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Hybrid Energy Storage Systems at Siemens Mobility Division

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Ingenuity for life

Siemens has an innovative history – Rail Systems are electric driven since more than 130 years

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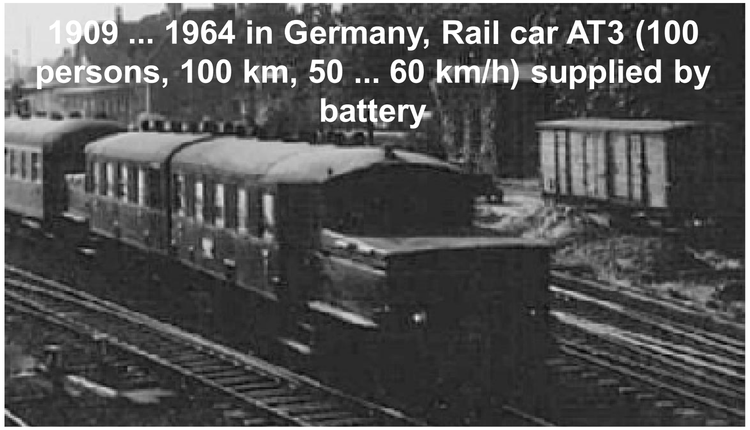
1879-05-31 in Berlin, Germany
130 V DC supplied by middle rail



1909 ... 1964 in Germany, Rail car AT3 (100 persons, 100 km, 50 ... 60 km/h) supplied by battery

1881-05-16 in Lichterfelde (Berlin)
180 V DC supplied by both rails

1930 ... 1961 in Germany, Shunter (90 t, 210 kW, 40 km/h) supplied by catenary and battery

Agenda

Why hybridization of energy storage systems?

Worldwide first application for HES-system – QEC project

Development and Engineering of energy storage systems at Siemens Mobility Division

Why hybridization of energy storage systems?

High capability for power transfer and high energy content of Energy Storage Systems (ESS) are necessary to fullfil operational requirements

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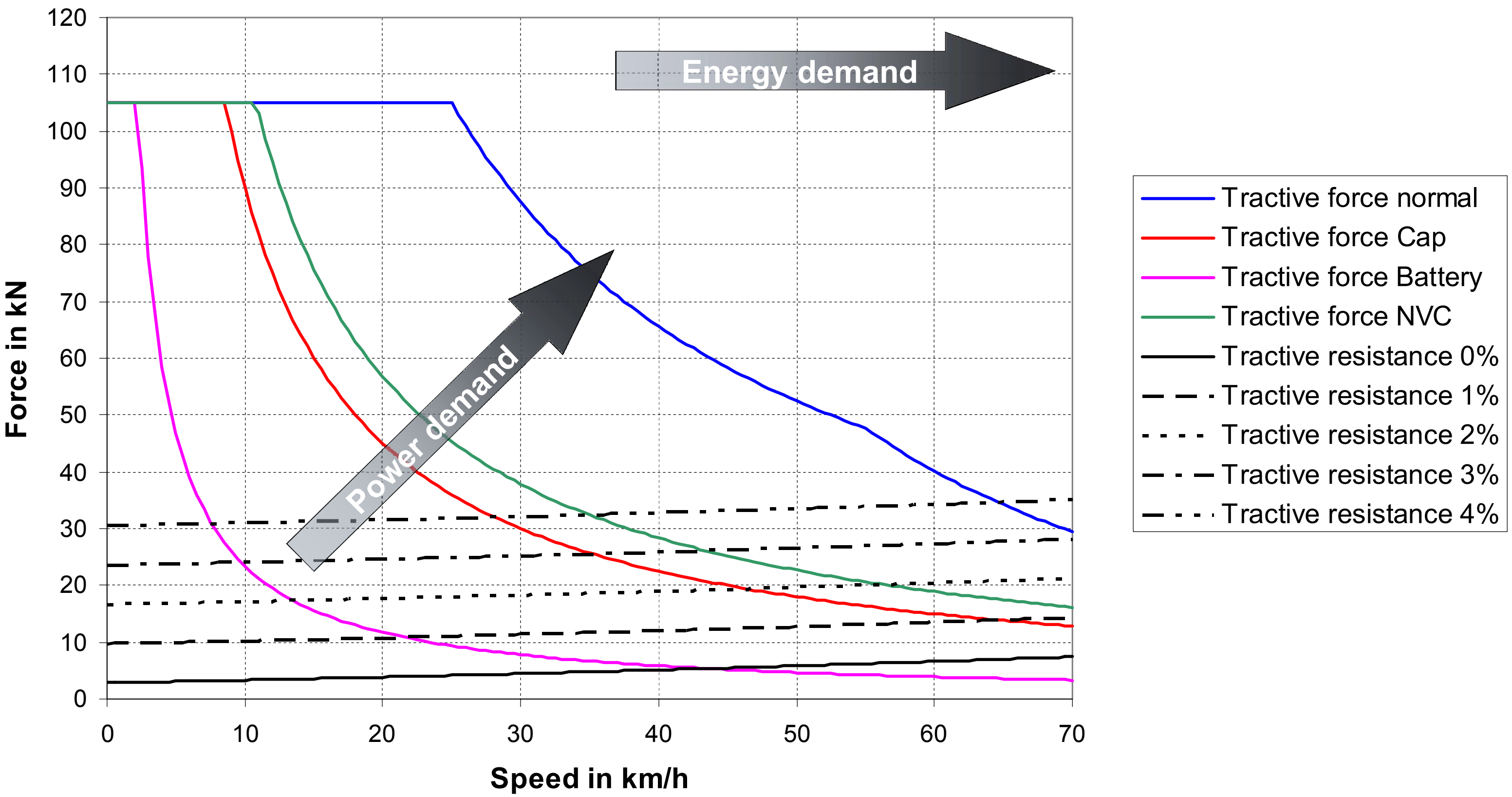

Hybrid-ESS installed on tram's roof at depot of customer MTS (Lisbon)

Why hybridization of energy storage systems?

