INTEGRATED INVERTER FOR BLDC MOTOR

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Abstract: The paper deals with the possibility of integration inverters to the body of motor. For the specific case was chosen BLDC motor. For the correct function always must be use an inverter, which essentially replaces the mechanical commutator. When using a sophisticated power components, may be possibility to create a compact unit inverter-motor and then consequently increase possibility of practical use, eventually reduce price.

Keywords: BDLC motor, inverter, compact drive unit

1. INTRODUCTION

Currently on the market there are so-called BLDC motors. Their principle is based on a DC motor. Unlike DC motor do not contain mechanical commutator. A commutator is an element determining the lifetime of the whole machine. Stator part includes a magnetic circuit and windings, rotor part includes a permanent magnets (PM). Switching the coils is carried out electronically, according to position on the shaft. These motors due to their design are mostly used in aeromodelling. To this category are determined by their construction, but especially the possibility of using permanent magnets made from rare earths. For small of modelers motors are mostly used type of Nd-Fe-B magnets. Magnets of this type form the largest energy product [up to 358 kJ/m^3]. In the area of traction with BLDC motors are used as the drive of electric bicycle. They can be integrated directly into the wheel hub, but not a rule. Control and power electronic is convenient placed inside body of the motor, if design of the motor allows this.

2. CONCEPTION OF COMPACT DRIVE UNIT

Possible structure of BLDC motor with integrated inverter is shown in Fig.1.

Description of Fig.1 is the following: (1) Stator, (2) Rotor with PM, (3) Sensor of the shaft position, (4) Inverter, (5) Fan

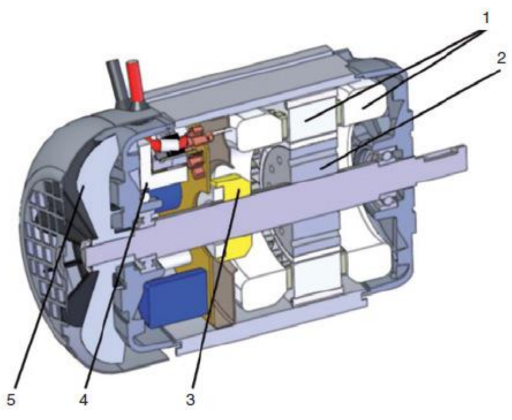


Figure 1: Section of BLDC motor with the integrated inverter[4]

Because for switching the coils of BLDC motor is used an electronic converter, may be motor three-phase, but also multiphase. Typically are used three phases. The multiphase system complicates construction of the drive. For correct switching of the coils is necessary to sense the position of the shaft. In the case of BLDC motor is sensing of the shaft position performed by Hall probes usually or by measuring of the induced voltage in disconnected phase. This possibility has a big disadvantage which is shown by the following equation:

$$u_i(t) = B \cdot l \cdot v(t) \tag{1}$$

Induced voltage (BEMF) in phase is directly proportional to current speed of rotor revolving. When the current speed is zero, is not possible to measure of induced voltage and determine position of the shaft. If it has motor a small torque load, is used for initial revolution a sequence of switching phase. This possibility is only used in small motor. Sensing with magnetic or optical sensor is used for a bigger motor.

2.1. COMPACT POWER MODULE

Currently exist in the market the single purpose modules. These modules combine of three-phase bridge with IGBT or MOSFET, driver for transistors and power supply for lower and upper drivers. Their advantage is in the compactness with the use minimum external electronic components. To provide power for the top drivers transistors are used charge pump with signal level shifting transistors. The principle is illustrated in Fig.2.a).

