

FLOW CONTROL OF BLDC ENGINES AT SMALL RPM

Grofu Florin, Assoc. Prof. PhD
 Marcus Răzvan , Assist. PhD Stud. Eng.

“Constantin Brâncuși” University from Târgu Jiu, ROMANIA

ABSTRACT: This paper is about the use of BLDC motors in applications to the detriment of induction or brush motors. We have developed a software controller in Matlab to control the BLDC motor in flow without hall sensors for low speeds and high power. By choosing small and precise speeds, both the stator flow and the rotor flow must be coordinated.

KEY WORDS: Electrical parameters, Brushless, BLDC, MathLab, controll , low speed

1. INTRODUCTION

I chose the BLDC motor type due to its advantages over the classic brushless DC motor and the three-phase induction motor. For example: by much more developed torque in relation to its geometric dimensions and the much lower degree of wear due to the almost insignificant mechanical parts. The presence of permanent magnets reduces the power required to induce in the rotor, a principle known for the three-phase induction motor.

Unlike the DC motor where the switching is done by mechanical contacts using carbon brushes, the switching of the BLDC motor is done electronically. The operation of the BLDC motor is based on the supply of windings on the stator. The magnetic field generated by the stator interacts with the magnetic field of the rotor, a process that realizes the rotational movement. The winding is fed on the basis of sequences established according to the position of the magnetic poles on the rotor. A frequently used method for controlling the BLDC motor is performed by reading the position of the rotor with Hall sensors, this method is presented in this paper. Hall sensors are distributed on the stator, and their number may differ depending on the motor. Three Hall sensors are usually used. Most BLDC motors have three stator windings connected

in the star connection. The magnetic poles generate invisible lines of magnetic force that propagate from the north pole (N) to the south pole (S). As shown in figure 1 [1], when the magnetic poles of opposite polarity face each other they generate an attractive force and in the case of identical polarity the generated force is repulsive fig.1.

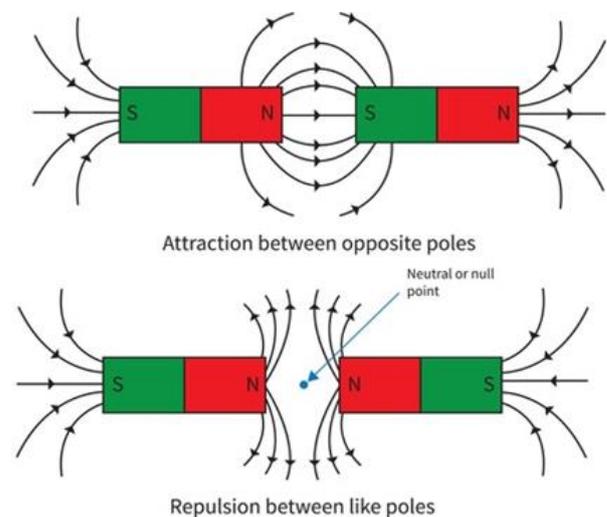


Fig. 1 Magnetic force

The mode of operation of the BLDC motor is based on the attraction or repulsion between the magnetic poles. Using a three-phase motor as shown in figure 2 the process begins when current propagates through one of the three stator windings and generates a magnetic pole that attracts the closest permanent magnet to the opposite pole.

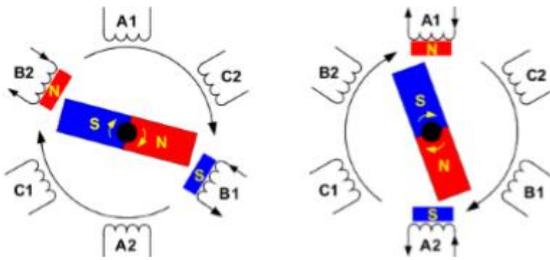


Fig.2 Rotating the BLDC motor

The rotor will move if the current switches to an adjacent winding. Sequentially, loading each winding will cause the rotor to follow the rotating field. The torque depends on the amplitude of the current, the number of active windings on the stator, the power and size of the permanent magnets and the air gap between the rotor and the windings.

