Solving the Multi-period Electric Vehicle Routing Problem with matheuristics

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1 Introduction

Recent innovations in battery technology are allowing to overcome electric vehicles' (EVs) restrictive driving range. As a result, companies using EVs for urban and semi-urban operations do not longer need to plan for mid-route battery charging and can restrict all charging operations to take place overnight (or between shifts) at the depot. However, the trivial policy of fully charging all vehicles every night can lead to poor fleet management decisions. First, this policy may simply be infeasible because of charging infrastructure constraints, such as grid constraints, maximum number of available chargers and duration of the charging operations. Second, this practice has a great and negative impact in the lifespan of the batteries (the most expensive and ecologically unfriendly component of an EV). To solve these issues, routing and charge scheduling decisions must be simultaneously made over a planning horizon of (at least) few days/shifts. The resulting problem is known as the Multi-period Electric Vehicle Routing Problem (MP-E-VRP) [1].

The MP-E-VRP consists on designing routes to be performed by a fleet of EVs to serve a set of customers over a planning horizon of several periods. EVs are charged at the depot at any time, subject to the charging infrastructure capacity constraints. Due to the impact of charging and routing practices on EVs battery aging, degradation costs are associated with charging operations and routes. The objective of the MP-E-VRP is to determine, for each period, a set of routes visiting all the customers and to schedule the charging operations of the EVs while minimizing the degradation costs. The MP-E-VRP integrates EV routing and depot charging scheduling, and has coupling constraints between days. These features make the MP-E-VRP a complex problem to solve. We define a restricted version of this problem by limiting the routing decisions to the selection of routes from a given pool (identified by the planner as attractive routes) while still considering charging decisions and keeping all constraints unchanged. We refer to it as the Multi-period Electric Vehicle Route Assignment and Charge Scheduling Problem (MP-E-VRACSP). We proposed in [1] and [2] continuous-time mixed integer linear programming (MILP) formulations of the MP-E-VRP and the MP-E-VRACSP (hereinafter referred to as F1 and F2). We showed in [2] that F1 can only solve small-size instances and therefore proposed a two-phase matheuristic embedding F2, that proves to be suitable for solving medium sized instances.

In this work, we describe a constructive heuristic for computing an initial solution to the MP-E-VRP by focusing on the solution space associated to the MP-E-VRACSP. We use this heuristic solution as a warm start when solving F1 and F2. We also introduce two local branching matheuristics to search for good quality solutions. We performed computational experiments to assess the effectiveness of the proposed methods in solving the MP-E-VRP. We identified better solutions to the MP-E-VRP than those reported in previous work. The results will be presented during the conference.

2 Matheuristics for the MP-E-VRP

2.1 Heuristic initial solution

To construct a heuristic solution to the problem, we decompose the problem into two stages to be solved sequentially : 1) generation of attractive routes, and 2) assignment of EVs to routes and scheduling of charging operations. For the first stage, we use a two-phase heuristic based on the multi-space sampling heuristic (MSH) proposed by Mendoza and Villegas [4]. In the first phase it builds a pool of routes (Ω) via a set of randomized route-first cluster-second heuristics. In the second phase, the algorithm solves a set partitioning formulation on Ω, obtaining the set of routes σ. The set partitioning formulation minimizes the energy consumption of the routes selected, as the energy consumption is directly related with the degradation costs associated to the routes. For the second stage, our constructive heuristic takes as input the set of routes σ. For each period, the heuristic assigns the route with the highest energy consumption to the EV with the most available energy and continues the assignment until all routes of the period are assigned. In addition, the heuristic checks for the satisfaction of the charging infrastructure capacity constraints.

2.2 Local branching matheuristics

We present two adapted versions of the local branching heuristic (LocBra) developed by Fischetti and Lodi [3]. LocBra performs local searches in neighborhoods obtained by adding linear inequalities to a MILP formulation. It consists on three main phases : neighborhood definition, intensification and diversification. We use F1 as the base MILP formulation for one of the versions of LocBra and F2 for the other. We adapt the neighborhood definition and the diversification strategy considering the properties of the MP-E-VRP, in order to improve the heuristic performance. LocBra requires as input an initial solution. This solution can be provided whether by solving F1 (or F2) with a time limit or by using the constructive heuristic presented before.

Références

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