A Survey on Congestion Avoidance and Optimal Charging Strategies for Electric Vehicles

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Abstract

Nowadays electric vehicles are widely promoting to improve transport efficiency. One of the disadvantages of the electric vehicles is its short driving range. So we have to recharge it in the midway in case of longer journeys. Concurrent and frequent demands for battery recharge will result in the queuing at the charging station and a battery recharge also takes several minutes. Thus the resulting waiting time at the charging station will increase the entire travelling time. Many approaches are used to provide optimal charging strategies for electric vehicles at the charging station. This paper provides a comparative study of different strategies used for the congestion avoidance and optimal charging of electric vehicles at the charging stations by considering these aspects entire journey time of electric vehicles can be reduced or optimized to an extent.

Keywords: Battery Recharge, Charging Station, Congestion Avoidance, Electric Vehicles, Optimal Charging Strategy

I. INTRODUCTION

In order to reduce the emission of carbon dioxide and greenhouse gases into the environment usage of electric vehicles are widely promoting. Even with the new technologies at the charging station a battery recharge is time consuming and thus it will result in the high queuing time and congestion at the charging station. Charging requests from multiple vehicles at the same time will also result in the congestion at the charging station. Entire travelling time of electric vehicles is also increasing as a result. Many approaches are using to reduce the congestion and to optimize the charging strategies for electric vehicles like the reservation system for charging of electric vehicles at the charging station [1]. Similarly for routing and load balancing congestion games models are used [4]. Using some approaches we can predict the prior blockage probabilities at the charging station [5] with respect to the intensity from the vehicles [2] using the technologies such as wireless communication [7]. There are options for charging electric vehicles at parking lots also in some approaches [6]. Likely in road transport network signal settings are optimized with respect to the demand of travel to a congested road [3], here considering electric vehicles only and the classification is based on the congestion avoidance and optimal charging strategies.

II. CLASSIFICATION OF OPTIMIZATION TECHNIQUES FOR CONGESTION AVOIDANCE AND CHARGING STRATEGIES

Following are the classification of optimization techniques for congestion avoidance and charging strategies as shown in fig 1.

![Classification of optimization techniques](image-url)

Fig. 1: classification of optimization techniques for congestion avoidance and charging strategies
A. Caravan-Optimization

CARAVAN is a Congestion Avoidance and Route Allocation using Virtual Agent Negotiation. It is a multi-agent based approach [8]. In this approach vehicle agents communicate with each other before the junctions or designated decision points along their route. Intervehicular communication is to transfer information and to perform processing. Each vehicle agent transfers their autonomously calculated preferred route to get the initial route allocations. This allocation is further improved using the number of successive virtual negotiations called deals. Physical communication is not required for deals. This approach is based on congestion management algorithm.

1) Advantages
   - Provides a promising strategy for traffic route allocation problem
   - Gain in travel time
   - Provides a low cost solution

B. Intension Aware Optimization

It proposes an Intension aware routing approach for electric vehicles [2]. If other vehicles choose the same charging station it is essential to reduce the significant queues at the charging station and it is done by collecting the information about the intentions that is the planned arrival time of vehicles at the charging station of other vehicle. Charging stations can convey their ability to allocate new vehicle on the basis of the queue length [9]. Thus the queuing time at the charging stations can be predicted. Known intentions and historic information’s are combining here to predict the congestion. Some other approaches uses dynamic pricing or similar signalling, price difference between the stations in order to control the congestion through demand response [10] [11]. This framework is more general and any type of graph that supports roadway power vehicles can be used [12]. To achieve best-case scenario here we use an approach and where the probability of selecting the alternative is directly related to the expected utility of the same alternative [13].

1) Advantages
   - Provide actual charging station location [15]
   - Time dependent road travel time distributions based on historic information
   - Origin-destination pair distribution for vehicles

C. Intelligent Scheduling of Electric Vehicles

This approach minimizes the waiting time for charging through an intelligently scheduled activities of charging in large road network [14]. It also takes the advantage of interoperability between electric vehicle and the charging station. A theoretical study is conducted here. By modelling and analyzing the behaviors of electricity charging and based on this study an efficient practical scheme is designing and a distributed scheduling protocol that minimizes the waiting time has been proposed. The average delays or queues can be minimized using decision policies [17] as used in the heterogenous queue control model.

1) Advantage
   - It can achieve performance close to the performance upper bound of various scenarios

2) Disadvantages
   - The case of deploying charging station and allocating charging outlets for saving electricity and lower charging costs are not considering here
   - Navigation of electric vehicles for minimal waiting time and travelling time are not considering

D. Optimal Charging Strategies for Unidirectional Vehicles

This approach that is vehicle to grid approach proposes a way to increase the adoption rate of electric vehicles [16]. In this work unidirectional regulation algorithm is developed to use by an aggregator. Several smart charging algorithms are also used to choose the set point about the rate of varying charge while performing the regulations. An aggregator profit maximization algorithm is formulated with optional system load and price constraint analogous to the smart charging algorithm.

1) Advantages
   - No after-market hardware is required
   - More customer acceptance
   - No interconnection issues
   - No battery degradation

2) Disadvantages
   - Decreased power levels
   - Reduced participation times because of the battery

E. Co-ordinated Charging Model

Goal of this approach is to co-operate or co-ordinate the valuable services and operation constraints of three actors such as electric vehicle owner, the fleet operator, and the distribution system operator or market operator [18]. It also considers the
driving requirement of individual electric vehicle owners, the thermal limits of the cables and transformers in the framework of proposed market. Initially a theoretical framework of market describes here. Then within this framework fleet operators represent their customer requirements that also guarantee the electric vehicle owners requirement for driving and lower cost energy. Congestion problem is solved here by the co-ordination between the distribution system operators and fleet operators through a distribution grid market scheme. Mathematical formulation of the market scheme is also presented here. Linear programming is used for the charging of electric vehicles and to produce an energy schedule of fleet operators.

1) Advantages
   - Provide flexibility and scalability

2) Disadvantages
   - Voltage control is not considering

F. Optimal Scheduling Model for Charging and Discharging

This approach describes an optimization model with an aim of minimizing the charging cost, achieving satisfactory state of energy levels, and optimal power balancing. Two methods can be used to optimize the charge scheduling first one uses a linear approximation of the battery behaviour and the second one uses a quadratic approximation [19]. Linear approximation is sufficient for charge scheduling. For electric vehicle charging and discharging local optimal scheduling schemes and global optimal scheduling schemes are used [20]. By formulating global scheduling optimization problem we can also optimize the charging powers to minimize the total cost of all electric vehicles. But the global optimal scheduling is impractical. By formulating local scheduling optimization problem can minimize the total cost in a local group and it is the most appropriate scheme for the electric vehicle charging and discharging with a large population and dynamic electric vehicle arrivals.

1) Advantages
   - Scalable
   - Resilient to the dynamic vehicle arrivals

III. Conclusion

This paper provides a survey of different models or techniques used for congestion avoidance and optimal charging strategies for electric vehicles. For that analyses six schemes namely CARAVAN optimization, Intension aware optimization, Intelligent scheduling model, Optimal charging strategies for unidirectional vehicles, Co-Ordinated charging model, and Optimal scheduling model for charging and discharging. From this survey can arrive at a conclusion that by the removal of congestion at the charging stations and optimal charging strategies used can improve the entire journey time of electric vehicles.

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