The specific parameters for energy-efficient operation and operation w/o OCL are in an other range compared to the automotive sector

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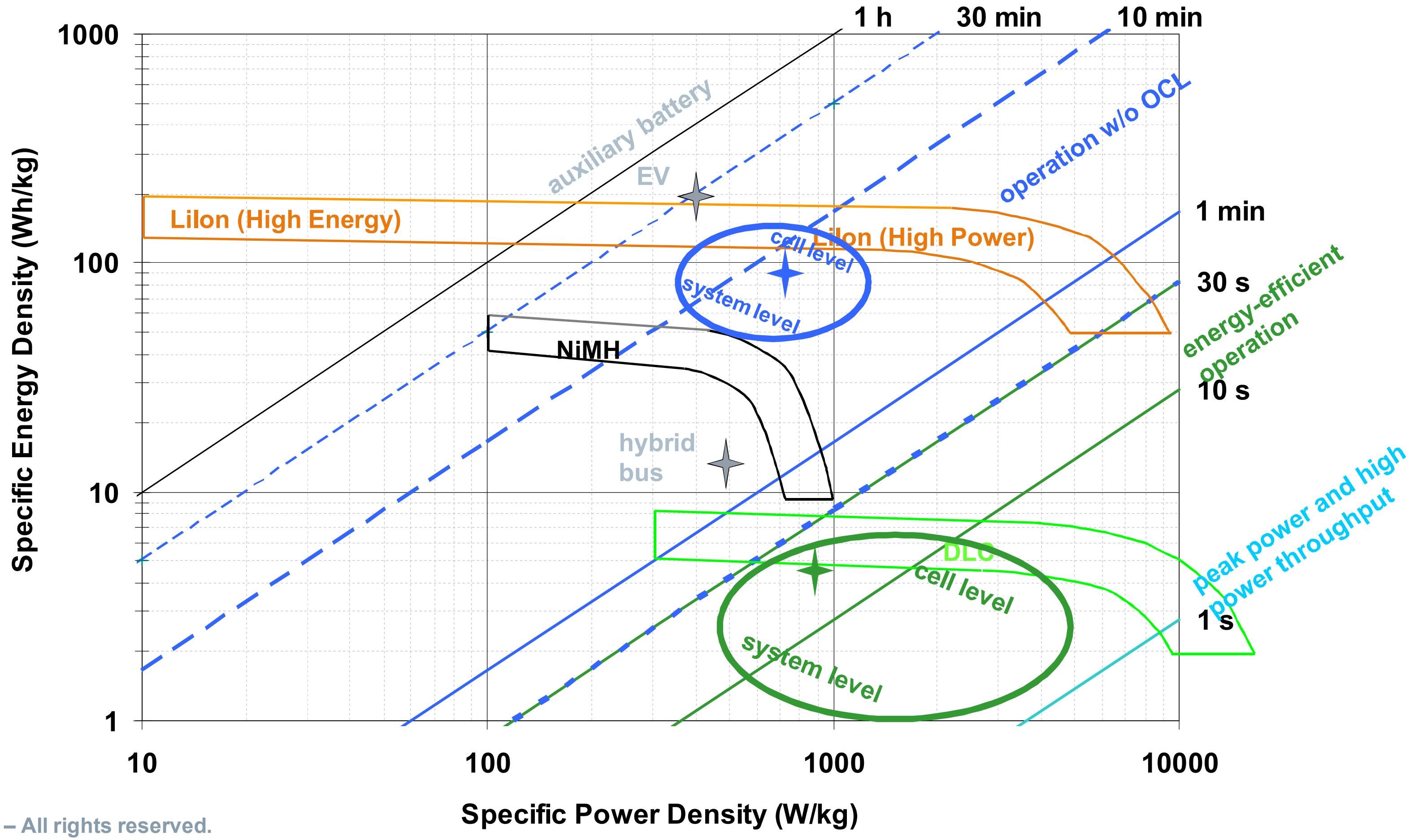

HES (Hybrid ESS) is the complementary combination of benefits

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Double-Layer Capacitors (DLC)

DLC-units ensure highest performance and short charging times

water-cooled DLC-module

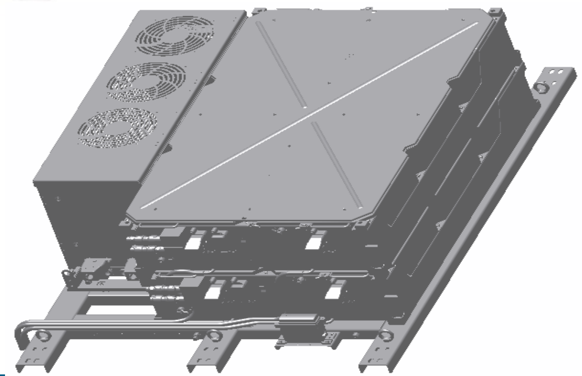
DCL-containers

High performance batteries

Batteries provide highest energy capacity for longer travelling time without overhead contact line as well as unexpected stops

water-cooled lithium ion battery module

battery-container with chiller



Agenda

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Why hybridization of energy storage systems?

Worldwide first application for HES-system – QEC project

Development and Engineering of energy storage systems
at Siemens Mobility Division

Project overview about Qatar Education City – People Mover System

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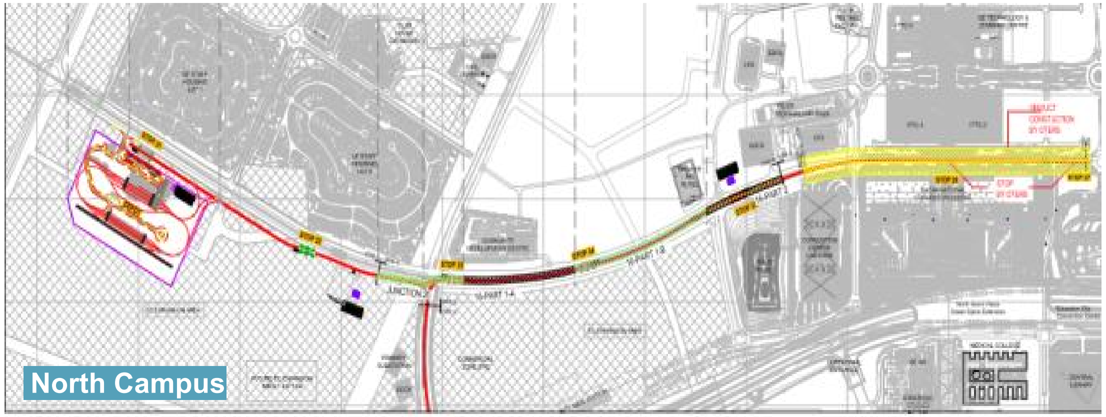
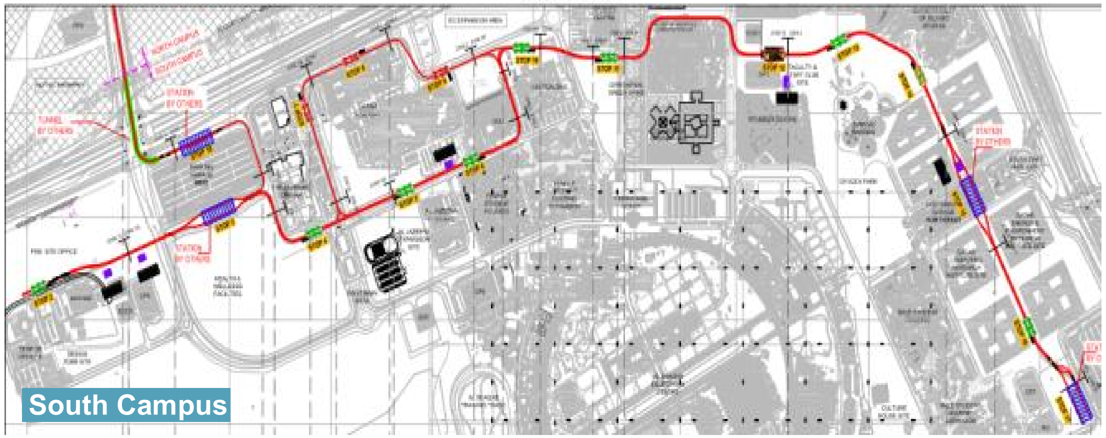




