

# Energy Dissipated by the Braking Rheostats: a Case Study

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## Objectives

- Introducing case study
- Describing measurement system
- Results presentation

# Analysed System

E464-041

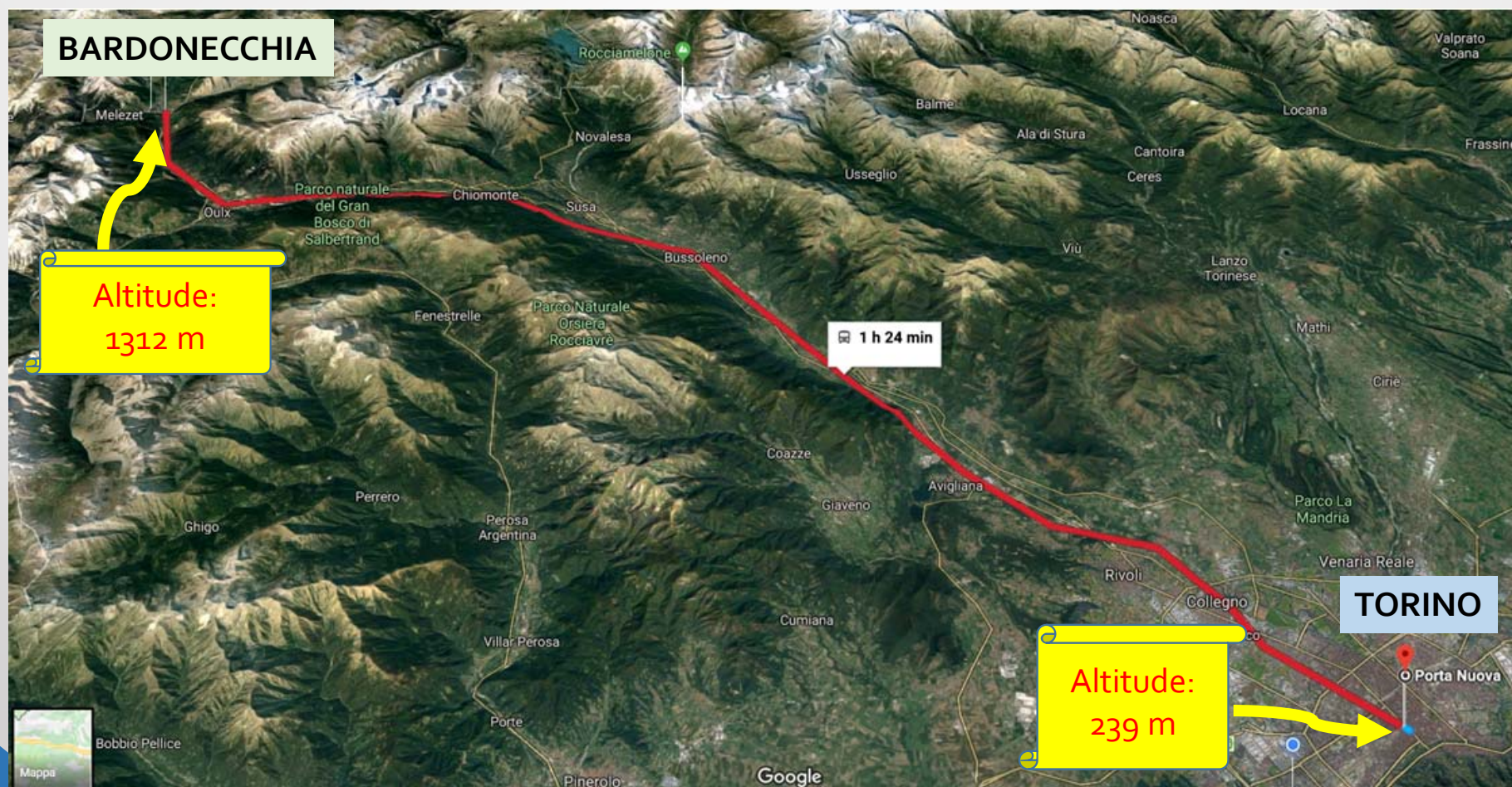


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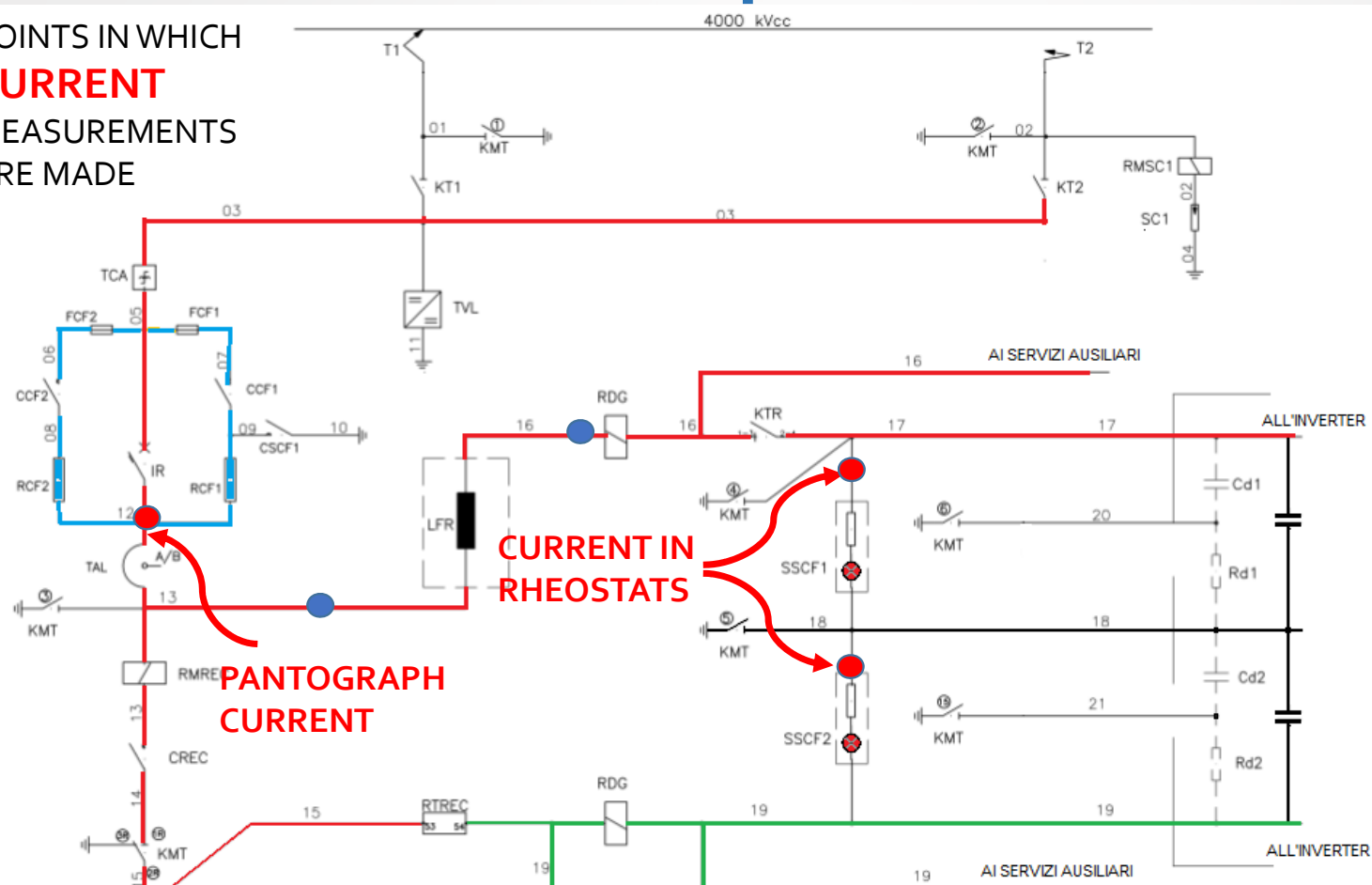


