INVERTER FOR THE ULTRACAPACITORS APPLICATION IN THE DRIVE STRUCTURE OF THE ELECTRIC SCOOTER

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ABSTRACT

In this paper, buck-boost inverter for the ultracapacitors application in the electric scooter drive structure design is described. The device consists of power supply, drive parameters sensing, regulation and power transistors driver circuitry. Main aims of inverter application is to ensure higher operation efficiency by flattening battery current value (suppressing current peaks) and by temporarily storing energy obtained by regenerative braking (which cannot be stored in present lead-acid batteries due to their low charging current).

1 INTRODUCTION

Ultracapacitors are electrical devices intended for energy storage. Although their principles are known for over 40 years, their serious commercial applications are relatively new. Generally, ultracapacitors behave more like conventional capacitors rather than common accumulator system (lead-acid, nickel-cadmium etc.), that means their voltage depends on actual charge state (however this dependence is not linear), can deliver higher current values, than accumulators, and finally, their expected cycle life is *much* higher, than accumulator's. These specifications predetermine their use in cyclic, high-current applications.[1]

Such an application could be in the independent electric traction system, where efficiency has direct influence on vehicle's ROA (Radius of Action). An example of such vehicle is electric scooter, designed and constructed by the Department of Power Electrical and Electronic Engineering FEEC BUT. Its drive was expanded with ultracapacitor (20 F, 69 V) and proper inverter to verify the influence on vehicle's ROA.

2 VEHICLE'S FORMER DRIVE

The drive of the electric scooter consists of power source, 3-phase inverter and asynchronous machine. As a power source, series connection of four lead-acid batteries is used. Each battery has voltage of 12 V and capacity of 40 A.h, VARTA's "SEMITRACTION" design – more vibration-proof and dischargeable to deeper level.

Inverter converts 48 V DC link voltage to the 3-phase, 48 V, variable frequency AC supply. There is only torque control (no speed control) present, which is basically slip control. Inverter's logic sets its output frequency according to actual speed (sensor on the asynchronous machine) and accelerator position. The asynchronous machine is standard 750 W type, just with rewound stator winding regarding to low supply voltage, and is operated at speed up to 7000 min^{-1}.

3 INVERTER FOR THE ULTRACAPACITORS

The inverter had to fulfill some construction requirements:

- former drive structure had not to be corrupted
- no changes in 3-phase inverter

to make ultracapacitor's removal easy. (Ultracapacitors and inverter are now in use in another experiment). So the inverter is connected to the DC-link of the drive, as could be seen in the dashed square in the Fig. 1:

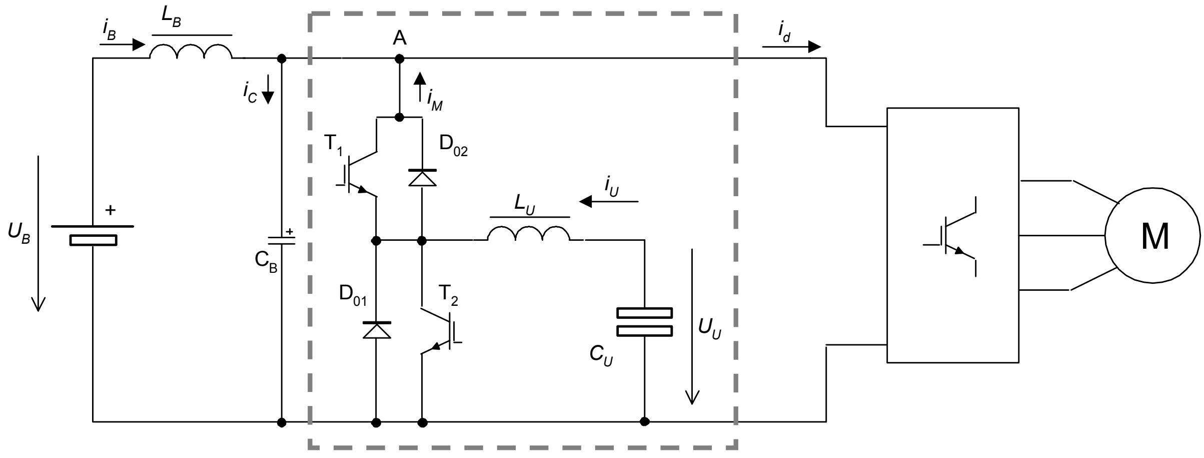

Fig. 1: *Inverter connection into the driver's former structure*

Inverter's control structure is in the Fig. 2. There are two "independent" control branches:

- The first reads deviations in battery current (through the block "COMPENSATION"), and sets the appropriate value of required current variable ("I_{CW}"), to maintain battery current deviations as low as possible.
- The second reads speed of the asynchronous machine (via the same sensor, as 3-phase inverter) and actual ultracapacitor's voltage, which approximately represents the amount of stored energy. There is a premise, that when vehicle runs at its top speed, the ultracapacitor's voltage should be at low level (regenerative braking and energy supply is expected), whereas vehicle stays, the voltage should be at top level, expecting energy demand for start. So appropriate value of required current to solve eventual unbalance is set.

