ACTUATE – Presentation

Advanced training for safe ecodriving of electrically powered vehicles
Tram

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Who benefits from ecodriving?

Ecodriving does not only mean actual savings in fuel.

- The driver
  - is more relaxed, not stressed
  - is less liable to fall ill, fewer accidents
- The passenger
  - feels safer because s/he senses the calmness of the driver through their driving behaviour
- The vehicle and the infrastructure
  - There is less wear, the drive systems are treated with more care and there is less stress on the expensive infrastructure

Who benefits from ecodriving?

- The environment
  - Less emissions are produced.
- The company
  - Ecodriving can realistically lead to an (additional and not technology-based) reduction in fuel consumption of c. 3 per cent, based on the experience of the ACTUATE partner company Leipziger Verkehrsbetriebe (LVB, Germany). A model calculation for the LVB: With a consumption of around 60 GWh per annum for traction current, savings of c. 1.8 GWh can be expected for Leipzig's fleet of trams. In financial terms this would means savings of around € 210,000 per annum for the LVB.

Basic knowledge

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Relevant factors for ecodriving behaviour in buses and trains:

- Driving behaviour of the driver
- Conscious use of auxiliary equipment (air-conditioning, heating)
- Routing, traffic density and occupation
- Conscious use of rolling phases
- Electronic control software

Higher average speed
is not achieved by individual speed peaks
but by an even manner of driving!

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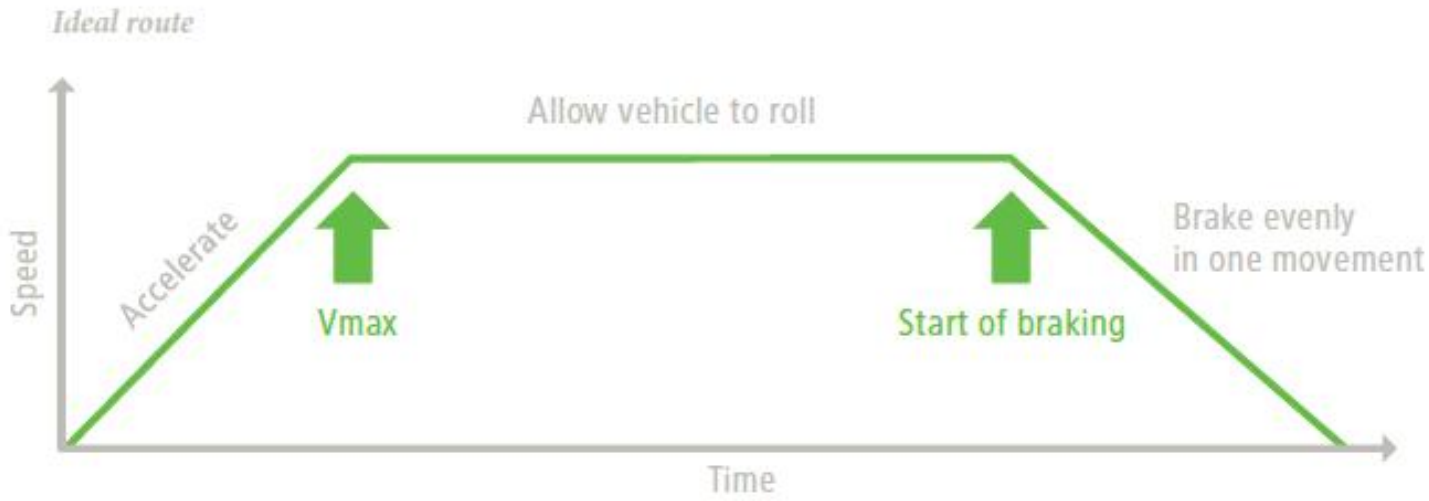
How can energy be saved?

Energy consumption too high on the section!

Possible reasons:

- stress
- erratic and hasty driving behaviour
- “playing” with the setpoint device
- acceleration too long
- rolling phases too short

Ideal driving behaviour on flat terrain



✓ Accelerate slowly and evenly (think of passengers' comfort)

✓ Let vehicle roll as long as possible

✓ Brake evenly and gently

Factors that influence the braking distance

- speed
- conditions of tracks
- conditions of line
- type and number of other brakes used
- vehicle occupation/load
- vehicle characteristics

If you double your speed, you quadruple your braking distance.

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Tram motors

separately excited DC motor
with (chopper) Tatra

three-phase asynchronous motor NGT 6 (Leoliner), NGT 12 (XXL)

Example: All public vehicles in Leipzig have regenerative braking! (energy recovery = regenerative brake):
67% (in the evening) - 98% (in rush hour) of recovered energy is used!

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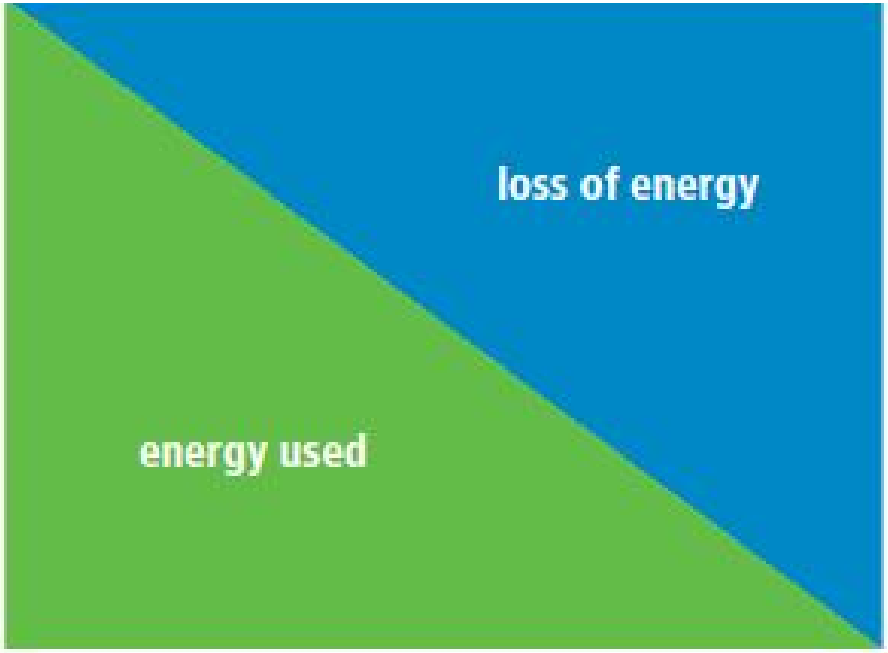
The control system is more important for fuel consumption than the motors

