Project Proposal

Designing an Efficient controller & Fast charger for Electric Vehicles

Submitted By

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Motivation & Objectives:

A multiphase buck converter for battery charging is a power electronics circuit commonly used in various applications to efficiently charge batteries. The motivations and objectives for using such a converter can vary depending on the specific application and requirements, but here are some common motivations and objectives

- **Efficiency Improvement:**

  One of the primary motivations for using a multiphase buck converter is to improve the overall efficiency of the battery charging process. Multiphase converters distribute the load among multiple phases, reducing the current flowing through each phase and thus reducing conduction losses. This leads to higher overall efficiency and less heat generation, which can be especially important in high-power battery charging applications.

- **Reduced Voltage Ripple**:

  Multiphase converters can also help reduce voltage ripple on the output, which is crucial for sensitive electronic devices or systems connected to the battery. Lower voltage ripple ensures a stable and clean supply voltage, which can extend the lifespan of the battery and the connected devices.

- **Fast Charging:**

  In many applications, there is a need for fast battery charging while maintaining safety and efficiency. Multiphase converters can handle higher power levels, allowing for faster charging without overheating or overloading the converter components.

  Size and Weight Reduction:

  Multiphase buck converters can be designed to be compact and lightweight, making them suitable for portable and mobile applications. This can be particularly important in electric vehicles (EVs), drones, and other battery-powered devices where space and weight constraints are significant.

- **Thermal Management:**

  Efficient thermal management is crucial when charging batteries, as excessive heat can degrade battery life and performance. Multiphase converters, by reducing heat generation through improved efficiency, contribute to better thermal management.

- **Voltage Regulation:**

  Multiphase buck converters can provide precise voltage regulation, ensuring that the battery receives the correct charging voltage, which is essential for preventing overcharging or undercharging, both of which can harm battery health.

- **Load Balancing:**

  In some applications with multiple batteries or cells connected in series or parallel, multiphase converters can help balance the charging current between the different batteries, ensuring that each cell is charged optimally.

- **Scalability:**

  Multiphase converters are scalable and can be adapted to different battery chemistries and charging requirements. This makes them versatile for a wide range of applications.

- **Reliability and Robustness:**

  Multiphase converters can be designed for high reliability and robustness, ensuring that they can operate in various environmental conditions and under different load scenarios.

In summary, the motivations and objectives for using a multiphase buck converter for battery charging are primarily focused on improving efficiency, reducing voltage ripple, enabling fast charging, and addressing specific requirements related to the application, such as size, thermal management, and voltage regulation. These converters play a vital role in modern battery-powered systems and help optimize the charging process while preserving battery health and performance.

Methodology

Theoretical Studies:

The EV battery charger considers an MBC, which has been designed with four phases, where (VG) is the input voltage and Vo is the output voltage. The output current is formed by the four phases of the converter, making this structure ideal for fast battery charging.

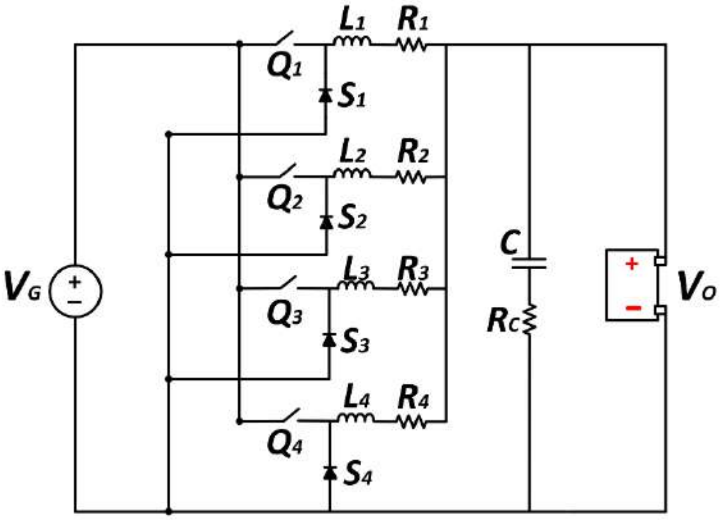

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Figure 1. MBC consisting of four phases for battery charging in EVs

Operation of the Multiphase Buck Converter:

The converter presents two modes of conduction: Continuous Conduction Mode (CCM) where the inductor current never reaches zero, and Discontinuous Conduction Mode (DCM) where the inductor current is zero during an interval of time in this paper; only the CCM is analyzed. The MBC is proposed for EV battery charging applications operating with overlapping control signals. The equivalent circuits proposed for the “ON and OFF” operating modes are only valid for the following duty cycle operating range $0.25 < D < 0.5$. The CCM has different operating states during a switching period (Ts), four in “ON mode” which correspond to turning ON switches $Q1$, $Q2$, $Q3$ and $Q4$ with 90° delay between each phase, while the diodes remain ON except for the diode where switch Q is active. Figure 2 presents the operating states in “ON mode” considering the duty cycle signals (D) of each phase in a switching period.

