energy efficiency increase of electrical local transport systems

recognise opportunities – evaluate effects

IT15.rail

Institut für Bahntechnik GmbH
Dipl.-Ing. (FH) Martin Jacob

agenda

1. motivation
2. load flow of electrical railway power supply systems
3. co-simulation tool for holistic system analysis
4. energy efficiency increase by network optimization
5. project example
6. conclusion

motivation

electrical energy may be generated from renewable resources

➔ traffic shall be powered by electrical energy

energy expense is a significant part of operating expense for operators

vehicle manufacturer and operator focus on energy efficiency increase

target: to control future energy cost

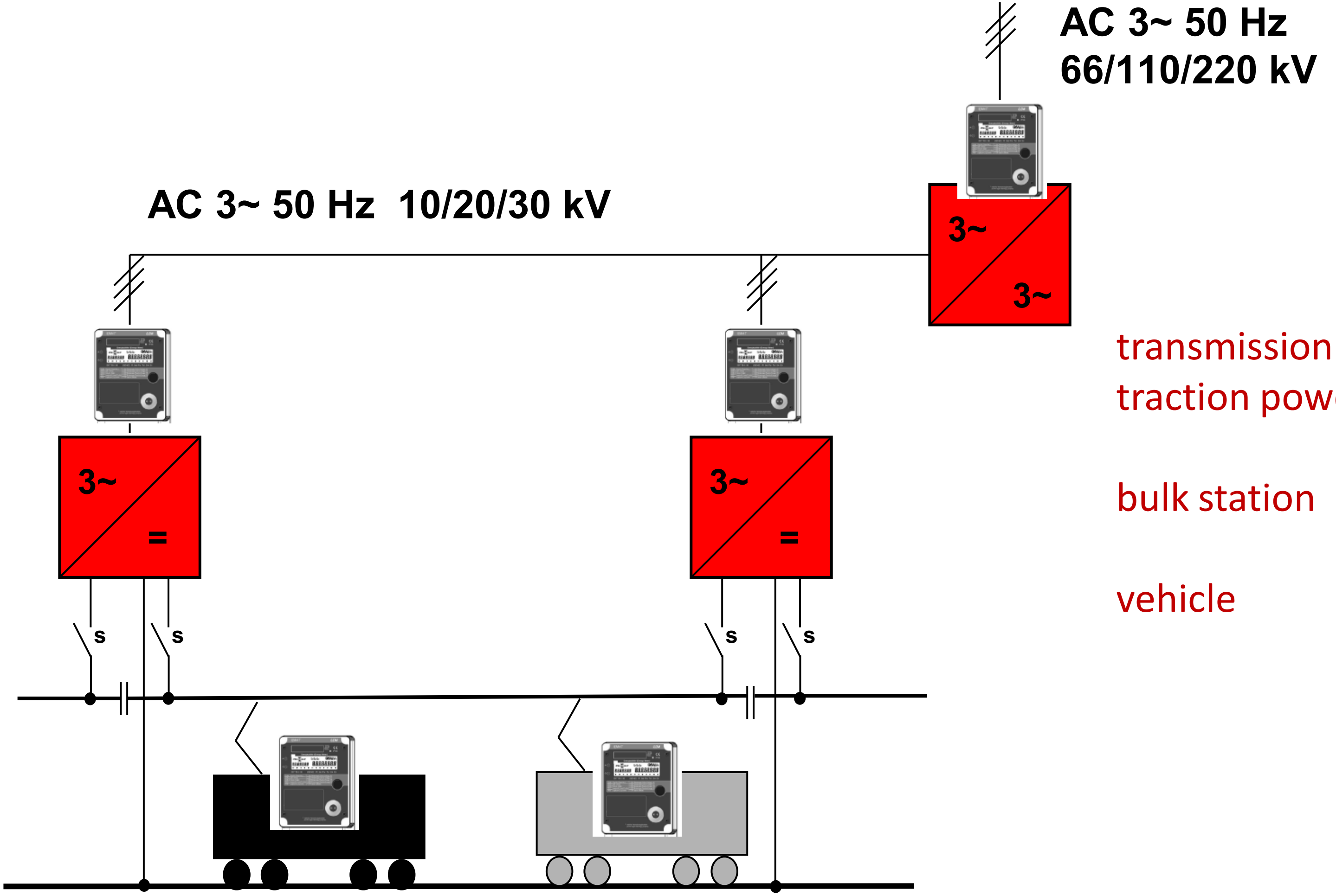
main target:

minimise energy consumption of transport

➔ optimisation on component level

➔ optimisation on system level (holistic approach)

Where is the billing?



transmission network at traction power substation

bulk station

vehicle

agenda

1. motivation
2. load flow of electrical railway power supply systems
3. co-simulation tool for holistic system analysis
4. energy efficiency increase by network optimization
5. project example
6. conclusion