## Analysed Route



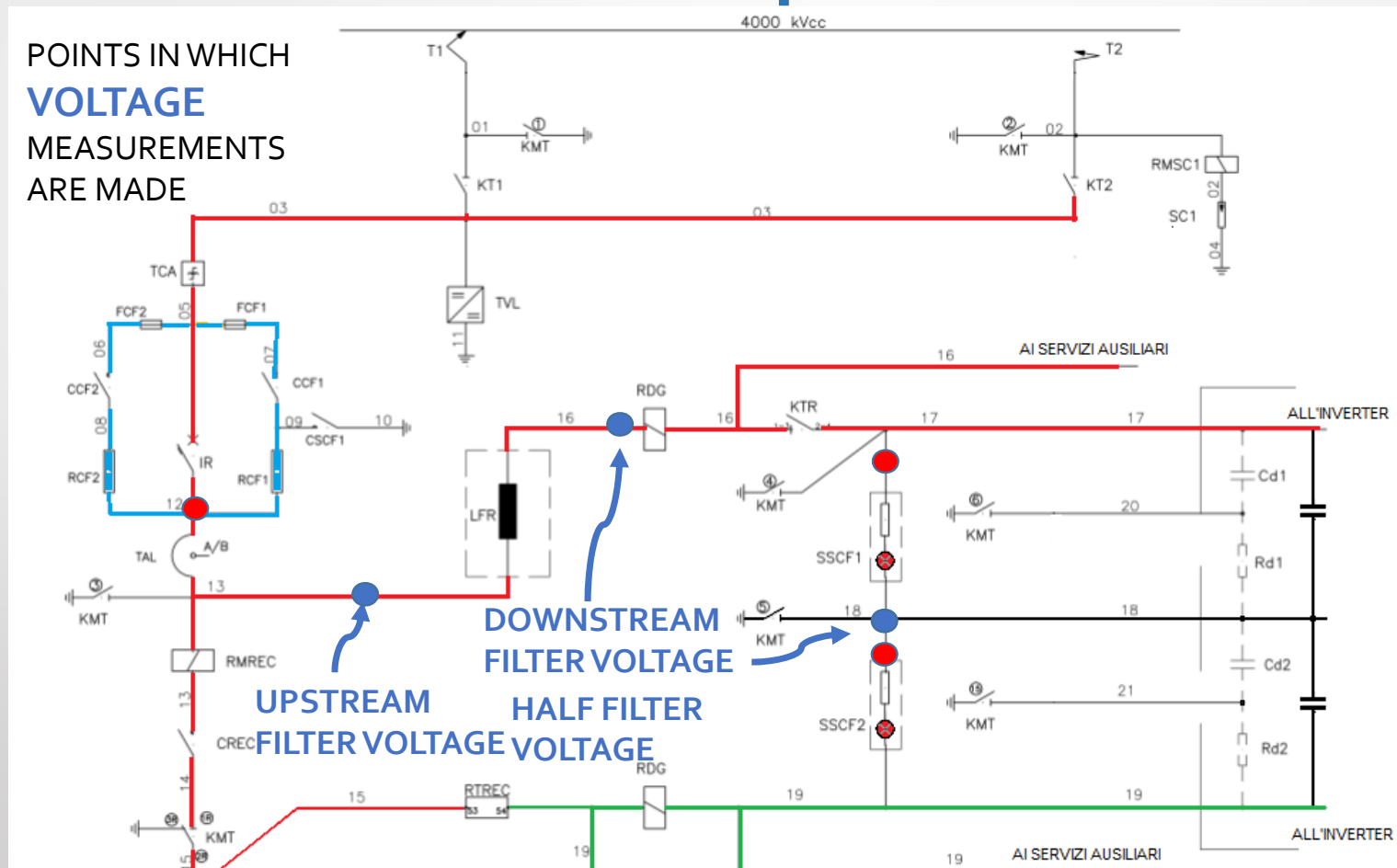
# Measurement points

POINTS IN WHICH  
**CURRENT**  
MEASUREMENTS  
ARE MADE



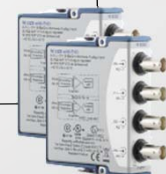
# Measurement points

POINTS IN WHICH  
**VOLTAGE**  
MEASUREMENTS  
ARE MADE





# Measurement System



SUPPLY SYSTEM

ACQUISITION SYSTEM

- 8 channels
- 50 kHz
- 16 bit

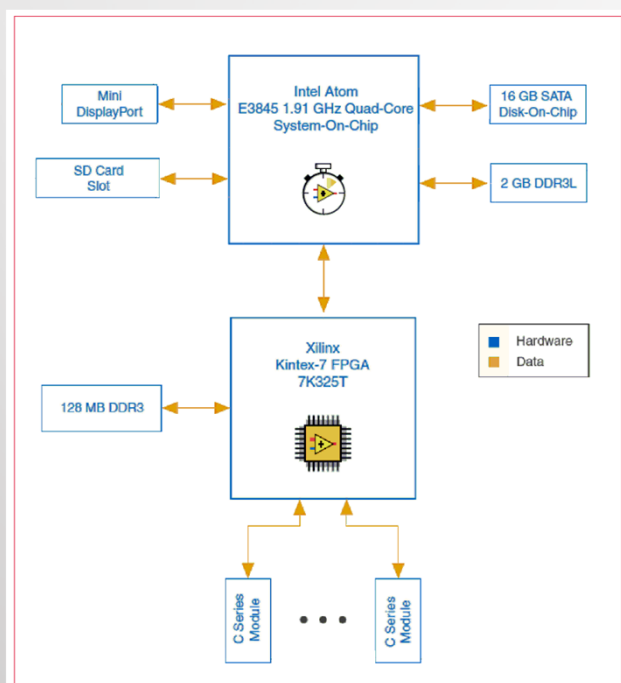
TRANSDUCERS

- 3 Voltages
- 5 Currents

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# Storage System



USING AN SD CARD OF **512 GB** THE DEVICE CAN RECORD FOR MORE THAN **9 DAYS CONTINUOUSLY!**

REPLACING THE SD, IT IS POSSIBLE **TO EXTEND MONITORING WITHOUT ANY DATA LOSS.**

THE RECORDING STARTED ON DECEMBER 7, 2018 AND IS **STILL IN PROGRESS**



# Acquisition System



NI 9223  
4 analog input Voltage channels  
**16 bit**  
SAR converter  
Simultaneous Sampling  
±200 ppm max  
**1 MSamples/s**  
±10V PEAK  
Input impedance >1 GΩ



NI 9211  
4-Channel **Temperature Module**  
14 Samples/s Aggregate, ±80 mV  
16 bit  
includes anti-aliasing filters,  
open-thermocouple detection,  
and cold-junction compensation  
for high-accuracy thermocouple  
measurements.

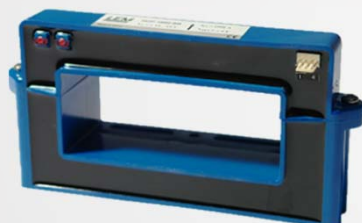


NI 9467 **GPS MODULE**

Pulse per second (PPS) accuracy of ±100  
ns, >99 percent typical

# CURRENT TRANSDUCERS

## HOP TRANSDUCER



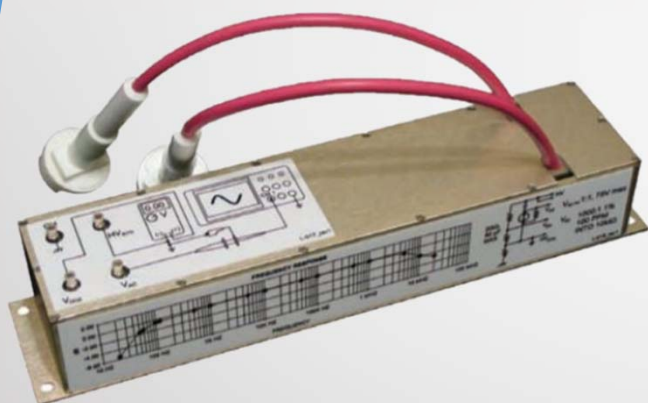
PRIMARY NOMINAL RMS CURRENT $I_{PN}$	2000A
OUTPUT VOLTAGE	$\pm 4V$
SUPPLY VOLTAGE ( $\pm 5\%$ )	12 .. 15 V
FREQUENCY BANDWIDTH (-1 dB)	DC .. 10 kHz
ACCURACY@ $I_{PN}$ , $T_A=25^\circ C$ , @12 .. 15 V	$\leq \pm 2\%$

## INRIM ROGOWSKI COIL WITH INTEGRATOR



NOMINAL TRANSDUCTION RATIO	20A/1V 100A/1V 1000A/1V 1000A/1V
OUTPUT VOLTAGE <sub>MAX</sub>	10V
SUPPLY VOLTAGE	220 .. 240V @50Hz

# VOLTAGE TRANSDUCERS



- THE NOMINAL TRANSDUCER RATIO IS 1000/1
- MAKE ACCURATE HV IN-LINE MEASUREMENTS
- VIEW AND MEASURE AC RIPPLE & NOISE ON DC HV
- MEASURE ABSOLUTE HV DC TO 0.25% @ 25 PPM STABILITY
- MEASURE & MONITOR SIGNALS FROM 35HZ TO 10MHZ
- VIEW SIGNALS FROM DC TO **20 MHZ**
- VIEW AND MEASURE AC MV ON DC KV
- VOLTAGE MEASUREMENT ARE ALL REFERRED TO THE GROUND