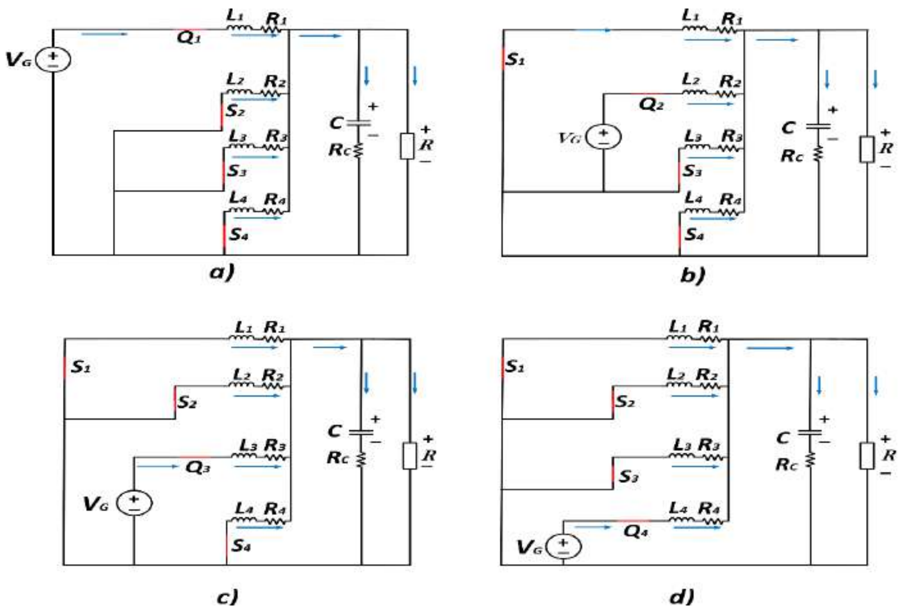

Figure 2. During the battery charging process, the equivalent circuits in “ON mode” for each phase elements, (a) $D1t2$, (b) $D2t4$, (c) $D3t6$, (d) $D4t$

During OFF mode, there are overlaps in the control signals, during a lapse of the switching period. The switch $Q1$ overlaps with the next phase that is 90° away; this phenomenon occurs for each phase in turn. Phase four overlaps with the next switching period. With the overlap of the control signals, the source (VG) is always present in the eight operating states of the converter. Figure 3 shows the four equivalent circuits of the OFF mode.

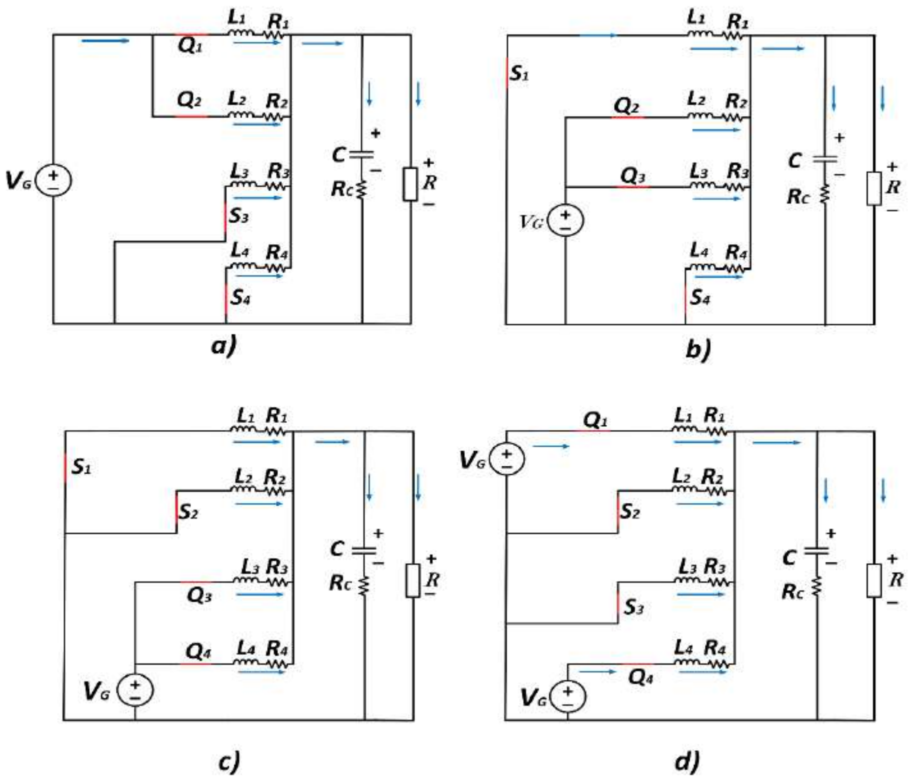

Figure 3. During the battery charging process, the equivalent circuits in "OFF mode" for each phase elements, (a) $D1D2t3$ (b) $D2D3t5$; (c) $D3D4t7$; (d) $D4D1t1$

