

Optimal design of energy-efficient ATO CBTC driving for metro lines based on NSGA-II with fuzzy parameters

W. Carvajal, A.P. Cucala, A. Fernández-Cardador

Abstract— One of the main priorities for metro line operators is the reduction of energy consumption, due to the environmental impact and economic cost. The new moving block signalling system CBTC (Communication Based Train Control) is being installed in order to increase the transport capacity of new metro lines, and to upgrade lines equipped with the former fixed block signalling systems. In addition, this new technology could be used to improve energy efficiency in the traffic operation, due to its capability to update the ATO (Automatic Train Operation) driving commands not only at stations but also along the journey.

In this paper a new optimization algorithm is proposed to design ATO CBTC speed profiles to minimize energy consumption, generating the Pareto optimal curve. The algorithm is a multi-objective NSGA-II-F based on simulation of the train motion under uncertainty. The main source of uncertainty in the consumption calculation is the mass of the train, which is dependent on the passenger load, and it is modeled as a fuzzy number. In addition, a new method is proposed to fill running time gaps with dominated points, providing a pseudo-Pareto curve.

The NSGA-II-F algorithm has been applied to design ATO CBTC optimal speed profiles in a case study of Metro de Madrid, providing additional energy savings up to 7.3% compared to former fixed block signalling systems and a well time-distributed pseudo-Pareto curve for the running times required by the traffic regulation system.

Index Terms— Energy efficiency; CBTC signalling system; ATO; Metro; Eco-driving; Fuzzy NSGA-II algorithm

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