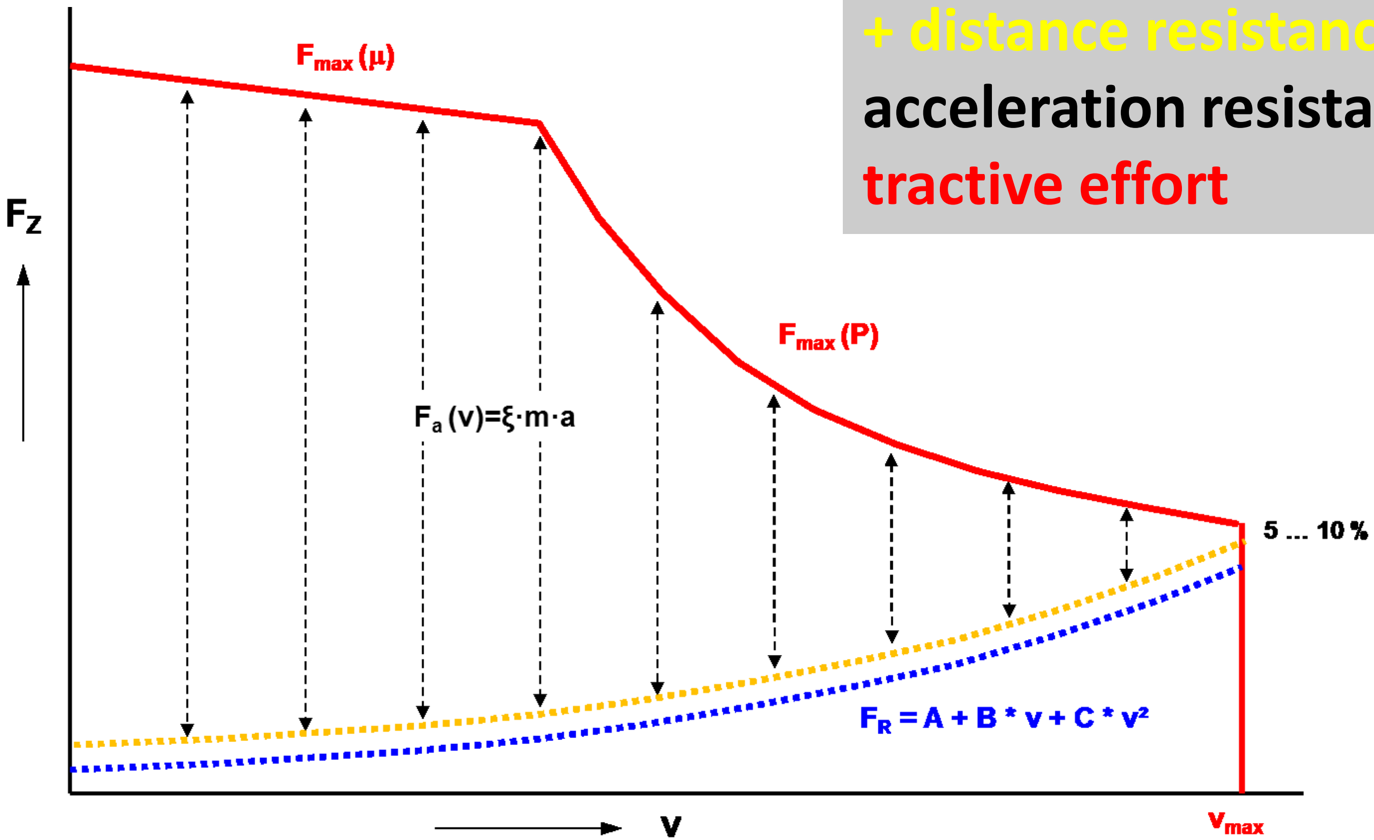
Where does the power demand come from?