# INSTALLATION

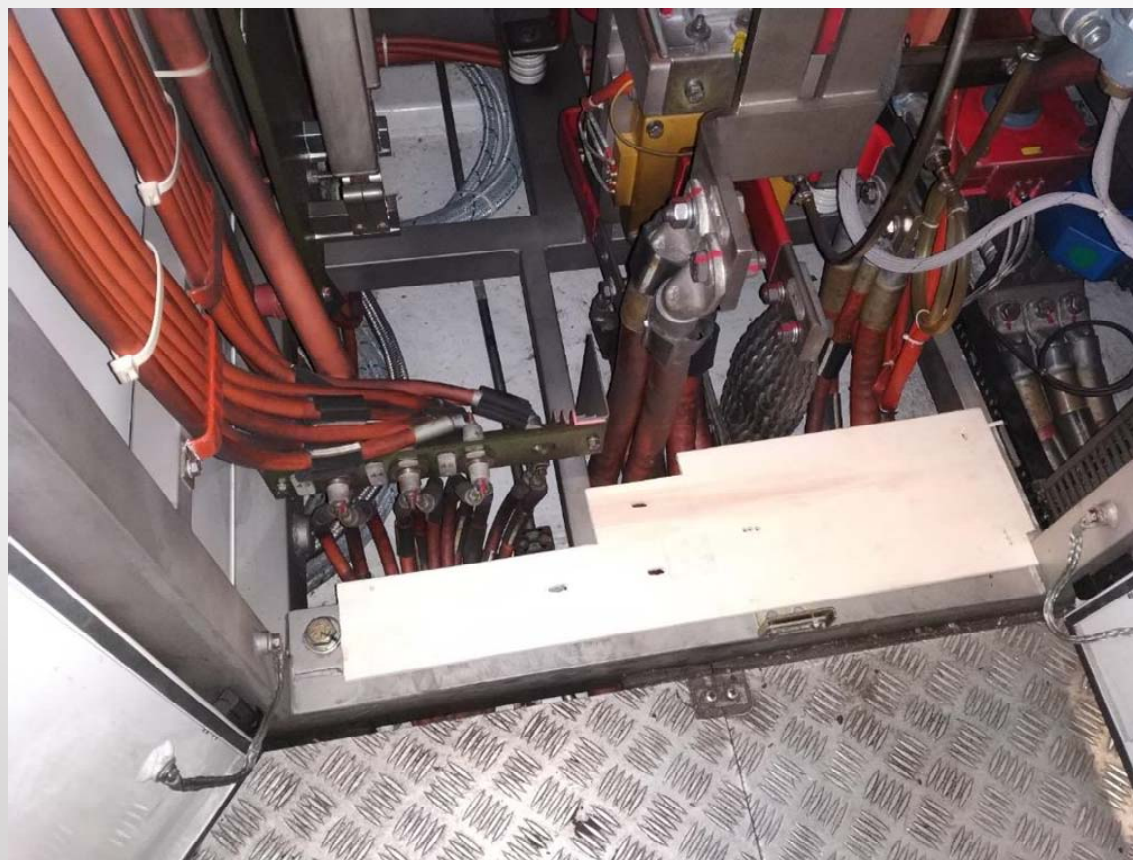


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# INSTALLATION



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# INSTALLATION



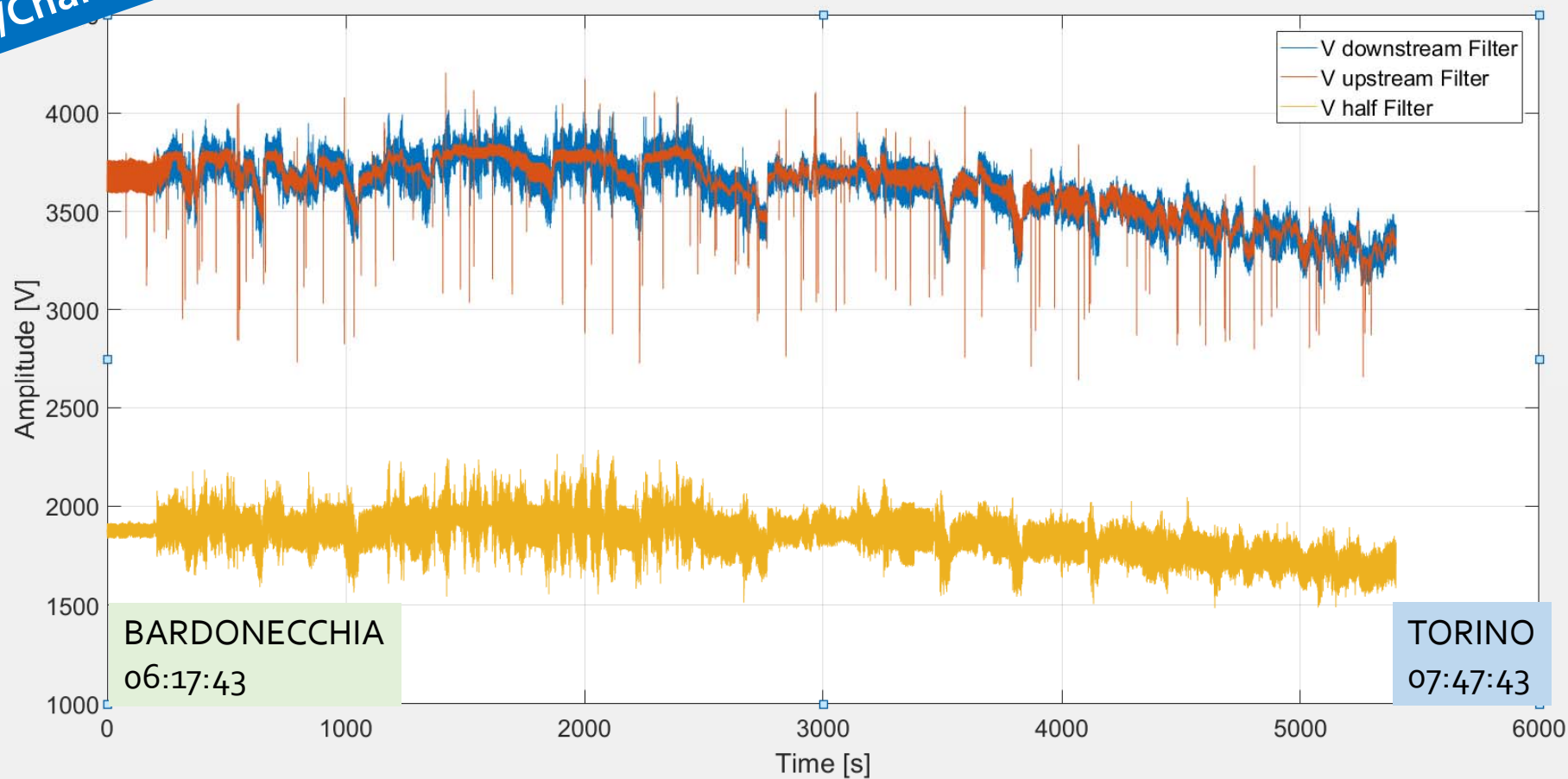
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# RESULTS

