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# PQ Events in DC Systems

## EMRAILS 2019

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# Objectives

- Brief state of the art on PQ in DC systems
- The complexity of measurements performed on-board trains in commercial services
- Overview on first data: line Bardonecchia -Torino
- The pantograph to overhead line electric arc as PQ event

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# Measurements on-board trains in commercial services: what an effort

- A locomotive in commercial service follows rigorously its scheduled time table. The measuring system and its maintenance has to be performed during a long stop of the locomotive
- The measurement setup must not impact on the power systems and monitoring system of the locomotive.
- This can have consequences on the accuracy of the measurements

# Spikes on line voltage

- Over a journey of about 1 hour and half, the voltage detected at the catenary shows many spikes.
- Are there due to induced or conducted effects?
- Are there due to electric arc occurring between pantograph and contact line?
- Do affect the railway system or communication system?

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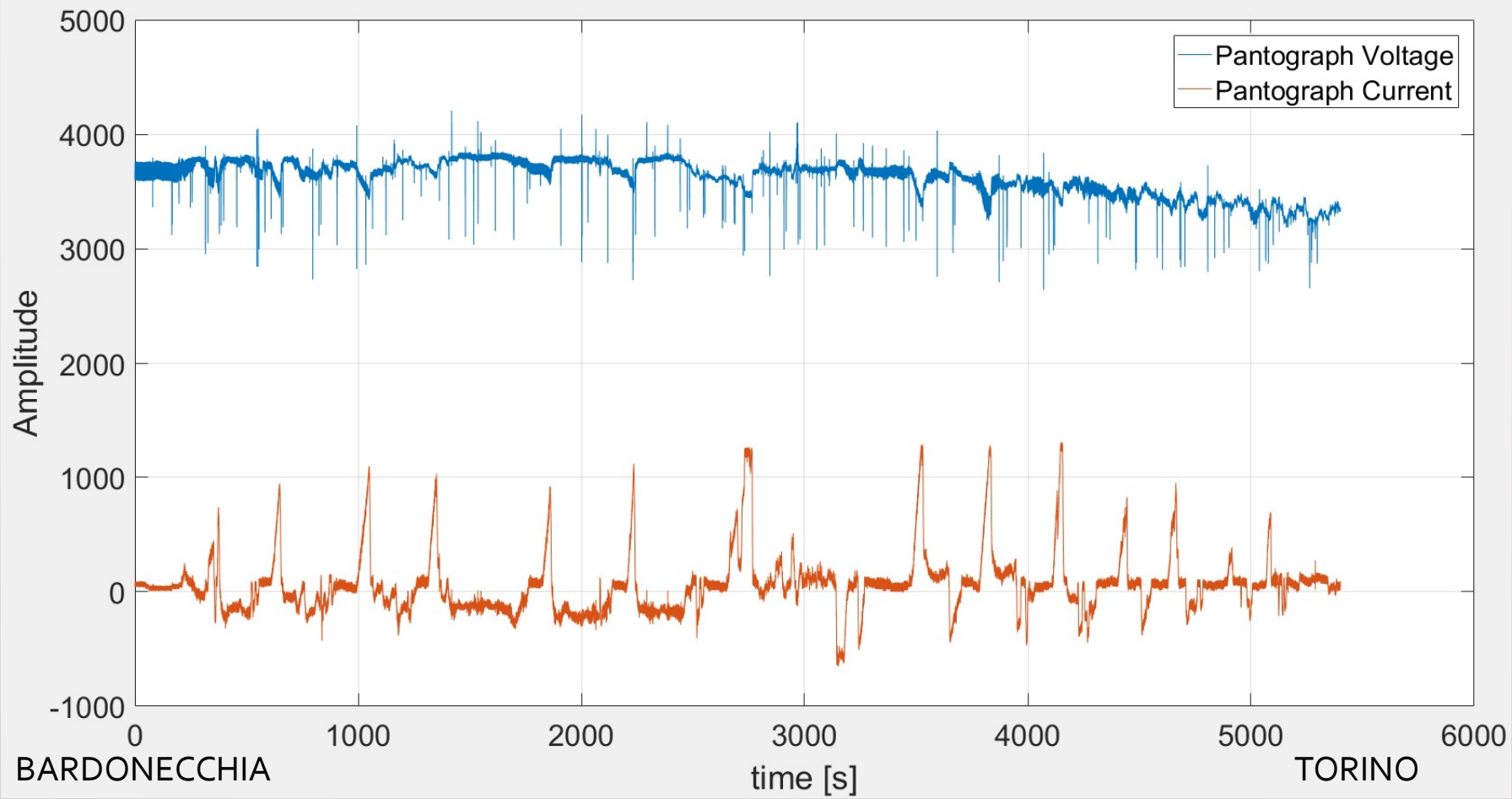
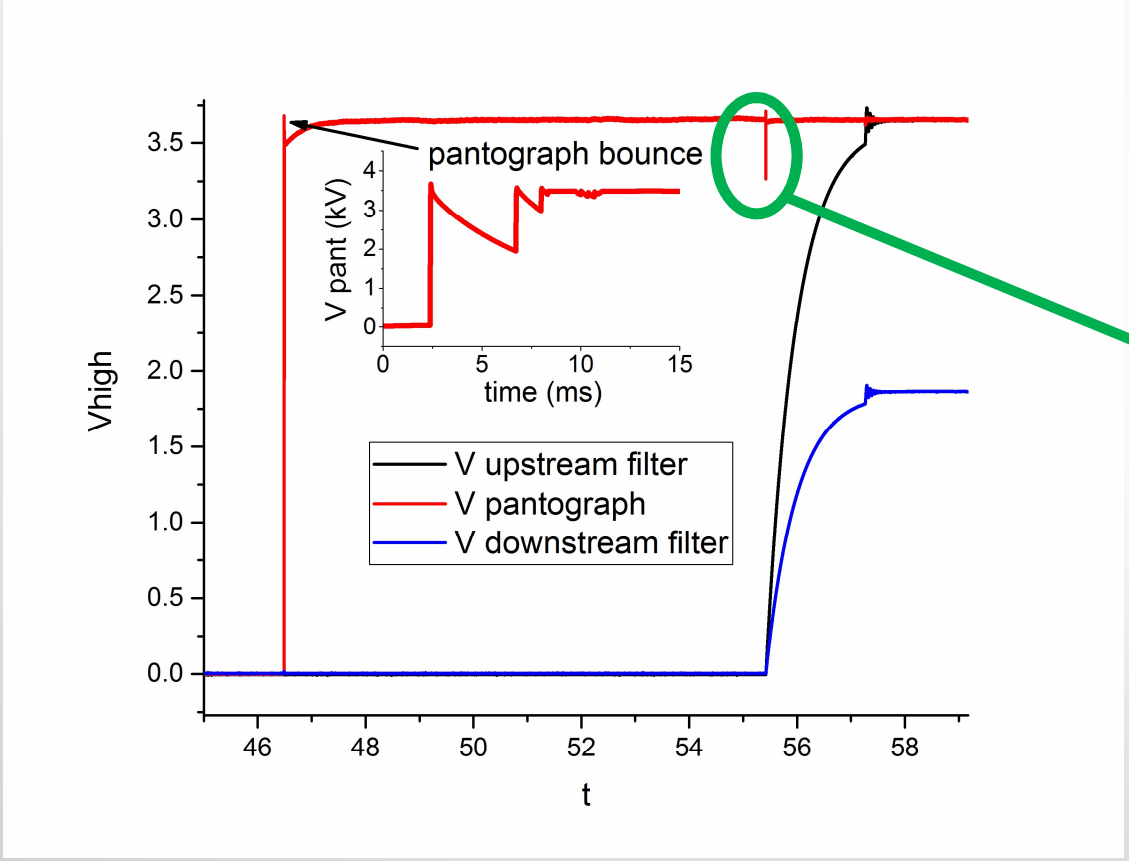
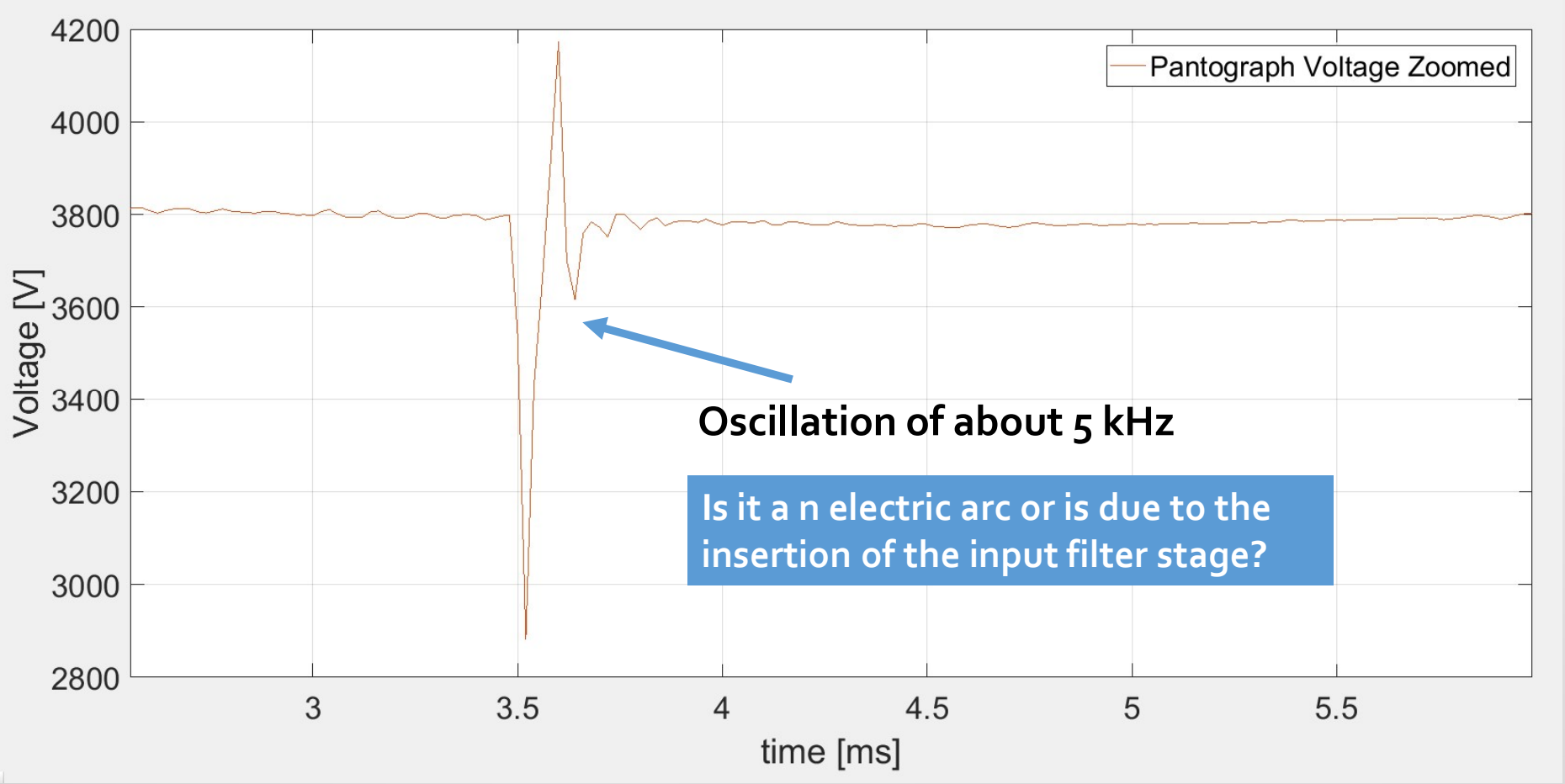





