POWERFUL TRACTION BATTERY CHARGER USING NEW SEMICONDUCTOR DEVICES

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Abstract: This article deals with the concept of the new powerful traction battery charger for electric vehicles. Because of the required minimum possible size and weight, while keeping the simplicity and reliability of the equipment, it was not easy to choose an appropriate design. There are also described problems occurring in the selected concepts and their subsequent solutions. This concept was implemented as a functional pattern, and then measurements were taken to verify the validation and functionality of the equipment.

Keywords: Diode SiC, tranzistor Cool-MOS, powerful charger.

1. INTRODUCTION

Today's electric vehicles have new batteries, which allow a high charging current. In the automotive industry there are high demands on price, size, weight and operation in difficult conditions for electrical equipment. For these reasons, the choice of concept and design of high power charger is very difficult. Converter topology is limited by the available magnetic circuits, materials and semiconductor devices.

2. REQUIRED PARAMETERS

Because of the use of converters in the automotive industry it is an attempt to make the entire equipment in smallest possible size and weight while maintaining a simple and cheap construction.

Powerful charger's required power is 16kW (output of one module, you can combine as needed to increase performance). Because of this fact, it's evident that the driver will be powered by a 3-phase network 3x400V/50Hz.

I	Output (charging) current	100A
U	Output voltage	160V
P	Output power	16kW
U_{in}	Input AC RMS voltage	3x400V
U_{DC}	DC link voltage (split DC-link)	2x280V
f	Switching frequency	100kHz
m	Mass	ca 15kg

Table 1: Basic technical specifications of the charger

In addition, there are requirements to these converter output values: 160V/100A DC (after adjusting the high frequency power transformer and the secondary circuit, this converter concept can work with other output voltages and currents).

3. CHOICE CONCEPT

Because of the required smallest size and weight it is necessary for the charger to work with a high switching frequency. For such a high switching frequency and power (current) it is not possible to use slower IGBT transistors and conventional diodes. Therefore, it is necessary to use Cool-MOS transistors and diodes based on SiC. Total switch-on and total switch-off time in Cool-MOS transistors is only about 100ns and SiC diodes with recovery time is about 10ns. Thanks to this, the problems with switching losses are reduced and it's possible to design such a charger (16kW/100kHz).

3.1. PARASITIC EFFECTS DUE TO HIGHT SWITCHING FREQUENCY AND THEIR ELIMINATION

The usage of Cool-MOS transistors and high switching frequency brings some new problems.

Large slope du/dt respectively di/dt during switching off the transistors:

For the Cool-MOS transistors there are special requirements for the design of driver (necessity of suppressing the so-called ringing - need of the little parasitic capacity of galvanic separation - ability to du/dt)

Large over-voltage peaks caused by the large slope of di/dt and parasitic inductance (damage of the transistors). It's necessary to use snubber circuits (snubber RCD circuits) for the switching off action.

EMI problems (also related to Ringing).

Large slope di/dt on secondary diodes:

Due to the influence of parasitic inductance and a large slope di/dt on the converter's secondary side the large over-voltage peaks appear at these diodes. This over-voltage peaks were not suppressed by the partial parallel connected snubber RC circuits.

Large dynamic losses on secondary diodes:

Due to poor dynamic properties of conventional diodes it is necessary to use the new fast diodes based on SiC.

Limited reverse voltage of Cool-MOS transistors:

Transistors with current-carrying capacity is required to produce maximum reverse voltage of 600V, it can not therefore be used to drive the DC link three-phase rectifier formed 6-pulsed network 3x400V (Cool-MOS transistors with a reverse voltage of 800V exist, but they have poor RDS_{on} parameter and smaller current-carrying capacity). The problem can be solved using the split DC bus voltage (twice 280V instead of one 560V bus). It will be demonstrated that adequate power circuit topologies can easily (without control) ensure conformity of the two halves of the bus voltage (link is composed of two in series connected capacitor battery).

A proper power circuit design can solve mentioned problems.

Due to high switching frequency 100kHz (for 16kW) it is advantageous to avoid the use of double-acting drive (creating "dead time " during switching period of 10μs would be an unpleasant task and an unnecessary complication). Due to divided circuit we use two single-acting permeable bridge inverters. This won't work in opposite tact to common chokes, but each will have its own one. The next chapter will make it clear that this solution automatically ensures a regular distribution of the rectified input voltage (560V) into two half DC-link.

3.2. SERIOUS PROBLEMS WITH REGULAR VOLTAGE DISTRIBUTION INTO THE TWO SERIAL DC-LINKS

Serious problems with regular voltage distribution into the two serial DC-links can appear in the configuration according to figure 1: Only one common output current I_L is present (common one output choke). If the duty cycle in both converters differs a bit each other (due to control circuits or driver circuits) then the peak values of i_{2A} and i_{2B} pulse currents are the same but their average values are different. Then also the input DC currents (rectangular pulses) from the DC-links have the same peak value each other, but different time duration. This means their average values are different. This is why one capacitor will be discharged more than the other - time integrating problem - the voltage distribution irregularity will increase (damage). The described effect is displayed in figure 2 [1].

