Power Quality Analysis in 25 kV 50 Hz AC Railway System Networks

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INTRODUCTION

Railway electricity networks are characterised by different power quality (PQ) phenomena from those of transmission and distribution electricity grids. Trains are mobile and continuously interact with overhead contact line and other trains, exchanging power during acceleration, coasting and notably during regenerative braking. This producer-consumer behaviour of the locomotive with the rest of the system deteriorates the PQ of the railway grid.

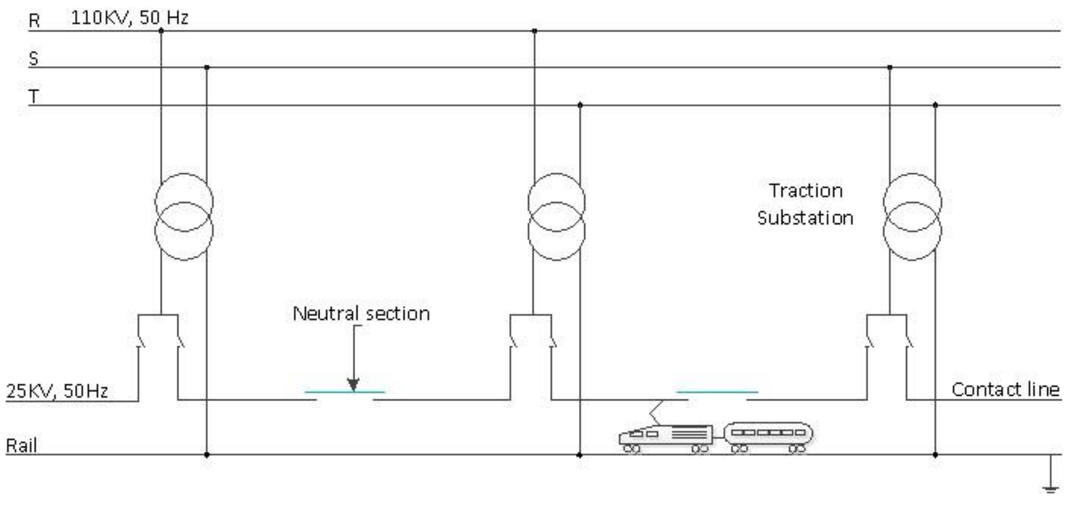
Presently, there are no standardized procedures focused on PQ measurement techniques explicitly for railway applications. This work evaluates whether the standard PQ measurement algorithms defined in IEC 61000-4-30 and used to monitor the quality of 50 Hz electrical grids are sufficient for an accurate application in 25 kV 50 Hz AC railways.

IMPROVED ESTIMATION TECHNIQUE FOR VOLTAGE INTERRUPTION

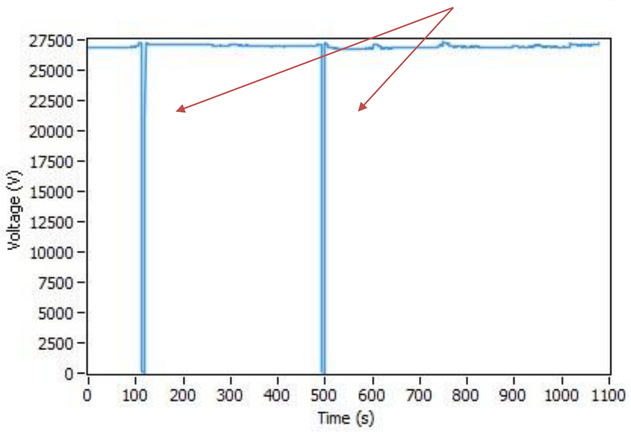
Supply voltage interruption of the locomotive, in addition to known sources (faults, equipment failure, tripping of protection) is caused due to the phase separation sections as part of the power supply network configuration.

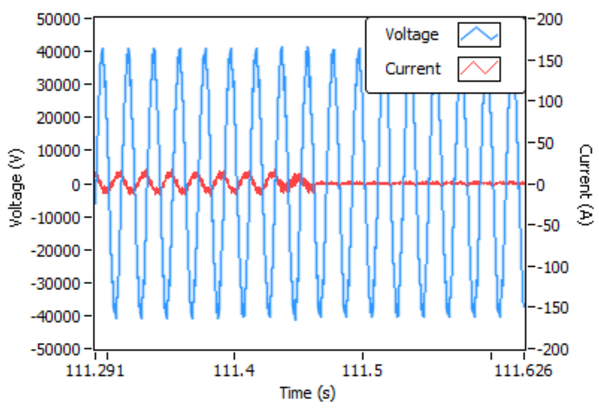
Measurement method defined in IEC 61000-4-30, is not suitable for the typical interruptions experienced in AC railways and is not able to discriminate between events caused by neutral sections and by other sources.