# Charge of the input filter stage of the locomotive

## Hypothesis

A strong inrush current produces a fast oscillation on the catenary voltage




**Oscillation of about 5 kHz**

**Is it a n electric arc or is due to the insertion of the input filter stage?**


The train is stationary, a spike on the voltage at catenary occurs.

probably in correspondence of the insertion of auxiliary services, ventilation, etc…

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# High amplitude of the 300 Hz tone on the pantograph voltage

- For the Bardonecchia – Torino line, a considerable 300 Hz tone of the voltage line has been detected closed to the Bardonecchia station.
- This tone affects the spectrum of the current absorbed by the locomotive

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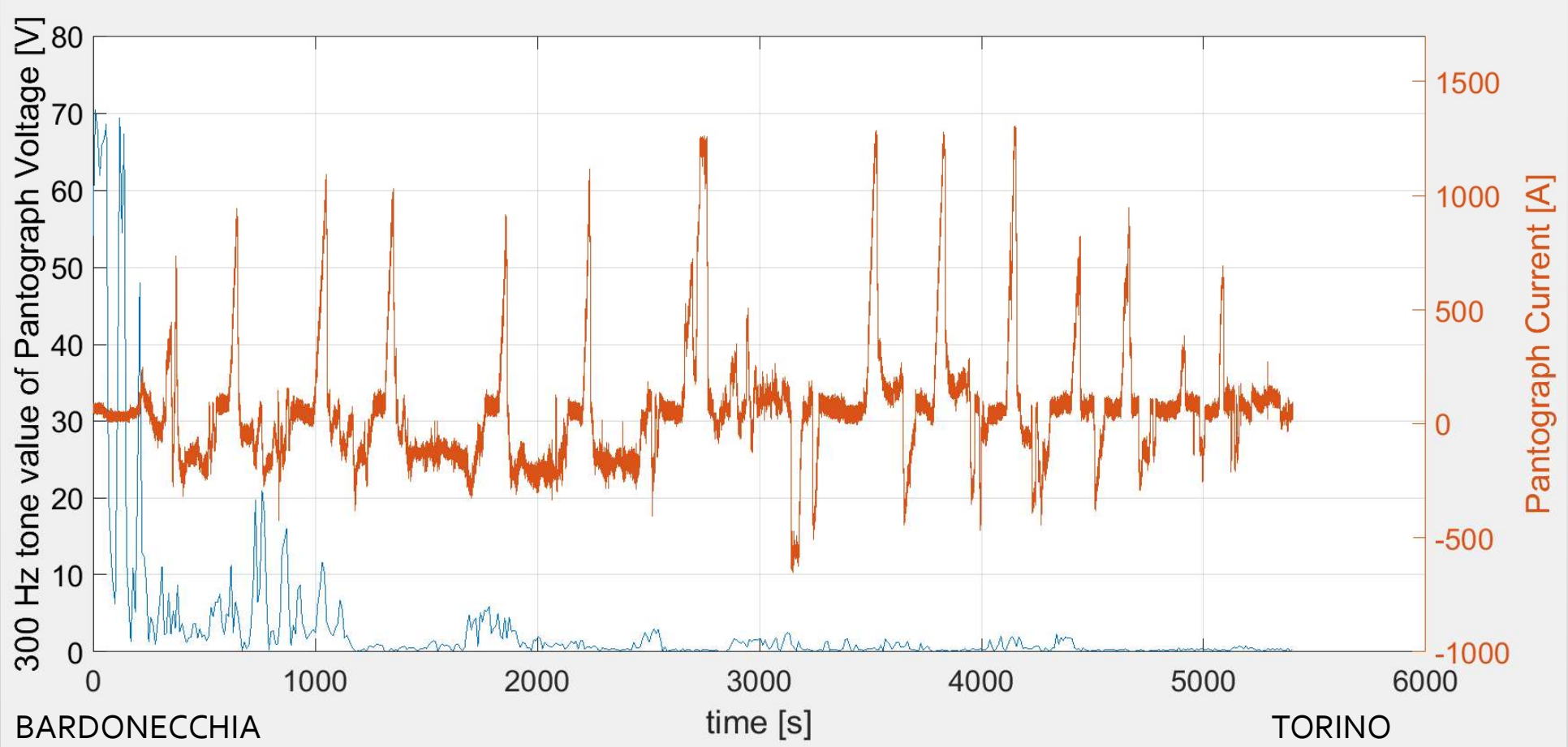
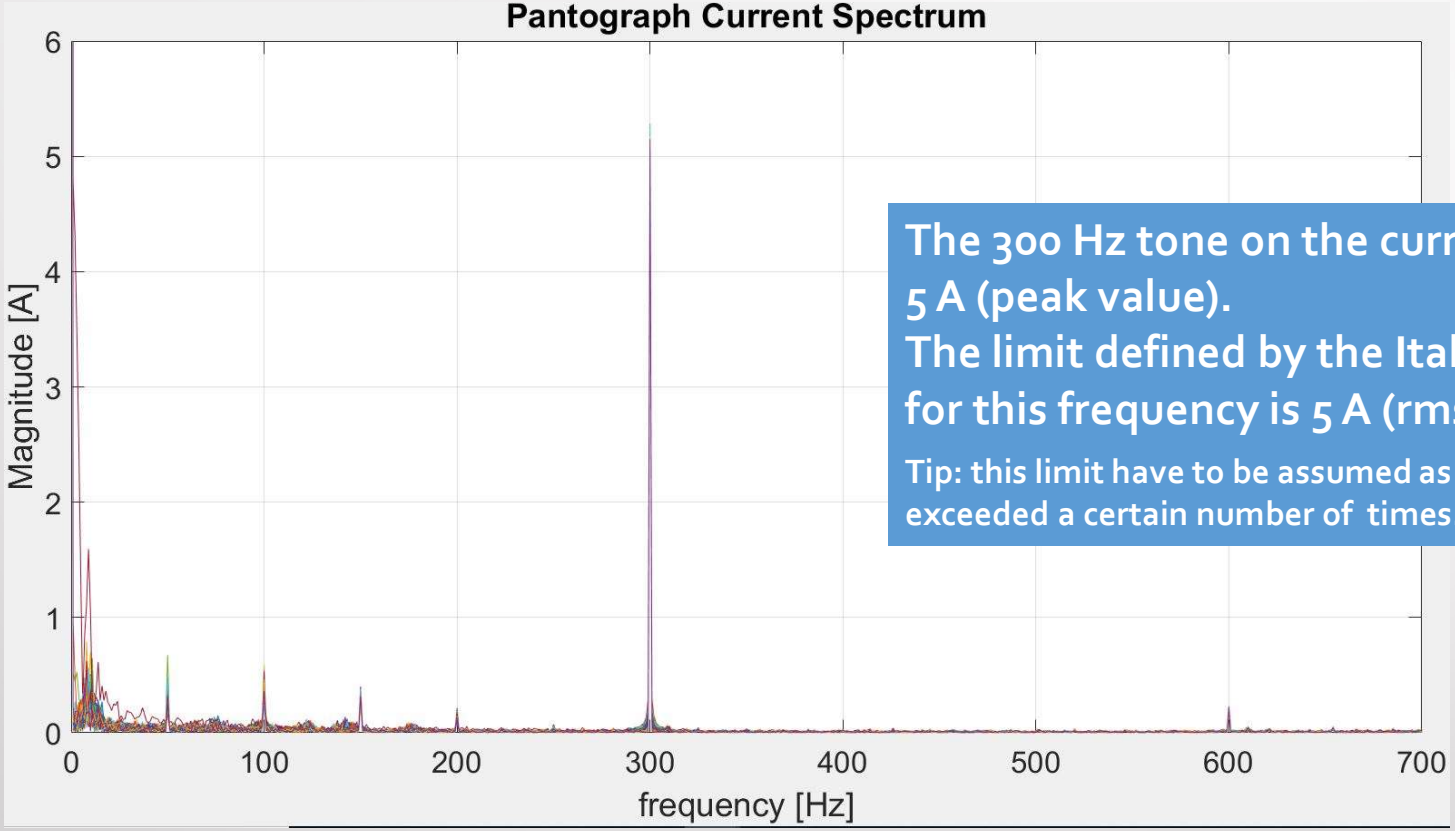
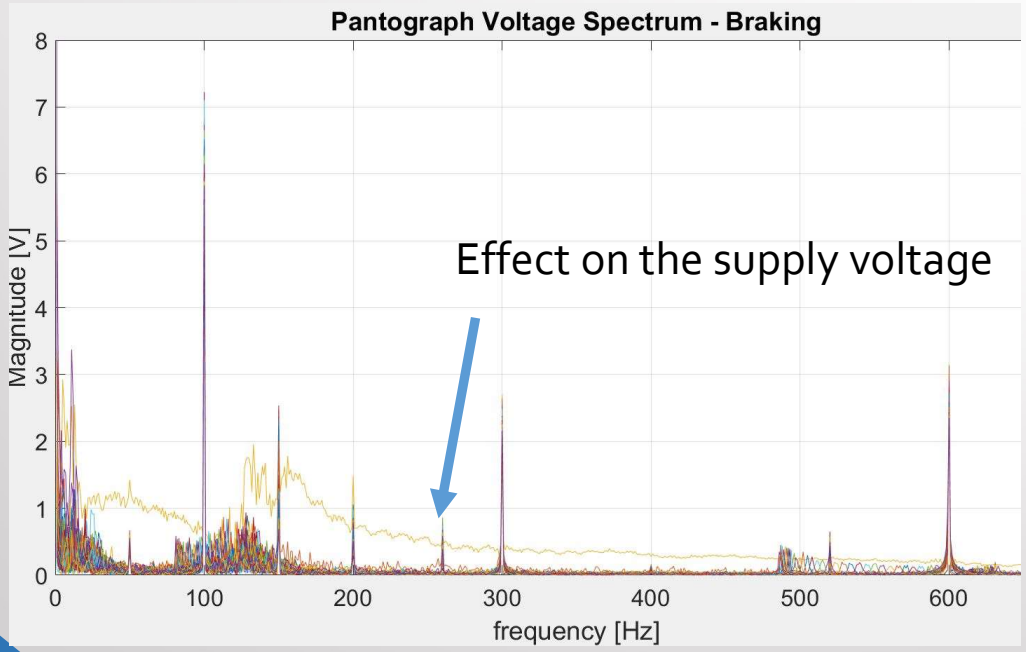