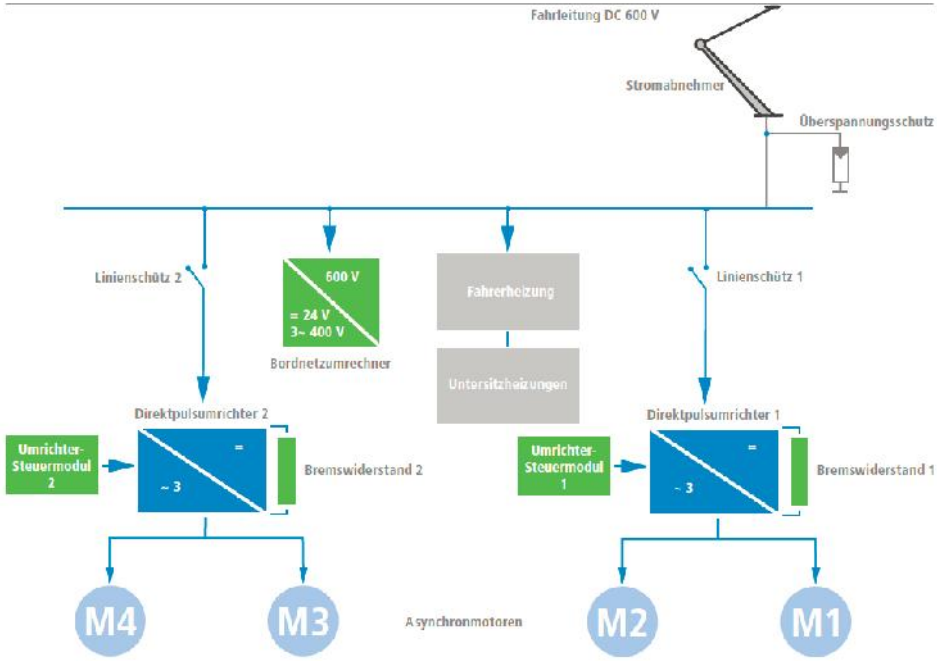
Energy loss from rheostatic control at optimum, constant high acceleration



Rheostatic control is undoubtedly the least cost-effective. 50% of energy take-up is converted into heat and lost even with optimum driving behaviour.

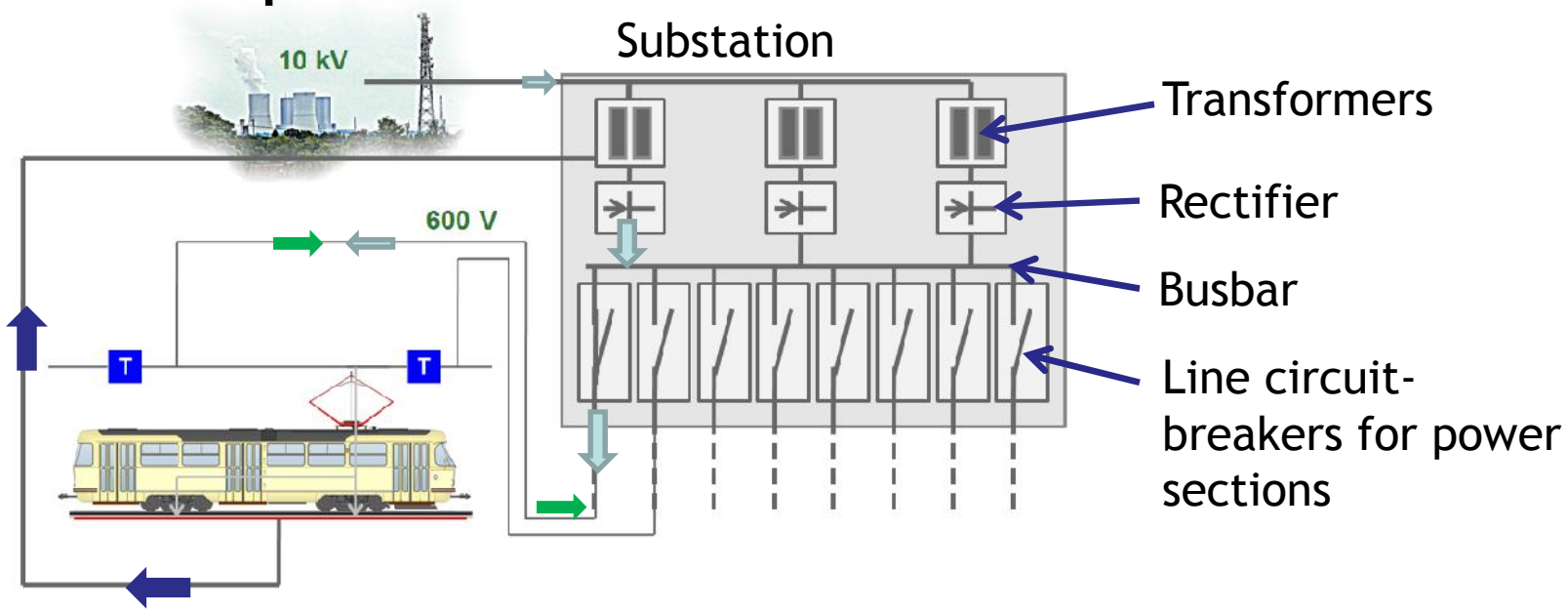
There is no energy recovery here!

