2021-01-1248 Published 21 Sep 2021

Intelligent Auxiliary Battery Control - A Connected Approach

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Citation: Kumar, V., Zhu, D., and Dadam, S.R., "Intelligent Auxiliary Battery Control - A Connected Approach," SAE Technical Paper 2021-01-1248, 2021, doi:10.4271/2021-01-1248.

Abstract

As vehicles are getting electrified and more intelligent, the energy consumption of the auxiliary system increases rapidly. The auxiliary battery acts as the backbone of the system to support the proper operation of the vehicle. It is important to ensure the auxiliary battery has enough energy to meet the basic loads regardless the vehicle is in park or running. However, the existing methods only focus on auxiliary energy management when the vehicle is in a dynamic event. To fulfill the gap, we propose an intelligent strategy that detects the low state of charge (SOC) condition, temporarily turns down the auxiliary loads based on their priorities and charges the auxiliary battery at the maximum efficiency of the auxiliary power unit. In addition, the proposed strategy allows the vehicle to get the park duration update and make intelligent decisions on charging the auxiliary battery. Simulation results indicate that our strategy closes the technology gap that is not addressed by the existing methods. As a result, the energy consumption remains low while the SOC of the auxiliary battery is sustained.

Introduction

There is no doubt that electrification is the primary means to achieve both energy consumption and emission reduction [1]. Unlike the energy management strategy for hybrid propulsion systems that has been studied in a tremendous number of literatures [2], the energy management strategy for the auxiliary battery hasn't drawn enough attention. The main purpose of the auxiliary battery is to support the safe operation of the auxiliary system [3, 4]. As the electrification revolution continues, more and more electronic devices that rely on the power from the auxiliary battery have been put in electrified vehicles to make them smarter and more powerful. With the increasing number of electronic devices to support connectivity and autonomous driving capability, the energy consumption on the auxiliary system is rising dramatically and foreseen to become more severe in the future.

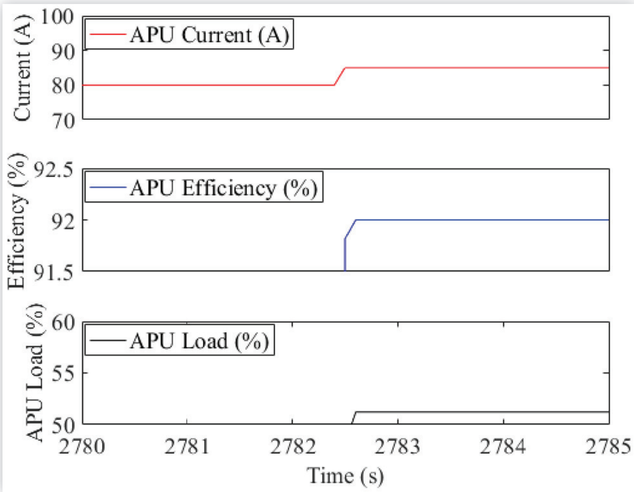
To maintain the state of charge (SOC) of the auxiliary battery, the alternator is often used to convert mechanical energy from the engine crankshaft via a serpentine belt into electrical energy in the conventional vehicle. The alternator consists of a stator, a rotor, several diodes, a voltage regulator, and a cooling fan. The alternative current (AC) from the stator and the rotor is transformed into a direct current (DC) to charge the auxiliary battery. The voltage regulator regulates the voltage. The cooling fan dissipates heat from the alternator and protects the alternator from overheating. However, the alternator is replaced by a DC-to-DC converter in the hybrid electric vehicle (HEV) and the electric vehicle. The DC-to-DC converter transfers energy from the high voltage system to the auxiliary system. For simplicity, we use auxiliary power unit (APU) to describe the DC-to-DC converter in this paper.

Like the alternator in the conventional vehicle, the APU also needs to be controlled to maintain the SOC of the auxiliary battery. The strategy that is used to decide how much and how fast energy flows from the HV system to the auxiliary battery via the APU is called APU energy management strategy. A group of researchers studies the APU energy management strategy in a fuel cell vehicle [5]. Three use cases such as load without the APU, load with the APU and load with a supercapacitor are investigated in their study. However, their strategy falls short in oversimplifying the APU operation.

A different group of researchers propose a fuzzy-based strategy for APUs in [6]. The fuzzy logic approach is chosen because they believe there is no simple model for estimating battery SOC and electrochemistry-based modeling is heavily dependent on knowledge of the battery internal parameters. In addition, they claim their strategy works for both batteries and supercapacitors. The battery SOC and the normalized APU current are used as the input and output of the fuzzy controller, respectively. The charge current is maintained in the best efficiency region most of the time.

A dual battery system with a Cuk converter used as the APU is proposed to fast charge electric vehicles in [7]. This battery system consists of a main battery with high energy density and an auxiliary battery with low energy density. The

FIGURE 14 Efficiency adjustment.



toward 10%. The APU kicks in when the SOC falls to 10%. The OBD load switches on to support the remaining OBD tests when the SOC claims to 25%. The HVAC load turns on once the SOC passed 60%.

The auxiliary battery voltage, APU efficiency and percent load are shown in Figure 13. Unlike Figure 9, the APU turns off once the SOC of the auxiliary battery reaches 95%. This difference is due to the current provided by the APU is greater than the maximum load in the use case. The proposed strategy also successfully adjusts the operating point to achieve the maximum efficiency in the key-off use case.

Conclusions

With more offering of drive assist functionality by vehicle manufacturers, there is increasing pressure on auxiliary battery to improve its efficiency and implement more advanced energy management strategy to maintain SOC during vehicle operations. In this work, we propose a strategy to detect low SOC condition, prioritize auxiliary loads as required and effectively manage charging of the auxiliary battery by APU at high operating efficiency level during the key-on and key-off use cases. The simulation results confirm that the low SOC condition is detected; auxiliary loads are shed; the APU adjusts its operating point to work at high efficiency. Our rule-based strategy is investigated in this paper. It can be easily implemented into PCM. PCM is the ideal place for our strategy because it has access to the signals from auxiliary battery, APU, HV battery pack, etc. PCM supervises the operation of APU that acts as a low-level controller. The proposed strategy is broadly applicable to electrified vehicles such as hybrids, battery electric, and fuel cell vehicles. We plan to move to the optimization domain and develop a multi-objective optimization-based strategy in the future.

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