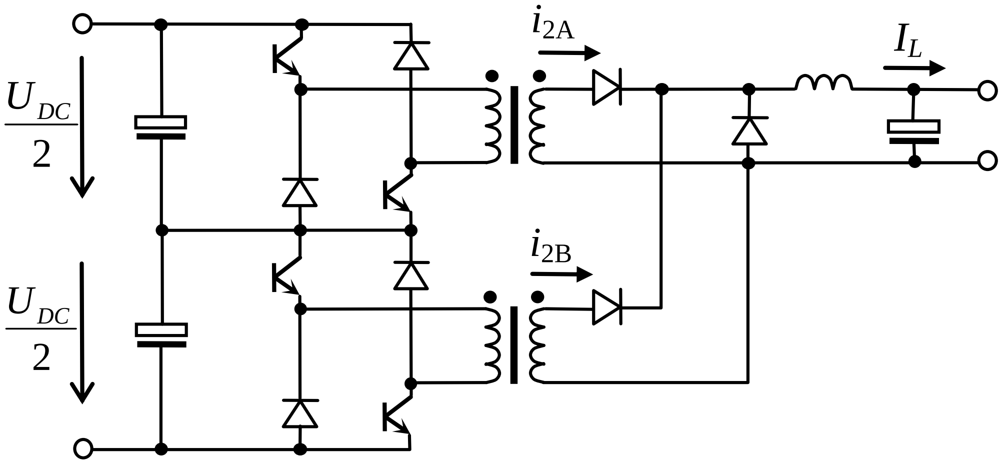

Figure 1: Split DC-link solution - problematic variant with respect to regular voltage distribution - not used [1].

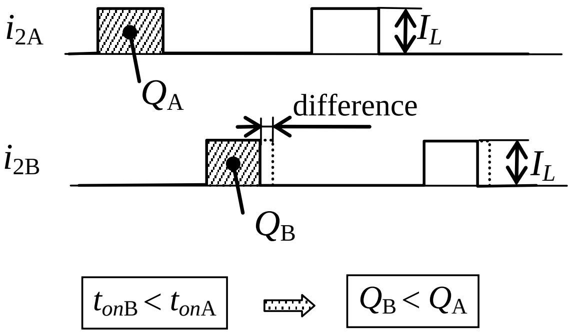

Figure 2: Current and charge distribution in the topology according to figure 1.

Therefore the solution drawn in figure 3 is used instead of figure 1 [1].

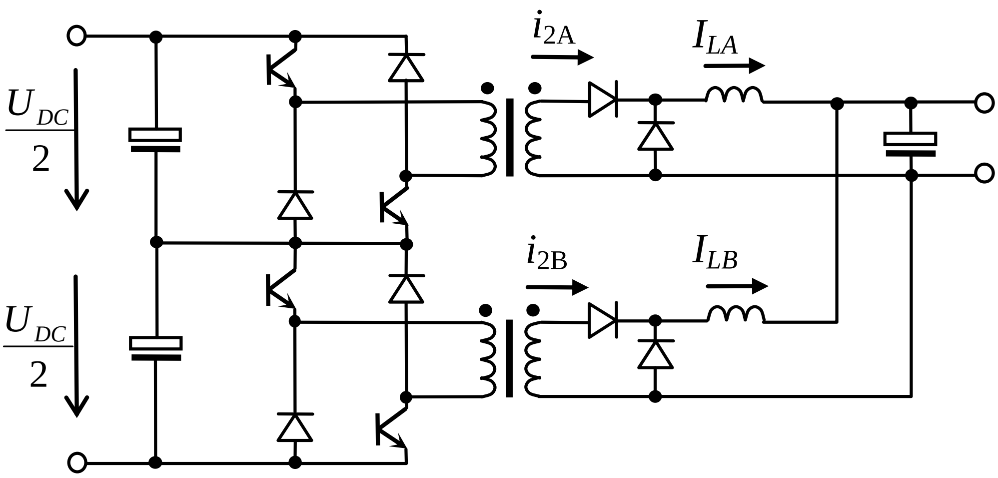

Figure 3: Split DC-link - optimum variant with respect to regular voltage distribution – used [1].

In this solution two separate output chokes are used. It means the converters can provide different output currents I_{LA} and I_{LB}. If a non-equivalence of average input currents appear (due to the duty cycle difference) - one capacitor starts to have a lower voltage than the other - then the converter supplied from the higher voltage starts to provide a higher output voltage too and therefore its output current increases - so its input current increases too - and its DC-link capacitor (with higher voltage) will be more discharged. So an automatic negative feedback is present - it hinders an uncontrolled voltage irregularity in the split DC-link. No additional electronic circuits controlling the voltage regular distribution are necessary! The situation is displayed in figure 4 [1].

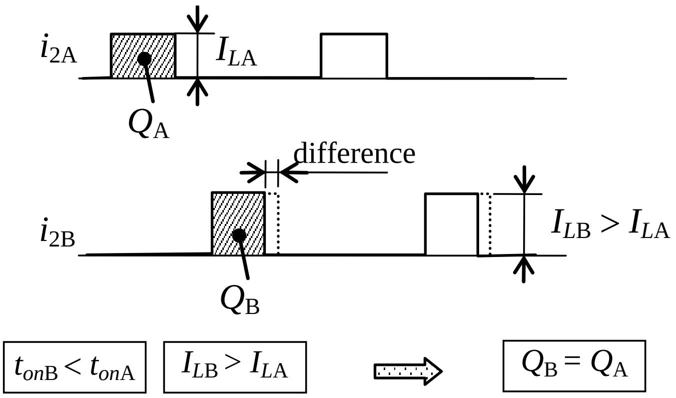

Figure 4: Current and charge distribution in the topology according to figure 3 [1].

4. CONCLUSION

This paper describes the concept of quick charger for new electric traction batteries, which allows high charging currents.

The smallest possible size and weight were required, it was necessary to work at high switching frequency. For this reason new semiconductor devices were needed enabling a large slope du/dt or di/dt. Cool-MOS transistors and diodes based on SiC were used. Using of these elements, however, requires a solution of new complications. The text describes how to solve individual problems. So the device should work properly. Secondly, a simple and reliable device it was required. The choice of appropriate approach was therefore very difficult. The fact that this concept is functional was verified on a functional sample.

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