Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or EURAMET. Neither the European Union nor the granting authority can be held responsible for them.

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EUROPEAN PARTNERSHIP

Co-funded by the European Union

METROLOGY PARTNERSHIP

EURAMET

E-TRENY

METROLOGY SUPPORT FOR ENHANCED ENERGY EFFICIENCY IN DC TRANSPORTATION SYSTEMS

SMART ELECTRICITY GRIDS

INRiM ISTITUTO NAZIONALE DI RICERCA METROLOGICA

www.inrim.it

P&E/SEG presentations
Metrology R&D projects

05/15/2024

DELFT - May 15th Measurements for Smart Electricity Grids

22NRM04 e-TRENY

Domenico Giordano



Overview

01 The EURAMET projects for transportation

02 The impact of 16ENG04 MyRailS project

03 22NRM04 e-TRENY project

The EURAMET projects for transportation

METROLOGY for HYDROGEN VEHICLES 2	Metrology for hydrogen vehicles 16ENG01 [2017 – 2021]. Energy call
MYRAILS	Metrology for smart energy management in electric railway systems 16ENG04 MyRails [2017 – 2021]. Energy call
EURAMET MICEV	Metrology for inductive charging of electric vehicles 16ENG08 MICEV [2017 – 2021]. Energy call
MetHyTrucks	Metrology to support standardization of hydrogen fuel sampling for heavy duty hydrogen transport MetHyTrucks [2023 – 2026]. Normative call
E-TRENY	Metrology support for enhanced energy efficiency in DC transportation systems [2023 – 2026]. Normative call

01

EURAMET for TRANSPORTATION

E-TRENY

02

MyRails inpac

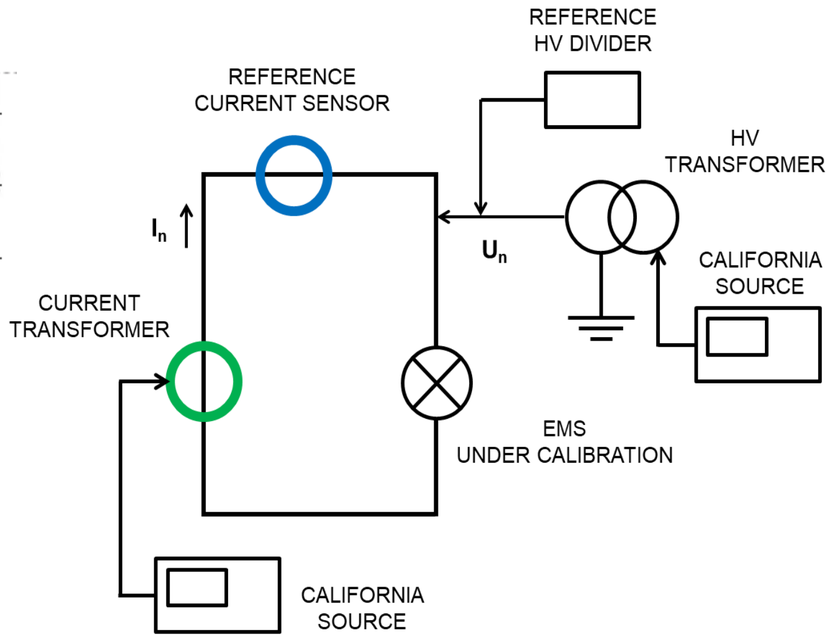
MyRails objectives

- To develop facilities for the calibration of energy measurement chains for AC 25 kV – 50 Hz, 15 kV, 16.7 Hz and DC railway/metro systems
- To develop measurement systems for power quality monitoring in AC and DC railway systems
- To accuratelly determine the braking energy in DC railway systems
- To develop and test accurate measurement systems for the determination of the ecodrive strategy improvement