Common power supply configuration of a railway grid



Supply voltage interruption

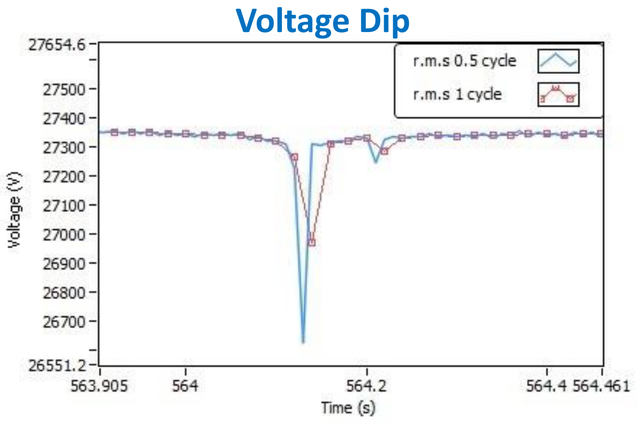




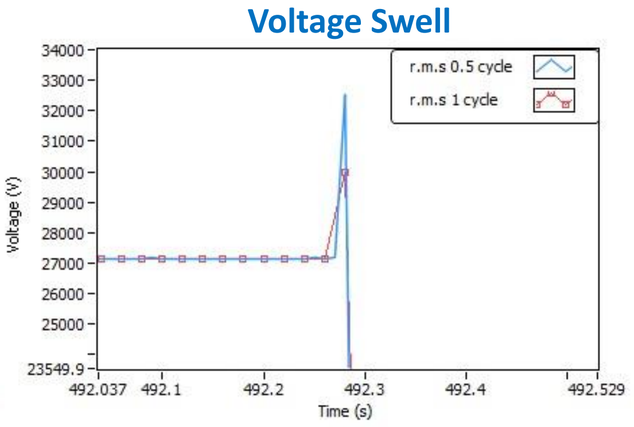
VOLTAGE DIPS AND SWELLS

Short variations of the voltage magnitude, that are typical in railway electricity girds, affect the rms value. Measurement method specified in IEC 61000-4-30 (**V.rms over 1 cycle**), does not accurately characterize the phenomena. RMS value measured over **half a cycle improves event classification** according EN 50160.

Voltage Dip



Voltage Swell



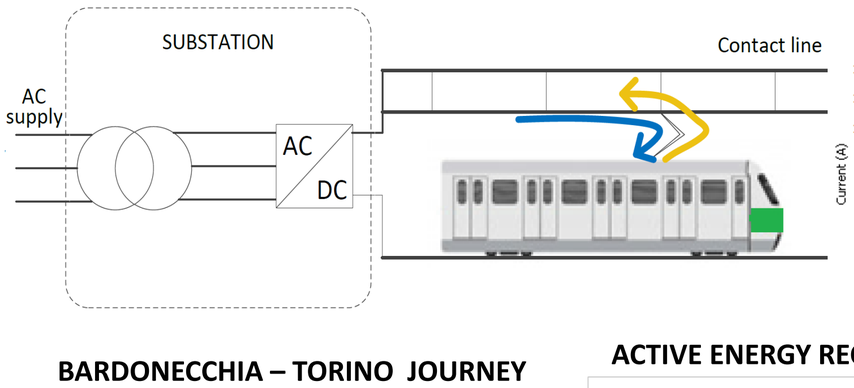
Voltage swell classification acc. EN 50160

Swell voltage *u* %	Duration *t* ms		
	$10 \le t \le 500$	$500 < t \le 5\,000$	$5\,000 < t \le 60\,000$
$u \ge 120$	CELL S1	CELL S2	CELL S3
$120 > u > 110$	CELL T1	CELL T2	CELL T3

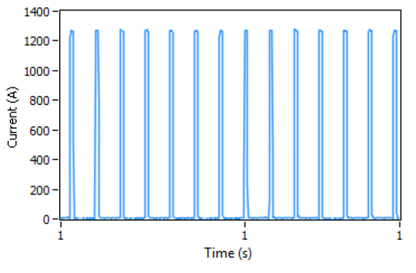
Event measured over:
-1/2 cycle; classified
-1 cycle; not considered a Swell

ENERGY RECOVERED AND WASTED DURING TRAIN BRAKING

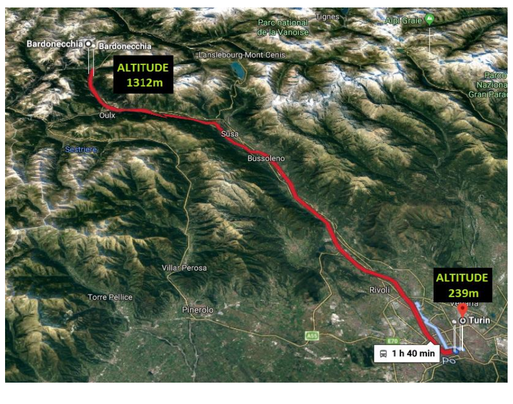
- Energy consumption of European railway transportation system is evaluated about **36.5 TWh / year**. The target of **reducing CO_2** emissions related to railway electricity consumption to **50%** by 2030, requires an efficient use of this energy.
- Large amounts of energy are produced during braking stages of the trains, where induction motors act as generators. However, DC railway electricity grids have limited receptivity and considerable amounts of energy are wasted in braking rheostats.
- Accurate knowledge of the energy exchange between trains and railway grid is fundamental to justify high cost of RSSs (reversible substations) investments, allowing bidirectional flow of energy between AC and DC systems and re-use of the regenerated energy.



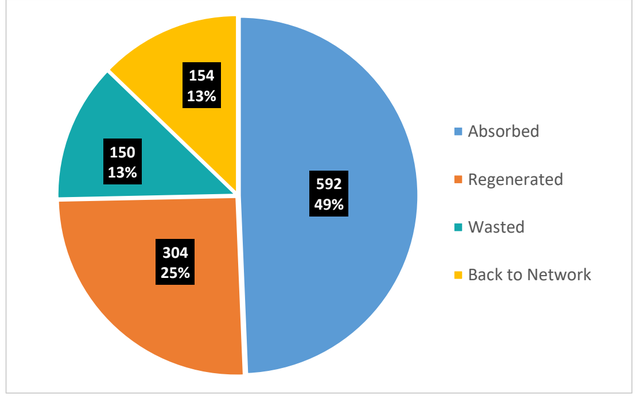
Current in rheostat



BARDONECCHIA – TORINO JOURNEY



ACTIVE ENERGY RECOVERED AND WASTED (kWh)



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