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Review on the use of energy storage systems in railway applications

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Abstract-

The imperative for moving towards a more sustainable world and against climate change and the immense potential for energy savings in electrified railway systems are well-established. Utilising regenerative energy generated during train braking represents a valuable opportunity for maximising these savings. Consequently, incorporating energy storage systems to store and reuse this regenerative energy has emerged as a crucial strategy. Energy storage technologies have become indispensable in achieving overall energy efficiency objectives.

The wide array of available technologies provides a range of options to suit specific applications within the railway domain. This review thoroughly describes the operational mechanisms and distinctive properties of energy storage technologies that can be integrated into railway systems. A research review is carried out to determine the operating parameters of each technology, which are subsequently analysed and compared against the desired characteristics essential for railway applications.

Despite their lower energy density, superconductive magnetic energy storage systems demonstrate superior efficiency, making them suitable for specific applications. In contrast, vanadium redox batteries face challenges for on board use due to maturity issues, heat emission requirements, and inefficiencies in charge/discharge cycles. Conversely, supercapacitors and Lithium-ion batteries are viable options for on board applications, and the first are preferred for their higher efficiency and cost-effectiveness. Based on their established operational maturity and performance, supercapacitors and flywheels are recommended for wayside energy storage systems. The insights from the analysis are supported by real-world examples of energy storage systems implementations in railway systems worldwide.

Index Terms- Energy storage; Railways systems; Regenerative energy; Energy efficiency; On board; Wayside

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