Grid-friendly high-power charging system for battery-electric rail vehicles

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In local rail passenger transport, BEMUs are increasingly being ordered to replace diesel traction vehicles for climate protection and financial reasons [1]. For operational reasons, recharging (with high power) may be necessary at stops that are not electrified. Such a charging system shall be built from existing, standardized components and be as inexpensive as possible. It makes sense to use a spatially limited overhead line system, allowing a maximum current of 80 A in standstill via the interface to the pantograph [2]. Using a medium voltage transformer only, i.e. without frequency conversion (in 16.7 Hz countries), increases reliability while saving cost as well.

However, the public grid operators specify limit values for the symmetrical load on the grid and for the influence of harmonics. These limits are based on the capacity of the power grid. Charging stations are primarily located in sparsely populated regions with a poorly developed grid. Strict limits are therefore to be expected. As the energy supply for railways is single-phase via the contact wire, symmetrical loading of the three-phase grid is a particular challenge.

Based on an idea from [3], the companies Rail Power Systems and F&S Prozessautomation have jointly developed and manufactured a transportable charging substation with the new voltage system AC 15 kV 50 Hz and a balancing converter [4] which can distribute the single-phase load symmetrically across the three-phase grid. This concept can be used with 25 kV traction current systems without any customizations, but keeping the frequency at 50 Hz represents an innovation in the 15 kV environment. Alstom as manufacturer of Coradia Continental class 1440 BEMUs agreed to upgrade their trains to be compatible with the AC 15 kV 50 Hz supply system. Thus, making it possible to test the overall charging system consisting of vehicle and infrastructure.

A test facility was set up at Annaberg-Buchholz Süd railway station in order to demonstrate the functionality of the concept and carry out measurements to proof compatibility to the grid. The successful tests shall support a common initiative to establish this frequency in combination with 15 kV too. Scientific support for the project is being provided by the Chair of Electrical Railways at TU Dresden [5].

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Using sensor data to assist decision-making for energy saving and capacity increasing

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Background

The urban rail transport systems in Stockholm are the most important parts of public transport, which provide cheap and time-efficient means of transport and help to ease congestion and pollution. Even if rail transport is energy-efficient and runs on green electricity, it still consumes a great amount of energy given its large transport volume. Meanwhile, the power supply systems of Stockholm's local rail transport are relatively old and weak, which lower energy efficiency and limit the increase in transport capacity. To meet the goal of a 15% electricity reduction, minimize the operational cost and increase transport capacity, based on sensor data from vehicle and infrastructure, a research project on finding solutions for more sustainable transport (financed by Vinnova) is conducted to set up a smart and cost-effective management plan for energy saving and capacity increasing.

Methodology

In practice, there are many different solutions to save energy and increase capacity, but the costs and benefits vary a lot from case to case. With the implementation of modern trains, much detailed information during train operation can be recorded through senors, e.g., speed, power, position, traction/braking, current, line voltage, indoor temperature, door opening, etc. All the information is related to operation and can be used for data analysis and modelling. To assist the business in making effective decisions, this work builds a business model to estimate the costs and benefits of different technical solutions to train operations, system upgrading and designs. The business model is divided into three groups of sub-models: technical models to estimate the effectiveness of different technical solutions, economical models to quantify the cost and benefits of different technical solutions, and decision-making assistance to make fair comparisons among different solutions. The cost and benefits of the suggested solutions can be quantified and taken as a key reference for decision-making.

Case study

With the help of the business model, a case study on the Stockholm's urban rail vehicles is performed. In this part, the costs and benefits of four technical solutions are studied: driving optimization, switching off some motors during cruising, resetting indoor temperature, passenger-control door opening, etc. Eventually, some suggestions for energy saving and capacity increase of the studied trains are given, and work for further developing the decision-making model is outlined, which can be implemented to different types of urban rail systems to assist future development.

Research on Multi-model Train Energy Consumption Evaluation Method

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Introduction

Climate is a global problem, and countries are actively looking for ways to reduce carbon emissions to achieve the goal of carbon neutrality. For vehicle manufacturers, how to accurately assess the energy consumption of the whole vehicle and components has become an important means to optimize the carbon emissions of vehicle manufacturers in the future. Therefore, CRRC-ZELC has developed a powerful software to simulate the energy consumption of a vehicle on a specific route, and based on this, we have identified a clearer direction for upgrading the vehicle.