rolling resistance

+ distance resistance

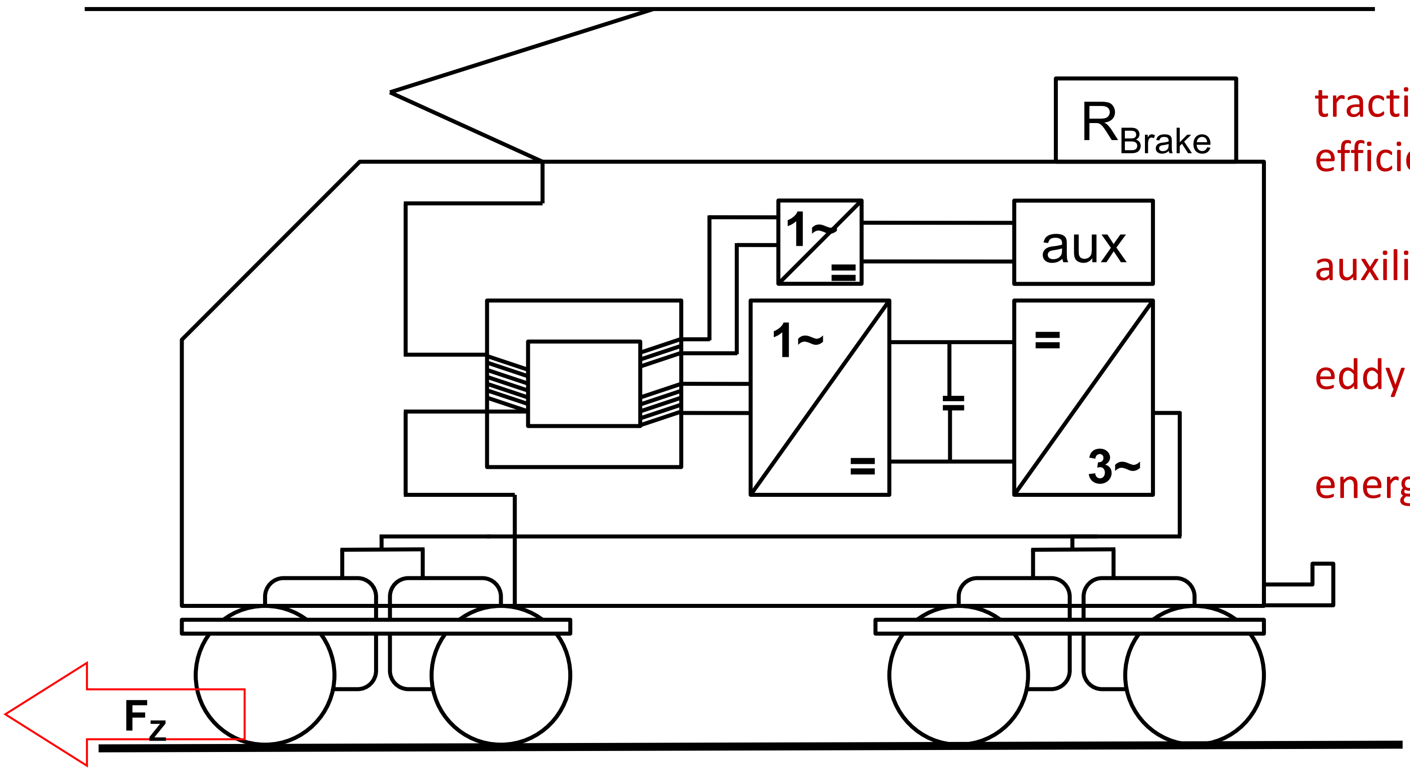
acceleration resistance

tractive effort



Institut für Bahntechnik GmbH

Where does the power demand come from?



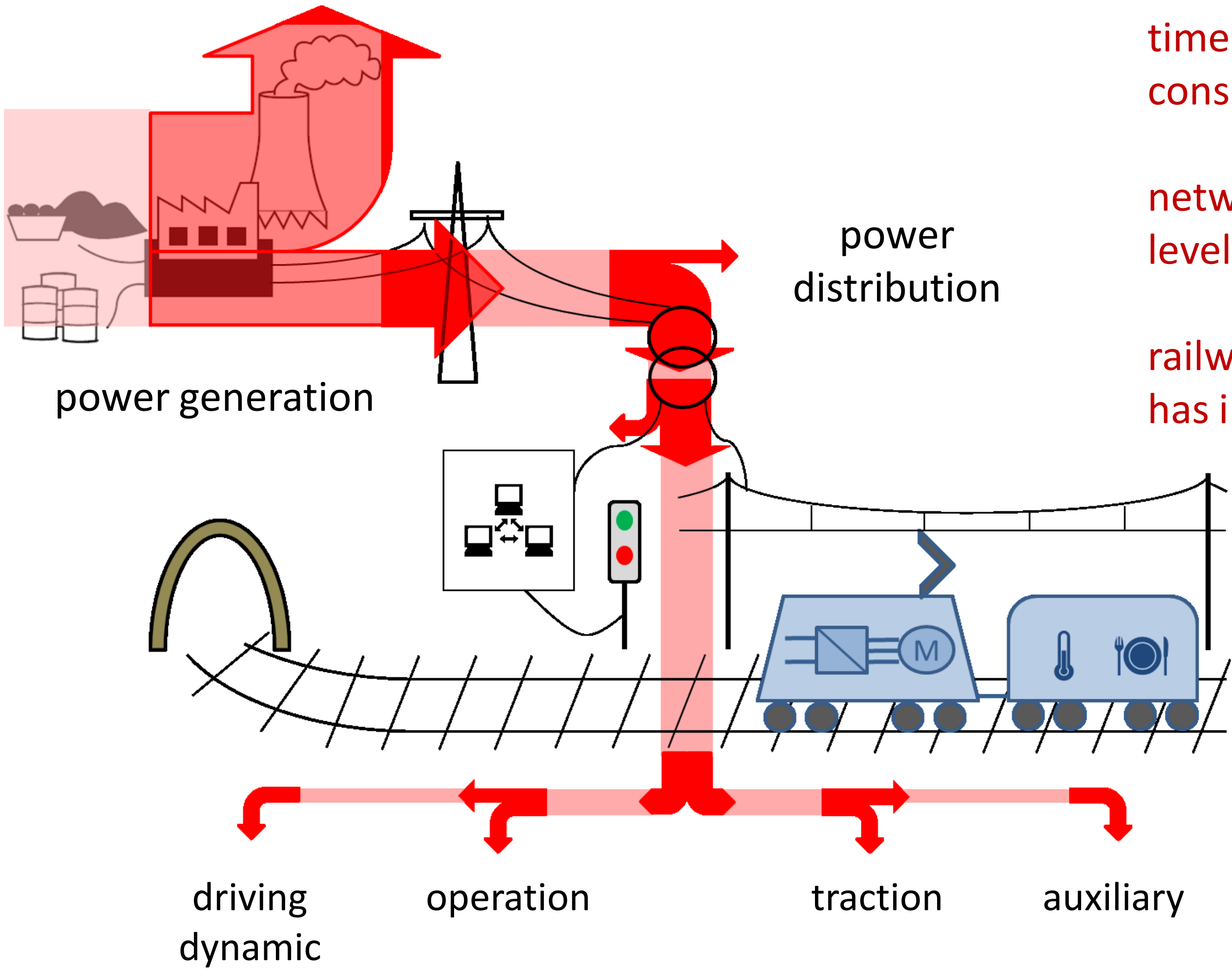
traction component efficiency

auxiliary power

eddy current break

energy storage (DC)

