講演番号	179

文献番号	20225179

Energy management for fuel cell powertrains optimizing hydrogen efficiency and component lifetime

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KEY WORDS: fuel cell electric vehicle, FCEV, predictive energy management, fuel cell aging, battery aging

Global climate change and the resulting need for zero-emission vehicles is pushing the industry to develop new powertrain technologies to meet upcoming emission targets. One solution towards zero-emission is a hydrogen-based PEM fuel cell (FC) powertrain for both passenger cars (PCs) and commercial vehicles (CVs). By using hydrogen as main energy source a superior energy density can be achieved which allows a larger driving range at the same vehicle weight and same payload compared to battery electric vehicles (BEVs). In addition, the refilling time of the hydrogen tanks is comparable to fossil fuel powered vehicles. Besides the mentioned advantages of fuel cell electric vehicles (FCEVs) the degradation of both fuel cell and battery system is one of the main challenges.

In this paper a predictive energy management including aging models of fuel cell and batter system is suggested to overcome this problem. By integrating aging models within the energy management, degradation effects can be minimized by keeping the powertrain efficiency on a high level. The differences in the application of FCEVs for PCs and CVs with focus on optimization of the energy management were discussed. The typically small battery size in PCs, which gives only small degree of freedom to the energy management and the high uncertainty in the prediction of the total power demand of the vehicle is limiting the potential for PC application.

Using predictive data within the energy management allows to pre-condition the powertrain for upcoming events in order to avoid inefficient or damaging operation points, but also prevents reaching system limits. This is achieved by optimizing the battery SOC over the upcoming route, which is equivalent to the power split between fuel cell and battery system for a known total power demand. To manage the high computation effort the optimization is split into two parts, considering a long range and short range optimization, as shown in Fig. 1. The long range optimization is typically performed before the start of the trip and calculates an efficient power split over the entire route on a coarser distance grid to cover long term events. The short range optimization uses the power split of the long range as an input and additionally considers online vehicle signals. The final output is the fuel cell setpoint which is forwarded to the real time control e.g. the vehicle control unit (VCU).

The aging models of fuel cell and battery system are used to calculate the effect of different operating points on component aging. This ensures that the planned target lifetime of the components and hence of the vehicle is achieved.

The benefit of a predictive energy management is shown in Fig. 2 for the application of a 42 ton long-haul truck on a typical highway cycle in Austria. By applying predictive control strategies, improvements of 4.4 % in hydrogen consumption can be achived. Via combining predictive energy management with component aging models the lifetime of the fuel cell and battery system can be increased while still minimizing fuel consumption. By applying predictive control strategies, improvements of 4.4 % in hydrogen consumption and up to 78 % in component lifetime at same vehicle performance can be achieved in the discussed drive cycle for a 42 ton long haul truck.

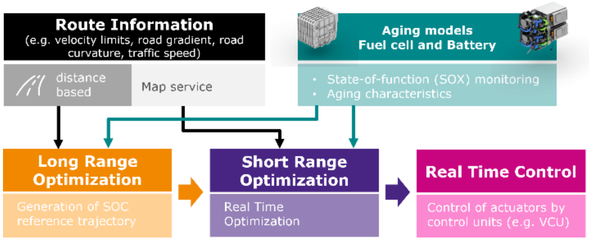

Fig. 1 High-level controller architecture of predictive energy management

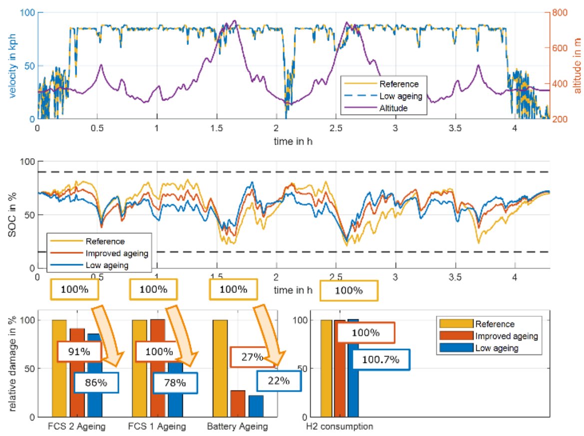

Fig. 2 Simulation results showing the impact of different calibrations of the predictive energy management on the vehicle efficiency and the potential on reduction of component aging

2022 JSAE Annual Congress (Spring) - Summarized Paper
Issued on May 20, 2022