

Energy Management Based on Driving Pattern Classification Using Clustering Methods

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In current series hybrid electric vehicles (HEVs), the state-of-charge (SOC) operating range is conservatively limited because future driving conditions are difficult to predict in advance, and sufficient SOC must be maintained to cope with a wide variety of driving scenarios. As a result, frequent engine starts and a high proportion of non-best-efficiency-point power generation can occur even during prolonged low-speed, low-load driving. To address this issue, this study proposes an energy management control strategy that estimates and classifies future driving patterns using navigation-provided driving information and switches both the SOC operating range and the power-generation decision map according to the predicted driving patterns (Fig.1).

In the proposed method, predicted driving energy is calculated from future vehicle speed, road gradient, and segment distance. Future driving patterns are classified and estimated using future vehicle speed and predicted driving energy. For driving-pattern classification, clusters are constructed using the k-means clustering method based on real-world driving data collected from a production series HEV, where average vehicle speed and average driving energy are used as features. Furthermore, future routes are divided into a “next segment” and a “subsequent segment,” and a power-generation decision map is selected according to the combination of clusters corresponding to these segments. Specifically, the proposed control switches between a map that prioritizes EV driving by suppressing engine starts and a map that allows engine starts more readily when best-efficiency-point power generation is expected, thereby achieving SOC management adapted to future driving patterns.

The proposed control was evaluated in a Model-in-the-Loop Simulation (MILS) environment. The results showed that the SOC distribution shifted toward a lower SOC region compared with the conventional control, confirming an expansion of the usable SOC range (Fig.2).

In addition, the engine start count was reduced by 8.33%, while trip fuel economy was improved by 1.37%. Furthermore, the proportion of non-best-efficiency-point generation decreased from 15.17% to 13.93%, and the engine-stop ratio increased from 68.98% to 70.62% (Fig.3).

These results demonstrate that the proposed control, which switches the power-generation decision map and the SOC operating range according to predicted future driving patterns, effectively reduces non-best-efficiency-point generation and increases the engine-stop ratio, thereby improving the fuel economy of series HEVs.

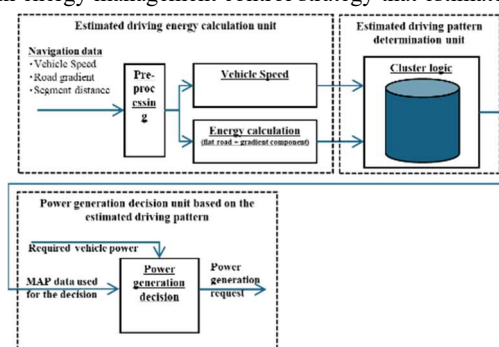


Fig.1 Proposed control logic

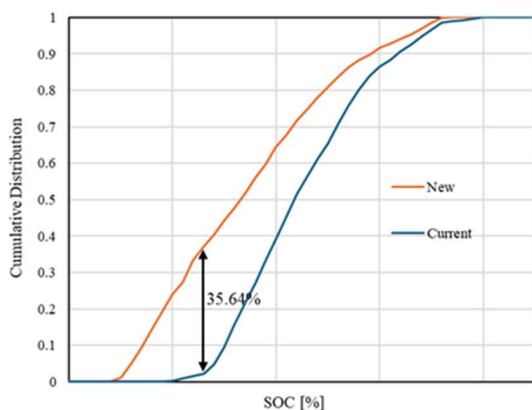


Fig.2 Cumulative Distribution of SOC

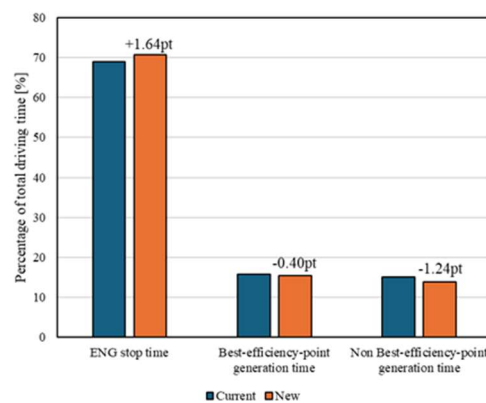


Fig.3 Percentage of total driving time