From Battery Cells Reduced Order Modeling to Real-time Planning and System Integration

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ABSTRACT

After nearly a century with the Internal Combustion Engine (ICE) dominating the personal transportation sector, it now appears that the Electric Vehicle (EV) is on the verge of becoming in its successor.

In addition, we have could observed a lot of movements and actions in this direction of both companies and some countries in the last years. The first ones, doing research and developing the market and the other ones, changing legislation for these purposes.

Therefore, it is clearly clarified the importance of developing this technology.

One key issue in the EV is that its performance is closely tied to the performance of the battery. For this reason, it is so fundamental to analyse this component of the car.

Most EVs have an onboard Battery Management System (BMS) that maintains safe and consistent operation of the battery module and optimize the performance of the battery system. In addition, the BMS needs a model to estimate the main variables of interest such as the State of Charge (SOC).

However, the empirical models used become inaccurate as the batteries degrade. Alternatively, there are physics-based models that are accurate but highly time-consuming to be of practical use in real-time applications.

Therefore, the first main of this work is to use a physic-based model (Newman's P2D Model which has been widely used in the literature [1], [2]) which is really accurate but not suitable to use in real-time applications.

The first step to achieve is that the simulation time of the model can be achieved in a reasonable time. To do that, we used a Model Order Reduction Technique (MORT): The Proper Orthogonal Decomposition (POD) [3]. The results show that the results with the POD are equal to the Model without the MORT for the naked eye because they are almost identical.

The second step is to achieve that the battery model can be simulated together with all the other systems which compound the EV for real-time simulations. The POD model is not suitable to achieve that so other alternatives are explored [4].

Here we propose to use the PGD regression [5] to obtain an algebraic expression for the behaviour of a battery cell according to different possible itineraries. We prove in this paper that we can model the behaviour of the ion-lithium cell analysed for such a wide range of itineraries using polynomials with the approach proposed. As we transformed the problem of the cell model in the evaluation of a polynomial there are no problems in coupling the battery model with the other systems which compound the EV. A detailed example of the accuracy and the range of use of the approach is discussed.

At the end, we show an example of simulation of the EV with the battery model that we extracted using the PGD regression. To simulate the EV, the ESI software SimulationX was used.

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