Facilities for the AC energy measurement fuction (EMF) calibration

FFII

FUNDACIÓN PARA EL FOMENTO DE LA INNOVACIÓN INDUSTRIAL
Spain





Reference HV Divider



DMM for voltage



Reference Current sensor



DMM for current

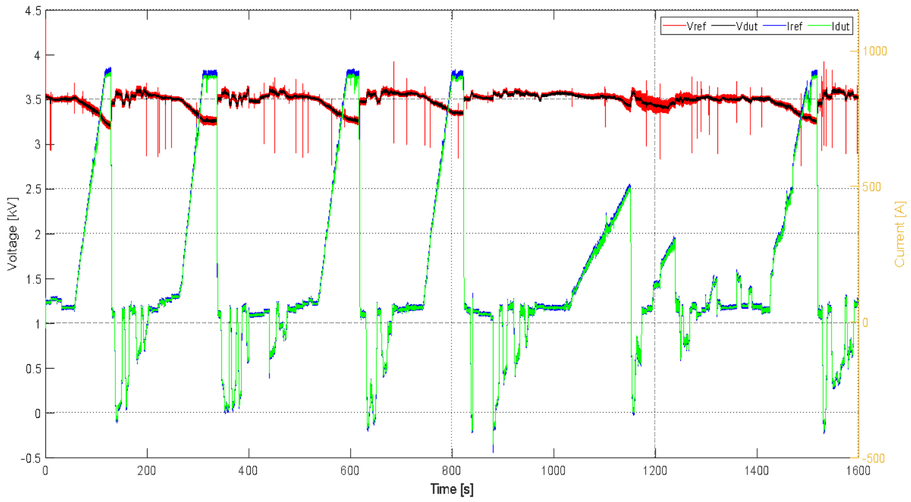
02

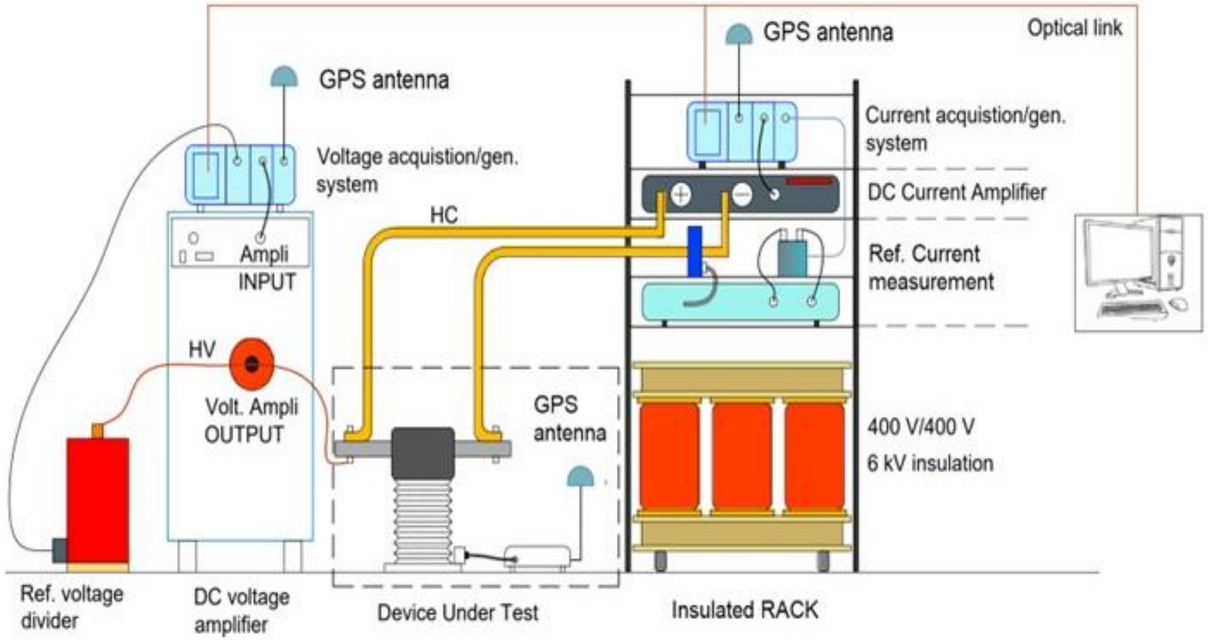
MyRails inpac

Facilities for the energy measurement fuction (EMF) calibration - DC

Capabilities:

- 4 kV
- 2.4 kA (1.2 kA)
- Voltage BW: 10 kHz
- Current BW: 2 kHz
- Generation of distortions, transients, etc...



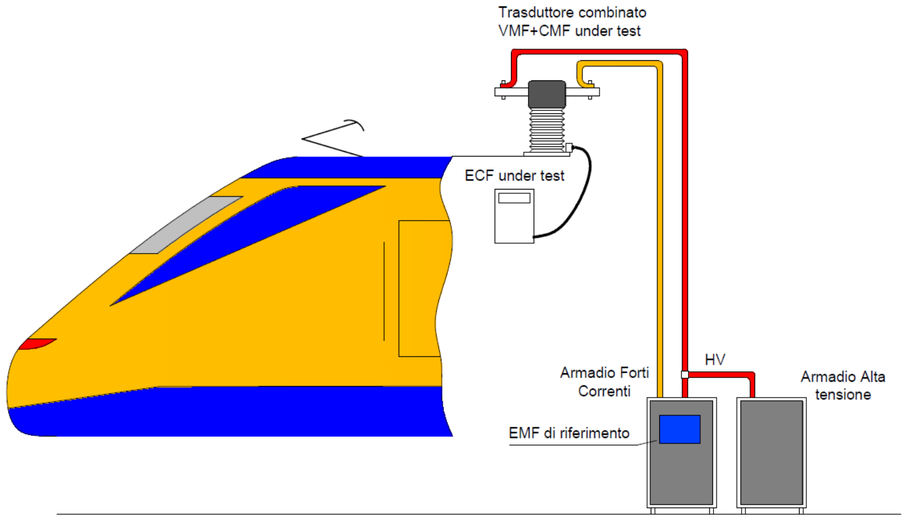


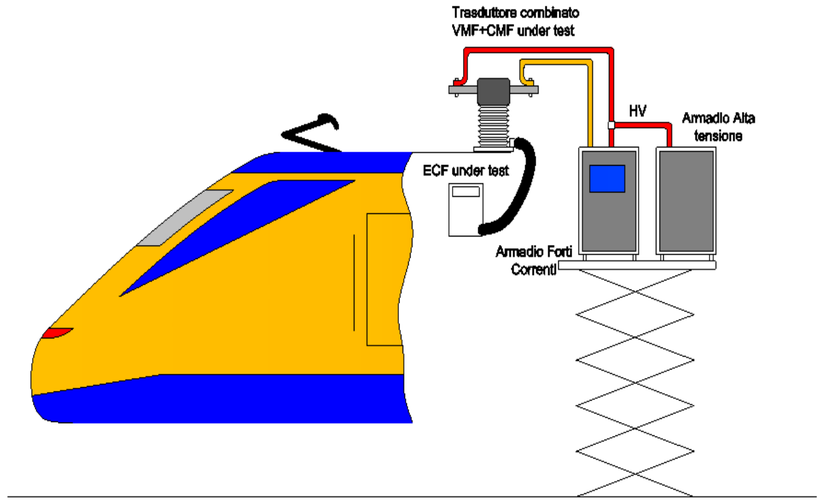
02

MyRails inpac

Facilities for the energy measurement fuction (EMF) calibration

Onsite re-verification





02

MyRails inpac

02

MyRails inpac

Facilities for the energy measurement fuction (EMF) calibration

Onsite re-verification – DEMO organized at Roma Termini train station - ITALCERTIFER





Facilities for the energy measurement fuction (EMF) calibration



02

MyRails inpac

Calibration Capabilities

NMI or DI	Quantity	Voltage	Current	Uncertainty	Remarks
LNE	AC power and energy: single phase (f <= 400Hz), active power	1 kV to 30 kV	0,05 A to 500 A	1.10^{-3} W/VA	Sinusoidal voltage and current. Fundamental frequency 45 Hz to 65 Hz; $\cos\varphi$: 0 to 1.
				5.10^{-3} W/VA	Sinusoidal voltage and current with harmonics up to 5 kHz, or 90° phase-fired current waveform. Fundamental frequency 45 Hz to 65 Hz; $\cos\varphi$ =1.
LCOE-FFII	AC power and energy: single phase (f <= 400Hz), active power	1 kV to 25 kV	10 A to 500 A	$2,2.10^{-3}$ W/VA	Sinusoidal voltage with harmonics up to 5 kHz and sinusoidal current. Fundamental frequency 16.7 Hz and 50Hz; $\cos\varphi$=0,85 to 1.
				2.10^{-3} W/VA to 5.10^{-3} W/VA	Sinusoidal voltage and phase-fired current waveform of 45°, 90° and 135°. Fundamental frequency 16.7 Hz and 50Hz; $\cos\varphi$=1.
INRIM	DC power	1 kV to 4 kV	5 A to 2000 A	90 µW/W to 200 µW/W	See attached INRIM document PT-EM.9.0-01 Rev. 00 03/22/2021
	DC power ratio error	1 kV to 4 kV	5 A to 2000 A	300 µW/W to 450 µW/W	
	DC power under dynamic conditions for voltage and current	2.5 kV to 3.8 kV	5 A to 2000 A	460 µW/W to 1200 µW/W	