Where does the power demand come from?



time and position dependent consumers

network structure and voltage level controls the load flow

railway power supply system has impact on energy demand

Where does the power demand come from?

low **line voltage** affects the vehicle traction

- increasing currents and losses with decreasing line voltage
- current, respectively power limitation, at low voltage ➔ increased travel time
- limited energy recovery due to maximum line voltage limitation (no energy absorption by the network)

retroactive effects have to be considered during simulation

- at AC less important due to usually stable line voltage
- at DC it is mandatory due to high voltage fluctuation

simulation of railway power supply systems require simultaneous information of the following physical processes:

- driving state of each train and power demand
- position of all vehicles within the electrical network
- structure and installed capacity of the railway power supply system

agenda

co-simulation tool for holistic system analysis

Railway Operation Simulation

OPENTRACK

"Co-Simulation"

Interaction

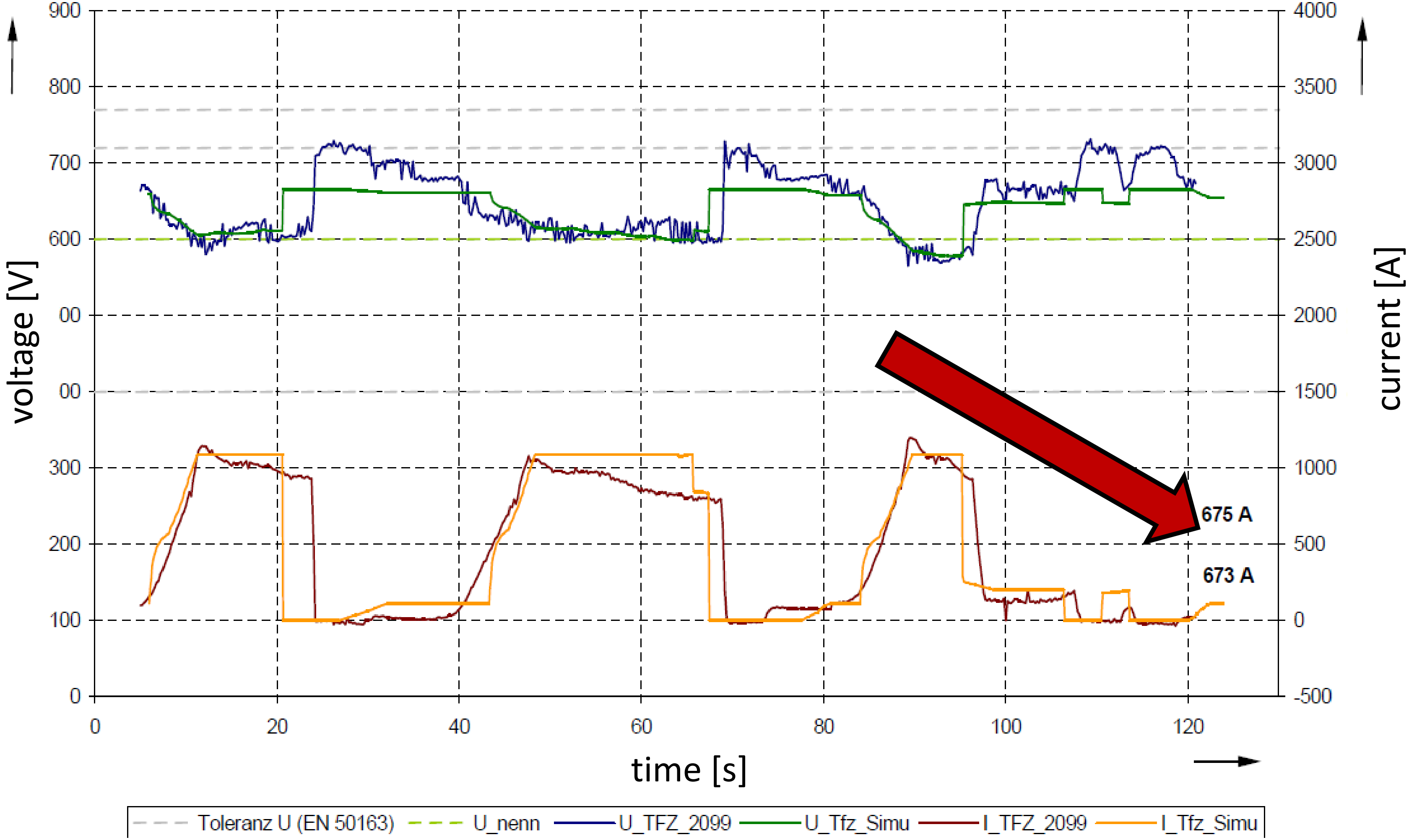
Load Flow Simulation

OpenPowerNet

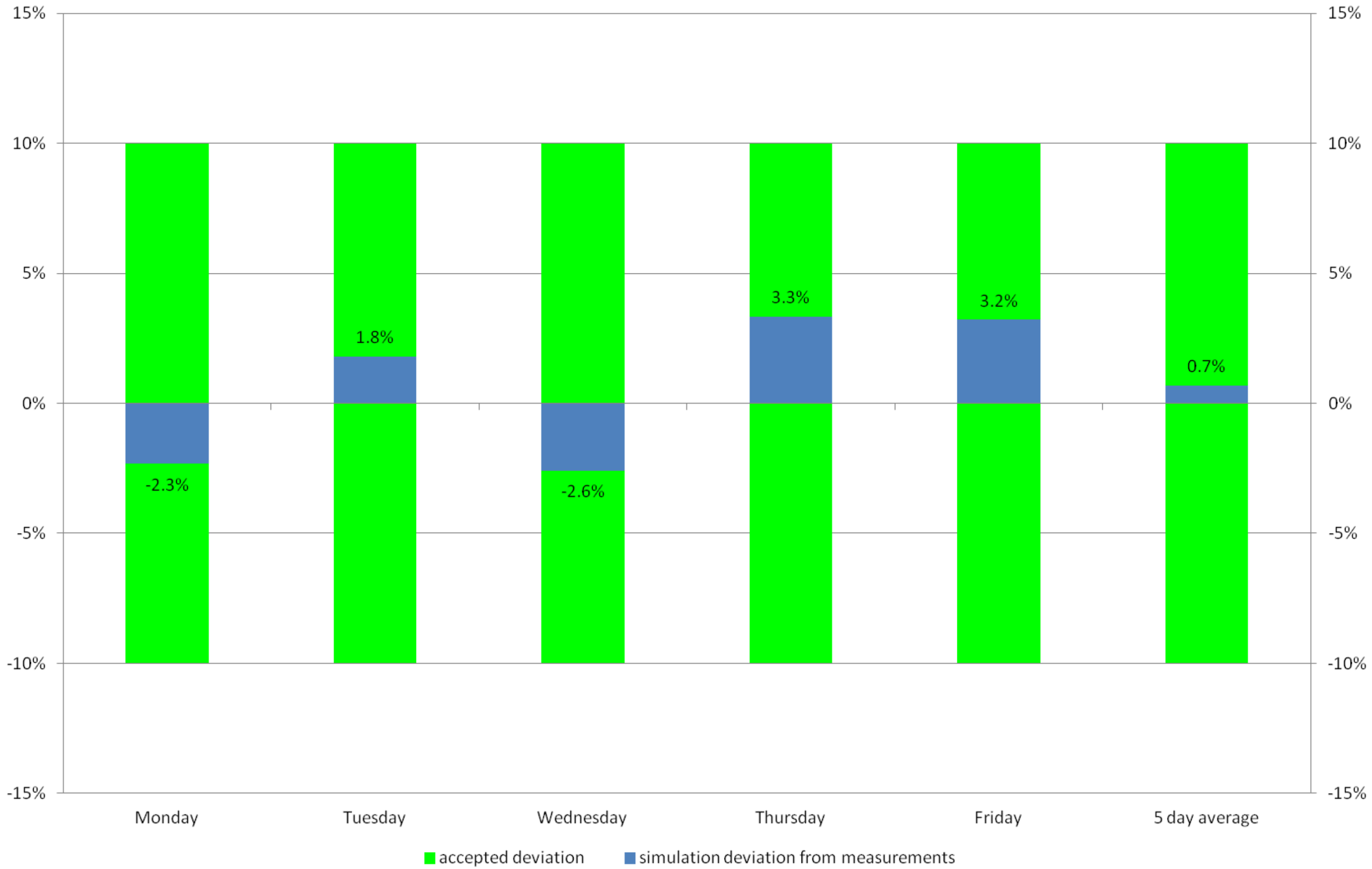
Propulsion Technology

Power Supply System

