Benoît ROBYNS

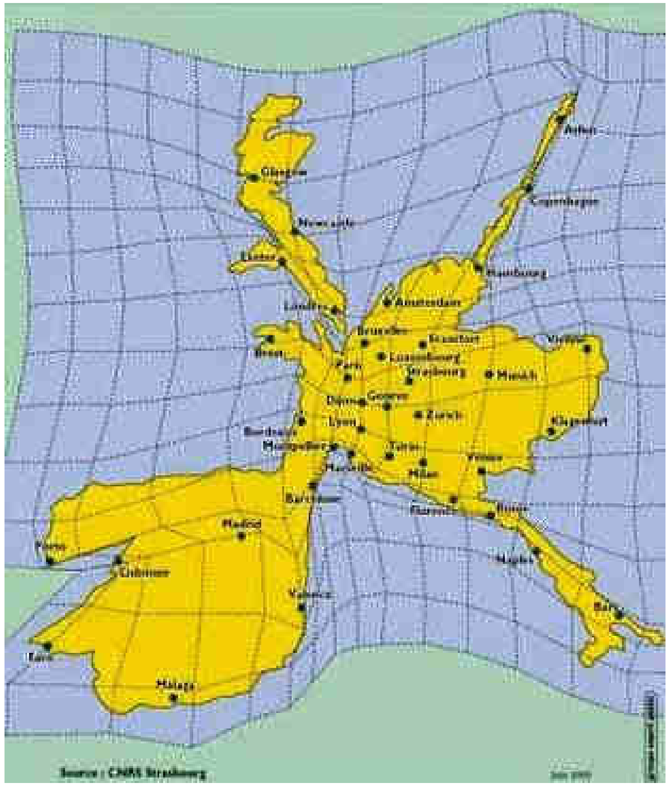
Guillaume GAZAIGNES

ETIP SNET 28-29 September 2017

SNCF, French mobility operator

INNOVATION & RESEARCH

Energy is the main fuel for transportation and for reducing time/distance



17 TWh energy consumption

for SNCF Group in 2016

10% of industrial electricity market

for SNCF railway activities in 2016

New energy policy

- Improve the economic efficiency
- Engage for energy transition
- Innovate and ceize business opportunities
- Make people move
  and extend engineering methods
- Make SNCF Group an influent stakeholder

Electrical Power System Team

Laboratory of Electrical Engineering and Power Electronics of Lille

L2EP Laboratoire d'électrotechnique et d'électronique de puissance de Lille

HEI Ingénieurs pour le monde | yncréa | Arts et Métiers ParisTech | centralelille

Expertises: Smart Grids

New energy management,

New electrical architectures and microgrids,

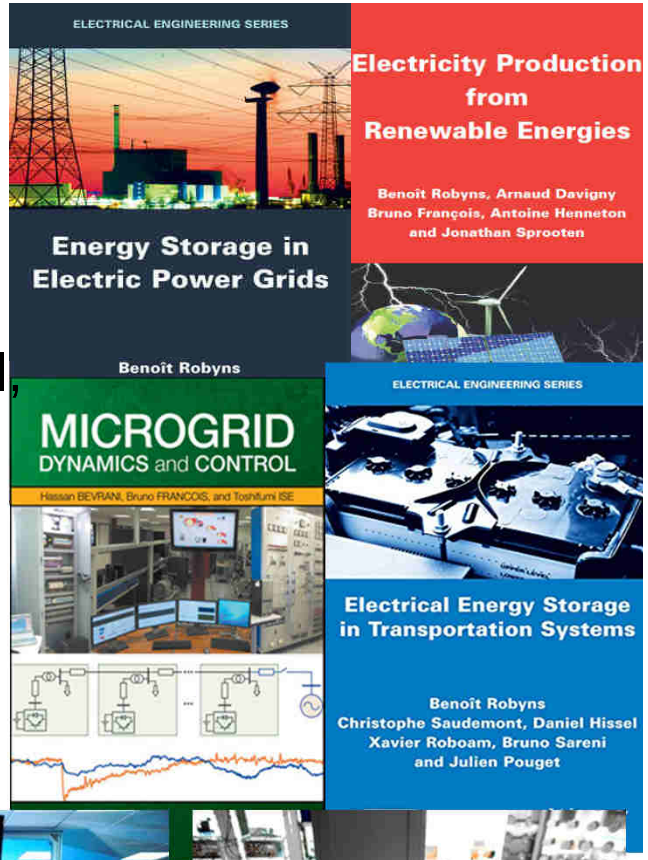
High Voltage DC networks and coupling in an AC grid,

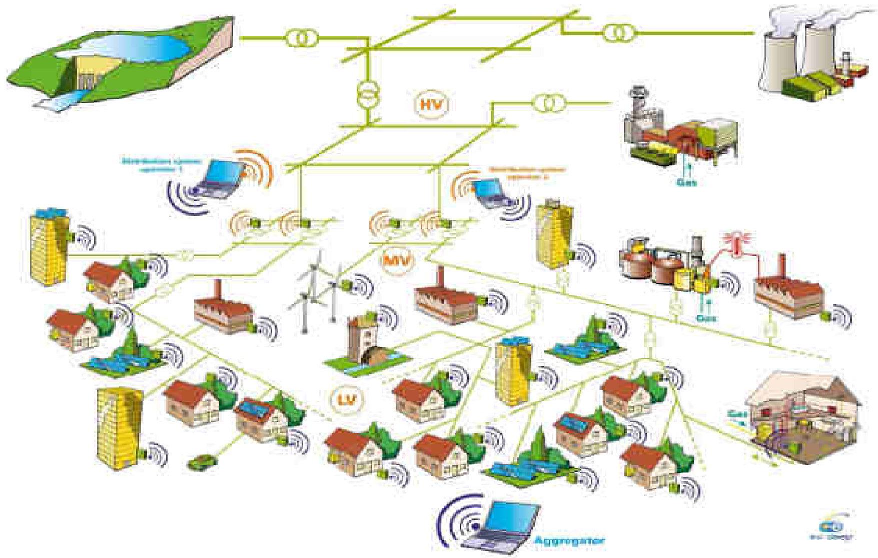
Advanced renewable energy based generators,

Applications of storage technologies for the grid management,

Integration of transportation systems in smart grids (Electrical vehicles, railway systems, metro,…),

