solutions.

Question & discussion

Thanks for your attention



« BIOGRAPHIES AND REFERENCES »

baoling.guo@hevs.ch

Dr. Baoling GUO
Postdoc researcher,
University of Applied Sciences Western Switzerland
PhD in Electrical Engineering at University Grenoble Alpes (2019)
Research topics: power electronics system modelling and control, renewable energy integration, variable speed hydropower, DC railway microgrid

julien.pouget @hevs.ch

Julien Pouget received the Ph.D. degree in electrical engineering from University of Franche-Comté, Belfort, France, in 2009. For three years, he worked on the optimal design of electrical railway traction motor within ALSTOM Transport. Since 2009, he has been a researcher and project leader with the Innovation and Research Department, French National Railway Company. Since 2019, he has been Associate Professor with HES-SO Valais Wallis. His research interests include DC railway micro-grid, hydrogen productive system, e-Mobility applications (V1G, V2G and V2X application).

- References -

1. Pouget, Julien, Baoling Guo, Luc Bossoney, Julien Coppex, Dominique Roggo, and Christoph Ellert. Energetic simulation of DC railway micro-grid interconnecting with PV solar panels, EV charger infrastructures and electrical railway network. In 2020 IEEE Vehicle Power and Propulsion Conference (VPPC), pp. 1-7. IEEE, 2020.Guo,

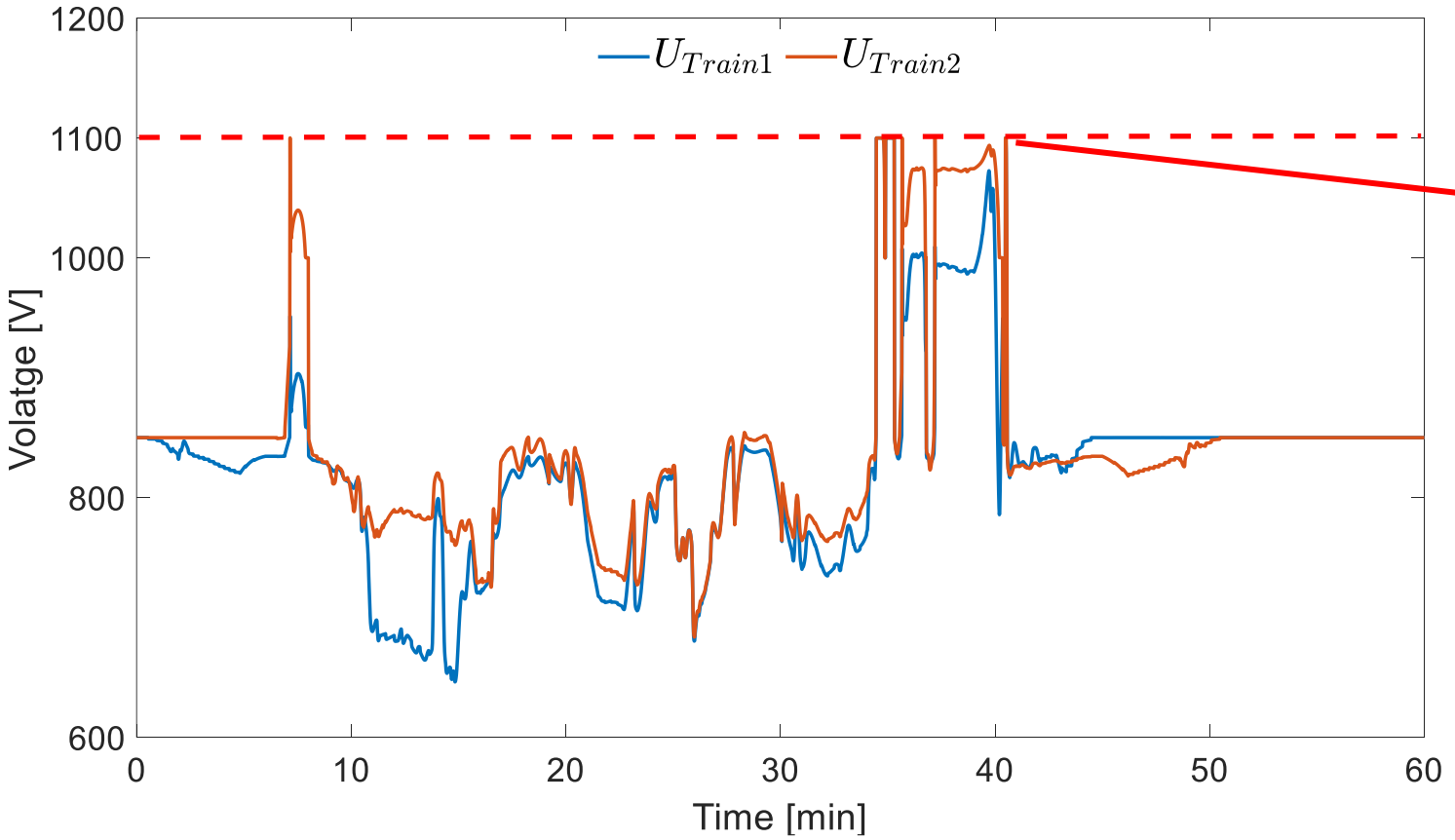
2. Baoling, Julien Pouget, Bossoney Luc, Mauro Carpita, Thomas Meier, and Jean-Paul Maye. Catenary overvoltage stabilization of DC railway electrical system by integrating EV charging stations. In ICHQP 2022 – The 20th International Conference on Harmonics and Quality of Powe.

