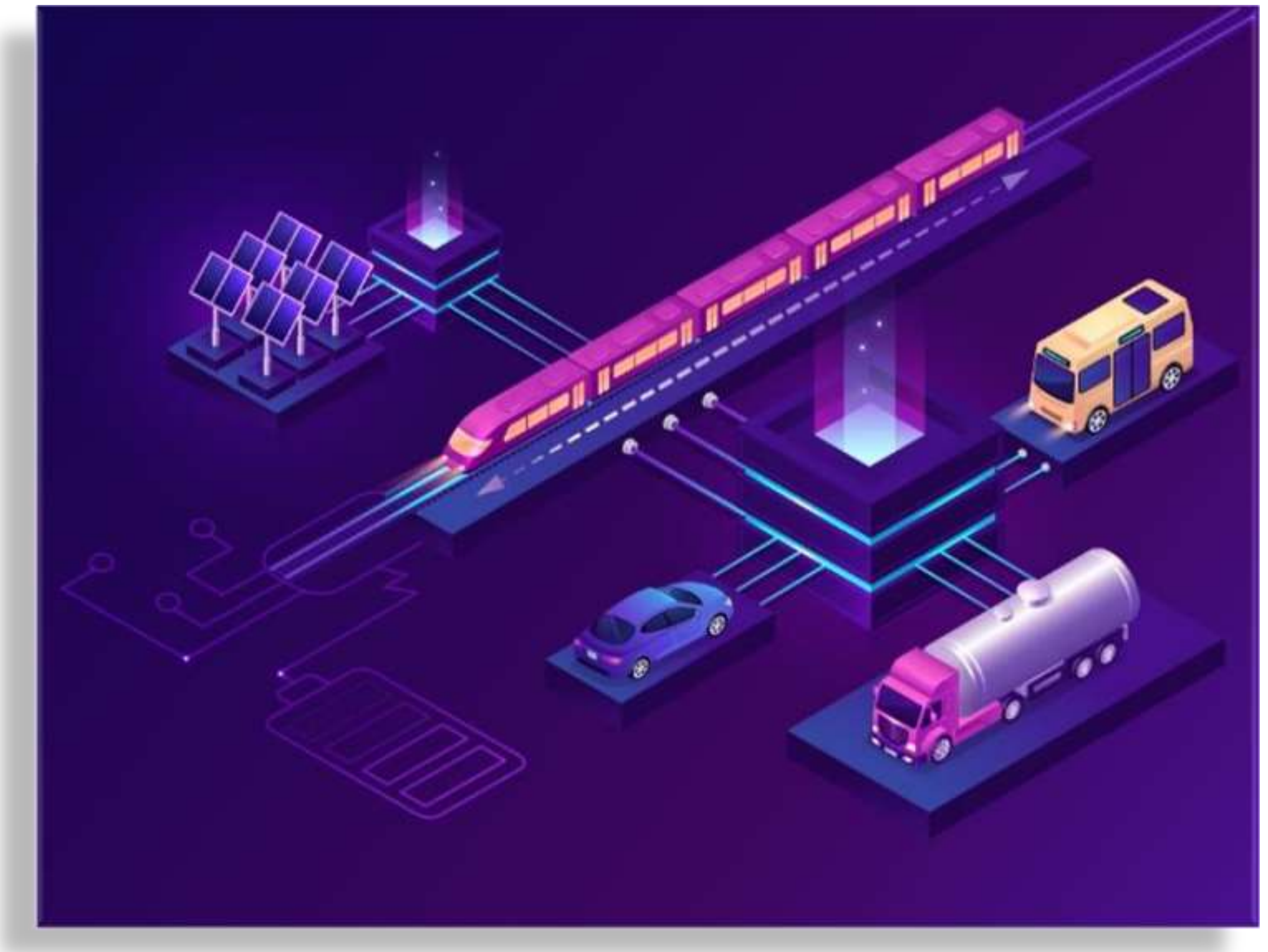
Welcome to the best practice workshop

ELECTRIC VEHICLES, EQUIPMENT AND RAIL GRID

INTERNATIONAL UNION OF RAILWAYS

Proposed by
the UIC Energy efficiency and CO_2 Emissions Sector



Organised by UIC & the Sector's core members:

Gerald Olde Monnikhof, ProRail
Denzel Collins, NR

Philippe Stefanos, UIC

22 November 2024

Welcome
Introduction

Please right click + rename in participants list (Name Company)
Please avoid leaving mic open if not speaking

Participation and organisation

As of 15/11/2024: 92 registered participants from the following companies:

ADIF
Alstom
ALSTOM Transport Deutschland GmbH
Alstom Transport UK Limited
Axia Ingénierie
Bane NOR
Bane NOR SF
Bike is Best Enterprise Kenya
CAF TE
CFL (Luxembourg)
CP - Comboios de Portugal
Cubris
DB AG
DB Energie GmbH
DB InfraGO
Department of Rail Transport (Thailand)
Dynniq
East Japan Railway Company
Ferrovie dello Stato Italiane (FS)
FGC
FS RFI (Infra)
Furrer + Frey AG
German Centre for Rail Traffic Research
Government Office of the Slovak Republic
Hellenic tarin
HiveMQ
Infrabel
IP - Infraestruturas de Portugal
Irish Rail
Kenya Railways Corporation
Krado
Lokaltog A/S
MATISA SA
National Capital Region Transport Corporation
PKP Polskie Linie Kolejowe S.A.
Platform for Electromobility
ProRail
Railway Technical Research Institute
RENFE
Ricardo
RTE
SBB AG
SBB Energy
SCLE sfe
Siemens Mobility GmbH
Siemens Stiftung
Slovenske železnice - Slovenian railways
SNCB
SNCF
SNCF Réseau
SNCF Voyageurs
Stevin / ProRail
Sustainable Development Foundation
TCDD
The Norwegian Railway Directorate
TTG Transportation Technology
TUC RAIL
(UIC)

Purpose of the workshop

Initial idea

Transition to EVs is happening :

Electric vehicles and equipment, charging infrastructure and rail electric infrastructure can be combined

Why

Enhance smart management of the energy, including

- Renewable & braking energy production & use maximisation
- Peak demand shaving (anticipation & recuperation)
- Emergency power
- Additional interface to public grid (Selling rail energy for charging or other electric load)
- Better integration of electric networks and correlated supply/shaving

Purpose of the workshop

How

By wide spreading digital management of energy
The idea is to make the most out of an efficient **(smart) power management** between the public grid, the railway grid, and any **energy storage systems** connected to it.

As direct benefits, it saves the whole grid's capacity and efficiency, **avoiding losses due to high load and wear** from intense use, and maximising renewable energy allocation into the grid and storage to **avoid the loss of production**.

This is an extremely powerful improvement to get the best out of an electric system, while **increasing useful energy storage capacity**.
This comes along the new **"Vehicle to grid" (V2G) approach**, enabling smart management of energy storage systems from electric vehicles to properly balance energy provision and demand by acting as a controlled buffer system and flexible load.

Detailed timeline

10:00	Welcome Introduction	UIC/Chairs
10:10	GUW+: Smart substation	Carsten Söffker Alstom
10:30	SmartCharging4Trains - Linking Battery Trains & EV Charging	Thorsten Frenzke Siemens
10:50	Using the Flexibility of Traction Batteries for the Railway Grid	Markus Halder SBB
11:10	Charging E-machines and trucks (railway excavators) at substation Vught	Ron Jasker ProRail
11:30	Charging electric vehicles from rail power supply	Paul Tobback Sam Breugelmans TucRail
11:50	Questions / discussion Closing remarks	All

Purpose of the workshop

Exploring challenges and solutions

The different speakers will introduce the findings and challenges regarding:

- Developed solutions
- Solutions in development
- Experience
- Technical aspects for connectivity
- Smart management development

To solve the challenges:

Creating the interface with road fleet

Implementation of a seamless management

Workshop timeline

10:00	Welcome Introduction	UIC/Chairs
10:10	GUW+: Smart substation	Alstom
10:30	SmartCharging4Trains - Linking Battery Trains & EV Charging	Siemens
10:50	Using the Flexibility of Traction Batteries for the Railway Grid	SBB
11:10	Charging E-machines and trucks (railway excavators) at substation Vught	ProRail
11:30	Charging electric vehicles	TucRail
11:50	Questions / discussion Closing remarks	All

INTERNATIONAL UNION OF RAILWAYS

Alstom

Dr. Carsten Söffker

Master Expert Energy Management, Digital & Integrated Systems

GUW+ - Smart Traction Sub-Station for the integrated energy supply of e-mobility in public transport

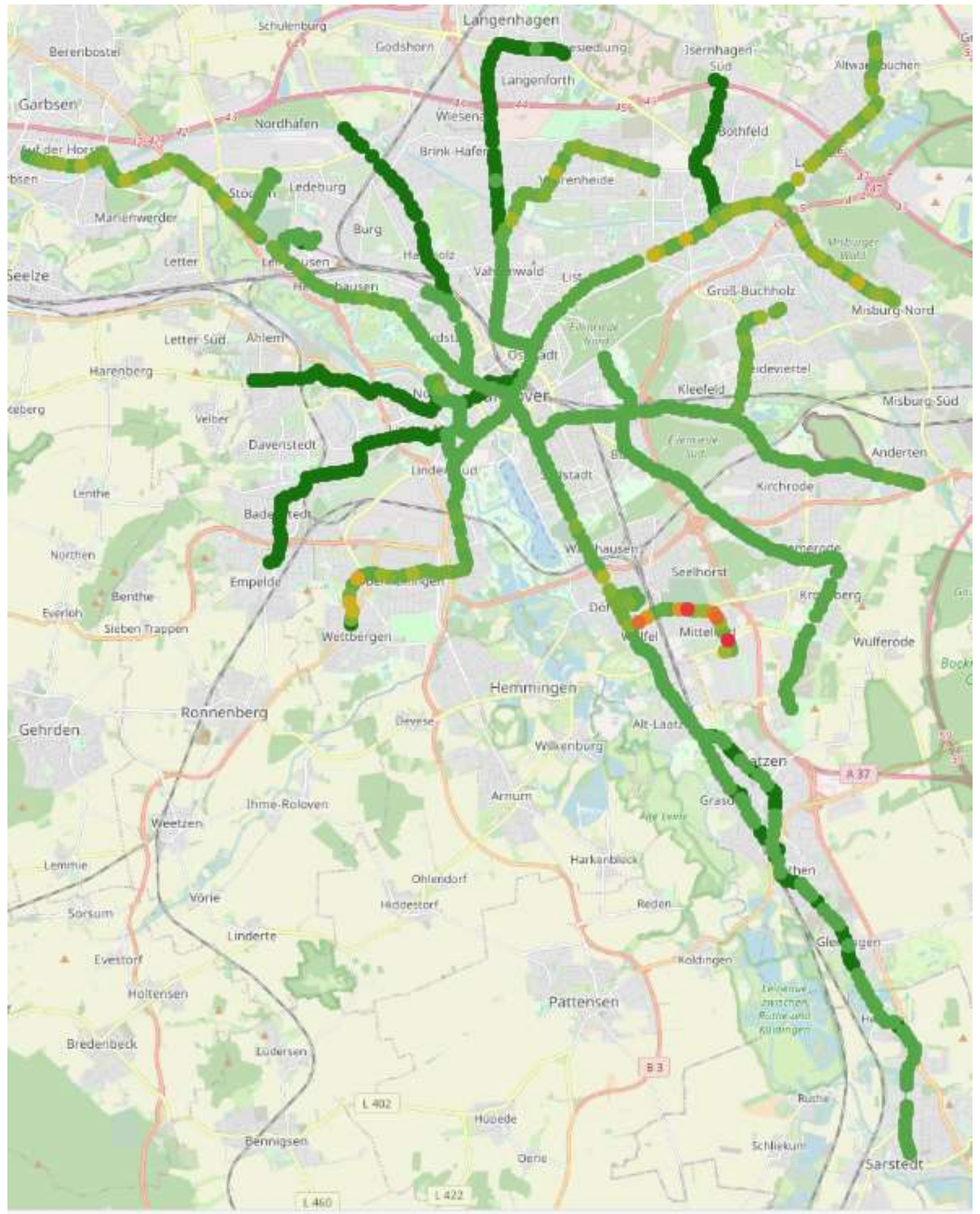
ALSTOM Transport, UIC Webinar, 22.11.2024

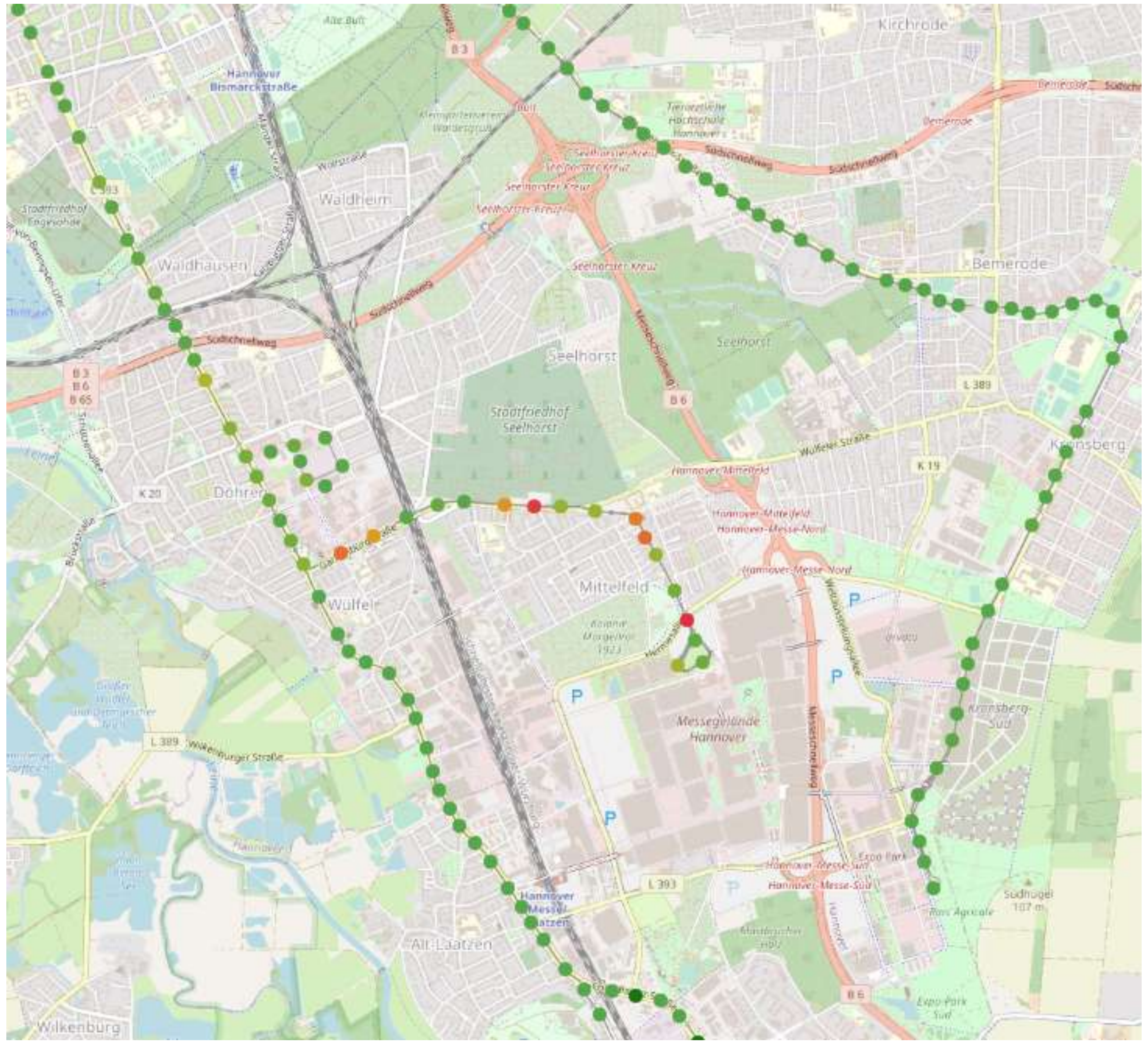
Agenda

- **Motivation of the "demonstration partner" ÜSTRA**
  - Energy efficiency
  - Integration of light rail & e-bus
  - Battery TCO
- **Design and implementation at the Döhren site**
- **Functions in interaction**
- **Project completion**
  - Further development in Hanover
  - Conclusion

1st motivator for the GUW+ research project
Further improvement of energy efficiency

- "The better is the enemy of the good" - braking energy is still being lost in Hanover



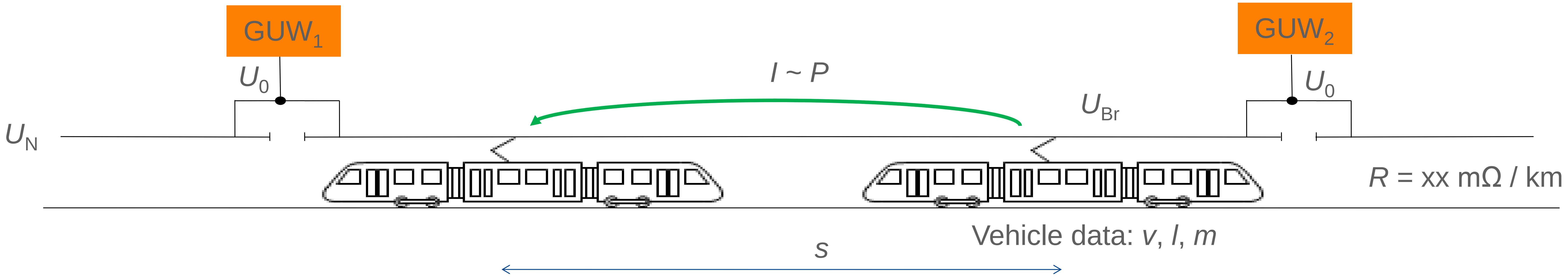


1st motivator: Energy efficiency

How can the energy exchange between the tracks be improved?

The aim is to increase the performance limit $P_{max} = I_{max} \cdot U_N = U_N \cdot \frac{U_{Br} - U_0}{R}$

- Increase rated voltage U_N : more long-term migration
- Increase brake voltage U_{Br} : Utilisation of normative limits under consideration of existing vehicles.
- Reduce open-circuit voltage U_0 : often conflicts with traction requirements or $I_{k,\ min}$
- (effective) Reduce loop resistance *R:*
  - Reduce distance *s* by decreasing the headway - but this also increases the number of vehicles that need power …
  - Change the design of the overhead line, additional feeder or return conductor cables



The local and temporal distribution of non-transferable braking energy "packets" depends on the grid.

2nd motivator for the GUW+ research project
Electrification campaign at ÜSTRA

52 existing light rail traction sub-stations

Electrification programme includes

- **48 e-buses (30 solo 12m buses, 18 articulated buses)**
- **7 locations with opportunity charging (300 kW)**
- **1 depot with night charging (50 kW)**
- **1 GUW+**

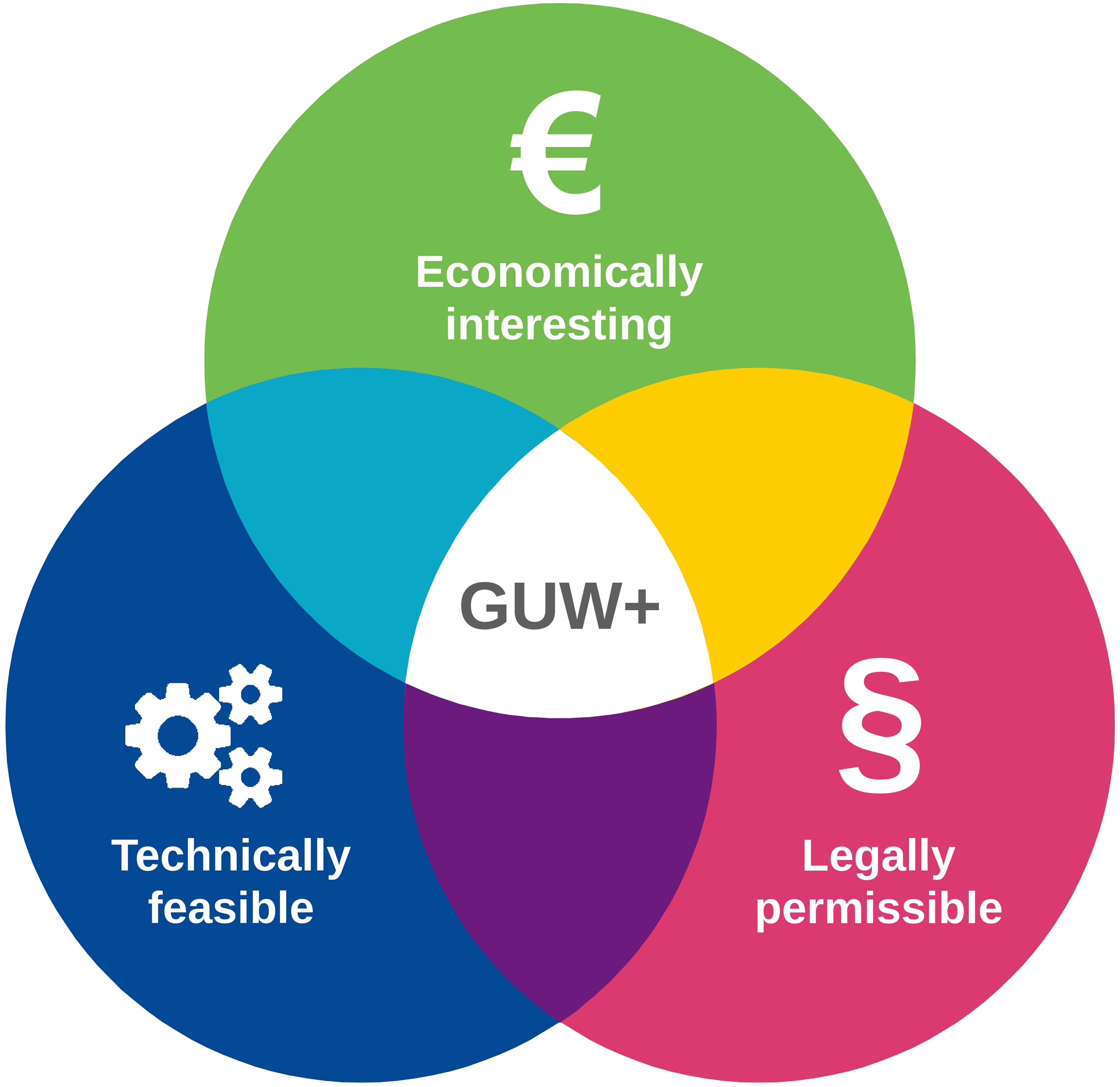
3^{rd} motivator for the GUW+ research project
A second life for disused eBus batteries

- Sustainability, energy efficiency and resource scarcity are important topics for ÜSTRA and are being analysed.
  - The batteries in electric buses offer new potential in this respect
  - They are the property of ÜSTRA. They could be returned to the supplier at the end of life, but do not have to be.
  - This means that the batteries can continue to be used in the GUW+ when they are no longer sufficient for driving (e.g. capacity falls below 80% of the nominal value leading in parallel to reduced charging power)

Sustainable concept for the Döhren site

Operator view (ÜSTRA)

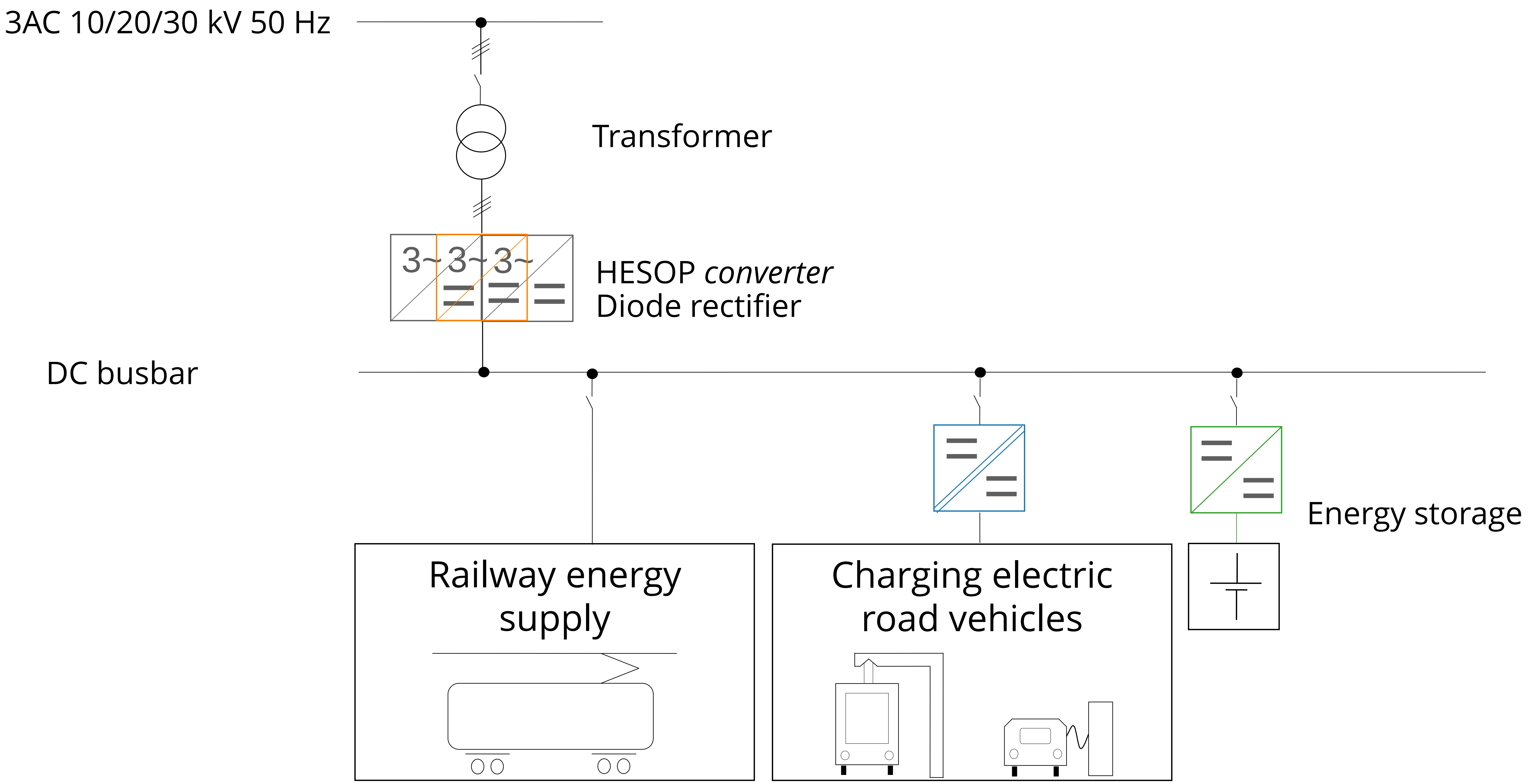
- Step-by-step conversion plan enables minimal operational intervention
- Investment costs:
  - +1 HESOP, 1 DC switchgear
  - E-bus charging is planned anyway
  - Energy storage as required
- Amortisation paths in operation:
  - Peak shaving for the bus
  - Braking energy potential low
  - Grid services in cooperation with Energy provider



Agenda

- Motivation of the "demonstration partner" ÜSTRA
  - Energy efficiency
  - Integration of light rail & e-bus
  - Battery TCO
- **Design and implementation at the Döhren site**
- Functions in interaction
- Project completion
  - Further development in Hanover
  - Conclusion

GUW+ operating modes



- Extension of the basic functions:
  - Enabling bus charging
  - Enabling car/truck charging
- Additional functionalities:
  - Peak load shaving (15min annual power peak)
  - Utilisation of previously unused braking energy potential
  - Short-term buffering of blackouts
  - Active voltage regulation on the DC busbar
  - Reactive power provision/ -compensation
  - Avoidance of excessive instantaneous power peaks
  - Electricity trading and control reserve

Realisation at the Döhren site
GUW+ construction process





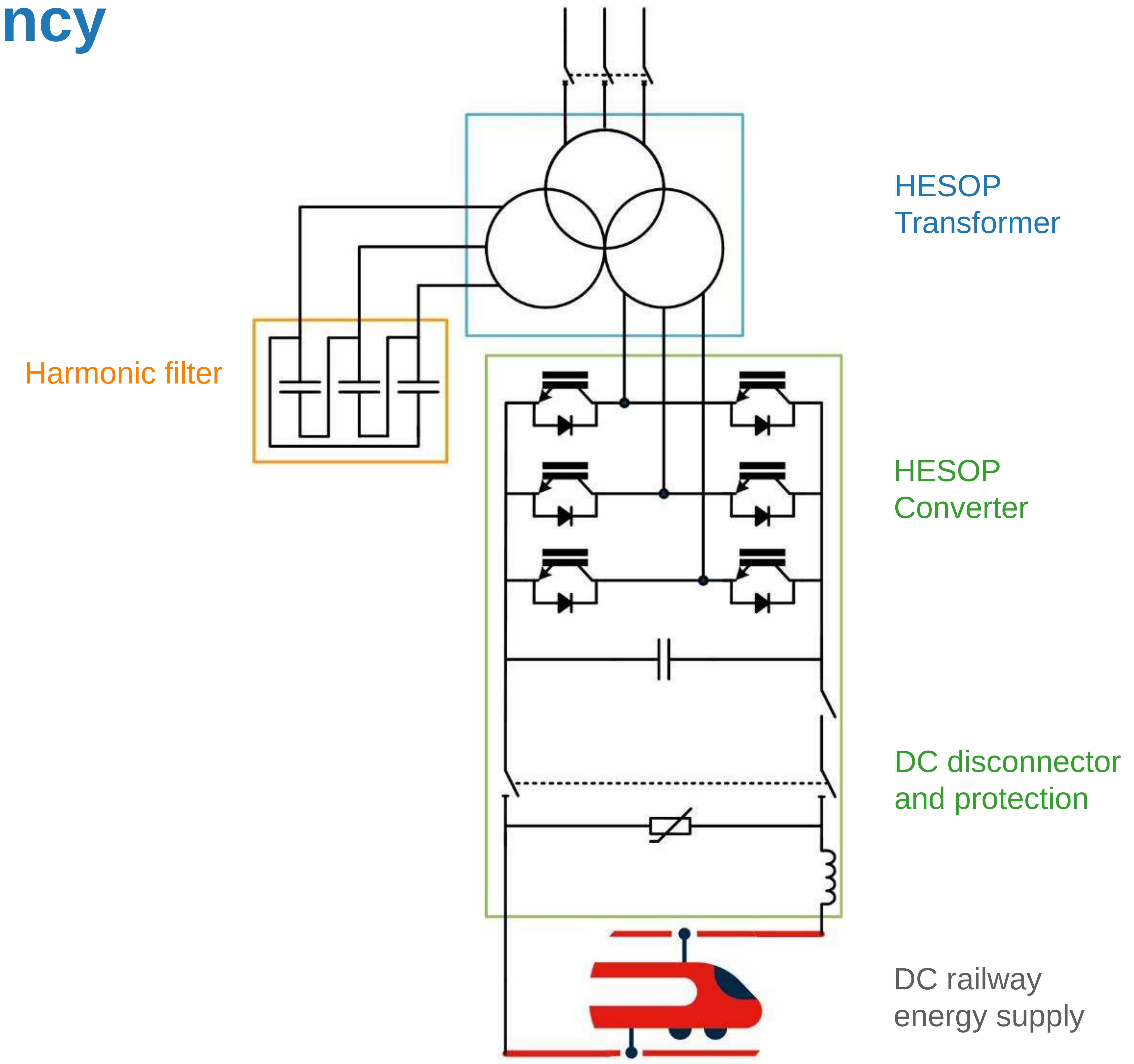



1st motivator: Increasing energy efficiency
HESOP converter system

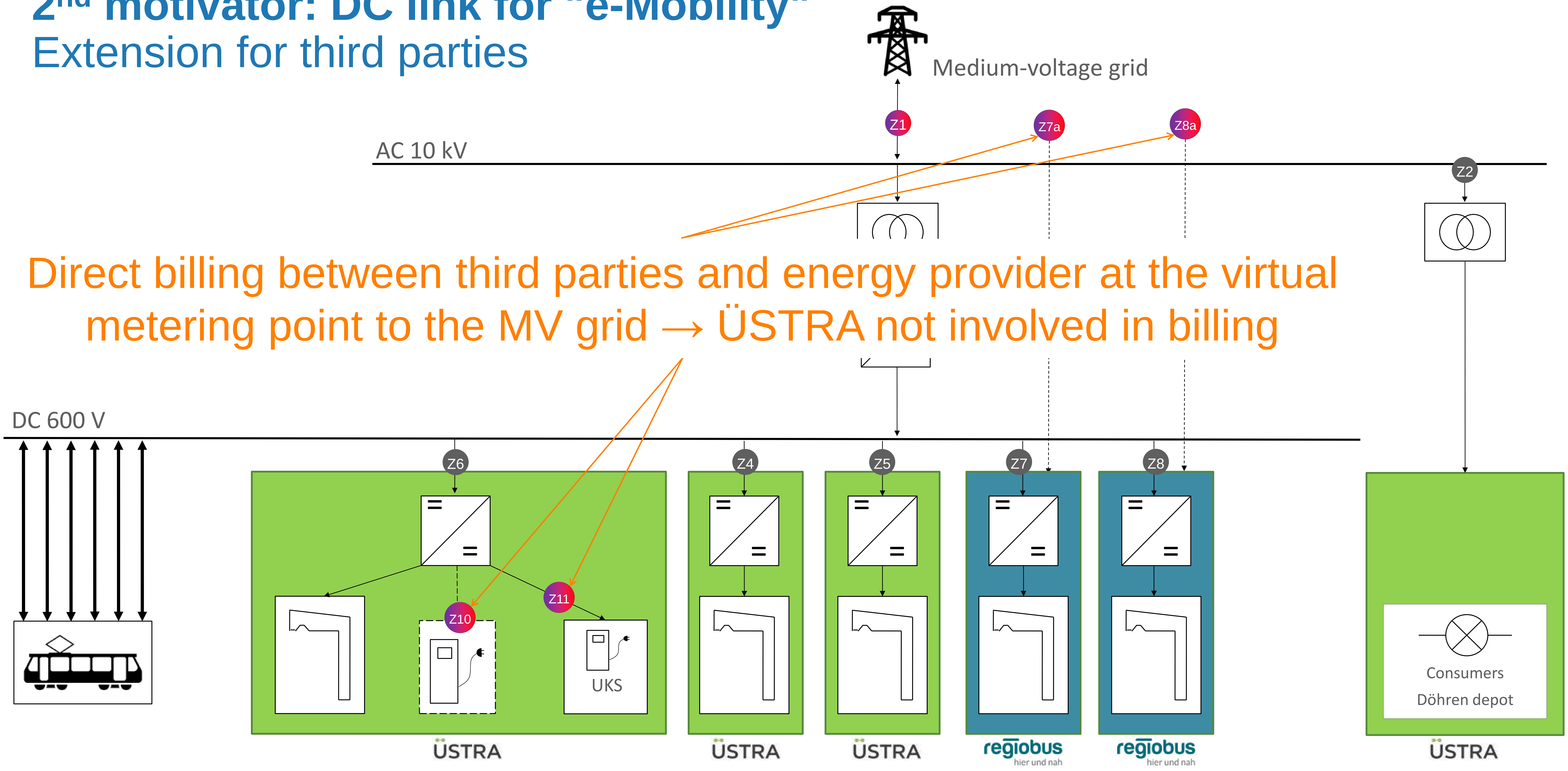
Architecture and main functions

- HESOP is a bidirectional power converter, consisting of an IGBT four-quadrant converter with PWM control.
- For DC grids from 600 V to 1500 V and from 1 MW to 4 MW (urban and regional lines).
  - Peak power: up to 12 MW
- Key advantages:
  - Dynamic voltage regulation for energy optimisation in traction mode.
  - Utilisation of available braking energy in regenerative mode.