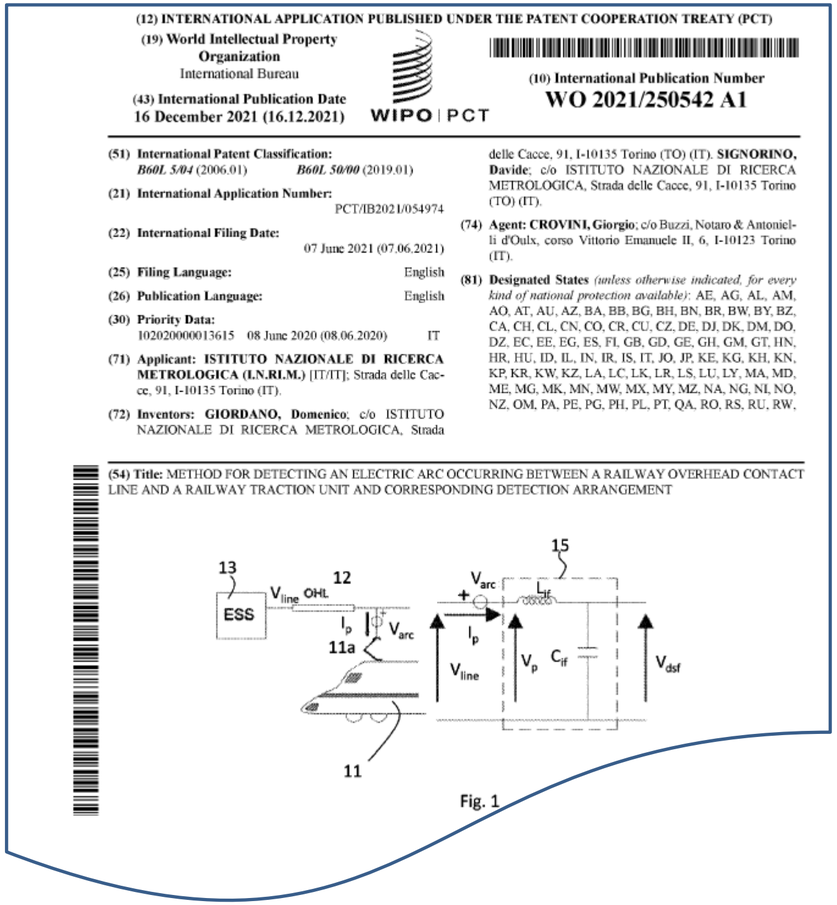
02

MyRails inpac

Patent

Method for detecting an electric arc occurring between a railway overhead contact line and arailway traction unit corresponding deection arrangement





(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

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International Bureau

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(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, IT, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW,

(54) Title: METHOD FOR DETECTING AN ELECTRIC ARC OCCURRING BETWEEN A RAILWAY OVERHEAD CONTACT LINE AND A RAILWAY TRACTION UNIT AND CORRESPONDING DETECTION ARRANGEMENT

Fig. 1

02

MyRails inpac

Patent EXPLOITATION

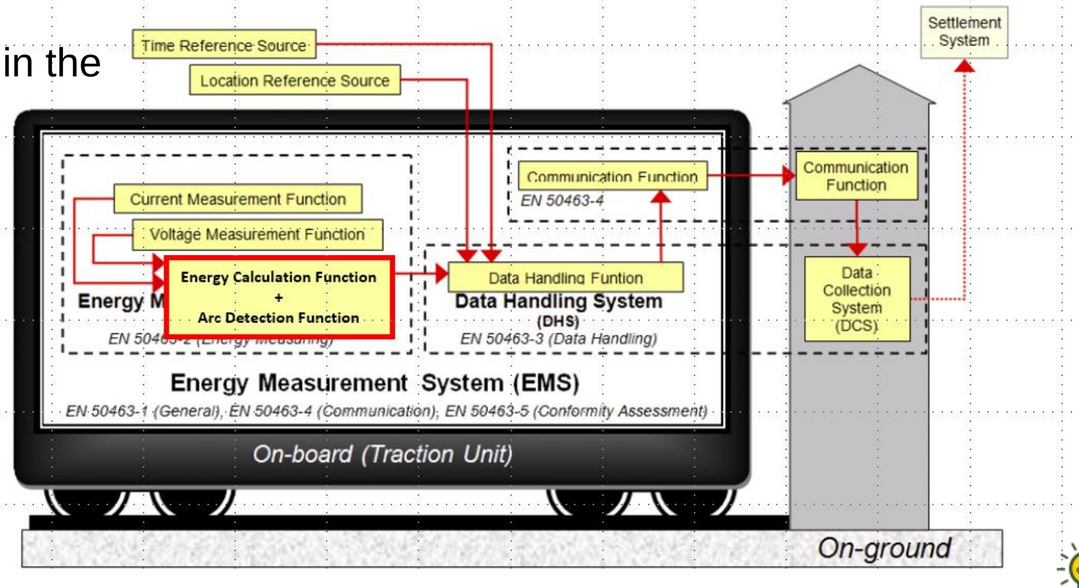
To embed the algorithm into the energy measurement function

To exploit the communication infrastructure to download to ground the arc event

To widespread the arc event detection

To use the data collected from field for pantograph predictive maintenance

Functions of the EMS as described in the IEC 62888, EN 50463 standard



Exploitation - agreement with industry under definition

02

MyRails inpac

Standardization contribution

Edition 2 CD stage

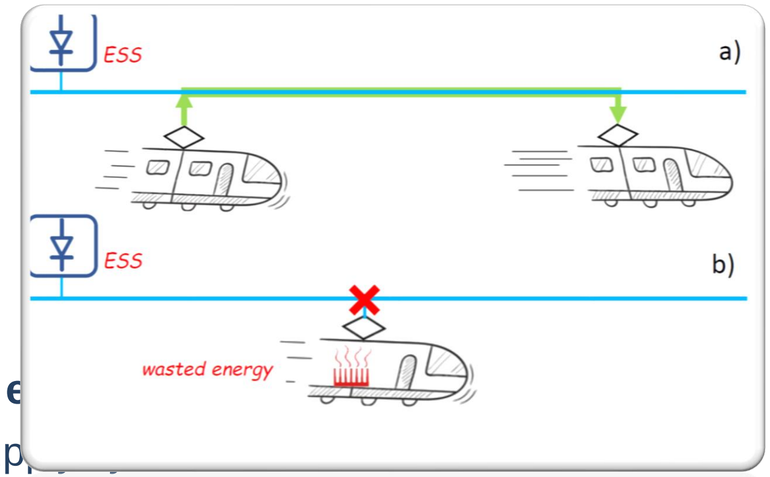
IEC 62888 Railway applications –
Energy measurement on board trains – Part 2: Energy measurement

- Annex C
  EMF accuracy and measurement uncertainty
  A rigourus metrological approach as been proposed
- New definitions for accuracy test of EMF.
- New functionalities for the EMS (arc event detection, Pq analysis, …).