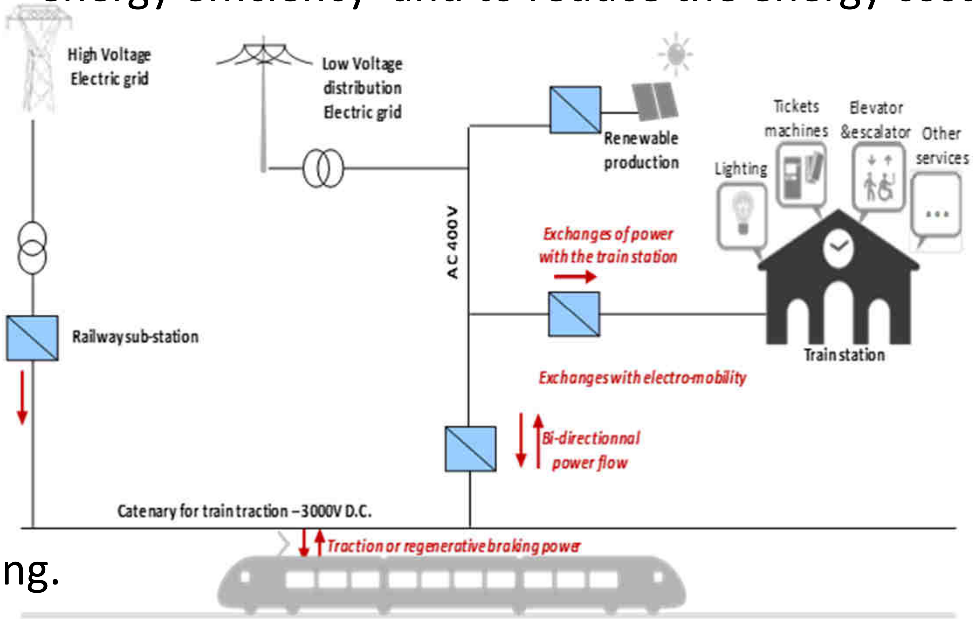
Experimentation approaches through real time simulation of power systems.





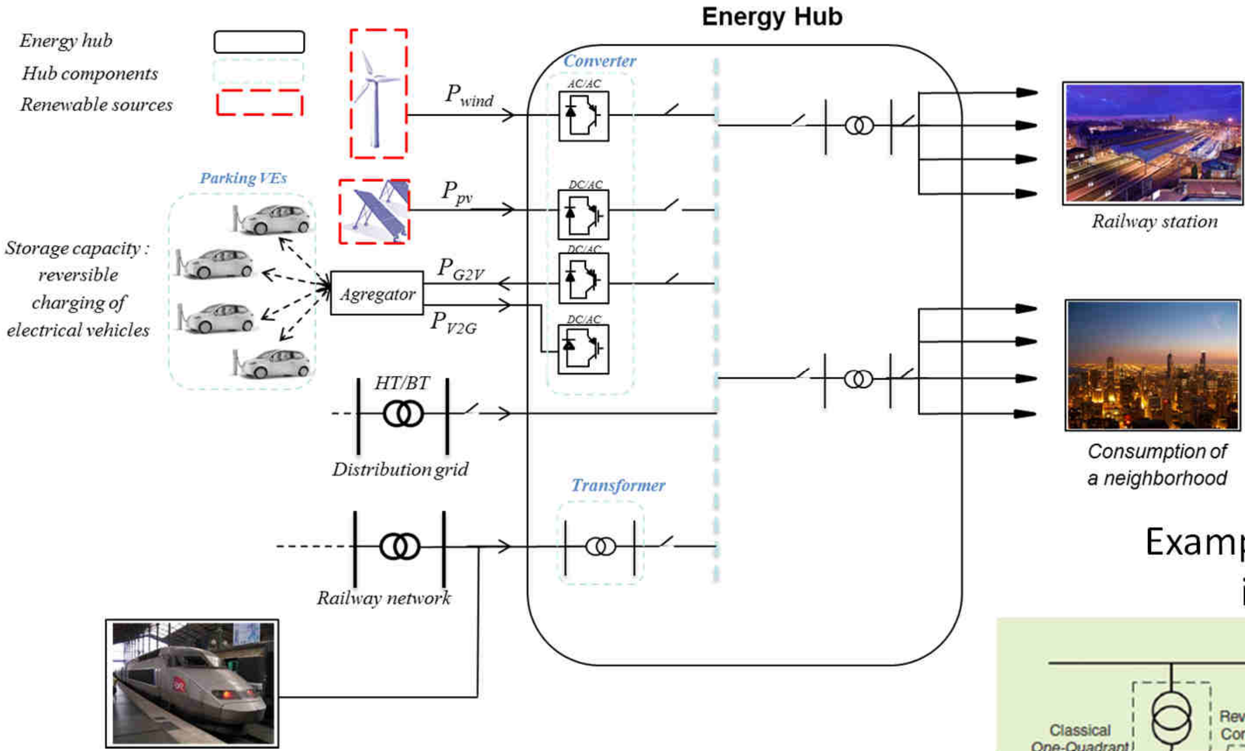
New communication technologies allow to increase the intelligence level of distribution and transmission grid, with the aim to optimize the management of new renewable sources, loads, storage system and the grid.

Smart grids technologies interest also the railway system to optimize the recovery of the braking energy of the trains, to integrate local renewable production and storage systems, to ensure high quality train supply and globally to increase the energy efficiency and to reduce the energy cost.



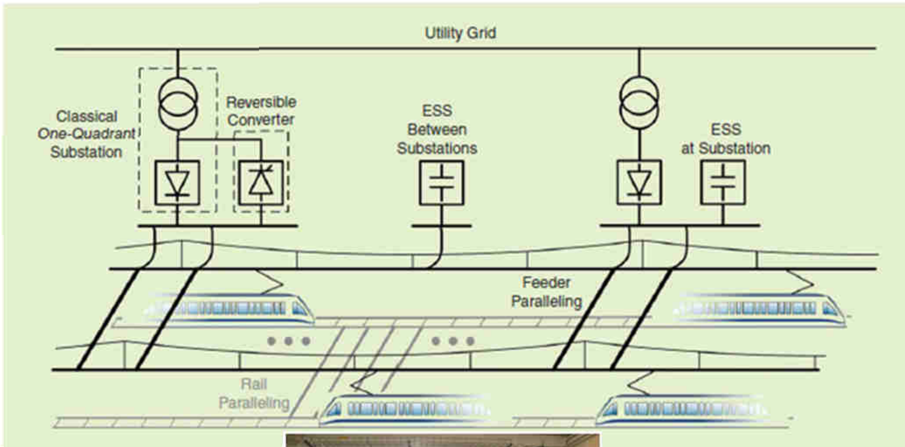
A particular difficulty to study smart grid in railway systems is that the main load is moving.