For further information, please refer to the following technical article:
Modernisation of existing DC railway power supply systems using HESOP
(Electric railways 115 [2017])



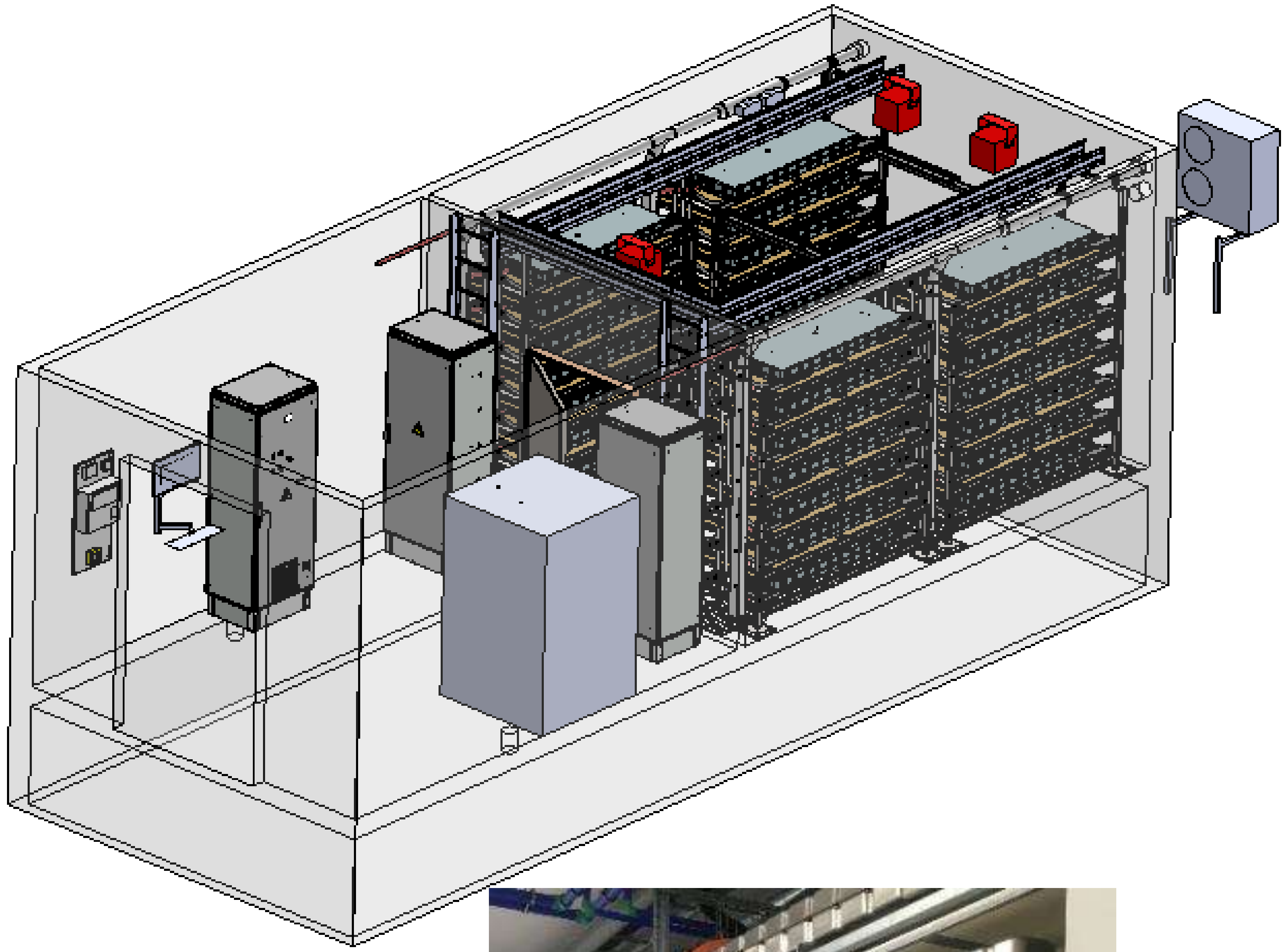
2nd motivator: DC link for "e-Mobility"
Extension for third parties



Direct billing between third parties and energy provider at the virtual metering point to the MV grid → ÜSTRA not involved in billing

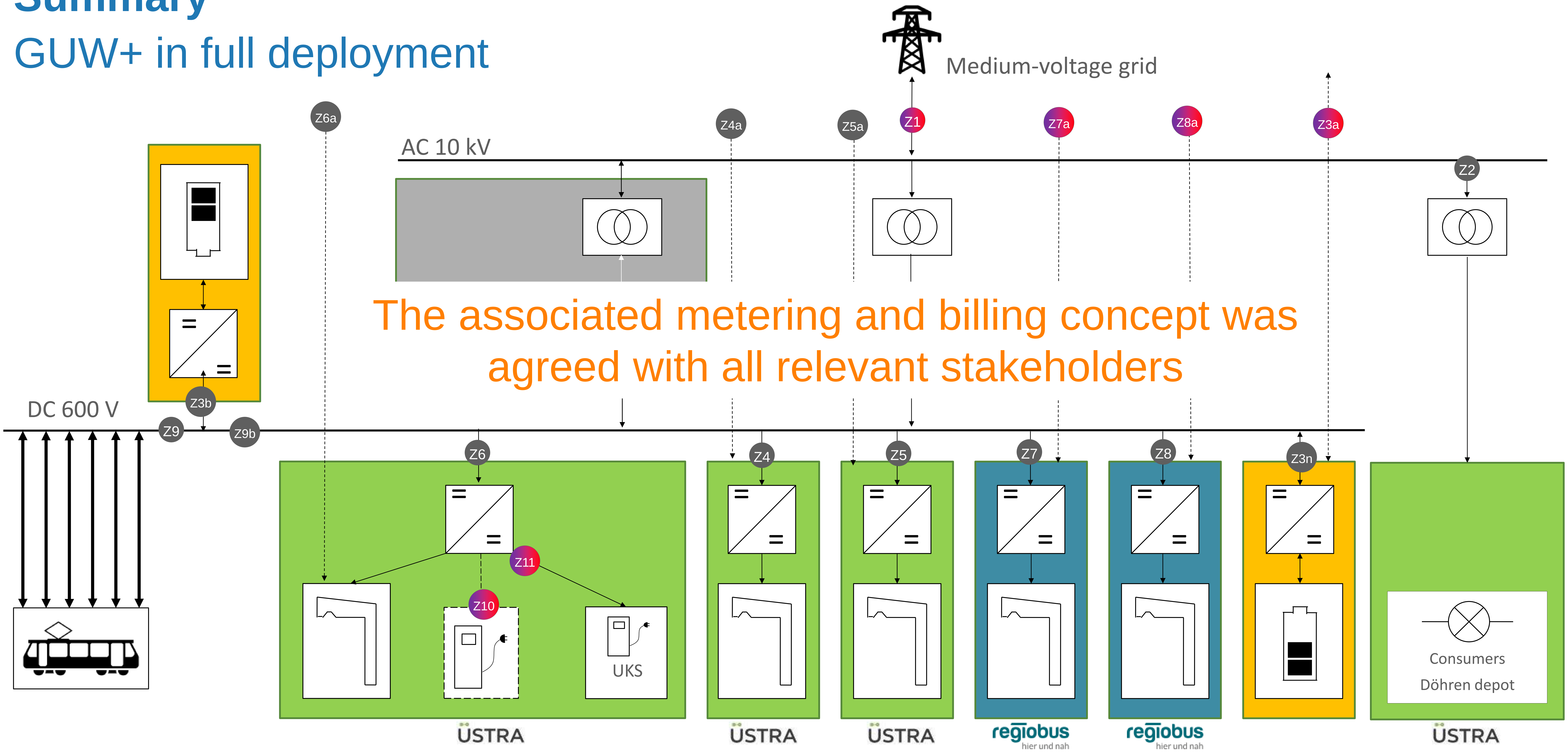
3rd motivator: Stationary energy storage
Realisation of 2nd-life battery storage

- 28 used traction battery modules from eCitaro bus
  - Use of the 15 OEM 37 PRC from Akasol
  - Split into two lines of 14 battery packs each
  - Nominal capacity when new: 700 kWh
  - Guaranteed minimum capacity: 500 kWh
  - Continuous current: 500 A
  - Voltage range: 522 - 740 V
- Integration of aerosol extinguishing generators and flue gas discharge
- Realisation by Mercedes Benz Energy



Summary

GUW+ in full deployment



The associated metering and billing concept was agreed with all relevant stakeholders

Agenda

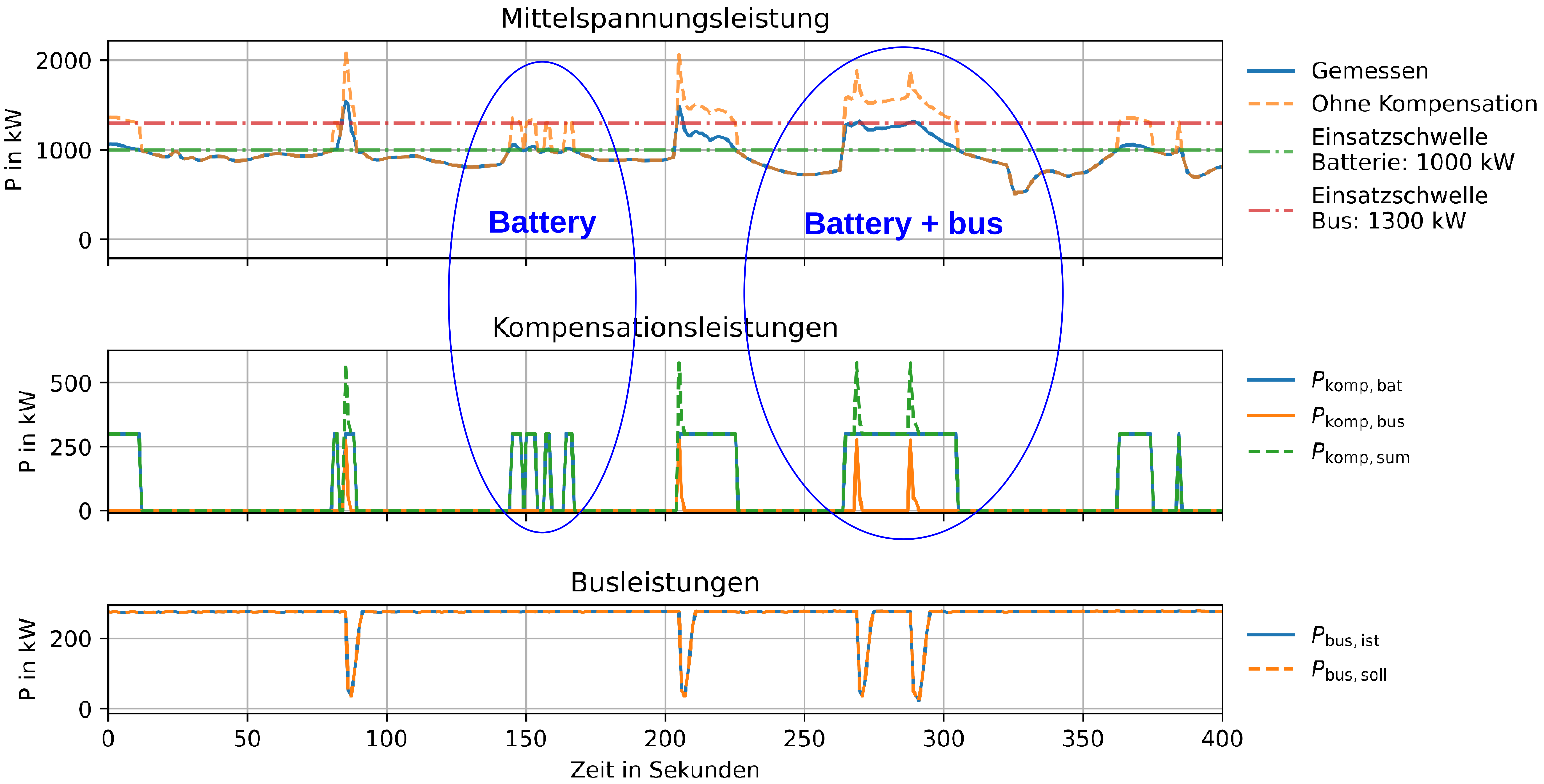
- **Motivation of the "demonstration partner" ÜSTRA**
  - Energy efficiency
  - Integration of light rail & e-bus
  - Battery TCO
- **Design and implementation at the Döhren site**
- **Functions in interaction**
- **Project completion**
  - Further development in Hanover
  - Conclusion

Summary 3rd phase
Functions in interaction

Function	Validation status	Open points
Voltage regulation	Complete	
Braking energy	Complete	
Annual peak load capping	Started	Evaluation over 1 winter
Instantaneous power limitation	Complete	
Primary control reserve + electricity trading	Concept available	Grid services cannot currently be validated
Reactive power	Complete	Interface to the grid operator
Blackout	Demonstrated	Optimisation for specific use cases

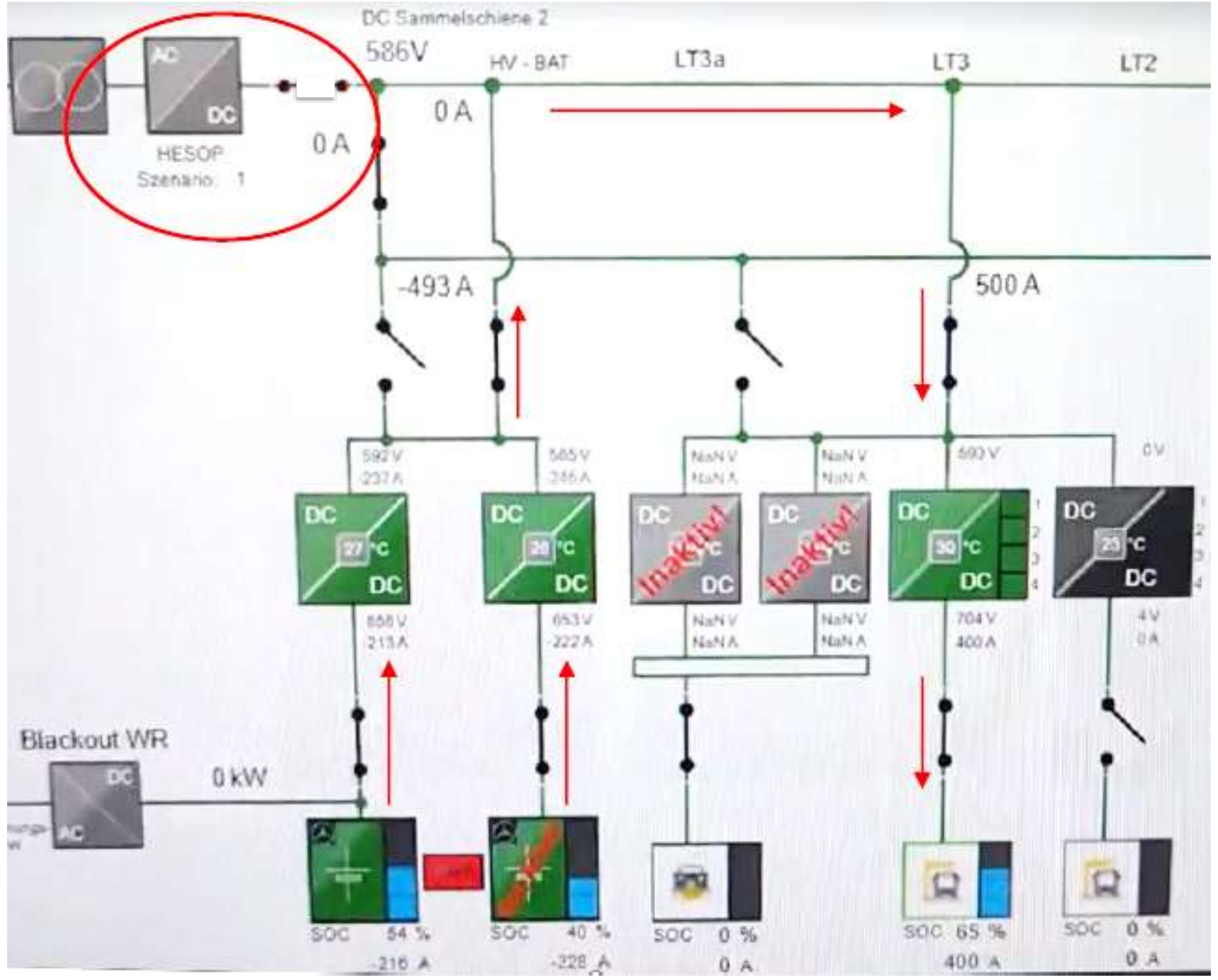
Interaction of functions
Instantaneous power limitation

- If (adjustable) power values are exceeded at the grid connection point, gradual measures are taken to limit any further increase:
  - Saving energy from the battery system
  - Additional short-term reduction of the bus load

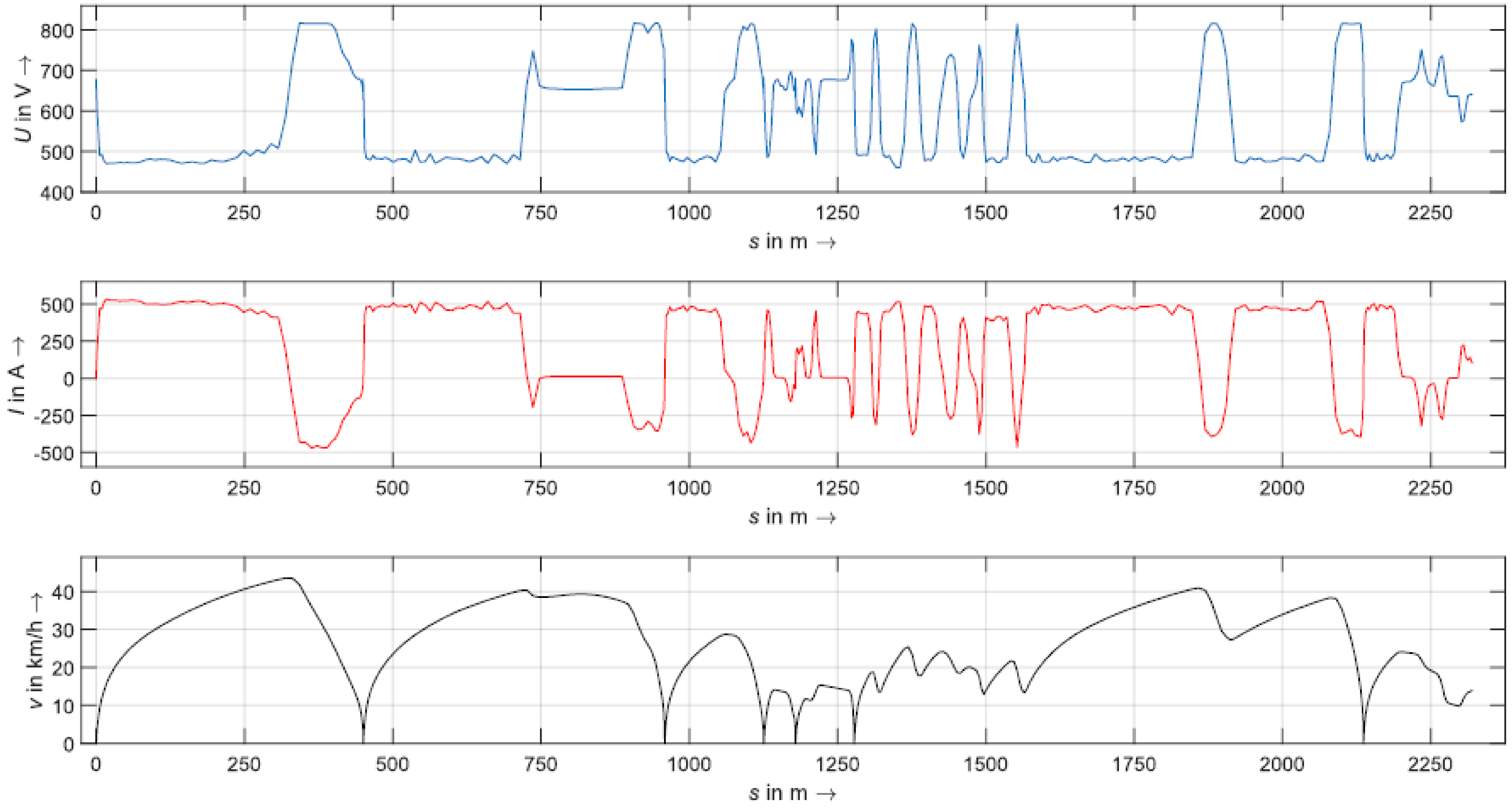


Functions in interaction
Dealing with supply interruptions

- E-bus charging during "blackout"



- Train journey during "blackout"



Agenda

- **Motivation of the "demonstration partner" ÜSTRA**
  - Energy efficiency
  - Integration of light rail & e-bus
  - Battery TCO
- **Design and implementation at the Döhren site**
- **Functions in interaction**
- **Project completion**
  - Further development in Hanover
  - Conclusion

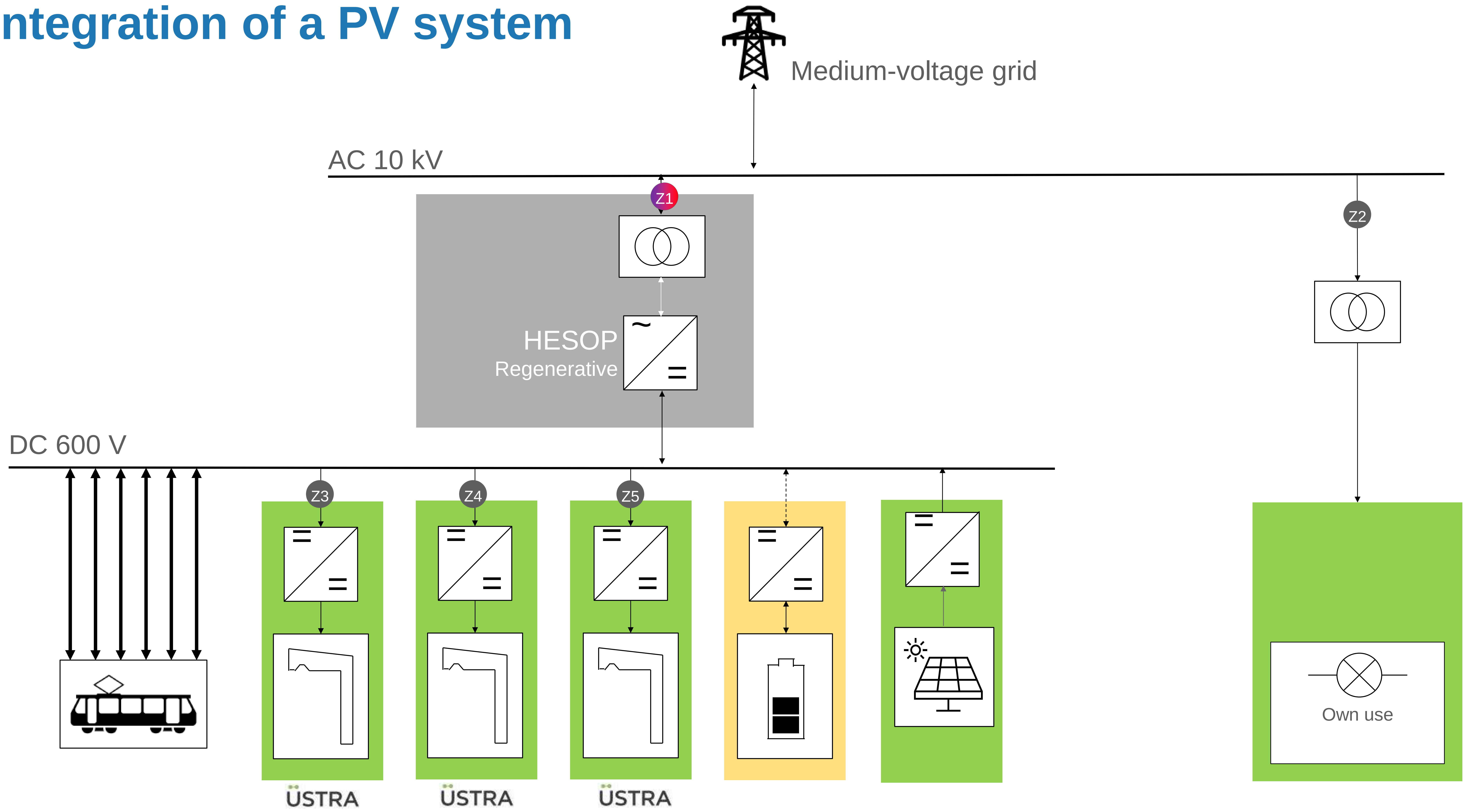
What happens next?

Next steps

Idea pool of ÜSTRA

- at short notice:
  - Full start of e-bus operation on the lines 128 and 134
  - Integration of photovoltaics on the roof of the GUW+ building (DC connection)
- in the medium term:
  - Linking the peak load shaving prediction with the central e-bus charging management system
  - Expansion of the charging technology for additional lines
  - Fitting 2nd battery room with "own" 2nd-life batteries (once they become available)
  - Provision of control reserve „in pool“ with Enercity storage power plant
- Further locations:
  - Investigation of the potential at other locations
  - Consideration of the boundary conditions in the entire ÜSTRA network

DC integration of a PV system

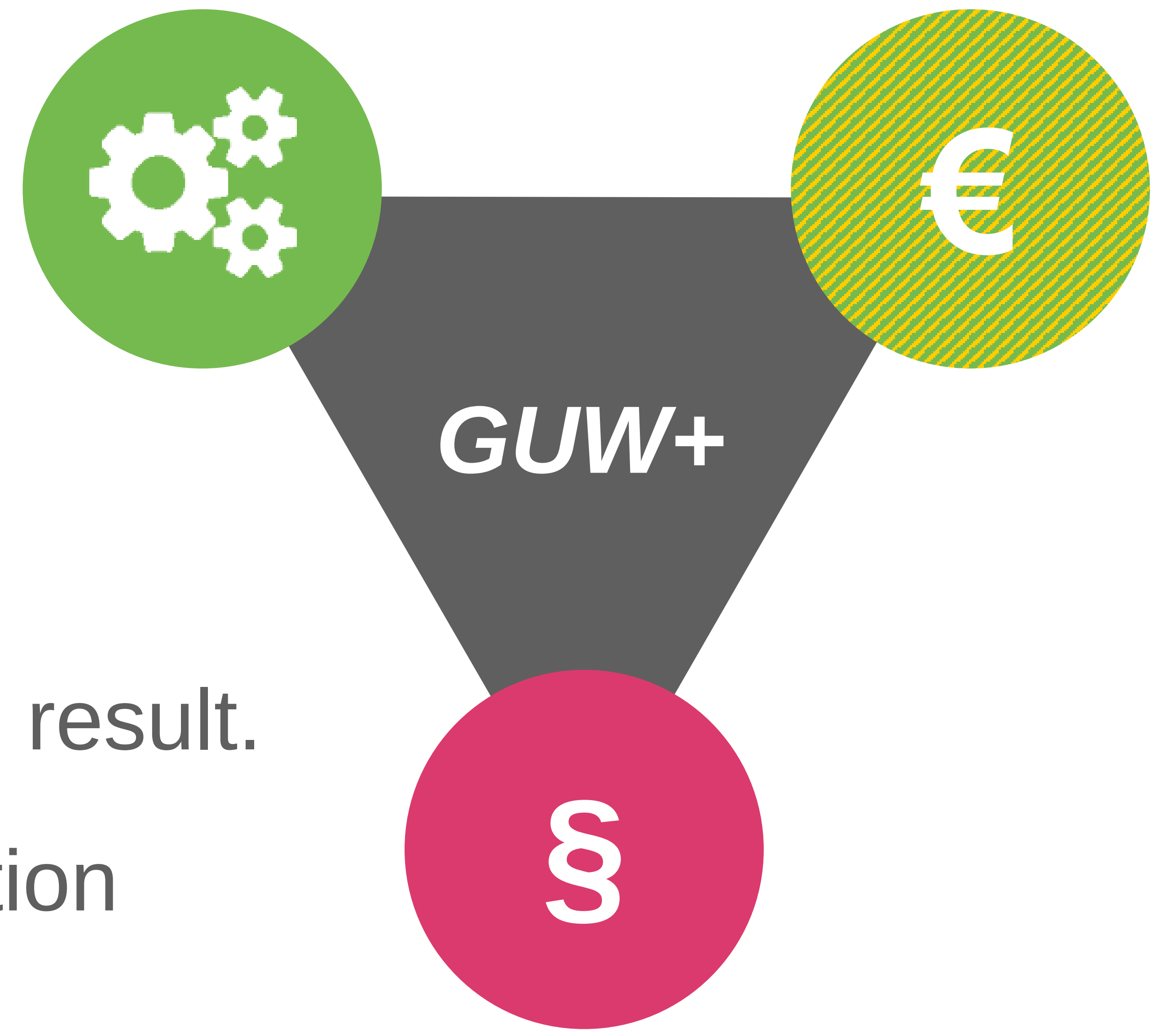


Innovative energy supply concept GUW+

Conclusion: GUW+ can boost e-mobility and thus the second phase of the energy transition

Large parts of the route were travelled in all three axes:

- Suitable components are available on the market and have been successfully "system-integrated„ (all values per Jan 2024):
  - Traction power supply > 5 GWh
  - Grid regeneration ~ 100 MWh
  - Bus charging > 100 MWh
  - Storage utilisation (charging/discharging time) > 1,500 h
- Relevant amortisation paths are available and robust, provided the local and operational parameters deliver a positive result.
- The legal risks have been significantly reduced thanks to in-depth coordination with many organisations. However, formal pre-qualification for the control reserve market and certification in accordance with VDE 4110 appear to be difficult to achieve due to the DC based architecture.