The control system is more important for fuel consumption than the motors



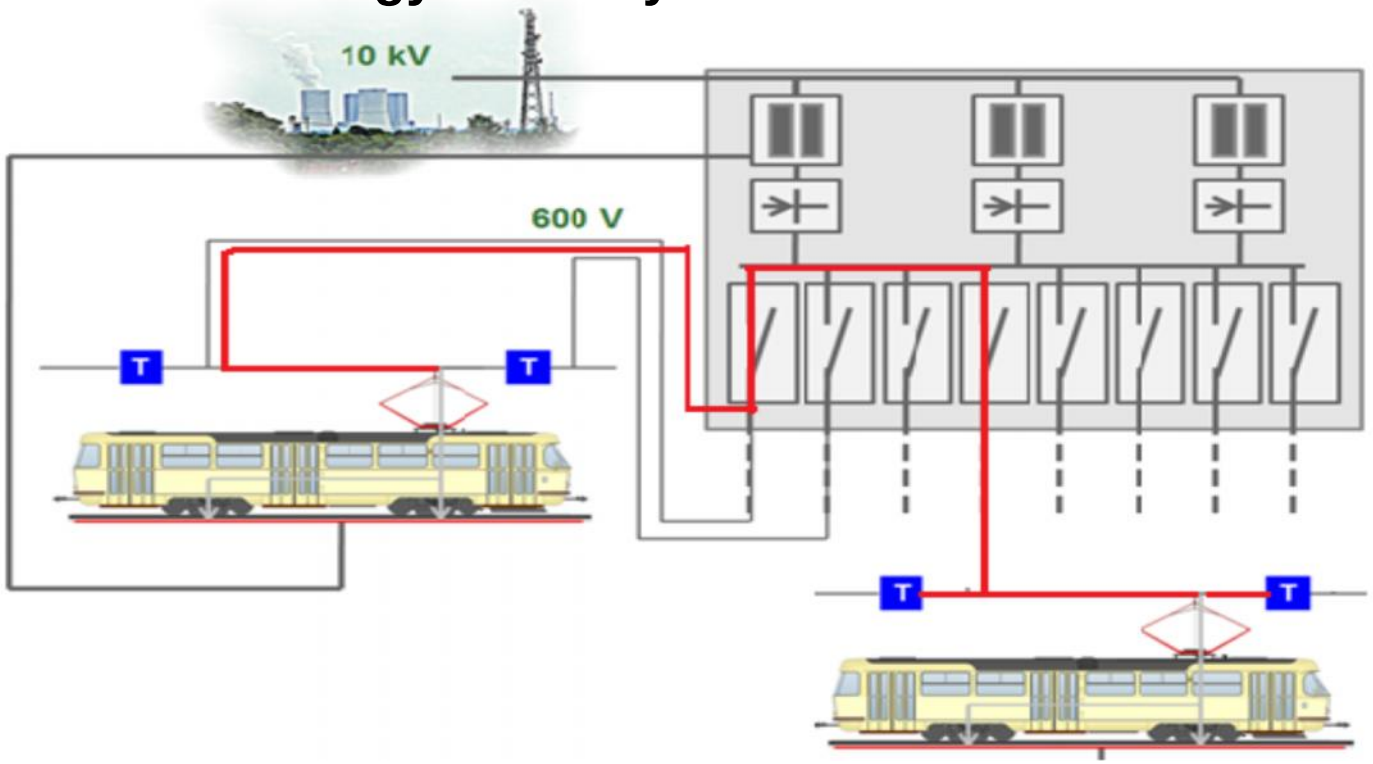
IGBT (Insulated Gate Bipolar Transistor) and chopper controls normally installed in new vehicles are very efficient.
Only the exact amount of electricity is taken up that the motor can use.
However, the driver determines how much electricity the motor will use because (s)he determines the amount of current absorbed via the setpoint device or accelerator and the length and intensity of energy recovery when braking.

Simple current profile



10 kV AC current is sent from the power station to the substation. It is converted to 600 V, rectified and fed into a busbar from which the individual power sections branch off. After being used in the vehicle, the electricity is fed back via the return cable (residual current).