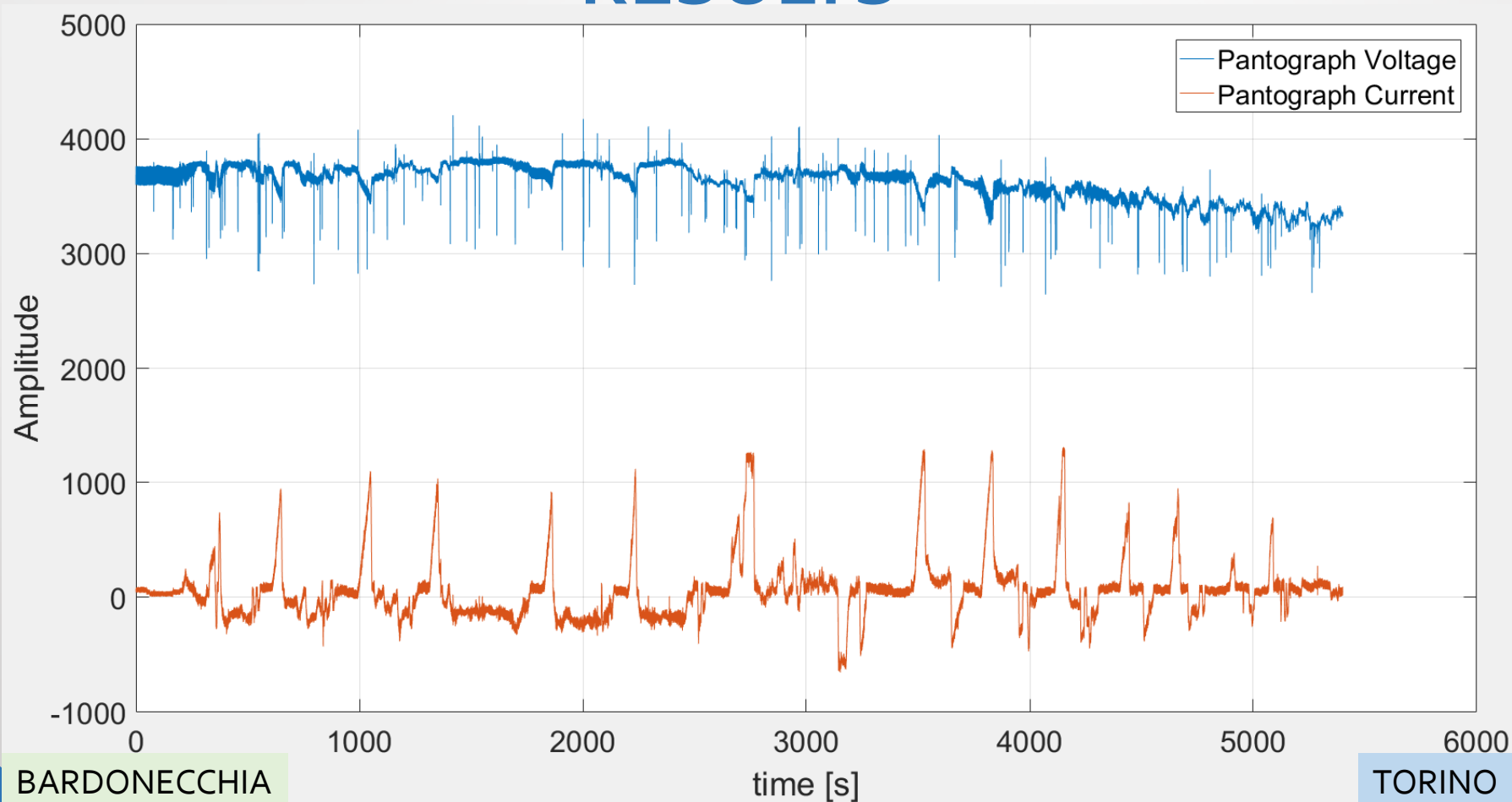
270 M  
Sample/Channel



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# RESULTS



BARDONECCHIA

06:17:43

ietrarsa, 21 February 2019

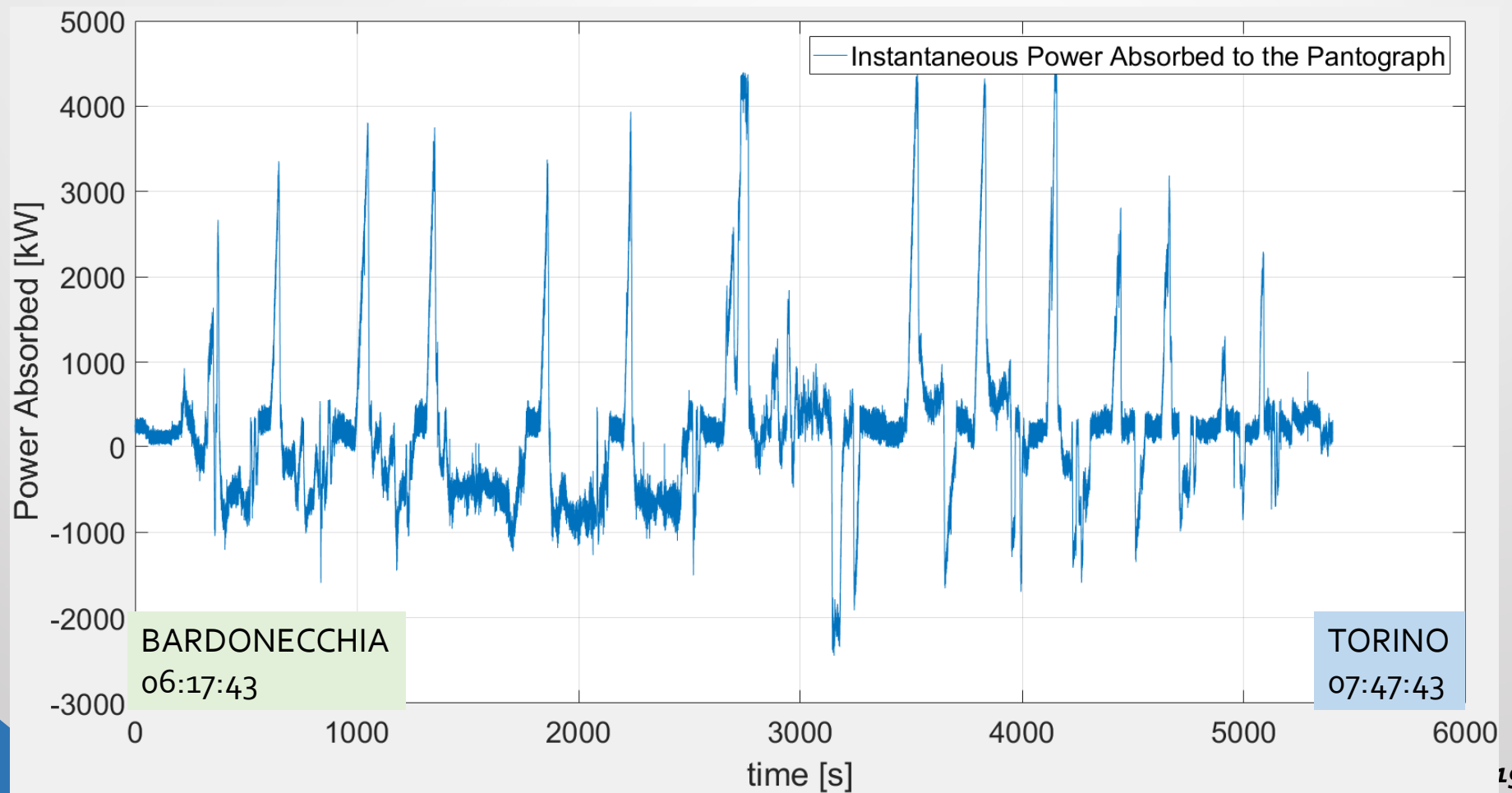