Survey on problem formulation for railway energy optimisation including OESS

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Introduction

Trains propelled by low-carbon energy sources are investigated as green and cost-efficient alternatives to operate on partially and non-electrified lines. However, improvements in energy-efficiency and management are crucial to increase their range and extending their possible applications. This work presents the synthesis of current research on optimisation and onboard energy storage systems (OESS) within railways, aiming to map current practices and ideas, and identifying future research directions.

Analysis

A systematic literature review is carried out covering approximately 80 publications, analysing the OESS modelling level, method and problem formulation. With the addition of OESS, the energy optimisation must consider more than one energy source and the power flow between these. Energy management strategies (EMS) are used to control the split of the train's power demand to ensure optimal efficiency of the traction chain.

The main findings indicate that most papers utilize a basic electrical circuit to model the OESS, with some incorporating the non-linear relationship between SoC and voltage for Li-Ion batteries. Despite more complex models available, the simplicity of the basic model is argued to provide sufficient accuracy and computational efficiency, crucial for real-time applications. The most common optimisation dimension is optimisation of the EMS, considering either offline global optimal EMS based on given power profiles, or online application based on e.g. sensitivity analysis, Leska et al. (2017). Furthermore, several papers consider a combined optimisation of EMS and capacity of OESS, or EMS and train trajectory. Only a handful articles focus on optimising the power infrastructure, whereas several papers consider the integration with infrastructure by introducing use cases with different electrification scenarios.

Conclusions

Initial trends have been identified in research focusing on energy railway optimisation. With the scope limited to OESS, there is a focus on studying the energy problem at train and traction chain level, with less optimisation of the infrastructure. Additionally, the modelling of OESS is predominantly based on simple models, as several parameters must be consider when formulating the energy optimisation problem at a higher level.

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Energy efficient operations of Railway Switch heaters

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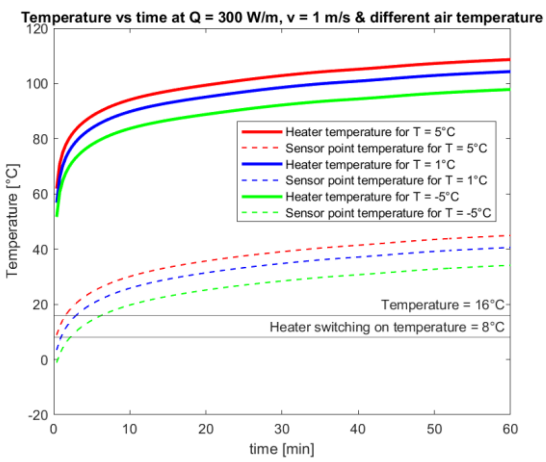
Introduction

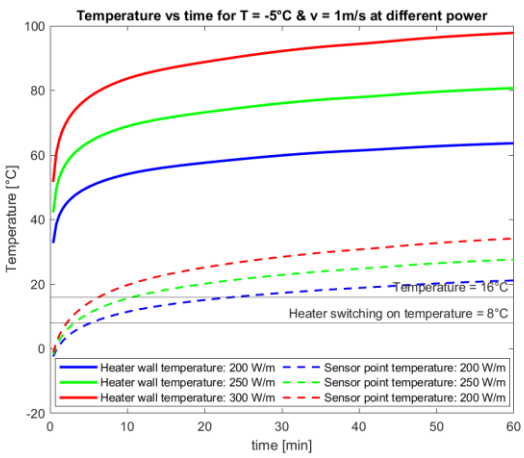
A railway switch is a vital component for its safe, reliable, and time-bound operations. Faults in switches are common in locations experiencing winters due to snow or ice buildup, despite using heating systems. The majority of switches are electrically heated, and guidelines for their efficient operations have been studied in this work. A computational model has been created to understand the temperature distributions in switch heating systems, and it has been verified from the annual heating data of an operational switch in Sweden. The results from a parametric study by varying ambient temperature, wind load, and heating element power can be used to implement heating control strategies in existing heaters, which will support their sustainable operations.

Analysis

Many switches operate in dual power modes, i.e., normal mode at lower power and boost mode at higher power, while some switches can only operate at single power, but their switching on-off cycle is based on a threshold rail temperature. By utilizing real-time weather, rail temperature monitoring, and a voltage control strategy, a wide range of heating power ranges can be adopted.

Using CFD modelling,at higher ambient temperatures and lower wind speeds, the rail temperature is fairly predictable, especially in non-snowing conditions. But for other boundary conditions, like sub-zero temperatures with different wind speeds, the rail temperature can deviate much from the threshold temperature.





Conclusions

The simulations agree closely with the measurement field data. The deviations can be attributed to unknown values of the wind speed, especially at lower temperatures.