The GUW+ represents an integrative transport concept that can bring advantages in operation and make the transition from diesel to electric buses more economical.

www.guwplus.de

ENERGY&CO_2 Sector

2024

INTERNATIONAL UNION OF RAILWAYS

Thank you for your attention

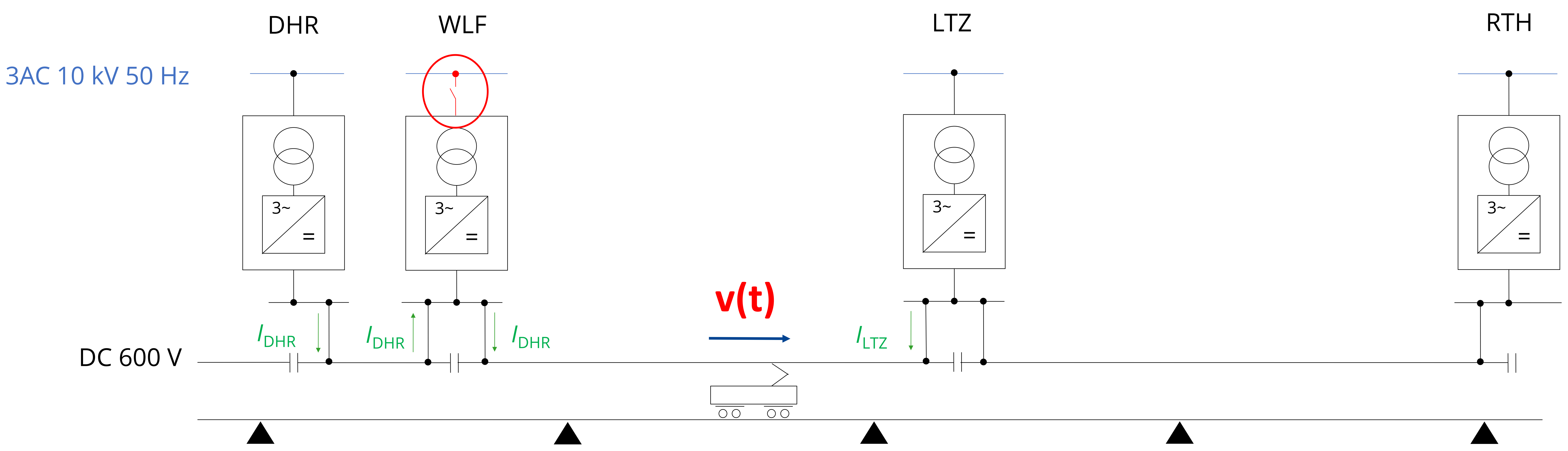
Dr. Carsten Söffker

Alstom

Back-Up

Validation planning for operating modes in field trials, example

Operating mode: Voltage regulation, Operating mode: Voltage **boost**



- Acceptance criterion:
  - Vehicle can travel on the section, possibly with power restrictions (voltage at pantograph greater than 400V)
  - DHR remains within the permissible limits at the grid connection point
- Driver required and person in the control room to set the required test environment
- Carried out during a break in operation in order to find defined boundary conditions

Interaction of functions
Voltage boost for N-1 supply

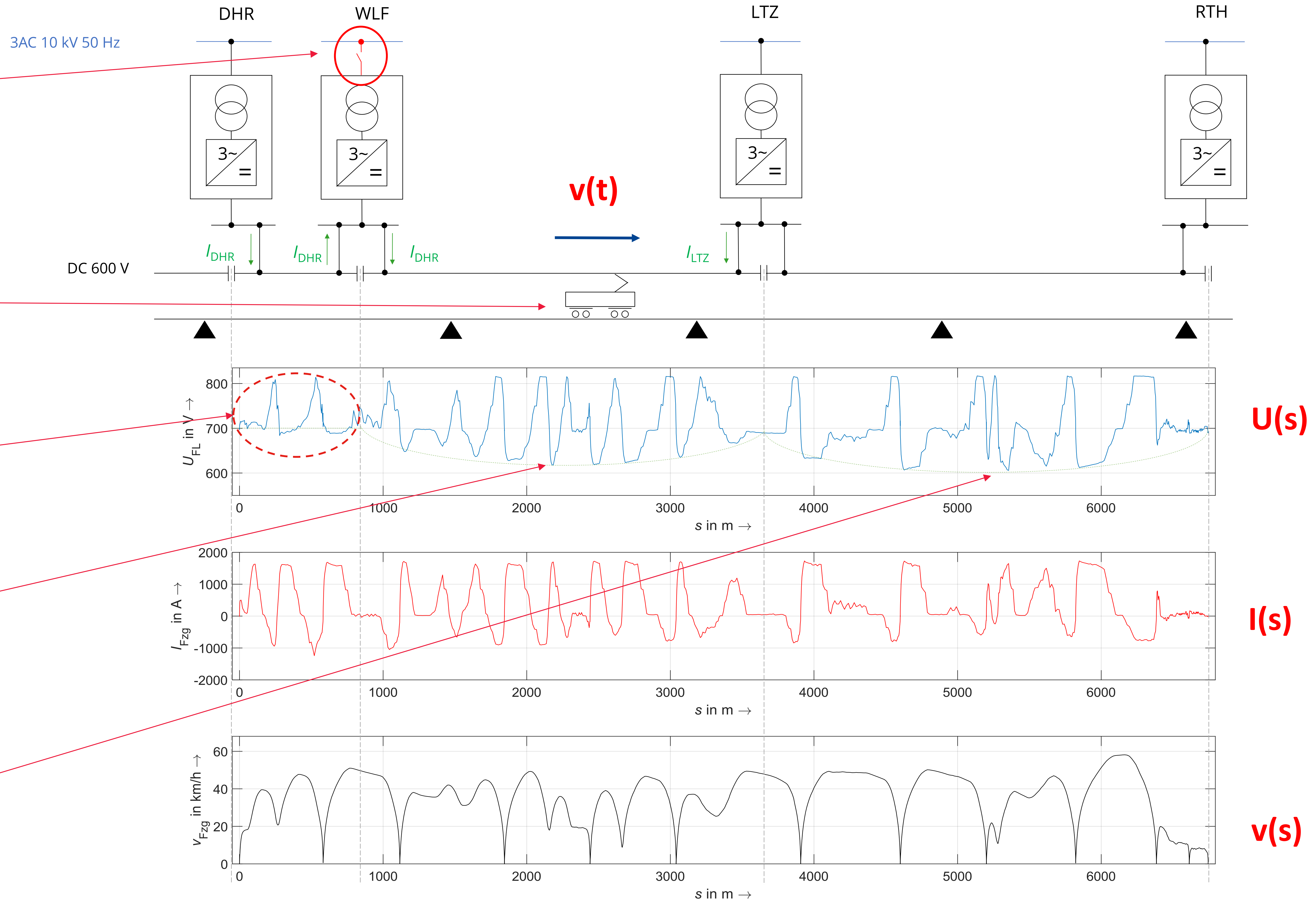
Test scenario: activation of the neighbouring Wülfel substation "WLF" (revision, failure)

Scheduled journey of a light rail triple traction over the entire route section

HESOP voltage boost (up to 750 V) compensates for the voltage drop across the track

The minimum voltage at the pantograph is well above 600V in the critical section!

Voltage maintenance in the section fed by rectifiers is worse …



Functions in interaction
Special battery functions

Brake energy recuperation

- Target:
  - The most complete possible intermediate storage of excess braking energy without negatively influencing the energy exchange between braking and accelerating paths
- Thesis:
  - An energy storage system can increase energy efficiency even if the grid is very well developed (overall storage efficiency greater than the average transmission efficiency). Work is being carried out on quantification by means of comparative energy storage utilisation with simultaneous observation of vehicles in the relevant supply area over a sufficiently long period of time.
- (selected) Mode of operation of the stationary energy storage system integrated in the GUW:
  - Energy storage: Specification of target battery power depending on the busbar voltage.
  - Energy storage: Specification of target battery power depending on the total power in the line fields.
  - Storage intervention only in part of the operating range and with a limited output of 500 kW. Any excess braking energy with a higher output can be fed back into the MV grid using HESOP.

Functions in interaction
Special battery functions

Peak load capping

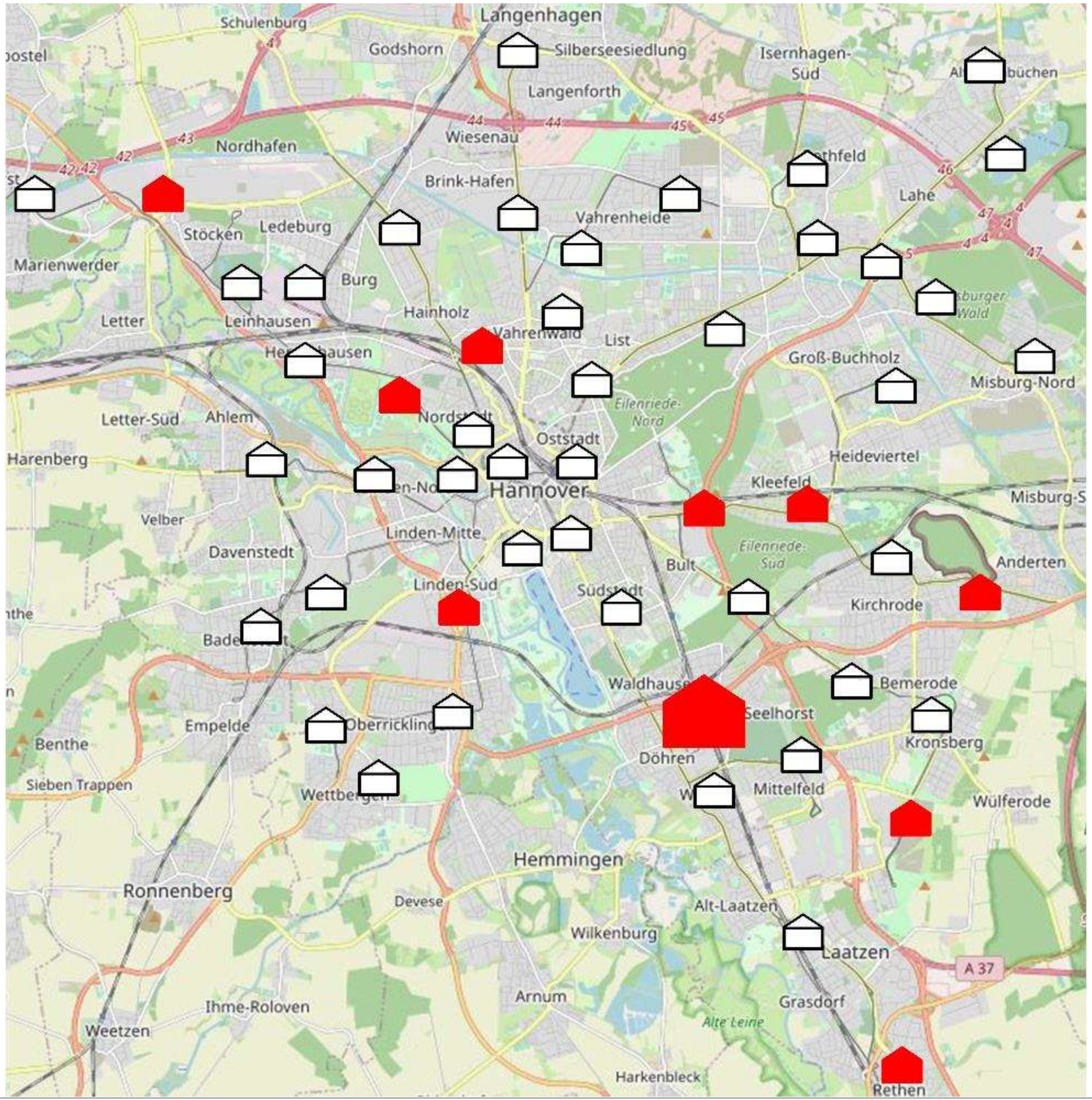
- The grid charge always comprises the components of the energy price (AP) for energy procurement and the power price (LP) for the provision of the requested power at the grid connection point (NAP). Operation of the light rail network means continuously high energy demand and therefore an interest in a low energy price (AP).
- Pooling the billing of several NAPs results in a change to annual usage duration >= 2500 h (ratio of annual energy quantity to annual peak load) due to the resulting passive peak load capping, tariff model characterised by low AP with high LP compared to annual usage duration < 2500 h.
  - Legal requirement Pooling: internal electrical connection of the NAP (here overhead line or conductor rail)
- Example: E-bus charging station(s) with a local connection to a GUW can be integrated into the (existing) pool.
  - Cost advantage through passive peak load capping, with a very high probability that the annual peak load of the pool will not fall in the same quarter of an hour of the year as the annual peak load of the individual consumer (here e-bus charging station(s))
- Targeted load peak capping as a further (cost) optimisation refers to influencing the level of the annual load peak that determines the LP (maximum average power value (15-minute interval) of the current year), for example by shifting charging times for the electric bus, intervening with vehicle heating, using energy storage...
- Prerequisite: performance of the pool can be predicted with sufficient accuracy and lead time

3rd motivator: 2nd-life for bus batteries

Stationary storage in the GUW

Peak load capping in 3 steps

- Step 1: Pooling of the individual NVP (GUW) leads to a levelling of the load profile of the light rail operation (passive load peak capping, "lived practice")
- Step 2: Integration of e-bus charging points into the existing pool (extended passive peak load capping)
- Step 3: Active peak load capping
  - Basis 1: Sufficiently accurate forecast of the load profile with sufficient lead time to prepare measures, implementation using an AI algorithm.
  - Basis 2: Real-time determination of the load profile for targeted load peak capping during operation, implementation by means of power measurement of selected NVP in the grid and extrapolation.



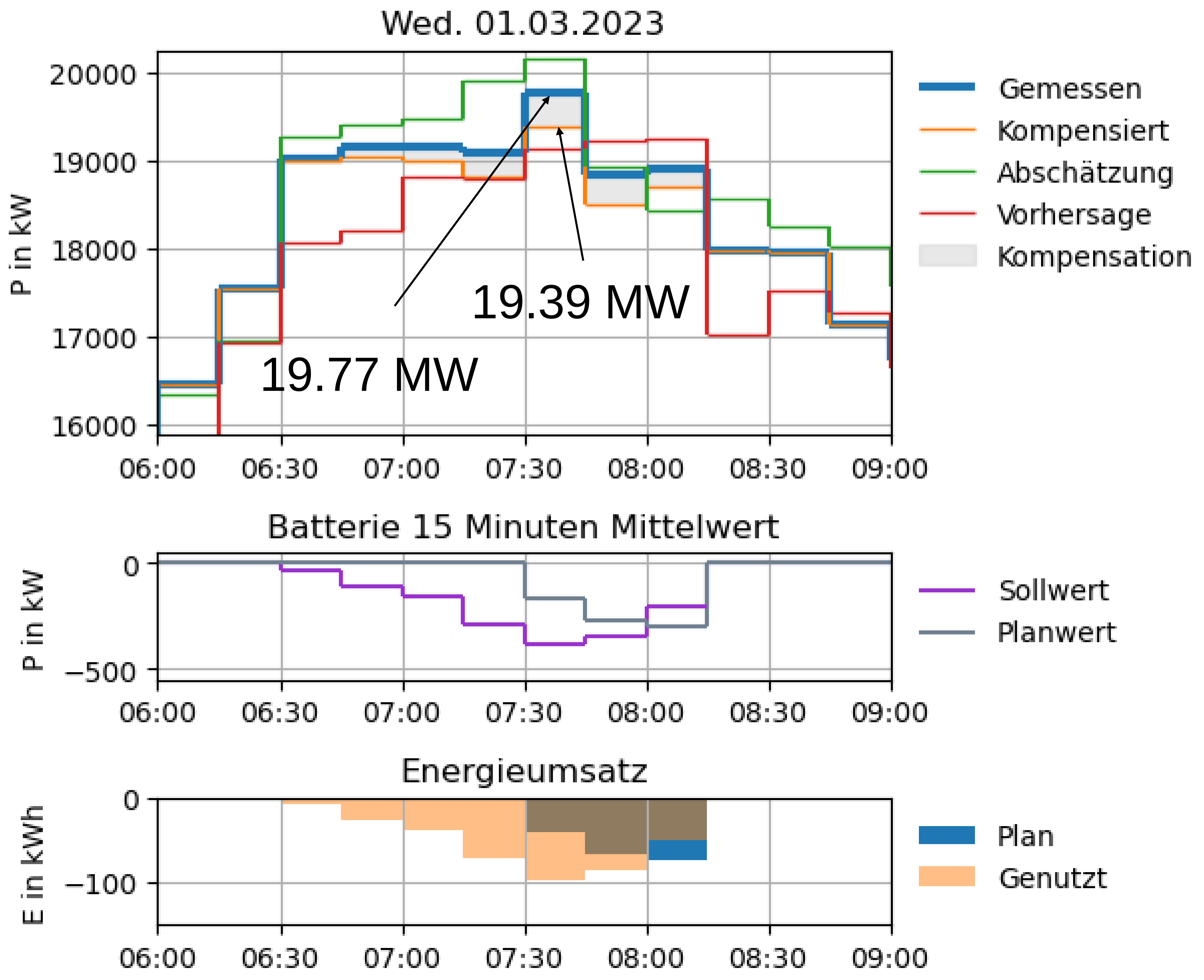
3rd motivator: 2nd-life for bus batteries

Stationary storage in the GUW

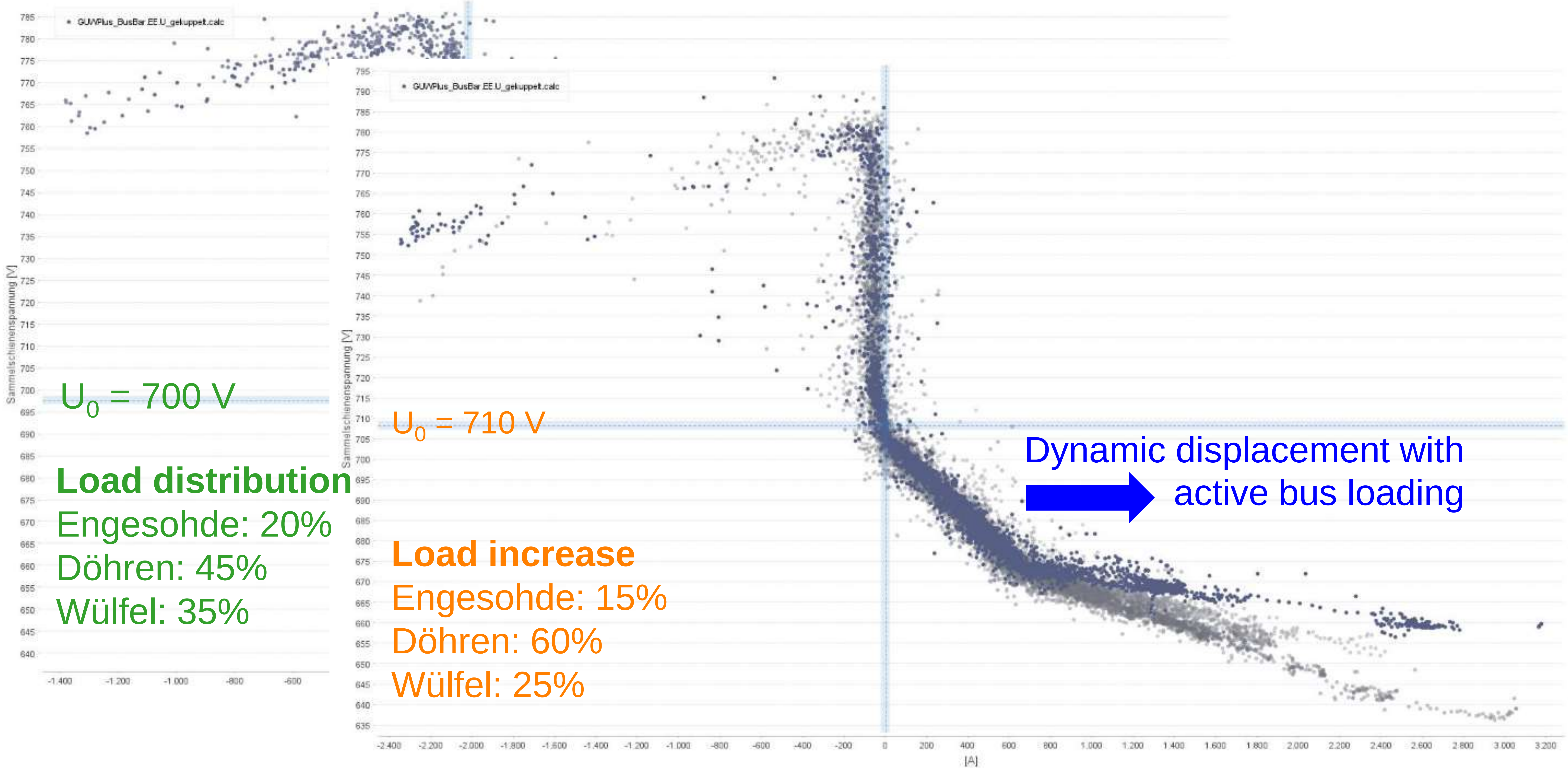
Active peak load capping

- Increasing load surges from 1 January 2023 and the annual load peak occurring on 1 March 2023 were forecast accordingly.
- If the energy storage system had been available earlier (500 kWh), a peak load reduction of around 380 kW could have been achieved.
- Validation in real operation will take place from 11/2023 until spring 2024.

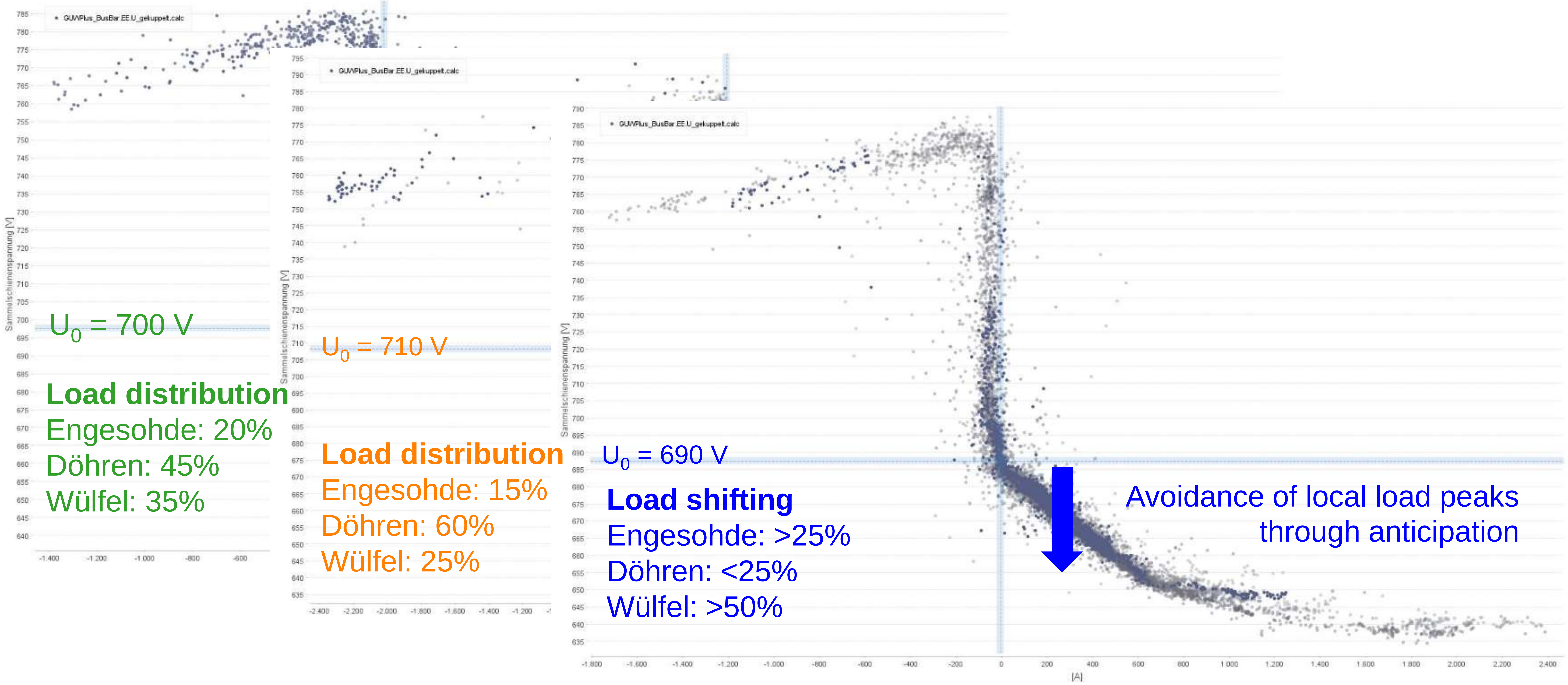
380 kW · 101 €/(kW*a) ~ 38,000 €/a



Interaction of functions
Load increase by means of HESOP voltage regulation



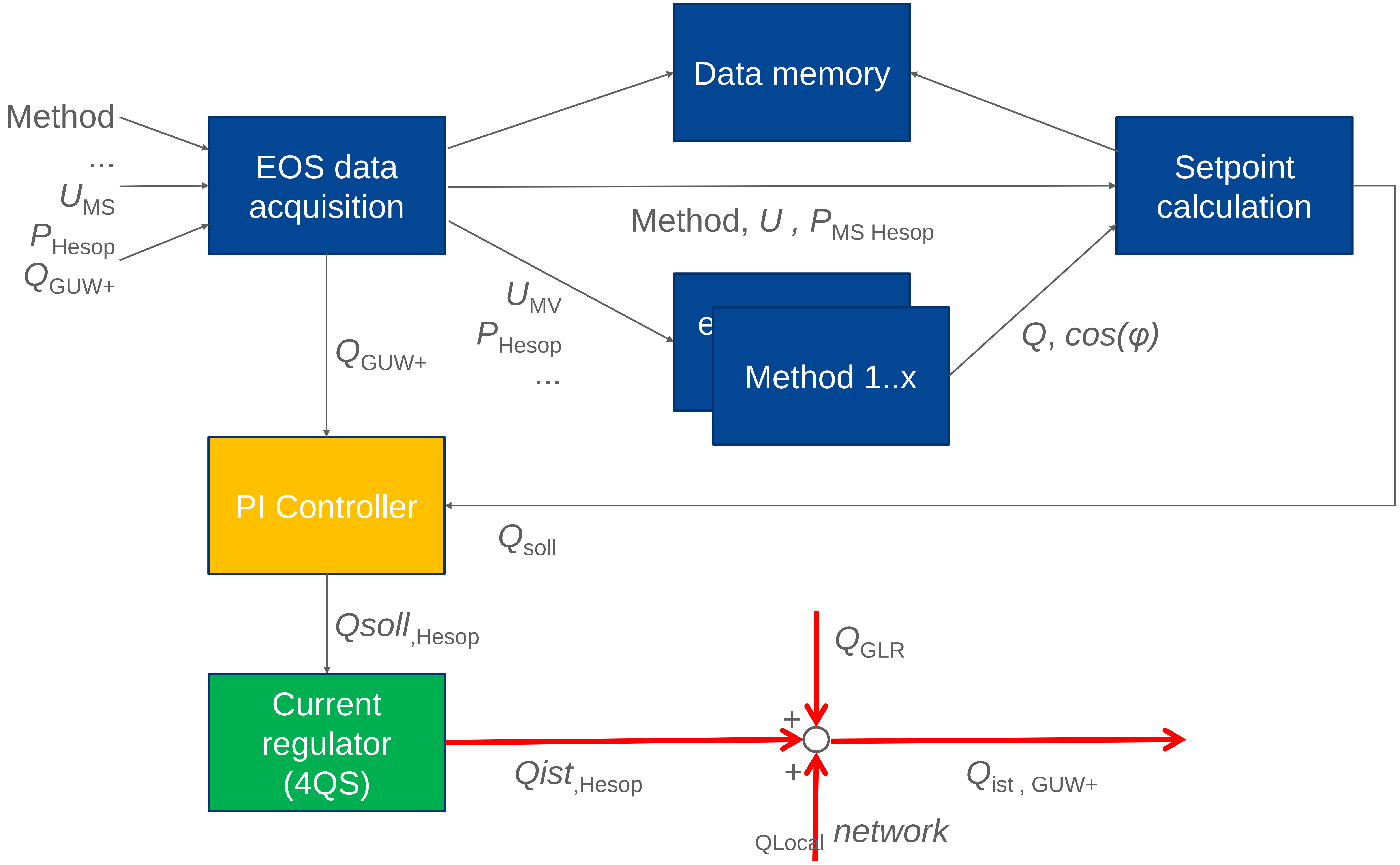
Interaction of functions
Utilisation of the HESOP voltage regulation



Interaction of functions
Reactive power at the grid connection point

Structure of the control

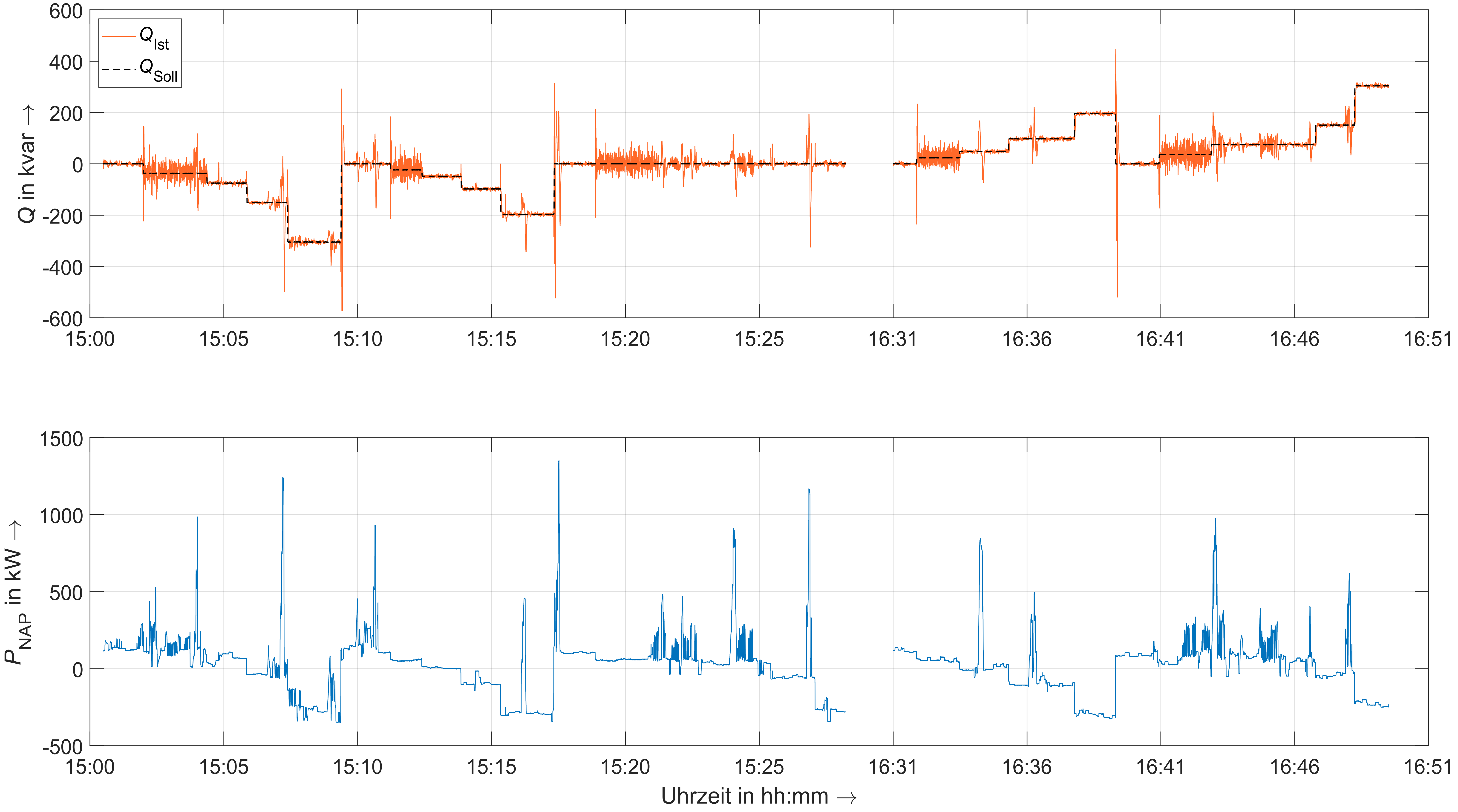
- Provision of reactive power according to the specific specifications of the distribution grid operator or in accordance with the new VDE 4110 directive (which provides for four different methods)
- HESOP can control the amount and phase of the mains current separately so that ±500 kvar can be requested (independent of the active power).
- Thanks to the closed control loop with PI controller, even the reactive power requirements of the rectifier and local power transformer are also regulated.



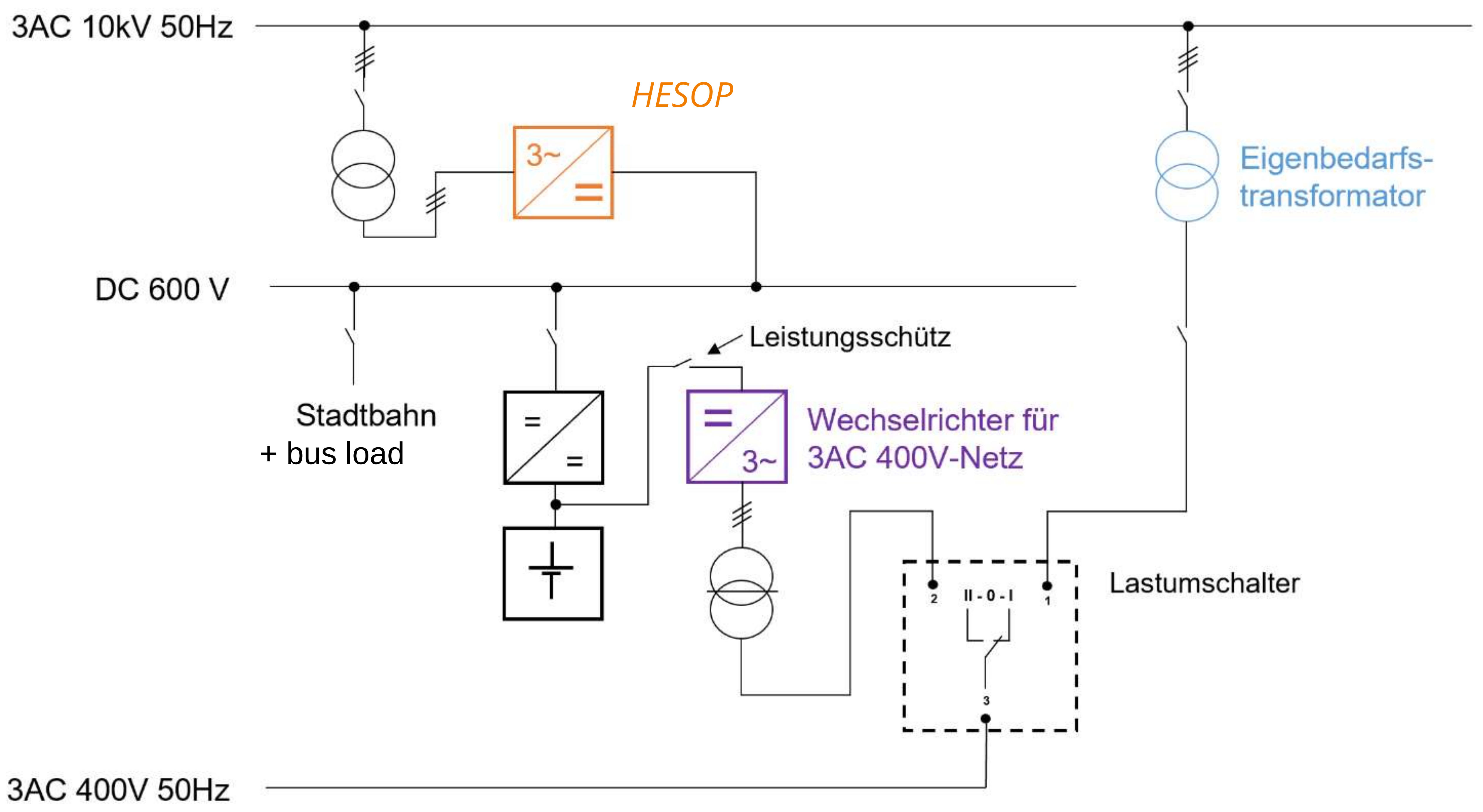
Functions in interaction

"Electricity trading" - here: Withdrawal into the distribution grid (feed-in)

- According to VDE 4110, the grid operator can specify various methods for grid support - here: constant power factor.
- Set parameters for test:
  - *cos(□)* = [0.8_{kap} ; 0.9_{kap} ; 1.0 ; 0.9_{ind} ; 0.8 $]_{ind}$
  - P_{ES} = [0; 50; 100; 200; 400] kW
- The setpoint calculation is correct and precise.
- The actual values are precisely controlled in a stationary state; in the event of transients at the NAP or low feed-in active power (50 kW), larger fluctuations occur.



Interaction of functions
Dealing with supply interruptions - General preliminary considerations



Realisation 1:
In the event of a blackout and thus the need to keep the light rail system running for a short time from the storage system, the low-voltage level must also be supplied so that cooling and other essential substation functions can be ensured.
An additional blackout inverter is required, which generates 230/400 V from the energy storage system.

Realisation 2:
In order to minimise the power requirement at the low-voltage level, a distinction must be made between relevant and non-relevant loads for blackout operation.
A simple load-break switch is provided, which only continues to supply relevant loads.

