Hybrid Electrical Vehicle using DC to DC Convertor

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Abstract— One of the most critical issues for the environment today is pollution generated by hydrocarbon combustion, which is one of the main sources of power for transportation. Hybrid electric vehicles (HEV) and full electric vehicles (EV) are rapidly advancing as alternative power trains for green transportation. The vehicles' electrification not only involves the traction parts, but it is also generating new applications for electric power conversion. One of the key blocks inside hybrid electric vehicles is the DC–DC converter for auxiliary power supply of electric loads. This converter has to be capable of handling the energy transfer from the 12V DC bus and the high voltage DC bus (used for the electric traction). The DC-DC converter enables the energy transfer between the high voltage side and low voltage side giving tremendous advantages in terms of cost, flexibility, and efficiency, increased due to the possibility of easy synchronous rectification implementation. Key features include resonant clamping implementation in the boost mode and soft-switching operation, due to phase shift modulation, in the buck mode, without additional devices, as well as high efficiency and simple control.

Keywords— Battery electric vehicles, DC to DC Conversion, Battery, Motor

I. INTRODUCTION

HEV and EV applications are a growing interest, related to the need to reduce both the polluting emissions and fuel consumption of land transportation vehicles with Internal Combustion Engines (ICE) by replacing or reducing the use of ICEs with electric propulsion.

Currently in HEVs and EVs, a high voltage battery pack supplies energy for cruising to the electric traction system. The conventional 12V system still exists to feed the usual car loads (an auxiliary battery supplies all the electric loads such as head and tail lights, heating fans, audio systems and so on), while the high voltage bus feeds the traction inverter and motor. Since a dual-voltage power system is present in the electric vehicle, it would be convenient to transfer energy between the two voltage systems. As a consequence, the new feature of both traction and auxiliary power converters in such an application is represented by the highly efficient management of the high voltage DC bus by the battery pack, which can range between 200V and 800V, according to the power of the electric motor.

The typical power request for auxiliary converters in HEVs is in the order of some kW [1], with overload capability because of several non-linear actuators. Considering that a 12V bus is still requested as a standard value due to compatibility with combustion engine cars, the output current level is considerably high, with a peak value around 200-250A. On top of this, the efficiency of the system is a key feature and a driving parameter for design choice.

Figure 1, DC-DC converter, is an auxiliary power converter that interfaces with the 12V bus system and the 200V-450V bus system. The solution is based on two switching converters, linked through a high frequency transformer, and it is able to achieve efficiency values higher than 90% over a wide load range at a reasonable cost. This is due to the use of the latest generation of ST Power MOSFETs and control strategies based on the use of phase shift techniques, synchronous rectification, and resonant clamping for the main power devices. The control scheme takes advantage of a microcontroller capable of generating the correct modulation pattern to drive the power devices.

Power electronic converters and new semiconductor devices are key components to meet the targets of extended mileage range and reduced pollution. Highly efficient DC/DC converters must be used to provide proper voltage levels and the power management between different energy sources and storage elements. A typical hybrid power train using two converters is shown in fig.1



Fig. 1: Component for the DC to DC Converter

In this schematic, 12 V is the standard voltage for instrumentation, actuators, and lighting, and is provided by the service battery. A 200-800 V DC link is used for the traction system. A DC/AC (Traction Inverter Module) converter. is also used for traction and designed for tens or hundreds of kilowatts, while the DC/DC auxiliary power converter is designed for hundreds or thousands of watts. The traction battery can be charged by the hybrid system control and/or the AC/DC converter from the Mains, while the 12V battery is charged from the traction battery via the DC/DC converter. In some cases, it might be necessary to charge the service battery from the traction battery of fig. 1 via the DC/DC converter. Because of the above considerations, the electric vehicle configuration may need a bidirectional or unidirectional system. The reliability of this converter is also a key point since a fault would lead to discharge of the 12V battery and, consequently, to the loss of all the powered accessories. On the other hand, efficiency and EMC problems cannot be neglected. As a consequence soft-switching and energy recovery techniques such as active clamping are very helpful.