02

MyRails inpac

From MyRails to e-TRENY



DC Supply systems

1 Diffusion

About 35% of European railway systems [1.5 kV – 3 kV]
About 100% of metro/tramway systems [650 V – 3 kV]

2 Unidirectional e

Conventional sup
can only deliver energy
to the railway system

3 Wasted energy

The energy generated by the electric braking and not absorbed by other trains is wasted

4 Non-conventional substations

Reversible substations (RSSs)
Storage systems
Smart energy management

03

E-TRENY

From MyRails to e-TRENY

Electric braking - Energy wasted

Rail Case

15 trains/day for commuter service route: 120 km → 1 GWh per year wasted = **360** Units of domestic energy consumption

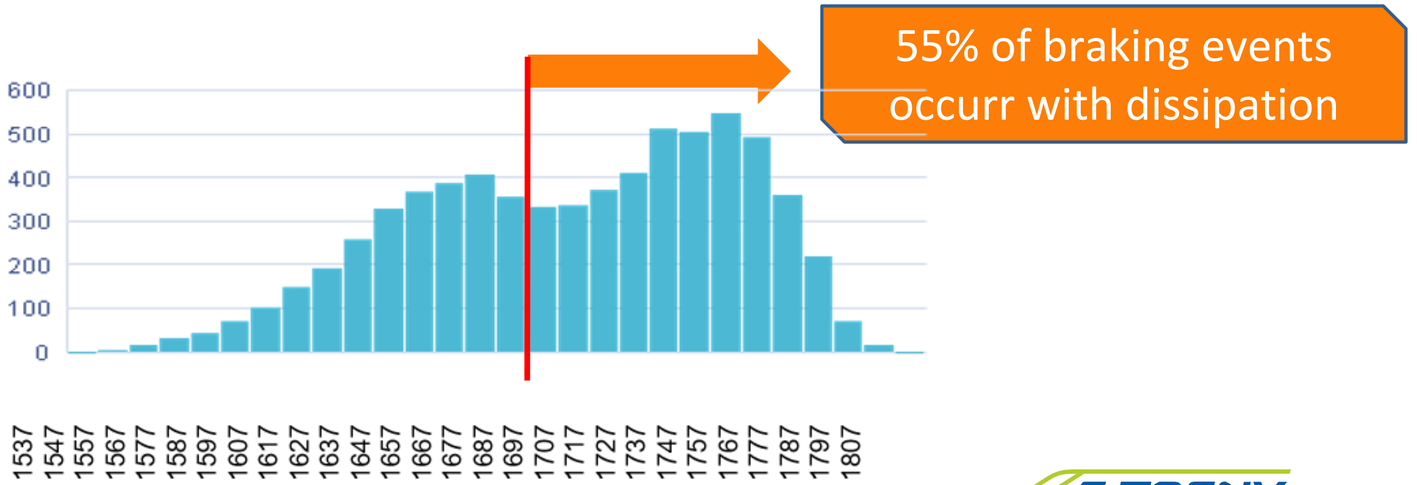


Metro Case

Braking Energy per day ~1 MWh for single train (13% wasted)

- Rated voltage: 1500 V
- V pantograph *> 1700 V: Braking energy wasted*

Pantograph voltage statistics with reversible substation



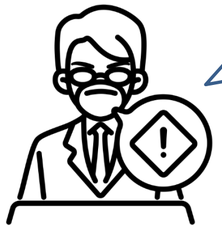
From MyRails to e-TRENY

- The adavntages of a reversible substation or a storage system can be neutralized if ther is not an overall coordination of the supply voltage that adresses correctly the power flow.
- A holistic approach (infrastructure and train operator) is required to collect data from field and control the voltage level.

Industrial need collected by e-TRENY consortium

IEC

IEC TC9
Chairman



To define the methodologies for the analysis of the performances of the non-conventional DC substations

To define rules for the efficient management of the DC supply systems

IEC TC14
Chairman



To define the methodologies for the on-site determination of power transformer losses under distorted conditions

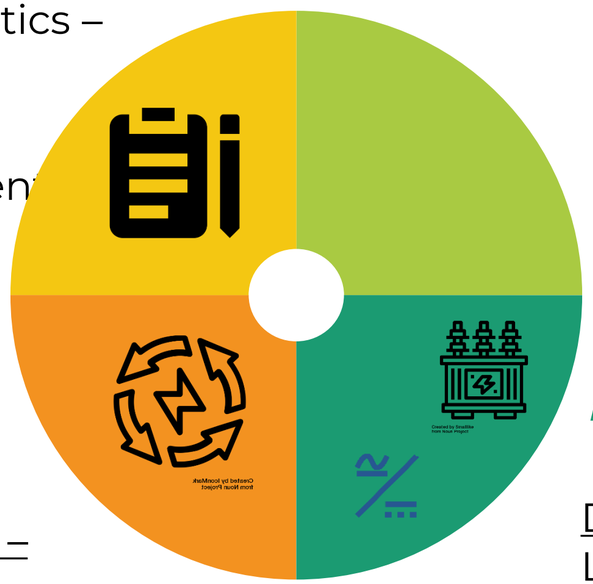
e-TRENY – Technical Objectives

Non-conventional DC substations

- SURVEY on design characteristics – expected energy saving
- TEST CASES analysis
- DESIGN of on-site measurement systems

Metrology for dynamic signals

DEVELOP AND APPLY the metrological infrastructure for dynamic DC signals 3kV, 1 kA, time scale from few hudreds of millisecond to few seconds



Energy saving

DEVELOP – CHARACTERIZEE – APPLY ONSITE

A tool for the determination of the energy saving provided by the new Electric substations.
HOLISTIC approach.

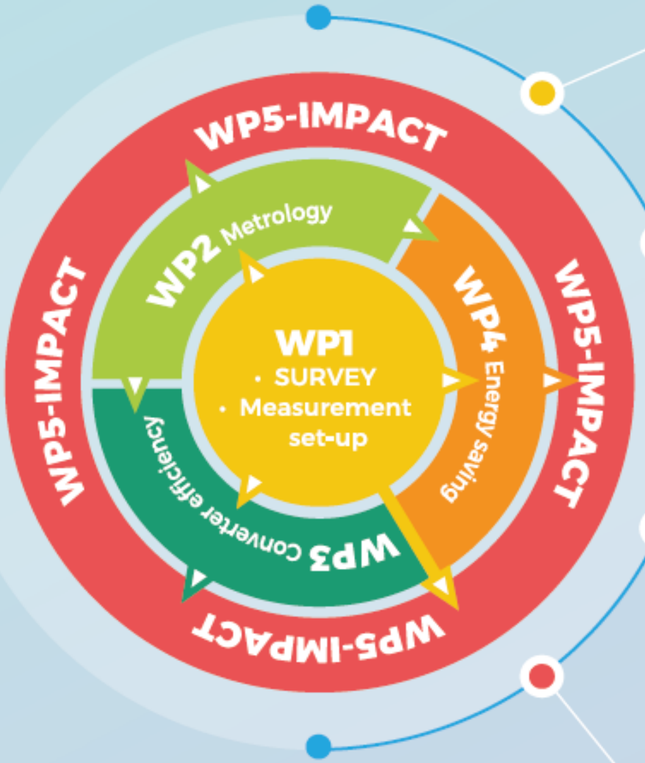
Power converter Efficiency

DEVELOP – CALIBRATE – APPLY ONSITE
Loss measuring system of power transformers, AC/DC-DC/AC-DC/DC, storage systems.
Uncertainty target: **10%, η=97% - frequency range 2 kHz**