To avoid possible conflicts between these two branches, the second one actuates through the "RAMP" block, which makes it slow enough so the current deviations are under the first branch sensitivity level.

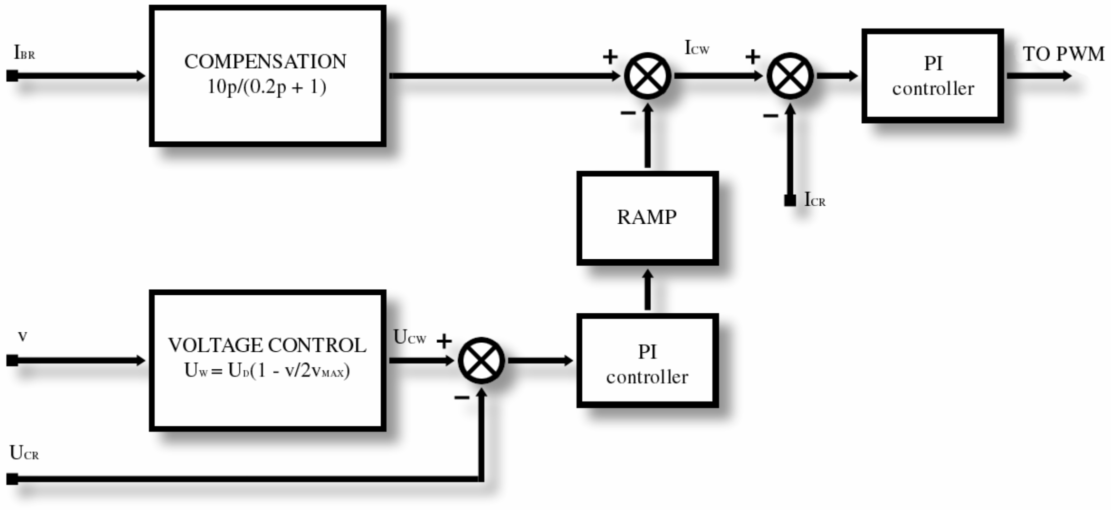

Fig. 2: *Control structure of the inverter for ultracapacitors*

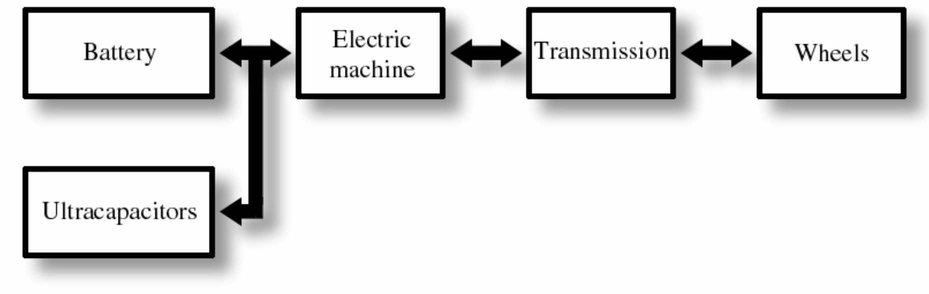

Fig. 3: *Schematic connection of ultracapacitor & inverter into vehicle's drive chain.*

Apart from control structures, the inverter also includes main power supply (Fig. 5. top-right quarter), for ±15 V for the operational amplifiers and +5 V for the logic IOs from 48 V DC-link, and approximately 1 MHz power supply (Fig. 5, bottom-left quarter) for the transistor's drives (Fig. 5, PCBs parallel to the camera). Each needs galvanic separation from control circuitry and from the another.

