Client	**GE Energy Power Conversion GmbH**	

Duration Aug - Oct 2014

Project manager Dr.-Ing. Sven Körner
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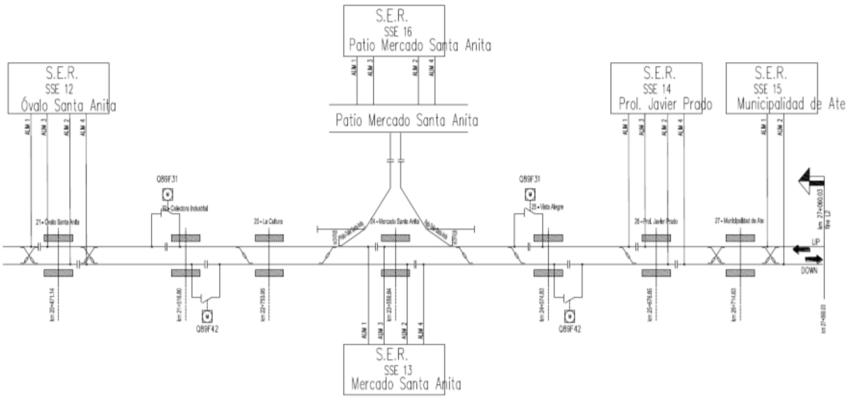
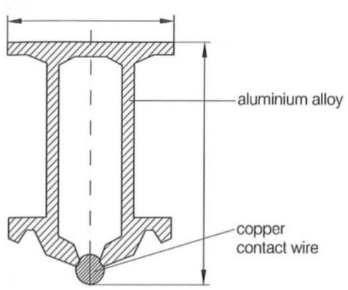




Power Supply Study Metro Lima

Description:

The aim of this study is the proof of a given preliminary design under given conditions for the metro lines 2 and 4 in Lima.

Network and vehicle Properties

- nominal voltage: 1500 V DC
- OHE: overhead conductor rails: aluminium alloy, copper contact wire
- vehicle traction power: 5089 kW, auxiliary power 270 kW
- Line 2:
  - 27.026 route km
  - 27 stations
  - Headway 80s
- Line 4:
  - 7.643 route km
  - 8 stations
  - Headway 300s

Tasks IFB:

Proof of single-line network design and compliance to requirements

For the Metro Lima project a multi-train DC traction power supply simulation was performed. Based on worst case assumptions for the:

- electrical network,
- timetable and
- vehicle load

several normal and outage simulations were carried out.

For the proof of design there was the need:

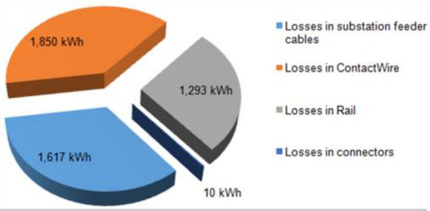
- to calculate the rectifier and cable currents/loads
- to calculate line voltages: minimum voltage at pantograph and maximum rail-earth voltage,
- to calculate stationary minimum short circuit currents,
- to verify the rating of the traction substations,
- to verify the rating of feeder and return feeder cables,
- to obtain the (n-1-outage) TSS-operation and
- to calculate the energy consumption.

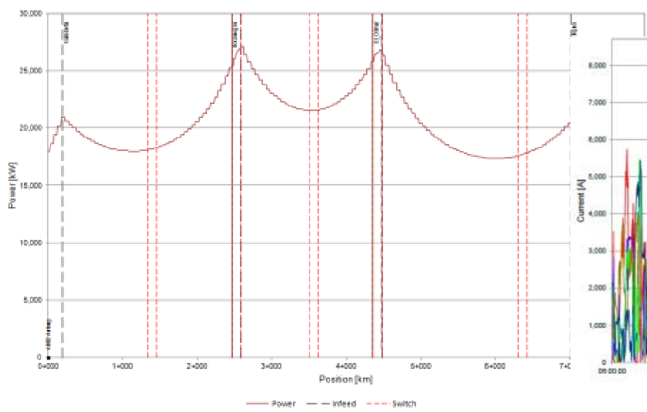
For the analysis coupled online simulations comprised by:

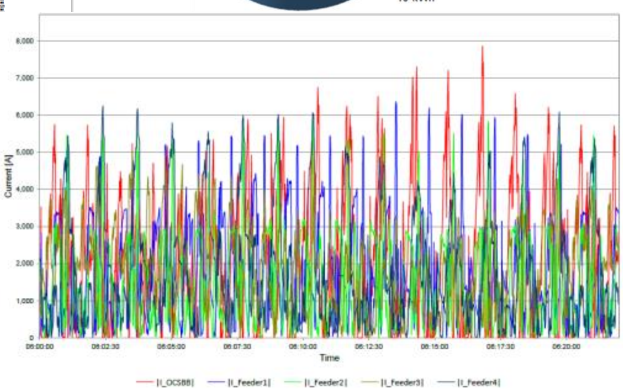
- operation simulations using OPENTRACK and
- electrical network and propulsion simulations using OpenPowerNet

were utilised.

Course	Formation	TKT tkm	Δt hh:mm:ss	U_{mu} V	E_{total} kWh	E_{spec} Wh/tkm	E_{con} kWh	E_{rec} kWh	ξ_{reg} %	E_{mtr} kWh	E_{mbr_req} kWh	E_{mbr_ach} kWh	ξ_{br} %	ξ_{br_net} %	E_{Al} kW
Total		357,665		1,535	14,715	41	37,820	23,105	61	28,641	30,328	29,301	97	76	6,4
2005	Metro_Lima	108	00:00:42	1,641	12	107	22	10	47	17	13	13	100	77	3
2006	Metro_Lima	100	00:01:00	1,466	6	60	17	11	65	12	16	15	93	71	5
2007	Metro_Lima	438	00:02:02	1,556	15	33	47	32	69	35	46	41	89	70	9
2008	Metro_Lima	613	00:02:15	1,518	0	0	38	38	100	26	51	48	93	73	1
2009	Metro_Lima	755	00:03:22	1,551	33	44	81	48	59	60	71	61	85	67	1







Institut für Bahntechnik GmbH

Client CODENSA S.A. ESP

Duration Jan - Feb 2014

Project manager Dr.-Ing. Sven Körner
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Power Supply Study Bus Rapid Transit System TRANSMILENIO Bogotá

Description:

Two-thirds of the electrical energy in Columbia is generated by hydro plants in an environmentally friendly and sustainable manner. In the capital Bogotá the Bus Rapid Transit System TransMilenio is the main public means of transport with a quantity of up to 47,000 passengers per hour and direction. Thus, the transport capacity of an underground is provided by diesel driven buses. Due to the global challenges and local effects of combustion motors there is a need for electric driven transports. One possibility is the substitution of the system to a Trolleybus-system. Various simulation scenarios are intended to show the basic technical feasibility of a Trolleybus-system.

Network Properties

- 110 km of trunk,
- 1400 articulated and bi-articulated buses in the morning peak hour,
- 116 bus stops.

