Dynamic Control Scheme of Hybrid Energy Storage System

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***Abstract*— The rapidly increasing demands for clean renewable energy sources paved the way for the innovative development of conventional energy storage systems. This research aims to realize a dynamic control scheme (DCS) for an energy storage utilizing the hybrid of battery and ultra-capacitor (UC) known as hybrid energy storage system (HESS). The DCS takes into consideration the dynamic behavior of the battery and ultra-capacitors at both charging and discharging phase. The control prioritizes the load supply and load management for both sources actively. This active load management aims to minimize the total power loss for the energy storage system through a deployed control model which realizes a state-of-the-art HESS implementation.**

Keywords – capacitors, energy source, hybrid energy storage system, lithium-ion, Battery

I. Introduction

Energy storage system (ESS) are in demand nowadays due to the increase in demand for a clean and renewable energy source [1]. Residential, commercial and industrial sectors are shifting to the use of hybrid energy storage systems (HESS) due to its advantage compared with conventional energy storage systems. HESS have three main advantages compared with conventional HESS such as 1) lower cost, reinforced system efficiency and 3) increased deployment lifetime. This advantage is in line with the capability of the HESS to handle high power density and high energy density applications which is the constraints of conventional ESS. The deployment of HESS requires a control scheme or algorithm to ensure maximum overall efficiency such as to reduce overall cost that includes maintenance cost and operational cost [2]. The control scheme ensures that that the HESS have minimum energy loss during operation which is in line with the transients and unstable load demand. Control scheme have various parameter consideration such as voltage, current, temperature, state-of-charge (SOC), state-of-health (SOH) and remaining useful life (RuL). Also, the proposed control scheme can be passive or active depending on the actual application whereas for this paper, the active dynamic control scheme (DCS) is proposed. In this papers' proposed approach, voltage and current is considered as the main control scheme parameter. This parameter is considered for the control of the DC-to-DC converters. This DC-to-DC converters are the actuators for the dynamic control scheme which is directly interfaced to the hybrid energy source.

II. Methodology

Fig. 1 shows the proposed Dynamic control scheme for hybrid energy storage system (HESS). The energy sources used for this proposed HESS are battery and ultracapacitor pack. The battery is connected to the DC bus via bi-directional DC/DC converter. UC is used as buffer power source and it is connected to a bi-directional DC/DC converter which is used to adjust the power of the DC bus to be able to meet the condition of the sudden change of vehicle power demand such as rapid acceleration and emergency braking [3]. The Main Control Unit (MCU) will be used is the Nvidia Jetson Xavier, the load and peak requirement of the HESS is learned and predicted by the uploaded algorithm in the system. This makes the HESS adaptive to a varying deployment parameter (demand load due to changing driving cycle) and applications. Two specific conditions are managed by the HESS through the learned parameters which are 1) utilize ultra-capacitors at peak power demand and 2) utilize batteries at stable power demand [4].

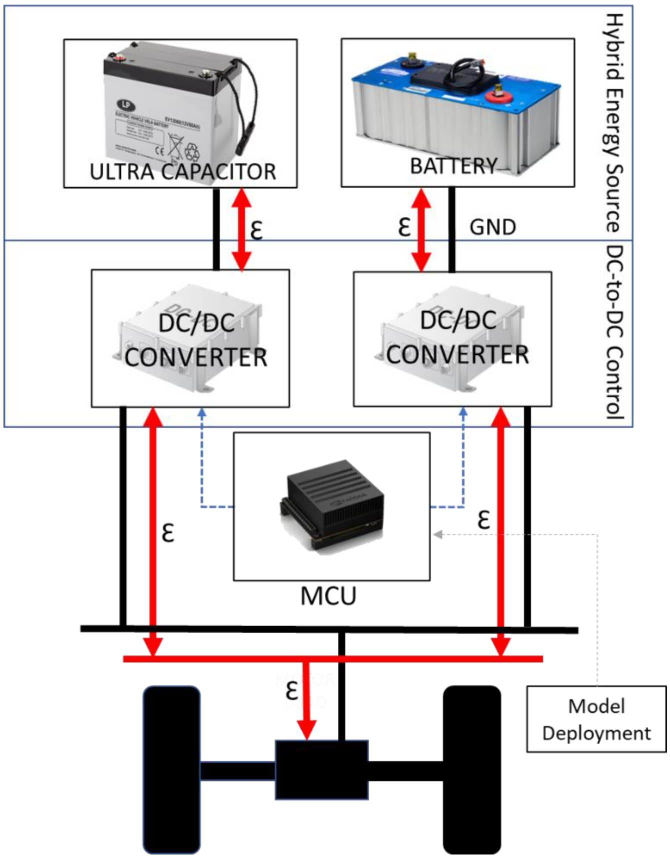

Fig. 1 Proposed contropl scheme for the hybrid energy storage system

The proposed algorithm is developed and tested using the MATLAB Simulink simulation platform. The HESS simulation parameters are modelled based on the actual energy storage source that we intend to deploy. Table I. shows the actual HESS deployment parameters for both the UC and battery cells from UC technology and Bexel company South Korea respectively.

TABLE 1

Hybrid energy source deployment parameters

UC	Minimum	2.7 V
	Nominal	3.6 V
	Maximum	4.2 V
Battery	Minimum	3.2 V
	Nominal	3.6 V
	Maximum	4.2 V

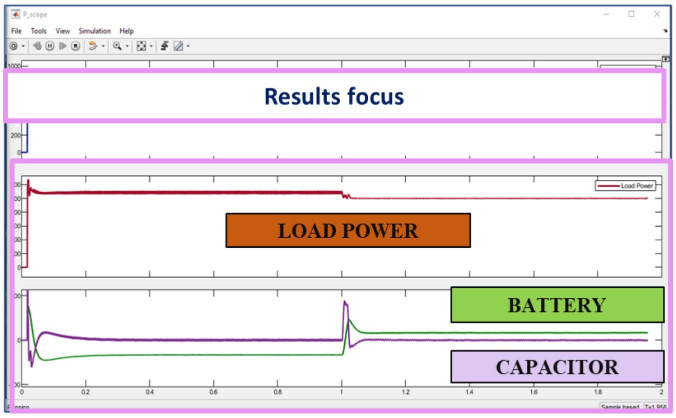

Fig. 2 Battery and UC equally meeet the power demand

III. Results and Discussion

The results presented in Fig. 2 gives emphasis to the DCS that we proposed for hybrid energy storage system application. The results show the actual load power demand by the load whereas the supplied energy by the HESS highlights a stable point of equalization to meet the total power demand of the system. This proves the successful algorithm deployment and development of a DCS for HESS based application. The supplied energy of both the battery and UC aligns with the total demand of the load which varies from one driving cycle to another. In this case, the DCS shows an accelerating driving cycle where the UC supports the battery pack equally to meet the system total power demand. This control scheme is applicable to varying driving cycle which shows its potential for a variety of HESS deployment.

IV. Conclusion

The proposed hybrid energy storage system's main goal is to minimize the total power loss of the hybrid energy storage system through deployment of the control model on Nvidia Jetson Xavier. The control model is dynamic in terms of addressing the total power demand of the system with respect to the supplied voltage of the two-energy storage (battery and UC). The control is adaptive to the deployment characteristics such as during constant speed, accelerating and sudden stop. In terms of this application, two different sources were used and tested for the DCS model namely, battery and ultracapacitor. The DCS based results presented in this paper shows an accelerating driving cycle where the UC supports the battery pack equally to meet the system total power demand.

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