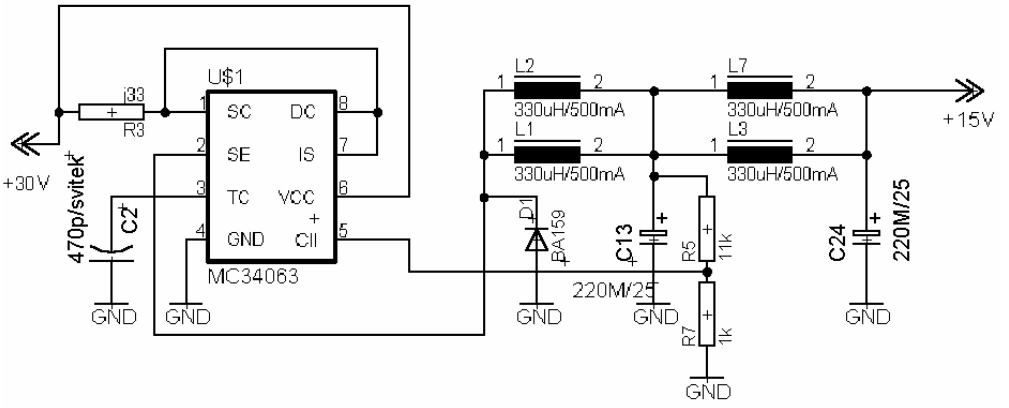

Fig. 4: *Example of a +15 V supply with MC34063*

The main power supply is designed with respect to minimal heat losses. Unfortunately, the applied integrated circuit's (MC34064, switched voltage control circuit) maximum operating voltage is 40 V, lower than the CD-link voltage (48 V), so the linear stabilizer had to be used, causing average loss approximately 5 W. Losses of the switched power supplies are almost negligible. An example of MC34064's circuitry is in the Fig. 4.

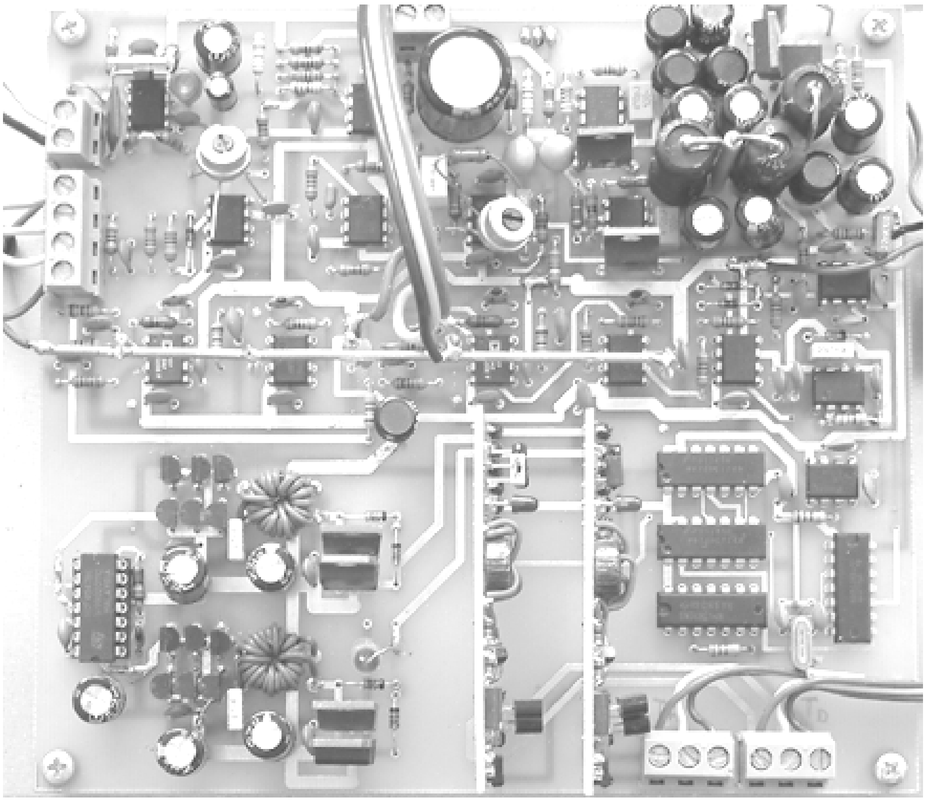

Fig. 5: *Inverter for ultracapacitors, control part*

4 PRACTICAL FUNCTION VERIFICATION

The inverter was together with ultracapacitor connected to the DC-link of the scooter's drive. Parameters of the two control structure's branches were adjusted to work properly, according to parameter difference between design and reality. Then the test rides were performed, once without ultracapacitor's inverter running (and without regenerative braking) and once with full functional vehicle's systems. Test track consist of several stop and start points, small hill climb (elevation approx. 4 m) and descend. Test stopped after steady-state value of lead-acid battery voltage didn't exceed 44 V. Due to the bad condition of the battery, the distance wasn't long. The result is:

test ride without ultracapacitor and regenerative braking:	12,6 km
test ride with all systems functional:	14,5 km

So there is a 16 % increase, which was supposed for such small vehicle with high losses (friction, air resistance) in proportion to its kinetic energy.

5 CONCLUSION

Ultracapacitor experimental application has shown its positive influence on the vehicles radius of action, increasing it by 16 %. Generally, increase would be more significant on bigger vehicles, for example electric bus (which naturally needs cooperation with industry). Designed inverter works well, although digital control structure could be more easily changed (reprogrammed) and could work with other digital devices, such a data recorders.

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