Current profile with energy recovery



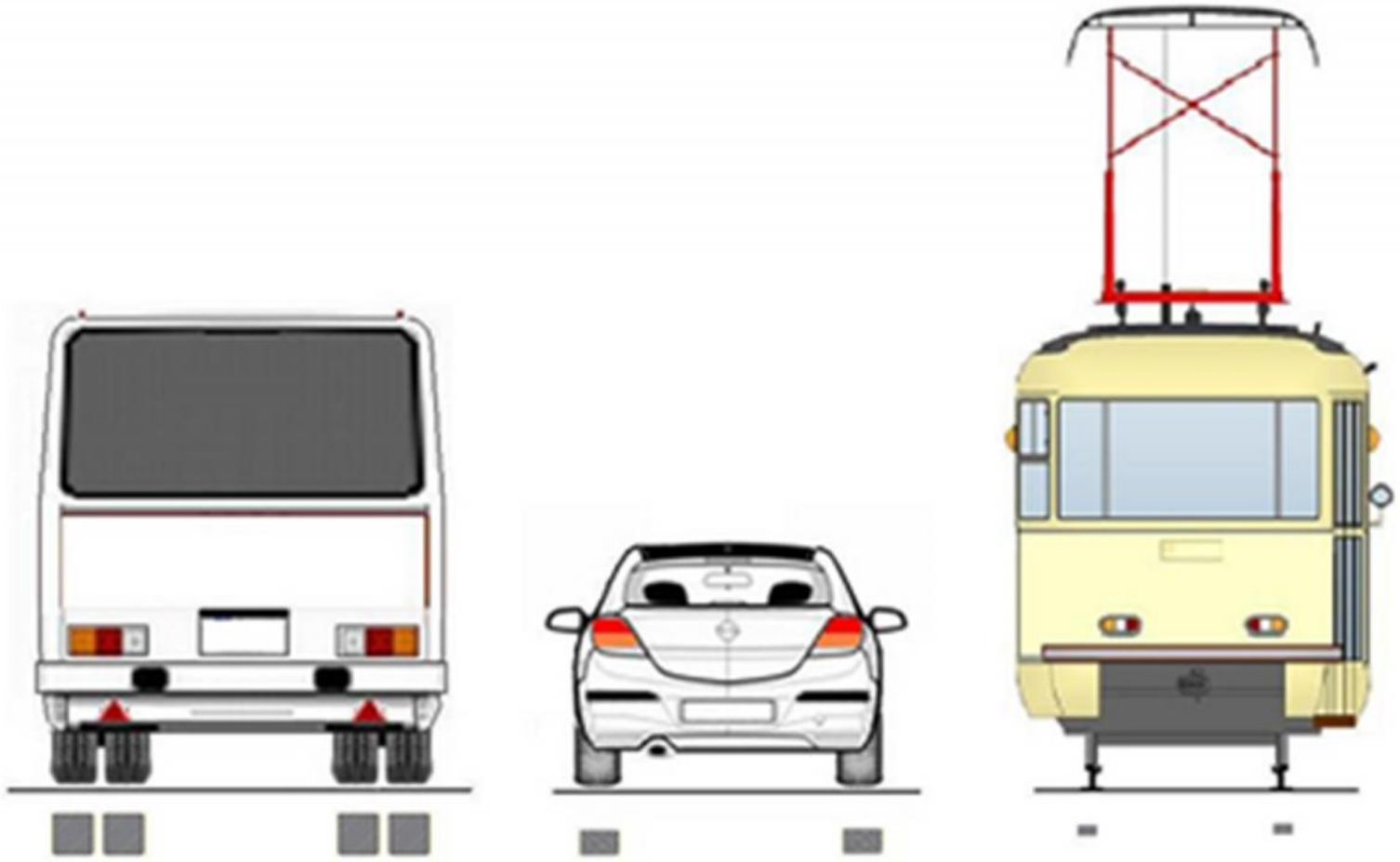
In energy recovery, the surplus current is fed back from the vehicle to the contact wire. The returned current is fed into the busbar so that it can be used by all vehicles taking power from the busbar of the relevant substation.

Vehicle dynamics: Inter-media

The forces between wheel and rail (adhesion traction force) depend on:

- Material characteristics
  - Steel on steel
- Inter-medium
  - Dirt, wear debris, oxide layers, leaves, sand, snow
- Total traction force of the vehicle
  - must always be less or at the most equal to the adhesion traction force
- Surface pressure
  - Contact area of the running area of the wheel on the surface of the Head of rail → Adhesive weight

Vehicle dynamics: Rolling friction



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Vehicle technology: DC motor with regenerative brake

- In the case of **electromotive brake**s, also regenerative brake, often called generator brake, the drive motor is used as a generator when braking.

- Energy is fed back into the power network (contact wire). In some trains the electricity generated is used to power the heating system or to charge the battery. However, additional equipment is required to do this.

- This process is called energy regeneration and the brakes are known as regenerative brakes.
  (recuperare = Latin for “recover”, “regain”)

Driving practice

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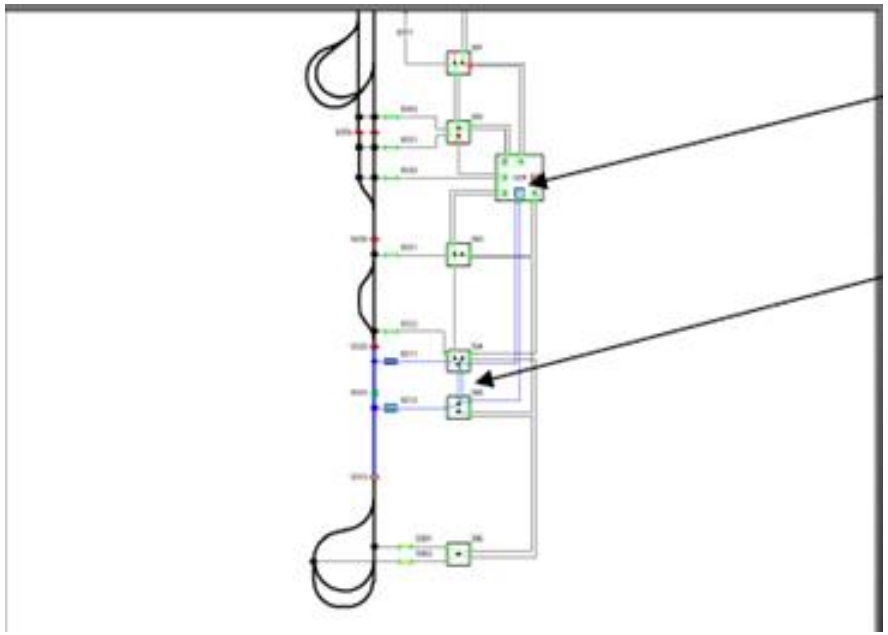
Tips on the practical part of training

