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ADVANCING RAILWAY ELECTRIFICATION: A TEST PLATFORM FOR TRACTION POWER CONVERTER OPTIMIZATION

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Summary: The railway sector is a key player in passenger and freight transportation, with 2023 marking a record high for rail passenger transport in the EU—reaching 428.9 billion passenger-kilometers, according to Eurostat. The rising demand for passenger coaches and electric multiple units (EMUs) is driving innovation in railway components, particularly in electrification. Notably, railway electrification has seen significant progress, with a 16.7 percentage point increase in electrified lines from 1990 to 2022. Portugal led this growth, increasing its electrification rate from 14.7% to 70.9%.

This abstract presents advancements in railway power converter tuning aimed at improving energy efficiency. Power converters are critical components in electrified rolling stock, converting electrical energy into mechanical power (as in traction converters) or transforming it into other electrical forms (as in auxiliary converters for coaches and EMUs).

As part of the Next Generation EU program and the Train Solutions Portugal project, a new control unit for the traction converter of a LE5600 series locomotive is being developed. This work stems from multiple master's dissertations focused on creating a testbench platform for traction power converter development.

The testbench consists of a 50 kW three-phase power converter and a 50 kW DC motor. On the AC side, a power inverter and control unit can be tested, while on the DC side—this abstract's main focus—a power converter for both traction and regenerative modes has been developed. The power converter comprises four key sections:

A DC/AC single-phase bridge that converts the 350 VDC bus into an AC waveform.
A high-frequency transformer providing a high step-down gain with galvanic isolation.
A diode rectifier stage.
Armature and field contactors that control motor rotation direction and transition between motor and generator modes.

To complement the testbench, a train emulation software was developed to replicate real-world train performance. The LE5600 locomotive, towing six carriages, was used as a case study. The proof of concept demonstrated successful operation in both traction and regenerative modes, achieving full motor speed (1000 RPM), corresponding to a 200 km/h train speed. Additionally, the system accurately linked motor speed with the train emulation software, allowing real-time interaction. A three-phase inverter was tested as the system under evaluation, with traction mode performance influenced by speed variations.

This research provides a controlled laboratory environment for testing traction converter control units, offering the flexibility to simulate different rolling stocks and hazardous conditions, such as wheel slippage. The developed platform paves the way for safer and more efficient railway power conversion systems.