Smart grid in railway system

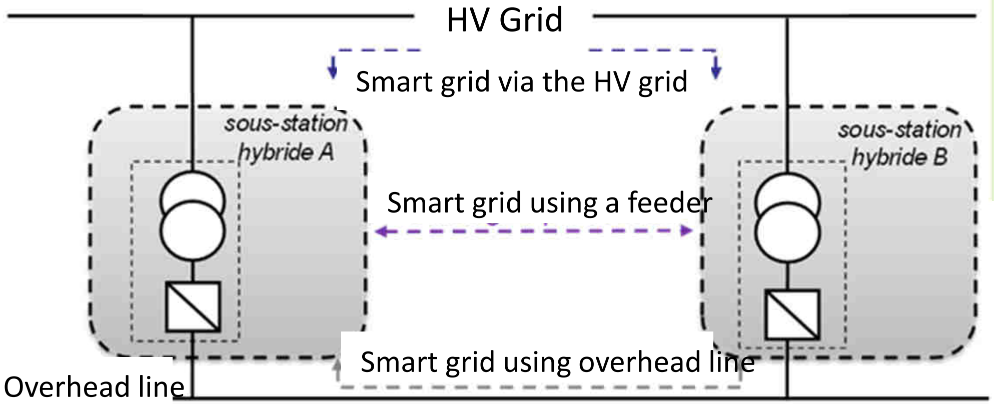


In the future, energy hub could be developped around the railway station and the railway network, to integrate renewable source, electrical vehicules with reversible load,… allowing an optimisazion of the power flow between trains, sources and loads

Example of energy recovery techniques in the DC railway power grid



Example of perspectives of power flow between substation

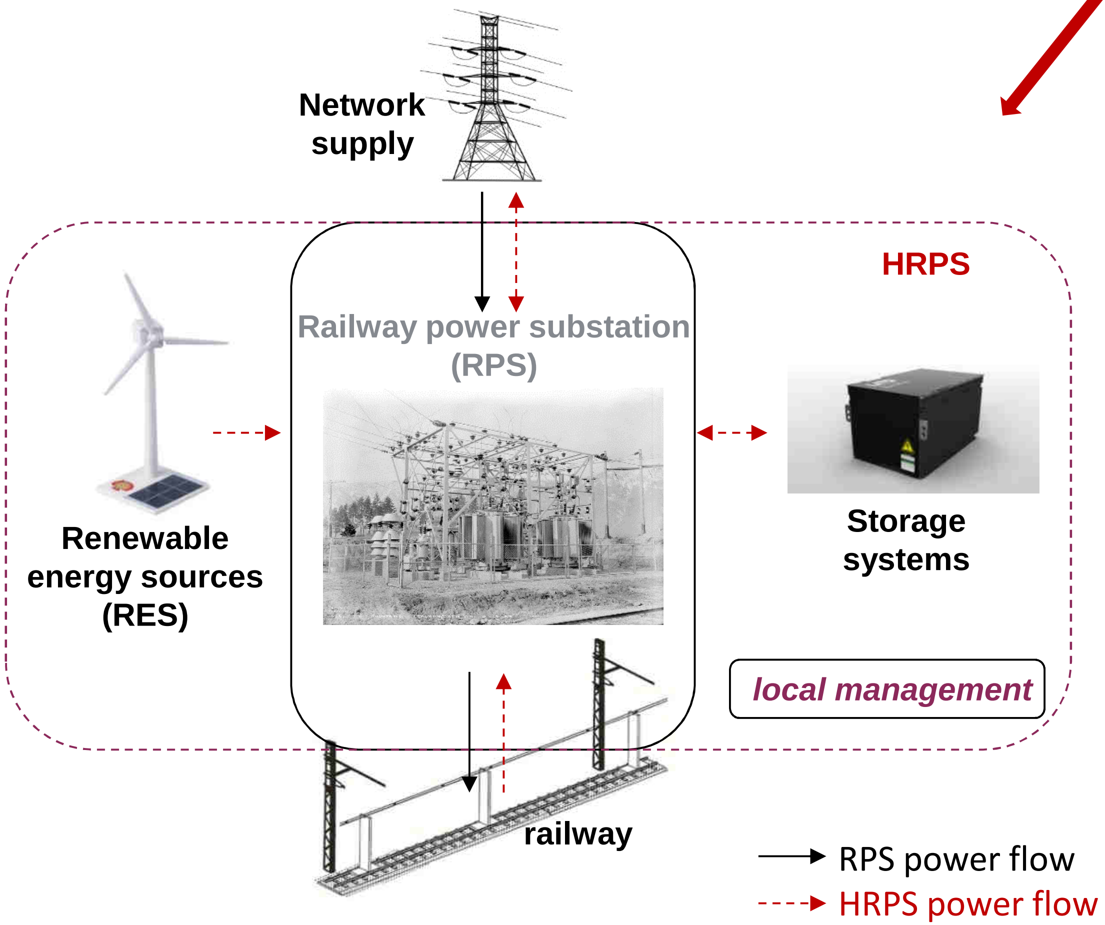


Context

- 90% railway traffic ensured by electrified lines (French railway network: 1500VDC & 25kV/50Hz AC)
- railway traffic increasing
- electricity market liberalization

New solutions to face future energy demand increase
(Hybrid Railway Power Substation)

CONIFER project : Innovative concept and tools for smart grid applied to railway transportation



Economic objectives:

Reduction in the energy bill:

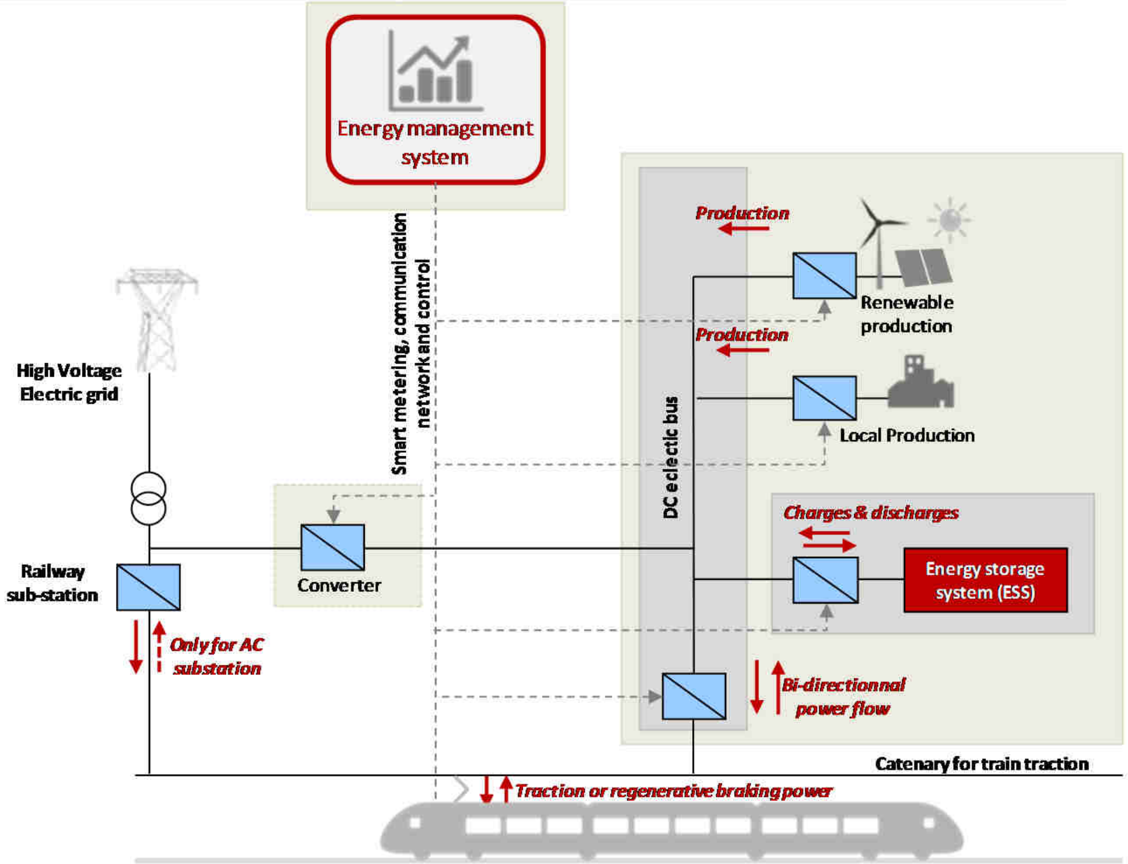
- according to the electricity market
- peak demand smoothing
- reduction in subscription fees