Customer	Qatar Foundation
Contract awarded	May 16, 2012
Route length	Approx. 12 km
Number of stations/stops	4 + 20
Vehicles	19 Avenio trams with Hybrid Energy Storage System
Operation mode	On-sight operation
Planned completion: North Campus	2017
Planned completion: South Campus	2017/2018

Worldwide first application for HES-system – QEC project

“Through the desert without catenaries“ – Special features of this project

First rail project in Qatar

High standards of design and architecture:
QEC is an expression of the future vision of Qatar

Catenary free operation between stations / stops

Use of a new HES-system

High climatic requirements

- Daily temperatures over 50°C
- High humidity
- High dust load
- Occasional heavy rain

High safety requirements

Siemens: operation and maintenance for 3 years

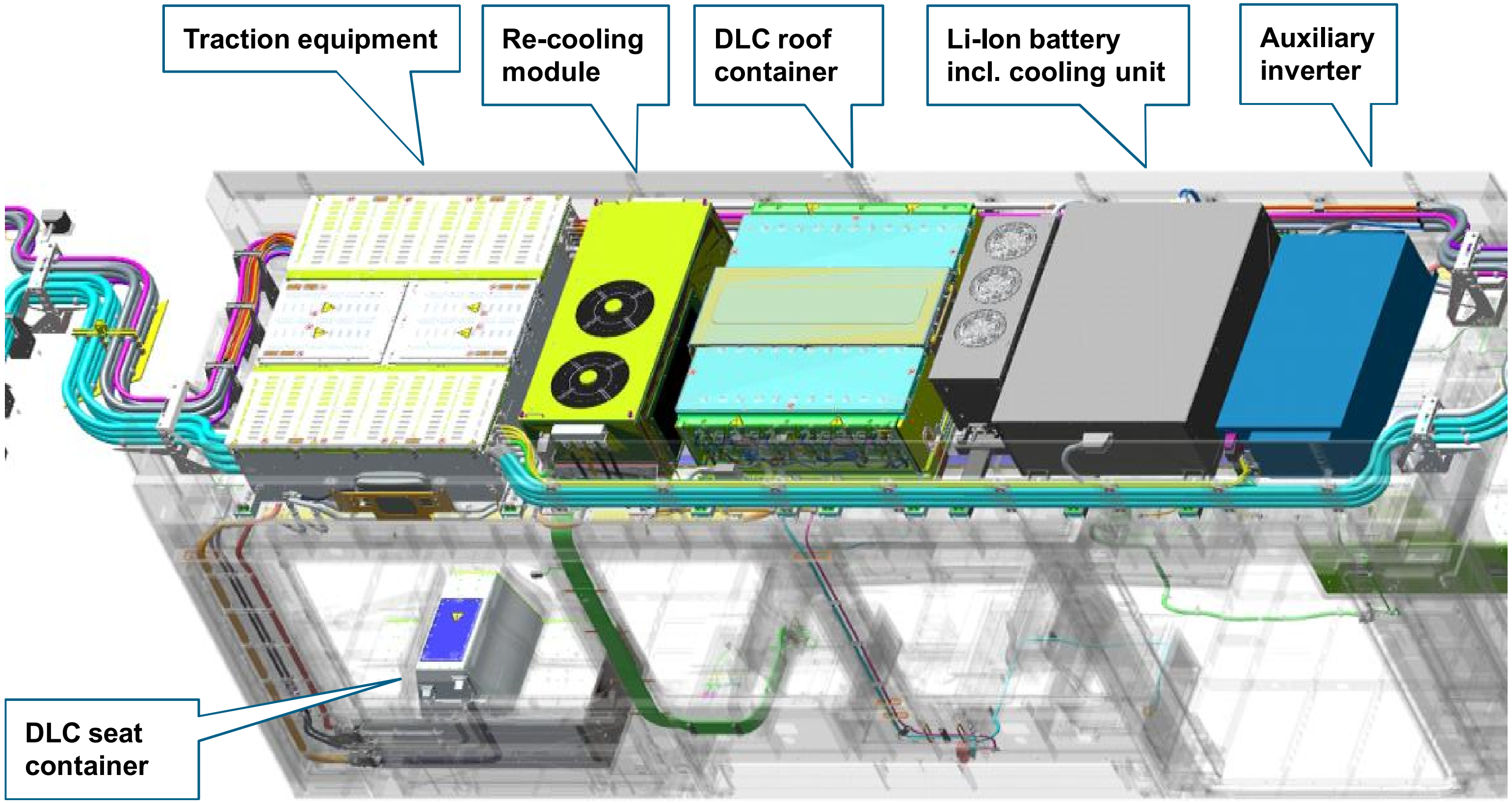
Worldwide first application for HES-system – QEC project

Avenio: 100 % low floor tram

Number of vehicles	19 vehicles
Year of delivery	2015 - 2016
Configuration	3 cars (bi-directional operation)
Wheel arrangement	Bo' 2' Bo'
Vehicle length	27,700 mm (over coupling)
Vehicle width	2,550 mm
Gauge	1,435 mm
Capacity (4 P/m²)	165 incl. 56 seats/3 tip-up seats
Floor height	350/435 mm
Special features	Adaptation to climatic conditions; Vehicle for fully catenary-free operation; WiFi and Infotainment; 3 double doors each side

