

# **Multi-stage optimization of the installation of energy storage systems in railway electrical infrastructures with nature-inspired optimization algorithms**

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## **Abstract-**

Installing railway systems implies considerable investments that must be assessed carefully. Therefore, it is often necessary to combine detailed railway simulations and decision support mechanisms. Unfortunately, most examples in the literature deal with this topic applying only a single-stage optimization approach: the whole installation is undertaken in a single step, assuming the total budget is available.

This paper presents a comprehensive methodology to assess the gradual deployment of the installations when the budget is split into different time periods. This approach is a common situation in real projects and has not been studied yet in the literature. Most often, this type of multi-stage problem is tackled by optimizing each stage independently. On the contrary, this paper proposes to take decisions considering the global impact of each rendering a more efficient solution.

This paper proposes a multi-stage formulation of two nature-inspired optimization algorithms (Genetic and Fireworks) to address the installation of ESSs in a realistic railway line. Results demonstrate the excellent behavior of the proposed multi-stage optimization.

**Index Terms-** Optimization of Energy Storage Systems; Nature-inspired optimization algorithms; Railway simulation; Railway power systems; Energy efficiency

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