Workshop timeline

10:00	Welcome Introduction	UIC/Chairs
10:10	GUW+: Smart substation	Alstom
10:30	SmartCharging4Trains - Linking Battery Trains & EV Charging	Siemens
10:50	Using the Flexibility of Traction Batteries for the Railway Grid	SBB
11:10	Charging E-machines and trucks (railway excavators) at substation Vught	ProRail
11:30	Charging electric vehicles	TucRail
11:50	Questions / discussion Closing remarks	All

INTERNATIONAL UNION
OF RAILWAYS

Siemens

Dr. Thorsten Frenzke

Development engineer for drive and energy storage systems in the railway and hybrid bus sector
Senior Engineer in Rolling Stock Engineering

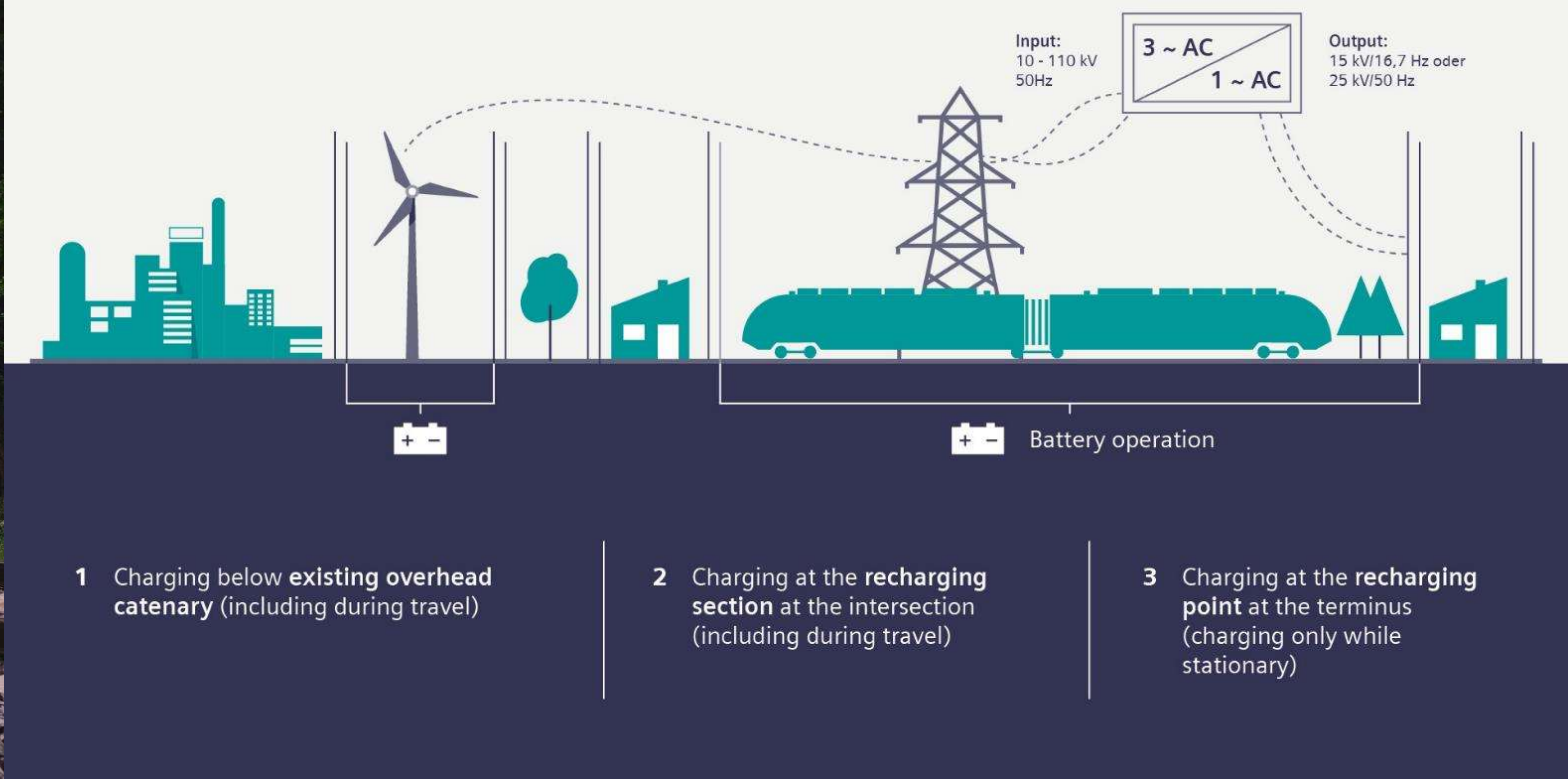
SmartCharging4Trains
Linking Battery Trains & EV Charging

Dr. Thorsten Frenzke & Dr. Sebastian Probst, Siemens Mobility

UIC Webinar Electric Vehicles (EV) charging & Rail power grid, 2024-11-22

SIEMENS

Battery trains are game changers



The use of battery vehicles

- creates completely new requirements for the energy supply of the vehicles
- offers new opportunities and possibilities

SIEMENS

Status @ Siemens – Smart charging

Driver Advisory System for battery / hydrogen trains

Smart charging already starts on board the vehicle during the train run!

- Driving Advices [1]
  → best possible use of battery's energy content
- Range prognosis [2]
  → Informs the driver if he can reach the next recharging point / electrified section
- Mission management [3]

Deep integration with train and charging control systems

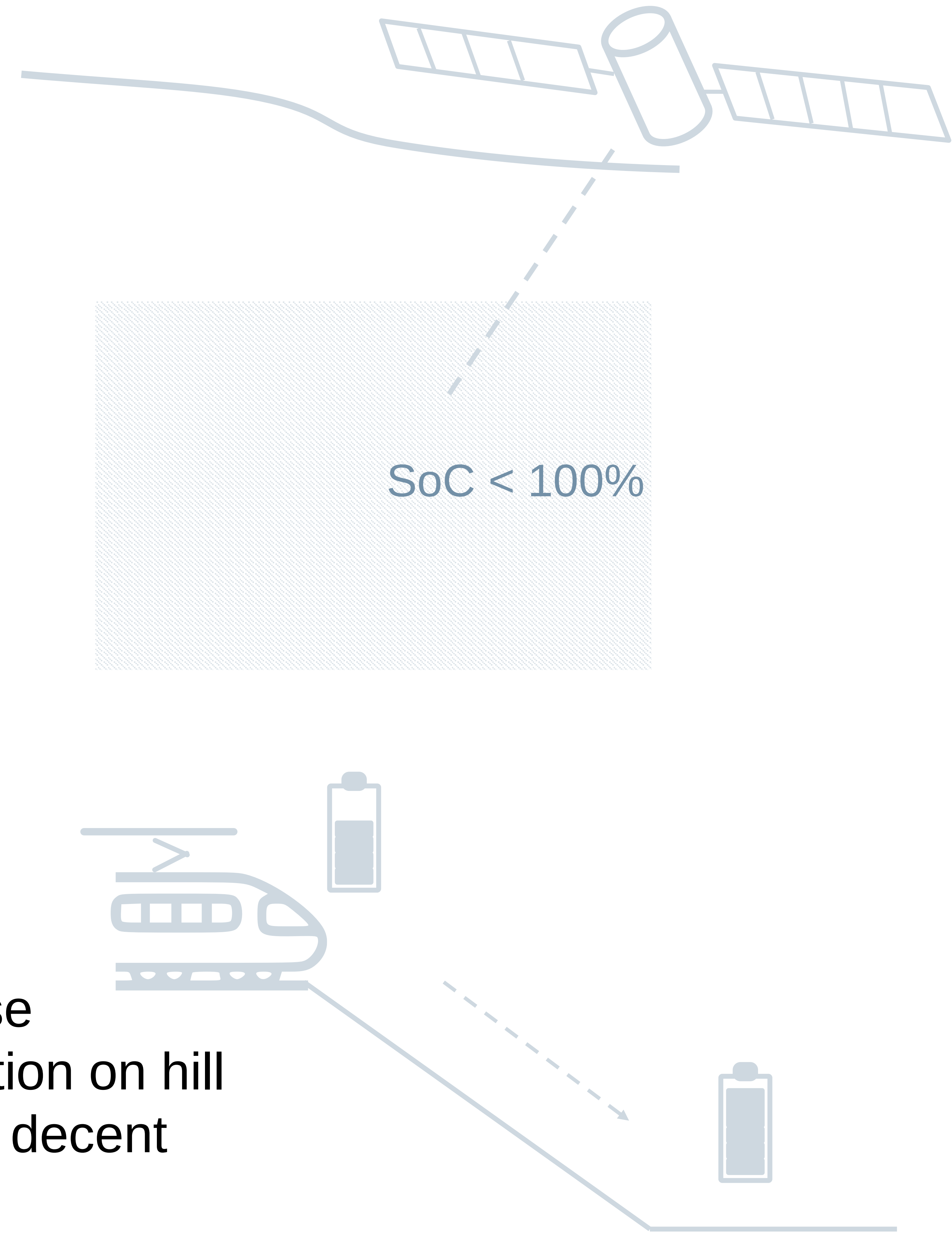
SIEMENS

Status @ Siemens – Smart charging

Smart charging

- Necessary State of Charge (SoC)?
- Charging power?
- Duration of recharging?

➢ Mission management [3] for optimized charging

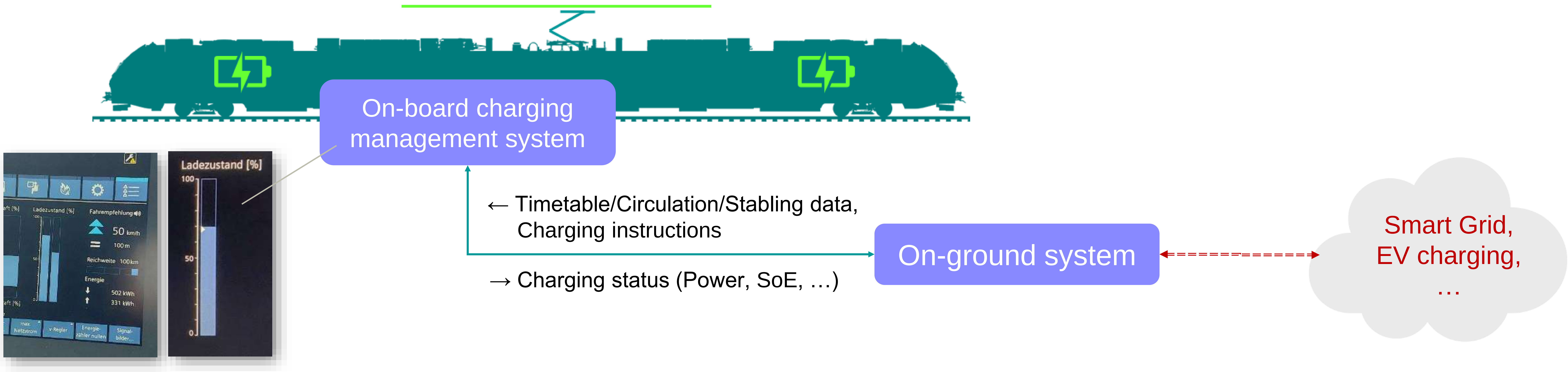


Example Use Case
- recharging station on hill
- Non-electrified decent
- Charge less

SIEMENS

Status @ Siemens – Smart charging

System overview

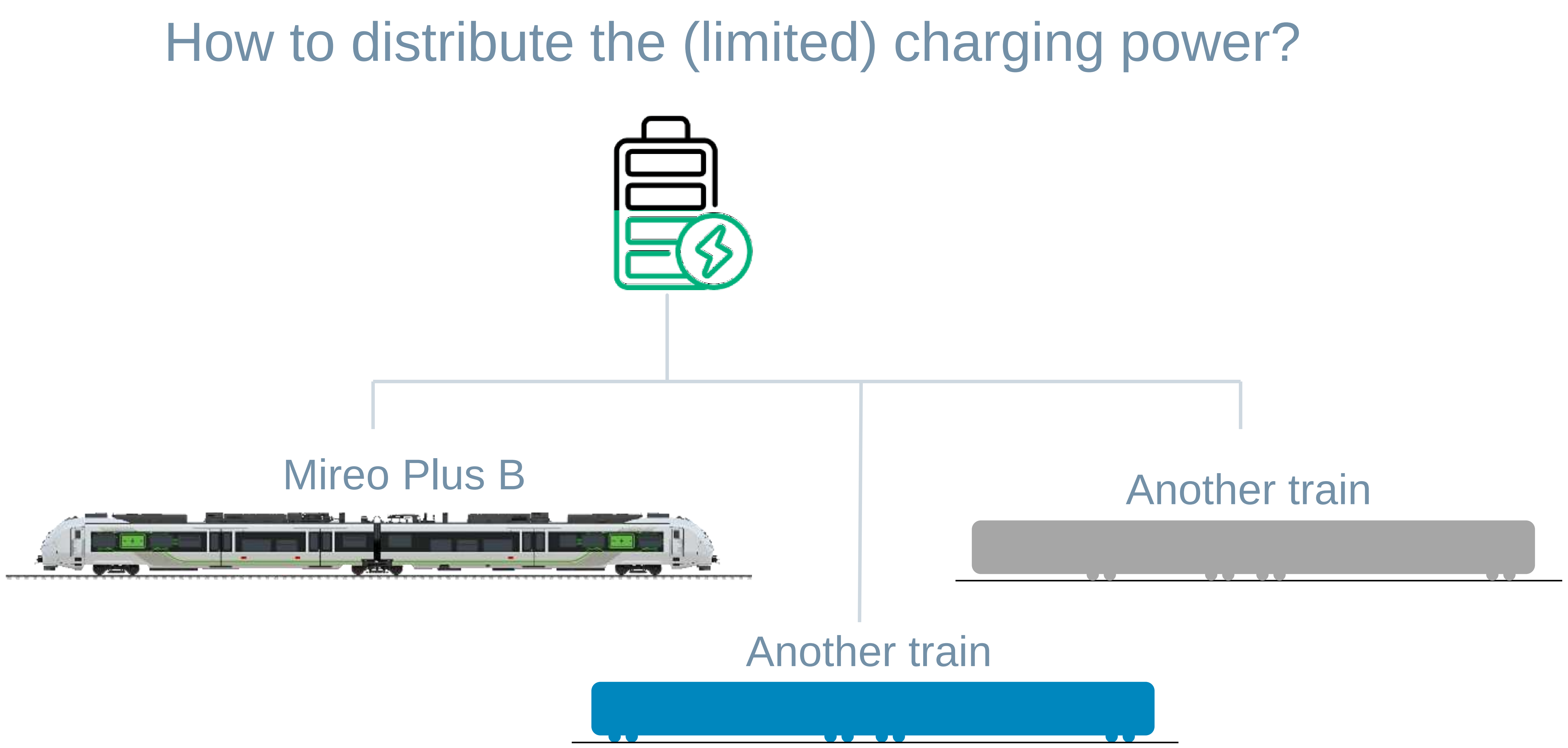


- DAS including smart charging on board (see pages 3,4) enables energy saving driving and automated and optimized recharging
- For DAS and charging, data exchange with a central on-ground system is necessary anyway
- The on-ground system enables an interface to a smart grid or EVs (in principle)

Challenges at charging stations - Problem statement

Limited charging power

- Charging point in remote locations
- Manage nightly stabling,
  timely train preparation
- Multiple trains,
  possibly different vehicle types



Challenges

- Ensure availability
- Trains must be sufficiently charged and prepared at departure

Opportunities

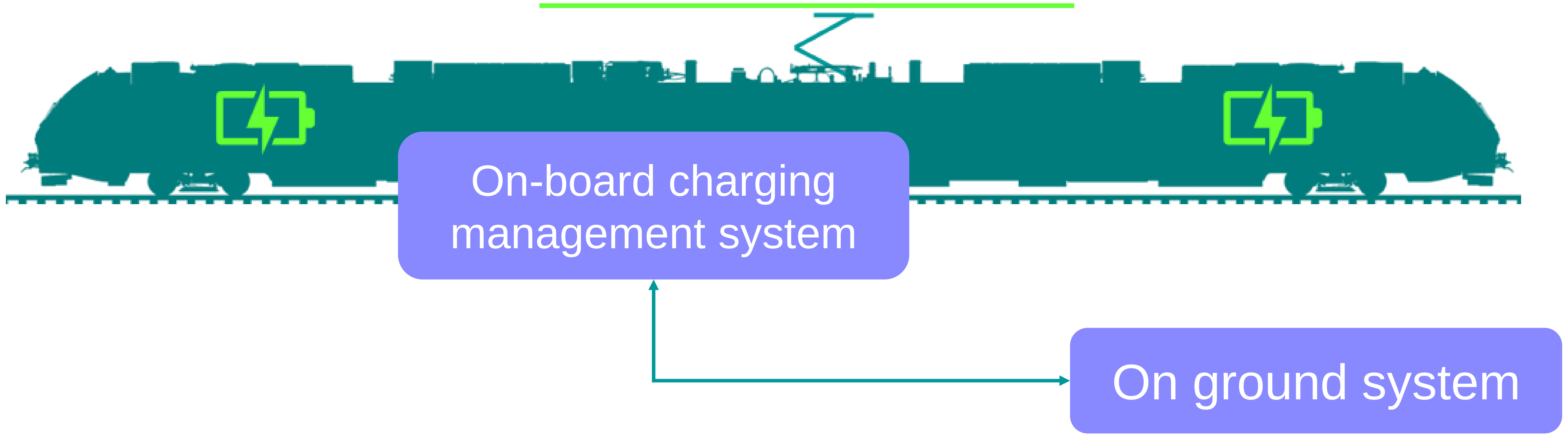
- Peak reduction
- Slow recharging (energy savings, increased battery lifetime)

SIEMENS

Trains at charging stations with power limits - Scenarios

(A) One train at charging station

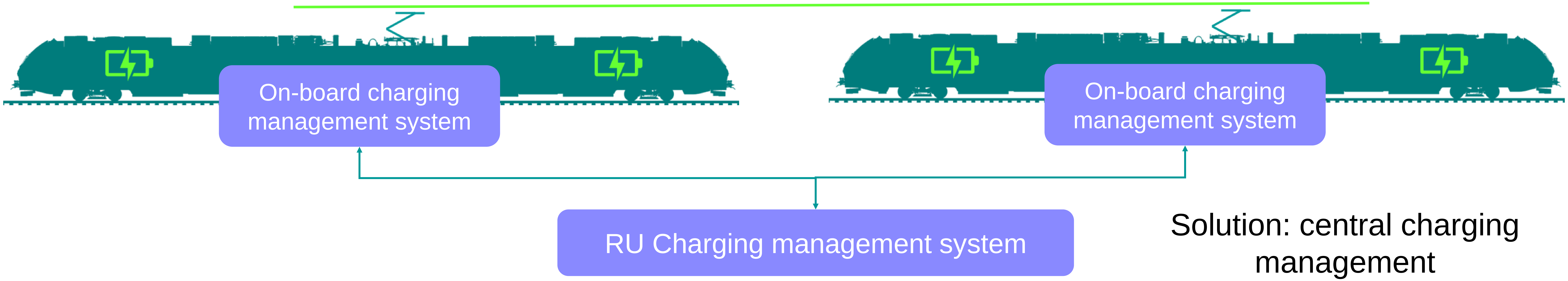
⇒ Difficult to manage manually



Solution: DAS incl. smart charging (see page 5)

(B) Two trains of the same Railway Undertaking

⇒ Automated solution required

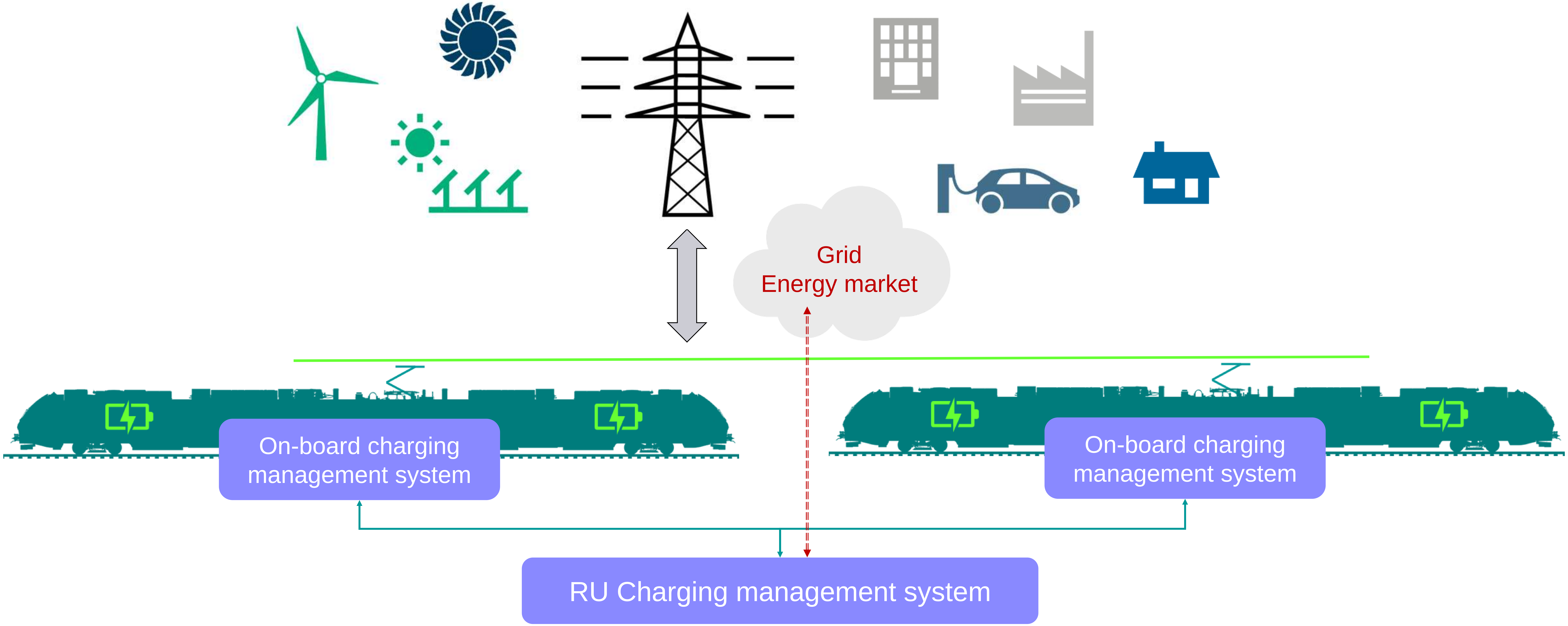


Solution: central charging management

SIEMENS

Trains at charging stations with power limits - Scenarios

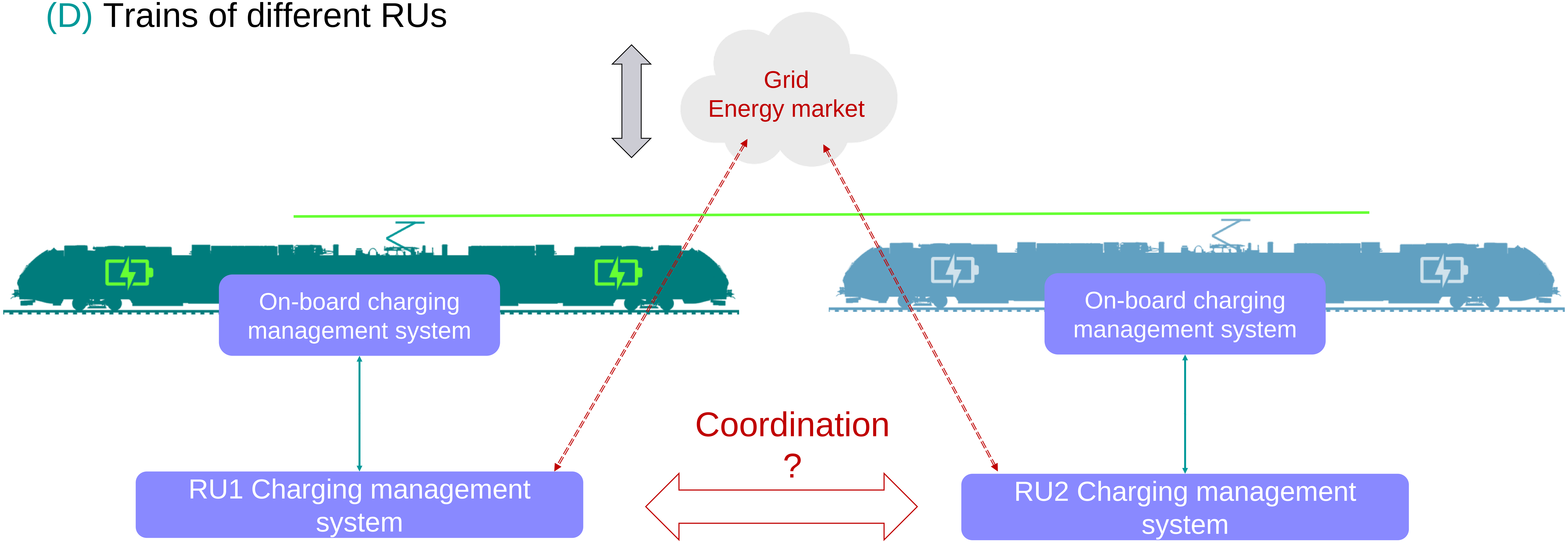
(C) Several trains of the same RU and variable power limits



SIEMENS

Trains at charging stations with power limits - Scenarios

(D) Trains of different RUs



Standard interfaces are necessary!

High-level Architecture proposal (simplified)

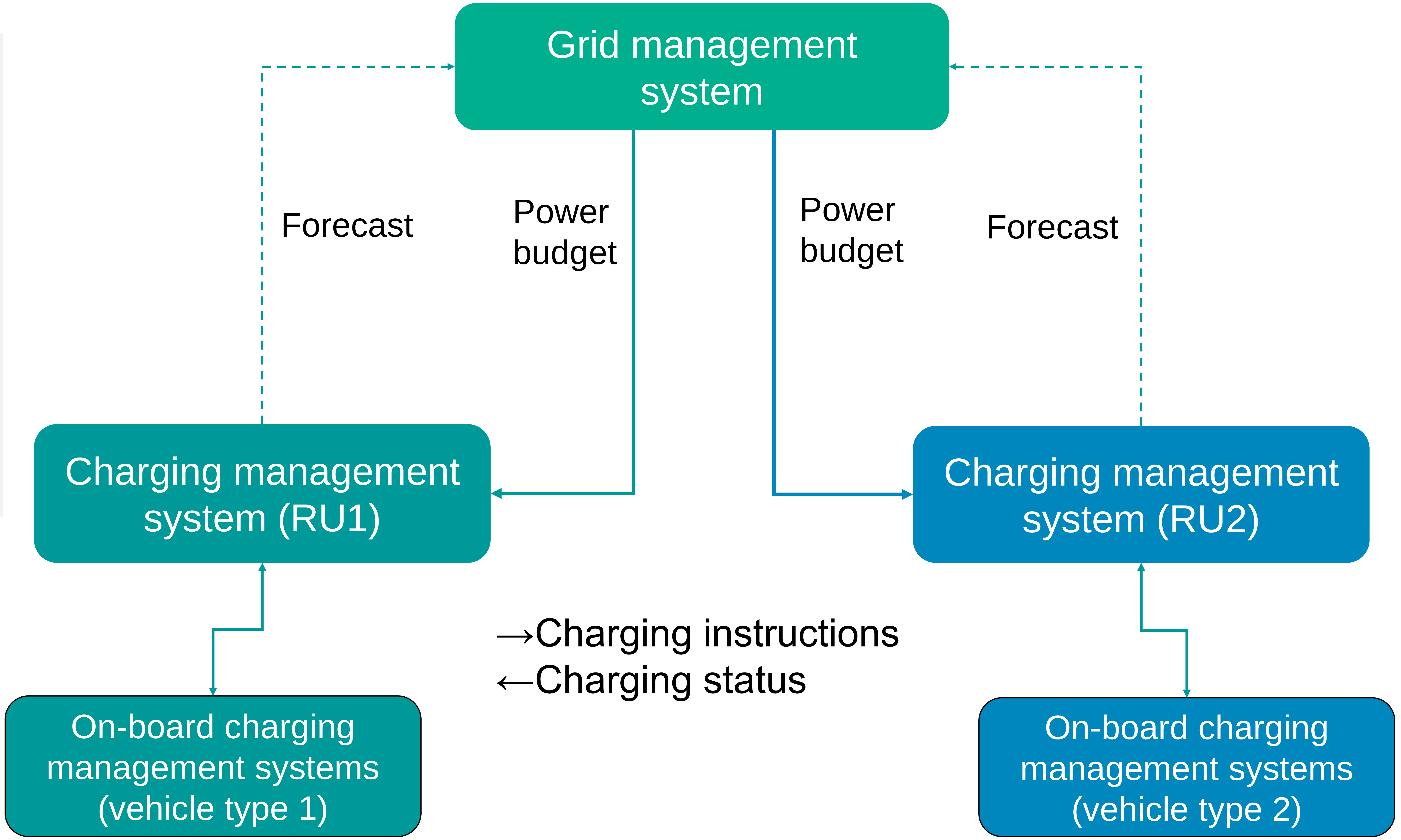
- ✓ Handle multiple RUs
- ✓ Interface to energy gid
- ✓ RU can optimize charging within its fleet

Central management system
Energy supplier
Charging station operators

↕ Need for standard interface

Wayside
Railway undertakings (RU)

Fleet
Railway undertakings



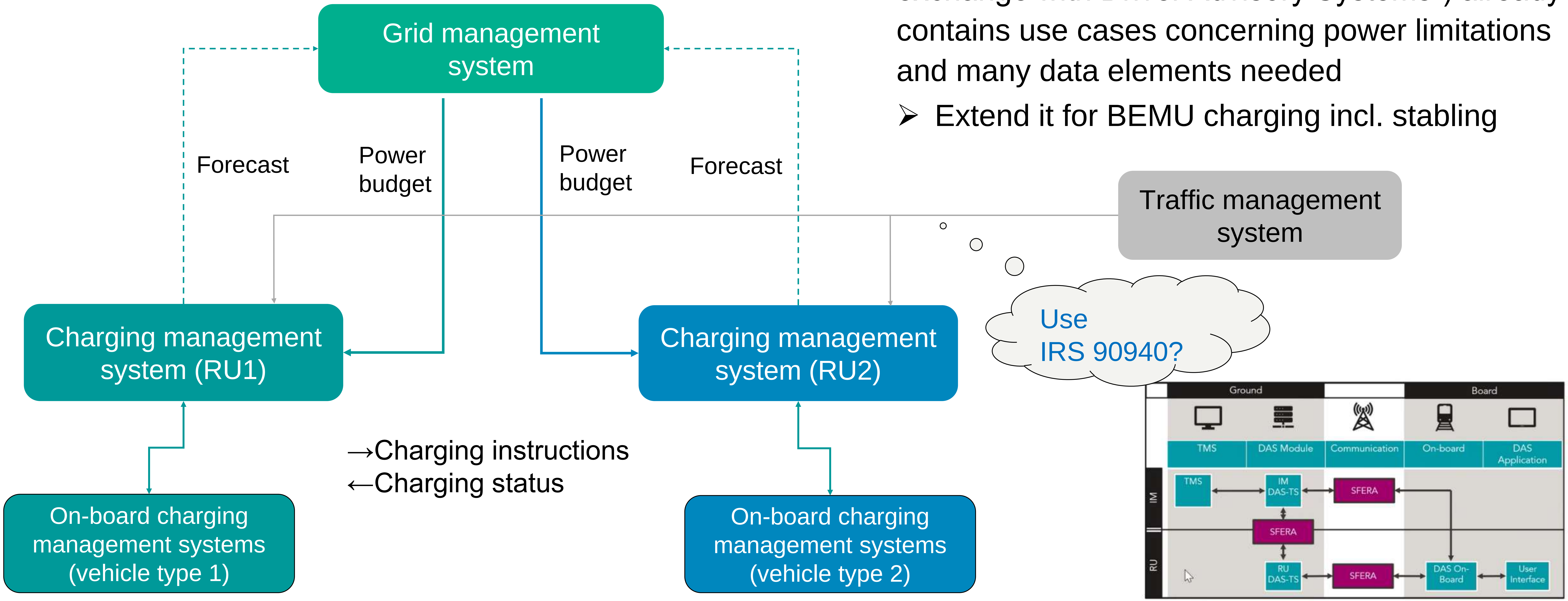
SIEMENS

High-level Architecture

Smart charging and "SFERA"

The SFERA standard **UIC IRS 90940** ("Data exchange with Driver Advisory Systems") already contains use cases concerning power limitations and many data elements needed

- ➢ Extend it for BEMU charging incl. stabling



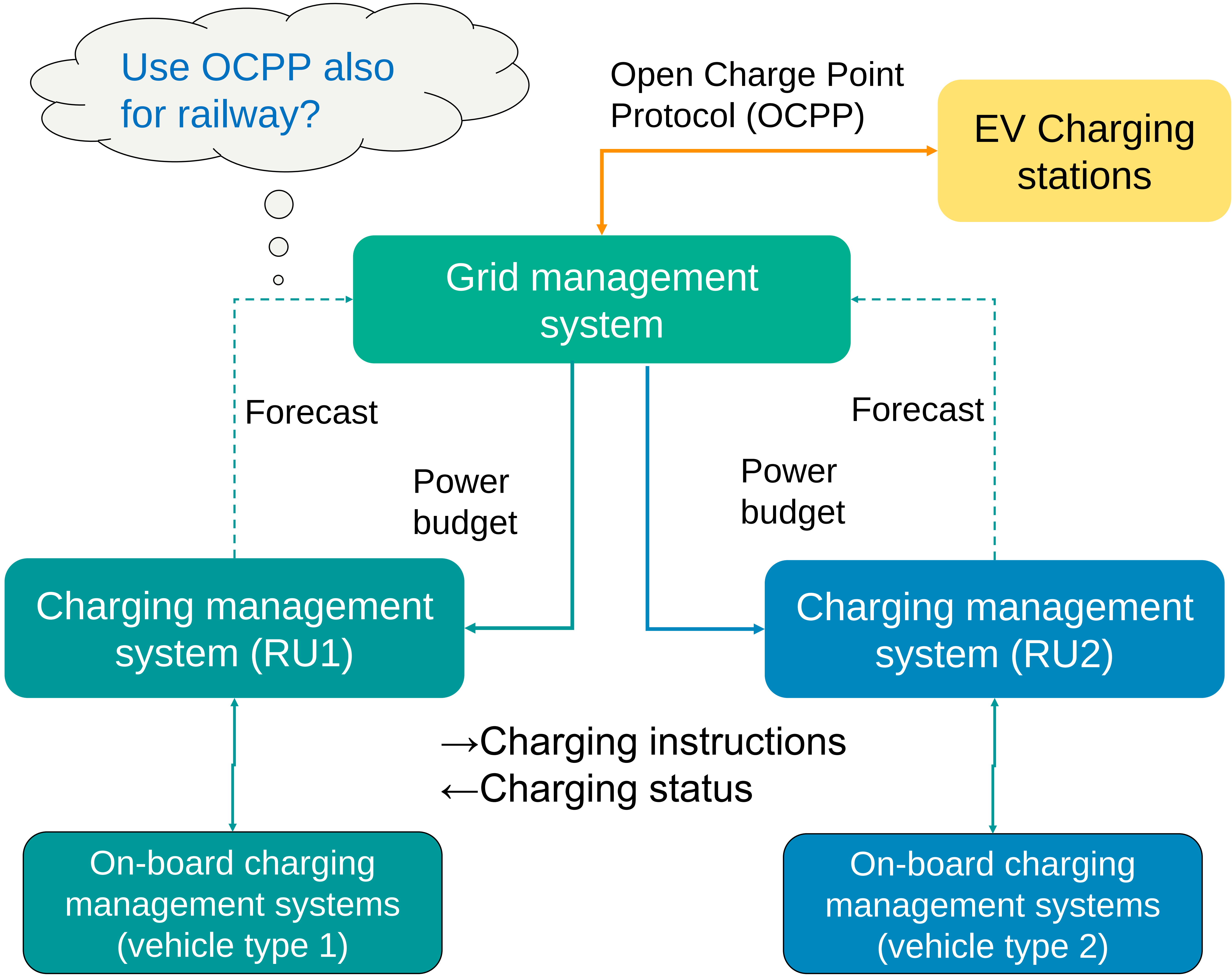
Battery trains & EV Charging

Linking battery trains with EV?

