Solving Electric Vehicle Scheduling Problem with Heuristics

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1 Introduction

This paper study the electric vehicle (EV) charging scheduling problem where EVs arrive at the charging station at unknown instants during the day with different charging demands and departure times. We consider the charging station designed as in [1] where each EV has its own parking place. The objective is to built a real time schedule that minimize the total tardiness subject to the physical constraints of the charging station. To solve large instances, we propose heuristic based on the Priority Rule for Total Tardiness criterion. We consider preemptive as well as non-preemptive schedules. Simulation results indicate that the proposed heuristic outperforms the existing heuristics previously developed for the same problem.

2 Problem formulation

We address the EV charging scheduling problem in the charging station described in [1]. The charging scheduling horizon starts at 00:00h for 24 hours and is divided into T regular time slots. We have a total of M EVs. Each EV i, $i = 1, ..., M$ has its own parking space and arrives at the station at random instants. This means that the arrival time r_i, charging time p_i and departure time d_i are prior unknown to the charging station before the actual arrival of the EV. As a result, the schedule must be built iteratively.

The station is fed with a three-phase current power. Thus, there are three conductors, each carry an alternating current of the same frequency and voltage amplitude. These conductors are called lines and each line j consists in N_j power outlets, $j = 1, 2, 3$. However, two constraints limit the number of outlets that can deliver power simultaneously. The first constraint (1) is related to the maximum power that can be drawn from each line j, $j = 1, 2, 3$, so that system overload can be avoided.

$$N_{j,t} \leq N \qquad \forall\ t \in T, j = 1, 2, 3 \tag{1}$$

Where $N_{j,t}$ represents the number of EVs being charged in line j at time slot t and N is the maximum of power outlets that can deliver power simultaneously in any line at any time. The second constraint (2) maintains the load balance between the three lines. In fact, in three phase power system, the load should be distributed evenly between the three lines by means of a parameter $\Delta \in [0, 1]$.

$$|N_{j,t} - N_{k,t}| \leq \Delta N \qquad \forall\ t \in T, j \neq k, k, j = 1, 2, 3 \tag{2}$$

By controlling the switching on and off of the power outlets, we aim to schedule the charging among all the EVs plugged in to their requested charging time such that the previous constraints are maintained and the the total tardiness is minimized, defined as:

$$\min \sum_{i=1}^{M} \max(0, C_i - d_i)$$

Where C_j denote the completion time of charging the EV i.

As an initial case study, we consider the non preemptive scheduling as in [2, 1], where the charging of an EV cannot be interrupted until it completes charging. Then, we investigate the case study where preemption is allowed. In this case, the charging of an EV can be interrupted and an another EV will be charged instead.

3 Solving the problem with heuristics

In the case where we have one line, the problem is equivalent to scheduling jobs on parallel machine $P|r_i|\sum_i T_i$ which is NP-Hard. Thus, we propose heuristics to solve both the preemptive and non preemptive charging scheduling problem based on the RPTT (Priority Rule for Total Tardiness) dispatching rule used in [3]. We define the PRTT of a job i at time t by:

$$PRTT_i^t = \max(d_i, t + p_i). \tag{3}$$

At each time slot, for each line, the PRTT of ready and not assigned jobs are calculated using the equation (3) in non preemptive scheduling. These jobs are ordered in increasing order of their PRTT values. Then, we schedule only the jobs that can be added to the schedule at time t in line j without breaking the constraints (1) and (2). We improve the assignments of jobs at the end of each time slot in case that an assignment of job breaks a previous imbalance constraint as it is expressed by (4). In this case, we redo the affectation for the time slot t.

$$\min\{|N_{k,t} + 1 - N_{j,t}| - \Delta N; k \in 1, 2, 3, k \neq j\} \leq 0 \tag{4}$$

For preemptive scheduling (pmtn), we modify the PRTT function to take into account only the remaining charging time of an EV instead of the whole charging time.

Considering the benchmarks proposed in [1], we compare the performance of our proposed heuristics to heuristics proposed in [1, 2]. The results are shown in table (1). Each value represents the sum of the tardiness (in hours) of the 30 instances of the problem with different values of the parameters Δ and N. An instance has 180 EVs distributed in the 3 lines. We can see that our heuristics outperform the existing ones especially when preemption is exploited.

N	Δ	LST [1]	PD [1]	EVS [2]	PRTT	PRTT pmtn
20	0.4	6633.33	4241.66	4120.40	3975.00	3030.10
20	0.8	4516.67	3808.34	3590.90	3454.70	2621.10
40	0.2	1933.34	646.67	735.00	712.90	235.00
40	0.4	75.09	27.92	14.00	14.10	2.00

TAB. 1: Comparison of results

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