Tasks IFB:

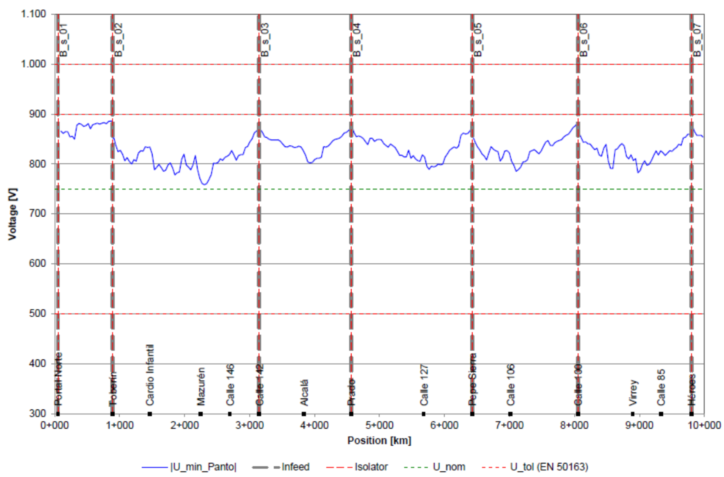
Rating and design of the traction power supply at the level of feasibility:

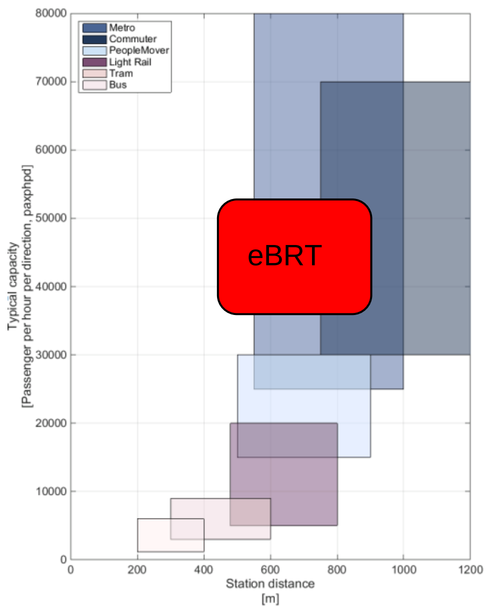
- Preparation of simulation track parameters based on GPS-data,
- Determination of the number and optimal localisation of DC traction substations,
- Proposal of suitable overhead equipment,
- Rating of electrical components,
- Calculation of the specific power and energy values,
- Calculation of maximum and RMS DC currents and loads,
- Compliance with normative limits.

- Preparation and execution of:
  - operation simulation using OPENTRACK and
  - electrical network and propulsion simulation using OpenPowerNet

- Determination of numbers of trolleybuses that are feasible in the system
- Proposal of preferred electrification scenario including the electrical design of the DC traction network and the preferred operation,
- Calculation of the total energy at traction power supplies for the peak hour,
- Workshop about the rating of electrical components.

Substation	Device	Type	Signal	$\lvert I\rvert_{max}$ A	I_{rms} A	I_{rms15} A	$\lvert S\rvert_{max}$ kVA	$\lvert P\rvert_{max}$ kW	$\lvert Q\rvert_{max}$ kvar	P_{rms} kW	P_{rms15} kW	E kWh	E_{loss} kWh
A_n_04	rec_n1	Rec	total	1831	818	861	1591	1591	0	722	760	668	11,367
A_n_04	rec_n2	Rec	total	1151	421	458	1013	1013	0	375	407	332	3,012





Client	**VR Track Oy**	VR TRACK
Duration	Feb - Aug 2016	
Project manager	Dr.-Ing. Sven Körner sk@bahntechnik.de +49 351 877 59 52	

Power Supply Study Light Rail Tampere

Description:

The aim of this study is the proof of a given preliminary design of the traction power supply under given conditions for the Light Rail Transit System in Tampere, Finland. The model of the power supply system is based on a preliminary operational and traction power supply design. This includes the locations of traction substations and their equipment, the kind of catenary system and return circuit (kind of conductors, cross-section and so on), the proposed vehicle configuration and a fundamental operation plan.

Network and vehicle Properties

- nominal voltage: 750 V DC
- OHE: overhead contact line with copper contact wire and messenger wire
- vehicle traction power: 810 kW, auxiliary power 60 kW
- The investigated tramway system is divided into two lines:
  - Part I-A (Pyynikintori – Sampola – Hervantajärvi)
  - Part I-B (Sampola – Lääkärinkatu)
- The line from Pyynikintori to Hervantajärvi has a length of about 12.2 km, from Pyynikintori to Lääkärinkatu it is about 5.2 km.

Tasks IFB:

Proof of single-line network design and compliance to requirements

For the PSS Tampere project a multi-train DC traction power supply simulation was performed. Based on worst case assumptions for the:

- traction power supply system,
- timetable and
- vehicle load

several normal and degraded mode simulations were carried out.

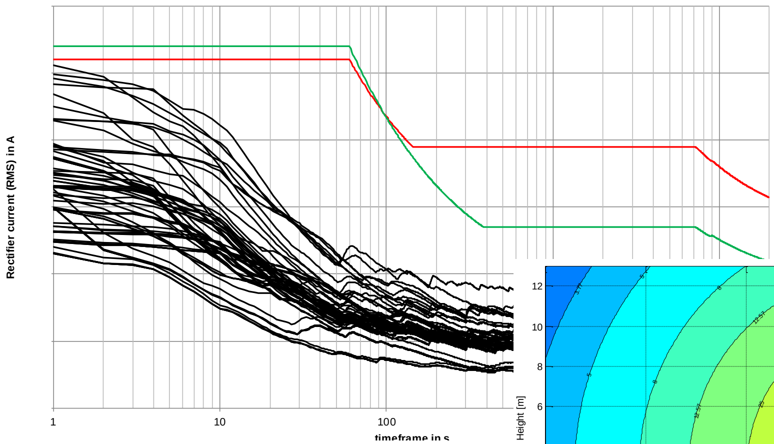
The aims of this simulation study are to calculate:

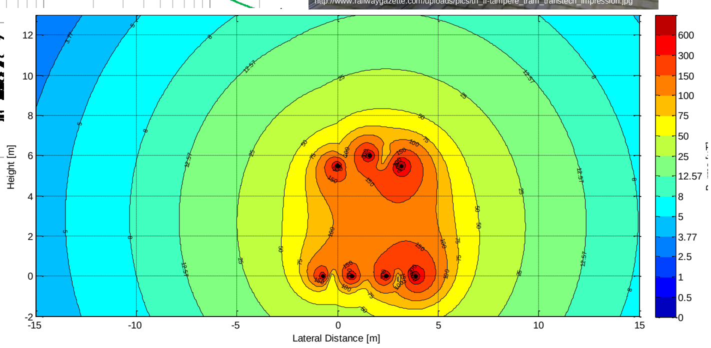
- minimum pantograph voltage along the lines,
- maximum rail-earth potential along the lines,
- substation busbar voltage and current (time characteristics),
- substation busbar-, feeder- and return feeder currents (time characteristics, average and maximum values, time-weighted characteristics),
- substation busbar and feeder load (time characteristics, 15-min-mean value, time-weighted characteristics),
- rectifier device load (time characteristics, time-weighted characteristics).

For the analysis coupled online simulations comprised by:

- operation simulations using OPENTRACK and
- electrical network and propulsion simulations using OpenPowerNet

were utilised.





Client **Bombardier Transportation GmbH** **BOMBARDIER**

Duration 11/2013 – 02/2014

Project Manager Dipl.-Ing. Holger Neumann
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Determination of the potential of recuperation of Metro Hongkong (Airport Express)

Description

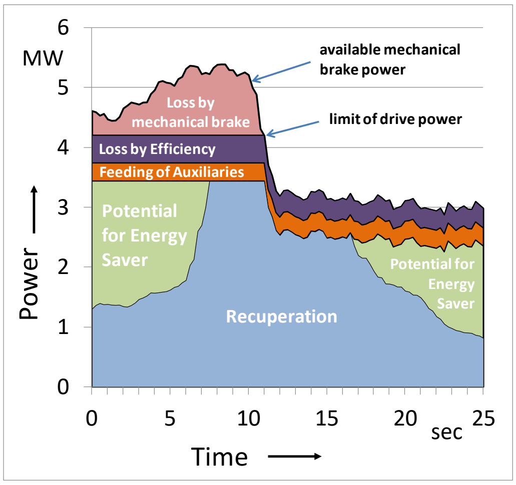
The Airport Express is part of the Mass Transit Railway (MRT) in Hongkong. For an increase of the system's efficiency the use of energy storages has been proposed.

Network properties:

- Length: approx. 35 km
- Power Supply: 1500 V DC
- Number of Traction Substations: 13

Aims of the project:

For the evaluation of the profitability of energy savers the potential of unused recuperated energy of all vehicle journeys has to be determined.



