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DESIGN OF UNIVERSAL CONTROL UNIT FOR BRUSHLESS DC MOTORS

J. Toman*, J. Hrbáček, V. Singule*****

Abstract: *The paper presents the design of both power and control electronics used to develop a universal BLDC (brushless DC) motor control unit intended for an aircraft fuel metering pump. The controller allows employing various methods for sensor and sensor-less control including frequency, trapezoidal, sinusoidal and fielding oriented control. The power subsystem provides three power totem-pole switches as well as a wide range of input and auxiliary circuitry. As needed by the target aircraft industry standards, conclusions of a thorough FMECA analysis of the resulting device are given.*

Keywords: ***BLDC motor, control unit, model based design***

1. Introduction

The Brushless Direct Current (BLDC) motors have recently gained substantial popularity among applications that require increased mechanical reliability, operation in explosive or otherwise harsh environments and accept slightly higher demands on the control unit. One of such applications is a fuel metering pump drive that is being developed as a part of the CESAR (Cost Effective Small Aircraft) EU project.

The operation of any aerospace actuator based on a BLDC motor (e.g. the fuel metering pump) is safety-critical and its safe operation requires a reliable control algorithm that ensures safe start-up and running of the BLDC motor in the whole operation range. Several applicable control algorithms and methods which have been evaluated within the CESAR project are described hereinafter as well as the controller itself that host these algorithms.

2. BLDC motor control theory

Brushless DC motor (BLDC, also known as electronically commutated motor) is from the construction point of view very similar to the synchronous motor with permanent magnets in the rotor. The main difference is usually different shape of the developed EMF waveform – trapezoidal for BLDC (simple block commutation optimization) and sinusoidal for synchronous motors (complex sinusoidal control).

From the modeling perspective, the trapezoidally wound BLDC motor can be perceived as a DC motor whose mechanical commutator is replaced by electronic means, i.e. by sequential switching of the windings to the power. This similarity implies that the quantities current-torque and voltage-speed are linearly dependent.

2.1. Frequency control

The basic control principle of the BLDC motors is frequency control. In its simplest form, called trapezoidal control or six-step commutation, it provides a winding power switching sequence as a replacement of the mechanical commutating device. The other technique – sinusoidal control – drives harmonically all three windings at the same time. Smoothly rotating current space vector has a constant magnitude and is always in the quadrature direction with respect to the rotor.

* Ing. Jiří Toman: UNIS, a.s., Department of Mechatronics, Jundrovska 33, Brno, Czech Republic, e-mail: jtoman@unis.cz

** Ing. Jan Hrbáček: Faculty of Mechanical Engineering, Brno Univesity of Technology, Technická 2, Brno, Czech Republic, e-mail: jan@hrbacek.info. Brno Ph.D. Talent Scholarship Holder

*** doc. Ing. Vladislav Singule, CSc.: Faculty of Mechanical Engineering, Brno Univesity of Technology, Technická 2, Brno, Czech Republic, e-mail: singule@fme.vutbr.cz

3. Control system architecture

The control system can be divided into two main parts – the control unit itself and a software tool for diagnostic/control purposes. The control unit is further comprised of its hardware platform (providing power electronics, sensory, computations means and auxiliary circuits) and firmware equipment (implementing described control algorithms).

4. Failure mode analysis – FMECA

Failure Mode, Effects, and Criticality Analysis is a mandatory part of the development of any electrical application in the aerospace industry. A preliminary FMECA study of the 3rd generation of electronics was carried out within the CESAR project. The main aim is to find the most critical components in the electrical design and provide a feedback to innovate or supersede critical components. About 859 possible failure states on about 386 failure positions have been analyzed. The most significant failures have been located along a short-circuit path through semiconductors in the device. Its risk factor RN is higher than 600. Reliability and safety analysis has found 9 possible failures of the electronic control unit, which can be critical. The most critical devices are semiconductor diodes.

5. Control algorithm test results

To evaluate the performance of the control system and the designed electronics, two types of the evaluation test were used. Firstly, the start sequence of the fuel pump was performed; it was verified for a step change request from 50 percent of the fuel flow. Acceptable start time 174 ms was achieved.

The stop time characteristic was much more difficult to measure. The fuel pump should stop from the nominal fuel flow and back pressure. The stop time of 83 ms was achieved which is acceptable.

6. Conclusion

Three evaluation versions of the BLDC motor control hardware have been developed within the CESAR project. With all three generations of electronics we have been able to verify the sensor and sensor-less control algorithms described hereinabove. The optimal control method for the fuel metering pump actuator system has been found: a combination of the sinusoidal frequency start-up phase with operational trapezoidal sensor mode control seems to best fit the needs. The requirements for a fluid metering pump control system have been fulfilled and requested dynamic behavior has been achieved.

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