Experimental Setup:

A functional prototype of the MBC was built . The current imbalance tests were carried out in an open-loop, where the converter operates in the scenarios used for the simulation.

Figure 4. Commutation signals for phases with the corresponding 90º phase shift and duty cycle (40%40%)

Method of Analysis:

It shows the waveforms, during one switching period, for the steady-state analysis of the MBC.

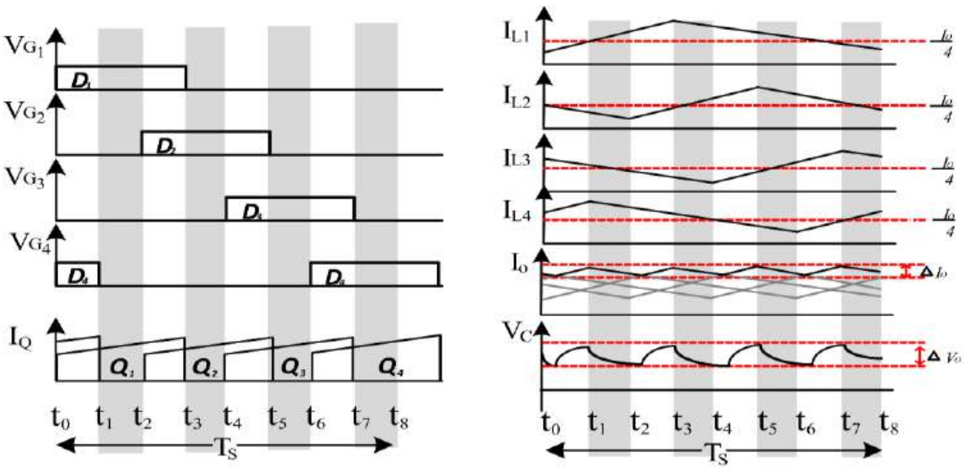

Figure 5. Waveforms during a commutation period

It shows that the inductor currents at the output of the MBC are interleaved, due to the effect of the phase difference between the control signals. The same improves the behavior of the converter by reducing the output current ripple and the converter output voltage. It also increases the frequency of the voltage and current at the output. It is important to note that reducing the current ripple size at the converter output also helps in decreasing the capacitance value at the output. Another advantage of the MBC is that the pulsed current demanded from the source (VG) is four times lower compared to a conventional buck converter, considering the same power requirements. The advantage of operating the converter with overlapping control signals is that the discontinuity of the input current demanded from the VG source is eliminated.

Expected Results:

The study of the effects of current imbalance in the MBC during the battery charging process. It focused mainly on the comparative study of the physical phenomena suffered by the converter, such as thermal stress and efficiency. It was proved that the effect of current imbalance directly affects the favorable characteristics of the MBC, such as power density and efficiency. To corroborate the theoretical results, an experimental prototype of the converter with a nominal power of 1.9 kW was built and tests were carried out under different power scenarios. The behavior of the switches temperatures in different power scenarios was presented experimentally, considering the balanced and imbalanced currents. The efficiency curves of converter with and without current balance scheme were presented, showing that current imbalance has a negative influence on efficiency. The efficiency at nominal power of the MBC shows a difference of 2.46% between the balanced and imbalanced currents. This converter has interesting and favorable characteristics for battery charging in electric vehicles due to its high power density and simple dynamic characteristics, but it is important to consider a good current balancing scheme in order not to lose these favorable characteristics. Future work includes the study of the effects of current imbalance on the battery life cycle and the analysis of the different current balancing strategies considering aspects such as cost and performance in the MBC.

Proposed Time Schedule:

Activity	Sept		Oct	Nov	Dec	Jan	Feb	
Collection of Literature	X							
Study of Literature		X						
Analysis of Proposed Scheme			X					
Preparation of Schemes / Model				X				
Implementation of Schemes/Model					X			
Analysis & Simulation						X		
Result Formulation							X	
Final Write-up & Thesis Submission								X

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