WORKSHOP

TORINO

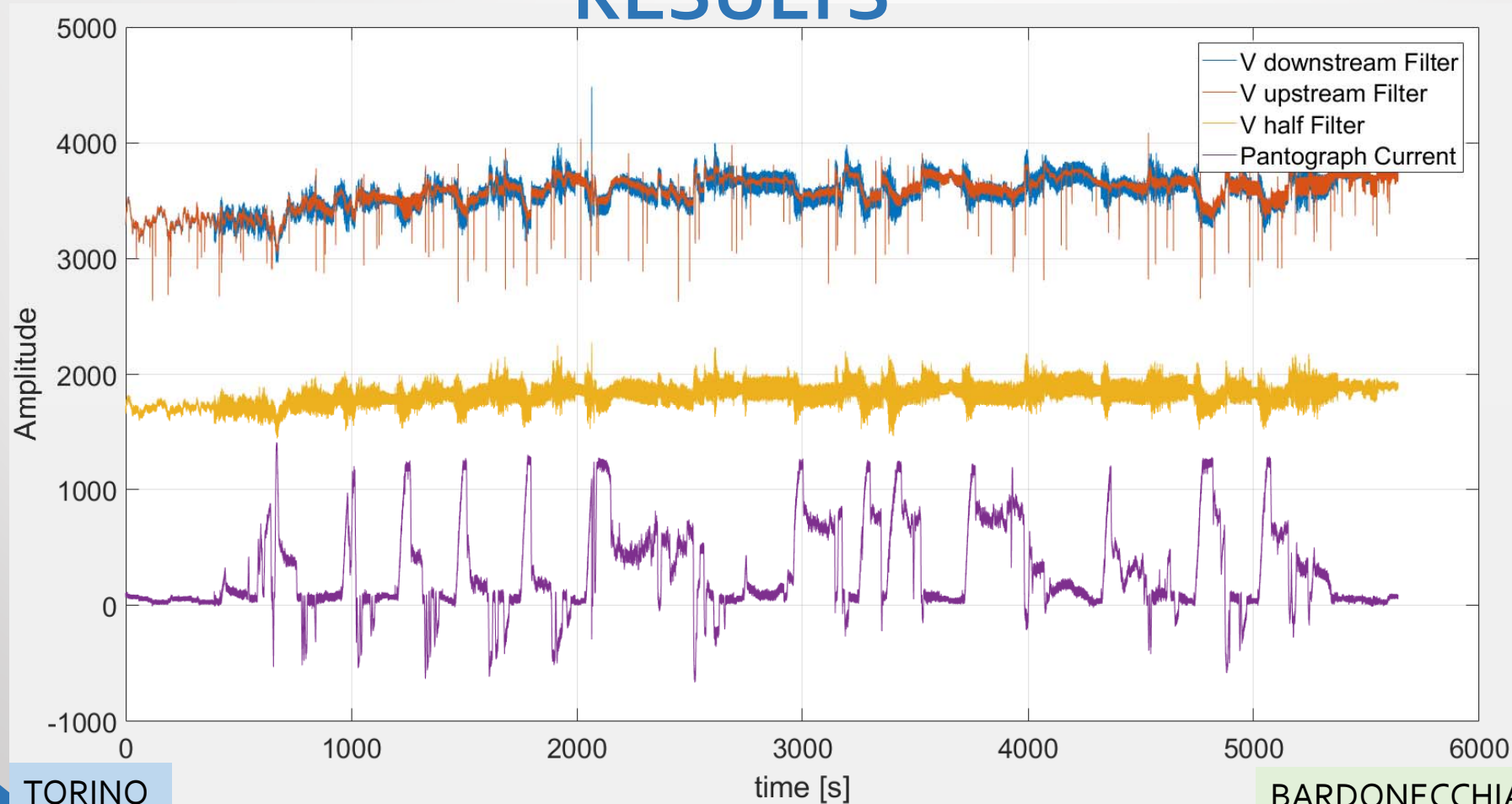
07:47:43

019

# RESULTS



## RESULTS



TORINO  
08:20:43

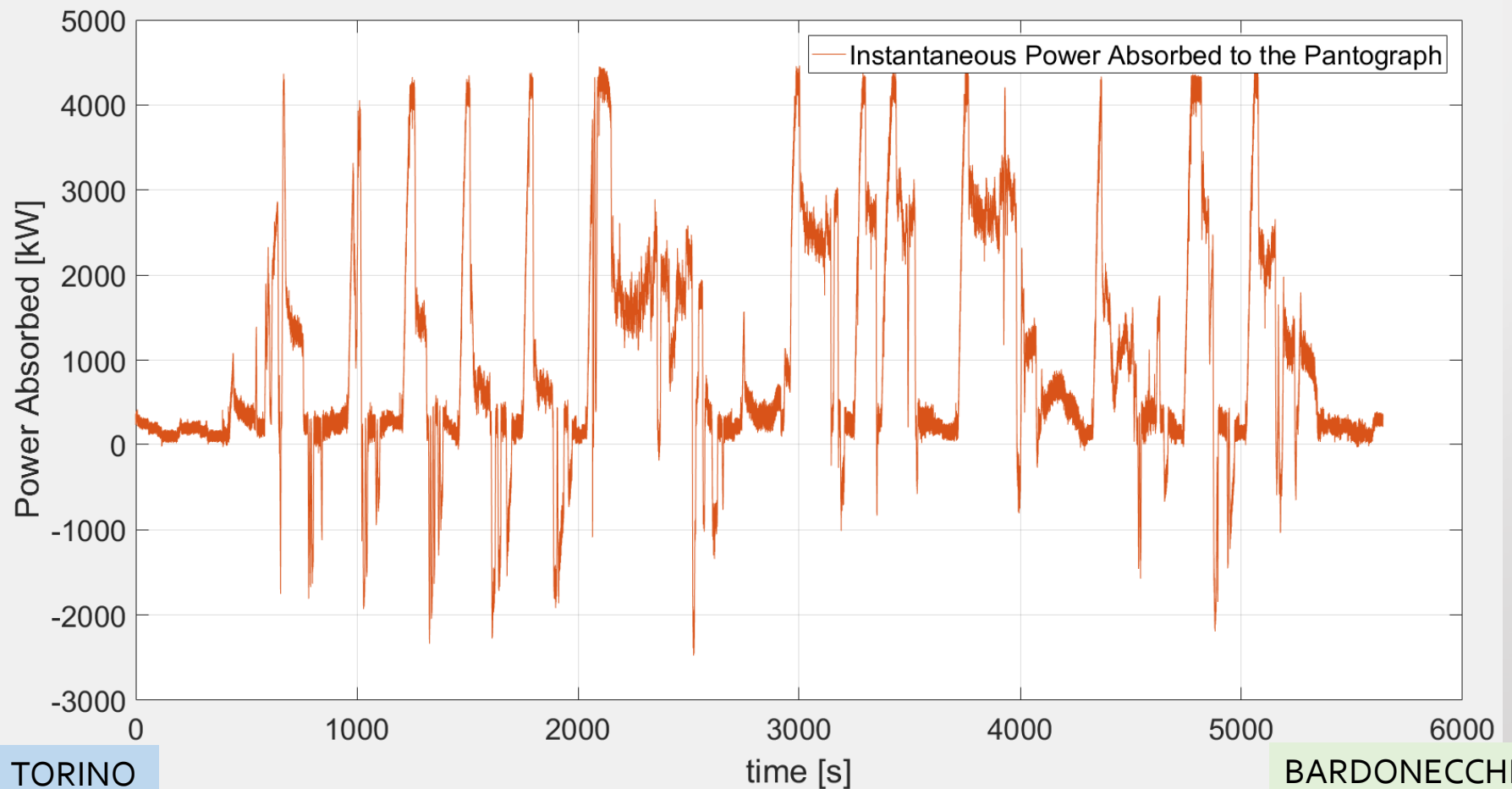
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WORK