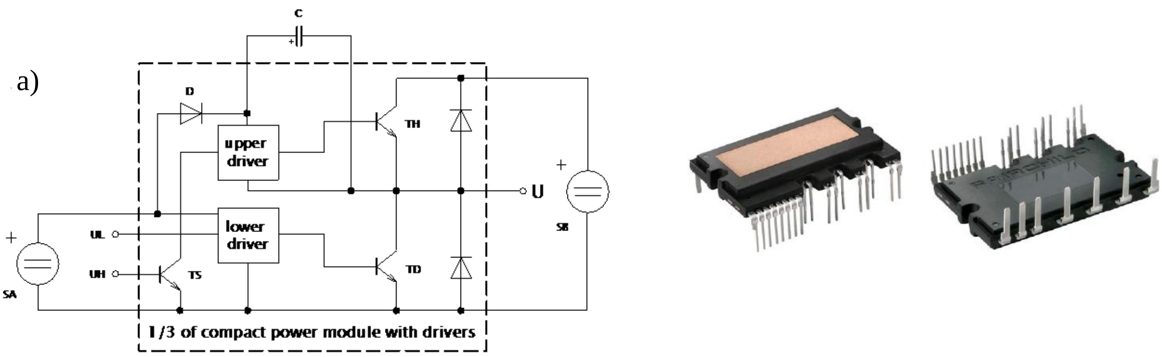


Figure 2: a) The principle of power supply the upper driver, b) Case of the compact power module[5]

Capacitor C is charged through the diode D for the time, when the transistor TD is closed. When the transistor TD is opened, upper driver is supplied from source SA. Control algorithm of compact power module must respect charge the capacitor C in any mode. If the upper driver is not enough supplied, may be critical state. Compact power module with drivers also contains function of block switching all power transistor in three-phase bridge. This function is used in case of overload or short-circuit current. Some modules contain integrated saturation protection of power transistor. The big advantage of compact power module is the location all the electronic elements in one case. Example of case construction the compact power module is in Fig.2.b). For this case is not problem calculate thermal resistance (required size of the cooling area). For calculate is needed junction to case thermal resistance, case to heat sink thermal resistance and total power dissipation. Thermal scheme for the calculation is shown in the Fig.3.

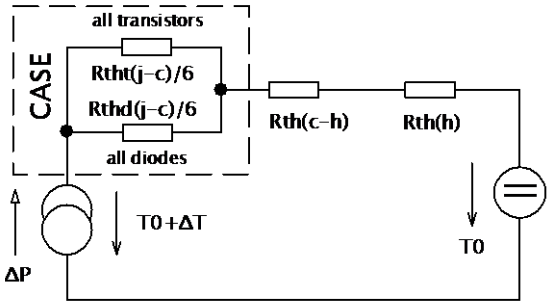


Figure 3: Thermal scheme for the case

$$R_{th(j-c)} = \frac{R_{tht(j-c)}/6 \cdot R_{thd(j-c)}/6}{R_{tht(j-c)}/6 + R_{thd(j-c)}/6} \tag{2}$$

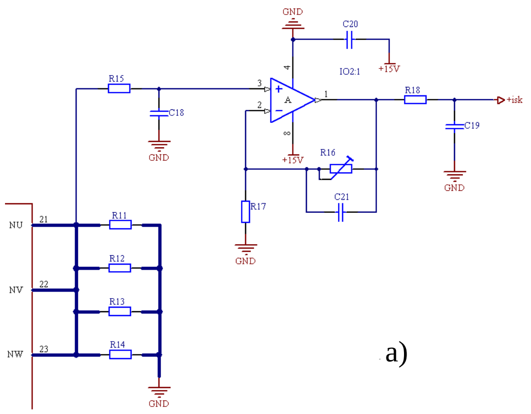
$$R_{th(h)} = \frac{\Delta T}{\Delta P} - R_{th(j-c)} - R_{th(c-h)} \tag{3}$$

$$R_{th(h)} = \frac{T_{\max} - T_0}{\Delta P} - R_{th(j-c)} - R_{th(c-h)} \tag{4}$$