- Selection of a “real” route/line for the practical part (ensure conditions are as realistic as possible, e.g. driving behind a scheduled bus) in order to simulate approaching, stopping and moving off from bus stops as close to reality as possible
- Determination of a certain sequence of drivers
- Prepare the energy measurement for the journey
- Application of “normal driving behaviour” (“before” run)
- If possible the same route and sequence of drivers should be retained for the “after” run
- Teach driving behaviour, including information provided during the theory part, during the “after” run
- Repeat energy measurements for a comparison of possible reductions in energy compared to the “before” run

Recording of consumption before and after training

1. Measuring individual journeys in a defined track section
2. Measuring the line in a defined track section
3. Individual evaluation of driving behaviour by observers



Measurements taken at the section take-off in the substation
Current and voltage measurements with power calculations

Auxiliary conditions:

single track section with signalling
no additional auxiliary equipment
partial use of road with motorised personal transport
passenger stops

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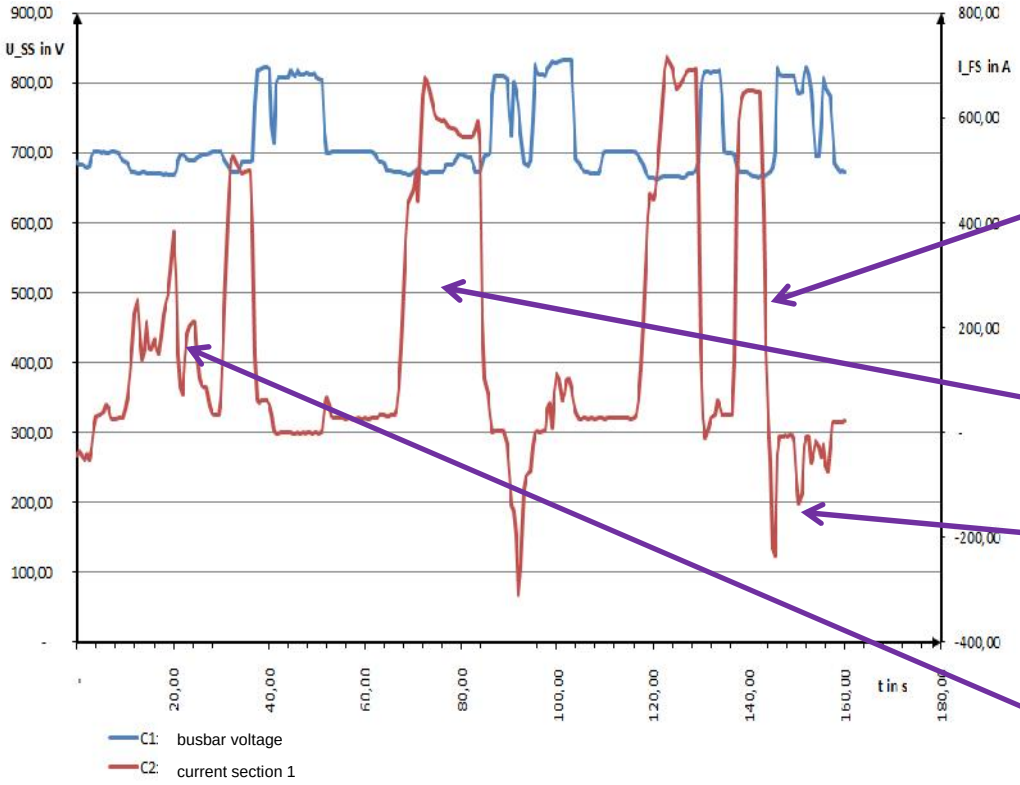
Energy consumption measurements

Measurements for untrained personnel → sub-optimal current curve due to agitated, stressful driving behaviour → setpoint device is moved continuously!