- EVs and battery-powered trains behave similarly from a grid perspective
- Benefit: Do they exchange a lot of energy?

However

- It makes sense to integrate both into a Smart Grid, e.g. to compensate for fluctuating energy generation from renewable energies
- This requires uniform, interoperable interfaces
  - already within the rail sector
  - within a Smart Grid to EVs



Contact

Dr. Thorsten Frenzke & Dr. Sebastian Probst

Siemens Mobility GmbH
SMO RS EEC EN PT SD

Siemenspromenade 4
91058 Erlangen, Germany
thorsten.frenzke@siemens.com
siemens.com/mobility

SIEMENS

Workshop timeline

10:00	Welcome Introduction	UIC/Chairs
10:10	GUW+: Smart substation	Alstom
10:30	SmartCharging4Trains - Linking Battery Trains & EV Charging	Siemens
10:50	Using the Flexibility of Traction Batteries for the Railway Grid	SBB
11:10	Charging E-machines and trucks (railway excavators) at substation Vught	ProRail
11:30	Charging electric vehicles	TucRail
11:50	Questions / discussion Closing remarks	All

INTERNATIONAL UNION
OF RAILWAYS

SBB CFF FFS

Markus Halder

Programme Manager, Load Management

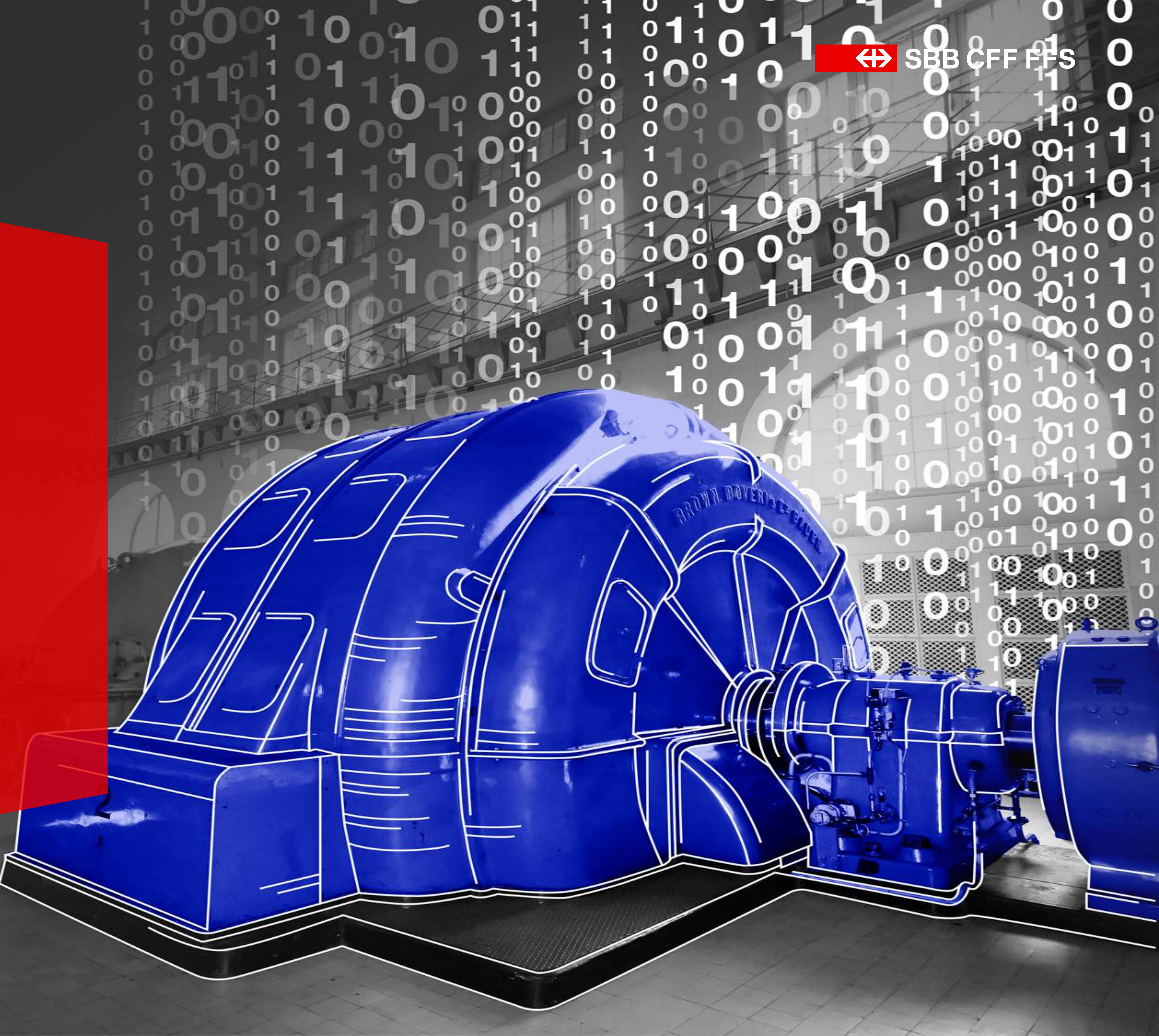
Energy infrastructure

SBB CFF FFS

Using the Flexibility of Traction Batteries for the Railway Grid.

Markus Halder, SBB Energy

UIC webinar, 22nd of November 2024

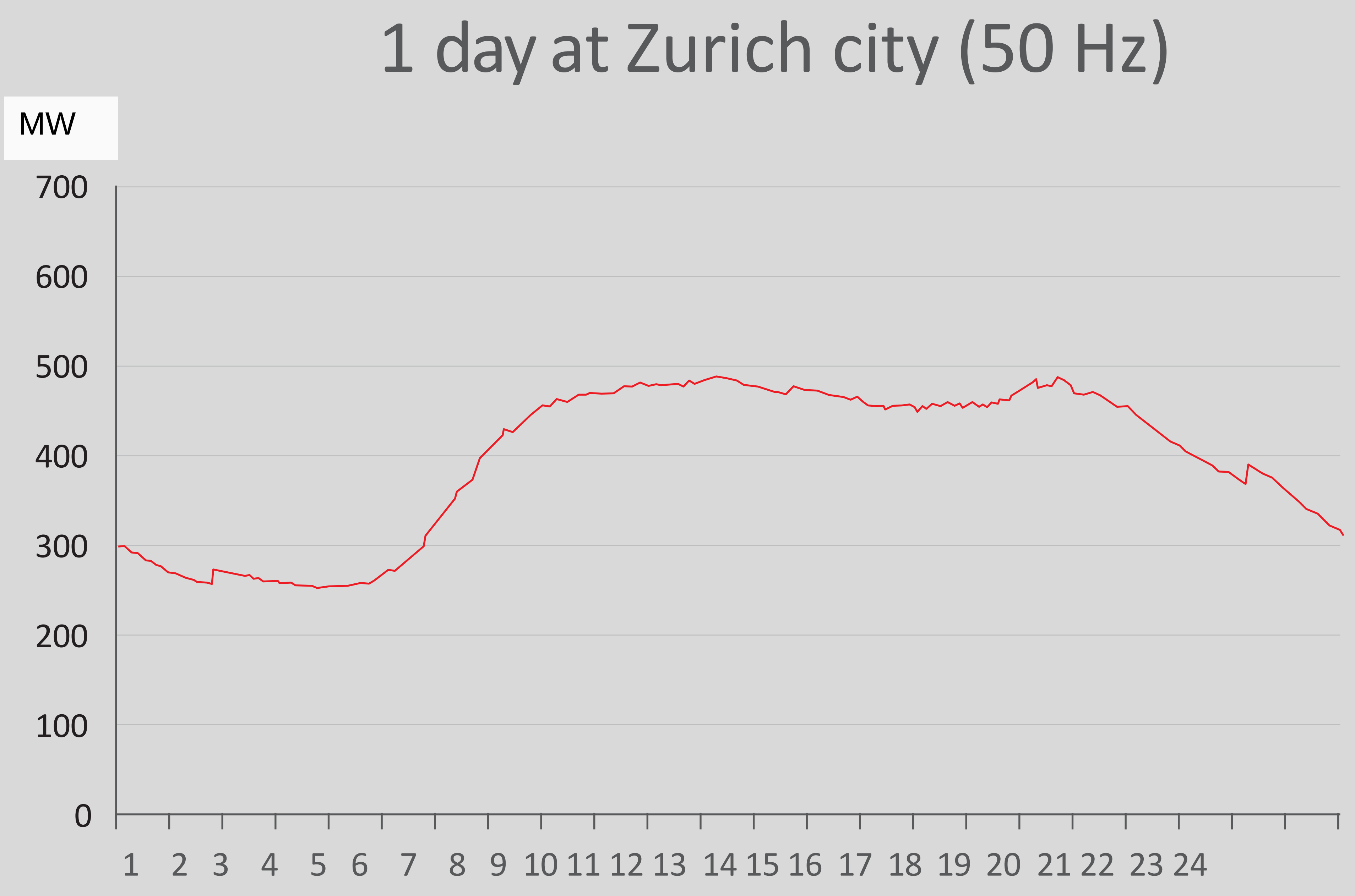


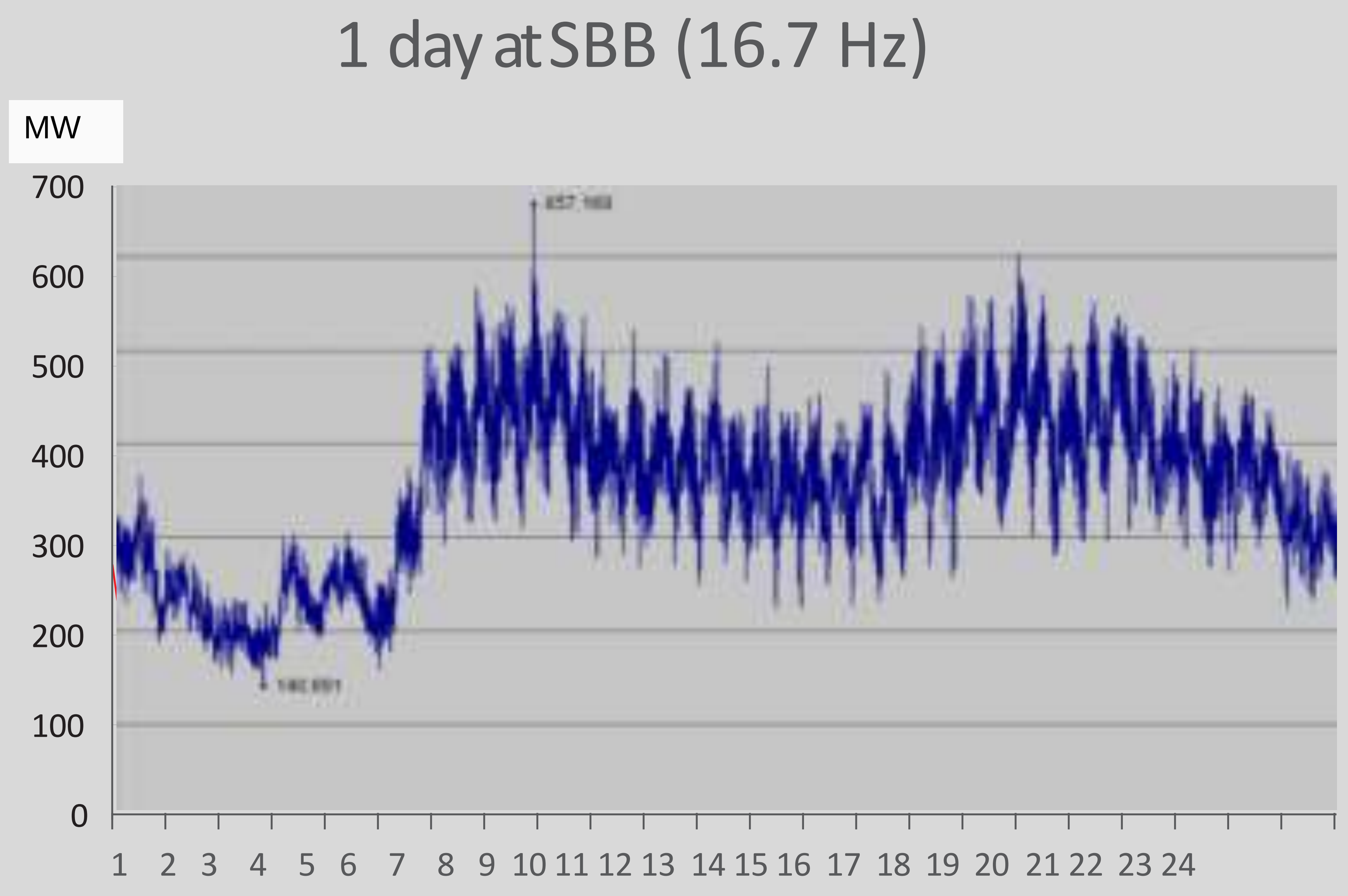
Agenda

1. SBB’s power demand management program
2. Batteries as flexibility
3. Battery friendly charging
4. BIENE battery manager

01
SBB‘s power demand management program

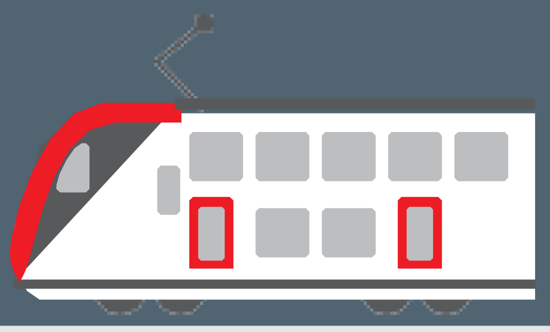
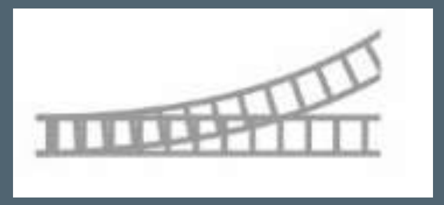
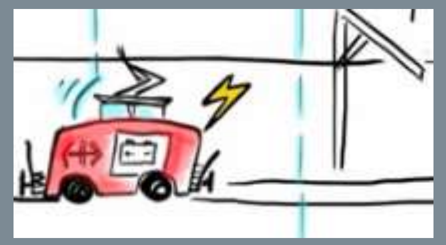
Traction current network (16.7 Hz).
Dynamic power profile is challenging and expensive.





Power demand management program.
Smart influencing of consumption demand.

Power demand management – Smart Grid @SBB

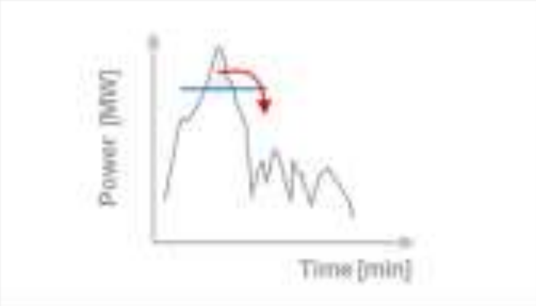
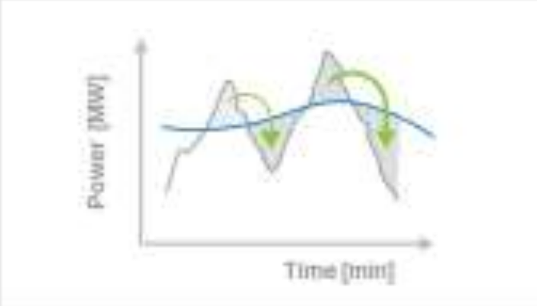
Car heaters	Point heaters	Traction	Batteries
Brief shutdowns at peak loads without loss of comfort.	Brief shutdowns at peak loads and predictive control.	Power reduction in overload situations via train drivers, in future automated.	Charging management for electrified diesel locomotives.
			

Stage 1: Peak shaving of thermic consumers

Stage 2: Integrating further distributed energy sources

Software System LMLS (Power demand management platform)

Power Demand Management Program: 2030 target vision.

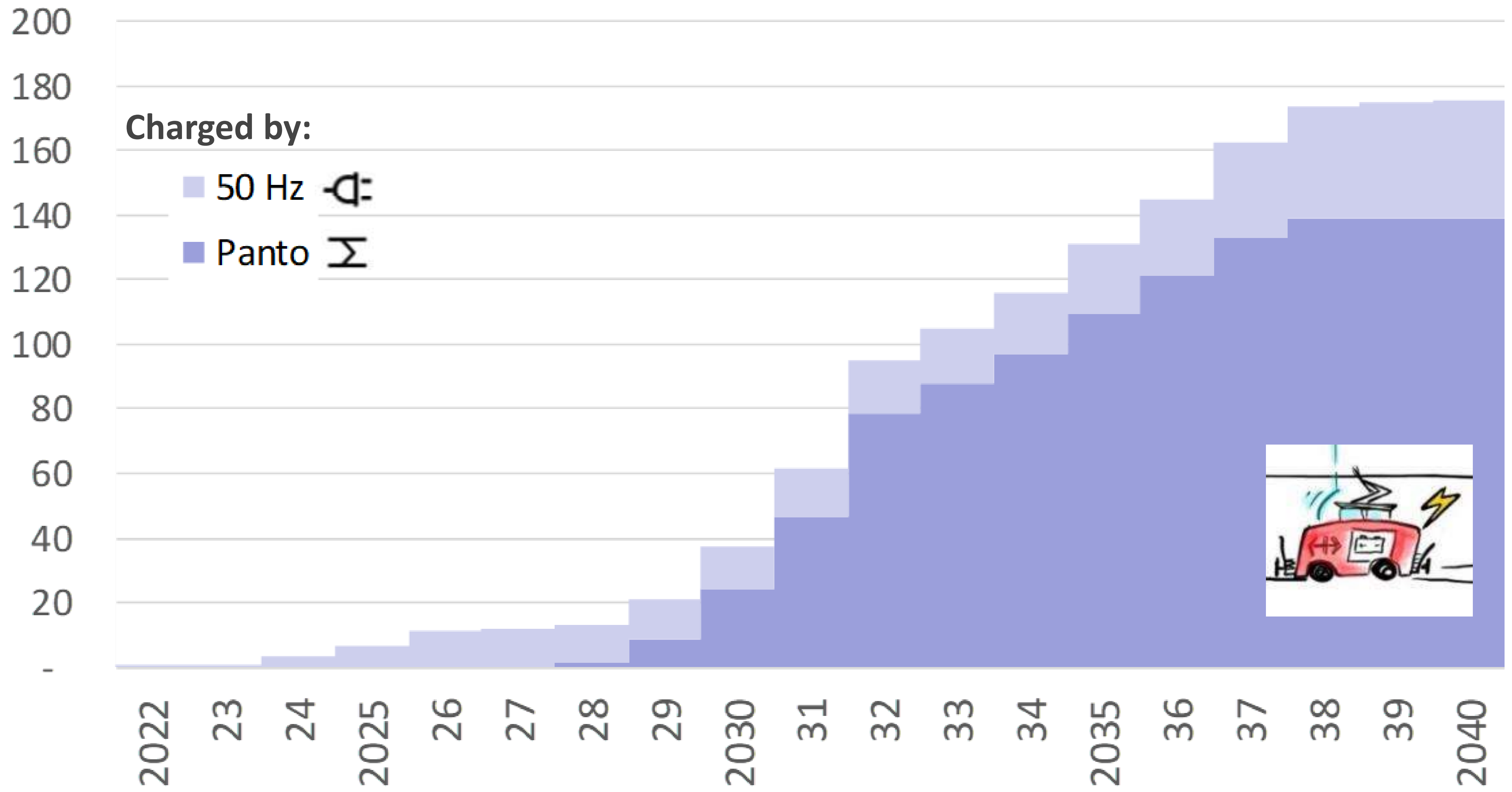
	Control Overload	Cutting Load Peaks	Smoothing load profile
	 Reducing demand in critical overload situations.	 Reducing expensive power reserves.	 Reduced wear on hydraulic machines. Improved load forecast.
Heating / Thermal Loads 	Reduce heating power in overload situations.	Switch off train car and point heaters during peak loads.	Predictively control point heating systems, reheating in "load valleys".
Traction 	Reduction of traction power via train driver.	Automatically reduce traction power during peak loads.	-
Batteries 	Discharge batteries in overload situations.	Short-term battery discharge during power peaks.	Battery charging preferably in systematic "load valleys".

Status 2024: Idea/Concept | Pilot | Realised

6

02
Batteries as flexibility

Climate neutral SBB: Electrification of diesel fleet



Forecast of installed battery capacity on different shunting and maintenance vehicles

SBB wants to be net zero by 2040.

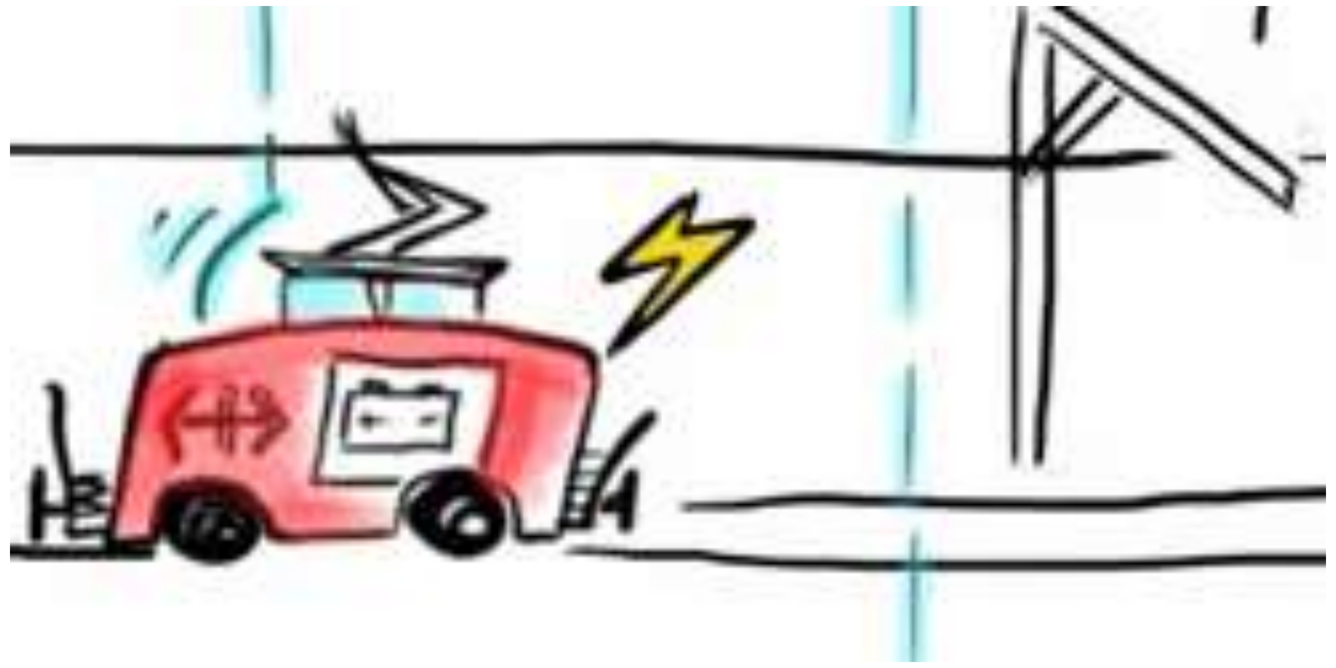
More than 40% of SBB's CO_2 emissions come from diesel traction and construction site power supply (12 Mio. l diesel / year).

From now on, all new and replacement purchases will be made using renewable energy instead of fossil fuels.

Phase OUT: fossile energy carriers
Phase IN: energy storage / batteries

BIENE Study (= BatterIEschwarm im BahnstromNEtz)

(Battery sworm in railway power grid)



Railway power grid as charging option.

Optimal charging infrastructure existing.

- Fast charging with high power.
- Charging while driving possible.
- Cheaper than 50 Hz public grid, much cheaper than diesel.
- Additional load not critical: max. 1 % of maximum load

Battery sworm as reserve power plant.

Flexibility of batteries very valuable.

60 MWh always available.

- Shifting power peaks
- Energy supply in critical grid situations.

-> Potential > 1 Mio. CHF / year due to reduced reserves.

Battery ageing can be significantly reduced.

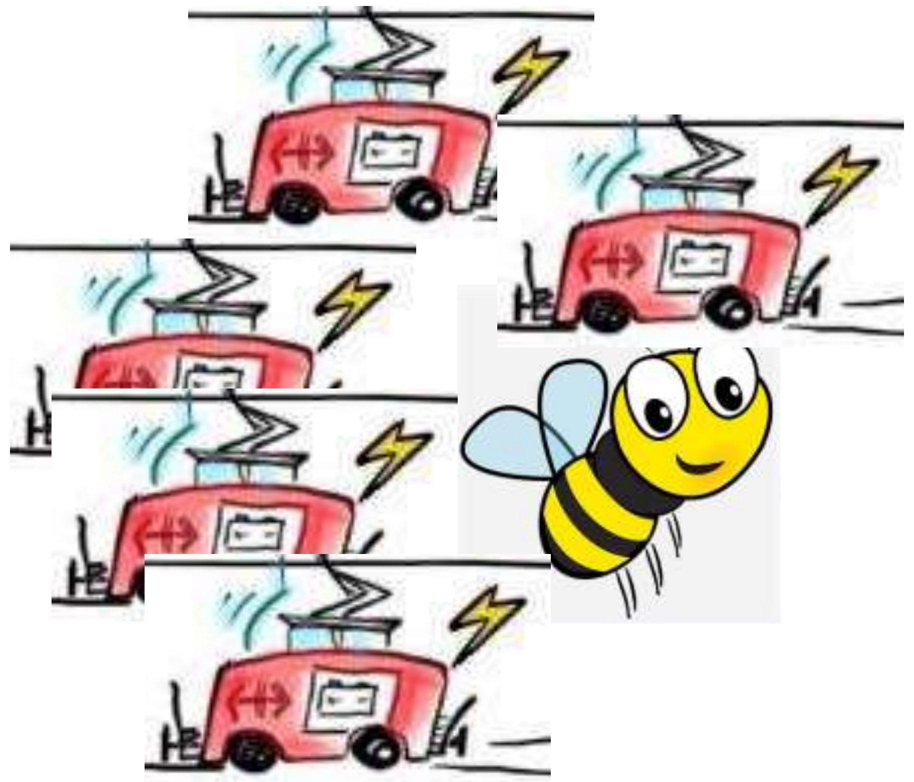
Often planned/typical services. Charging can be adjusted for longer battery life time.

- Later replacement of battery (rail vehicle lifetime longer than battery lifetime)
- Preparation for 2nd life usage.

-> Potential > 1 Mio. CHF / year due to reduced aging.

Comparison of
classical power plant with 'BIENE reserve power plant'

60 MW
(new 16.7Hz Turbine & Generator)



60 MW für 1h
120 MW für ½ h
(when fleet is fully electrified)

Continuous use for energy production and balancing energy.

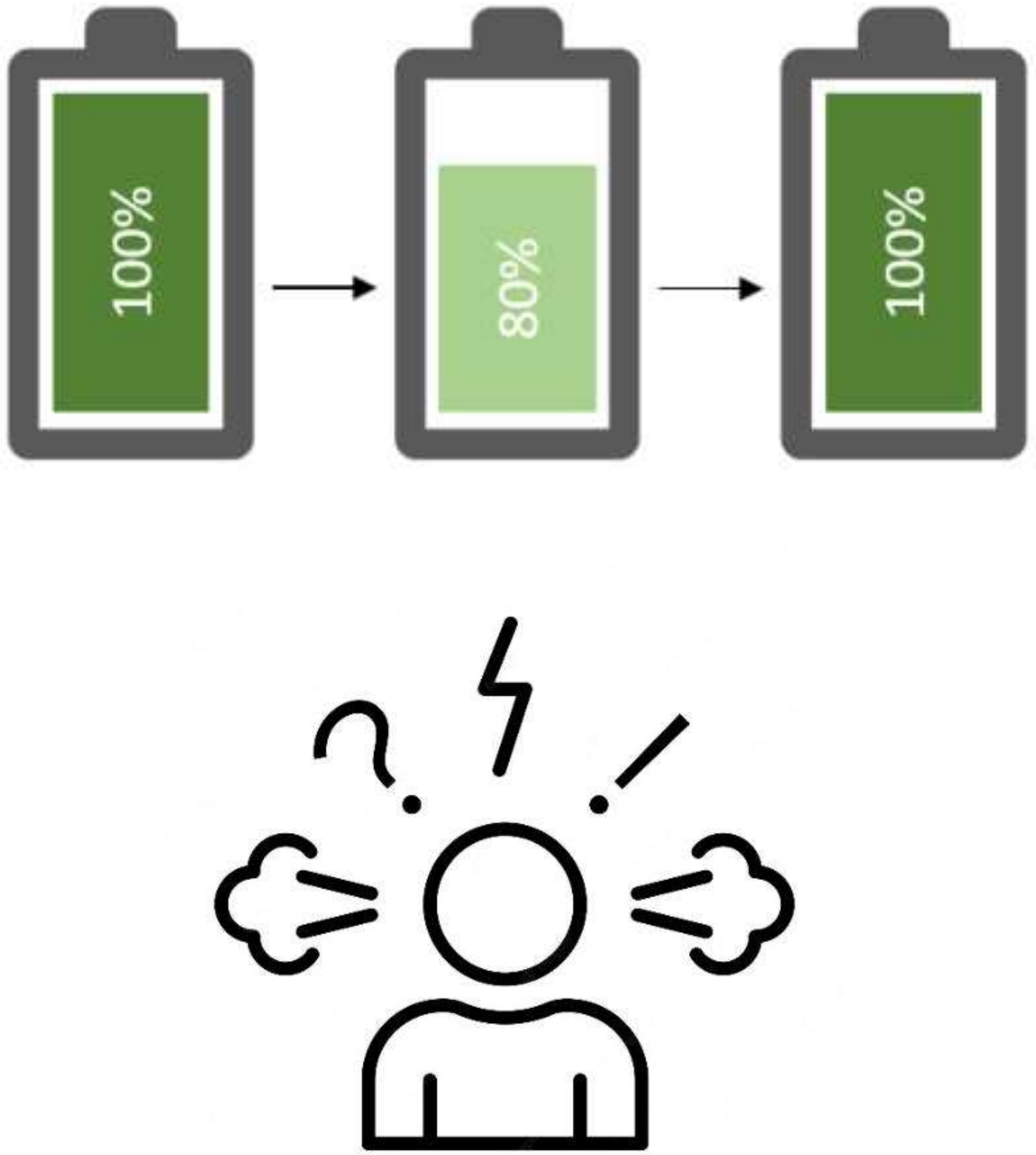
Use as a reserve

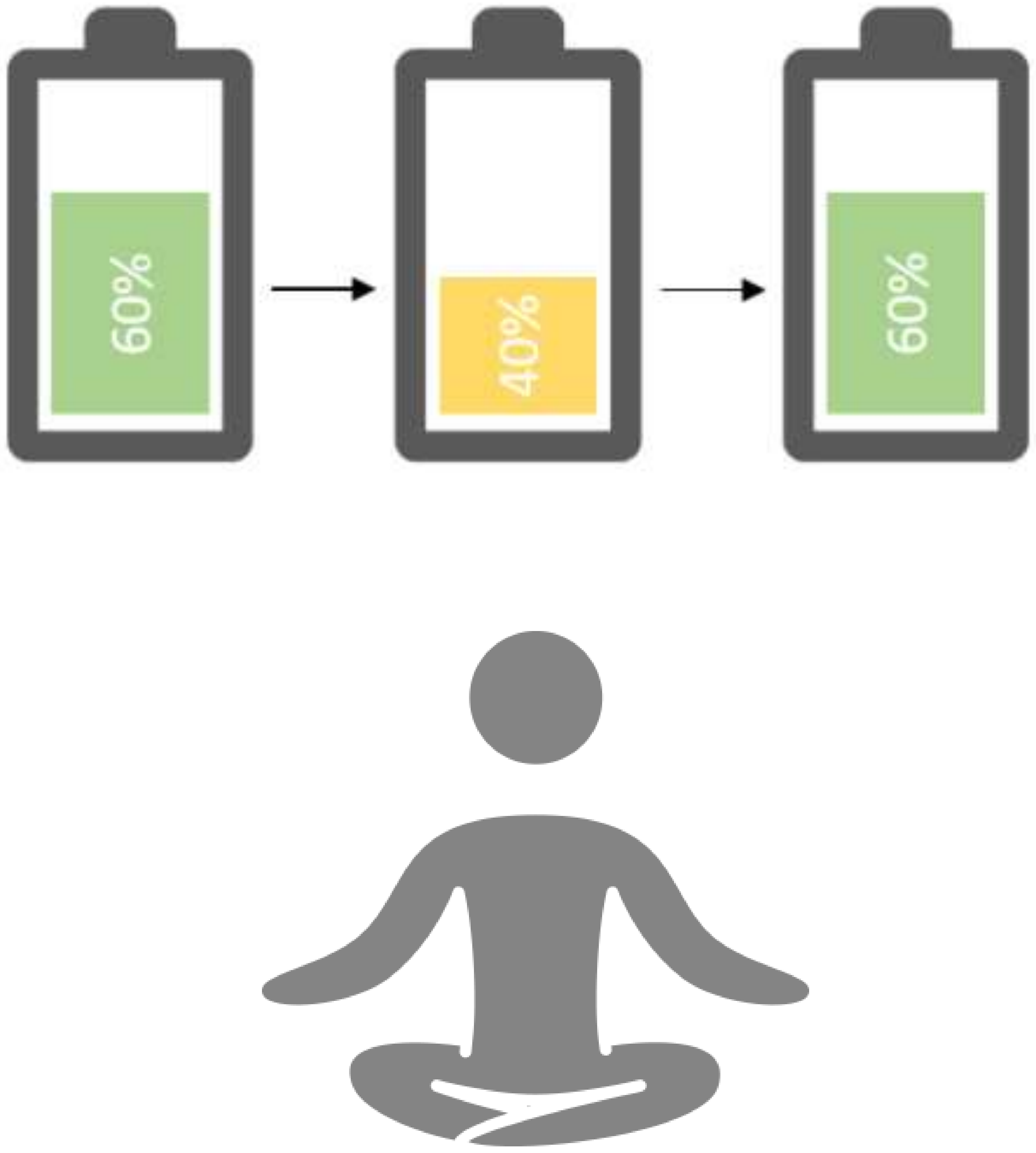
- Very rare: in case of critical overload due to serious system failure.
- Very short: to cover extreme load peaks of a few seconds.

