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Review

An assessment of available measures to reduce traction energy use in railway networks

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A R T I C L E I N F O

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A B S T R A C T

Rail is becoming an increasingly popular choice to satisfy transportation demands locally, nationally and internationally, due to its inherent efficiency and high capacity. Despite this, operators are facing pressure to reduce rail energy consumption to meet efficiency targets, whilst still maintaining service quality and managing increased demand. A number of individual measures have been proposed to reduce energy in the rail sector, often showing good results on specific case studies. It is generally agreed that the attainable savings of a given measure change dependant on the route, vehicle and service characteristics. However, there is little information in the literature specifically regarding which measures are most suitable for given network types, or how they interact. This paper therefore aims to begin evaluating the available measures in terms of their suitability for different systems. Firstly, networks are defined in terms of their distinguishing features. As traction accounts for the majority of all energy use in the rail sector, the traction flow through a vehicle is considered as the starting point for an evaluation of measures. Current technologies and procedures are reviewed and categorised based on which area of traction use they target. Thought is given to the factors that affect implementation and the networks where they are applied. A key output of this paper is a comparison of the achievable energy savings of different measures dependent on the network type. It is hoped that this will provide a good starting point for identifying which measures are most applicable for a given network, and the characteristics that affect their success.

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Contents

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Nomenclature

AC	Alternating Current
ATO	Automatic Train Operation
ATP	Automatic Train Protection
BYZ	Beijing Yizhuang Line
CBTC	Communications Based Train Control
C-DAS	Connected Driver Advisory System
DAS	Driver Advisory Systems
DC	Direct Current
DTC	Direct Torque Control
ECML	East Coast Main Line
ETCS	European Train Control System
EDLC	Electrochemical Double Layer Capacitors
ERTMS	European Rail Traffic Management System
ESS	Energy Storage Systems
FBS	Fixed Block Signalling
GA	Genetic Algorithm
GSM-R	Global System for Mobile Communications-Railway
HS	High Speed Rail
HS1	High Speed One
HVAC	Heating, Ventilation, Air Conditioning
IC	Inter City
LED	Light Emitting Diode
LP	Linear Programming
PMSM	Permanent Magnet Synchronous Motor
RBE	Recovered Braking Energy
RTCR	Reversible Thyristor Controlled Rectifier
T2K	Ticket to Kyoto
TMS	Traffic Management System
UIC	International Union of Railways
VVVF	Variable Voltage, Variable Frequency
WESS	Wayside Energy Storage System

1. Introduction

Rail transport is arguably one of the most efficient methods for mass transportation of passengers. This makes it a popular choice for satisfying increasing transport demands in an environmentally concerned economy [1]. However, despite the inherent efficiency, European Union reports show there is still significant energy usage by the rail industry [2]. The increased demand placed on rail services by a growing population will no doubt further increase consumption [3]. As such, environmental objectives have been set by international organisations aiming to improve energy efficiency and reduce carbon emissions, whilst also acknowledging growth predictions. Targets in Great Britain to improve efficiency by 50%, and reduce carbon emissions by 25% are already in place [4,5], with similar targets identified for countries across the world.

In order to meet the specified energy efficiency targets railway networks have to be improved. A wide variety of measures can be applied to save energy and improve network efficiency. Specific applications may involve changes to the infrastructure, operations or rolling stock on a particular network or line, or in more than one of these areas. Through the development of accurate models and simulators, researchers are better able to predict the energy savings from implementation of measures [6]. However, many researched methods are very limited, being only applicable to small line sections or certain types of railway under exact conditions. Network Operators therefore face a difficult decision when choosing combinations of methods to implement. Current research often simplifies the network complexity and focusses on single methods without considering the interactions between them. It is also important that whilst improving energy efficiency the railway is able to provide a punctual, timely, affordable service with greater capacity for the future [3].

As traction energy use accounts for the majority of the total energy consumption in rail, between 60% and 80% [7–9], it is a key area for energy reduction and the focus of this review. Successful implementation of an energy saving measure can depend upon the route, vehicle and service characteristics of where it is implemented. Therefore, identifying the features which differentiate networks is a key step in recognising which characteristics impact on the success of measures. The traction energy flow through systems is then evaluated, highlighting the key areas for energy reduction. A comprehensive overview of available measures is conducted, in terms of the savings achieved for each network type. Finally, conclusions are presented which aim to give guidance on the most suitable methods for a given system.

2. Defining rail systems

Throughout the course of this review, numerous terms have been found to describe similar networks. For example metro, mass transit, light rail, suburban, rapid transit, etc. Although differences do exist between these types, they are subtle in comparison to the characteristic differences between routes such as metro and intercity, or metro and high speed. The following section defines a way to categorise lines into one of three types: Urban, High Speed

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