= bad driving behaviour

Hitting the brake before accelerating

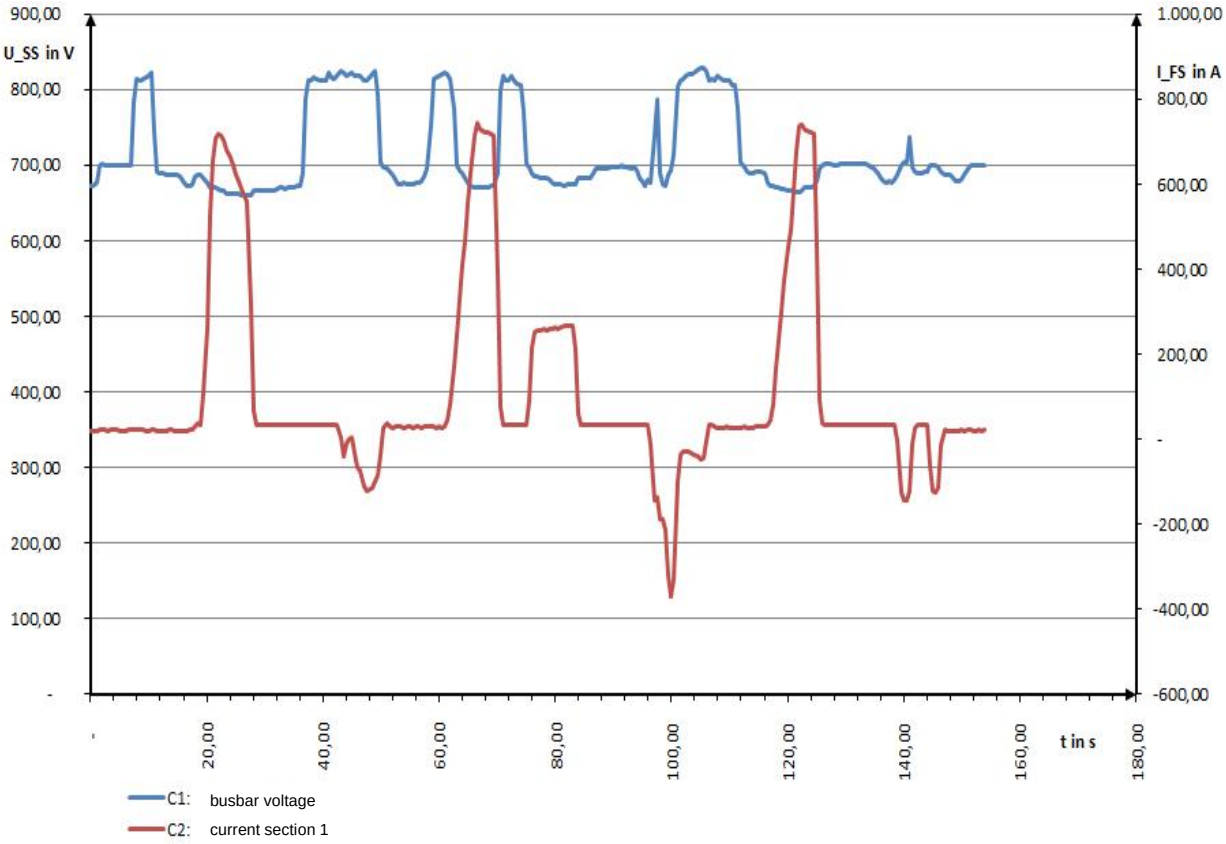
Long acceleration

Braking with energy recovery

Uneven, long, unbalanced acceleration

Energy consumption measurements

Measurements for trained personnel → ideal current curve due to calm, easy driving behaviour



= good driving behaviour

3x short, sharp accelerations and intermediate acceleration

3 braking actions with energy recovery

Results of energy measurements in Leipzig

Tram Evaluation T4D/T4D/NB4 =Tatra with a trailer vehicle from Bombardier

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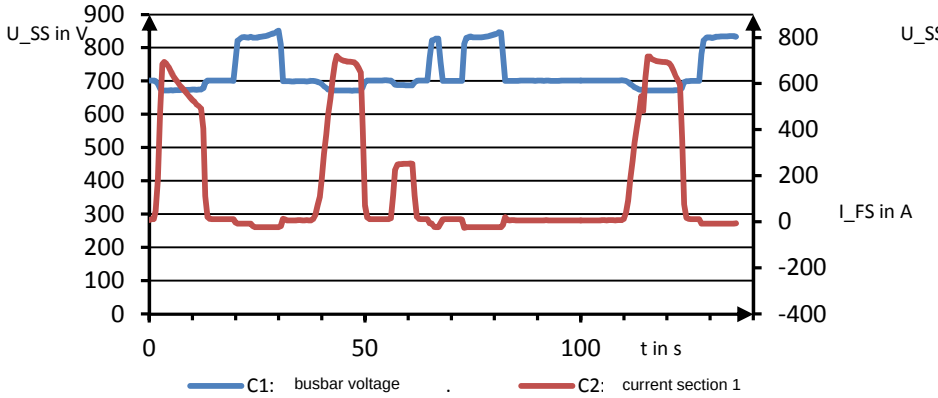
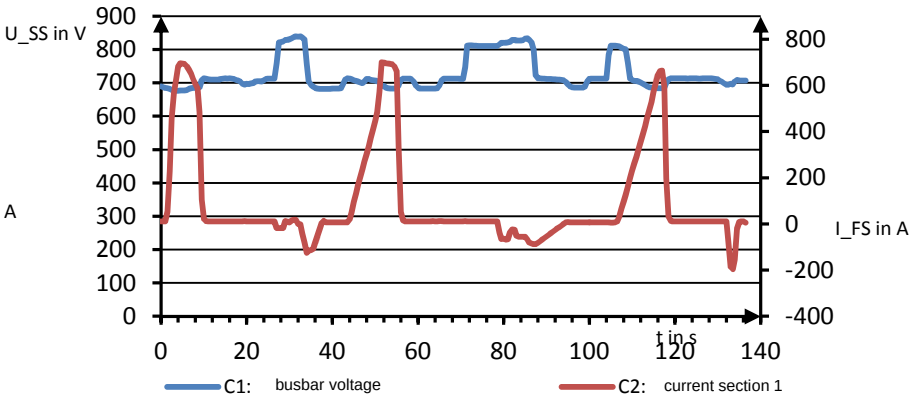
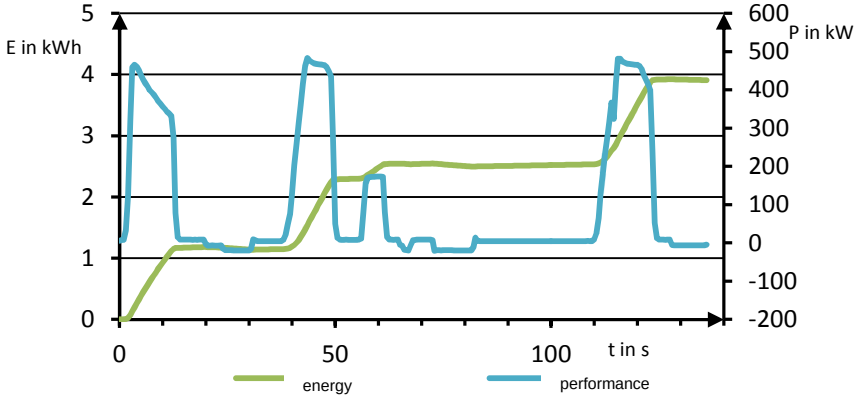
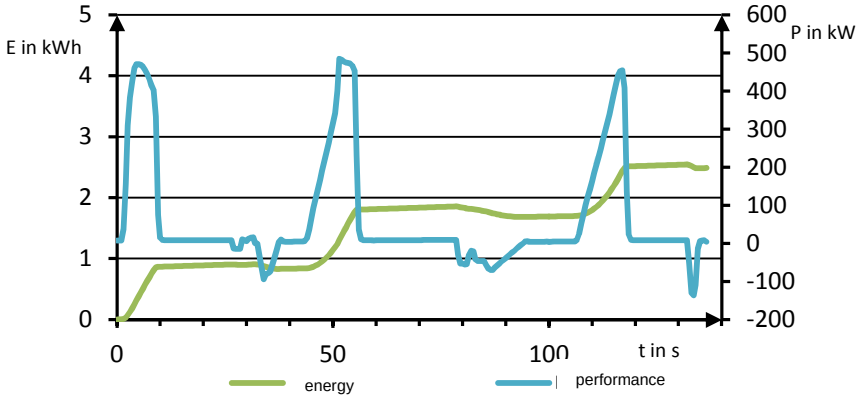
Tram Evaluation T4D/T4D/NB4 before and after training