-> Negligible influence on battery ageing and vehicle operation.

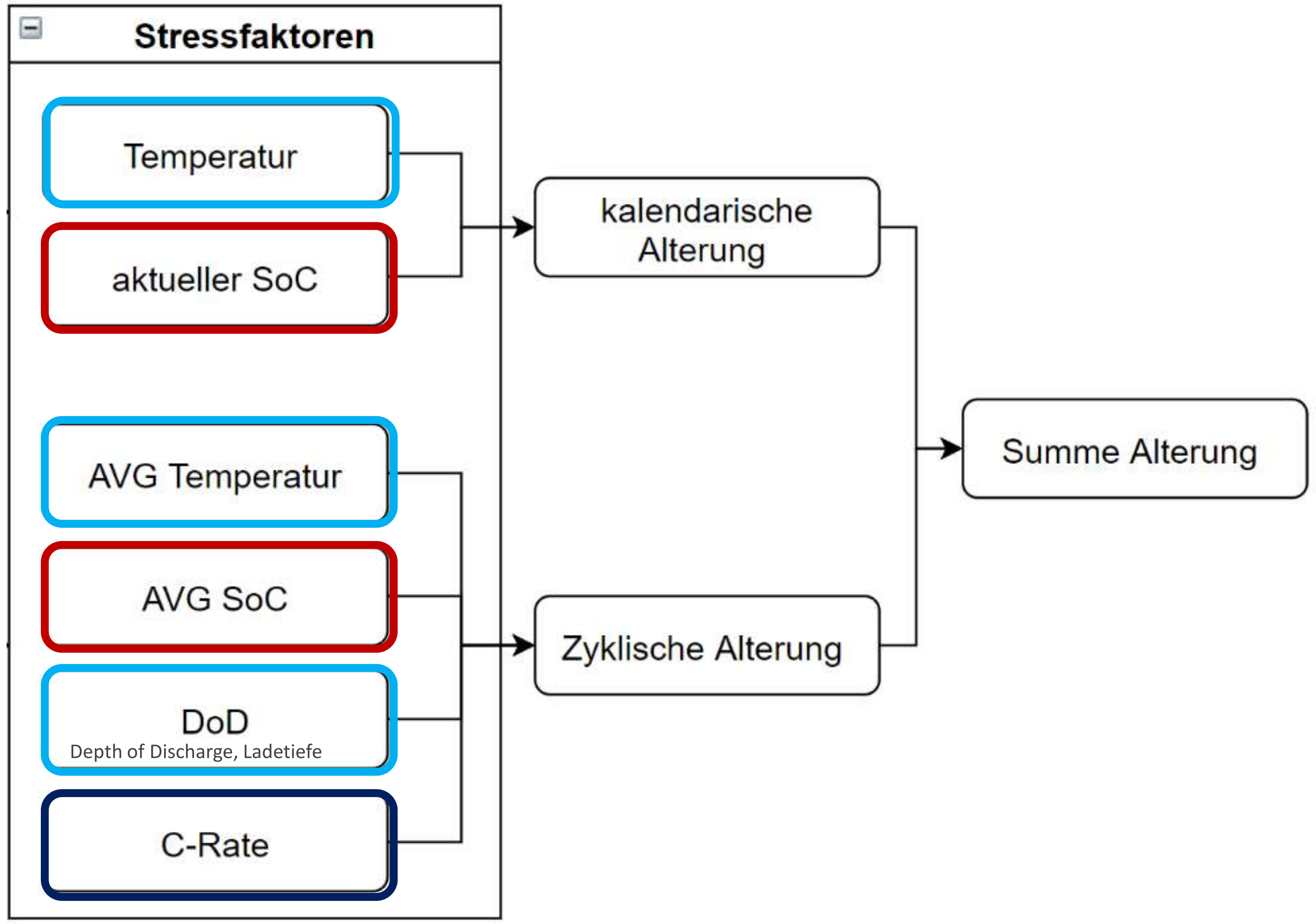
03
Battery friendly charging

Example: Depth of discharge of 20 % of capacity stresses the battery more at high storage level (SoC).





Operational influences on battery ageing – Approaches for central battery management.

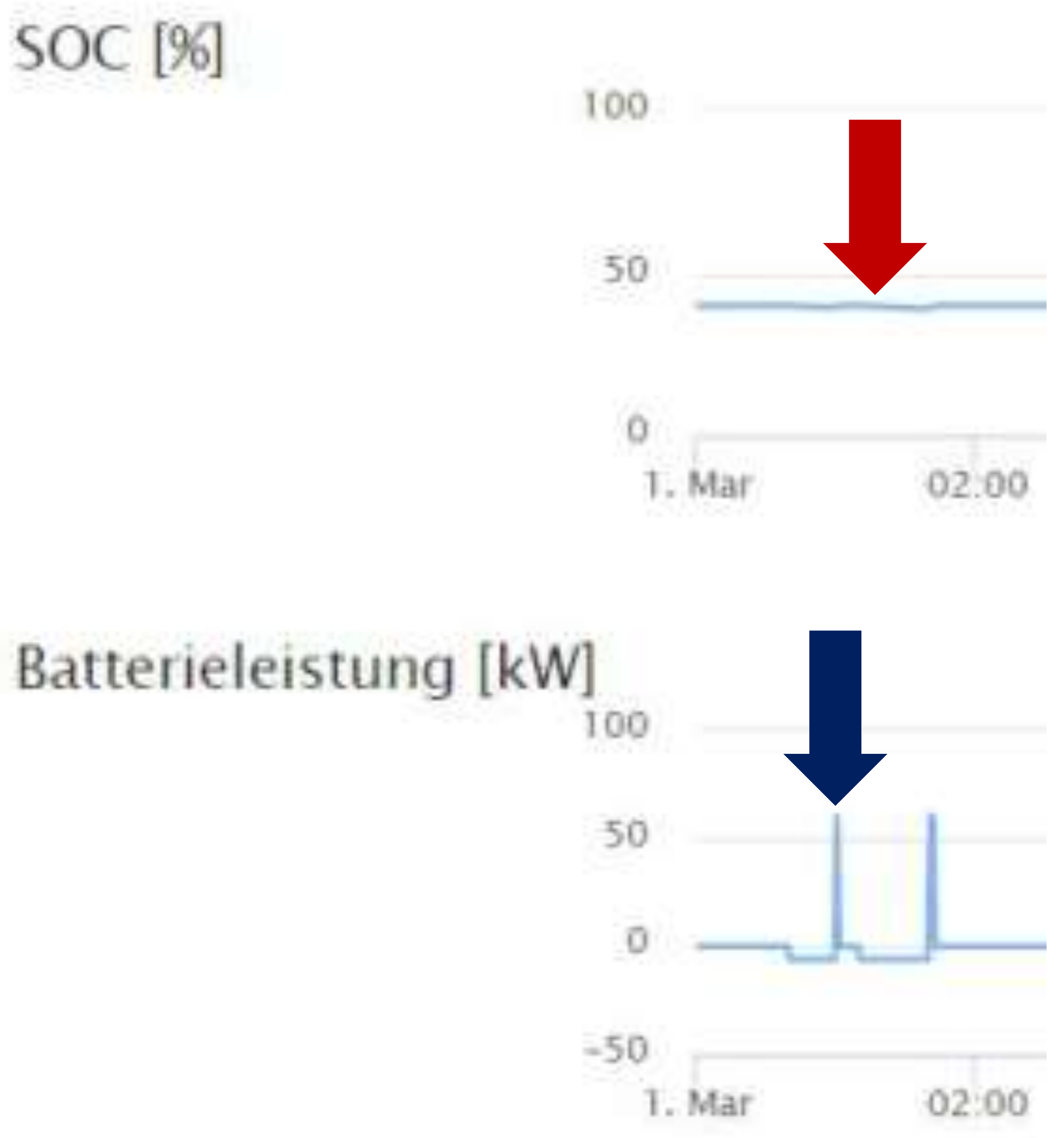


BIENE Batterie-management-Plattform

Lower State of Charge (SoC)

Reduced Charging Power (C-Rate)

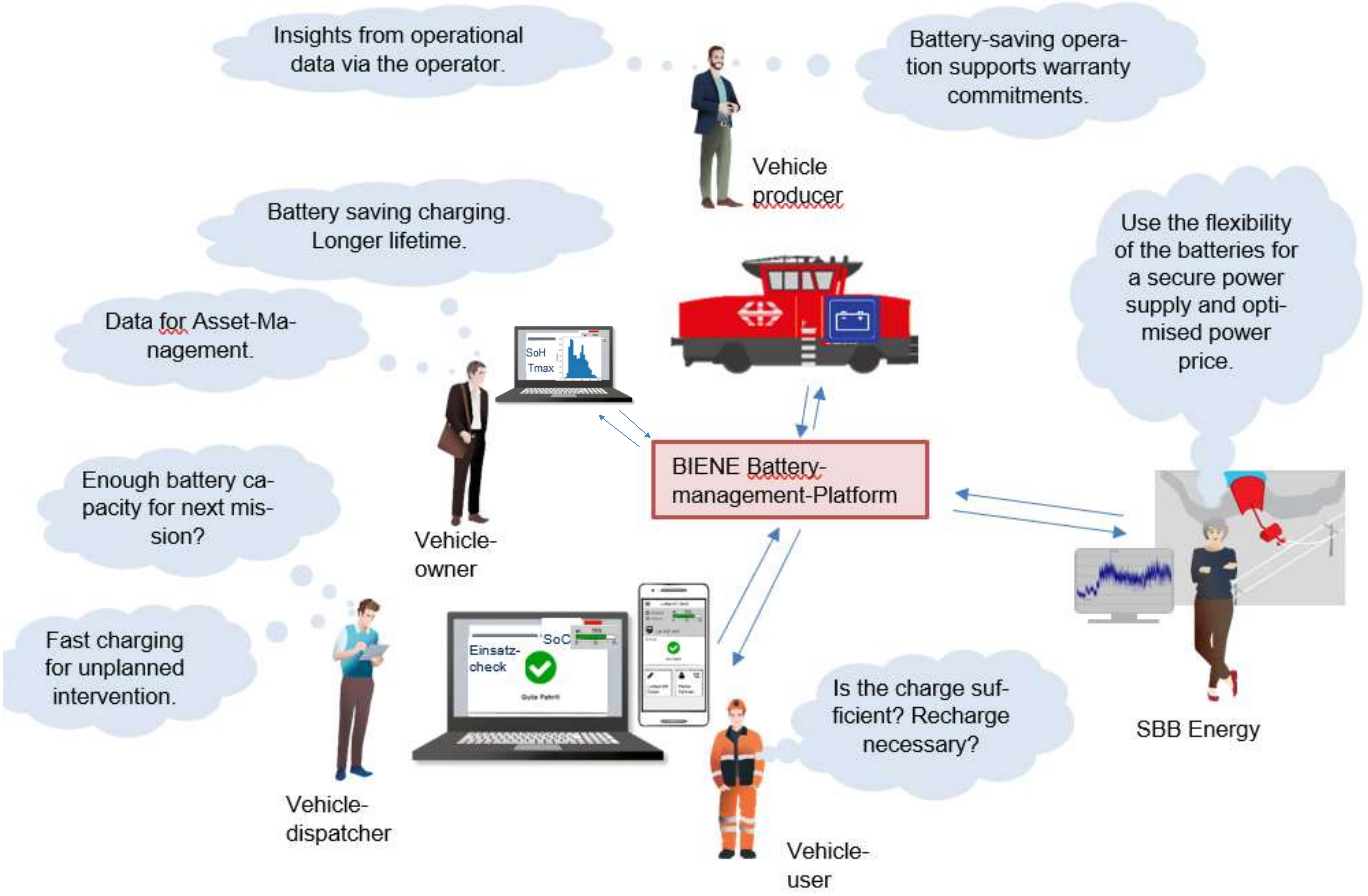
Monitor temperatures, charge depth,... with battery monitoring



Quelle: BIENE-Abschlussbericht, 2022

04
BIENE battery manager

User expectations of a central battery management system.

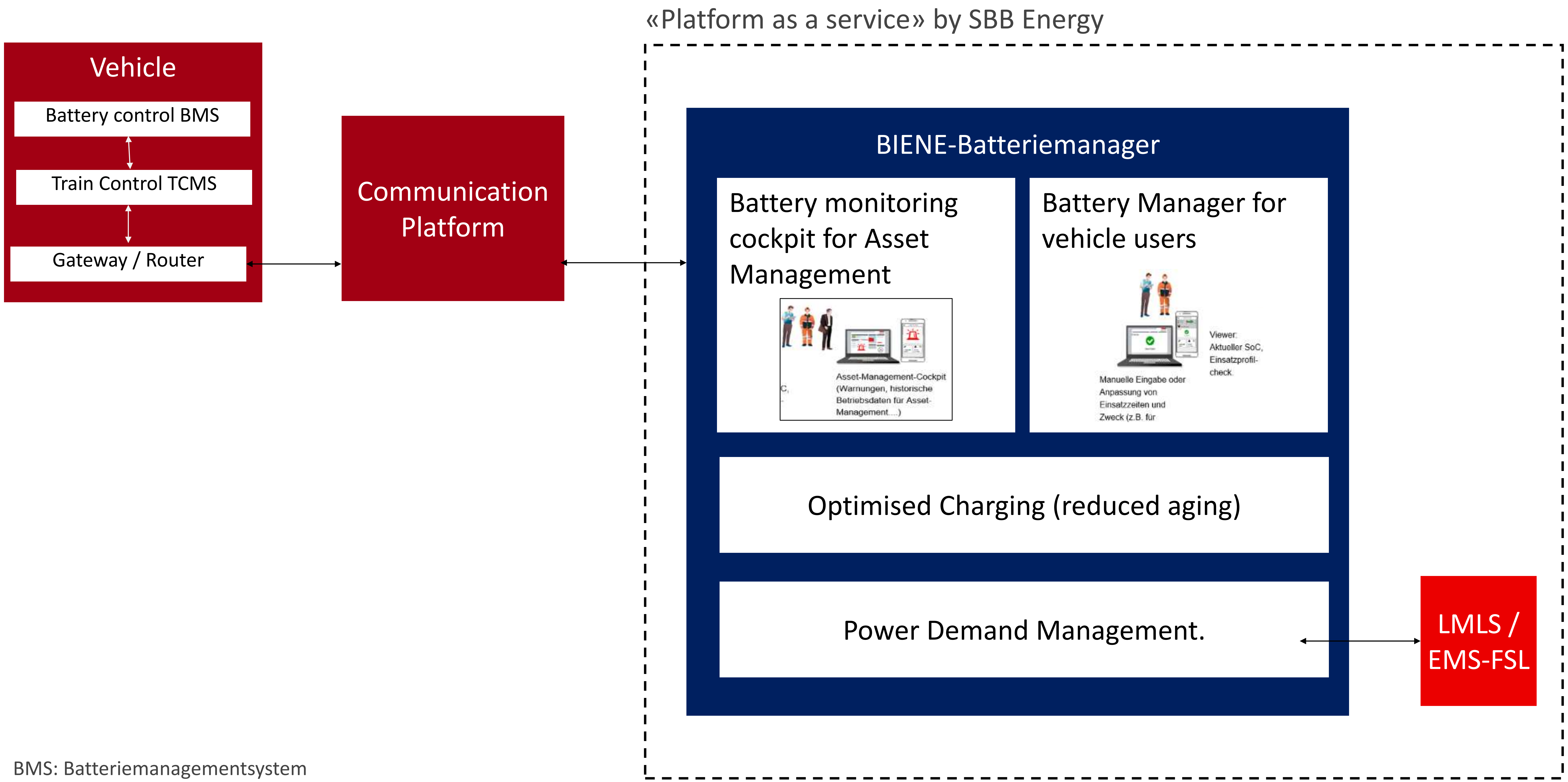


Pilot Project «BIENE Battery Manager».

Project from 2023-2026
Funded by Swiss Federal Office of Energy SFOE.

Project partner:
- SBB: Software development,
  Pilot vehicle Tafag Hocharbeitsbühne
- RhB: Pilot vehicle shunting locomotive Geaf 2/2
- BFH Center Energy storage: scientific support, battery models,…

Features BIENE-Battery Manager.



BMS: Batteriemanagementsystem
TCMS: Train Control Management System, Fahrzeugleitgerät
LMLS: Lastmanagement-Laststeuerung, existing power demand management platform from SBB Energy
EMS-FSL: Energiemanagement- und Fahrstromleitsystem, existing system for control of power supply

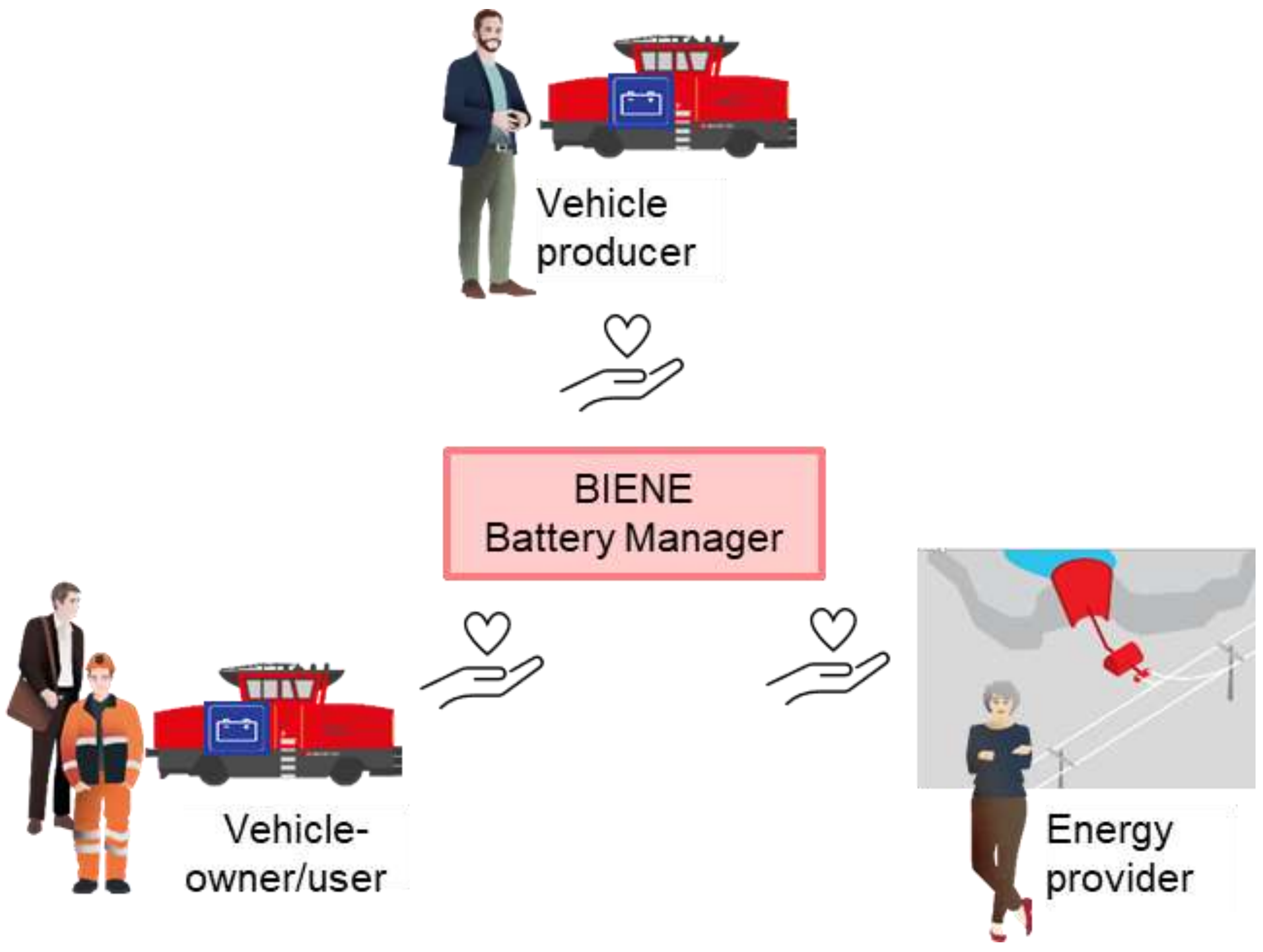
BIENE-Batteriemanager as railway sector approach.

Using synergies: one solution for all.

SBB Energy as system leader for traction current wants to support the energy transition:

- Efficient electrification of diesel fleet
- Economic, secure and sustainable traction current supply.

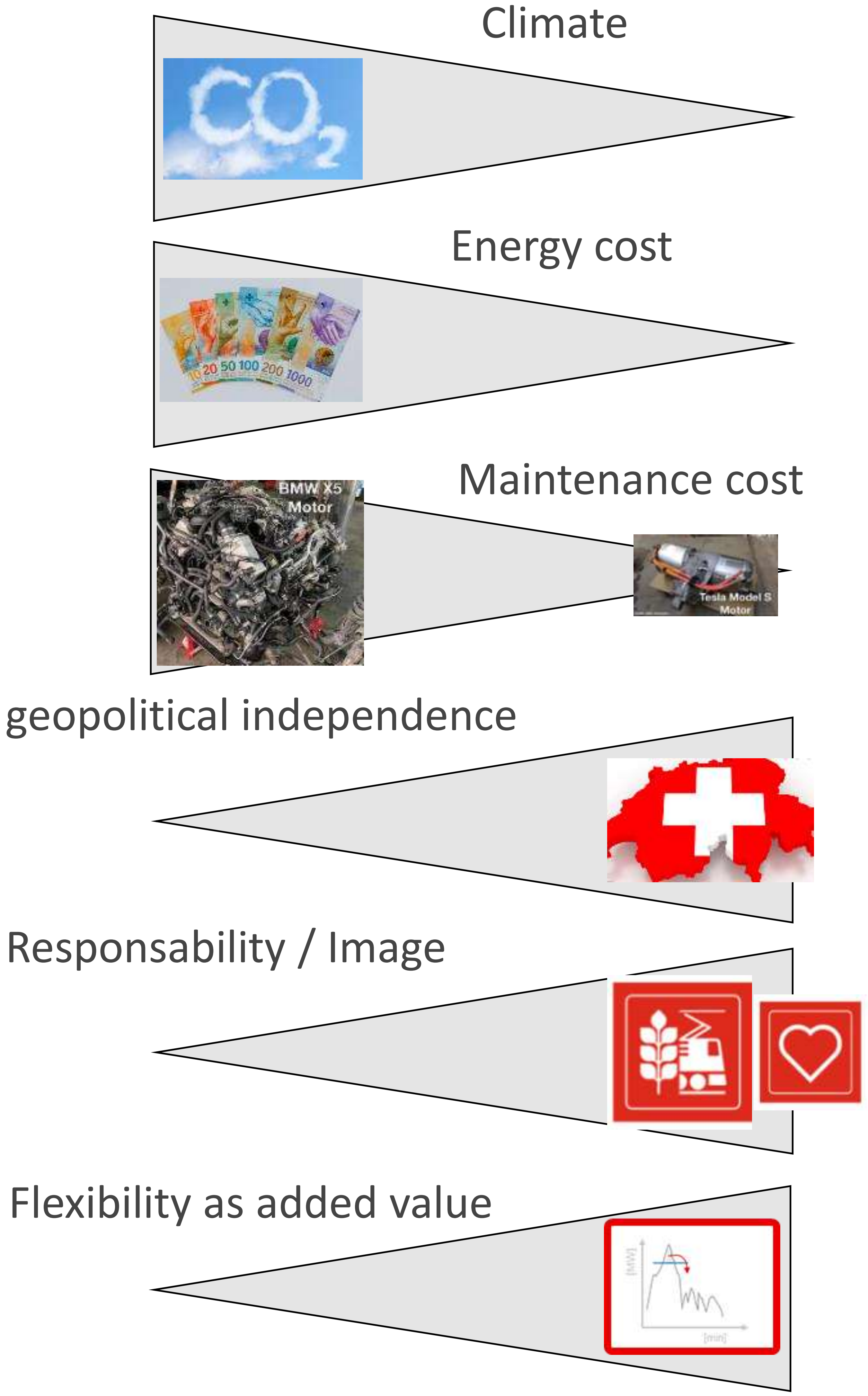
Standard specification document for vehicle procurement defining requirements for connection to centralized battery management platform.
(Draft version)

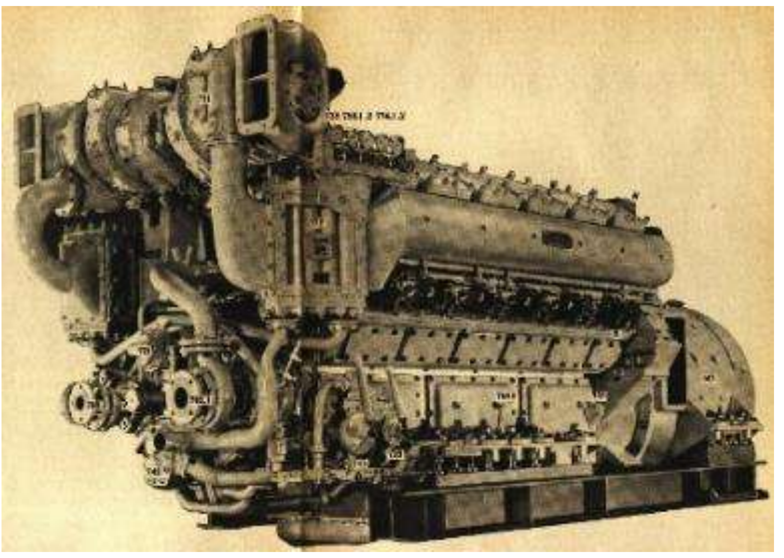


Using the flexibility of vehicle batteries: Better starting position for railways compared to road transport.

		
Benefit potential: Price fluctuations due to renewable energies, need for grid expansion	High potential.	Very high potential due to dynamic of railway grid
Realisation potential: • Complexity due to number of players	Many individual players	Few players, mostly in same company
• Technical prerequisites	Challenge: regenerative charging stations and vehicles.	16.7 Hz Grid and vehicles regenerative.

Diesel → Electricity/Battery





ENERGY&CO_2 Sector

2024

INTERNATIONAL UNION OF RAILWAYS

Thank you
for your attention

Markus Hadler
Programme Manager, Load Management
Energy infrastructure
SBB

Workshop timeline

10:00	Welcome Introduction	UIC/Chairs
10:10	GUW+: Smart substation	Alstom
10:30	SmartCharging4Trains - Linking Battery Trains & EV Charging	Siemens
10:50	Using the Flexibility of Traction Batteries for the Railway Grid	SBB
11:10	Charging E-machines and trucks (railway excavators) at substation Vught	ProRail
11:30	Charging electric vehicles	TucRail
11:50	Questions / discussion Closing remarks	All

INTERNATIONAL UNION
OF RAILWAYS

ProRail

Ron Jasker
Sustainability implementation manager

Charging E-machines at substation Vught

UIC - Rail grid & EV charging online workshop,
Ron Jasker, 22-11-2024

Covenant Clean and Emission free Construction Site signed Oct. 2023 (SEB)

Gemeente Utrecht | VERAS bouwt aan slopen | Leasir Neder | VERENIGING VERTICAAL TRANSPORT | Netbeheer Nederland | Elaadnl | NVAF

ip Interprovinciaal Overleg | Emissieloos Netwerk Infra | 's-Hertogenbosch | Bouwend Nederland | Rijkswaterstaat Ministerie van Infrastructuur en Waterstaat | gasunie | TenneT

GEMEENTE TILBURG | MKB-INFRA BRANCHEORGANISATIE | GEMEENTE Arnhem | CUMELA | Ministerie van Landbouw, Natuur en Voedselkwaliteit | ONDERHOUD NL | Ministerie van Defensie | Nijmegen

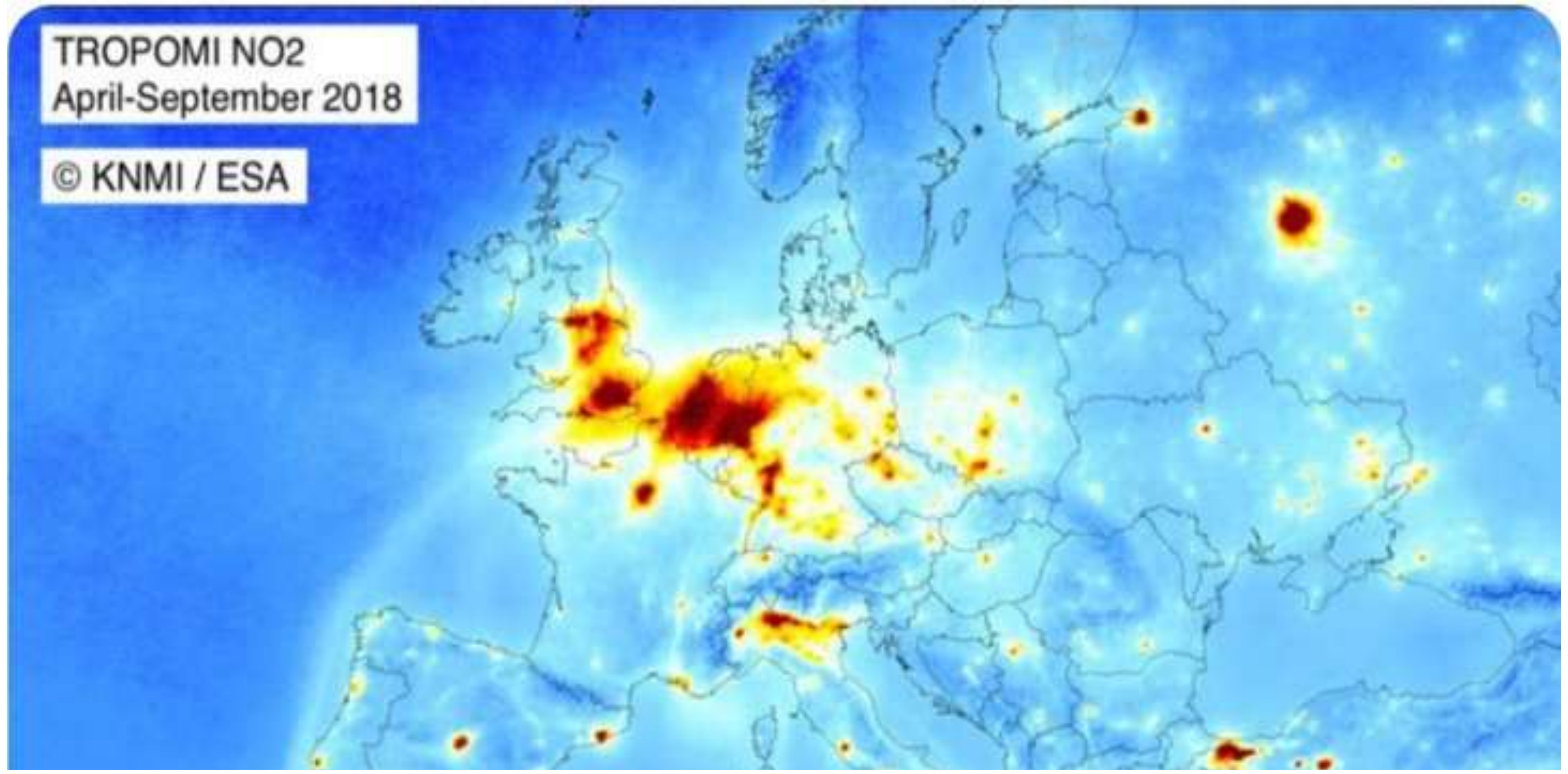
Den Haag | bouwen met staal | UNIE VAN WATERSCHAPPEN | Fedecom | AFNL Aannemersfederatie Nederland Bouw & Infra | Betonhuis | TLN | gemeente harderwijk | Rijksvastgoedbedrijf Ministerie van Binnenlandse Zaken en Koninkrijksrelaties

Gemeente Breda | BMWT | EINDHOVEN | rai vereniging | Leiden | Ministerie van Economische Zaken en Klimaat | VERENIGING VAN WATERBOUWERS | ProRail

ProRail | SEB

Climate change mitigation:

- Greenhouse gasses ($CO_{2\text{-eq.}}$)
- Nitrogen (NOx)
- Particulate matter (PM)



Implementation covenant SEB

Roadmap SEB focuses on projects and maintenance

- Ambition: **zero emission 2030**
- Budget in the Netherlands approx. 1 billion Euro.

