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## Management scheme of lead-acid/lithium-ion/supercapacitor hybrid energy storage system for automotive power system application

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The vehicle electrical power systems of both internal combustion engine and electric vehicles are constrained by fuel economy, ecology, and by new automotive electronics functions for improvement of safety, comfort, ergonomics and reliability. These requirements lead to increase overall requisite electrical performance with much higher load demand and fluctuations. The existing single electrochemical energy storage system such as lead-acid battery, etc. is yet to achieve high energy and power characteristics, high life-cycle, safety, low cost and wide range of ambient temperature necessary to meet up with the electrical needs of present and future automotive vehicles. Combining multiple energy storage systems to form a single pack hybrid battery system is a promising solution that allows beneficial attributes of different energy storage to be harnessed and used. This paper presents lead-acid/lithium-ion/super-capacitor hybrid energy storage system (LLS-HESS) for the automotive electric power system applications. This work uses battery state estimation methods such as State-of-Charge (SoC), State-of-health (SoH) and State-of-Life (SoL) for battery performance characteristics. The battery variables; voltage, current, cell temperature and ambient temperature are used to determine the feasibility of Lead-Acid/Lithium-Ion/Super-capacitor HESS. This hybrid is analyzed for efficiency and practicability as automotive hybrid energy storage alternative. The paper also develops a fuzzy-logic based intelligent supervisory control algorithm for efficient management of the LLS-HESS. The supervisory control model is simulated with MATLAB/Simulink for validation of its effectiveness to manage the performance of the LLS-HESS. The developed LLS-HESS is compared and evaluated against the Lead-Acid battery in terms of performance and efficiency. LLS-HESS exhibits better performance as compared to Lead-Acid battery. The LLS-HESS efficiently handle transient load requirements, minimizes the component stress and very robust for the automotive electronics functions. These in turn lead to cost reduction, battery life-cycle improvement and overall efficiency in the automotive battery application.

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