Tasks IFB:

A multi-train DC traction power supply simulation was performed. For the calculation the following simulation programs were used:

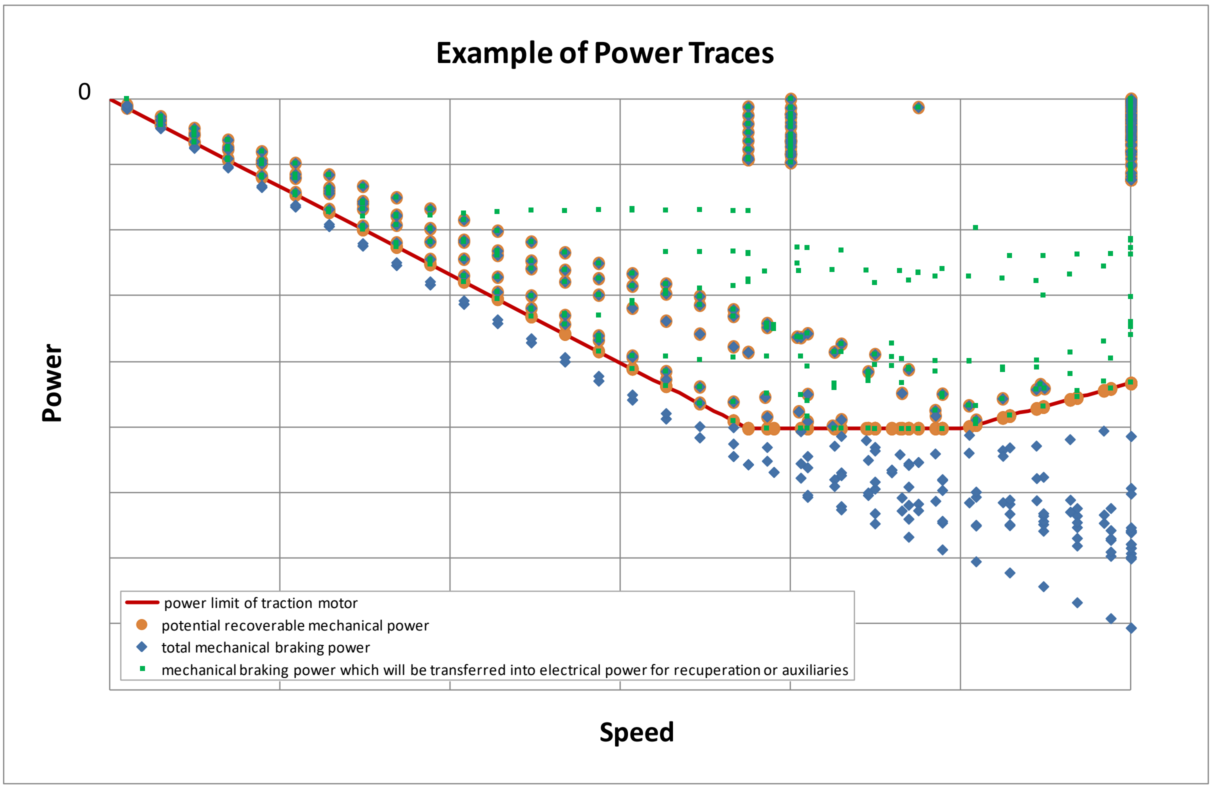
- Railway operation simulation using OPENTRACK
- Electrical network and propulsion simulation using OpenPowerNet

The simulation models were developed under consideration of the actual alignment of the line, the actual timetable and the corresponding train categories. For the electrical network simulation the propulsion systems of all vehicles, the traction substation configuration and the electrical parameters of the overhead contact line were taken into consideration.

During braking the kinetic energy of the train can be converted into electrical energy. This energy is split up into 3 parts:

- Recuperation into contact line system;
- Vehicles auxiliaries; and
- Braking resistor on-board of the vehicles.

The part which is fed to the braking resistor can be stored in energy storage(s). Thus the stored energy can be used for traction purposes or auxiliaries afterwards. The “energy consumption” of the braking resistors of all vehicles was determined by means of the results of the traction power supply simulation study.



Client Keolis S.A.

Duration Jun - Oct 2015

Project manager Dr.-Ing. Sven Körner
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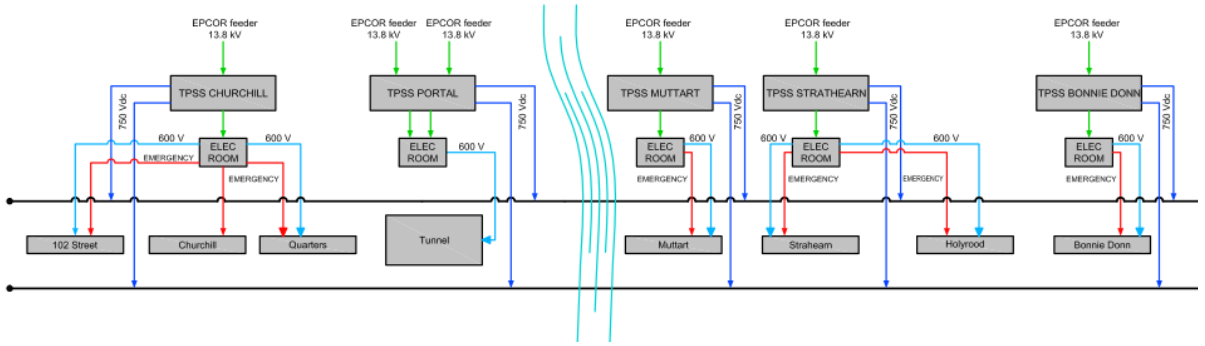


Energy Consumption Model Light Rail Transit Edmonton

Description:

This study is performed on behalf of Keolis S.A. as a member of the MovingYEG consortium within the bidding process for the P³ Valley Line Light Rail Transit project of the City of Edmonton. The studies' aim is to predict the entire energy consumption in a period of 30 years on a monthly basis. Therefore a complex simulation model was created, considering the main influencing parameters and environmental conditions. Additionally to the energy calculation a sensitivity analysis has been performed to show the influence of single parameters on the power demand for the concrete system. For the acceptance of the vehicles take-over IFB reviewed the test and measurement design developed by Keolis.

Network and vehicle Properties

- nominal voltage: 750 V DC
- OHE: contact wire: Cu ETP 350 kcmil + messenger wire: CU ETP 400 kcmil
- vehicle traction power: 750 kW, max auxiliary power: 90 kW (CAF Urbos)
- Valley Line Edmonton:
  - 13.1 route km
  - 12 passenger stations and additional stops
  - 3 different headways and service levels
  - consideration of non-operating vehicles and infrastructure consumers

Tasks IFB:

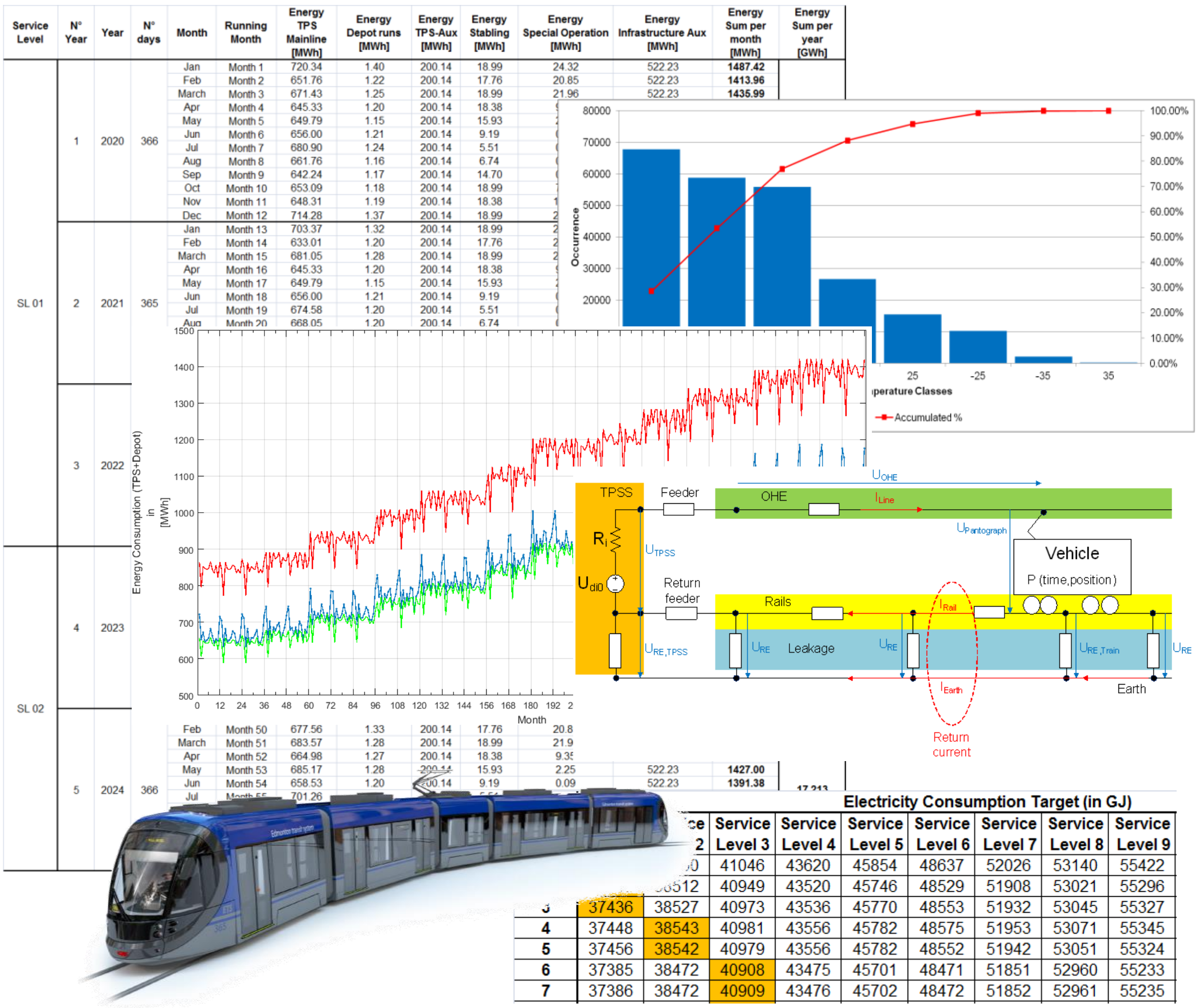
Calculation of the annual energy consumption on a monthly basis

To calculate the annual energy consumption for the future operation a methodology based on separate constituents of energy consumers under consideration of the last 30 years weather-conditions was developed. As a result several hundred multi-train DC traction power supply simulations were performed within a short period of time, considering vehicle payloads, vehicle propulsion efficiency and auxiliary demands (influenced by weather conditions), recuperation, headways, special operation, non-operating vehicles and infrastructure power demands. The study was reviewed by ARDANUY, which confirmed the methodology and results.

For the simulations the coupled online simulation programs comprising :

- operation simulations using OPENTRACK and
- electrical network and propulsion simulations using OpenPowerNet

were utilised.



Project Reference | Analysis and Optimization of Tram and Trolleybus network Zurich

Institut für Bahntechnik GmbH

Client	Verkehrsbetriebe Zürich (VBZ)

Duration	April - August 2007
Contact	Dr.-Ing. Sven Körner
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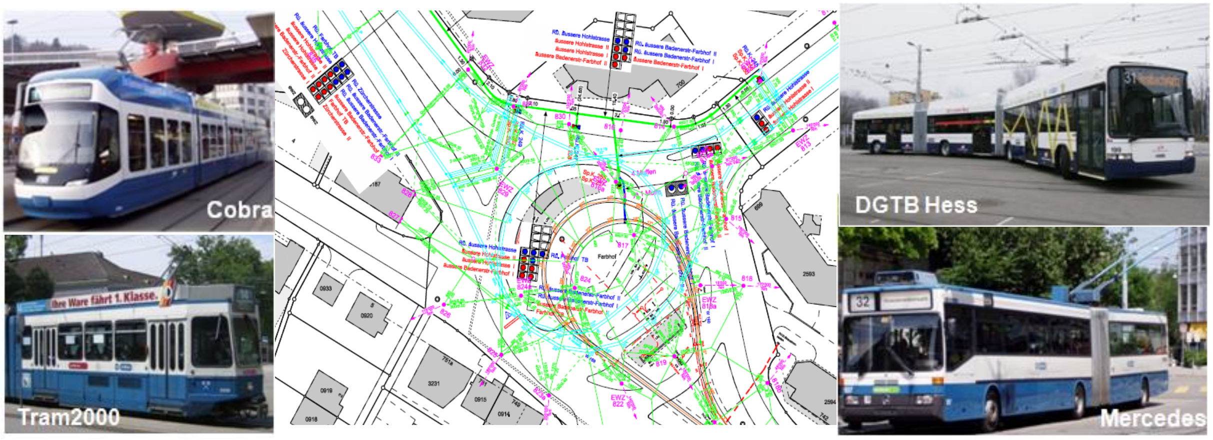


Description:

The purpose of the investigation was a weak point analysis for the DC traction power supply system and afterwards a network optimisation study for future operation and rolling stock scenarios. Considering a tram network length of approximately 300 km and an electrical connected trolleybus network of 220 km length with more than 40 traction substations in total the peak hour operation with 7.5 min headway on each line without separating any parts of the operation or the electrical network for 4 different operation scenarios have been investigated, analysed and optimised. The simulation results of OpenPowerNet have been validated, verified and confirmed by measurements.

Network and vehicle Properties

- nominal voltage: 600 V DC
- OHE: different OHE configurations for tram and trolleybus
- vehicles: 5 different tram types, 3 different trolleybus types
- Zurich tram and trolleybus network:
  - 300 route km tram
  - 220 route km trolleybus
  - passenger stations and additional stops
  - 7.5 min headway
  - 4 operation scenarios (year 2007, 2010, 2015, 2020)

Tasks IFB:

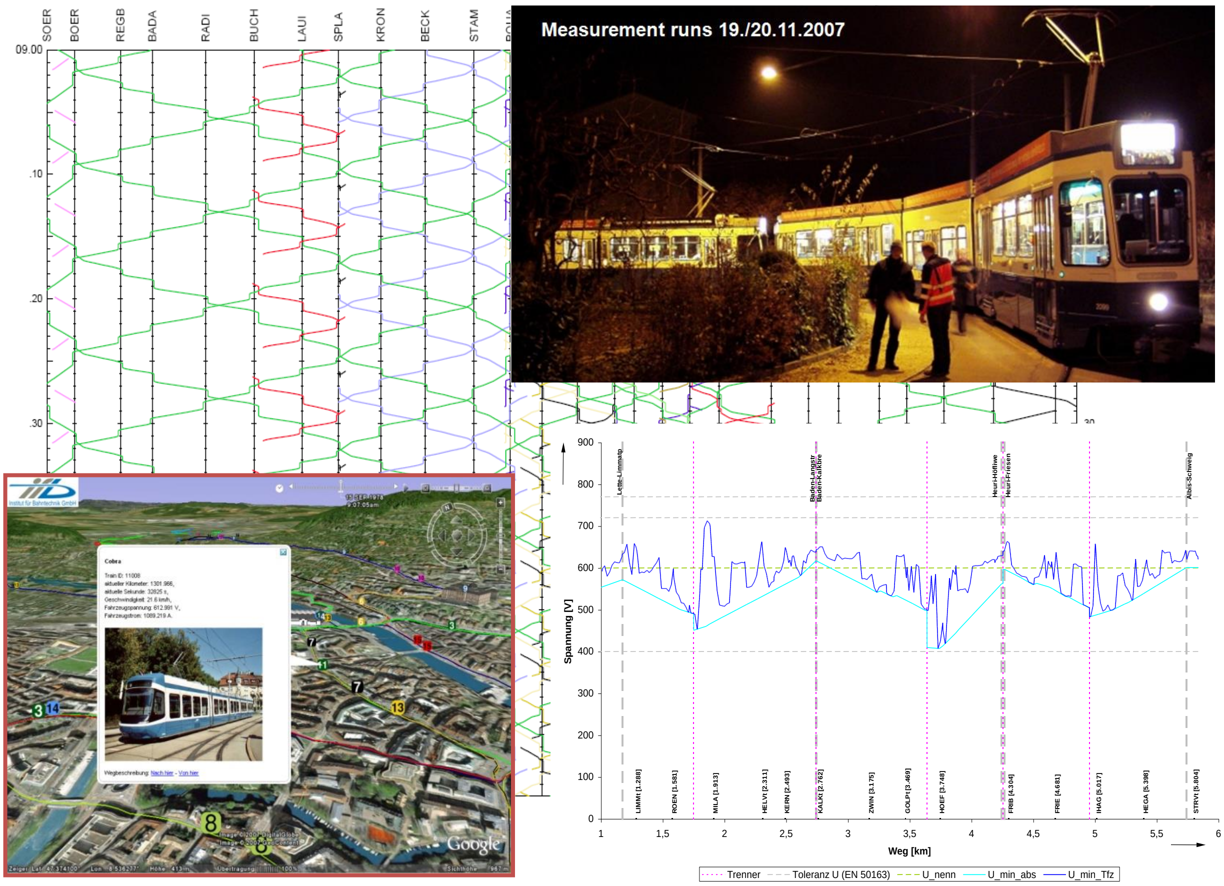
Weak point analysis and optimization study

