EV Charging Problem Formulation

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1 Relate Works

Reference [1] formed the EV charging problem as an optimal control problem whose object is valley filling.

Reference [2] formed it as a scheduling problem with an object of maximize total consumer utility.

Reference [3] study the energy efficiency of scheduling problem, which I found is similar to our problem.

2 Problem Formulation

2.1 Symbols

N	number of EVs.
T	horizon of scheduling, usually being a day.
t	time slot, $t \in T = \{1, \ldots, T\}$.
ΔT	length of time slots.
$r_i(t)$	charging rate of EV i at time t.
$r(t)$	charging rate vector $\{r_1(t), \ldots, r_N(t)\}$.
$E_i(t)$	remaining capacity to be charged of EV i at time t.
$D(t)$	state of the grid at time t, non-EV load at time t.
$L(t)$	total load at time t.
$C(L(t))$	total cost at time t.
$u()$	user utility function.

2.2 Problem 1 Valley Filling

Total load at time t is

$$L(t) = D(t) + \sum_{i=1}^{N} r_i(t)$$

suppose the flattened load is V_{flat}, then valley fill can be formed as

$$\sum_{i=1}^{N} r_i(t) = \max\{0, V_{flat} - D(t)\}$$

when cost function $C()$ is strictly convex, valley-filling is equal to cost minimization [1]

$$\begin{aligned} \min \quad & C(D(t) + \textstyle\sum_{i=1}^{N} r_i(t)) \\ \text{s.t.} \quad & 0 \le r_i(t) \le r_i^{max}, t \in T, n \in N \end{aligned}$$

2.3 Problem 2 Aggregate Utility

Assume users are equally satisfied as long as EV charging meet deadline. The user utility decreases as the remaining capacity after deadline increases.

Define each user's utility:

$$u_i = u(E_i(t_{deadline}))$$

Assume utility function $u : \Re \rightarrow \Re$ to be concave, the problem of maximize aggregated utility can be formed as

$$\max \quad \sum_{i=1}^{N} u_i$$

References

[1] Gan, Lingwen, Ufuk Topcu, and Steven H. Low. "Optimal decentralized protocol for electric vehicle charging." (2012): 1-12.

[2] Xu, Yunjian, and Feng Pan. "Scheduling for charging plug-in hybrid electric vehicles." Decision and Control (CDC), 2012 IEEE 51st Annual Conference on. IEEE, 2012.

[3] Sinha, Amit, and Anantha P. Chandrakasan. "Energy efficient real-time scheduling." Proceedings of the 2001 IEEE/ACM international conference on Computer-aided design. IEEE Press, 2001.