model verification, measurement and simulation at Zurich Public Transport



Queensland Rail Proof of Concept – comparing energy demand



agenda

1. motivation
2. load flow of electrical railway power supply systems
3. co-simulation tool for holistic system analysis
4. energy efficiency increase by network optimization
5. project example
6. conclusion

Institut für Bahntechnik GmbH

characteristic values to assess energy efficiency

1. **vehicle related recovery coefficient**

$$\xi_{\text{vehicle}} = \frac{E_{\text{brake}} - E_{\text{auxiliary,brake}}}{E_{\text{trction}} + E_{\text{auxiliary,traction}}}$$

2. **network related recovery coefficient**

$$\xi_{\text{Netz}} = \frac{E_{\text{recovered}}}{E_{\text{mbr\_required}}}$$

3. **system related recovery coefficient**

$$\xi_{\text{sys}} = \frac{E_{\text{recovered}}}{E_{\text{recovered}} + E_{\text{FS\_supplied}}}$$

energy efficiency increase by network optimization

Institut für Bahntechnik GmbH

1. Network analysis at actual state for different operational scenarios (timetable)

2. evaluation of network optimization changes, e.g.
   - change of network structure and/or nominal voltage
   - change of feeding station no load voltage
   - integration of energy storage
   - comparison of different changes