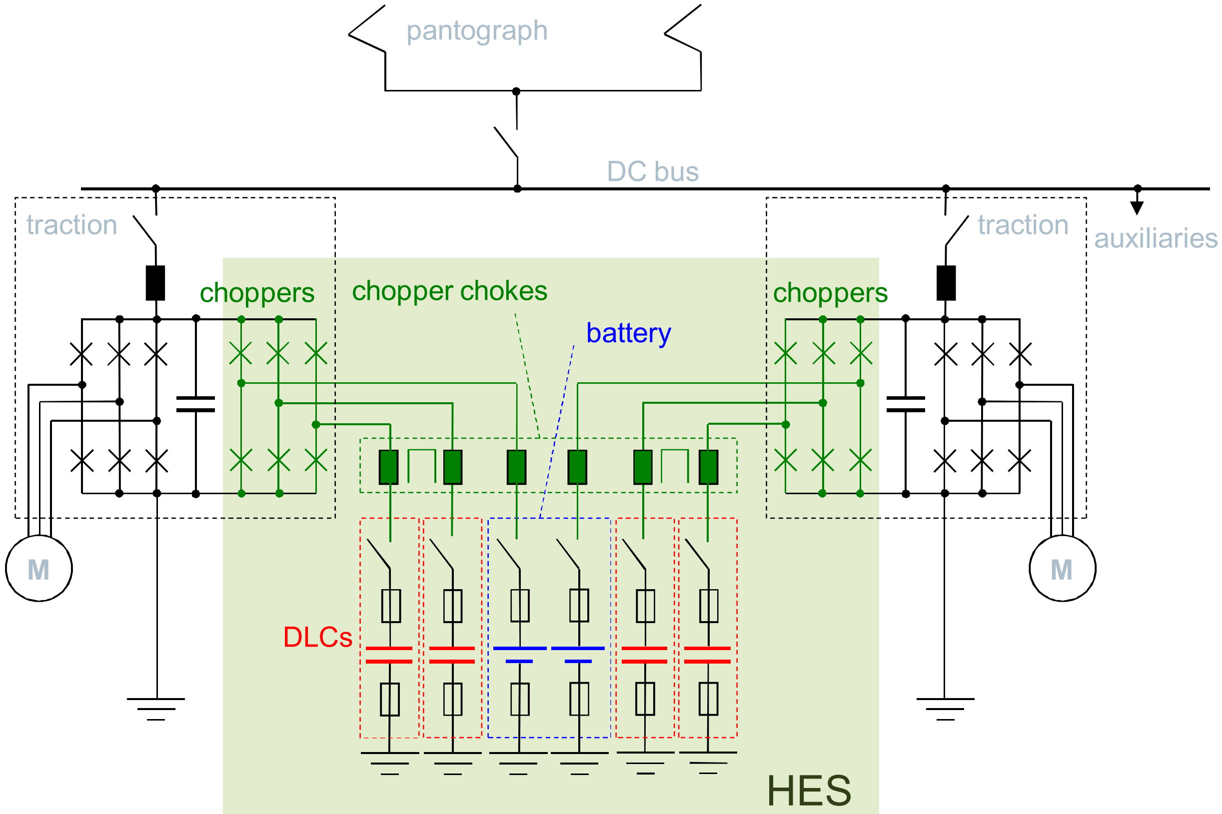
Worldwide first application for HES-system – QEC project

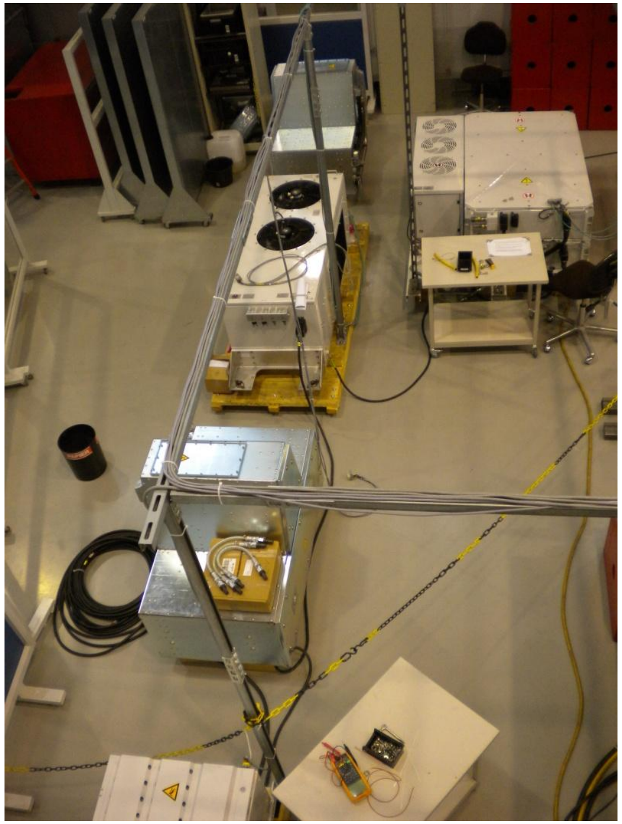
Technical implementation on the middle car