Energetic objectives:

- prioritizing local wind and photovoltaic energy consumption
- recover braking energy

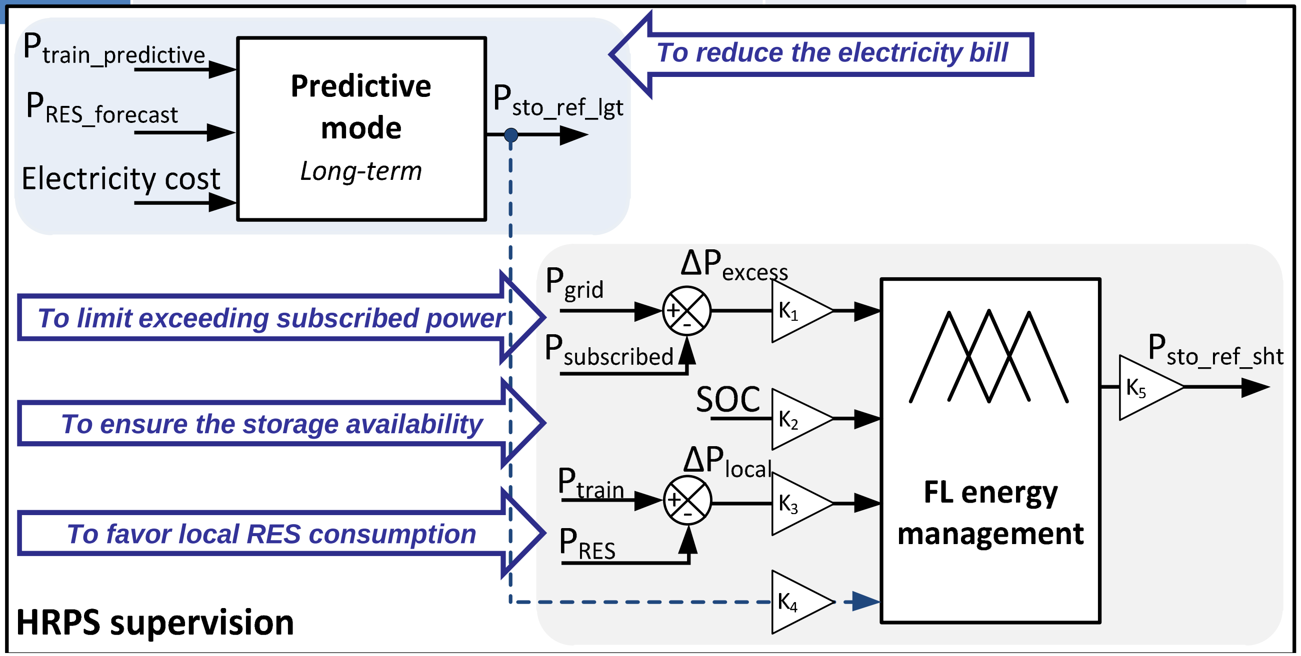
Hybrid railway power substation (HRPS)

"Railway infrastructure" services	"Electricity transmission grid" services	"Renewable energy producer" services
Peak demand smoothing	Frequency control	Injection report
Overhead line voltage control	Voltage control	Production guarantee
Backup power supply	Congestion management	Production smoothing
Quality of the energy at the level of the overhead line		
Quality of the energy withdrawn from the transmission grid		
Recovery of braking energy		

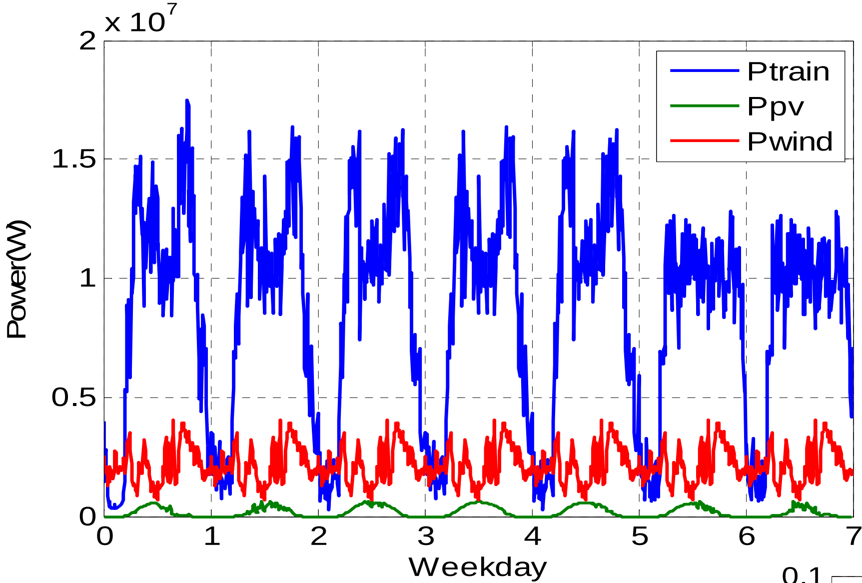


Hybrid railway power substation (HRPS)

Objectives	Constraints	Means of action
Long-term/Medium-term (Forecast supervision)		
Reduction in the energy bill: ➢ **according to the electricity market**	Estimate of train power consumption Estimate of the development of renewable energies Storage limits Estimate of energy purchase rates	Estimated storage power setpoint
Short-term (Real time adaptive supervision)		
Reduction in the energy bill by: ➢ **peak demand smoothing** ➢ **reduction in subscription fees** **Prioritizing local wind and photovoltaic energy consumption** **Ensuring storage availability**	Contract power Storage limits Availability of renewable energy sources	storage power set point (Estimate adjustment)