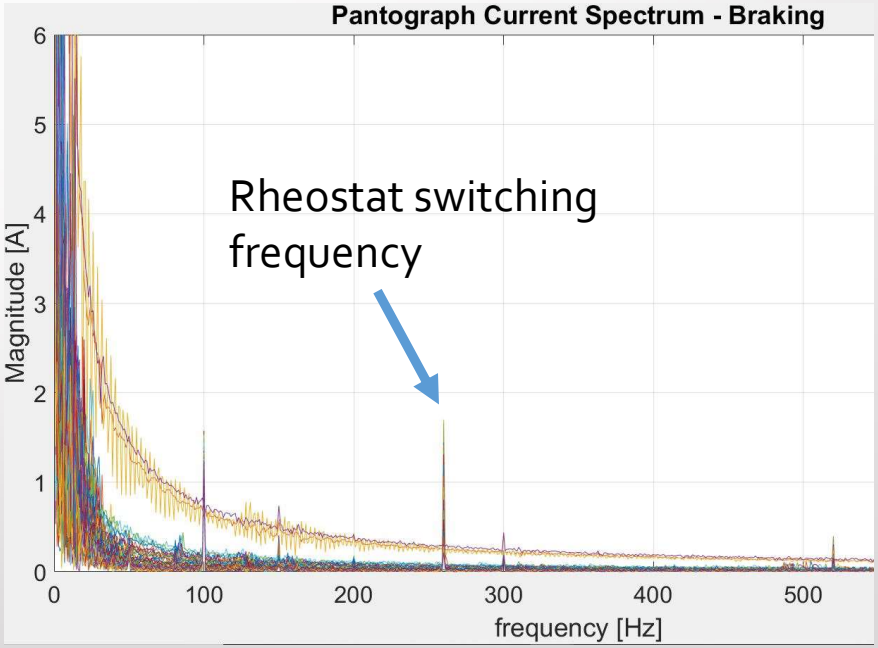

**The 300 Hz tone on the current is higher than 5 A (peak value).**
**The limit defined by the Italian railway system for this frequency is 5 A (rms)**

**Tip: this limit have to be assumed as stochastic limit, it can be exceeded a certain number of times.**

# Braking stage: recovery and dissipative braking




**Current injected in the overhead line**



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# Pantograph-to-OHL Arc as PQ event

| | |
|---|---|
| ***Aim***: | To develop a monitoring system that, exploiting the measuring chain for the energy and power quality, is able to identify the pantograph-to-OHL events. |
| ***Impact***: | This tool can foster the predictive maintenance related with both the pantograph shoe and the overhead line |
| ***Challenge***: | identification of such events in strongly distorted waveforms with a defined level of reliability by the analysis of the electrical quantities at pantograph. |

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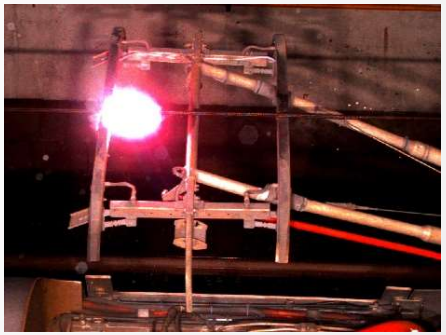
## Reason of arcing phenomena:

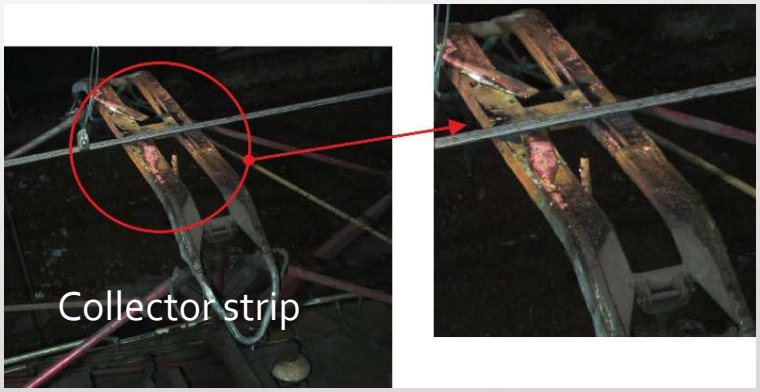
- Track irregularities
- Irregularities of catenary
- High speed
- Weather conditions (snow, ice, frost)



https://www.youtube.com/watch?v=TBe48QJdPtk

## Consequences:

- Fast degradation of the collector strip
- Increase of arc events
- Decrease of power quality
- Accidents



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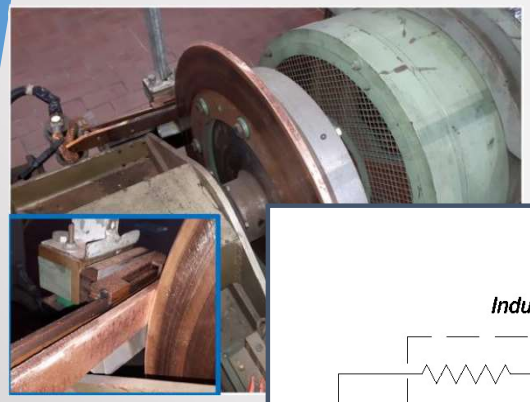
# State of the art of the research activities