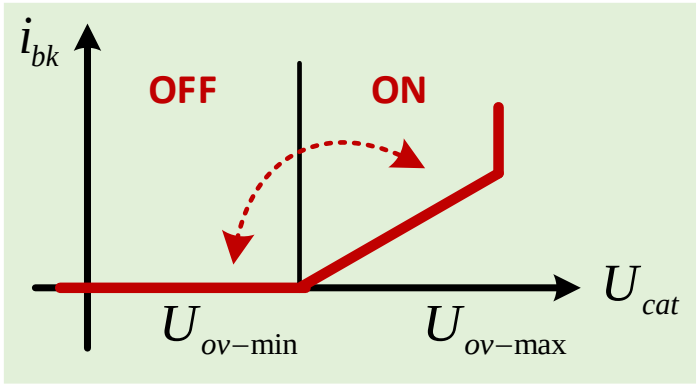
3. Guo, Baoling, Julien Pouget, Tavernier François, and Bossoney Luc. Electric bus charging station supplied by urban electrical DC railway network. In CIRED 2021-The 26th International Conference and Exhibition on Electricity Distribution, vol. 2021, pp. 2218-2222. IET, 2021.

« Appendix»

Introduction

- Catenary overvoltage problem





Brake 'ON'

$I_{train} < 0$ & $U_{cat} \geq U_{ov-min}$

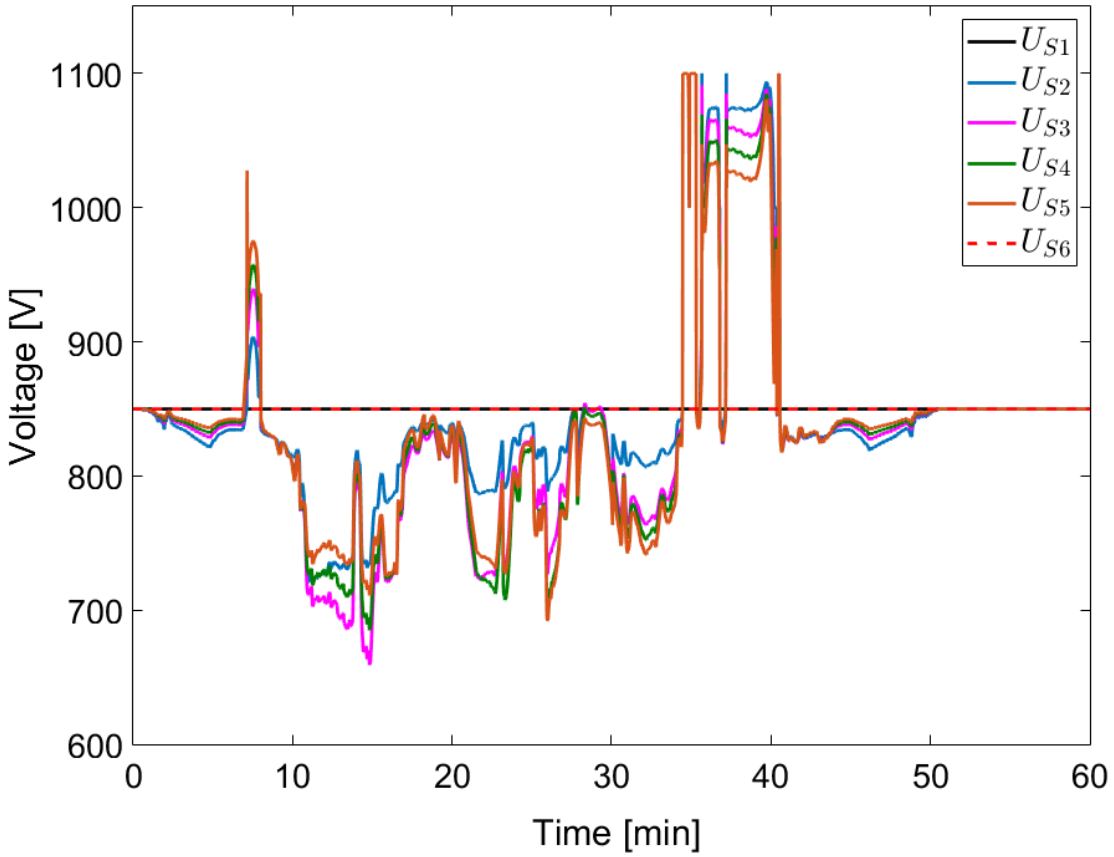
Brake 'OFF'