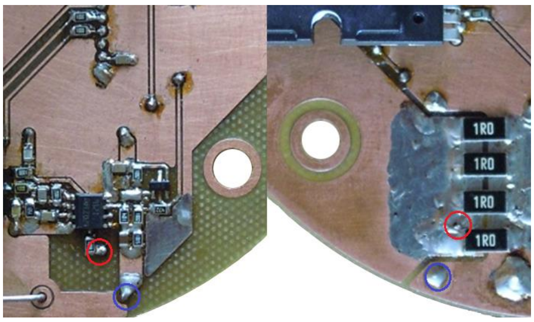
2.2. CURRENT MEASUREMENT

Information about the instantaneous value of current is used for the current loop. Existing two ways, how to measure the DC current. Can be used probe with Hall sensor or shunt. In view of the limited space and the requirement for a low cost solution is offered shunt with operational amplifier. That possibility has one disadvantage. Is sensitive to noise, which arises due to pulse width modulation. By appropriate circuits and PCB design can be greatly suppressed this disadvantage. Operational amplifier must be placed close to the shunt. In the input and output operational amplifier must be used RC filters. At this time does exist operational amplifier of type rail-to-rail. Their advantage is unbalanced supply voltage. The output voltage is in the full range of the supply voltage, so from 0 V to the value of the supply voltage. Suitable solution of the current measurement is shown in the Fig.4.a)

Fig.4.b) shows the suitable implementation in the PCB. Very short wires between shunt and amplifier reduces the parasitic inductance and it reduces the effect of interference.



a)



b)

Figure 4: a) Shunt with the rail-to-rail operational amplifier, b) Detail of the connection between shunt and amplifier

2.3. CONTROL UNIT

This variant can be solved by using single purpose analog circuit. Manufacturer of these circuits is the company SANYO for example. Exactly it's a circuit LB11696V. Sensing the position of the shaft in the case of this circuit is performed by using three Hall sensors. The circuit allows reversing the motor, stop switching of transistor, smooth speed control of a DC voltage or duty cycle, and acquisition the information about speed. It integrates over current protection, which can be out of operation and use custom. More information is specified in the manufacturer's datasheet. Block diagram of the control unit is shown in the Fig.5.

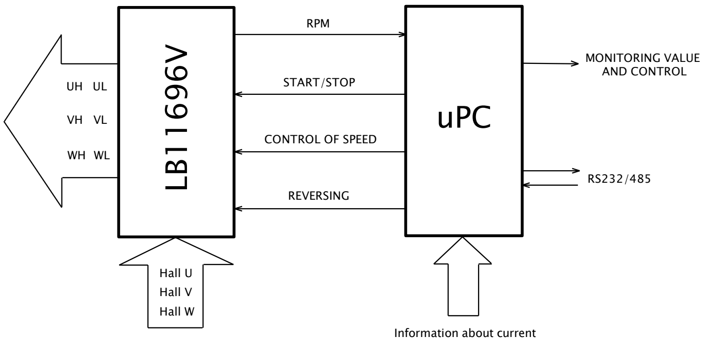


Figure 5: Block diagram of control unit

2.4. THE MEASUREMENT RESULTS

The resulting waveforms were measured on the first prototype of inverter. Load of the inverter was the motor with parameters 24V and 600W. The inverter able to operate reliably in the maximum size of the phase current is 12A and the maximum size of the phase voltage 150V. Delta voltage is 300V and is equal to the DC bus voltage.