03

E-TRENY

e-TRENY – Activities organization



WP1 **Substation architecture**
- Literature – waveform analysis
- Design – implementation of measurement setups

WP2 **Metrological infrastructure**
- Traceability for non-stationary signals
- Measurement setup calibration

WP3 **Converter efficiency**
- Two test cases
- Efficiency determination - PQ analysis

WP4 **Energy saving**
- Metro test case
- Hybride method [measurement + power flow] for energy saving determination

WP5

Stakeholder Committee
40% profit-making entities

Scientific pubblications
6 papers, **8** conferences

3 professional workshops, exibitions

3 white papers

14 Standards committees/TC/WG involved

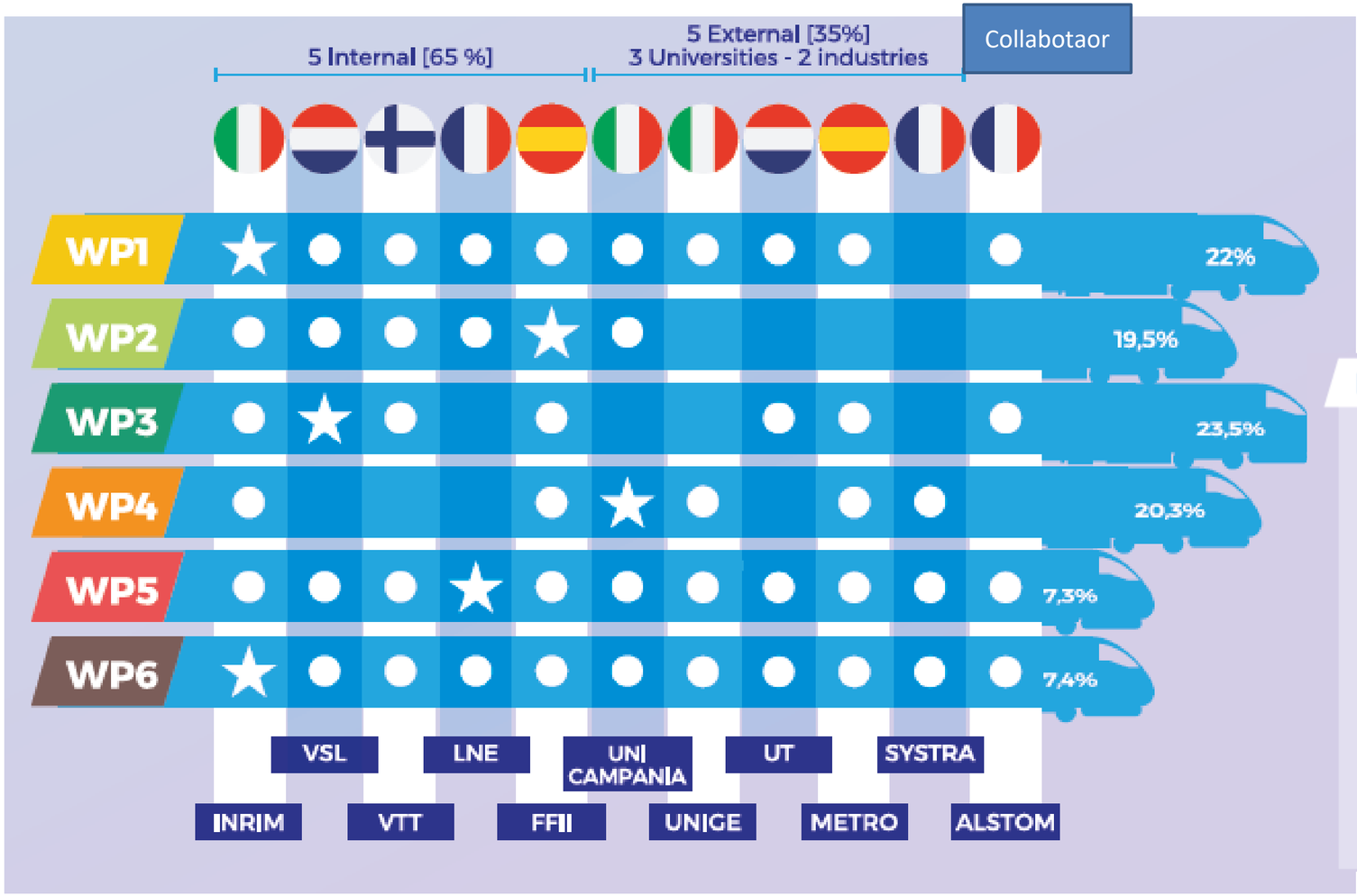
Social media, General public engagement, newsletter, website

Link to industrial network, **Europe's rail partnership**.

Best practice guide on efficiency measurement

Waveform dataset

e-TRENY consortium



KNOW-HOW

- High voltage, high current and sensor metrology
- Power Converters
- Transportation infrastructure management
- Distributed measurements
- Transportation System simulation
- Direct link with standard WGs

Outcomes

- New measurement-model tool supporting the implementation of holistic energy flow management
- New measurement infrastrcuture for on-site losses – efficiency for MV power transformer AC/DC, DC/DC converters
- New calibration services for dynamic signals
- Input for new standardization processes (IEC PT63477)

03

E-TRENY

Questionnaire

Devoted to power sistem designers, transportation infrastructure managers, railway companies

