1. Introduction

Nowadays, land vehicles can be classified in to three main categories, namely, conventional vehicles, Hybrid Electric Vehicles (HEVs) and Electric Vehicles (EVs). Conventional vehicles with an internal combustion engine (ICE) are the most common type in today’s market. In ICEs, chemical energy (e.g., ethanol, gasoline, diesel etc.) is converted into kinetic energy in a process that has significant power losses. On the other hand, the EV is an alternative-design automobile that relies on battery power to provide the electricity to activate the vehicle by an electrical motor. Furthermore, The HEV is powered by two types of energy sources, namely, ICE and electrical motor with ESS. As a combination of the high fuel economy and low harmful emissions. Due to the necessity to reduce the air pollution and harmful harmful vehicle emissions, a high impact on reducing emissions significant research has been focused on. Developing the HEVs and EVs. Energy storage systems have become a significant issue in the stand-alone applications. Batteries offer a wide range of the clean energy. Furthermore, they have high energy density and low power density due to chemical processes to deliver and store the energy [1]. As the main drawbacks are life-cycle, and long recharging times. In addition, the immediate response to sudden load changes in charging and discharging could potentially reduce the battery’s lifetime. There are several kinds of chemical batteries that are currently available in the market such as lead-acid, nickel cadmium (NiCd), nickel metal hydride (NiMH) and lithium-ion (Li-Ion). The supercapacitors are another energy storage technology used in electric double layer capacitor (EDLC) or a pseudo-capacitor which These differ in the ways they store energy and charge [3]. Compared to batteries, the supercapacitors have relatively low specific energy density and high specific power density. They are ideally used as auxiliary an energy storage device due to the dependence of terminal voltage on the state of charge. Nevertheless, various benefits can achieved when using the supercapacitors as an auxiliary power source [4]. The low value of the terminal voltage is a core limit of supercapacitors. 2.5 volts is the maximum terminal voltage that can be provided by a single unit of supercapacitor stack. However, several units of supercapacitors are connected in series and in parallel to achieve the required operation voltage and energy capacity as-by the powerful applications. Consequently, many researchers have attempted to develop/improve the performance of the ESS by combining high power devices like supercapacitors or flywheels in parallel with the battery. The main purpose of the Hybrid Energy Storage System (HESS) is to extend the efficacy of each power source [5]. This paper work designs the semi-active HESS by comparing different battery in parallel form with supercapacitors through a DC-DC converter, with the aim of increasing the merits of the two devices, and decrease their limitations [6].

The essential challenge in the design of a HESS for EV is to manage the current flow between the supercapacitors and the battery. The advantages and disadvantages of many topologies of HESS have been reviewed extensively in the existing literature [7]. Furthermore, in the literature, the HESS is the literature used
This research aims to design a control algorithm for hybrid energy storage system (HESS) for electric vehicles (EV). Two control strategies of R-B LQR were proposed to be implemented as controllers in EV applications. Due to their simplicity, they are implemented and short computation time compared with the optimization methods. The limit R-B LQR aims to limit the battery current to $i_{b_{max}}$, while the share limit R-B LQR aims to limit the battery current to $i_{b_{share}}$, and share the load current between the battery and supercapacitor. Dual control layers were used in this approach to obtain the desired supercapacitor current during the load demand. The LQR was used to drive the DC-DC converter by manipulating the duty cycle of the PWM. In addition, the LQR controller can guarantee good close-loop behavior for the DC-DC converter and is relatively insensitive to external disturbances, since the controller feedback gain-vector has to be determined optimally.

This paper is organized as follows. Section 2 discusses the HESS configuration. Section 3 discusses the modeling of the HESS and EV. Section 4 contains the proposed controller algorithm. The simulation results of the proposed controller are presented in Section 5. While Section 6 summaries the conclusion concludes of this research.

2. System Configuration

In EV applications, a practical HESS should be light, highly reliable, and have fast response for load variation. Due to the previous reasons, the semi-active topology in Figure 1(b) was selected to be implemented in this configuration. Figure 2 shows the semi-active topology of HESS in Matlab/Simulink. The battery model is connected directly to the EV model as a power source, and the supercapacitor model is connected to the EV model through a DC-DC converter model as an auxiliary energy source. Three different standard drive cycles, namely, UDDS, NYCC, and Japan1015, were used to validate the performance of the proposed controllers.