Approach ProRail:

- 1. **Procurement & Contracting**: award criteria, contract requirements, compensation for early adopters and frontrunners.
- 2. Developing **charging infrastructure** in the energy networks of ProRail.
- 3. Stimulating innovation towards more sustainable **heavy / specialist rail stock**

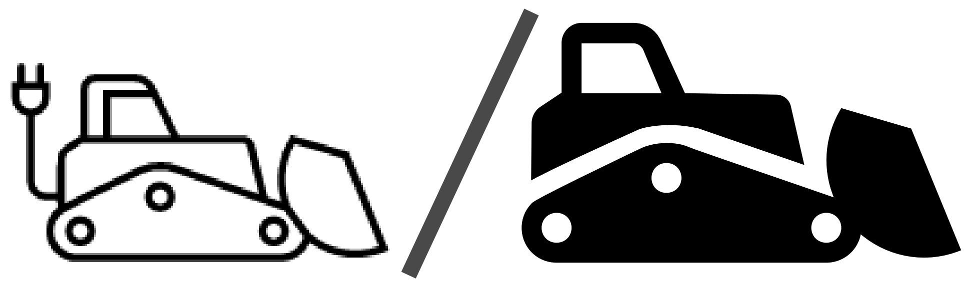
Base level machinery and transport

	2023-2024	2025-2027	2028-2029	2030 e.v.
Light	cleaner diesel vehicles	cleaner diesel vehicles	100% ZE	100% ZE
Middle/ heavy	cleaner diesel vehicles	cleaner diesel Vehicles	cleaner diesel vehicles	100% ZE (2030-2035)
Specialistic / very heavy			cleaner diesel vehicles	100% ZE (2035-2040)

Frontrunner approach

- Award criterium % ZE in tenders

- **% ZE = Total electrical energie / total energy (electric + diesel)**
- **Total energy predicted by project**
- Start with 0-25% ZE
- Contract advantage 10 %



- **Frontrunner approach 2024**

  - In ca. 30-40 projects. More to come. In 2030 all projects

ProRail

Examples electrical rail bound excavators (May 2024)

BAM Rail

BAM Rail

Strukton Rail

Berende

Van Oosterwijk Rail

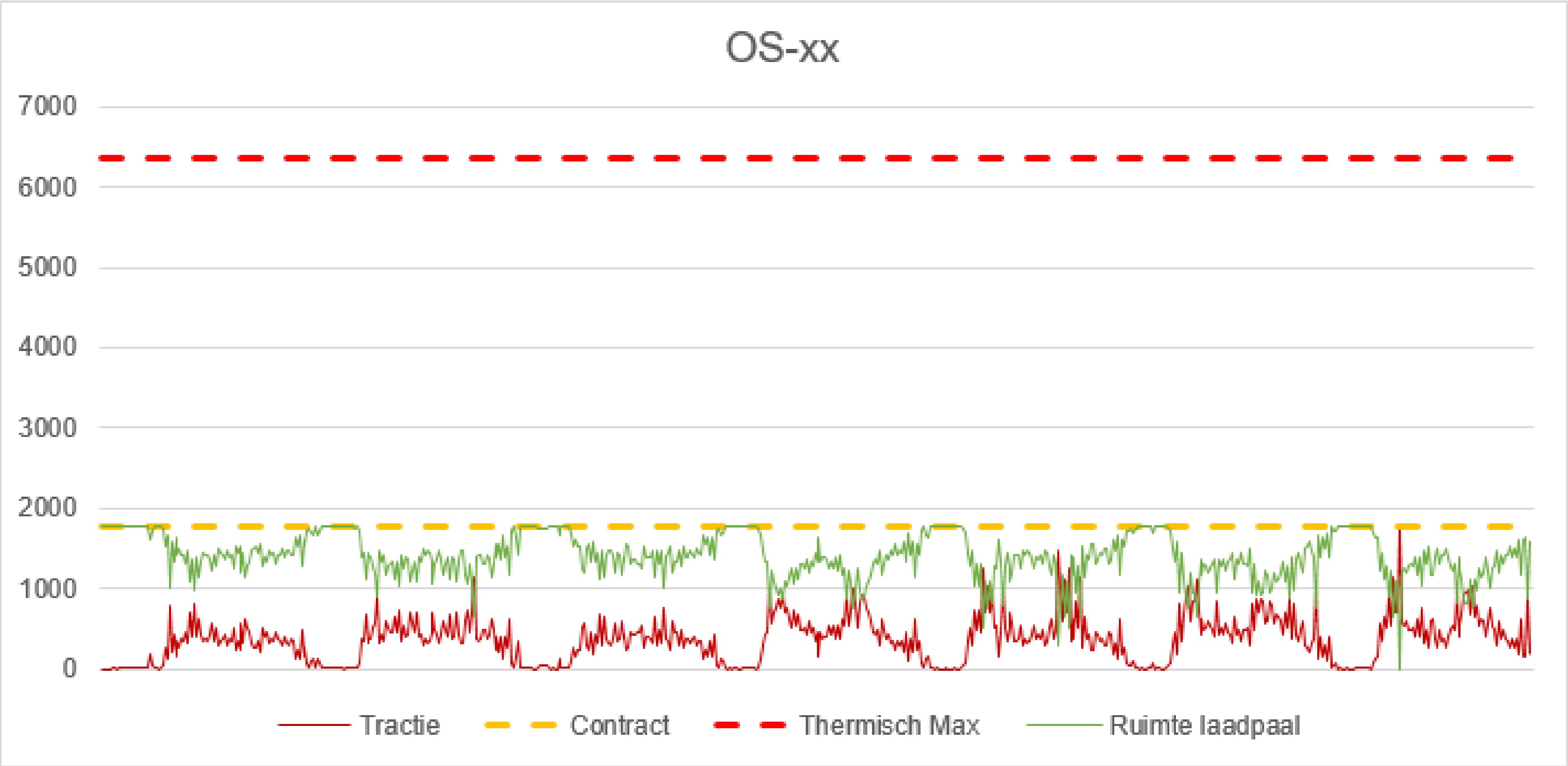
De Ridder

Van de Mheen

Van Roon

Charging infrastructure ProRail

- Increasing number of ZE-machines, charging is running behind
- Starting point in tenders: contractor responsible for charging
- Major network congestion in the Netherlands. It's very difficult to get a connection from a DSO with sufficient power.
- ProRail wants to use its own systems



Main development directions

Facilitate connections to ProRail System (e.g. power grid) for projects

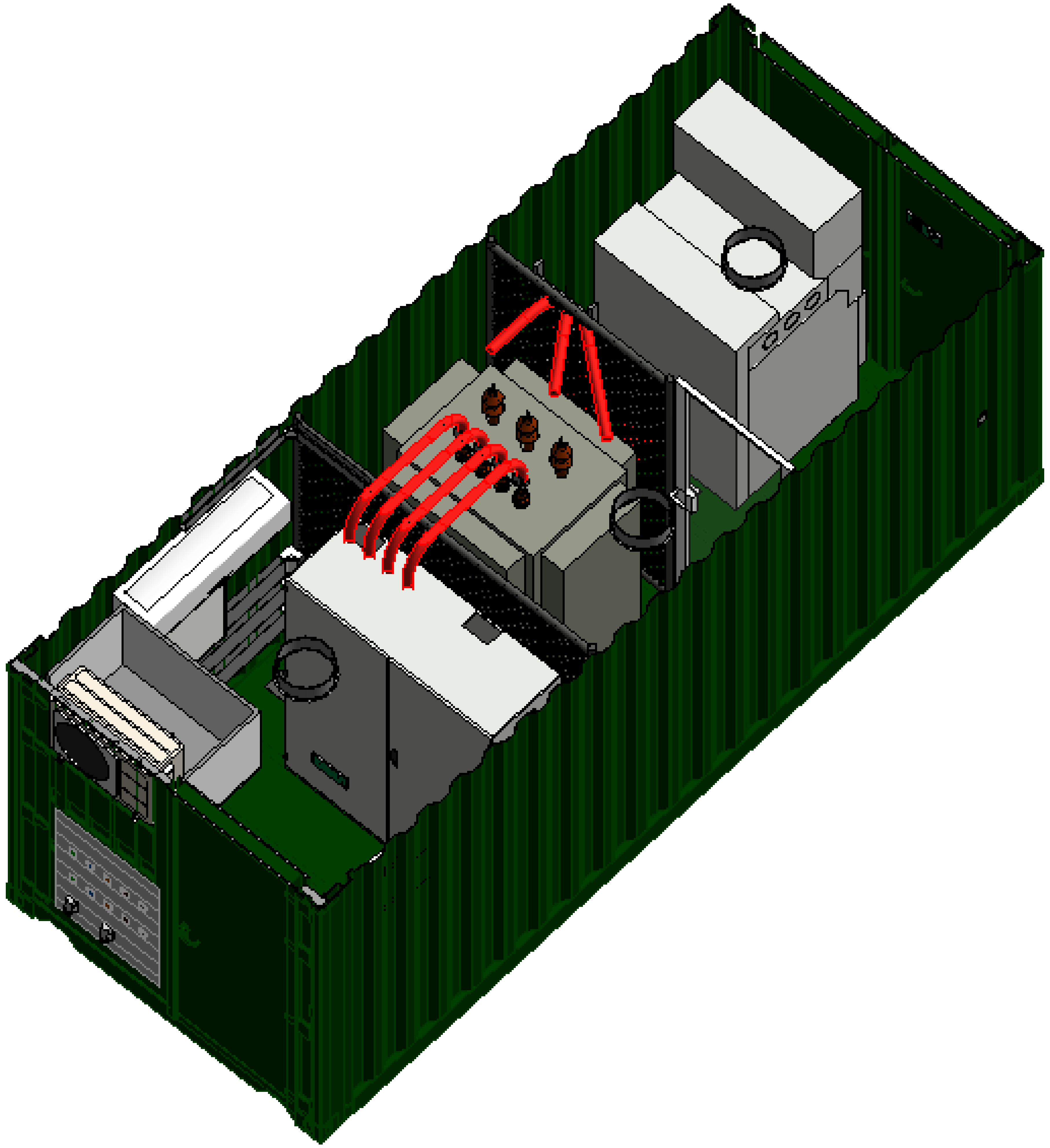
Develop charging plazas on locations with high demand

Pilot ‘Vught’

- Large ProRail-project, 2 km semi tunnel
- First pilot to use energy of the traction power grid
- Mobile charging installation (green container) connected to sub station
- 4 fast chargers in total 800 kW
- Energy management system to prevent exceeding of contract level
- Opened July 2024
- Tender mobile charging installations considered

ProRail

Charging container

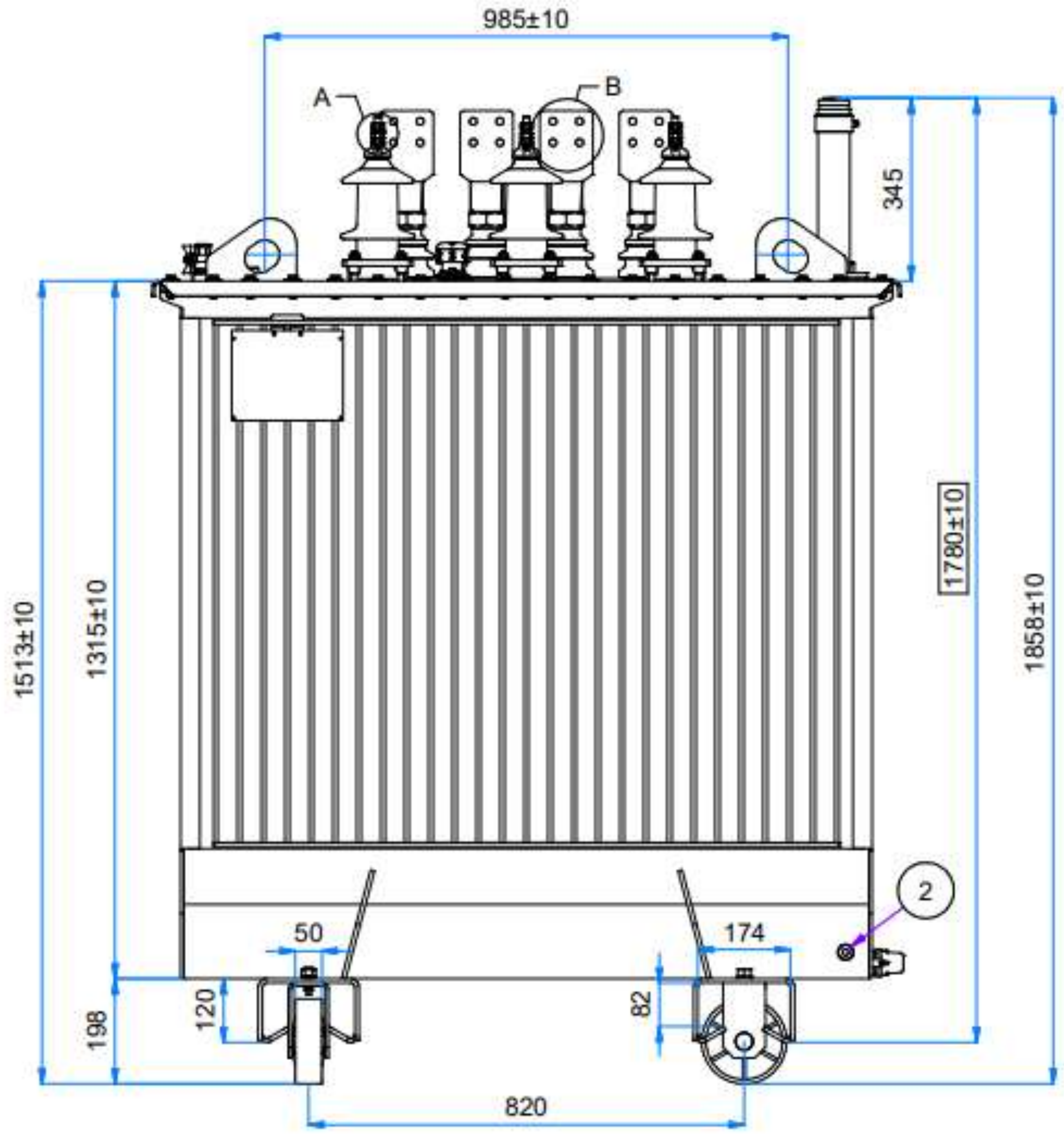


Ring Main Unit

- W/H/D 1050mm x 1400mm x 775mm
- Rated voltage 10kV
- Rated continuous current 630A
- 50 Hz Rated peak withstand current 63A

Threephase oil immersed transformer

- Rating power 1000 kVA
- Primary winding 10750 V
- Secondary winding 420 V
- Weight 3240 kg
- Noise emmission 54 dB
- Frequency 50 Hz

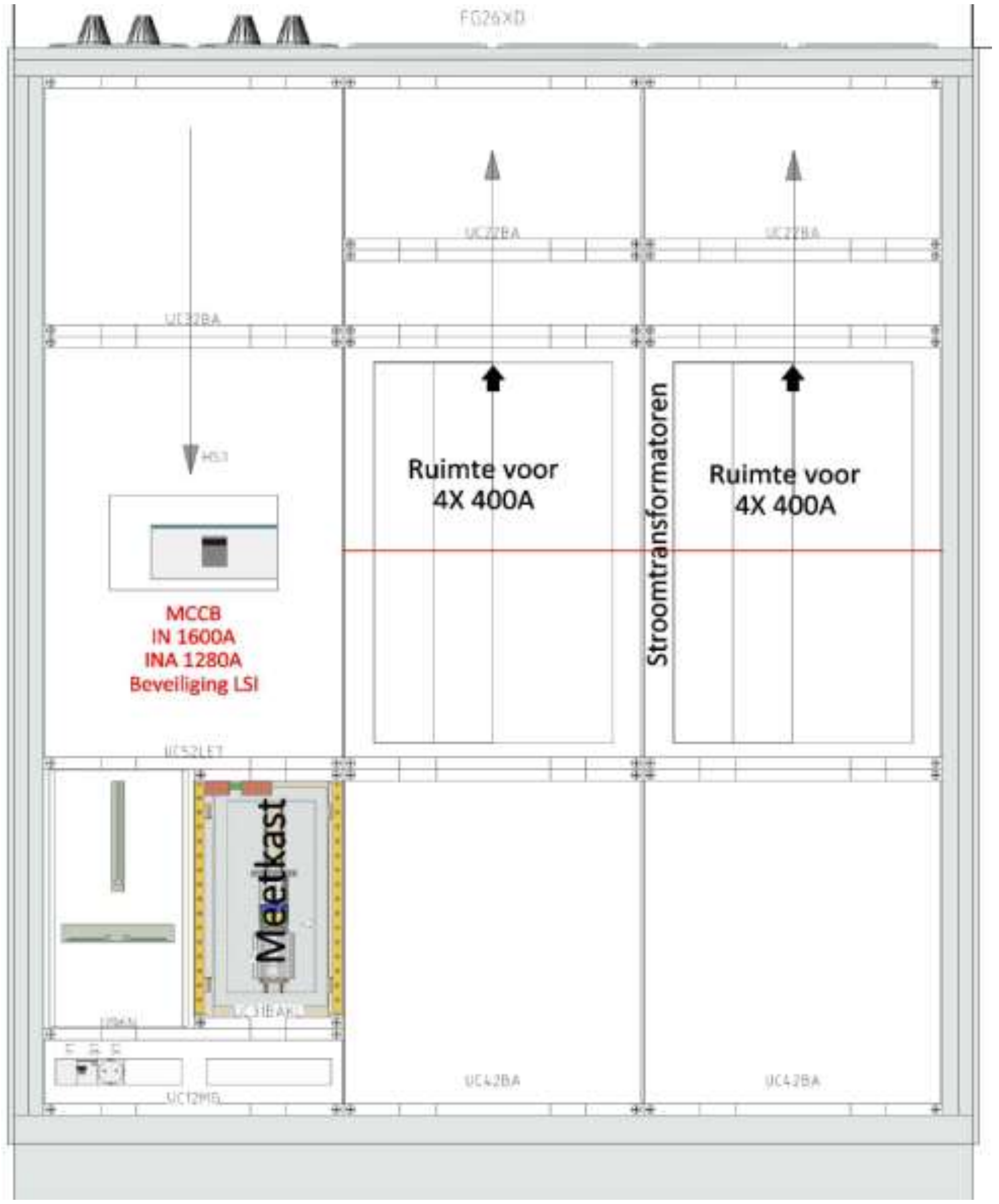


ProRail

Low distribution device

- W/D/H 1600mm x 600mm x 2000mm
- Rated voltage 230/400V
- Main rail system 1600A
- 8 fields

  * Field 1 & 2 powerlock
  * Field 3 construction connections
  * Field 5 & 6 reserve
  * Field 7 AC Unit 1
  * Field 8 power supply LK1



ProRail

Workshop timeline

10:00	Welcome Introduction	UIC/Chairs
10:10	GUW+: Smart substation	Alstom
10:30	SmartCharging4Trains - Linking Battery Trains & EV Charging	Siemens
10:50	Using the Flexibility of Traction Batteries for the Railway Grid	SBB
11:10	Charging E-machines and trucks (railway excavators) at substation Vught	ProRail
11:30	Charging electric vehicles	TucRail
11:50	Questions / discussion Closing remarks	All

TUC RAIL

Paul Tobback
Lead Design Engineer
Competence Centre Electrification – OCL Expert

Sam Breugelmans
Design engineer power distribution
Competence Centre Signaling & Power

INTERNATIONAL UNION OF RAILWAYS

TUC RAIL

BELGIAN RAIL ENGINEERING

Paul TOBBACK

Energy & Electrification Expert, T-ENE

UIC EV charging, storage and rail grid, 19 November 2024

DIRECT FEED OF 3AC CHARGING STATIONS FOR E-VEHICLES

from a DC 3 kV overhead contact line installation

Paul TOBBACK

Energy & Electrification Expert, T-ENE

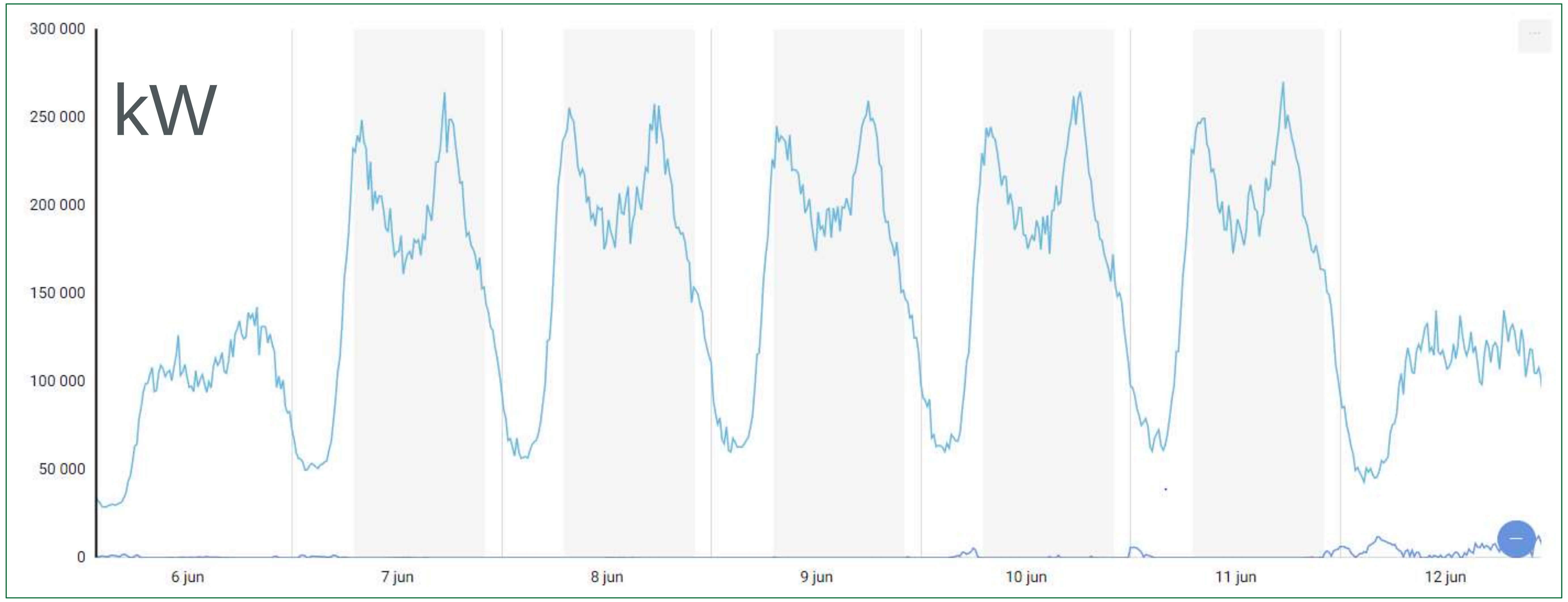
UIC EV charging, storage and rail grid, 19 November 2024

Outline

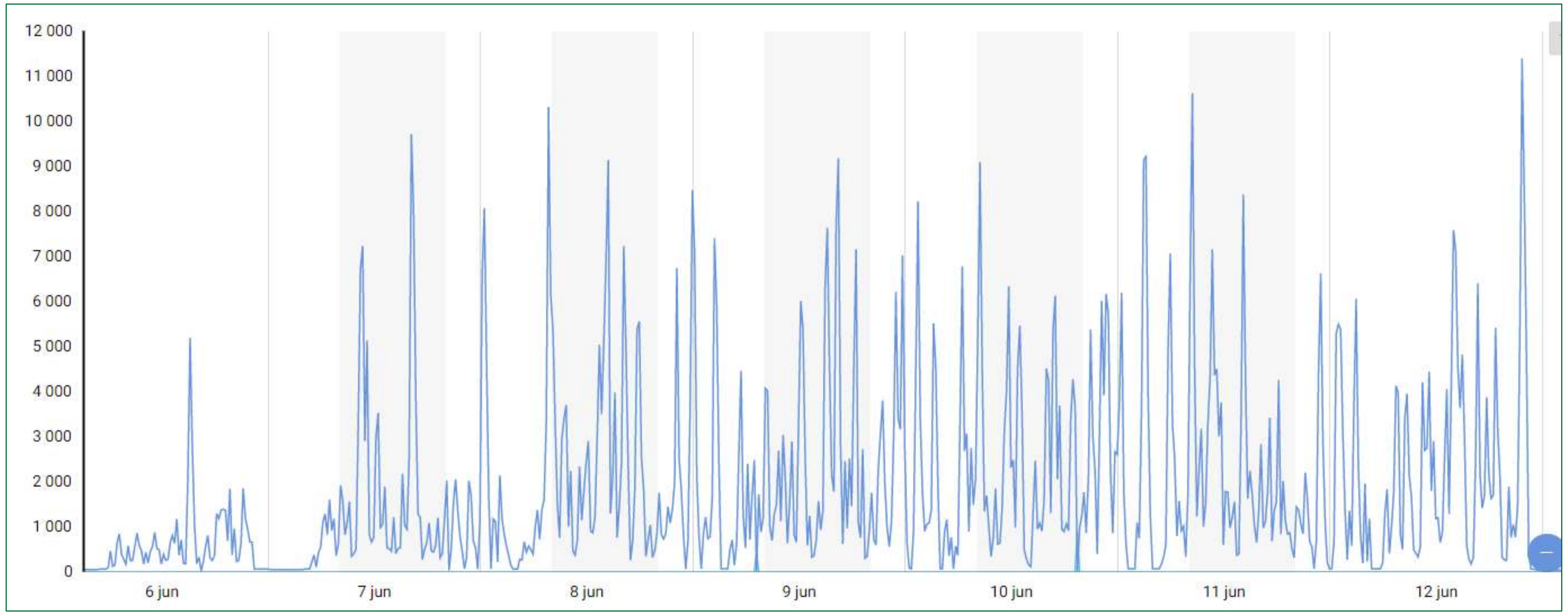
- Introduction
- Description of the system
- On site tests of the complete system
- Electromagnetic compatibility (EMC)
- Future developments
- Conclusion

Power supply & Energy demand

Sun 6 – Sat 12 June



global



INFRABEL Right On Track

1 substation

Completely new ?!

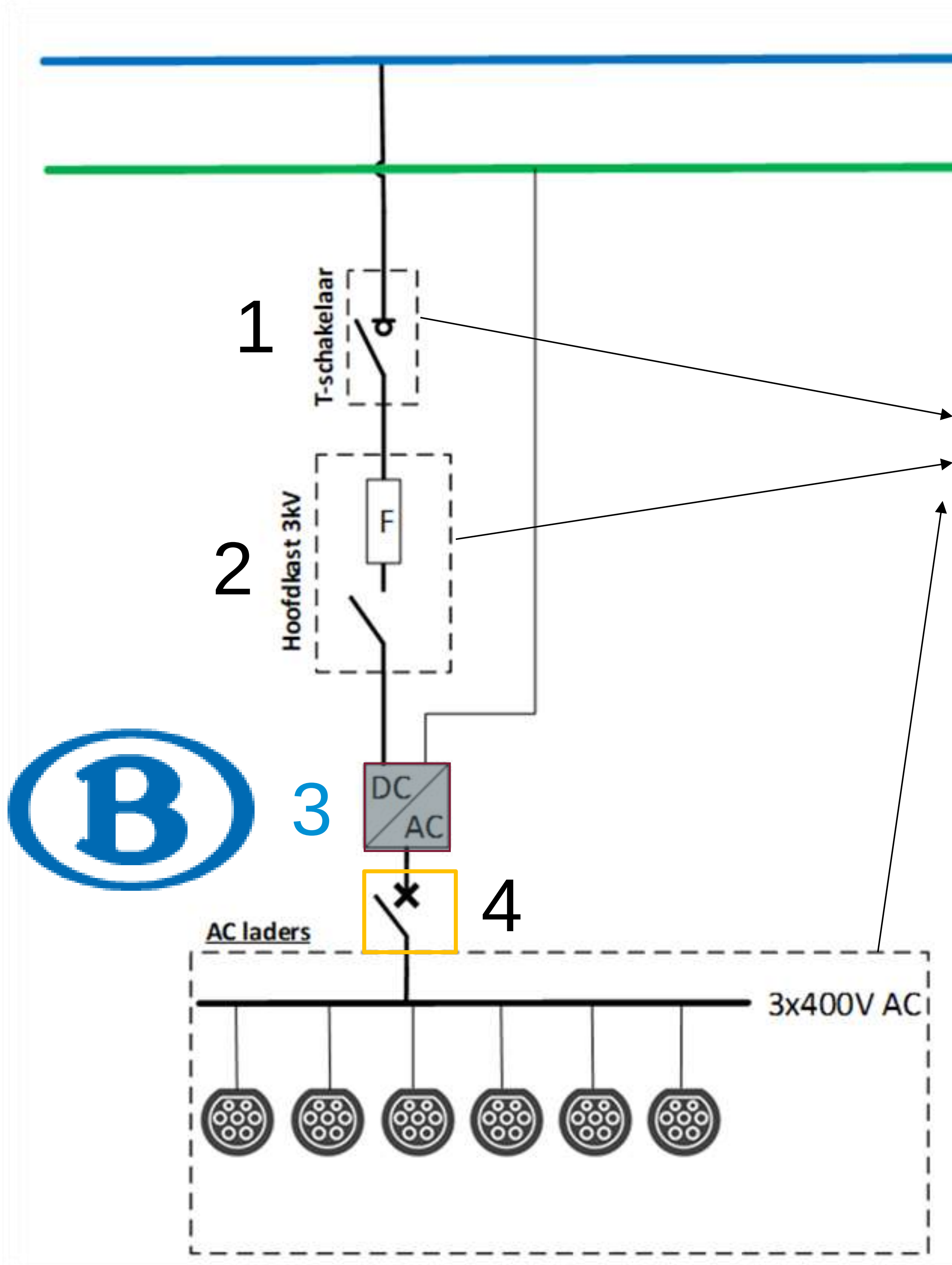
50 kW Fast charger in Málaga (ES)

Ferrolinera®

Outline

- Introduction
- Description of the system
  - Main functionalities
  - Safety: Earthing concept & Remote control
- On site tests of the complete system
- Electromagnetic compatibility (EMC)
- Future developments
- Conclusion

Main functionalities



Existing & available technology (off the shelf): preheating equipment for trains

or

1 – load switch, connected to the OCL

2 – main 3 kV cabinet

3 – container with the invertor 3 kV DC / 3AC 400 V

4 – 3AC 400 V main low voltage distribution board (LVDB)

Safety: Earthing concept & Remote control

5 – insulated 3 kV cable (1 x 120 mm²)

6 – remote control box for the switch

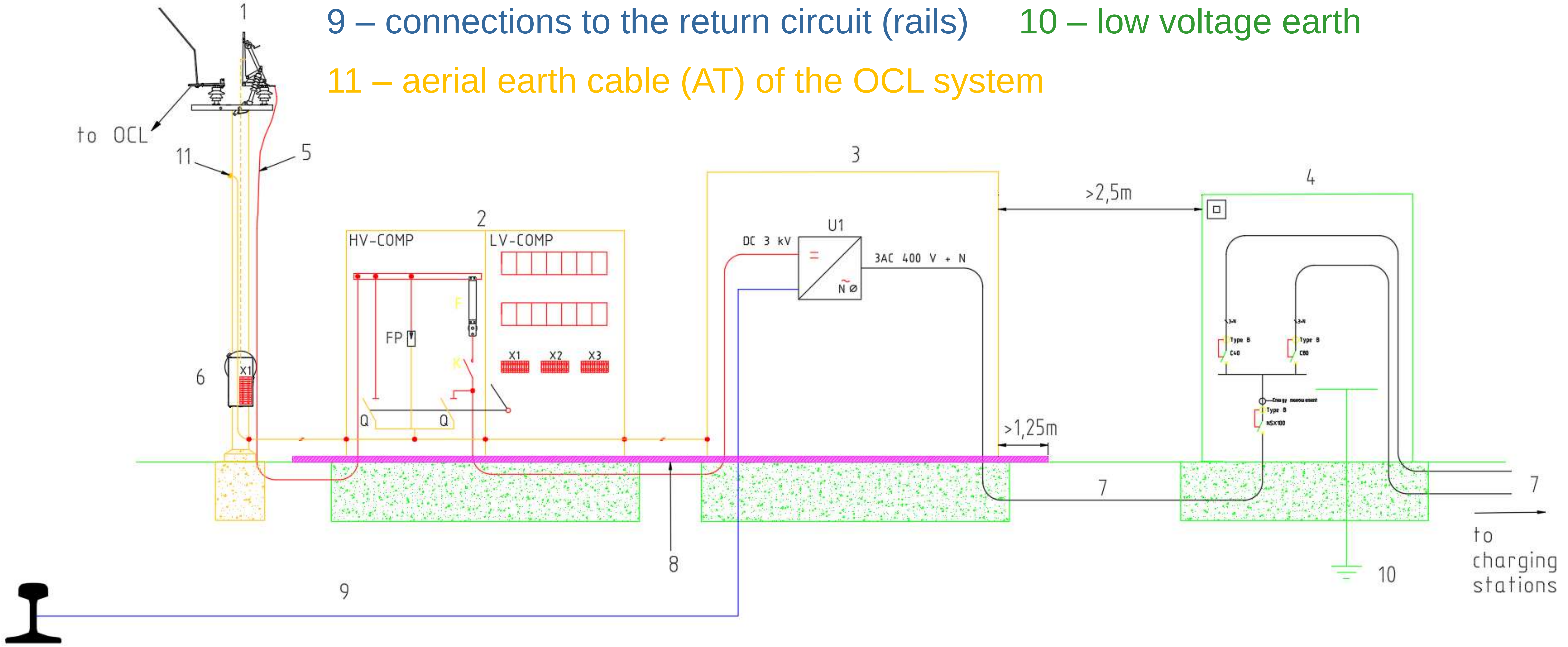
7 – 400 V cables

8 – insulated floor & insulated supports

9 – connections to the return circuit (rails)

10 – low voltage earth

11 – aerial earth cable (AT) of the OCL system



Earthing concept – pros & cons

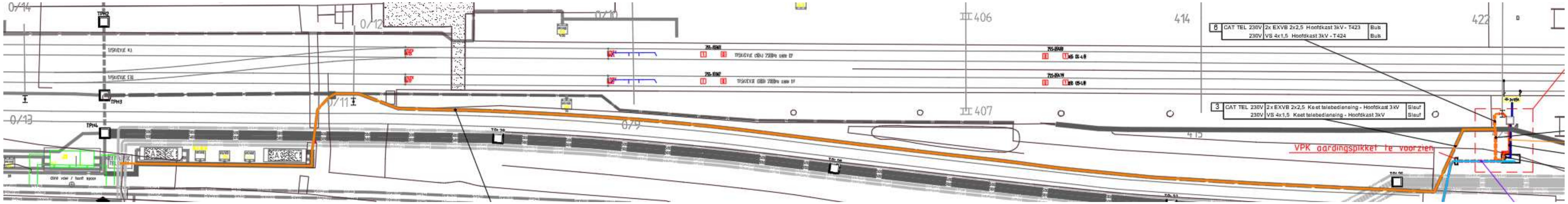
	PRO	CONTRA
Floating – AT (OCL)	Low price	AT is taken out of the gauge Overvoltages (lightning strikes)
Floating – return current	Highly reliable feedback to the return circuit Like supply in carriages Least cable works No problems with overvoltage	Insulation of the return circuit!! Return circuit is taken out of the gauge Return circuit is not a real grounding
Equipotential – local earth	No insulation required (Quid border with certification according to General Regulation on Electrical Installations ? → Different curves touch voltages)	VLD required → Quid high short circuit currents ?