BARDONECCHIA  
09:54:53



# RESULTS



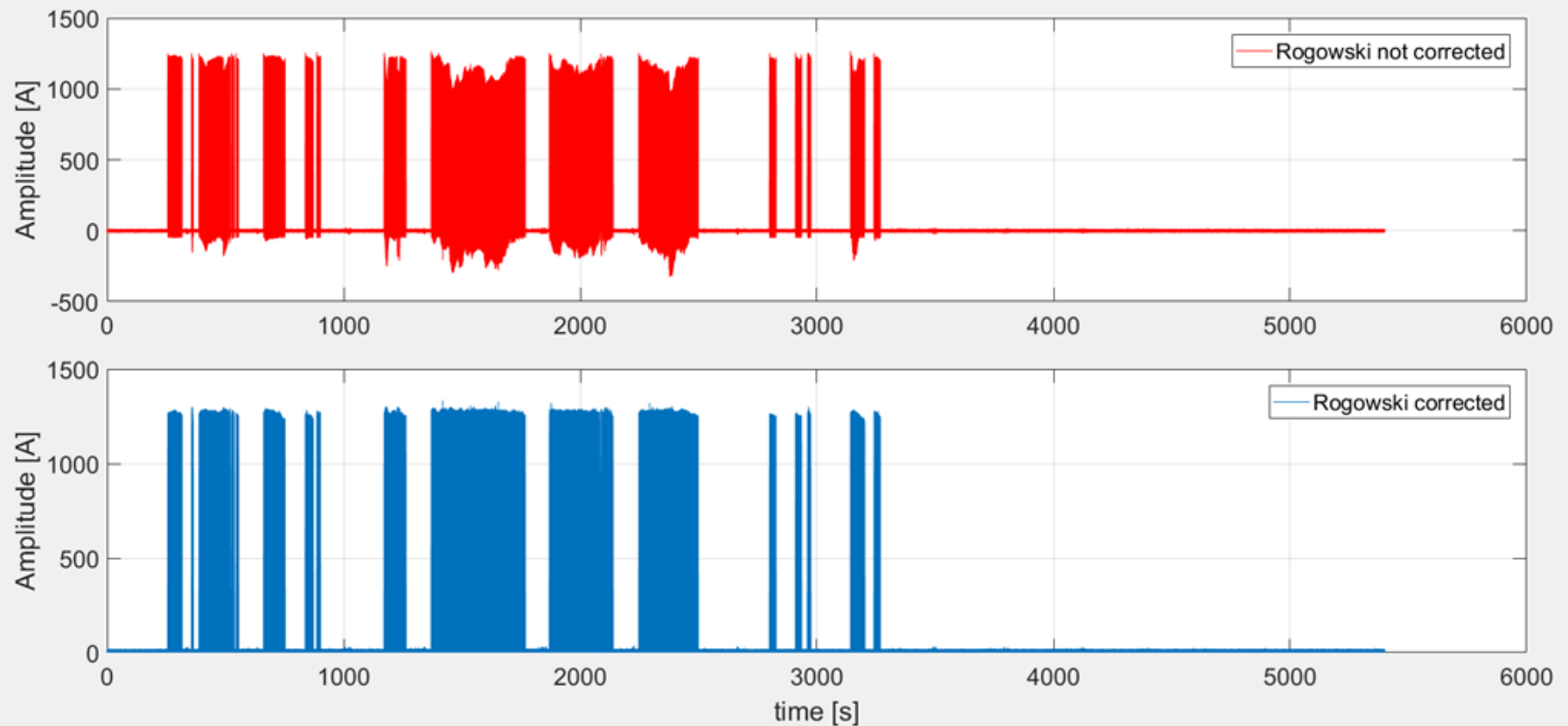
TORINO  
08:20:43

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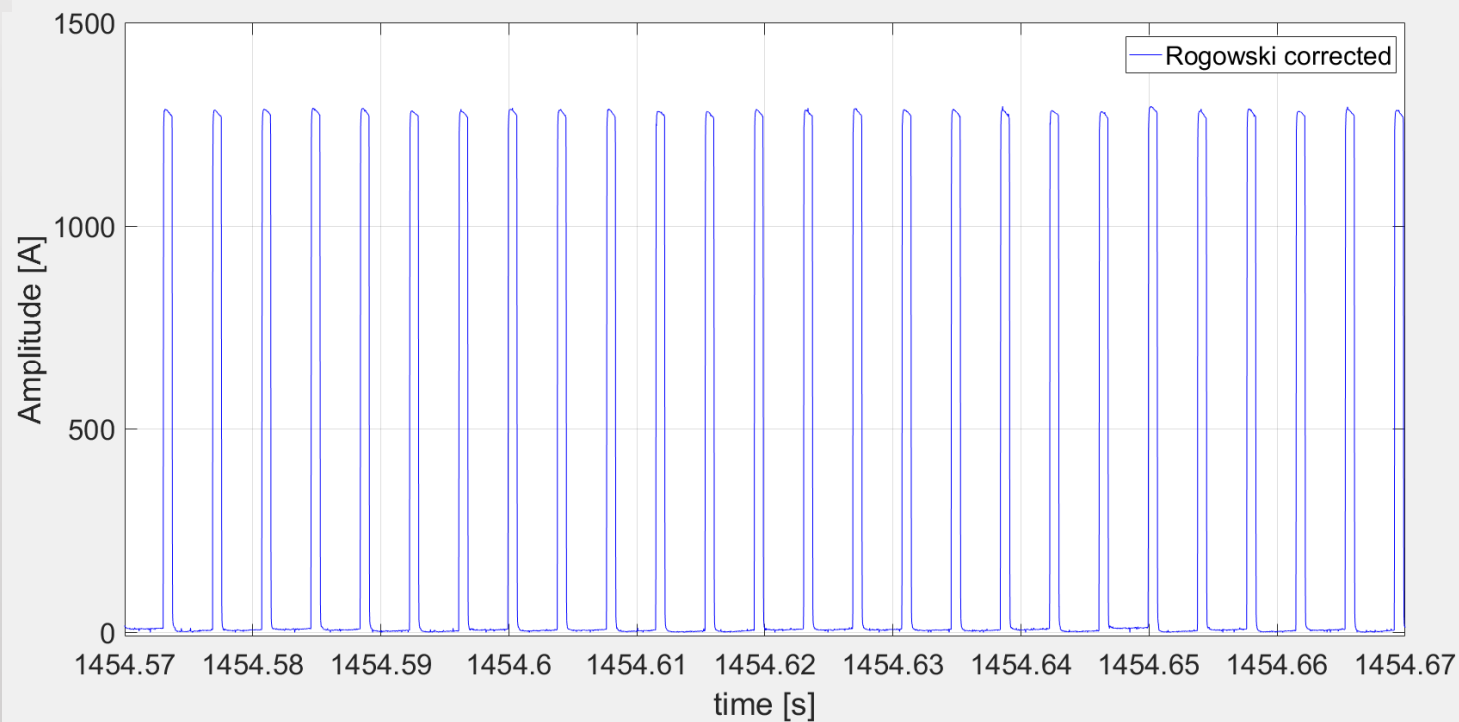
WORK