- compliance of voltage levels compared to standards (line voltage, rail-earth)
- localisation of low voltage areas (restriction of vehicle power demand)
- thermal overload of electric devices
- analysis of protection settings (max operational currents / min short-circuit currents)
- load of cables, conductors, rectifiers and transformers vs. load capabilities
- analysis of the network structure and feeding concept
- analysis for status quo and future operation scenarios for normal and failure traction substation conditions
- analysis of energy consumption (total energy demand, recuperation rate, recovery rate, balance of load losses)

For the simulations the coupled online simulation programs comprising :

- operation simulations using OPENTRACK and
- electrical network and propulsion simulations using OpenPowerNet

were utilised.



Project Reference | Femern Belt Fixed Link

Institut für Bahntechnik GmbH

Client	**Femern A/S (Main client)**	Femern Sund≈Bælt
Contractor	**Ingenieurbüro Vössing GmbH** **Consortium IBV-IFB-Bossen&Hansen**	INGENIEURBÜRO VÖSSING

Duration since 2009 (ongoing project)
Commercial operation 2024

Project volume 5 500 000 000 Euro

Budget IFB 2 300 000 Euro

Project manager Dipl.-Ing. Eckert Fritz
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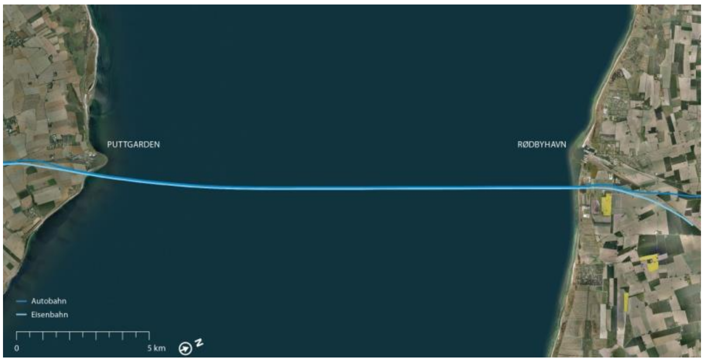
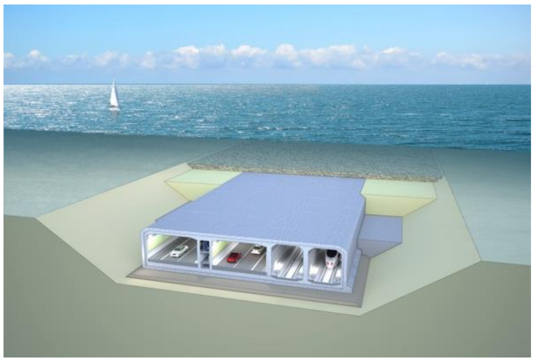




Description

Immersed tunnel (approx. 18 km) between Femern island (D) and Lolland island (DK) including:

- 2 road tubes,
- 2 railway tubes (speed up to 200 km/h),
- 1 service gallery.

Tasks IFB:

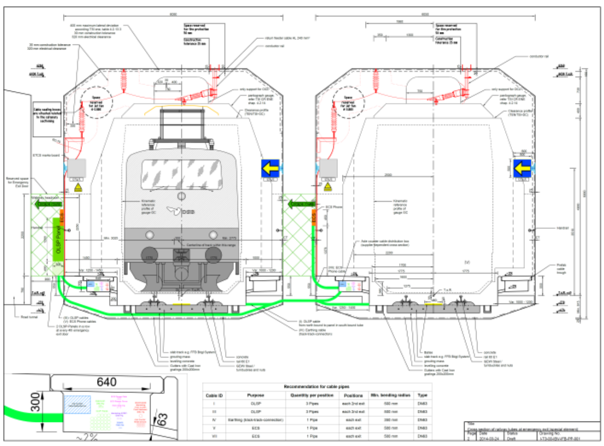
Planning and design of Railway subsystems of Femern Belt Fixed Link:

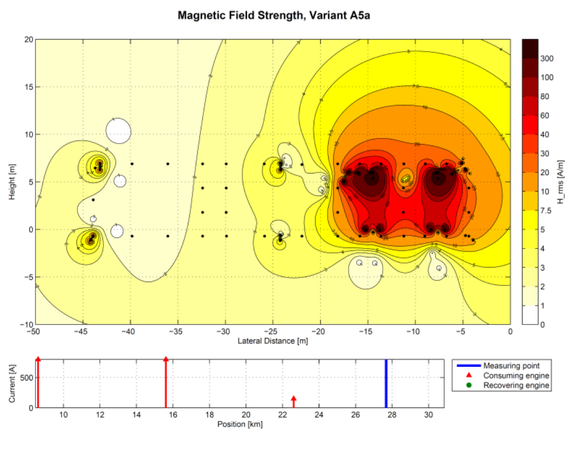
- **Traction power supply,**
- **Catenary system and**
- **Signalling & communication.**

- Preparation of:
  - Conceptual Design
  - Preliminary Design
  - Tender Documents

  for railway subsystems

- Support to the German approval process (Planfeststellung)
- Interface clarification to parallel subsystems
- Interface clarification to Deutsche Bahn and Banedanmark
- support of earthing & bonding and EMC design common for Railway, Electrical & Mechanical and constructions
- Assessment Prequalification of Bidders for railway subsystems
- Support of the bidding phase for the Electrical & Mechanical, Portal, Ramps, Landworks and tunnel construction contracts,
- control and revision of cost calculation (investment and maintenance) for railway equipment





Institut für Bahntechnik GmbH

Client **State Railway of Thailand**

Contractor **MHPM Co., Ltd. Thailand**
Rail Systems Engineering Sdn. Bhd.

Duration 12/2016 – 03/2017

Project Manager Dipl.-Ing. Enrico Brandes
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Preliminary Design Study of Electrification for State Railway of Thailand

Description

The State Railway of Thailand plans to extend the existing single tracks around the capital Bangkok. Also, it is intended to build an electrified railway network with a total length of approximately 800 km.

The company MHPM Ltd. in Bangkok was awarded with the design of the railway lines. The company Rail Systems Engineering Sdn Bhd (RSE) and IFB Institut für Bahntechnik GmbH was contacted by MHPM to provide a power supply simulation study.

Aim of the study is the preparation of a preliminary design of the traction power supply system including AC traction substations, autotransformer stations and the contact line system.