Detail of designed or implemented energy efficiency solutions

Maintenance Considerations

Provisions for energy efficiency and energy saving

Network Topology Information

Design of energy efficient system / substation

Procurement, Contract Specifications

Measurement Methodology

Power electronics devices

Design of the energy efficiency location

Importance and Technology Preference

It will be sent to about 30 stakeholders

E-TRENY

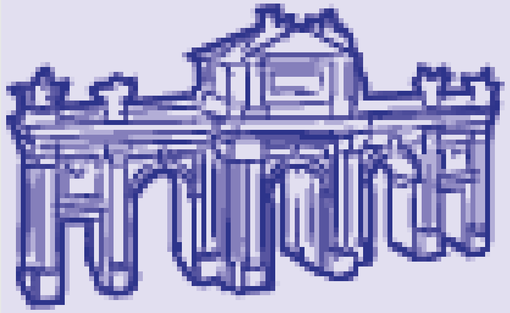
Test cases

Converter Efficiency



Hannover tramway
750 V with reversible substation and storage system

Energy saving



Metro de Madrid
1500 V with reversible substation

ALSTOM · mobility by nature ·

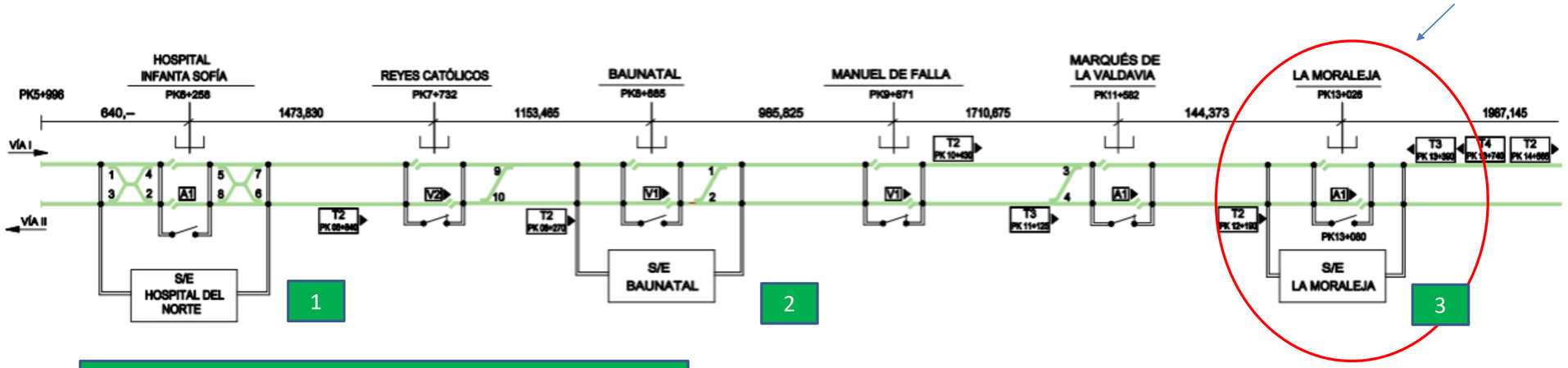
ÜSTRA

Metro Spain

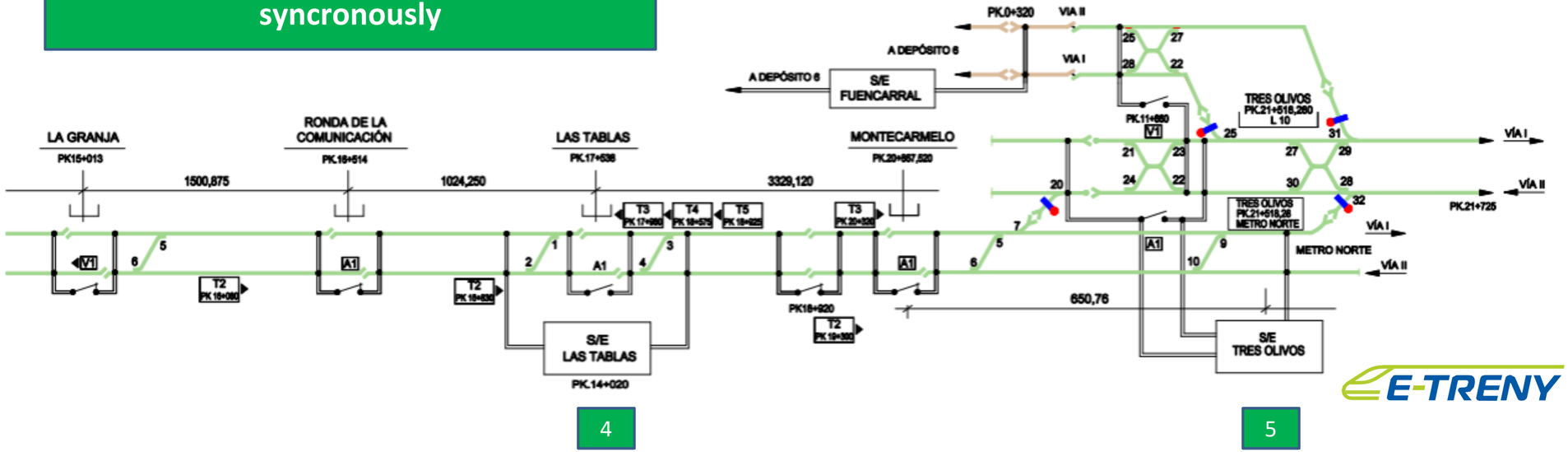
E-TRENY

Metro de Madrid line 10B

Reversible substation
The erngy can flow back to the upstream 15 kV grid

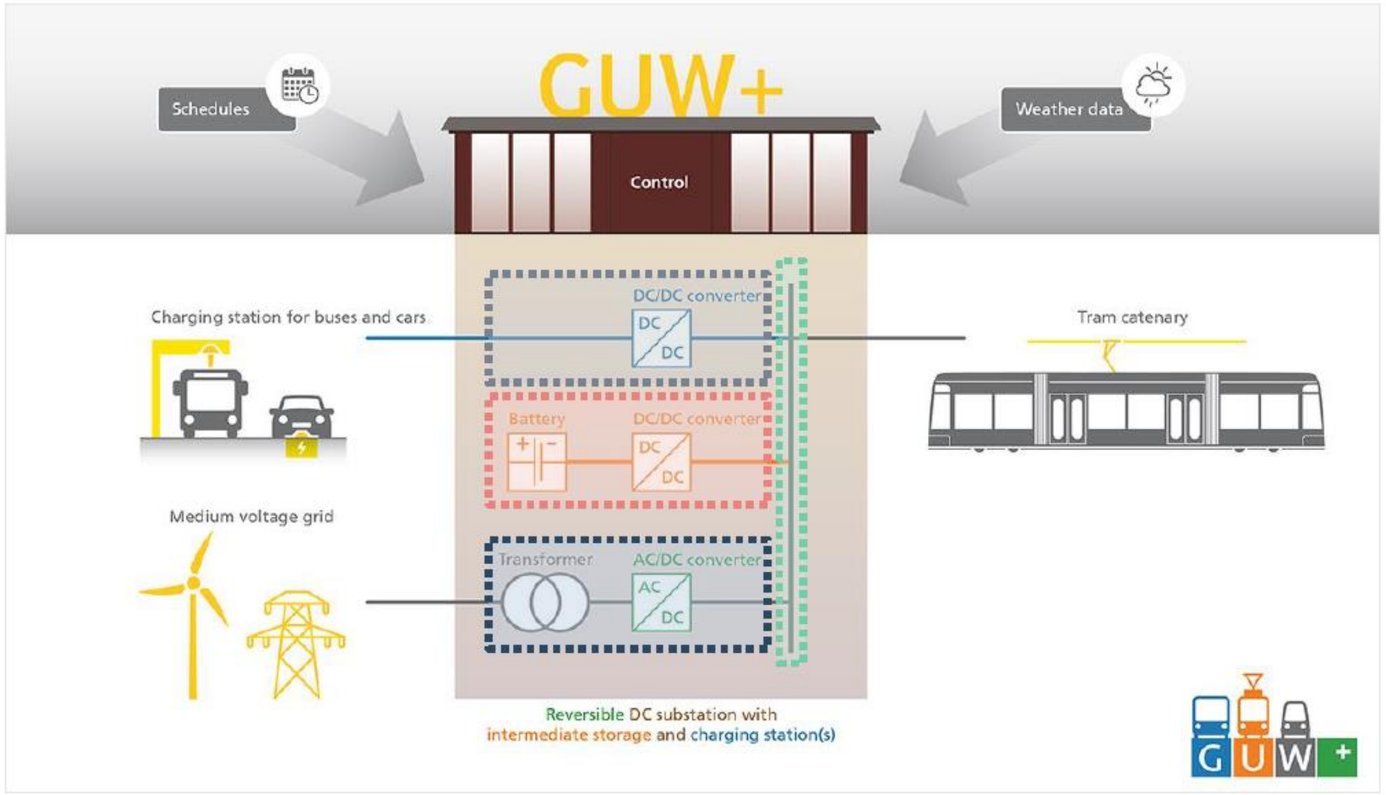


5 measurement points (MP)