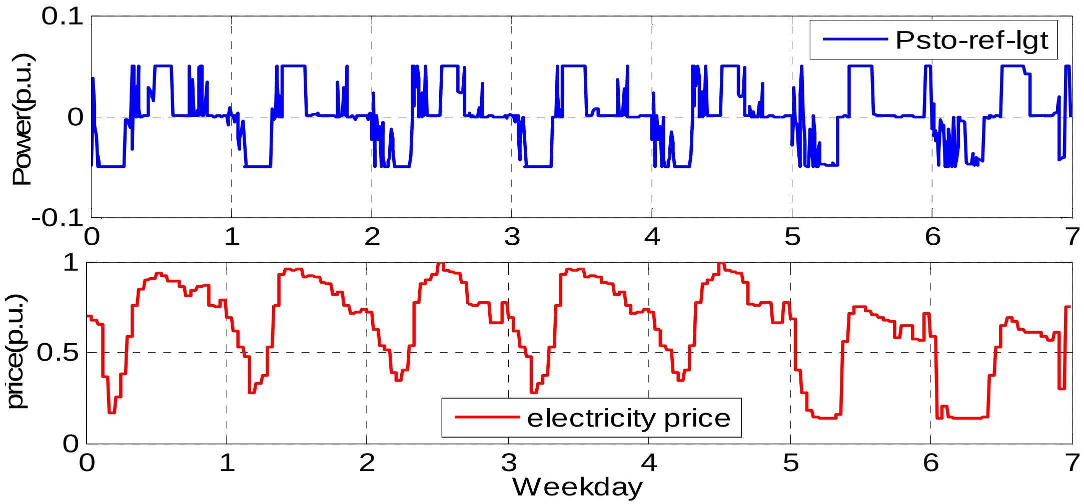
Example of simulation result



One week consumption profile at the level of the Drancy-Mitry 20 MW substation (in Paris suburb) based on a sample collected every 10 min.

Wind and PV production profile assumptions.

One week forecast storage profile (determined by the long term supervisor)
and average hourly tariff of the electrical energy purchased.

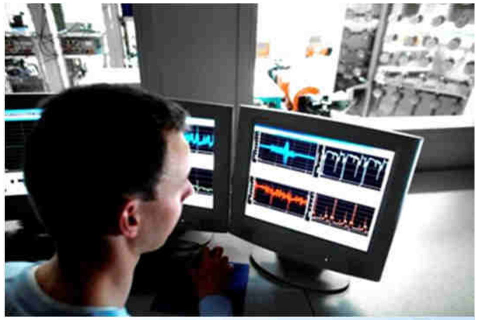


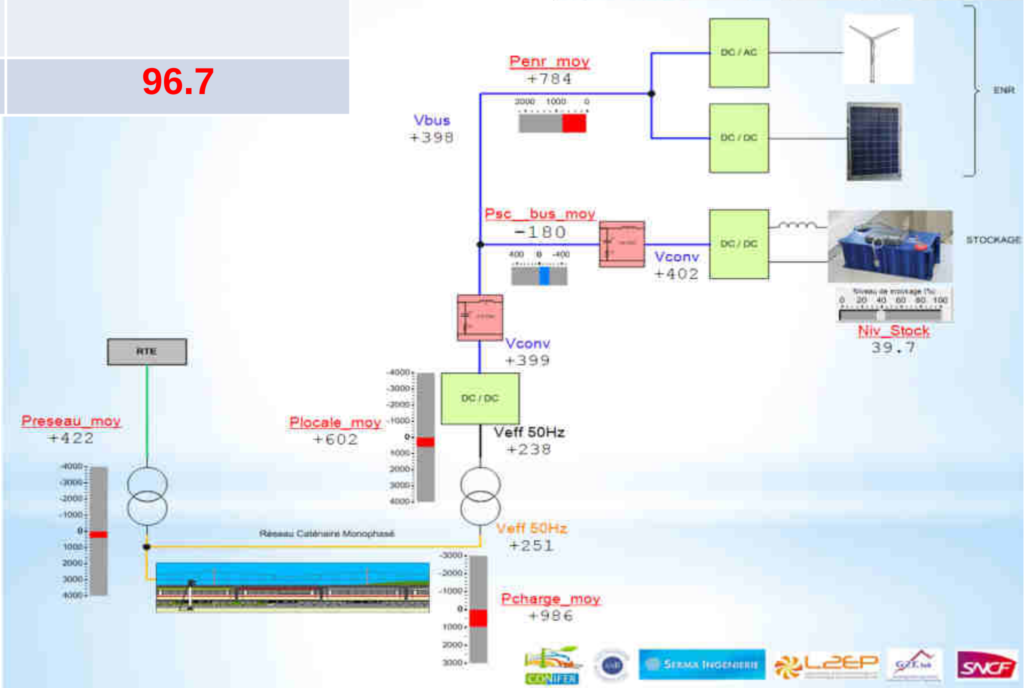
Hybrid railway power substation (HRPS)

Indicators:

- *CMDPS : monthly component of the **exceeding subscribed power***
- ***Economic imbalance*** : difference between the power purchased in the market and the power actually consumed
- *Ratio between the **locally consumed renewable energy** and the produced one*

Indicators	Individual L.M.T. management case	Individual S.T. management case	L.M.T. and S.T management adjustment case
CMDPS (€)	1000	1036	**954.112**
Economic imbalance (€)	557	1755	**1582.1**
I_{EnR} (%)	96.51	95.56	**96.7**





HRPS development methods

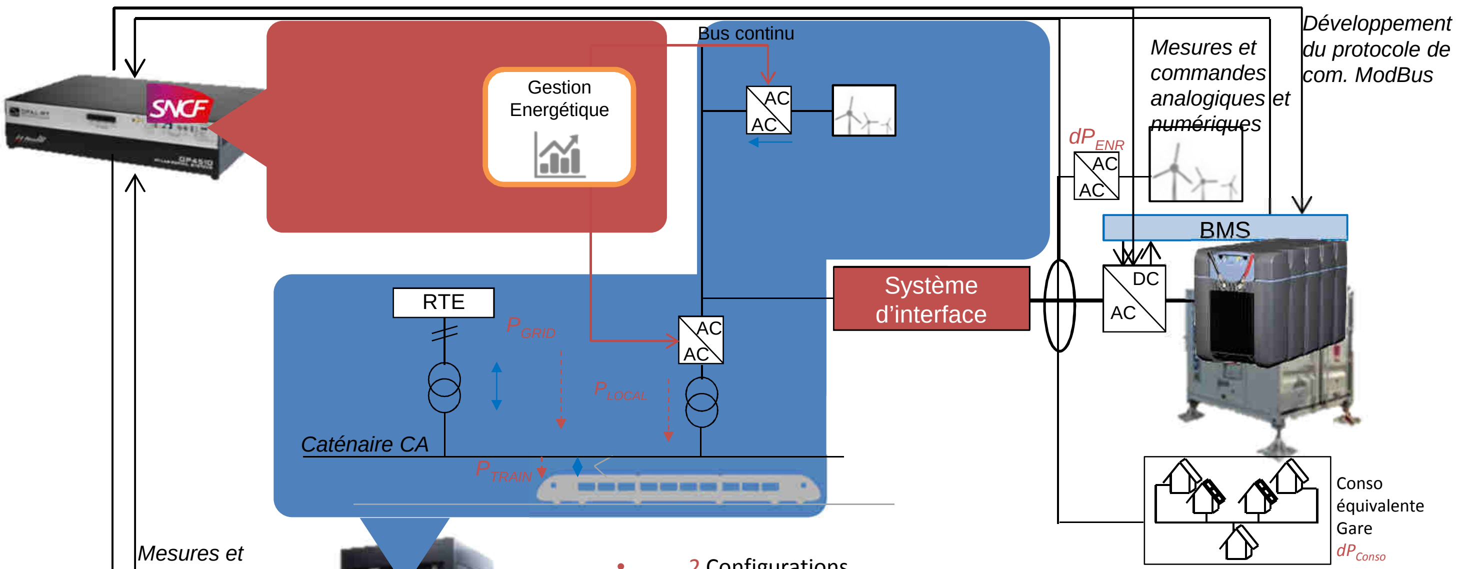
Hardware-in-the-Loop method is the way to prepare industrialization