3. analyse implication of the changes
   - efficiency of the changes (investment ⇔ savings)
   - line voltage, rail-earth potential, short circuit currents, …
   - n-1 operation
   - actual equipment load compared to load capability

agenda

project example #1

new rollingstock

during test drives low voltage conditions noticed

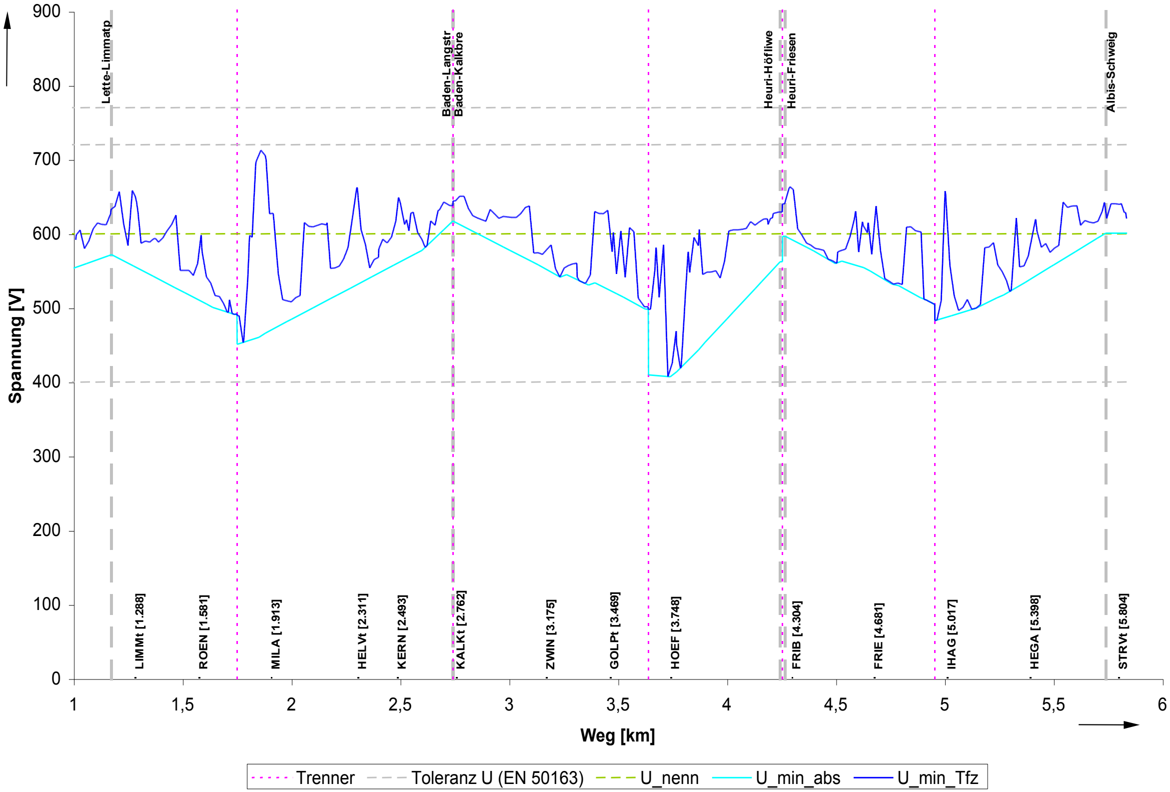
VBZ: Be 5/6 „Cobra-Tram“

bi-articulated trolley bus

week point analysis and network optimization of 300 km tram and 220 km trolley bus system