2 current, 1 voltage acquired at each MP syncronously



Hannover

GUW+ is **more** than just a DC substation...



GUW+ substation is a brick assembly composed of:

CHARGING STATION
E-vehicles supply

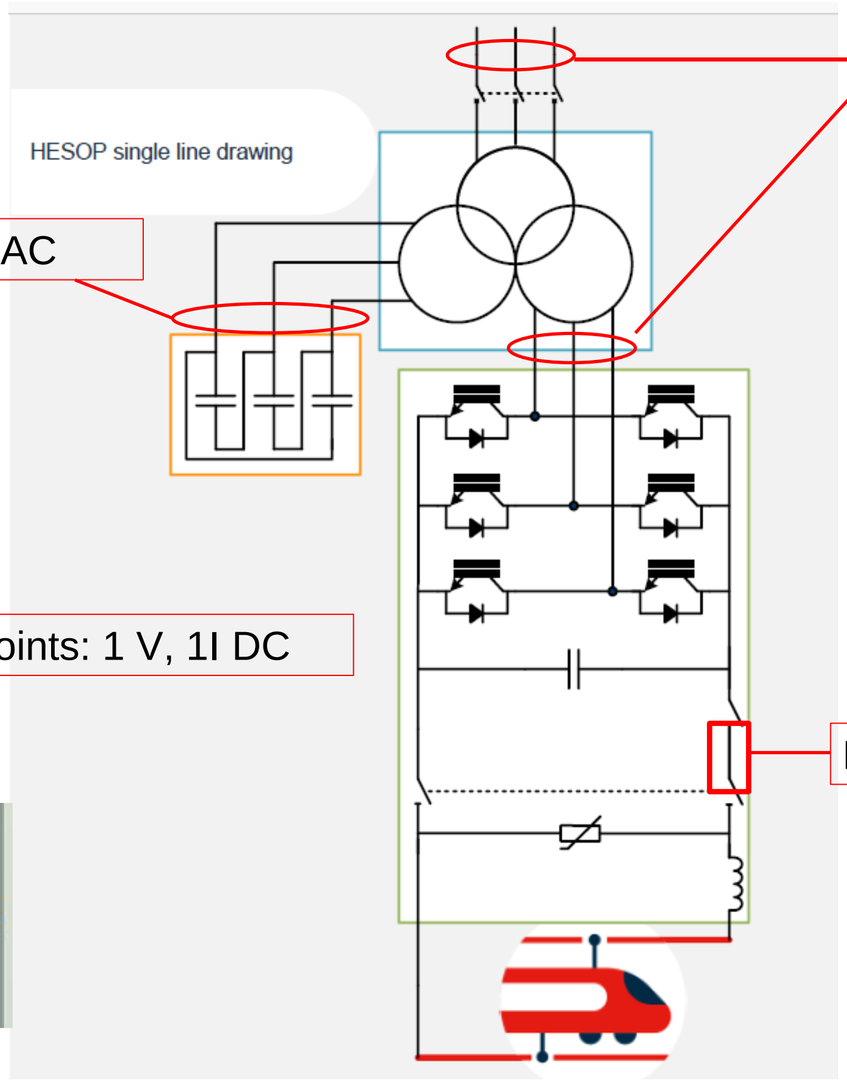
BATTERY STORAGE
Emergency reserve

CONVERTER GROUP
Energy supply & recovery

= HESOP™

750 VDC "BUS"
Energy transit area

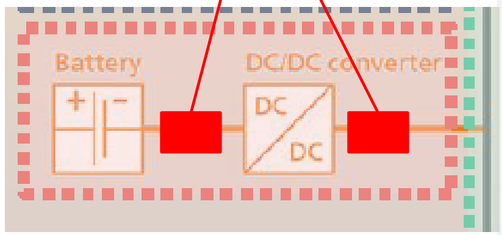
Hannover



Measurement points: 3x2 V, 3x2I AC

Measurement point: 3 V, 3I AC

Measurement points: 1 V, 1I DC



Measurement point: 1 V, 1I DC

IT4PQ
Instrument Transformers for Power Quality

Outcomes on voltage sensor transdusers were fundamental in the selction of on-site transducers

03

E-TRENY

E-TRENY

Metrology support for accurate on-site efficieny measurement

- The electrical efficiency of a converter, computed as the ratio between the output electric power over the input one is affected by transient events.



Do not process the voltage and current signals when transient event occur!



