Designing Flexible Charging Optimization for Electrical Vehicles: A Review

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ABSTRACT: Hybrid Electric Vehicles (HEV) are expected as one of the key solutions for mobility in the future, with reduced pollutions and better fuel economy alternative. Hence one of the primary requirements for the automobile manufacturers has to come up with alternative modern vehicle design technologies that could support reduced pollution and improved useful energy efficiency. With the year on year increase on the number of the light-duty vehicles on road, the effect of emissions polluting the environment is also proportionally increasing. Although the use of other modes of transport like the ships and flights are increasing, the road transport mode will still continue to be the prominent one. Basically, there are three main concerns in driving the conventional fossil fuel based vehicles that stimulates the automobile manufacturers to look for an alternative mode of vehicle technologies. They are pollution of the environment, vehicle dependency on fossil fuel, which is non-renewable and the global warming effect due to emissions. There are several research agencies which are working on improving road transport vehicle efficiency and reducing the emissions.

Introduction:
Conventional fossil fuel based automobiles are considered as one of the key sources for atmospheric pollution and related effects on the environment. Hence one of the primary requirements for the automobile manufacturers has to come up with alternative modern vehicle design technologies that could support reduced pollution and improved useful energy efficiency. With the year on year increase on the number of the light-duty vehicles on road, the effect of emissions polluting the environment is also proportionally increasing. Although the use of other modes of transport like the ships and flights are increasing, the road transport mode will still continue to be the prominent one. Basically, there are three main concerns in driving the conventional fossil fuel based vehicles that stimulates the automobile manufacturers to look for an alternative mode of vehicle technologies. They are pollution of the environment, vehicle dependency on fossil fuel, which is nonrenewable and the global warming effect due to emissions.

Also the fossil fuels are shared resources and they are also used for other processes like power generation, industries etc., hence it becomes imperative, either to find new additional resources of fossil fuels that could cater to the increasing market demand or to find alternative technologies that enable the vehicle to have less or no dependency on fossil fuels. Also, the stringent emission norms set by the pollution control authorities to reduce pollution and global warming, demand better alternate technology on the vehicle to meet the same. There are several technologies that are under research and proposal by different countries that could alleviate the current situation and reduce the dependency on conventional fossil fuels. Some of the proposed technologies include usage of Ethanol, hydrogen fuel based automobiles and usage of biofuels. Although the proposed technologies have the advantage of substituting conventional fossil fuels, they are also having their own disadvantages. The key disadvantage is that the usage of these different form of fuel requires the automobile manufacturers to design and develop specific power trains for each of the technology. Although this is practically feasible, the manufacturers have to invest a large amount of money to develop such power trains, but in contrast, there are no clear policies proposed by the government that would support and sustain such technologies to enable the manufacturers to produce such alternative fuel based vehicles on a large scale.

There are several research agencies which are working on improving road transport vehicle efficiency and reducing the emissions. Some of the key agencies include The United Nations Environment Programme (UNEP), the International Energy Agency (IEA), and the International Transport Forum (ITF). They are working together to almost double the fuel efficiency by 2050 and hence decreasing emissions by almost 50%. One of the best approaches and forecast provided and supported by those agencies is to migrate to pure electric vehicles. The electric vehicles are pollution free and silent, and hence proves to be pure eco-friendly vehicles. Although car manufacturers are into the production such pure electric vehicles on a small scale, there are some disadvantages currently that prevents them to move into mass production. One other vehicle technology that combines the advantages of the electric vehicle and conventional fossil fuel based vehicle is Hybrid Electric Vehicle (HEV).
Considering the current technology trend the HEV seems to be a promising alternative technology that could effectively replace conventional fossil fuel based vehicles.

Literature Review:
The suggested scheme notifies the vehicle owner whenever the SOC of the battery reaches the preset value. But, the investigated method does not give the location of the CS and the available status of the CS.

