Pantograph catenary dynamic interaction modeling based on advanced multibody and finite element co-simulation

Philippe Constant[1], Arnaud Capitaine[1] and Jean-Philippe Bianchi[2]

[1] *Electric Traction Department, SNCF Reseau I&P, {philippe.constant, arnaud.capitaine}@reseau.sncf.fr*
[2] *SDTools, bianchi@sdtools.com*

The performance of railway systems was historically improved by inline tests. However, the constant increase of traffic and the needs to reduce costs have drawn SNCF Reseau to lean towards numerical methods in order to assess new components and to optimize maintenance periodicity. OSCAR (Outil de Simulation du CAptage pour la Reconnaissance des défauts) has been developed by SNCF for more than ten years and is certified against EN50318 European Standard since 2007. It offers a reliable pantograph catenary dynamic analysis tool based on the Structural Dynamics Toolbox for MATLAB. Catenaries are modelled using three-dimensional finite elements (FE) that interact with a multibody (MBD) model of the pantograph.

In order to model pantographs accurately, using specialized multibody solvers is a necessity. Indeed, Multibody modelling allows taking into account realistic pantograph geometry, large kinematic displacements of flexible components and non linearities in pantograph head suspensions or base damper. This implies to create a co-simulation environment that allows both solvers (FE and MBD) to communicate efficiently.

The FE solver uses large fixed time steps and an implicit Newmark scheme, while the MBD solver uses variable time steps based on Runge-Kutta method. Since detailed contact modelling is desired at the contact wire/contact strip interface, Hertz contact with Coulomb friction is retained. Integration of such contact and verification of further constraints of impenetrability, gap between bodies, and energy conservation require small time steps and must thus be done in the MBD model. Therefore an interface element that moves along with the catenary contact wire has been created. However the time steps of the FE and MBD solver are different, hence the need to enforce time steps in the MBD solver to match at least all the time steps of the constant time step FE solver. In order to avoid computational issues with the interface elements displacements, an interpolation scheme is applied to the interface elements displacement between two main FE time steps.

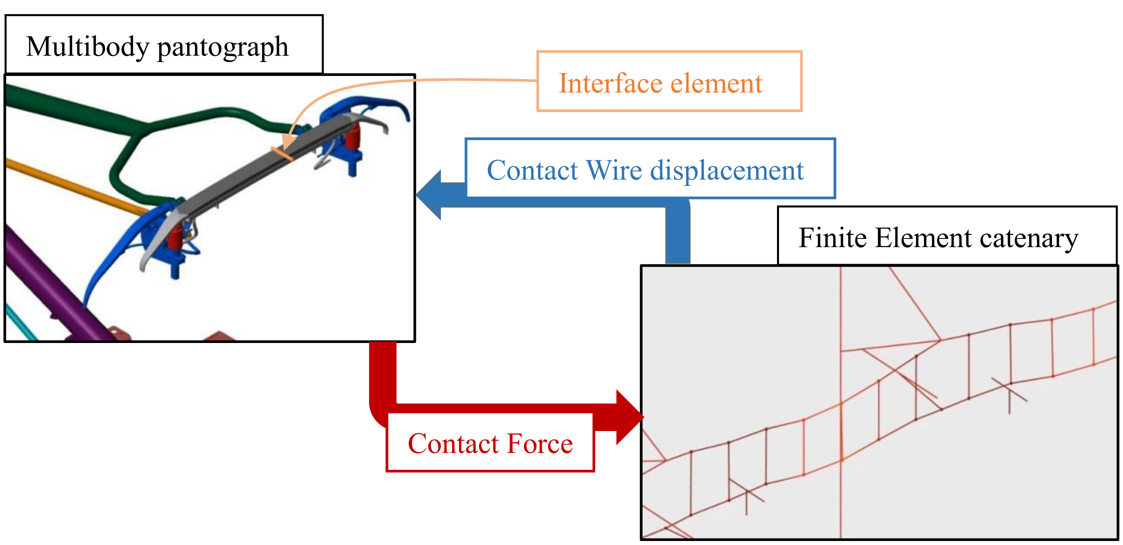

Fig. 1: The FE solver transfers contact wire displacements to an interface element in the MBD software. In return the contact force between the interface element and the pantograph contact strip is sent back to the FE solver to compute the next time step.

The co-simulation process is validated by comparing the contact force computed via co-simulation (using a lumped-mass model within the MBD software) to the contact force computed with a lumped-mass model within the FE software :

Value	Finite Elements only		Co-simulation	
	Front pantograph	**Rear pantograph**	**Front pantograph**	**Rear pantograph**
F_m (mean contact force)	132,5	132,7	130,9	131,2
σ (standard deviation)	34,5	47,1	34,1	46,5
σ/F_m (current collection quality)	0,260	0,355	0,260	0,354
F_{min} (minimum contact force)	46,1	25,7	47,0	23,0
F_{max} (maximum contact force)	229,3	254,7	232,9	252,0

Tab 1 : Comparison of co-simulation results for a given pantograph catenary configuration (two pantographs raised on the same train 200 m apart at 300 $km.h^{-1}$ on a high speed 25 kV line). Statistical values of the contact force

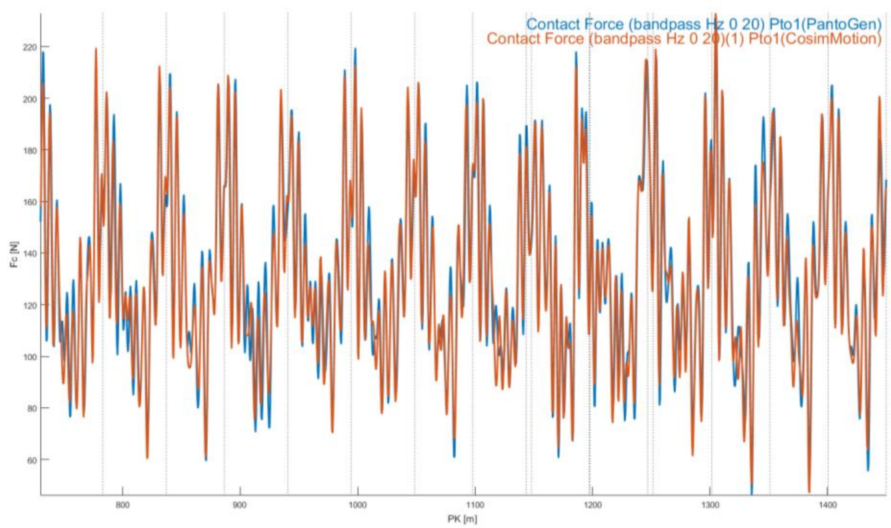

Fig. 2: Comparison of co-simulation results for a given pantograph catenary configuration (two pantographs raised on the same train 200 m apart at 300 $km.h^{-1}$ on a high speed 25 kV line). Evolution of contact force with train position. The *red* curve shows the co-simulation results and the *blue* curve shows the FE only results both filtered at 20 Hz.

References

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