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Optimizing EV Battery Performance with Bidirectional DC/DC On-Board Chargers for V2G and G2V Applications

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ABSTRACT

A better option for V2G and G2V compatibility is a bidirectional dc/dc on-board charger for EV battery discharging/charging application. Since isolated converters like operating with high power densities over a range of loads, it is helpful for EV applications. The bidirectional converter handles all power switches in both directions by step up and stepdown at zero voltage switching. EVs can be linked to the grid through either direct or indirect architectures, which represent two distinct forms of design. The EV and the grid system operator have only one communication channel accessible under the direct architecture. This article mostly discusses the older design. Charge-discharge cycles are ongoing when electric vehicles (EVs) link to the grid to offer different V2G services. The cost of the EV batteries' deterioration has to be looked into and analysed, thus these cycles could be very concerning to the car owners. A solution that is near to the ideal solution obtained by using dynamic programming will be presented by the reinforced learning approach.

Keywords: *Energy Management; Dynamic Programming; Simulation; Discrete Transition; Optimal Power split.*

1.0 Introduction

Plug-in hybrid electric vehicles (PHEVs) are gaining popularity in the global vehicle industry due to their improved fuel efficiency. These vehicles offer a combination of benefits from both conventional and electric vehicles (EVs). HEVs, or hybrid electric vehicles, are automobiles that minimize the release of fossil fuel emissions. PHEVs, or plug-in hybrid electric cars, exemplify the advantages of superior fuel efficiency, environmental benefits, and the capability for all-electric drive[1].The primary sources of power in these vehicles are electric motors and fuel cells, which are used in comparison to internal combustion engines (ICEs) found in PHEVs and other hybrid electric vehicles (HEVs). This can enable the car to be powered by a more advanced energy storage system. The effective management of this power division has a substantial influence on the performance of a parallel hybrid electric vehicle (HEV) system. Controllers that utilize heuristic control techniques relying on simple rules or maps seem to be falling behind controllers that prioritize minimizing fuel consumption. The optimal control problem for power management can be mathematically formulated as a nonlinear finite-horizon problem.The user's text is enclosed in tags.

Dynamic programming (DP) is a highly popular approach for solving the control problem mentioned earlier, out of the various methods described.

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The mathematical foundations of this approach are straightforward, ensuring that the chosen solution is optimal within a specified tolerance. Additionally, it can be easily implemented in a concise computer program. The two predominant energy management procedures used in the development of supervisory controls are instantaneous optimization and finite-horizon optimization. Real-time applications are supported by instantaneous power flow based on different approaches.

Optimal theories are highly viable options for regulating the distribution of energy in HEVs and PHEVs[3-4]. Dynamic programming (DP) can optimize fuel efficiency in a hybrid electric vehicle (HEV) or plug-in hybrid electric vehicle (PHEV) based on trip data. Nevertheless, the online applicability of DP is limited due to its protracted computation time. In order to decrease the amount of time required for calculations, a two-scale dynamic programming method was employed. To enhance energy management, this approach partitions the entire journey into multiple segments and employs dynamic programming (DP) twice, both for the entire trip and for each individual segment[5]. The energy management of the plug-in hybrid electric vehicle (PHEV) was conducted using the quadratic programming (QP) method. This method involves representing the fuel rate of the engine as a set of quadratic equations that are dependent on the battery currents at different driveline powers and vehicle speeds. To determine the engine-on power, additional advanced techniques are necessary.

2.0 Energy Management Strategies

An energy management technique is employed to regulate power and must be capable of meeting the demands specified by the drive profile [6]. The power is divided into two components, namely Internal Combustion Engine (ICE) and Electric Motor (EM), and the strategies are depicted as.

2.1 Regulatory-based control methodology

The different criterion the vehicle model are maintained while putting focus on optimizing fuel economy by formulating the problem of expected energy cost [7]

$$J_{xt}(SOC(t) = \int_{t}^{t_f} m(t,u)dt$$

Where Jxt is the cost function of SOC(t). within this constraint, there is a time limit tf from the initial position xt to the final position [8].

2.2 MPC approach to the path

The problem formulation and it solution is run online in a repetitive scenario by considering the rolling horizon and is expressed as[9] –

$$SOC(i+1) = f(SOC, u(i))$$

The expression “SOC(i + 1) – estimated state of charge” refers to the difference between the estimated state of charge at time i+1 and the actual state of charge.

2.3 Optimization methods

The problem formulation for the n number of steps is as shown below-

$$J_{tot}(k) = J_p(k) + \alpha \sum_{j=0}^{N} \left\| f(k) - fopt.(k^1) \right\|^2$$

The process will get the optimal vector and then the progressive computation has been performed with the help of MPC[9]. There is no use of convex optimization because it will then make it compulsory to select feasible technology.

2.4 Performance measures

$$M_{abs} = \frac{1}{k} \sum_t \left[\frac{|y(t) - y'(t)|}{y(t)} \right]$$

$$R_{rel} = \sqrt{\frac{1}{\sum_t y(t)} \sum_t \left[\frac{|y(t) - y'(t)|}{y(t)} \right]^2 y(t)}$$

The strategy is evaluated in terms of real and predicted values which makes the performance indices and this comparison is done on different levels of time [10]

3.0 Model Description

The following table shows the specifications of the concurrent hybrid electric vehicle model.