In [4], a CS suggestion scheme for EV taxies is developed. This method is capable of calculating the total travel time to the CS and it recommends the nearest CS. However, the proposed scheme is not able to provide the actual status of the CSs to book a charging slot.

In [5], a charging scheduling algorithm to minimize the travelling time is proposed using a game-theory model. The developed algorithm also minimizes the EV charging time and the idle time of charging point.

In [6], a traction power estimation model is used for CS suggestion to the EV users. This is developed based on a range-indicator. A range-indicator is used to show the distance covered by the EV with the power left at the battery. Although the system indicates the range, this method could not provide the actual status of the CS.

In [7] an activity-based model is developed to analyze the queuing delay in CSs and provides decision support for the EV user to select a CS. It is assumed that the charging option for the EV user decreases whenever a CS is not chosen on the drive. Further, this method is based on numerical calculation and hence doesn’t provide the CS status to the user.

Based on the same activity-based model, a method is proposed in [8] to find and select the CS to minimize the range anxiety of the EV user. However, this method suggests only the location of the CS and it doesn’t provide any option to reserve the charging slot.

A mobile based Vehicle to Anything (V2A) application system is developed in [9] to help the EV user. The developed application alerts the driver about the remaining power left on the battery, the distance covered, location of the CSs, etc.

In [10] trip planning scheme for the EV driver is formulated by optimizing the trip parameters. A driving pattern is suggested to optimize the battery efficiency and to minimize the range anxiety. However, the speed of the vehicle is determined by the EV user behaviour. But, the user behaviour differs from user to user. Further, the proposed method does not consider the location of CS, route to the CS and actual status of the CS.

Based on the driver’s behaviour an approach is developed in [11] to reduce the stress on range anxiety. The characteristics of the EV drivers are analyzed from their trips. Various factors such as vehicle type, mileage of the vehicle, etc., are considered in this approach.

By considering the queue in the CS and the demand of EVs, a model is proposed for an optimal charging [12]. A price stimulus method is developed to assist the user to select the CS in order to minimize the charging cost. However, it is assumed that the user selects the CS nearer to their location. It makes the user to wait for more time, so congestion is created in the CS.

In [13], GA is used to optimize the charging routes for the EVs. By using this method, a user can be directed to a CS which is already congested. Therefore, developing an application to provide the exact status of the CSs in a particular region is of high-priority. The charging station recommendation models are getting attention for wide acceptance of EVs in the market.

Some research works [10-13] are recommended for the EV charging through an aggregator and finding an optimal CS based on some mathematical formulation.

Apart from the privacy concern of the user and acquiring the real-time status of CS, the application should be beneficial to the PL operators for EV load forecasting. The following literatures are discussed to show the important of the EV load forecasting for a CS.

In [14], the authors assumed only electric sedan type EVs and also pretended that the vehicles are charging the battery only in the evening. But, the travelling pattern of an EV varies from user to user and from day-to-day.

In [15], sedan type EVs are considered for predicting the EV charging load at CSs in different regions. However, the assumed number of EVs and vehicle types cannot replicate the real-time data.

An EV charging load is considered in [16], and it is partitioned as mild hybrid vehicles, hybrid vehicles charging. An EV load forecasting is examined in [17] using the traffic and metrological records. A tree decision algorithm classifies the performance of the EV charging. But, the drawback in the study are only the EVs with a small capacity is charging once in a day.

A Monte-Carlo and support vector machines are used to forecast the EV load demand in [18]. But, a decision-maker requires a precise forecast of power demand.

The variation in EV charging cost may affect the user choice as most of the users are likely to charge their EV when the price is low. Also, suggesting the charging slot accessibility in various CSs would reduce the congestion. Hence, an inadequate number of CSs can have an impact on load forecasting and also in power distribution for the customers.

Accordingly, a server-based real-time EV load forecasting application could be used for EV load scheduling at CSs and to intimate the actual status of CSs the EV user. The real-time status of CSs include the charging cost, location and distance of CS, reservation and fast charging availability, etc.