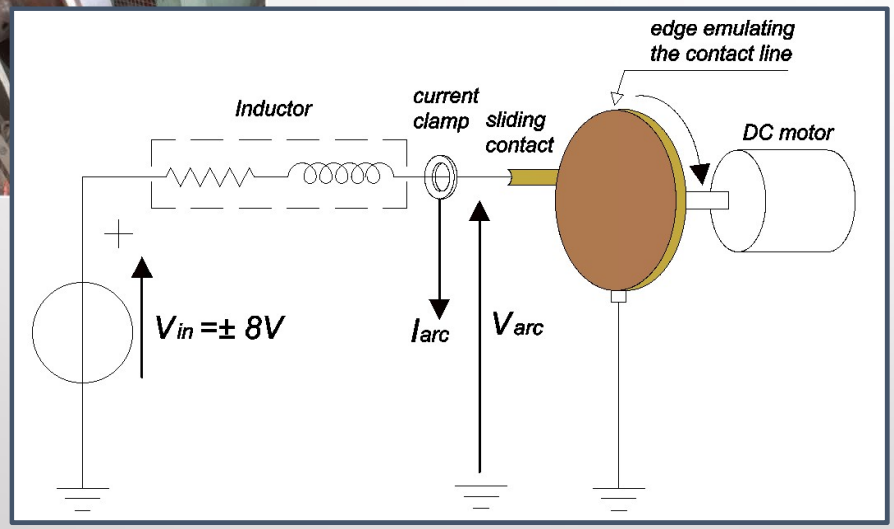
The researches are directed to:

- the accurate estimation of the induced (high frequency) effects produced by arcing in the railway systems
- the analysis of the contact strip degradation with different material composition
- the influence of some parameters affecting the arc phenomena, i.e. the power factor, the direct current (DC) polarity
- The majority of such works addressed the alternating current (AC) railway supply systems, neglecting DC systems

**Our aim is to study the conducted effects at some kilohertz**

# Experiment for the arc voltage characterization






Supply DC voltage: ± 8V
Inductor: 156 µH, 3.59 mΩ

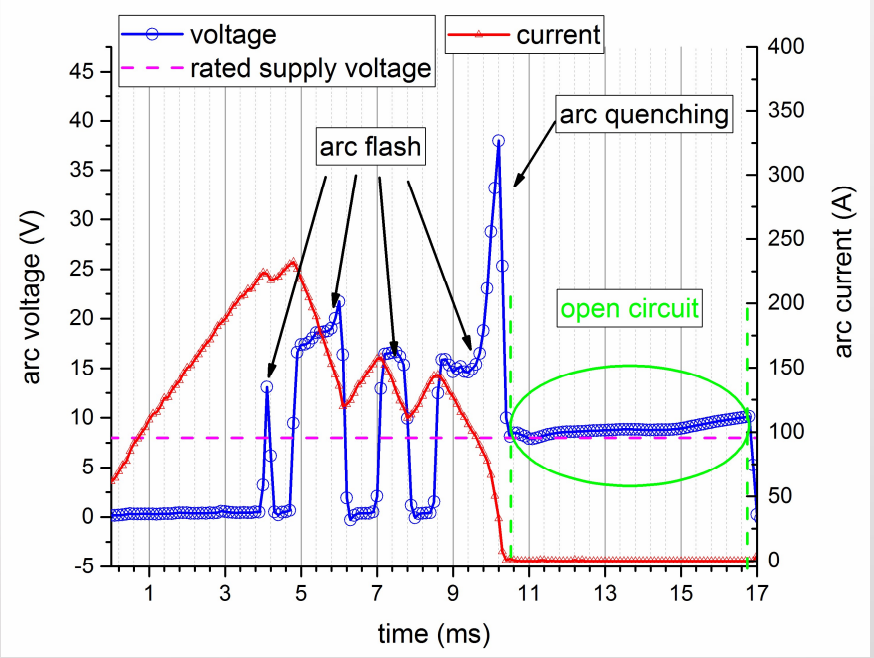
Acquisition system:

- DEWETRON platform with DAQP-DMM signal conditioners
- current transducers are Chauvin Arnoux PAC12 clamps, bandwidth from DC to 5 kHz.
- Sampling frequency: 10 kHz

# Experimental results

Burning arcs on the wheel: (left) good contact, (middle) arc elongation, (right) quenching

Equivalent speed 139 km/h




**Tip:**

**The setup does not reproduce the real mechanical conditions experienced in railway sliding contact**

**It is a good arc generator**

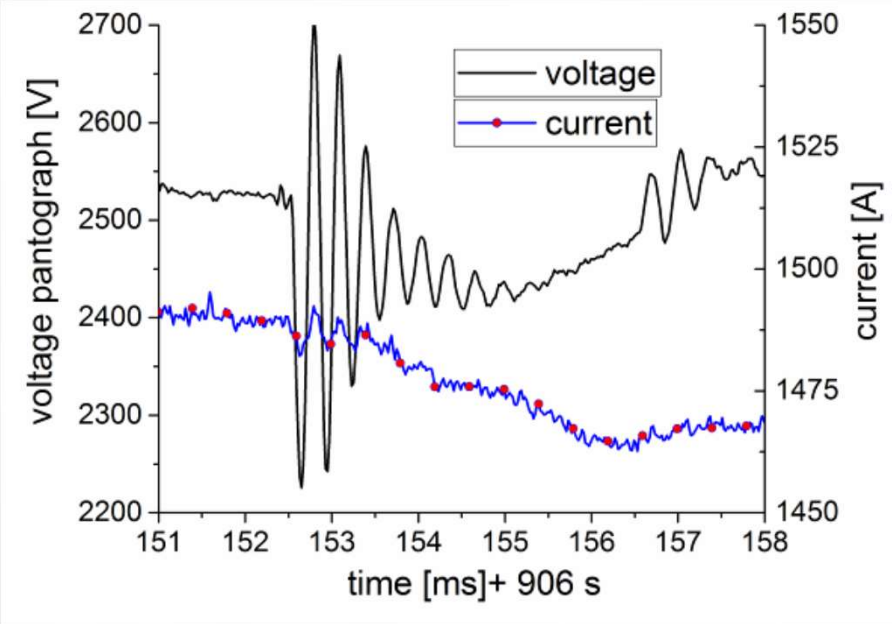
# Measurement site for ETR600 Approval test (2008): Pisa-Collesalvetti