Worldwide first application for HES-system – QEC project

Traction electric circuit diagram and system test



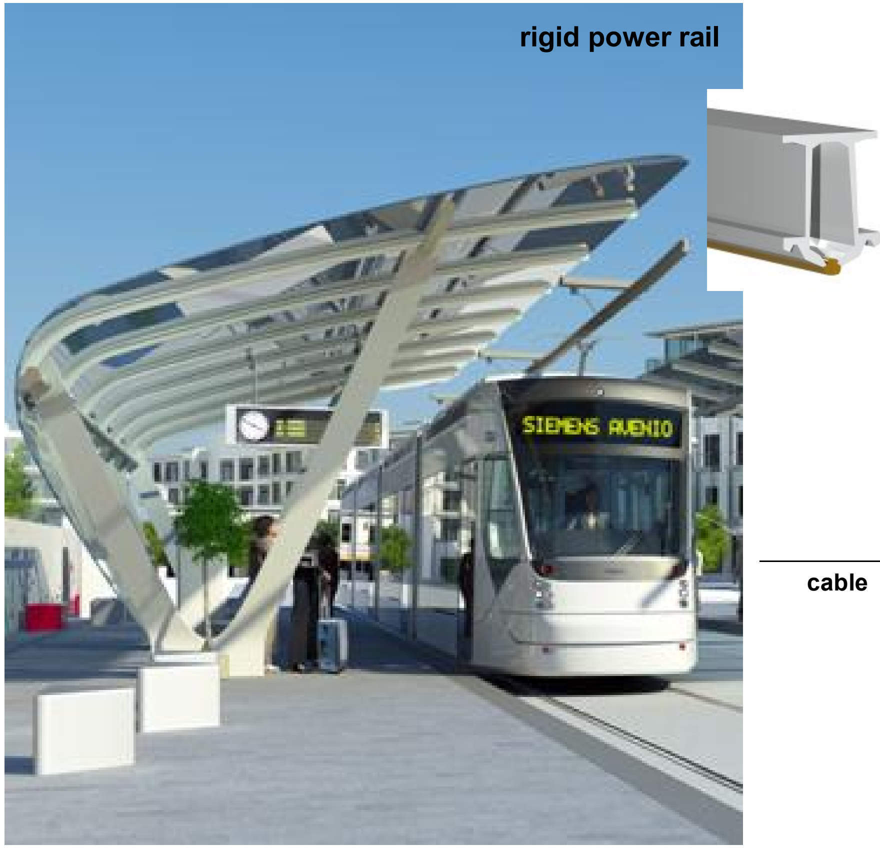


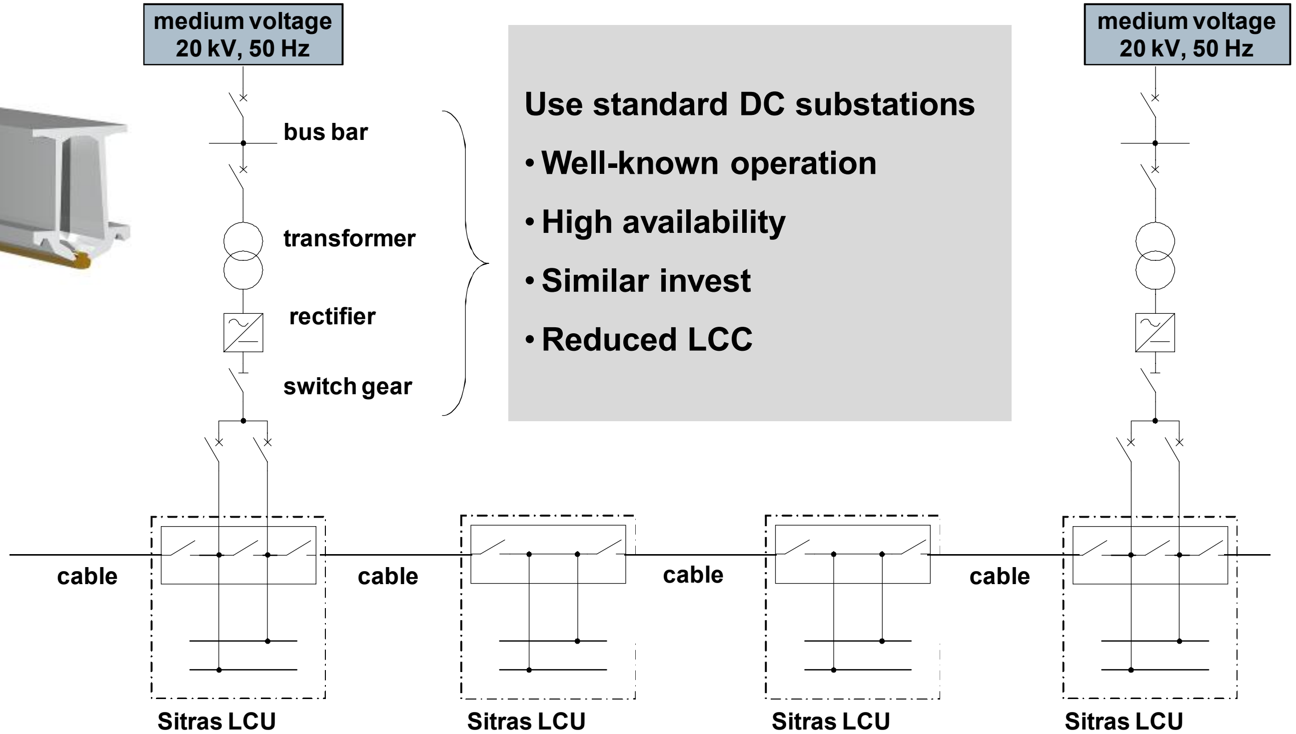
Worldwide first application for HES-system – QEC project
Principle for operation of Non-Visible Contact line (NVC)

- Trams run without overhead contact line between stations (typical distance of 300 … 500m)
- The tram is supplied by hybrid energy storage system and/or local charging units and/or overhead contact lines
- At local charging units (in stations) the energy storage system is recharged within the dwell time of 20 s
- The rigid conductor rail is used recharging of the hybrid energy storage system when the panto has its mechanical contact, especially for tram's acceleration
- The local charging units are passiv (DC 750 V)

Design parameter

Worldwide first application for HES-system – QEC project
Circuit diagram of Local Charging Unit (LCU)





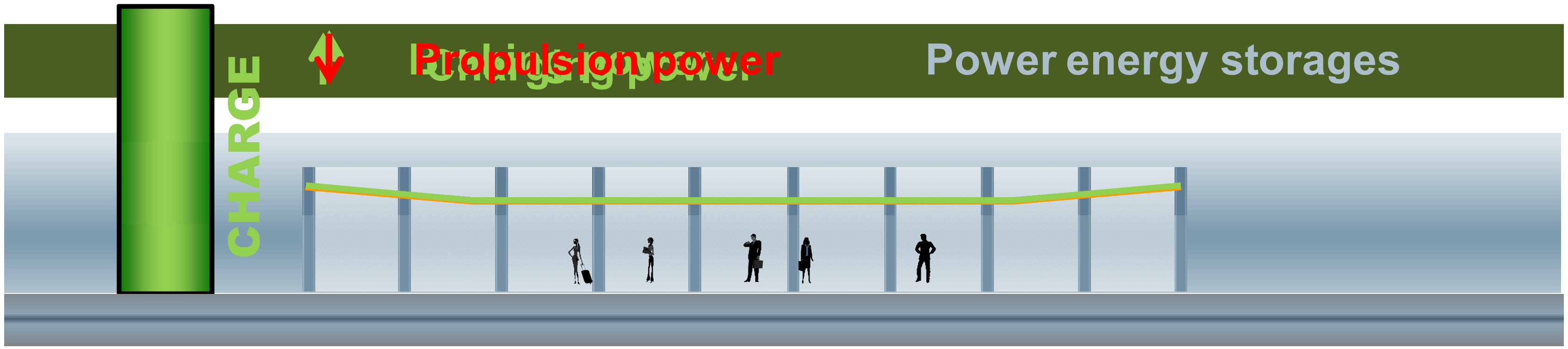
Use standard DC substations

- **Well-known operation**
- **High availability**
- **Similar invest**
- **Reduced LCC**

replace catenary with cables and charging units only

Worldwide first application for HES-system – QEC project
Charging Principles as smart but simple design