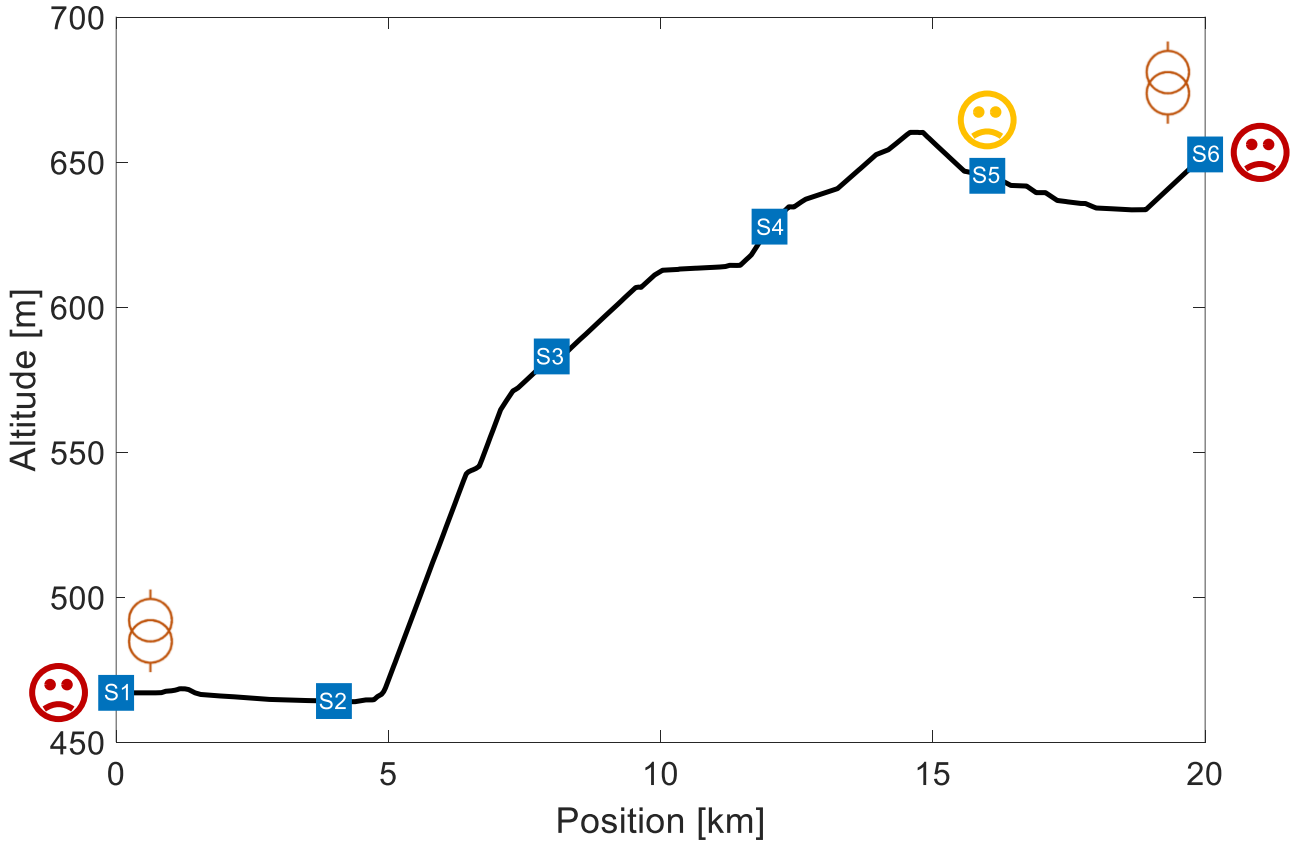
$I_{train} \geq 0$ & $U_{cat} < U_{ov-min}$

Ref: Mayet, Clément, et al. Non-linear switched model for accurate voltage estimation and power flow analysis of DC railway systems. IET Electrical Systems in Transportation, 10 (4) (2020).

V1G solution for catenary overvoltage stabilization

- Choosing EV charging station site





Results analysis

- Choosing EV charging station site