Based on the literatures, the charging scheduling of EVs to minimize the cost of PL operator is solved by many researchers. But, many of the researchers are focused on the same power range of the chargers and vehicles. Further, the charging limit of the PL is not considered. Besides, an aggregator is required to reserve a charging slot in a CS. All these issues listed out by the researchers are attended in this thesis.

Comparison of Reviewed Research Work:
The comparison of research work is shown in the table 1

Table 1 Comparison of the Reviewed Research Works to the Proposed Application

Year	Objective	Simulation Tool	Interference
2018	EV charging price minimization via a coordinated charging scheme.	Matlab	Establishing smart meters in the EV charging places (house, office) could bring challenges on privacy. Hence, the information of the users' needs to be safe and secured.
2011	Minimization of EV charging cost and time using a heuristic algorithm.	Matlab	The estimated EV trip model and its energy requirement are not accurate always. The charging control sequence of charging duration and charging types are controlled by an aggregator.
2010	To control the charging rate and sequence for computing an optimal EV charging.	Matlab	Based on an agreement between the aggregator and user, the aggregator becomes the authority for charging and discharging of an EV battery.
2012	To implement a reliable EV charging by satisfying various constraints.	NA	EV and user information are exchanged with three operators, and the information sharing becomes complicated.
2019	To reduce the charging price using advanced charging control by a price-responsive scheme.	CPLEX 12.6	EV charging control is divided into the local controller and an upper-level controller. Small scale charging coordination is monitored and implemented by the local controller vice-versa for large scale coordination. However, the proposed method avoids charging when the charging price is high. Hence, it leads to error in load forecasting.
2018	To manage EV charging to minimize user trip duration using intermediate charging at CSs	NA	The global aggregator decides the charging of EVs in the power network. If the operator fails, the whole charging network suffers. In particular, the system will suffer severely in security aspects.
2017	To enable the smart charging for an optimized charging cost considering the user preference.	MATLAB	The user can avail three separate tariffs according to their preference. Based on this, the aggregator needs to optimize the EV charging to minimize the cost.
2012	To reduce the electricity cost through a risk-based analysis scheme.	Monte Carlo simulation	The regulation capacity and the charging cost are determined by the contract made between the user and the service provider. The uncertainties concerning the power market are simulated using the Monte Carlo method.
2013	To make an optimal schedule based on the price signal declared by the utility.	Optimal control theory with convex function	The digitalized energy system does not guarantee the confidentiality of the user information.
2014	To provide a coordinated charging for cost minimization by		The business markets can affect a private EV with unnecessary services. Hence, privacy is essential in the modern world.

	combining the public and private transports.	V-Charge	
2014	To support the EV users by monitoring the battery status and to provide a dynamic range prediction.	GPS	The proposed scheme does not support the user by providing the status of CSs. The user may not know that the CS is currently functioning or not.
2015	To reduce the user concern on range anxiety.	MS-Excel	This model is developed using historical data. The proposed scheme calculates the range of the EV with power left at the battery.
2017	To develop a CS recommendation scheme based on a range indicator.	Traction power estimation	A range indicator using SOC calculation model is developed to alert the EV user about the range. It assumes that the system can book a charging slot in a CS.

Conclusion:

A detailed review of the literature was done on various vehicle topologies such as ICEV, BEV, HEV, PHEV, FCEV, and SEV. Also, a survey on the design optimization, energy management optimization approach and combined DO and EMO approaches for component sizing were carried out. Based on the literature, with the formulation of an optimization strategy, neither the determination of component sizes of the HES nor the design of the EMS is carried out for a Solar - Fuel cell Battery hybrid electric vehicle so far. This research gap is the driving force behind the proposed work aimed at developing an optimization approach to the Solar-FC-Battery-Hybrid Energy System component sizing.

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