project example #1

application of new rollingstock – results

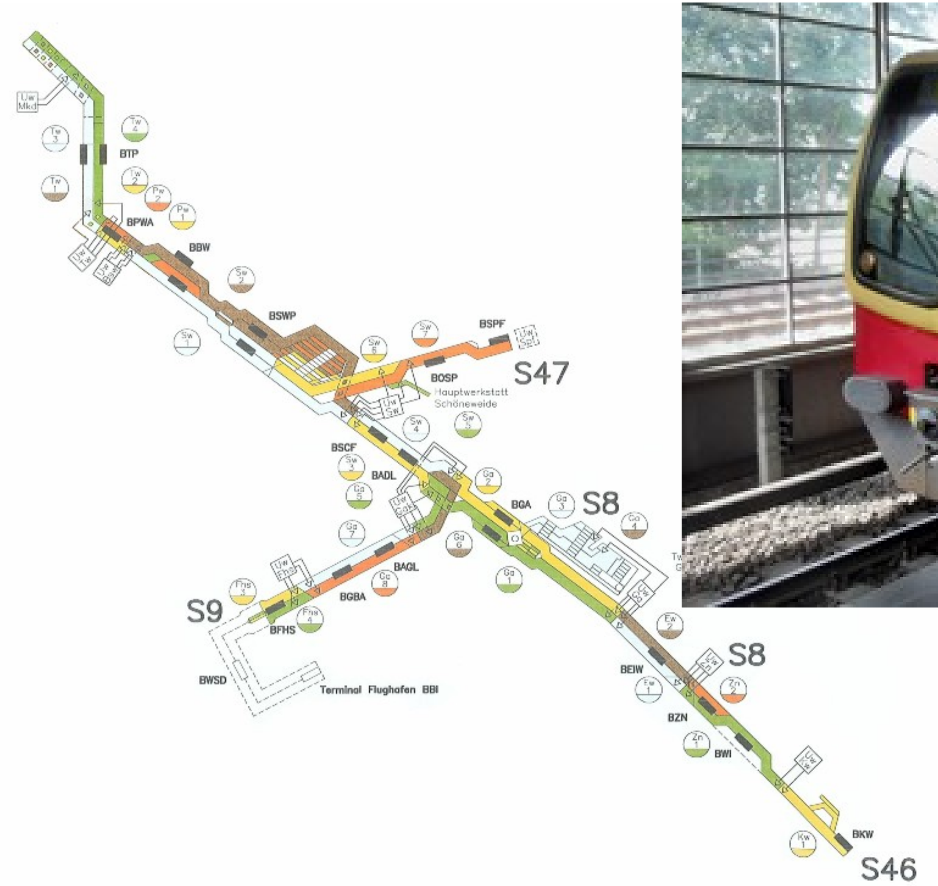


minimum line voltage at vehicle

- listing measures
- new feeding locations
- shifting of section isolators
- new feeder and return feeder
- amended feeding concept
- protection setting of section circuit breaker

amendment of no load feeding voltage

influence of line voltage level to total energy consumption

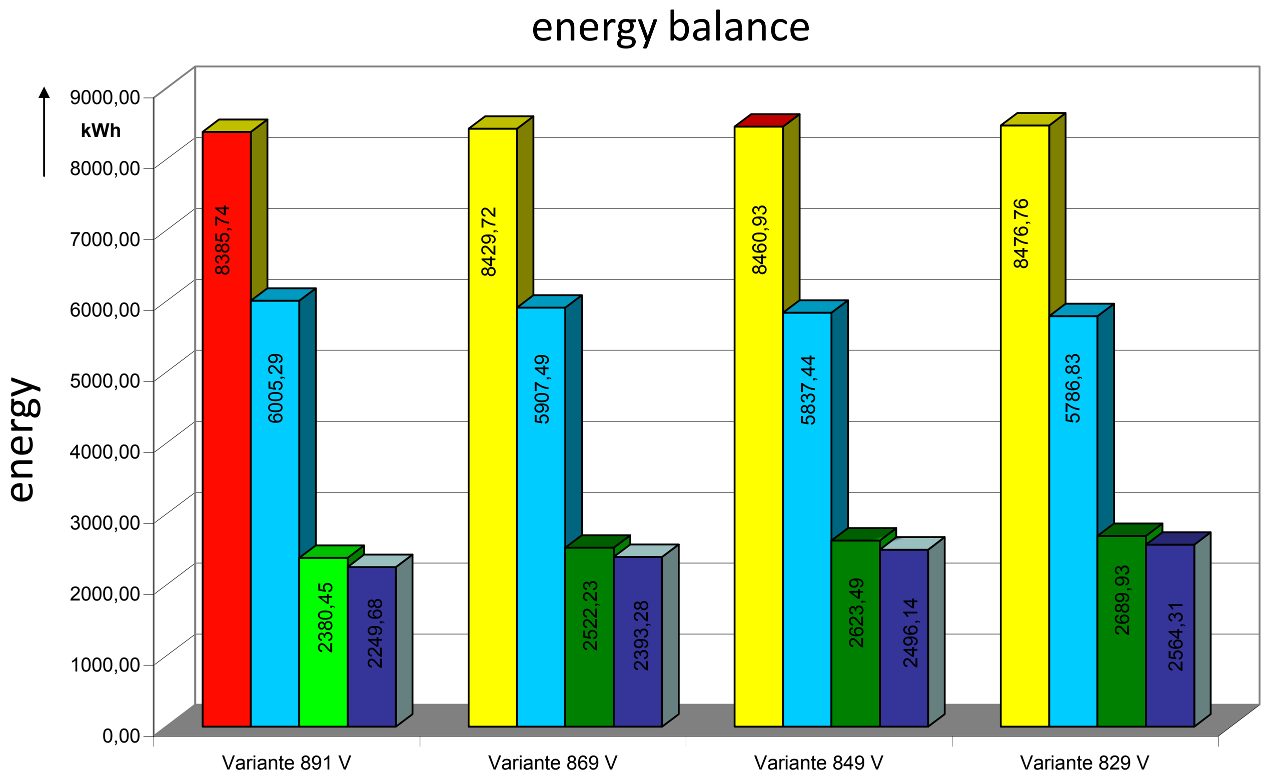


class 481

sub network snipped S-Bahn Berlin

Institut für Bahntechnik GmbH

amendment of no load feeding voltage-results



increasing total energy with decreasing U_0, FS provided energy decreases!

there is a optimum reflecting energy consumption and all relevant boundary conditions