BARDONECCHIA  
09:54:53

# Braking Analysis



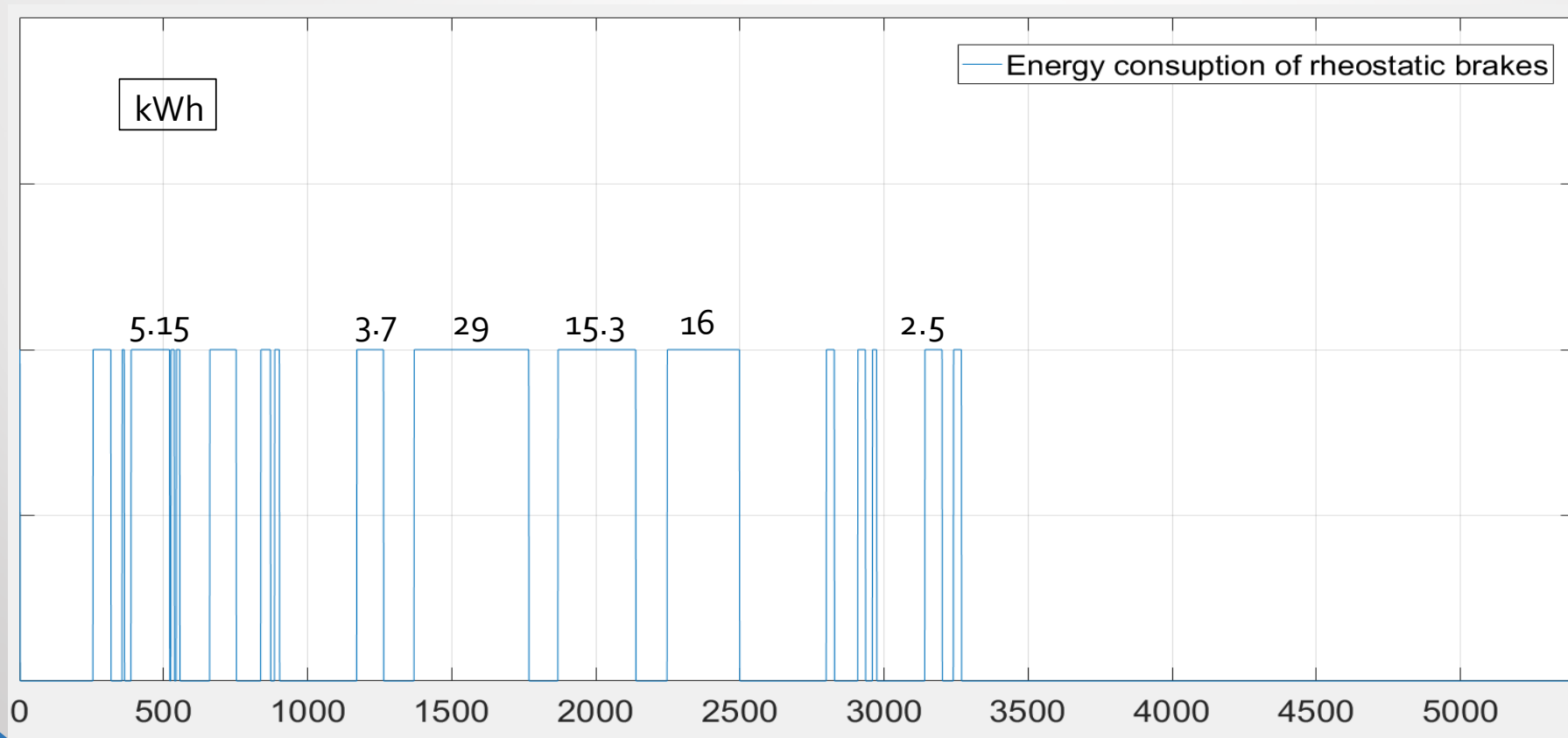
# Braking Analysis



$$\bar{f} = 240 \text{ Hz} \rightarrow T = \frac{1}{240} \text{ s}$$

$$\rightarrow \text{offset} = \frac{1}{T} \int_t^{t+T} i(t) dt$$

# Braking Analysis



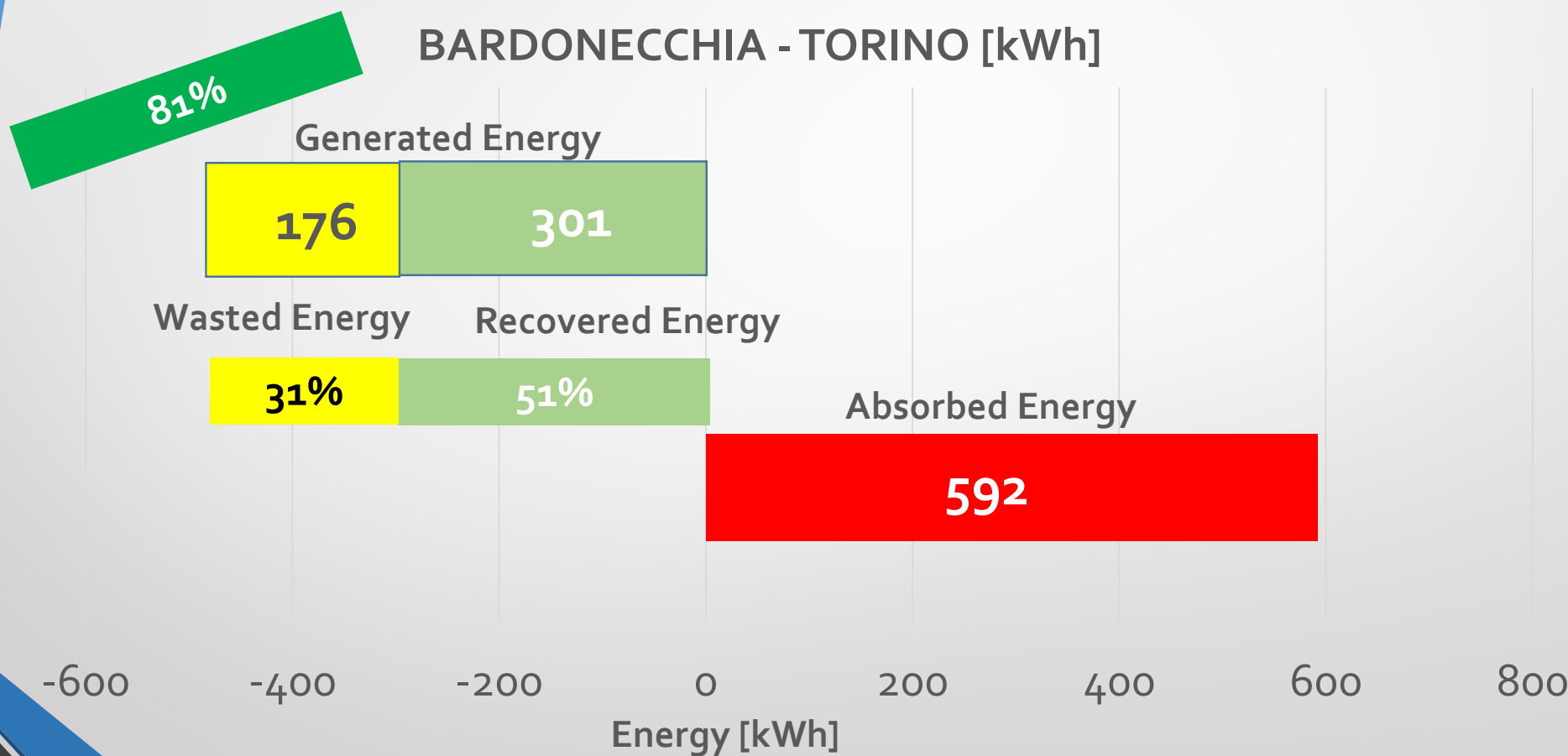
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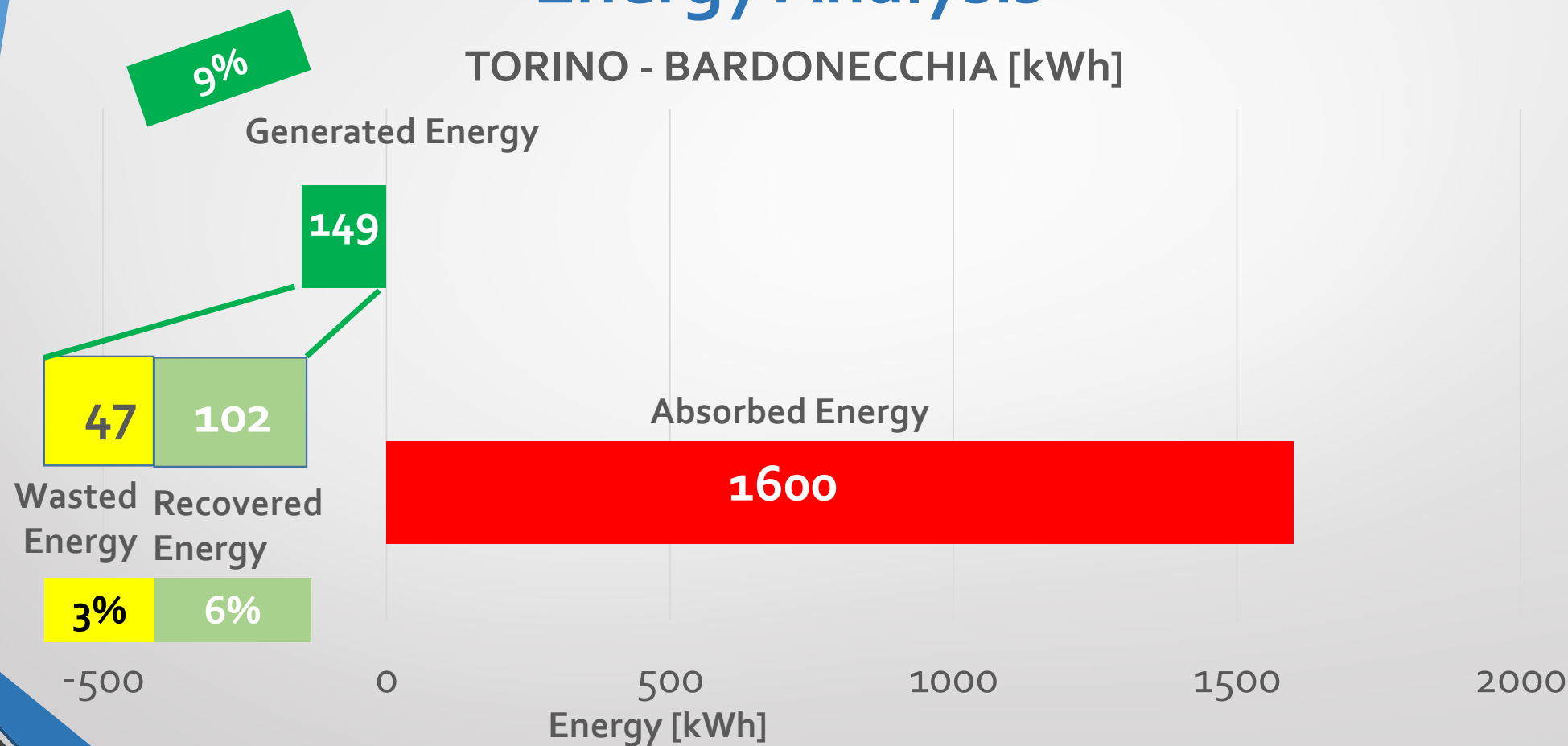
# Energy Analysis

BARDONECCHIA - TORINO [kWh]