**Aim of the measurement campaign performed in 2008:**

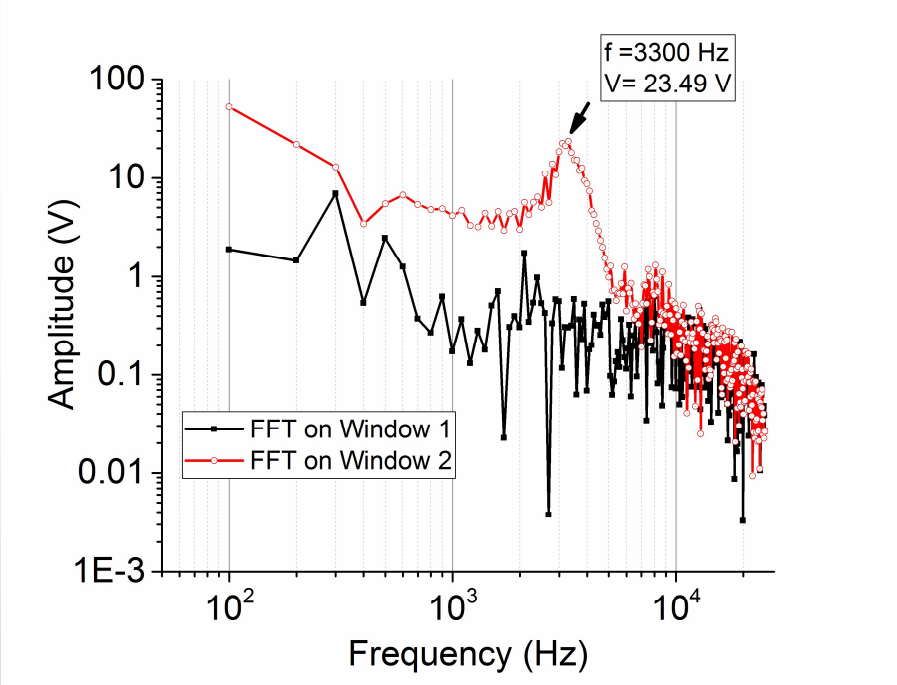
- To verify the performances of the ETR 470 under low supply voltage .
- This section line has selected because its low overhead line section

- Single track line
- Total overhead line section: **440 mm²**
- Distance between two substations: **20 km**