Tram evaluation

energy consumption T4D/T4D/NB4

comparison

	kWh	kWh/km	t/s
Before training	3.98	4.55	137
After training	2.49	2.98	138
Effect	-44.5%		+0.7%

Tram evaluation NGT12 Bombardier Classic

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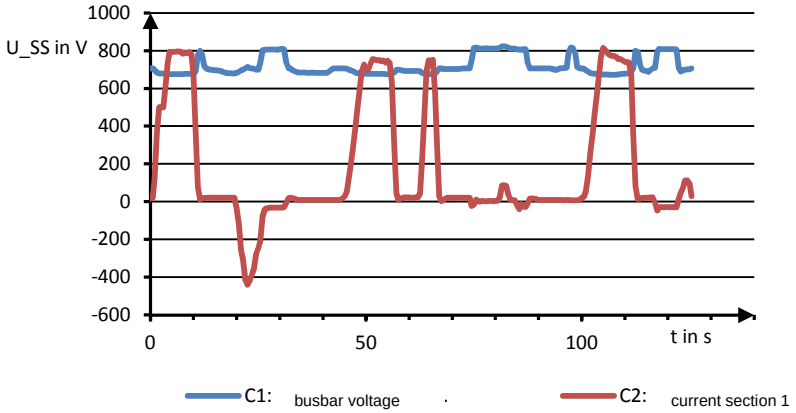
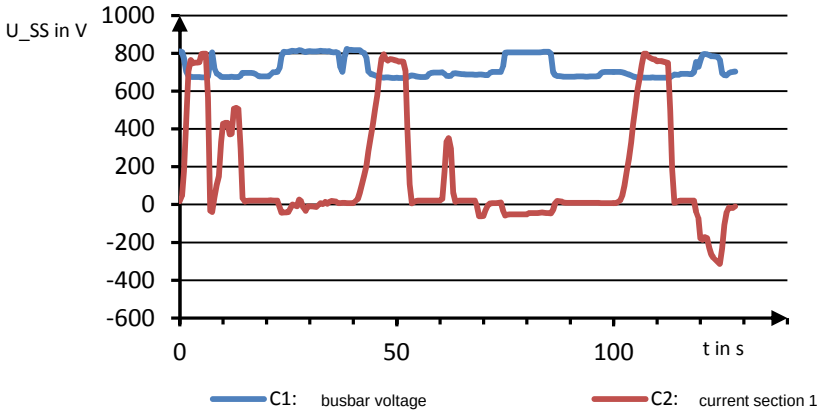
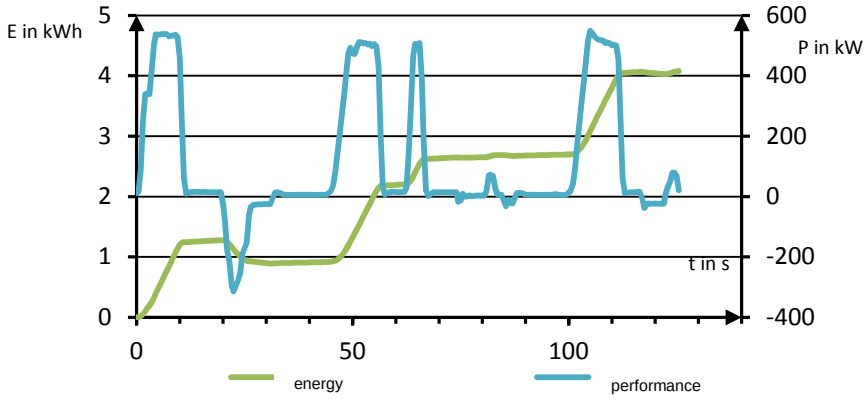
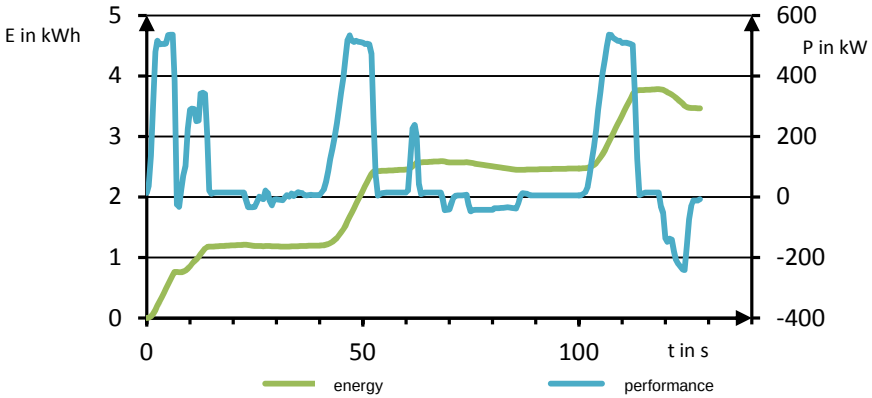
Tram evaluation NGT12 before and after training