Railway network and operation properties:

- Total line length: 800 km
- 2 AC 25 kV 50Hz auto-transformer system
- Number of traction substations: 13
- Number of autotransformer stations: 43
- Almost double track line consisting of 1070 mm gauge track
- Consideration of passenger (suburban, express) and freight trains
- Simulated timetable: 24 hours

Tasks IFB

A multi-train AC traction power supply simulation was performed. For the calculation of the power demand the following simulation programs were used:

- Railway operation simulation using OPENTRACK
- Electrical network and propulsion simulation using OpenPowerNet

The simulation models were developed under consideration of the preliminary alignment of the line, the expected timetable in future and the corresponding rolling stock types. For the electrical network simulation, the propulsion systems of all vehicles, the substation configuration and the electrical parameters of the overhead contact line were taken into consideration. The magnetic field influences of all conductors are calculated for every time step.

Results of the power supply study under normal operation are:

- Minimum line voltage versus position
- Rail-earth potential versus position
- Current load of all conductors versus position
- Load of traction transformers
- Load of auto-transformers
- Load of feeder and return cables
- Comparison of load and load capability for power supply system equipment (transformers, overhead catenary system, cables)
- Adjustment in sizing of power supply system equipment (transformers, overhead catenary system, cables)

Based on the results of the simulation runs the locations of traction power supply substations were confirmed. The required power demand of each substation is used to optimize the sizing of transformer stations.

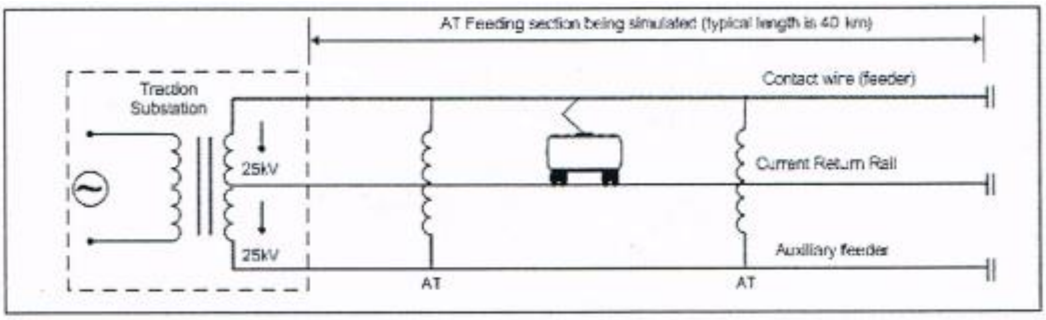

Figure 1 – Scheme for auto-transformer supplied system

Institut für Bahntechnik GmbH

Client GELEŽINKELIŲ PROJEKTAVIMAS (GELPRO)

Duration 08/2015 – 12/2016

Project Manager Dipl.-Ing. Eckert Fritz
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Feasibility Study of Electrification of TEN-T railway corridor in Lithuania

Description

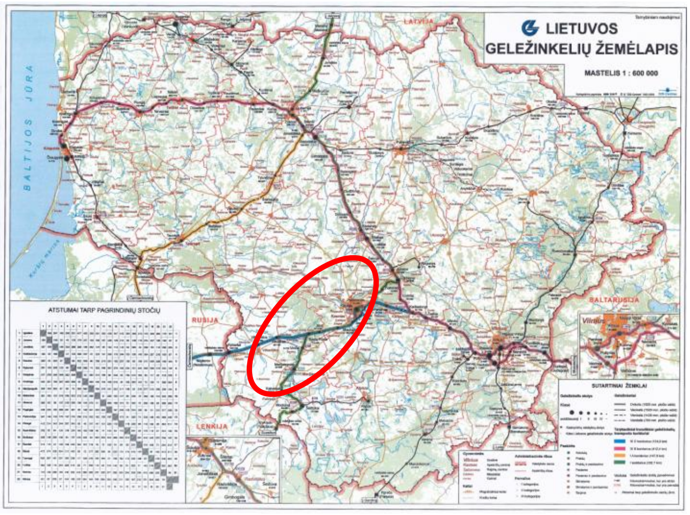
The TEN-T railway corridor shall connect the North Sea region and Baltic region. One part of the corridor will pass the country of Lithuania. In the study, the railway line between the Polish – Lithuanian state border and Kaunas via Marijampole and Kazlu Ruda was considered.

Network properties:

- Total length: 125 km
- Number of substations: 4
- Double track line consisting of a 1435mm gauge track and a 1520mm gauge track
- Consideration of passenger and freight trains on both gauges

Aims of the feasibility study are:

- determination of substation locations;
- calculation of power demand of the substations; and
- cost estimation of substations and Overhead Contact Line equipment.



Tasks IFB:

A multi-train AC traction power supply simulation was performed. For the calculation of the power demand the following simulation programs were used:

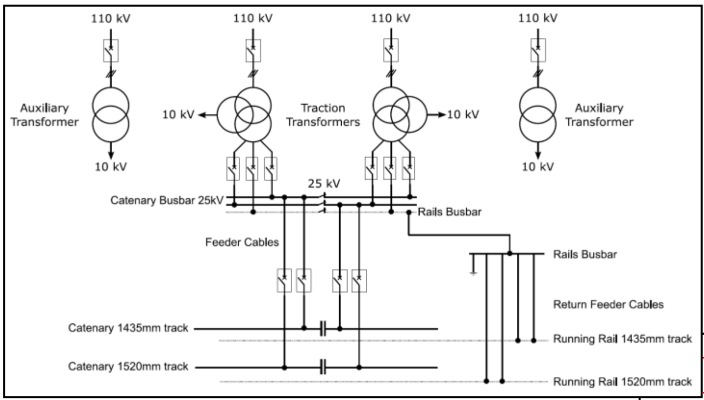
- Railway operation simulation using OPENTRACK
- Electrical network and propulsion simulation using OpenPowerNet

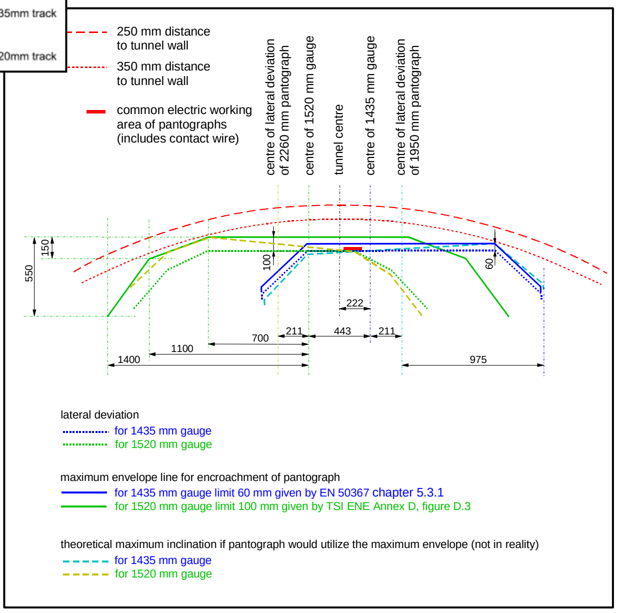
The simulation models were developed under consideration of the actual alignment of the line, the expected timetable in 2055 and the corresponding train categories. For the electrical network simulation the propulsion systems of all vehicles, the substation configuration and the electrical parameters of the overhead contact line were taken into consideration.

Based on the results of the simulation runs reasonable locations of traction power supply substations were proposed and the required power demand of each substation was determined. Subsequently, the simulation results were used to estimate the investment costs of all substations and the overhead contact line equipment.

Additionally, a special investigation regarding an integrated dual track of 1435mm gauge and 1520mm gauge in the Kaunas tunnel has been performed. The catenary position has been determined in order for trains to run on both tracks.

Finally, an Earthing measurement campaign was performed on-site.





Client OBERMEYER Planen und Beraten GmbH

OBERMEYER
PLANEN + BERATEN GmbH

Duration 06/2007 – 12/2008

Contact Dr.-Ing. Sven Körner
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Traction Power Supply Study of the Chinese High Speed Line Wuhan-Guangzhou

Description

For the Chinese high speed line from Wuhan to Guangzhou the rating of the entire traction power supply system and return current system were examined and the energy consumption was calculated.