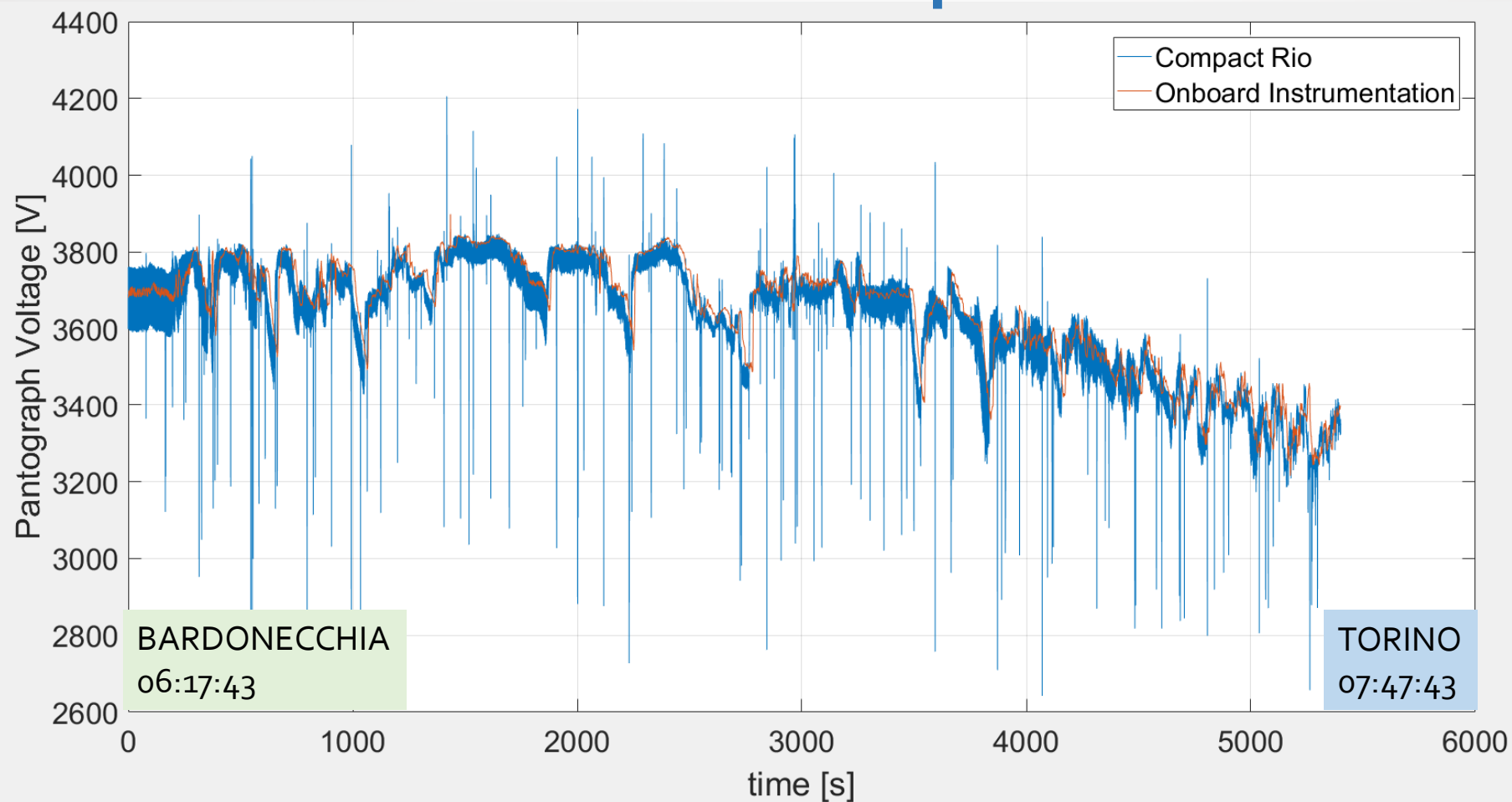


# Energy Analysis

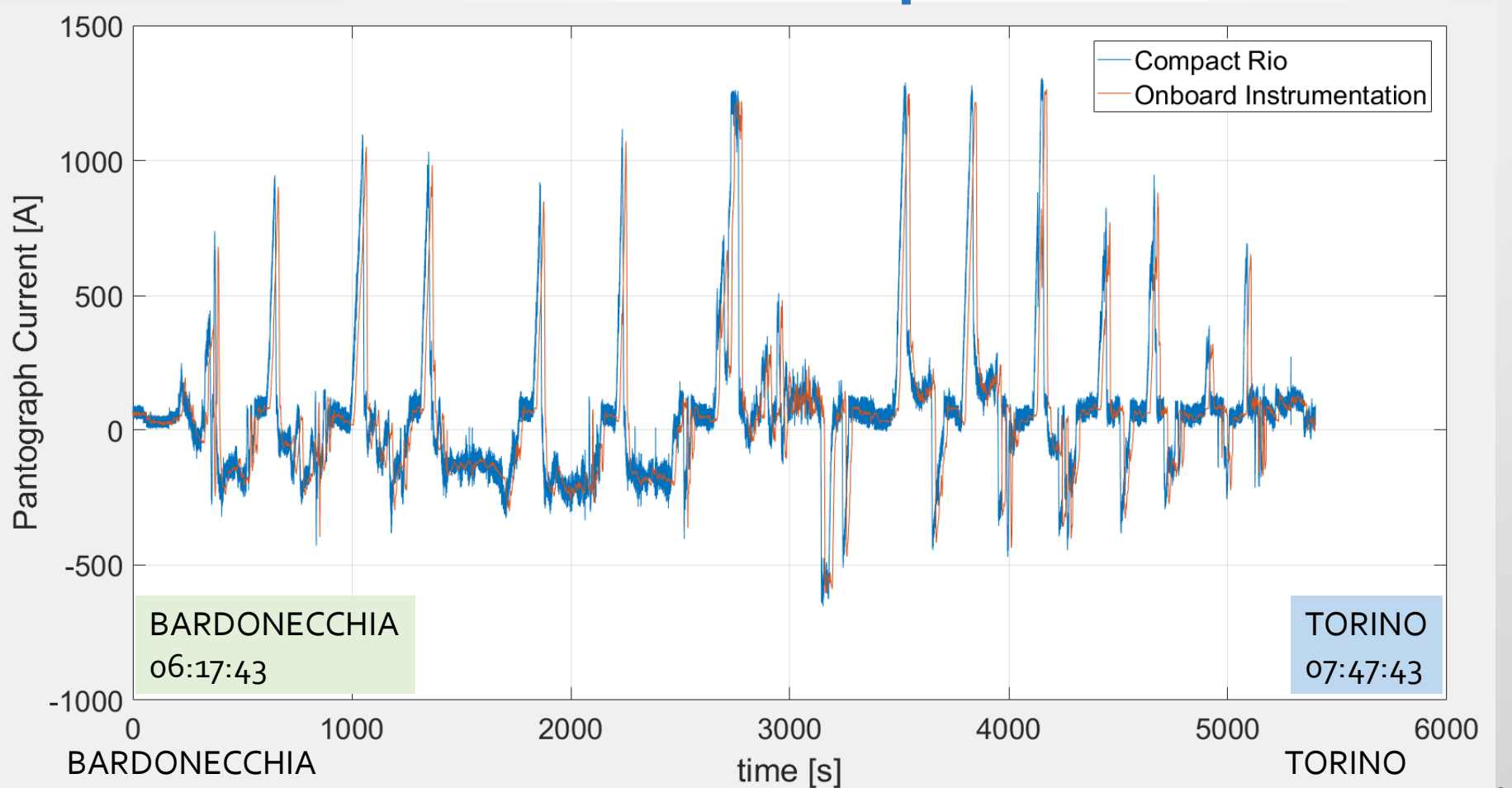
TORINO - BARDONECCHIA [kWh]



# Measurement Comparison

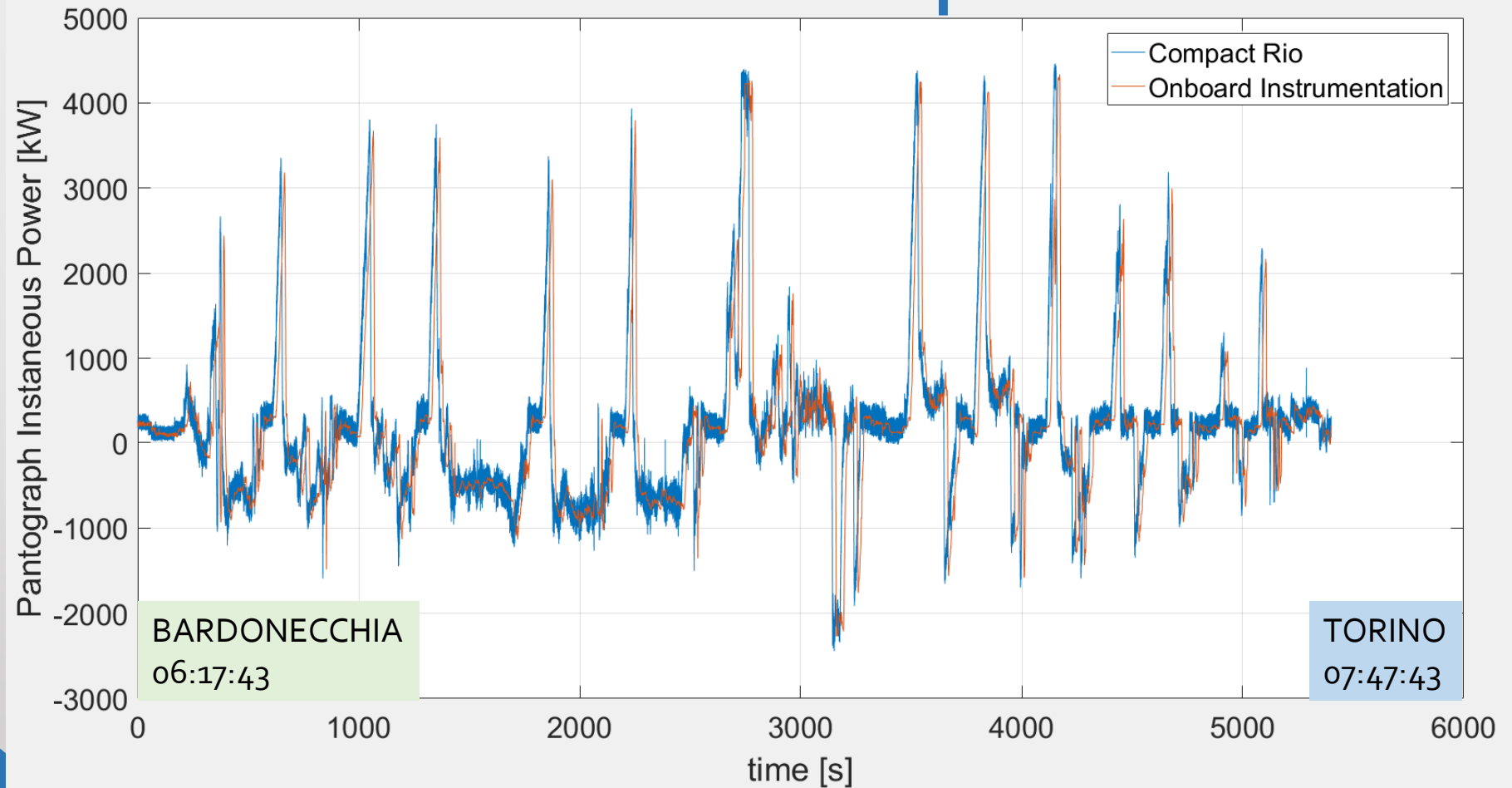


# Measurement Comparison





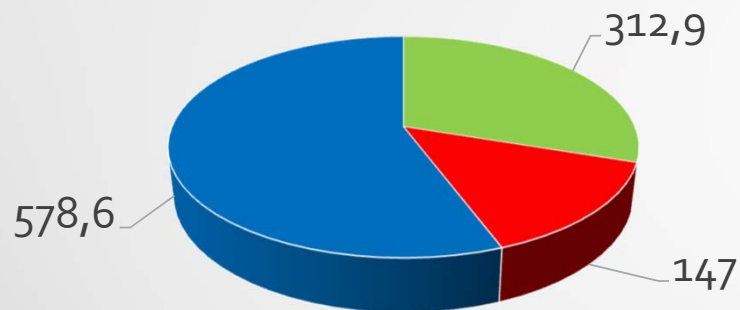
# Measurement Comparison



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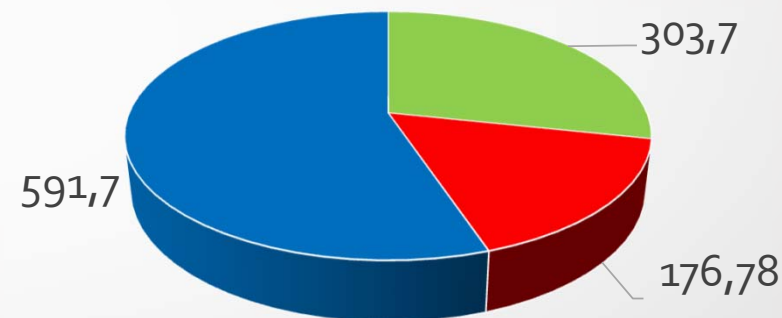
## Custom Measurement System [kWh]



- ENERGY SENT BACK TO THE CATENARY
- RHEOSTATIC ENERGY
- DISSIPATED ENERGY TO THE PANTOGRAPH

Error = 2.21%

## Train Measurement System [kWh]



- ENERGY SENT BACK TO THE CATENARY
- RHEOSTATIC ENERGY
- DISSIPATED ENERGY TO THE PANTOGRAPH

Error = 3.03%

Error = 16.85%

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*Thank you*

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