Remote control

1 – Pole 423: load switch (T-switch) controlled by the central energy dispatcher

2 – 230 V cabling until remote control box

3 – container with invertor



2

six parking places with charging stations

3

± 200 m

Outline

- Introduction
- Description of the system
- On site tests of the complete system
- Electromagnetic compatibility (EMC)
- Future developments
- Conclusion

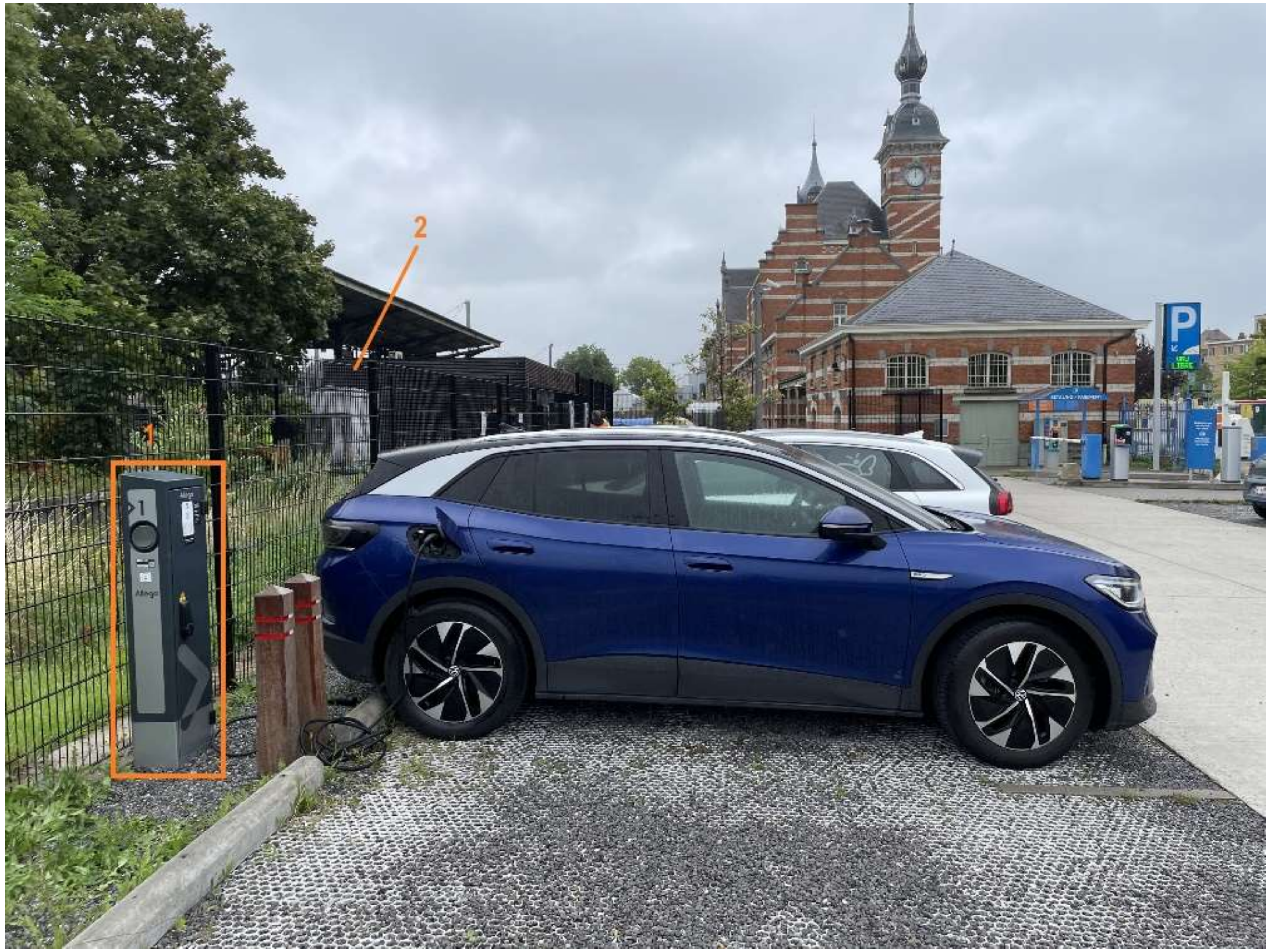
Let’s push the top button !

On site tests

1 – one of 3 Allego charging stations, 2 outlets for 11 kW

2 – container with invertor 3 kV DC / 3AC 400 V

Instability ID.4



On site tests

Stress test – 6 cars; 60 kW; 1,5 h

No stress !

Outline

- Introduction
- Description of the system
- On site tests of the complete system
- Electromagnetic compatibility (EMC)
  - Purpose of the measurements and methods
  - Track circuits, axle counters & electromagnetic fields
  - Instabilities & solution
- Future developments
- Conclusion

EMC - Purpose of the measurements

- important differences between feeding the charging installation from
  - a public distribution grid
  - the railway traction power supply system
- invertor = electric load on the overhead contact line ≈ rolling stock

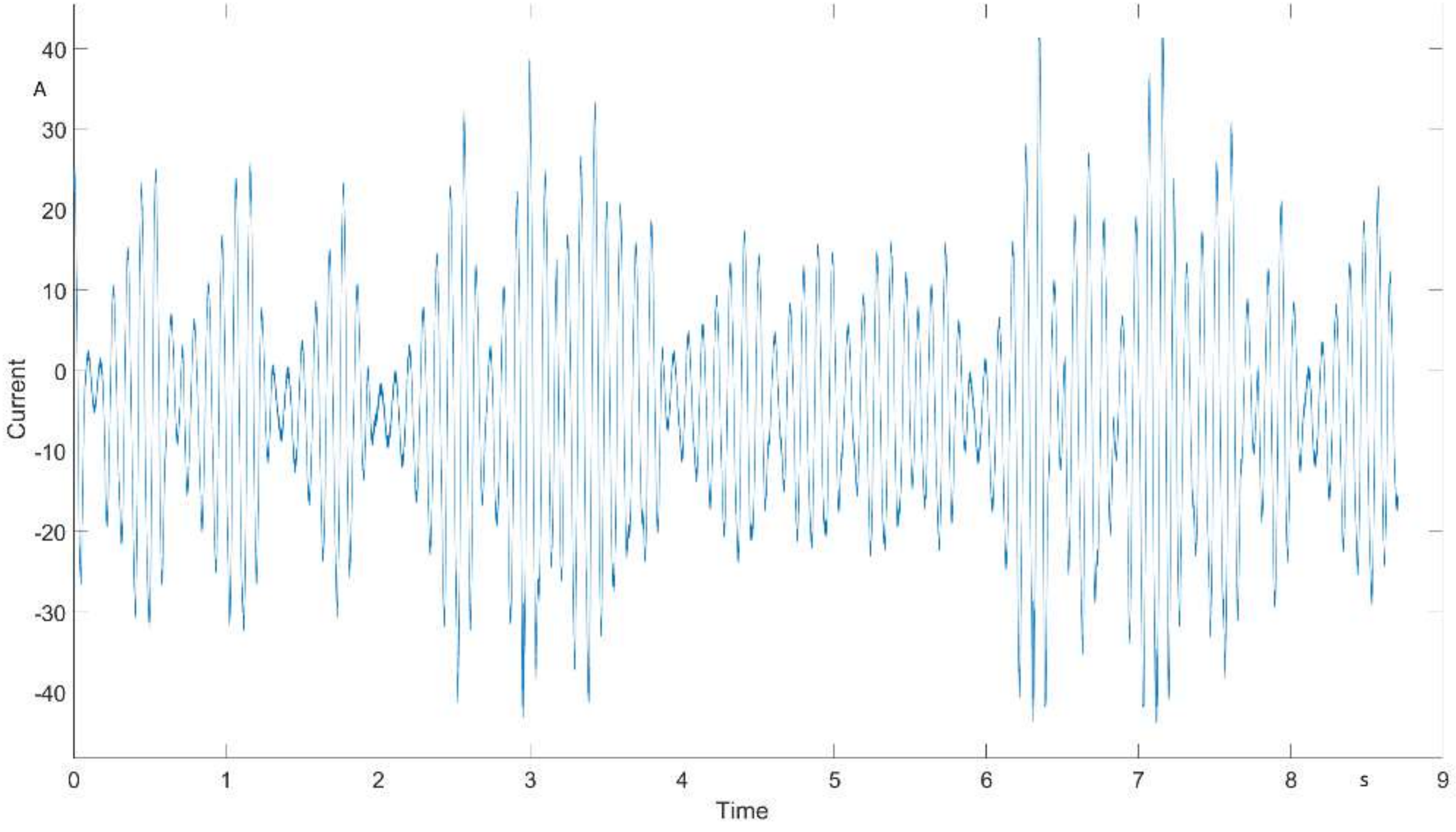
  → Requirements shall also be applied to the invertor

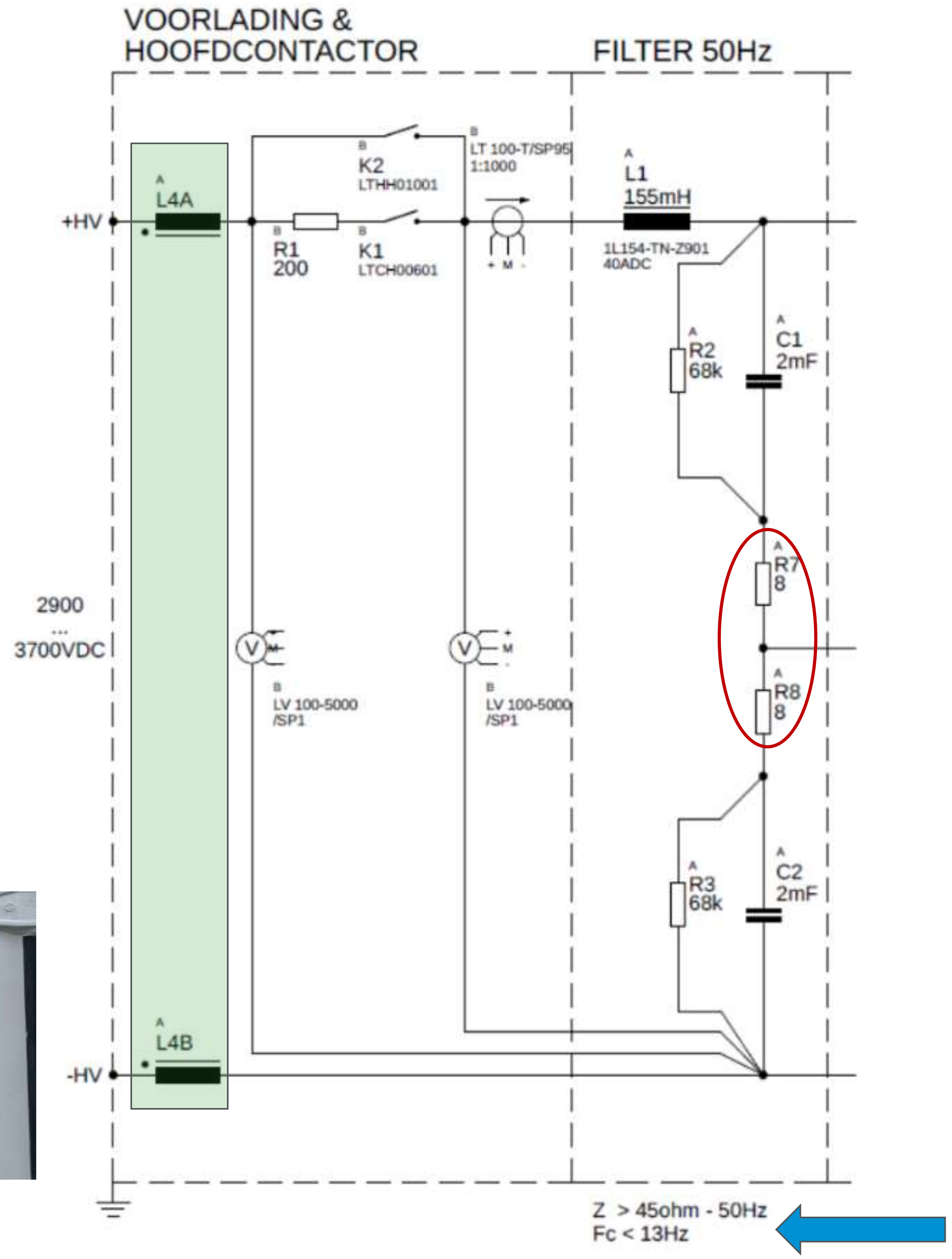
1. on the prototype in the SNCB workshop of Mechelen
2. after improving & finishing the invertor construction, integrating everything in the container, on site in Schaarbeek, Brussels

Solution charging instabilities

Resonance with ID.4 @ 11,5 Hz !

- current peaks of up to about 40 A
- strong ripple of up to 820 V peak-to-peak on the OCL voltage & short-term peak voltage of 3,83 kV > 3,8 kV (BE-limit; see Table 1, EN 50163:2004)





Outline

- Introduction
- Description of the system
- On site tests of the complete system
- Electromagnetic compatibility (EMC)
- Future developments
  - Challenges for future large-scale rollout on the railway network
  - Protection against short circuits
- Conclusion

Challenges for future large-scale rollout on the railway network

- train traffic shall never be affected negatively

- volume of charging infrastructure to be connected depends on:

SAFETY FIRST

1. safety first: protection against short circuits !
2. current carrying capacity (ampacity) of the OCL
3. nominal power of the transformer-rectifier groups in the substations
4. distances between substations

Protection against short circuits

t – time, $i(t)$ – current, di/dt – current derivative

1 and 1' – base load current I_0 of **500 A** before the short circuit occurs at 26 km

2 and 2' – base load current I_0 of **1500 A** before the short circuit occurs at 26 km

3 and 3' – base load current I_0 of **500 A** before the short circuit occurs at 15 km

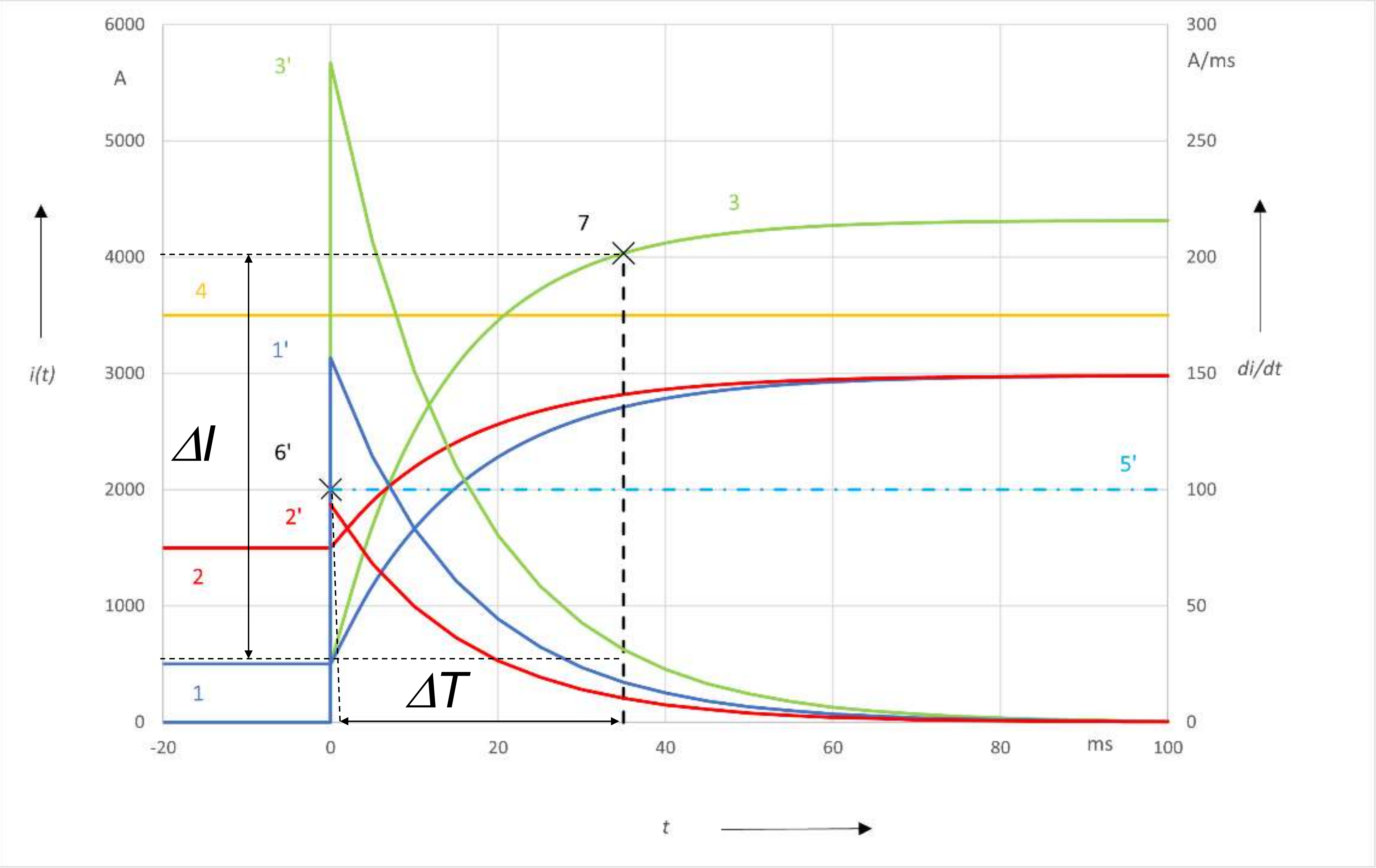
4 – I_{max} 3500 A

5' – D_1, threshold di/dt for starting detection

6' – start detection short circuit 3 (or 1, not 2 !)

7 – switching-off short circuit 3, at current value $I_0+\Delta I$ (500 A + 3533 A = 4033 A), after delay ΔT (approx. 35 ms)

calculated curves for short circuits occurring at t = 0 on a standard compound OCL labeled C1-TSI, with U_0 = 3450 V



Future developments

- **500 A** a safe target for 3 kV DC ?
  ±136 electric cars simultaneously on standard 11 kW slow AC chargers per feeding sector (± 20 km) and per track
- full potential of the traction power supply system only by **load balancing systems**

- DC-DC converters and AC-DC rectifiers: there is a market !

Conclusion ?

dcrps.

Perspective !

- combining efforts of INFRABEL, TUC RAIL & SNCB clearly demonstrates how the path to an **all-electric mobility** can look like
- motivation & inspiration for engineers of all ages and involved parties to innovate
- According to article 14 of EU-regulation 2023/1804 from 13th of September 2023, by **31 December 2024**, each Member State shall prepare and transmit to the European Commission a **draft national policy framework** for the development of the market as regards **alternative fuels in the transport sector and the deployment of the relevant infrastructure**
- **railway sector-wide collaboration** between infrastructure managers, train operators, suppliers and contractors

INTERNATIONAL UNION
OF RAILWAYS

CHARGING OF E-BUSES OF THE PUBLIC TRANSPORT COMPANY MIVB/STIB ON RAILWAY AUXILIARY POWER SUPPLY SYSTEM

Sam BREUGELMANS
Senior Design Engineer, T-ENE

UIC EV charging, storage and rail grid, 19 November 2024

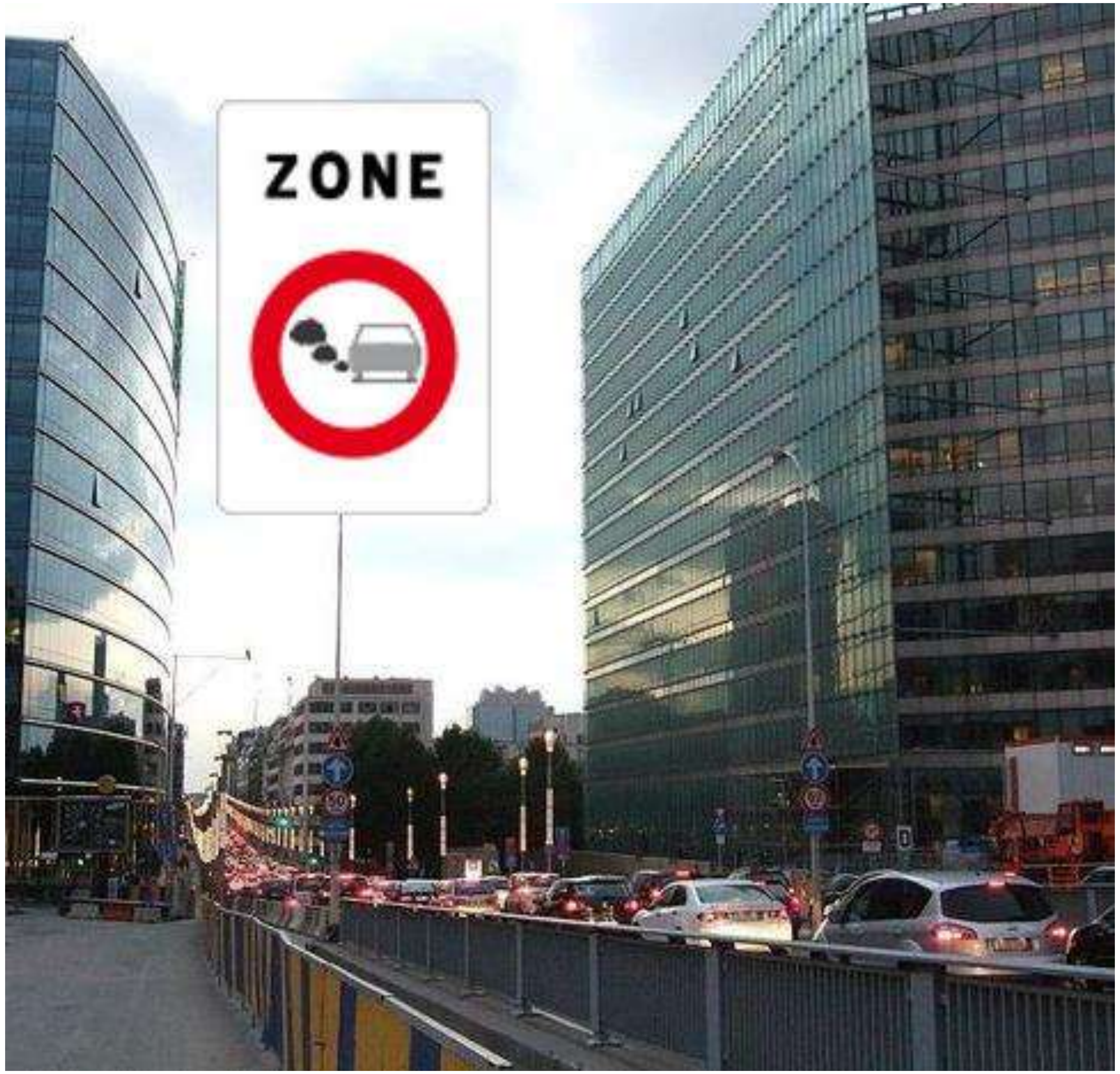
Railway tunnel Brussels North-South

Railway tunnel Brussels North-South: smoke extraction system

Railway tunnel Brussels North-South: smoke extraction system

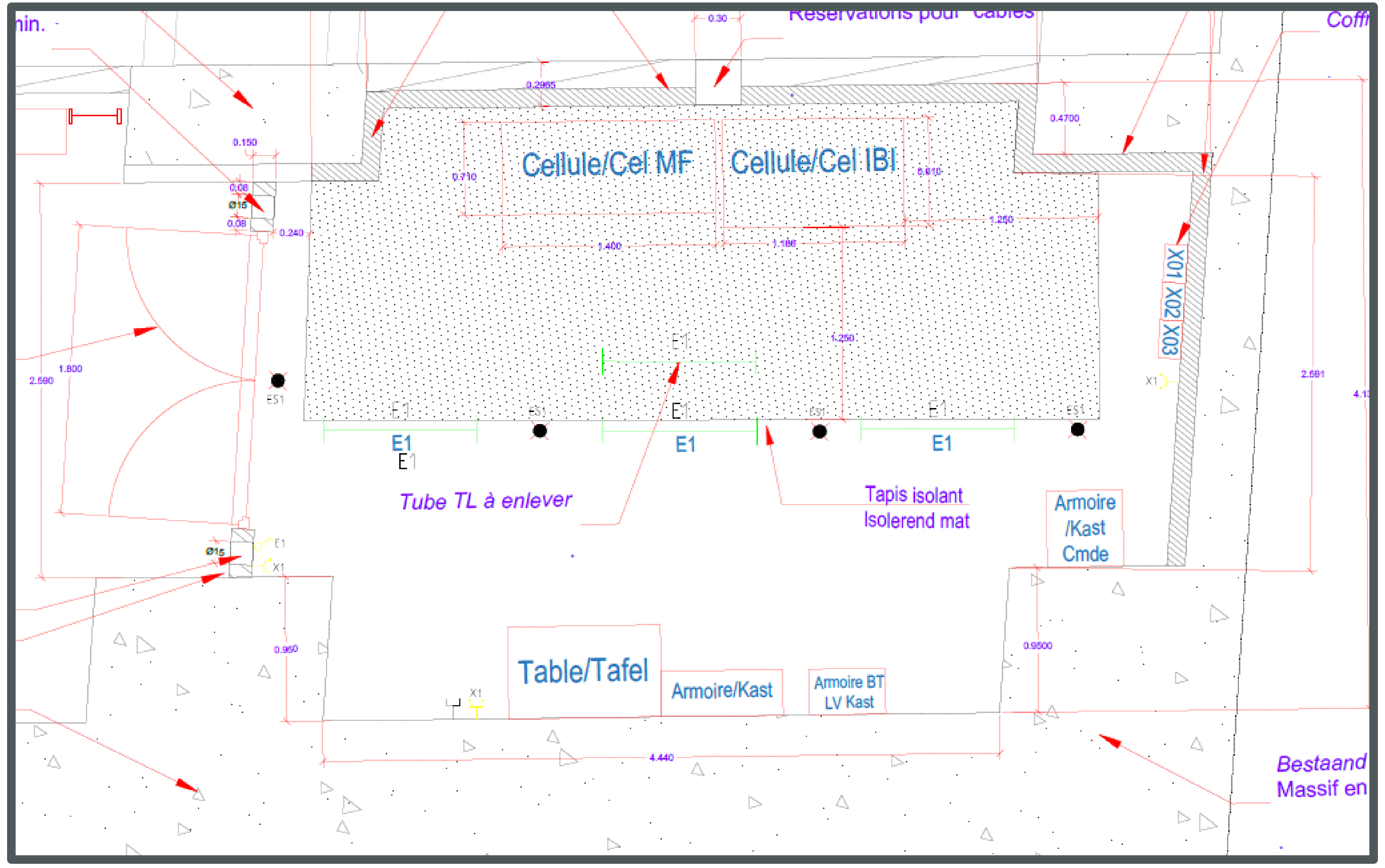
Infrabel 3x11kV network

Roll-out of E-Buses in Brussels



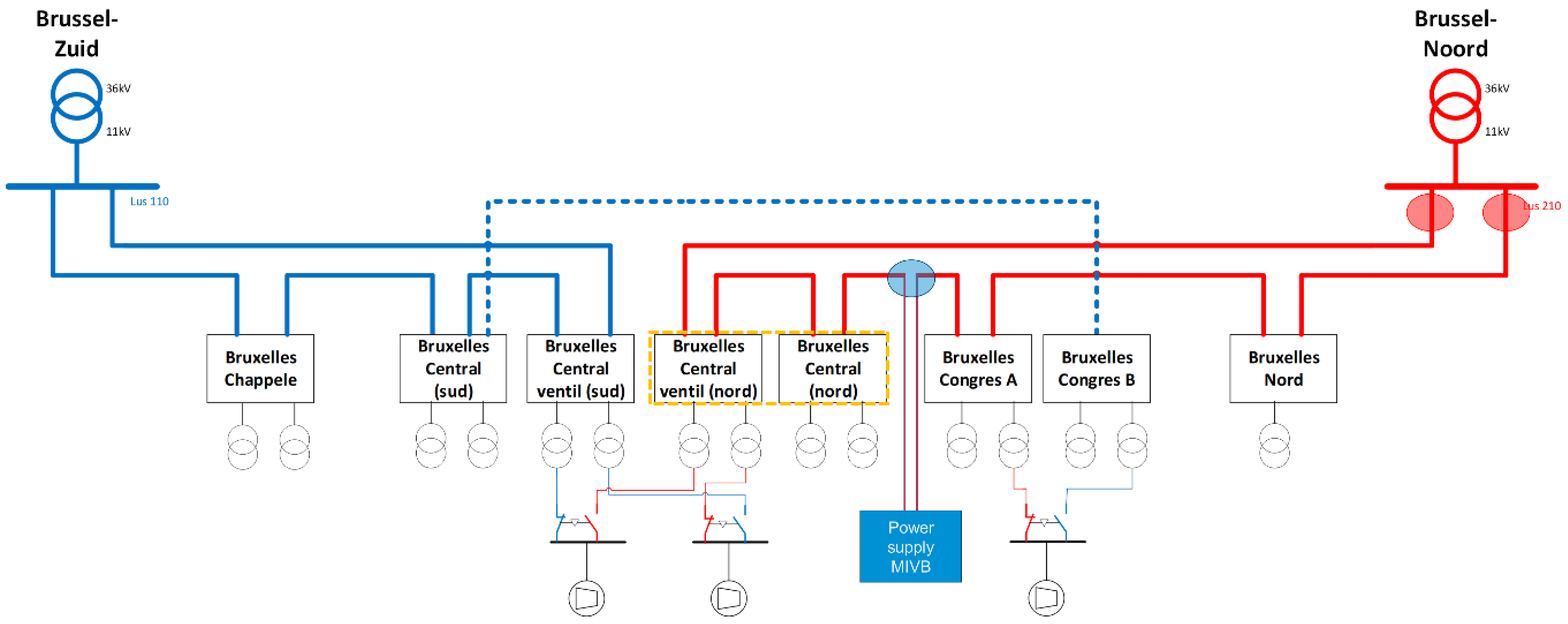
Legal framework

Infrabel 3x11kV network



Infrabel 3x11kV network: power supply MIVB

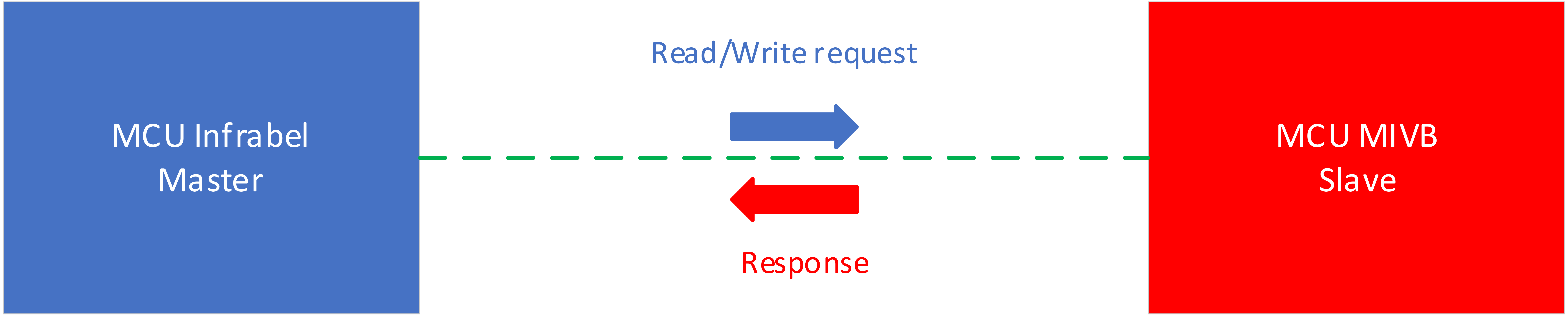
- Feeding fire protection system → remains priority!
- Load balancing based on power consumption on MV grid
- If power consumption on grid increases above limit → signal to reduce power
- Safety system opens circuit breaker if bus chargers don't reduce their power



Load balancing based on power consumption

Modbus communication of power limit

- Modbus protocol with register list was established to exchange data



Planning

- Testing: September 2025
- In service: End 2025

When we bring together the right resources and expertise, one plus one equals three

INTERNATIONAL UNION
OF RAILWAYS

Thank you
for your attention

Sam Breugelmans
Senior Design Engineer
M +32 490 65 09 59
sam.breugelmans@tucrail.be

Paul Tobback
Expert
M +32 477 47 13 04
paul.tobback@tucrail.be

Workshop timeline

10:00	Welcome Introduction	UIC/Chairs
10:10	GUW+: Smart substation	Alstom
10:30	SmartCharging4Trains - Linking Battery Trains & EV Charging	Siemens
10:50	Using the Flexibility of Traction Batteries for the Railway Grid	SBB
11:10	Charging E-machines and trucks (railway excavators) at substation Vught	ProRail
11:30	Charging electric vehicles	TucRail
11:50	Questions / discussion Closing remarks	All

Panel discussion
Questions and answers

Alstom

Siemens

SBB

ProRail

TucRail

UIC

INTERNATIONAL UNION
OF RAILWAYS

Media to be made available on the event page

Thank you
for your attention

Philippe Stefanos
Sustainability – Energy & emissions advisor
Stefanos@uic.org

Credits:
Workshop funded and proposed by the:

UIC ENERGY&CO_2 Sector

Co-organised by UIC & the Sector's chairs:

Gerald Olde Monnikhof, ProRail
Denzel Collins, NR

Philippe Stefanos, UIC