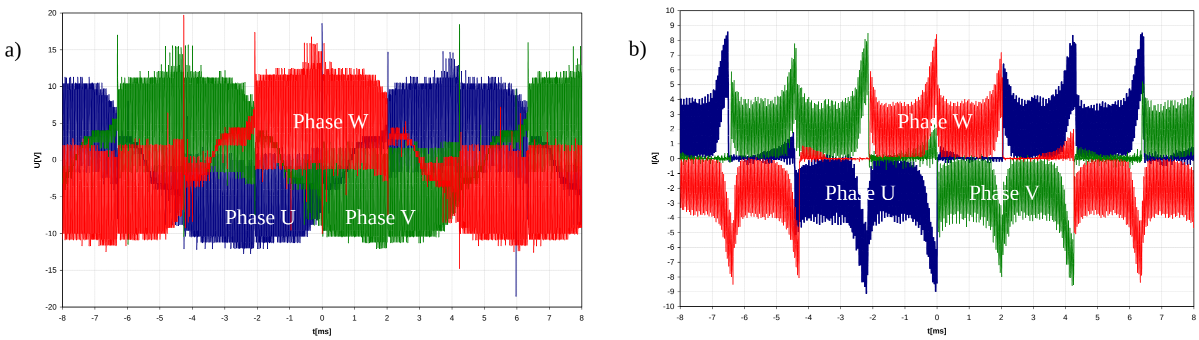


Figure 6: a) Phase voltage at half speed, motor is no-load[1], b) Phase current at half speed, motor is no load[1]

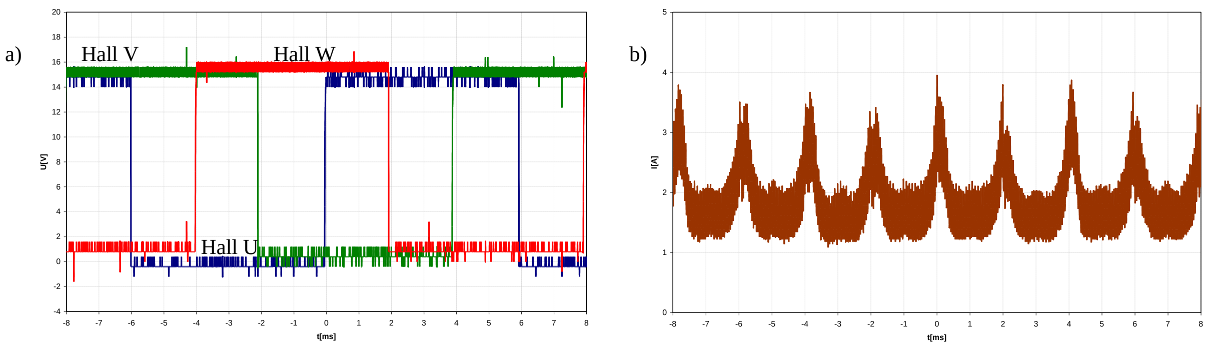


Figure 7: a) Signal from Hall probes at half speed1], b) Current taken from the DC link of inverter[1]

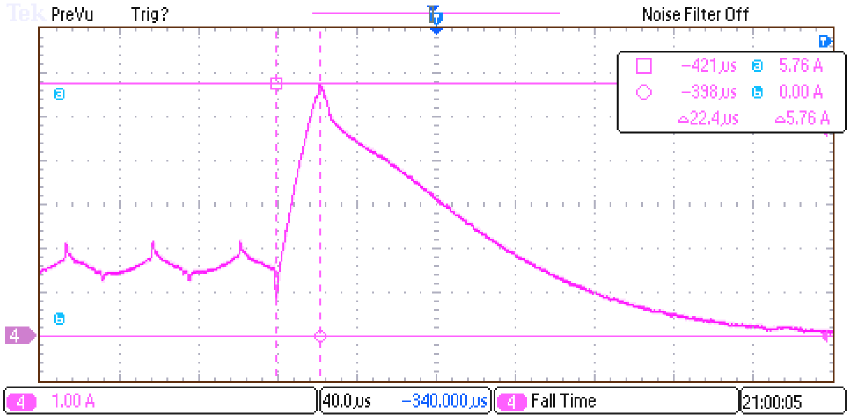


Figure 6: Reaction time of short-circuit protection and consequent decrease of the current taken from the DC link[1]

3. CONCLUSION

This paper aims to point the possibility of realization integrated converters with use a single purpose electronic circuits. Using these circuits it is possible to achieve a very simple construction and in the case of mass production low price too. The control unit consisting of special power and control circuits can be extended about the processor containing PI speed regulator, a communication protocol, measuring interface, etc. Thanks to the fact, that the control and power section is analog only, will also increase the operating reliability of compact drive unit. It is a drive units with input power about 2 kW.

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