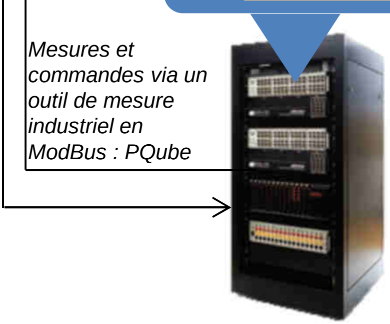
SNCF INNOVATION & RESEARCH

2011 — 2015: Simulated environment

2015 — 2017: Semi-virtual environment (HIL simulation)

Real prototype (TECH4RAIL, Shift2Rail)





- 2 Configurations
  - 4 scénarii pour la Configuration A
    - Nominal,
    - Mode défaut,
    - Essai de robustesse,
    - Effacement.
  - 1 scénario pour la Configuration B
    - Mode nominal
- 5 jours d'essais / 6 heures d'essais journalier
- Date : 20 - 24 mars, 2017

HRPS development methods

Hardware-in-the-Loop method is the way to engage industrialization

INNOVATION & RESEARCH

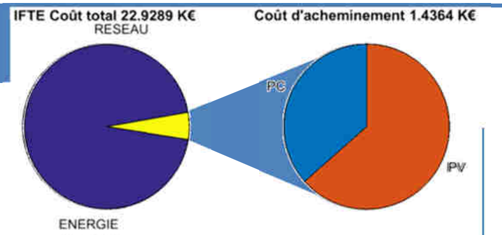
Technical aspects

- The Energy Management System works !
- **Performance** and **robustness** of the system
- **Communications** protocols with battery
- **First multi-services** battery application (demand-response, prioritization…)
- **New networks and markets** for utilities

Finance

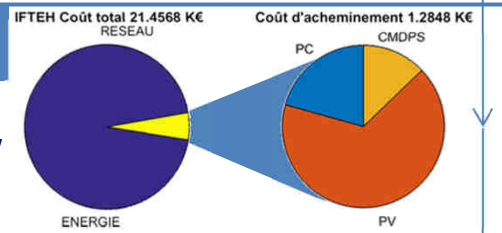
- Energy bill savings **6%**, up to **25% on electricity transportation**
- **Optimal investment** has been challenged for railway services. A more powered storage system wil mainly benefit from **network services** such as DR

- IFTE



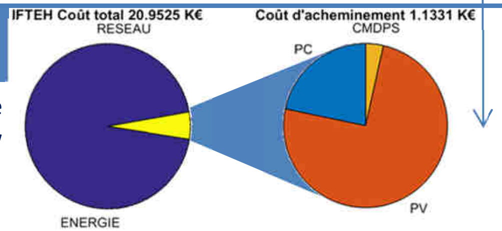
- IFTEH – Configuration A : Dimensionnement Optimal

Batterie
69,6 kWh/132 kW



- IFTEH – Configuration B: Batterie forte capacité

Batterie forte capacité
2,5 MWh/5 MW



Masséna, 1500V DC reversible substation

Trains braking energy recovery is crucial for railway energy efficiency

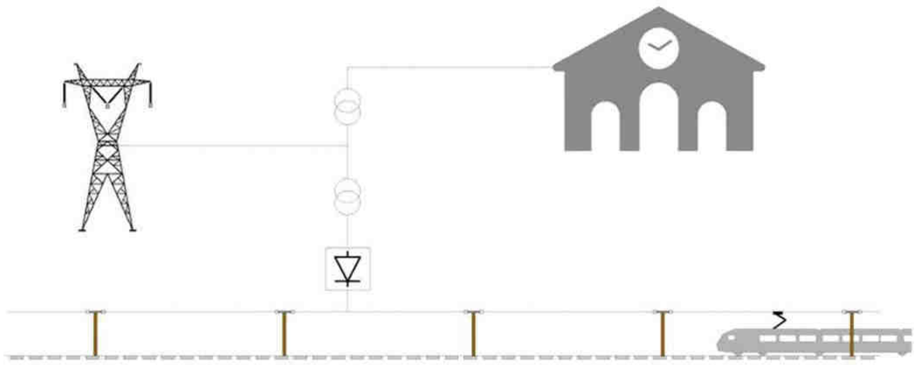
INNOVATION & RESEARCH

Problematic:

- **Mass transit** zone : lot of traffic
- **Irreversible** : DC power supply
- Dissipated energy : quick rise of **temperature** due to braking resistor, or fine particulate matter due to **wear of brake blocks**
- **Energy loss** : 8% to 25% of total energy

Objective:

Using the braking energy of trains equipped with regenerative braking to feed it back into the French electricity network and the railway smart grid



Masséna, 1500V DC reversible substation

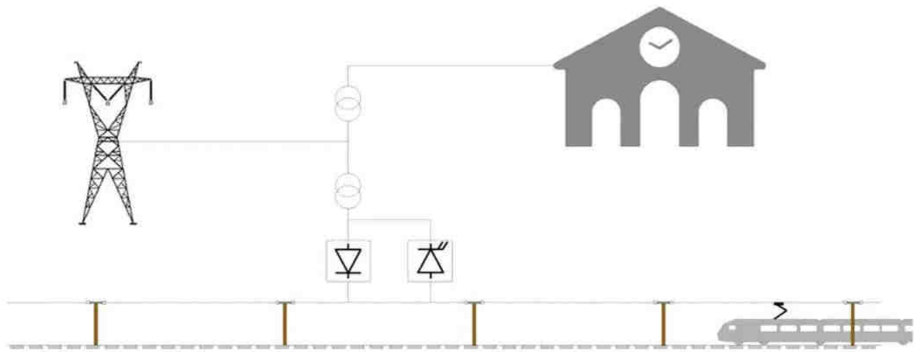
The reversible substation will fuel several research works

↗ Partners

SNCF Group
SNCF Network
SNCF Mobility

↗ Target market:

Reinforcing the DC power supply system : about 500 substations serving the 5863 km of the French 1500 V DC railway network