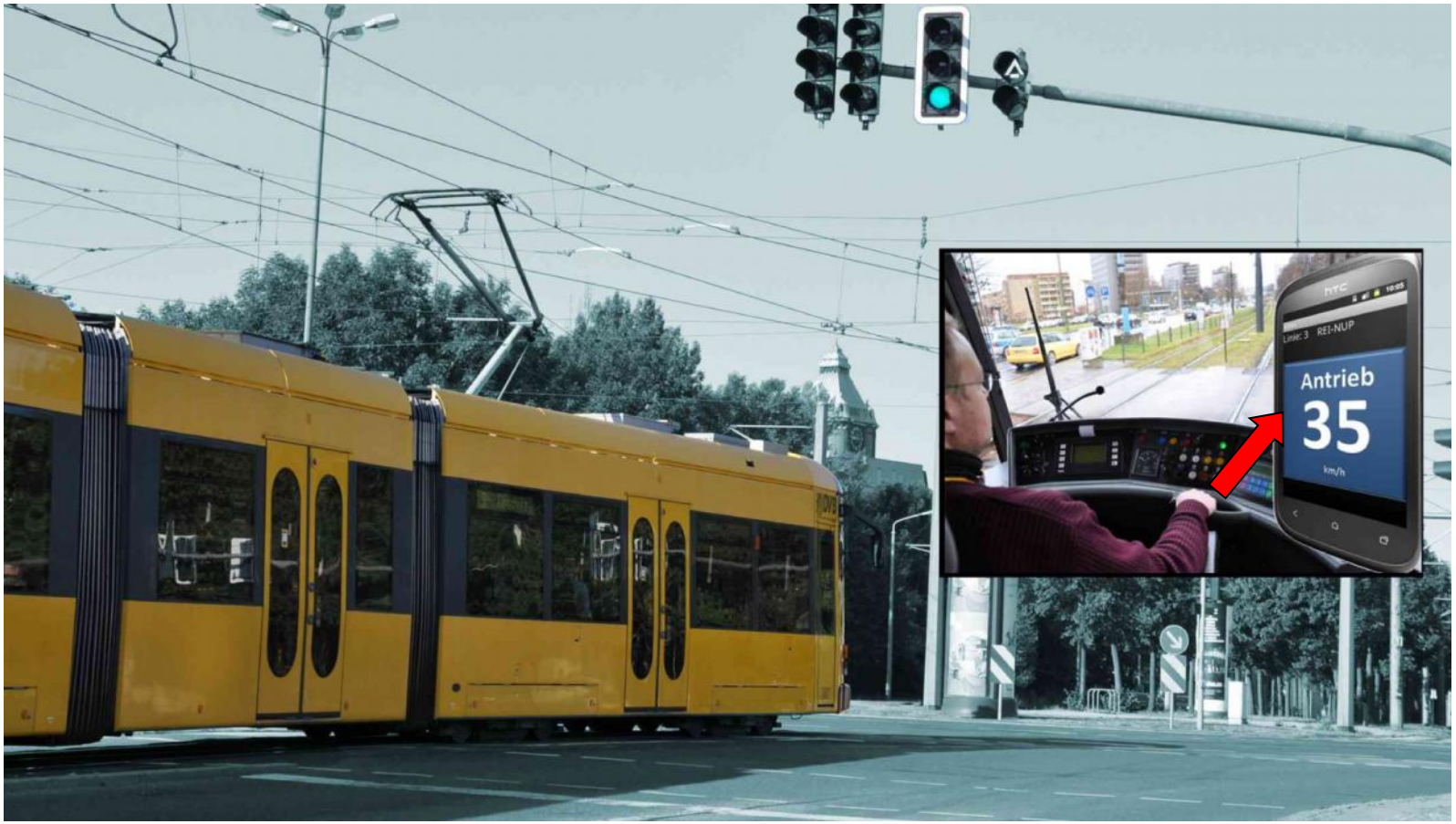


Tram evaluation

Energy consumption NGT12 Bombardier Classic comparison

	kWh	kWh/km	t/s
Before training	4.02	4.60	127 s
After training	3.48	3.98	128 s
Effect	-14.5%		+0.8%

New systems can be used, they define driving behaviour like a line protocol.



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6 golden rules for ecodriving!

- Accelerate vehicle slowly and evenly
- Consider adhesion when accelerating
- When the required speed is reached, go into neutral and allow the vehicle to roll
- Always think ahead when driving
- Start to apply the brakes in good time
- Brake evenly

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Safety aspects for trams

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Action to take if the tram derails

- Principle of Secure - Save - Report
- Immediately disconnect pantograph, power down vehicle,
- only then allow passengers to dismount
- put on hi-viz jacket before leaving the tram
- open doors manually and allow passengers to descend
- secure vehicle on all sides
- If the vehicle is obstructing other tracks, these must be secured also
- Inform traffic control and wait for the emergency vehicle from the workshop (to re-rail the tram)
- Once vehicle is re-railed drive to depot without passengers at 20 km/h max.

Action if the contact wire is damaged

- Principle: Secure - Save - Report
- Cordon off the area with hanging contact wires leaving a safe distance to the contact wire parts
- Do not touch under any circumstances (direct current → there is a risk of becoming stuck to the part)
- All hanging contact wire parts must be treated as live parts even though the circuit-breaker in the substation normally responds to contact wire damage by deactivating the section automatically
- it is forbidden to touch hanging sections of the contact wire
- Inform traffic control
- If the catenary power should, exceptionally, not be turned off, this will be done immediately from the power station via remote control

Loss of catenary power due to overload

- Use any momentum available to roll to the next section insulator (power might be available in the next section)
- Leave the pantograph attached on the first coach, disconnect the pantograph on the second coach (because of the auxiliary equipment that cannot be turned off)
- Inform traffic control
- If the power is restored, drive the first coach at a low speed to the next section insulator
- Once the first coach is there, the other coaches should follow in a similar fashion

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Thank you for your attention!

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