- NVC is designed considering the use of well-known components/subsystems and their electrical and mechanical interactions based on intelligent interface management
- Use of ramps for a smooth contact between conductor rails and pantograph
- Automatic energy flow control / optimization by predicted operation to avoid arcs
- No „intelligence“ in charging stations



Worldwide first application for HES-system – QEC project

Simulated example of energy usage @ EOL

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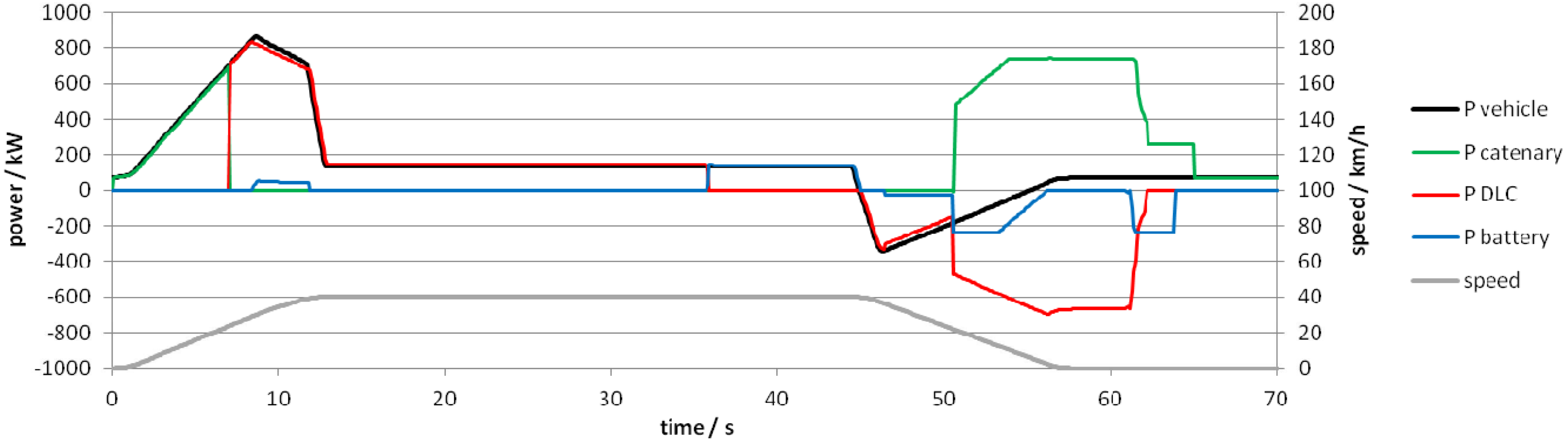


Energy balance for

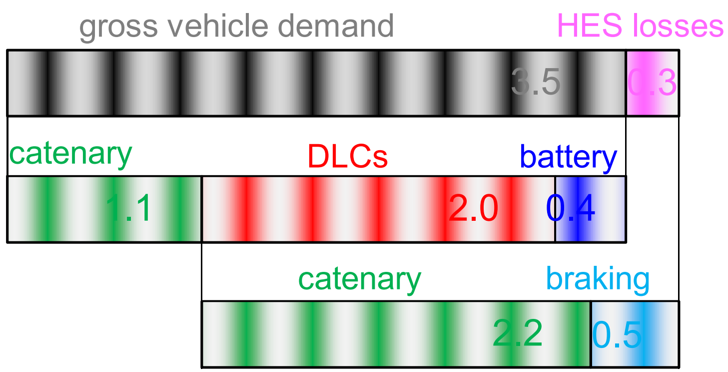
500 m trip

@ 70 kW aux. power

energy demand

supplied by…

recharged from…



Worldwide first application for HES-system – QEC project
Balanced design for load cycles and emergency scenario