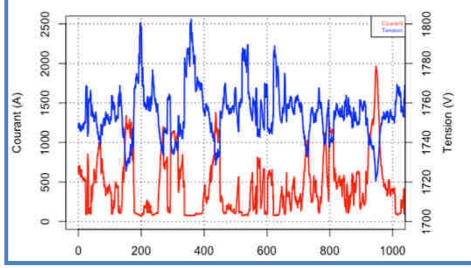


Masséna, 1500V DC reversible substation

Stochastic modeling is used to override complexity and volatility in physical models

- **Objective of this research work:**
  Developing a statistical model of energy consumption complementing the deterministic models used by SNCF

Substation measurements



statistic line model

Z2N Train measurements

stochastic drivers model

Statistic model of braking energy

Macroscopic substation and traffic data

Potential site identification

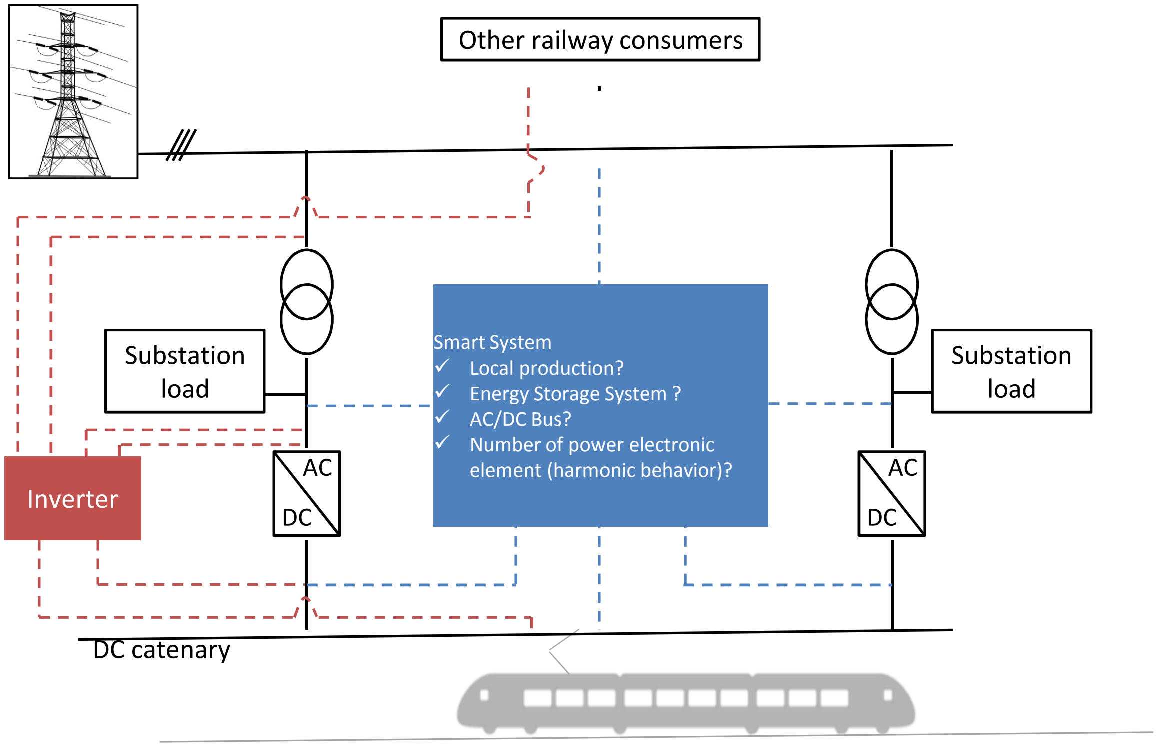
Masséna, 1500V DC reversible substation

Trains braking energy recovery can fuel the railway smart grid

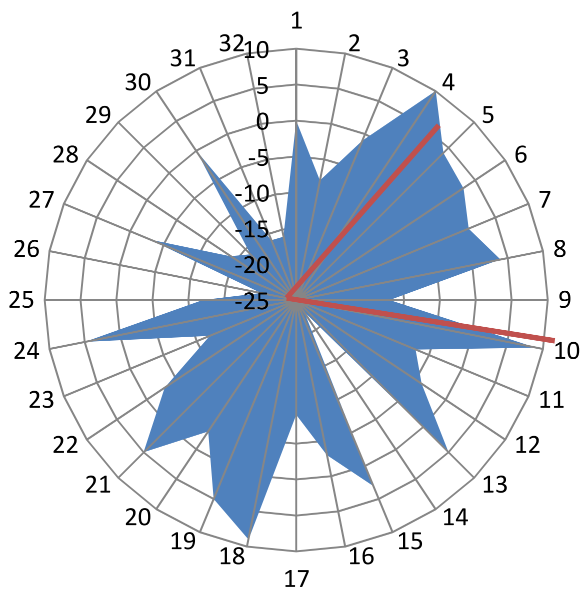
Objective of this research work:

Setting up the energy management of the Railway Smart Grid in real time
for smart grid typology decision

Smartgrid ready substation's architectures



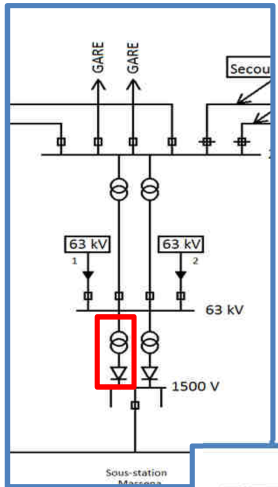
Decision matrix development



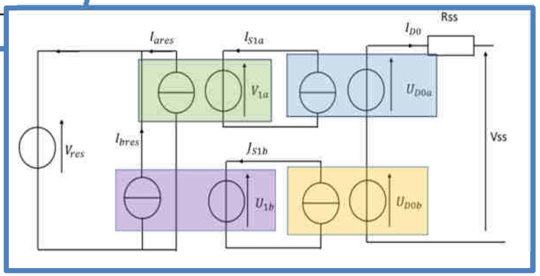
Many typologies versus several criteria : costs, railway services, electrical network services, electric losses…