Table1: Vehicle Configuration for Modeling Purposes

Mass of the vehicle	15000 Kg
Motor specs (wattage)	43 KW
Torque	200 nm
Engine performance evaluations	120 hp
Power source	VRLA
Energy storage capacity	110 Ah
Voltage at terminals	145 V

3.1 Driving cycle

The study is made more reasonable by graphical representation of the five different types of drive cycles. These cycles are repeated in a specific order to ensure that the total simulation time is sufficient for system testing and that significant differences can be observed [12].

4.0 Results

The velocity profile of the four velocity profiles i.e. UDDS, ECE, are specified in the following below figures fig.1 and fig.2 respectively.

In order to make the study more reasonable, the different five types of drive cycles are taken here which are shown graphically in the figures. These cycles are taken in the repetitive sequence so that the total simulation time can be long enough to test system properly and the differences can be observed significantly.

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Figure 1: UDDS Drive Cycle

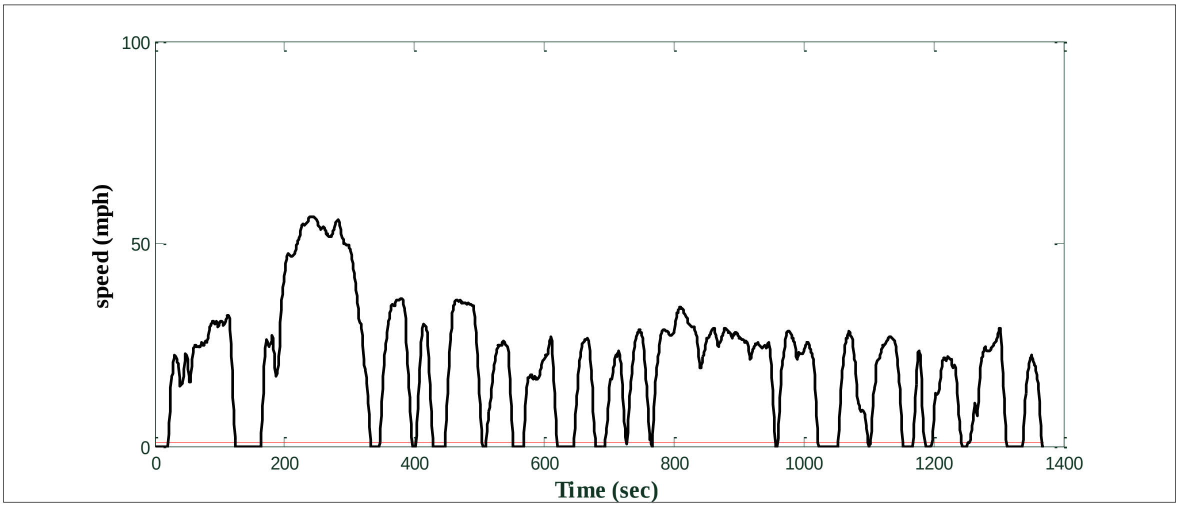
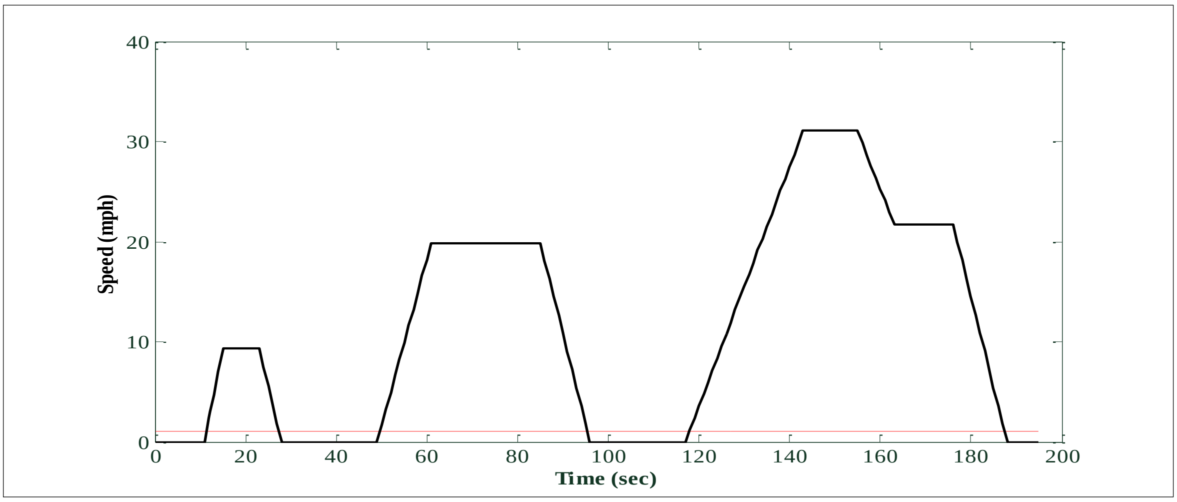


Figure 2: ECE Drive Cycle



5.0 Conclusion

Continual charge-discharge cycles are a feature of electric vehicle (EV) connectivity to the grid and the V2G services it offers. Vehicle owners may be very worried about these cycles because they necessitate research and analysis into the costs associated with EV battery degradation. Consequently, the battery's cycle life (CL) is an important factor to consider when talking about its degradation. This study uses the state of charge parameter to assess the outcomes of sequential simulations for different drive cycles.

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