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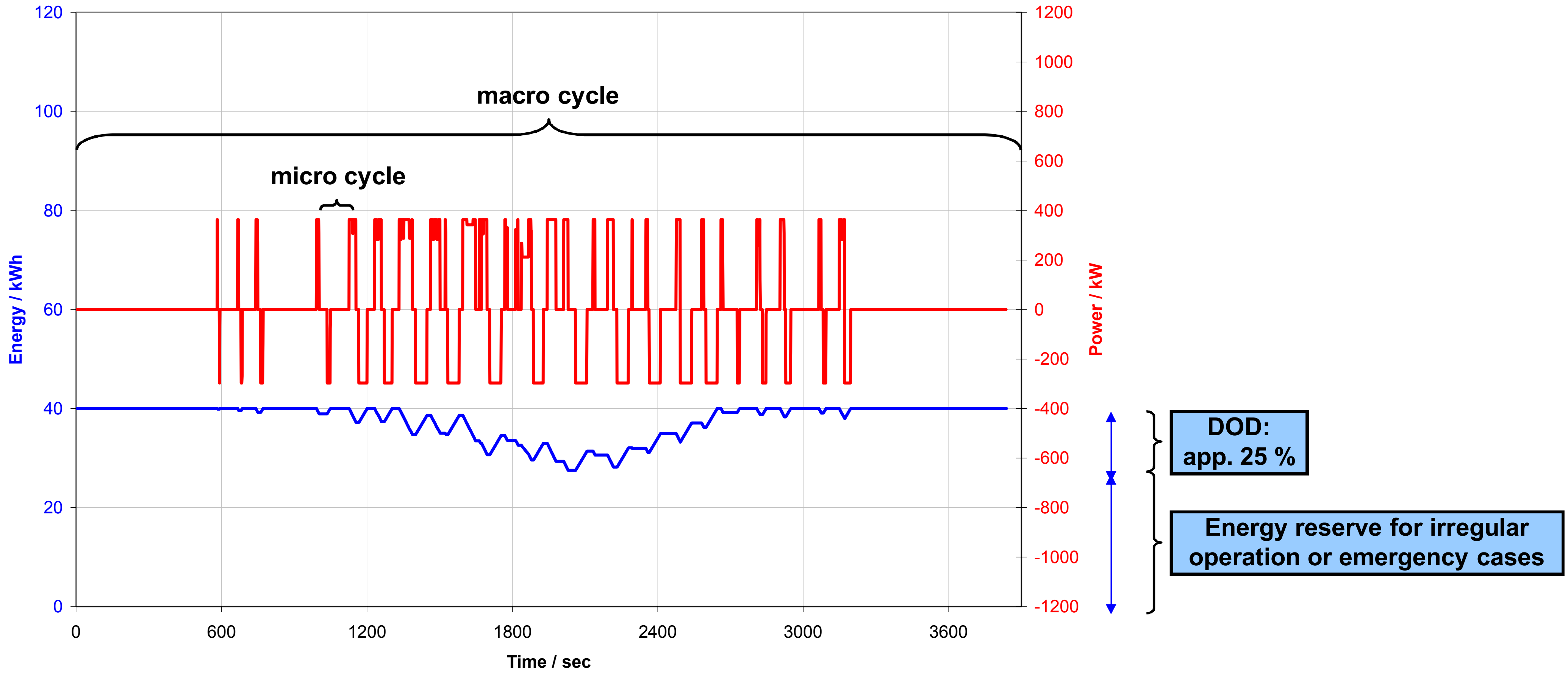
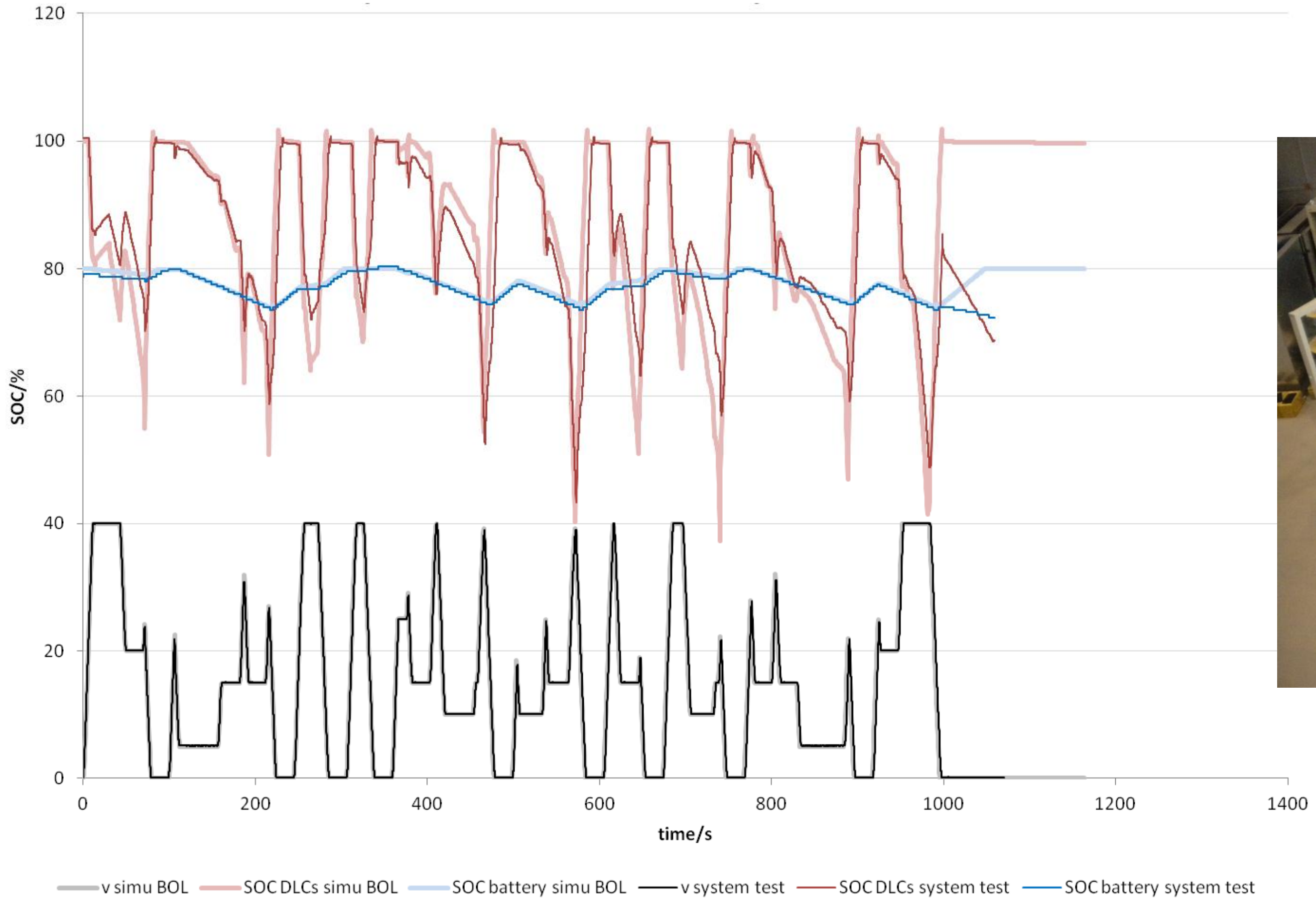
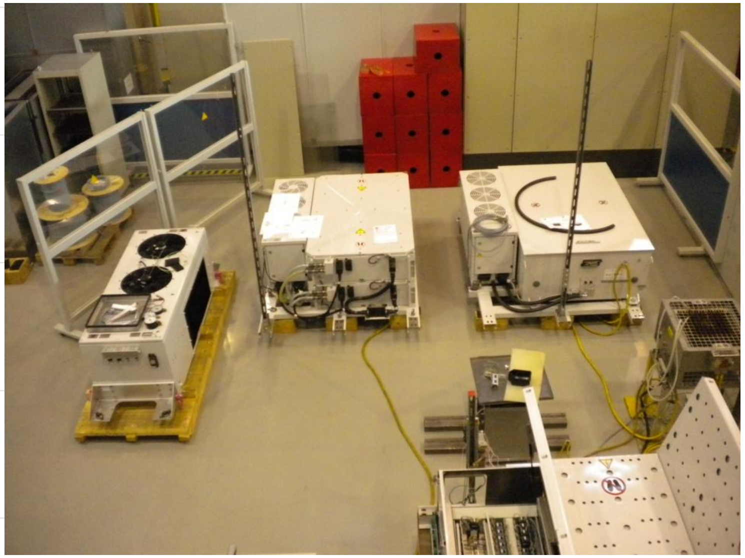


Worldwide first application for HES-system – QEC project
Comparison of calculation and measurement is proven





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Worldwide first application for HES-system – QEC project

Development and Engineering of energy storage systems
at Siemens Mobility Division