Masséna, 1500V DC reversible substation

Industrial perspectives



Model the infrastructure to define the possible use of train braking energy

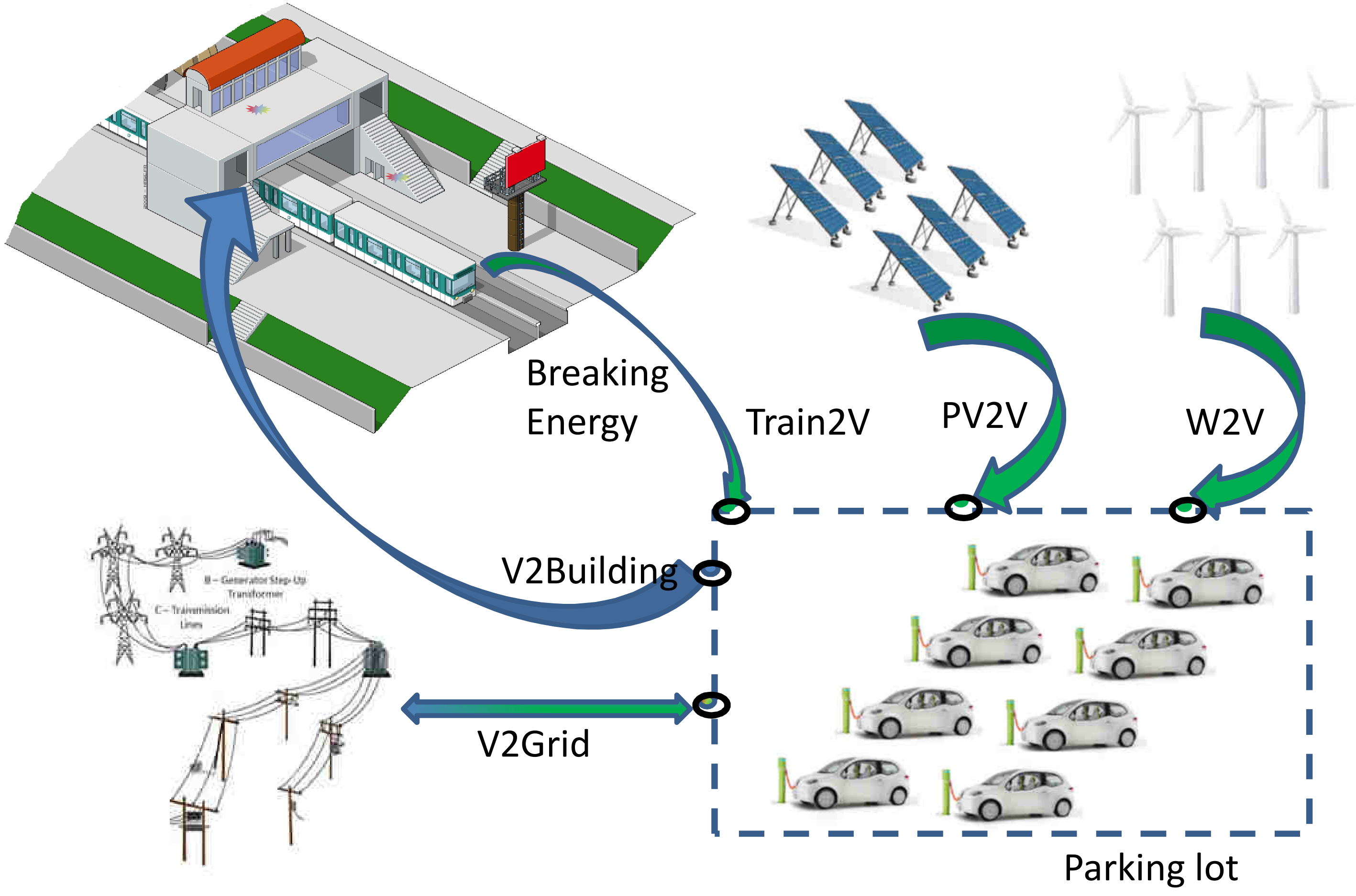


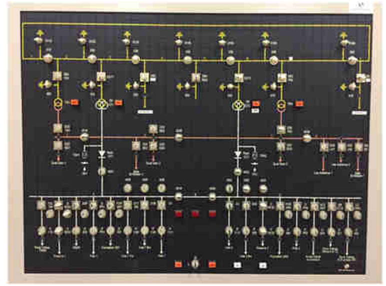
Develop a Real time Energy Management Strategy to offer new services (consumers, rail, suppliers)

Integration of EMS in substations and benefits validation

Energy hub

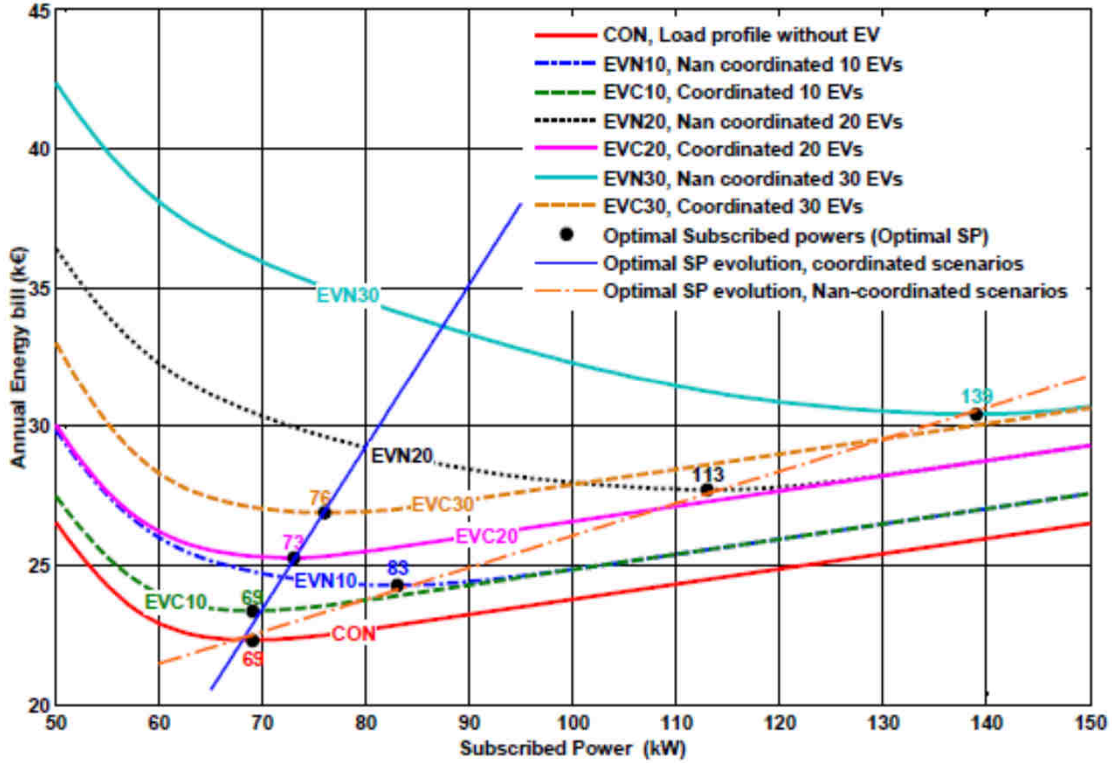
Contribution of the Vehicle-to-Grid (V2G) to a railway station through the management of a VE fleet and Hybrid Rechargeable Vehicles connected on a local electrical distribution network.





Impact and contribution of EV/V2G on railway station parking lots

Example of results :
Comparison of optimum subscribed power evolution in function of number of vehicles for non-coordinated and coordinated scenarios.



Example of scenarios studied to reduce the energy bill with V2G based on
- Regulatory Tarif Sales
- Spot Market Tarif

Energy is the main fuel for transportation

What worked ?

- Engineering Hardware-in-the-Loop methods
- EMS development, optimal for both design and operations
- Multi-purpose batteries between railway and electrical networks

What to investigate ?

- Regulation of DR must evolve to help railway participate
- Multi-layer energy management systems
- Statistical and deterministic models coupling

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