Network properties:

- Length: approx. 1,000 km
- Power Supply: 2 AC 25 kV 50 Hz Autotransformer (AT) system
- Number of Traction Substations: 20
- Number of AT-Stations: 39

Aims of the traction power supply study are:

- Evaluation of the traction power supply design of the Chinese High Speed Line Wuhan - Guangzhou in terms of line voltage stability, rail-earth potentials and traction substation rating,
- Calculation of the energy consumption of the traction power supply system.

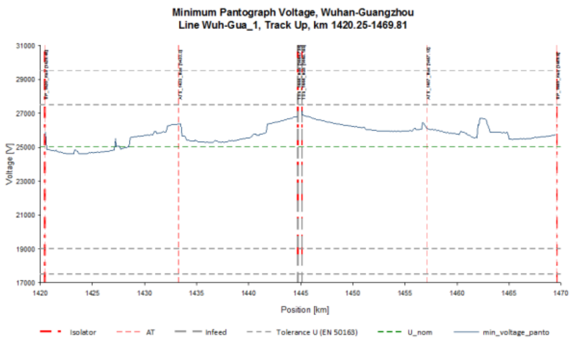
Tasks IFB:

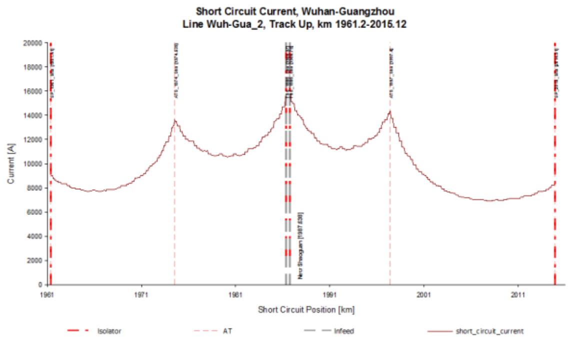
A multi-train AC traction power supply simulation was performed. For the calculation the following simulation programs were used:

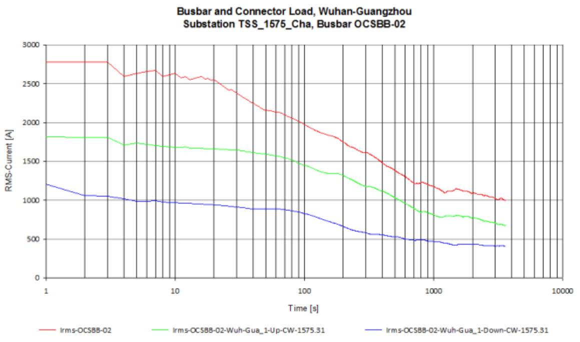
- Railway operation simulation using OPENTRACK
- Electrical network and propulsion simulation using OpenPowerNet

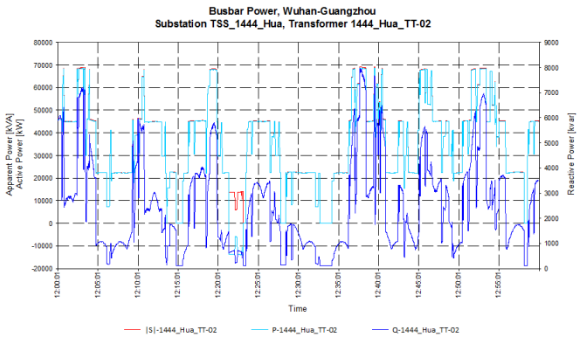
For the regular daily operation with high speed and regional trains a minimum operating headway of 3 min was required. As results the following values and characteristics were obtained for a 2 hours peak operation phase:

- train diagrams (speed profiles, graphical timetables),
- train current characteristics,
- minimum and maximum pantograph and overhead line voltages,
- contact wire and cable currents,
- transformer loads,
- power and energy consumption on substation and power grid level,
- total energy balance,
- efficiency characteristics including component-related power losses balance, and
- rail-earth potentials.









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Studies for Traction Power Supply Systems

Institut für Bahntechnik GmbH (IFB) offers consulting services for traction power supply systems and propulsion technologies of modern rolling stocks.

Using our in-house developed simulation tool OpenPowerNet, we provide modeling, simulating and analyzing services for all common traction power supply systems (DC, 1 AC, 2 AC Autotransformer, Boostertransformer, Static Frequency Converter, etc.) for means of transportation like railway, tram and bus systems.

Assisting levels of design studies during tender procedure

- Conceptual Design Study
- Feasibility Design Study
- Preliminary Design Study
- Detailed Design Study

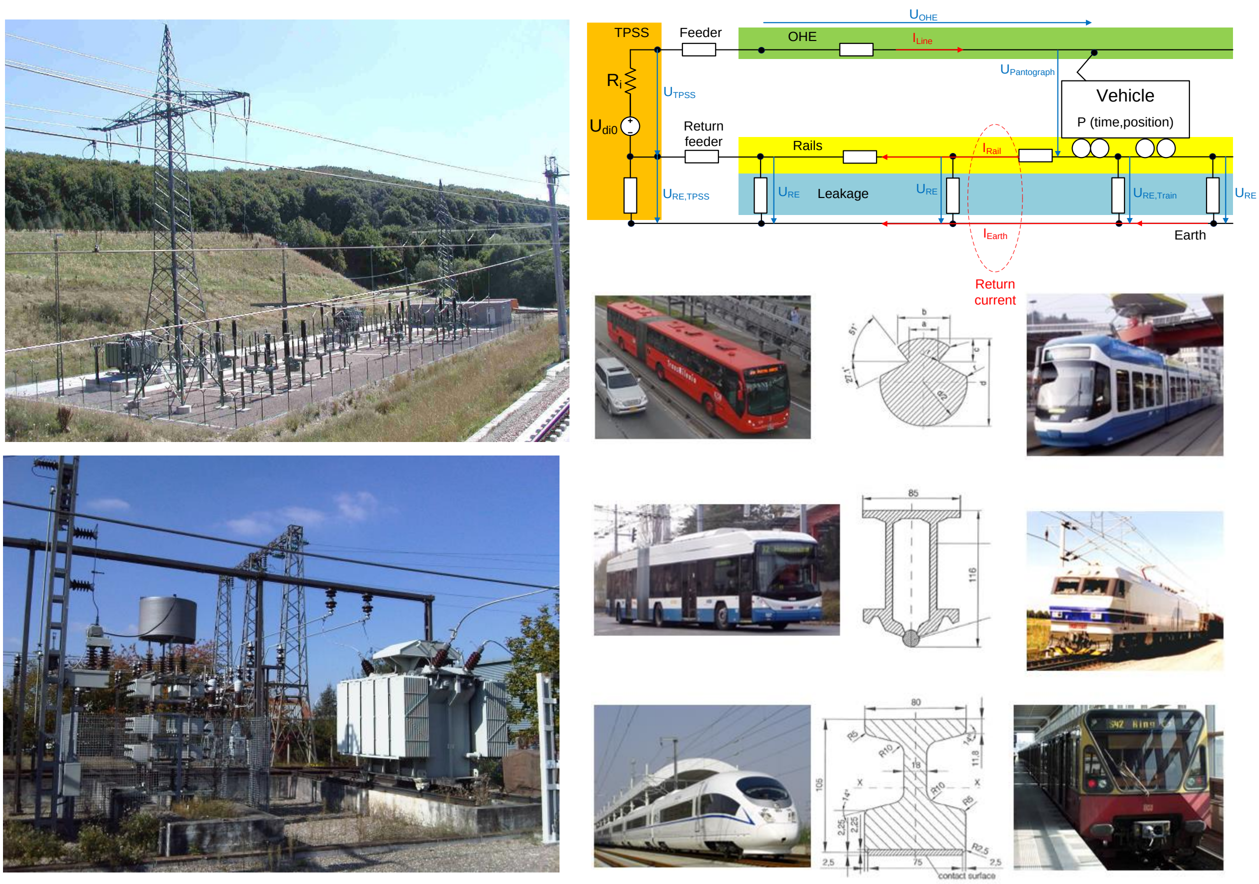

Figure 1: Different parts of traction power supply systems, types of contact lines, and vehicles

Consulting services for power supply systems and propulsion technologies:

- Load flow analysis and power demand (see Figure 2)
- Short-Circuit analysis
- Preliminary Traction Power System Study
- Power Supply System Design Philosophy
- Emergency Trip System Philosophy
- Conceptual design for railway earthing systems
- Traction Power Load Study
- Calculation of energy consumption and power demand Study
- Power Supply Equipment Sizing Study
- Harmonic Study
- Fault Current Study
- Voltage Study
- Power Factor Study
- Flicker Study
- Voltage Unbalance Study
- Protection Relay Coordination Study
- Corrosion Control Protection Study
- Electromagnetic compatibility (EMC) Study
- Touch Potential Study
- Thermal rating of wires and cables (postprocessing) and Size Calculation
- Equipment Specifications
- Evaluation of future rolling stock propulsion systems
- Dimensioning of stationary and vehicle energy savers
- Power supply system optimization
- Outage calculations and interaction to operational planning (timetable)

The results are evaluated in such a way that they provide a reliable basis for main investment decisions related to your project.