Development and Engineering of ESS

A continuous development allows the use of ESS in railway applications

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Technology-Scouting	**1999 – 2001:**	**BMBF-Study ALTAS (Alternative traction systems)** **➔ Recommendation of electric energy storage unit**
R&D-projects	**2001 – 2006:**	**Development and Test of electric energy storage unit** **➔ Recommendation of prototyping at customer‘s site**
	2007 – 2016:	**Hybrid Energy Storage System installed on a tram south of Lisbon and supervision for „lessons learnt“**

Creation of Products	• Sitras MES / HES	Double-layer capacitor / combination with traction battery
	• Sitras ESM 125	Core element for mobile and stationary ESS
	• Sitras SES	Stationary ESS for mass transit
	• Sitras LCU	Local charging unit, galvanic contact
Synergies due to other R&Ds	• RailEnergy	EU-funding, Definition of duty cycles for main line
	• EnergyCap	BMWi-funding, Doubling of energy density
	• CleanER-D	EU-funding, SP7 Hybridization for diesel-driven main line, Simu-Tool
	• Osiris	EU-funding, Definition of duty cycles for mass transit, traction battery

Market development

- Presentations for customers and press (Rollout) in Lisbon
- Support for sales department
- Conferences, fairs, publications and trainings (RailAcademy, extern)
- Expert within two standardizations on IEC-level (series hybrid, Lithium Ion traction batteries)

Development and Engineering of ESS

HES in operation since 2008 in Lisbon, Portugal

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Only the combination of capacitors and traction batteries

- ➢ **provides highest availability and flexibility for a tram system without catenary**
- ➢ **is able to cover all emergency situations**

The recovery and storage of braking energy results in

- ➢ **20 % less energy consumption and**
- ➢ **hence 20 % less CO2-emissions**

Development and Engineering of ESS

Knowledge of over 15 years will be used for upscaling and adaption of ESS for other application fields

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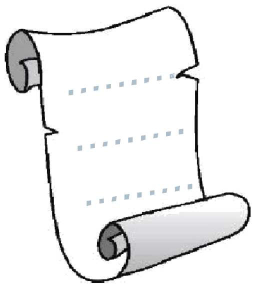
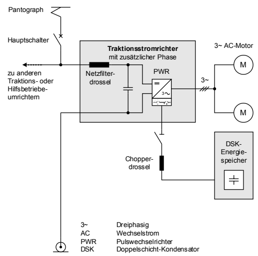
Market success | **2012 – 2016f:** | **Project QEC, Doha:**
1st complete tram system worldwide for operation w/o overhead contact line and HES

market's requests and definition of product → concept and design → realization and prototype → system's integration and tests → verification and production → sales and market





2014 – 2016f: **Due to sustainable engineering the knowhow transfer for further application fields is ensured by repetitive steps**

Development and Engineering of ESS

Energy and power density of traction batteries were sustainably increased

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2009 NiMH

- 1 x 0.52 x 1.67 m³
- 825 kg + 75 kg
- 18 kWh
- +105 / -12 kW

2015 LiIon

- 1.2 x 0.67 x 1.7 m³
- 1040 kg + 60 kg
- 45 kWh
- +190 / -190 kW

Increase at nearly similar costs, improved cooling and full redundancy

1. Energy density
   - volumetric (kWh/m³) ca. 60 %
   - gravimetric (kWh/kg) > 100 %
2. Power density
   - discharging (kW/kg) ca. 50 %
   - charging (kW/kg) ca. 1200 %

Knowhow transfer took place for bus and truck applications succesfully

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2014 eHighway, Li-Ion

- 120 kWh
- 300 kW
- Onboard charging: DC 750 V, output power 320 kW
- Offboard charging: 3 AC 400 V, output power 10 kW or 20 kW

2015 Airport, Li-Ion

- 85 kWh
- Onboard charging: 3 AC 400 V to DC 700 V, output power 14 kW
- Offboard charging: DC 700 V, output power 30 kW or 60 kW

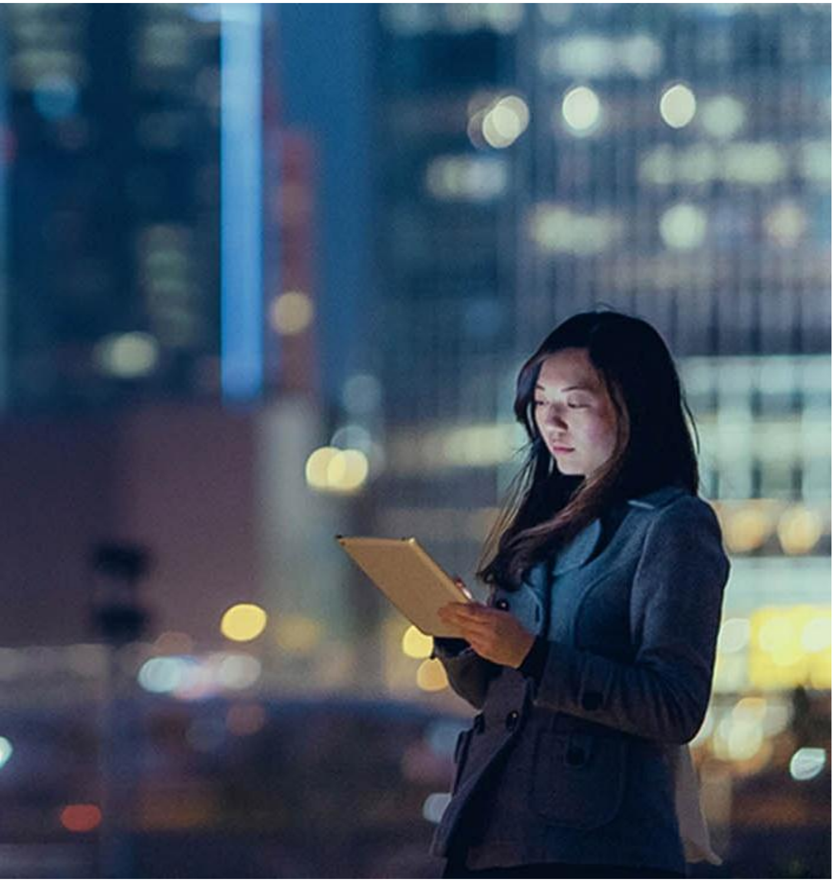
2016/17 Charger HPCC 2.0 for eBus

- Modular output power: 150, 300 … 600 kW
- Output voltage: DC (0) 250 … 750 V
- Flexible input: e.g. 3 AC 400 V to 20 kV, as well as DC 700 V

„Great ideas need landing gear as well as wings.“

C. D. Jackson (1902 – 1964)

Contact



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