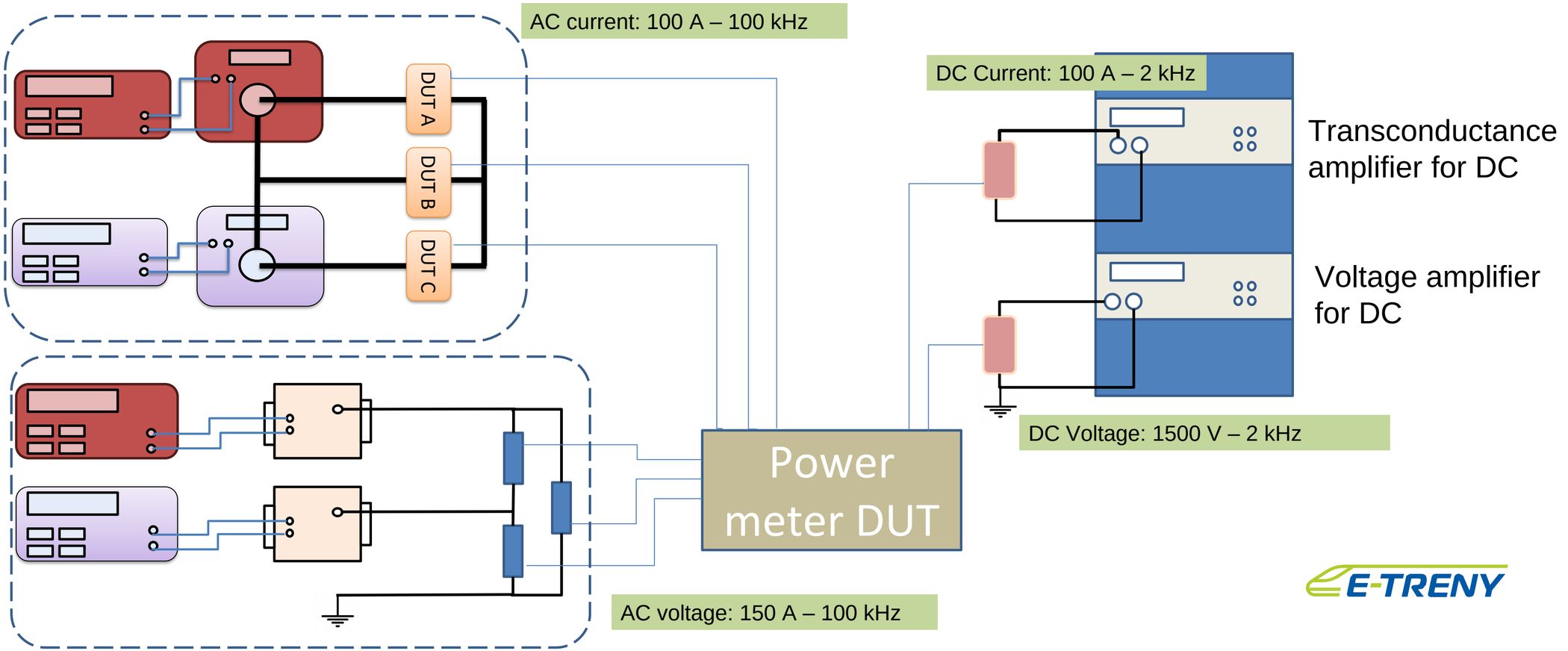
- To flag the acquired data in order to remove the transient events in the efficiency determination

03

E-TRENY

Metrology support for accurate on-site efficieny measurement

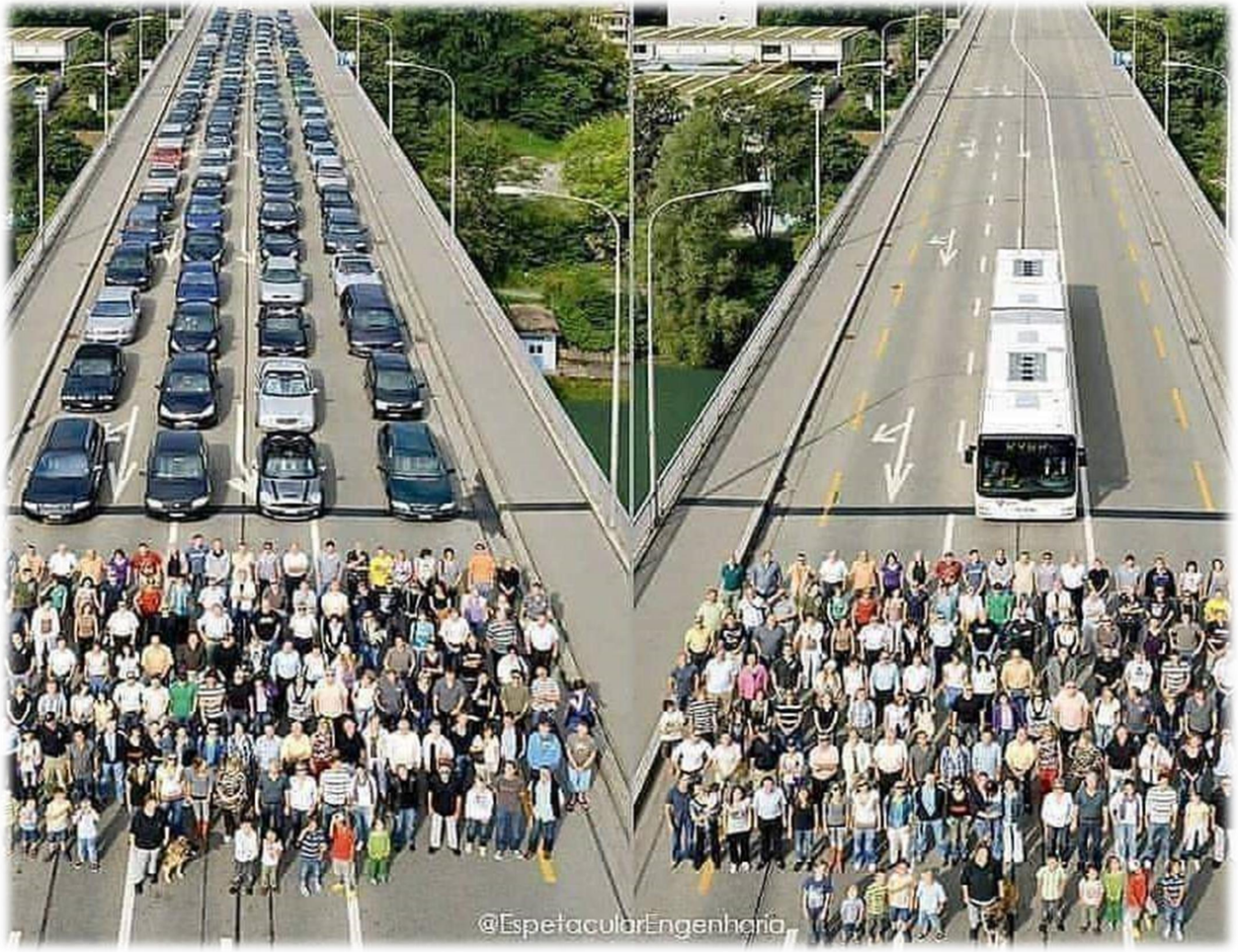
A setup for the calibration of Energy Efficiency Measuring system has been designed



03

E-TRENY

The strength of public transport



03

E-TRENY

Thank you for your attention

Internal funded partners

Italy | Spain | France | Netherlands | Finland

External funded partners

Spain | Italy | France | Italy | Netherlands

d.giordano@inrim.it