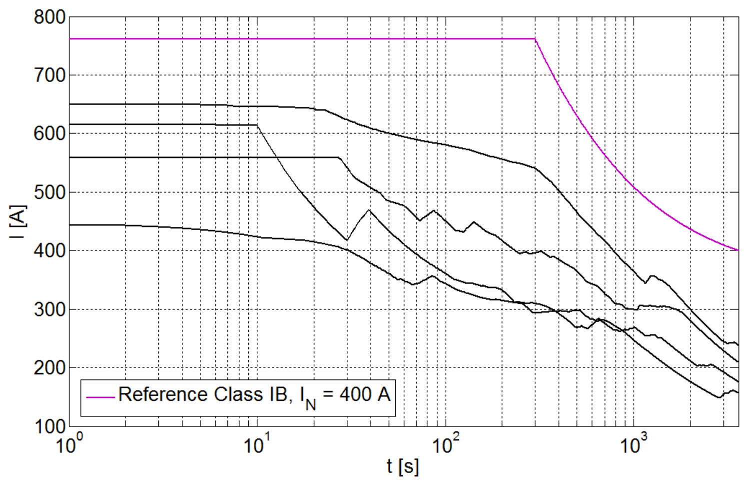

Figure 2: Traction substation time-rated-load-period-curves and load capability curve

OpenPowerNet *is an in-house development and distributed worldwide to industry companies, universities, consultancies and operators. Licenses are available for commercial and academic use since 2009.*

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OpenPowerNet (OPN) is a traction power supply system and engine simulation software. It allows modeling, simulating and analyzing for all common traction power supply systems (DC, 1 AC, 2 AC, etc.) for means of transportation like railway, tram and bus systems.

OpenPowerNet is an in-house development by Institut für Bahntechnik Dresden and the software is distributed worldwide to industry companies, universities, consultancies and operators. Licenses are available for commercial and academic use (limited functionality) since 2009.

All calculations by the OPN integrator are done by coupled online simulation (co-simulation) with the well-established railway operation software OPENTRACK which is used by railways, the supplying industry, consultancies and universities in more than 36 countries.

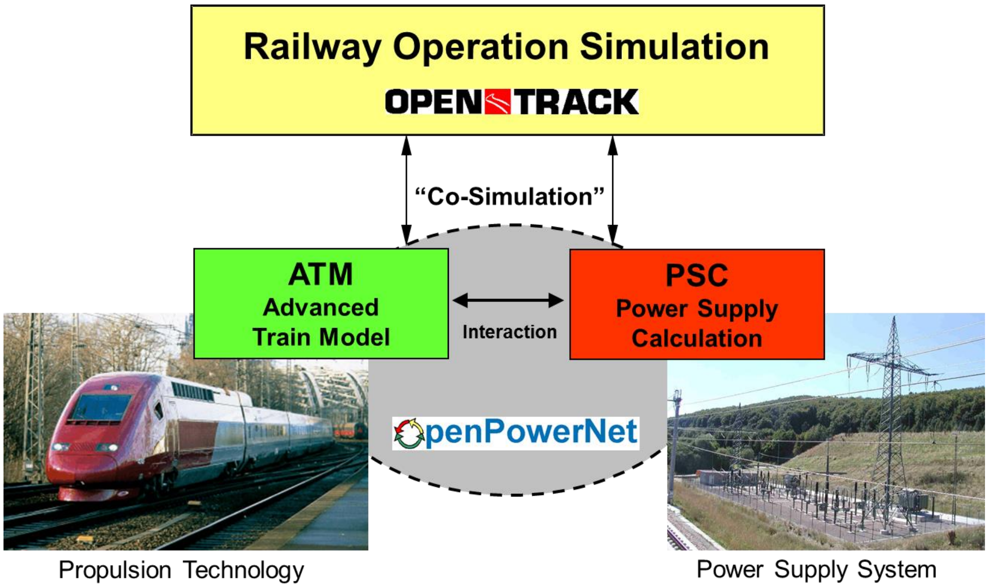

Figure 1 Principles of modules' interaction during coupled online simulation

Key Features of OpenPowerNet:

- built-in online calculation of inductive coupling of all parallel conductors
- usable for all common ac and dc systems (transformer, rectifier, auto-transformer, booster transformer, converter, voltage limiting devices)
- calculation of retroactive effects towards the vehicles' driving dynamics
- dynamic modification of switching status during simulation
- power supply system evaluation under constant current or voltage at pantograph
- possible use of on-board or stationary energy saver technologies
- individually user-defined analysis of simulation results

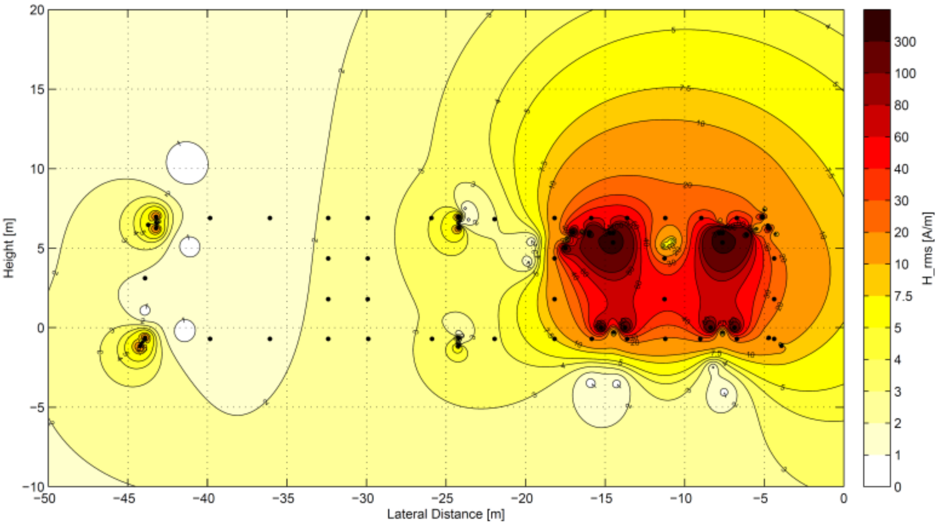

Figure 2: Magnetic field strength, OpenPowerNet

Applications

The main field of application of this software is to obtain and evaluate the results in a way that main investment decisions related to your own or your clients' projects can be reached. Planning and consulting services can be supported with OpenPowerNet. For example, it is possible to perform:

- Load flow analysis of traction power supply systems
- Short-Circuit analysis
- Evaluation of future rolling stock propulsion systems
- Evaluation of electromagnetic compatibility (EMC)
- Assessment of touch potential
- Rating of substation devices (Rectifier, Transformer, Autotransformer, Boostertransformer, Static Frequency Converter, switchgear, cables, etc.)
- Thermal rating of wires and cables (postprocessing)
- Calculation of energy consumption and power demand
- Rating of stationary and vehicle onboard batteries and super capacitors
- Power supply system optimization
- Failure scenario calculations and interaction to operational planning (timetable)