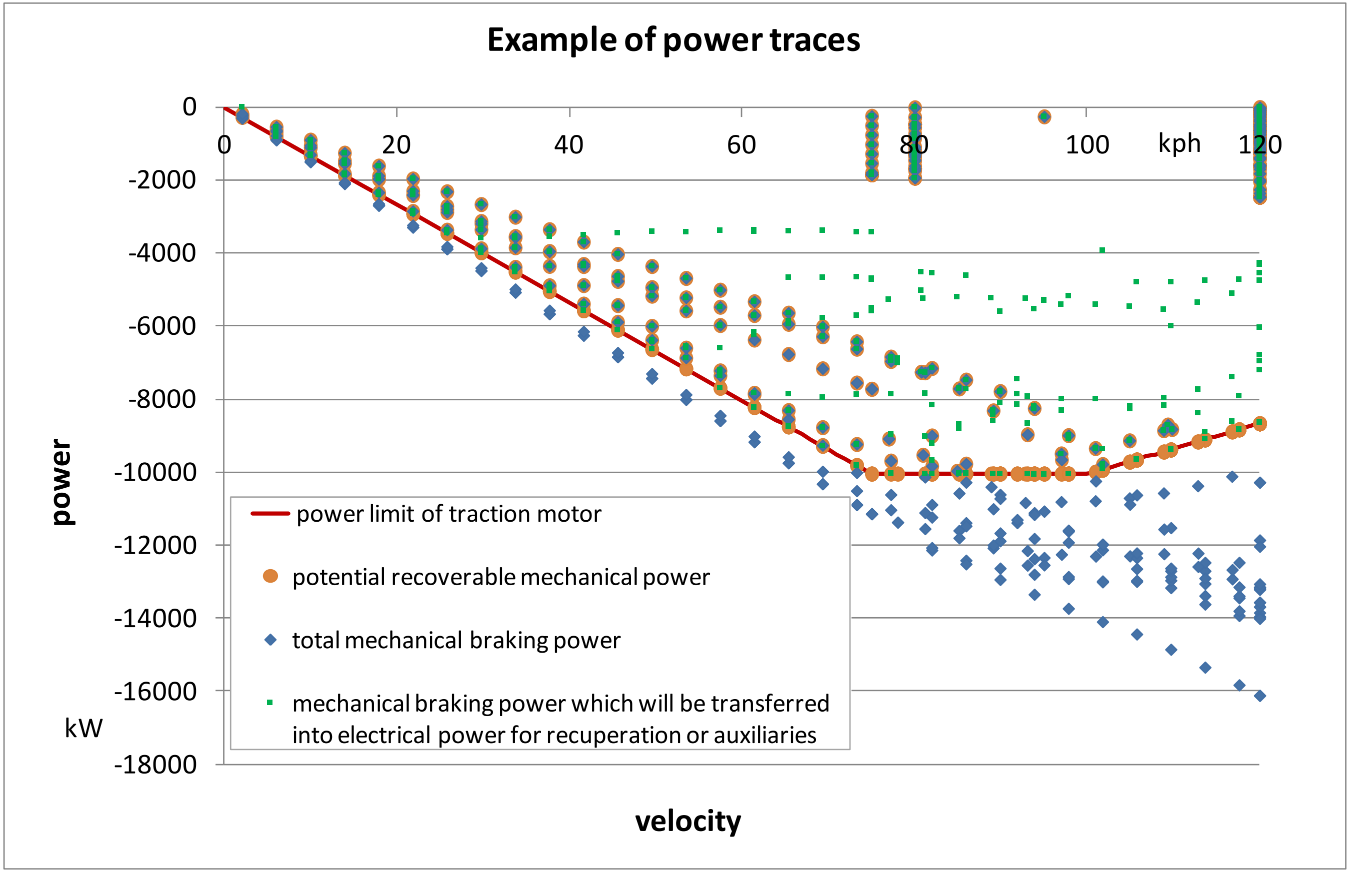
energy saving (849 V): 360-445 kWh / h ~7 % provided energy

total energy consumed
provided energy by feeding stations (FS)
used braking energy, inclusive vehicle auxiliary power
recovered energy from vehicle to network

Institut für Bahntechnik GmbH

integration of mobile energy storages – results

30 % energy savings!?



evaluation of potential savings

14 % energy saving referring to potential recoverable mechanical power

2-5 % energy saving referring to total energy consumption of vehicle

50-120kWh per trip

➔ type and dimensioning of energy storage

agenda

1. motivation
2. load flow of electrical railway power supply systems
3. co-simulation tool for holistic system analysis
4. energy efficiency increase by network optimization
5. project example
6. conclusion

conclusion

Institut für Bahntechnik GmbH

- **energy cost is and will be an important cost factor**
  ➔ efficiency is important

- **energy savings are possible at different subsystems**
  ➔ holistic approach including all relevant subsystems

- **impact of parameter changes easily checked in verified simulation software**
  ➔ OpenTrack and OpenPowerNet as the basis of infrastructure investment decisions

- **there are a lot of cheap measures to increase the energy efficiency**

- **it is worthwhile to have a closer look**

contact

Contact:
IFB – Institut für Bahntechnik GmbH
Dipl.-Ing. (FH) Martin Jacob
Wiener Straße 114-116
01219 Dresden

Tel.: +49 (0)351 877 59 42
Fax: +49 (0)351 877 59 90
E-Mail: mj@bahntechnik.de
Internet: www.bahntechnik.de, www.openpowernet.de