## Zoom of the event considered

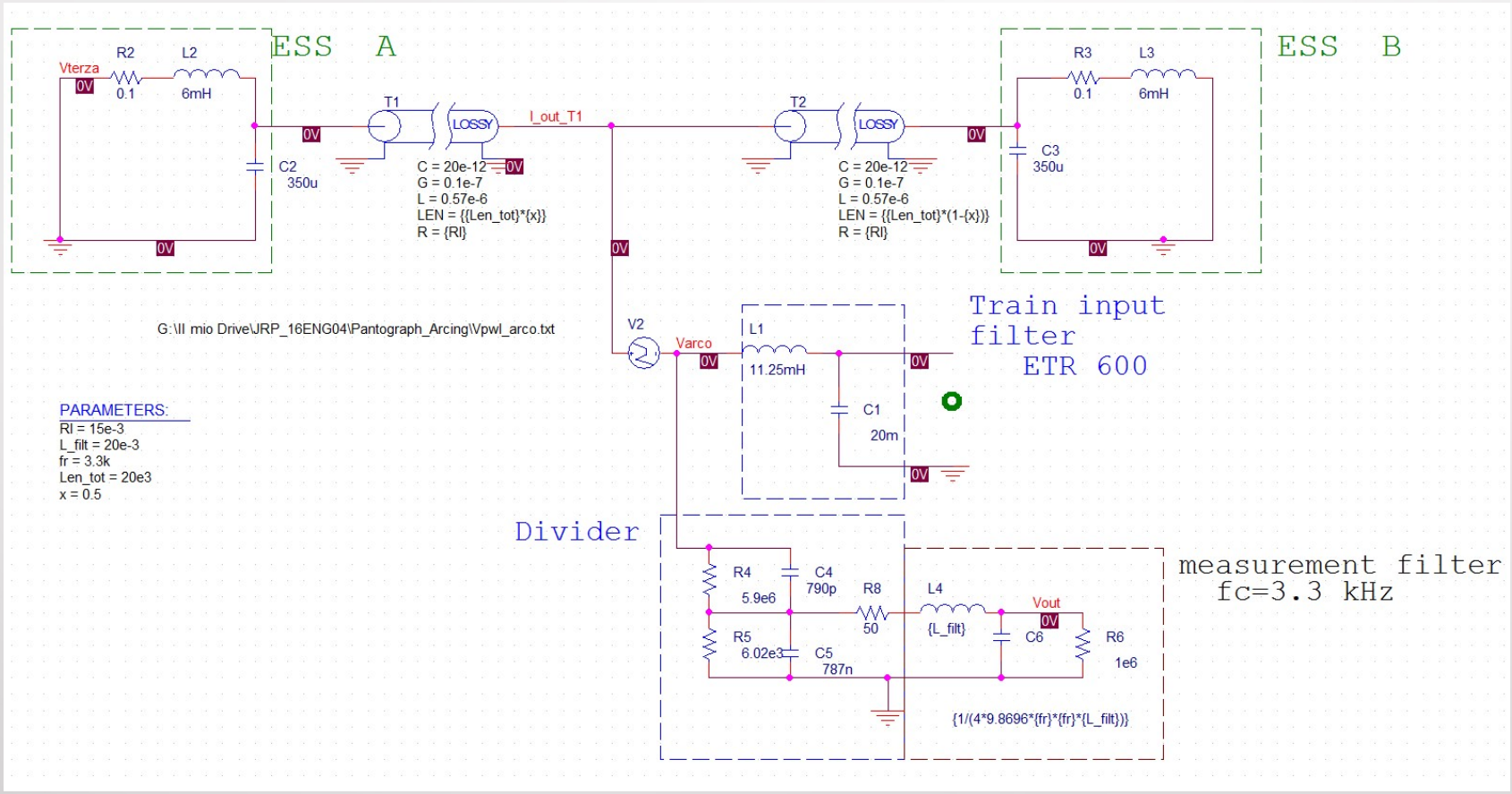


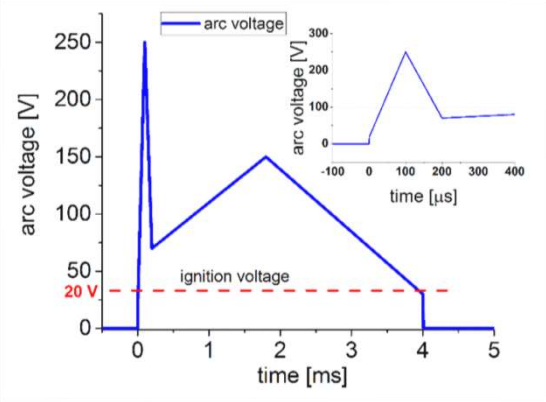

## FFT before (black) and during (Red) the event



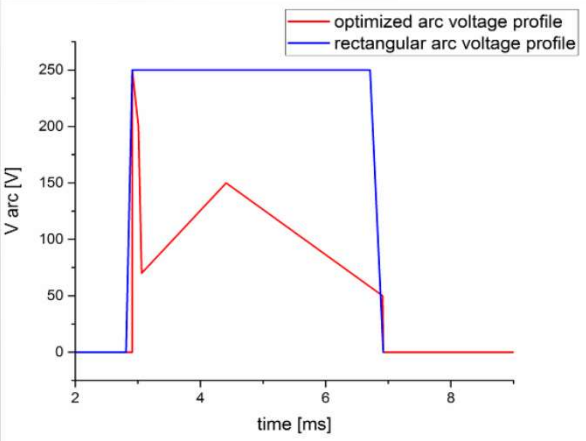
# Circuital model to study the conducted effect of the arc

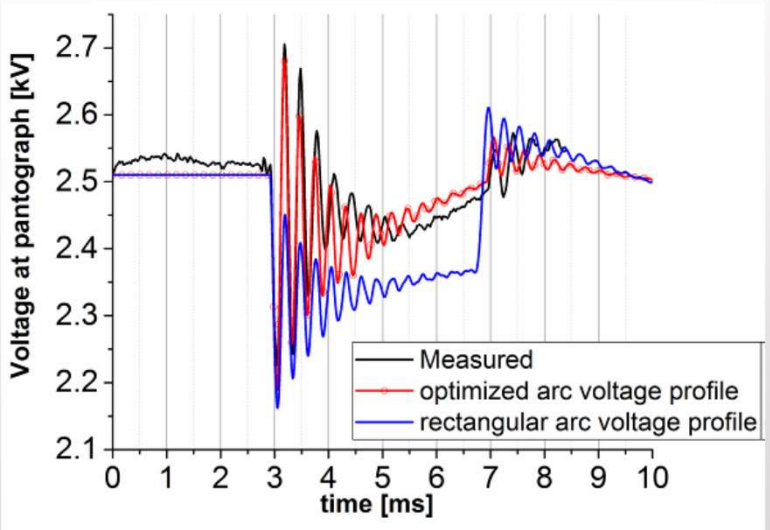
- A complete circuital model has been developed in order to study the conducted effects of an arc event.
- It involves:
  - The two ESS supplying the line
  - The stray parameters simulating the contact line and track
  - The arc event
  - The input filter stage of the considered train
  - The measurement chain employed to detect the voltage at the pantograph.


ESS A
ESS B
Vterza
R2
L2
0.1
6mH
0V
C2
350u
T1
LOSSY
I_out_T1
C = 20e-12
G = 0.1e-7
L = 0.57e-6
LEN = {{Len_tot}*{x}}
R = {Rl}
T2
LOSSY
C = 20e-12
G = 0.1e-7
L = 0.57e-6
LEN = {{Len_tot}*(1-{x})}
R = {Rl}
R3
L3
0.1
6mH
C3
350u
G:\Il mio Drive\JRP_16ENG04\Pantograph_Arcing\Vpwl_arco.txt
V2
Varco
L1
11.25mH
C1
20m
Train input filter
ETR 600
PARAMETERS:
Rl = 15e-3
L_filt = 20e-3
fr = 3.3k
Len_tot = 20e3
x = 0.5
Divider
R4
5.9e6
C4
790p
R8
50
L4
{L_filt}
Vout
C6
R6
1e6
R5
6.02e3
C5
787n
{1/(4*9.8696*{fr}*{fr}*{L_filt})}
measurement filter
fc=3.3 kHz




The arc voltage profile has been selected thanks to the knowledge gathered in the test laboratory and by qualitative considerations about mechanical dynamic of the pantograph during a detachment.




The conducted effects of the arc voltage profile is shown

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# Thank you

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Napoli - Pietrarsa, 21 February 2019