II. CONTROL STRATEGY:

Two control algorithms are provided: one based on an 8-bit microcontroller and the other one based on a 32 bit microcontroller for unidirectional and bidirectional energy flow handling respectively.

The adopted control techniques for the two power transfer directions are different, but they both consist of gate signals control generation with feedback loop based on the output current and voltage regulation. For the step-down operation, that is the low voltage battery charge direction, the control signals for the full bridge use phase shift modulation.

A. Service battery charge (Step-down operation)

During this operation, the DC/DC converter works as a step down converter, reducing the voltage from 288V nominal to 12V. The switches in the low voltage side in principle could be not driven, and their freewheeling diodes would just operate as a voltage rectification stage, but to increase the converter efficiency, a synchronous rectification strategy is preferable. Instead, for the high voltage side, a phase shift modulation allows ZVS operation for the Power MOSFETs to be achieved, almost removing the turn-on losses. In the phase shift modulation, the two devices belonging to the same leg are driven with two complimentary signals with a fixed duty cycle of 50% and with a proper dead time setting, while between the two legs, the signals are phase shifted by an angle imposed through the feedback loop. This method allows a symmetrical usage of the transformer, preventing the core saturation. The overlap imposed by the phase shift sets up the duty cycle for the buck converter to regulate the output voltage. The described control signals are shown in fig. 2.



Fig. 2: Phase Shift Modulation

B. High voltage battery pack charge (Step-up operation):

In this case, the DC/DC converter transfers the energy back to the high voltage battery pack, elevating the voltage from 12V to 288V. The switches of the high voltage side bridge are not driven, and the freewheeling diodes just perform a voltage rectification. In the low voltage side, instead, the two switches M1 and M2 are properly controlled in order to perform a boost stage operation for the inductance and drive the high frequency transformer as a push pull stage. Service battery charge (Step-down operation) At the beginning of the automobile's history, two main competing approaches to engine-driven vehicles existed: one with internal combustion engine (ICE) and another one with an electric drive train. Already in 1834, the American inventor Thomas Davenport built The first electric car. The first ICEV was developed in 1886 by Benz and Daimler in Germany.





The two PWM signals that are shifted by 180° have a duty cycle always higher than 50%. This is because an overlapping period where the two switches are simultaneously closed is necessary to charge the input inductances while necessarily avoiding a situation where both switches are open to avoid generating an unclamped situation for the input inductance that would lead to a dangerous overvoltage across the devices.

Nevertheless, the transformer leakage inductance during the device turn-off transient causes an over voltage spike and a clamp circuit needs to be used. The active clamp we described before will contain this energy, but it needs to be controlled by an additional signal as shown in fig. 3. The active clamp device is turned on immediately following the one of the dual device turn-off, and it is kept on for a fixed time of 500ns.

III. CONCLUSIONS

This paper shows how to implement an efficient bidirectional or unidirectional DC/DC converter aimed at exchanging energy between the high voltage battery and low voltage service battery present in HEV applications. In these applications, other than the cost, the efficiency of the design has to be taken under serious considerations. The efficiency improvement, in fact, will also save costs for the full solution as, for example, a liquid cooling system is no longer necessary.

Using the latest control techniques for standard industrial converters, combined together to implement a bidirectional battery charger for HEV, we have presented a straightforward way to reduce the size of electronics in the newly emerging electric vehicle, to simplify the mechanical complexity of the assembly, and to maximize the energy usage. Furthermore, the communications features (CAN) of the microcontroller we feature also allows easy power management that can be controlled by the central unit installed in the car.

The DC-DC converter exemplifies how the wide range of STMicroelectronics (ST) power devices and microcontrollers can address this application and provides a good platform to evaluate new silicon devices dedicated to the electric transportation.

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