2. THE PROPOSED SYSTEM

The proposed system is by determining the motor parameters and its control in load is by using two identical BLDC motors which are connected shaft to shaft present in figure 3. We chose this solution because one is the controlled motor and the second fulfills the function of generator. BLDC motors can perform both the motor function and the regenerative function when they are rotated by an external force.

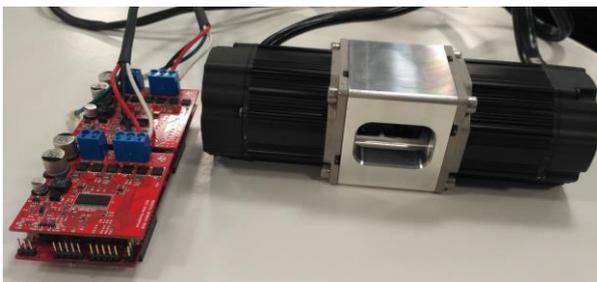


Fig.3 BLDC motors and controller

In order to be able to control these motors we need a control plate with the help of which we can send values to the motor, to control its poles and thus its acceleration and from the second motor we can read the input parameters all inside of a single application.

I chose as the centralized control board that makes both the control for the engine but can read the parameters on the generator to compile everything in one application, is from Texas Instruments, LAUNCHXL-F28069.

This board [2] is equipped with a microcontroller with a processor of 90 MHz, has 16 channels enhanced pulse with modulator, 16 channels 12-bit analog-to-digital converter.

LAUNCHXL-F28069M is a low cost evaluation and development tool for the F2806x series as well as the InstaSPIN-FOC and InstaSPIN-MOTION enabled F2806x series in the TI MCU LaunchPad ecosystem which is compatible with various plug-on BoosterPacks (suggested under the Recommended BoosterPacks in the Features section below). This extended version of the LaunchPad supports the connection of two BoosterPacks. The LaunchPad provides a standardized and easy to use platform to use while developing your next application.

Because we need both the control part where the data must be transmitted and the data from the generator to be read, we need 2 modules that can be inserted in the controller board that can collaborate between them and we can get the desired result. It is also produced by Texas Instruments and is called BOOSTXL-DRV8323RS. It can be used for an input voltage between 6 and 54 volts DC, a maximum current of 15A and can perform the 3 phases from DC to AC or can directly evaluate 3 phases from AC, it can also be called power management. The assembly between the control board and the driver are present in figure 4.

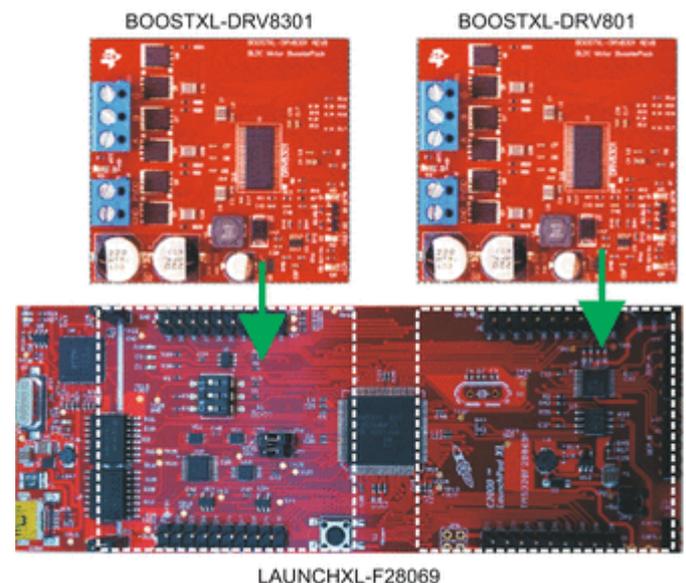


Fig.4 Lanchpad and 2 boostxl drivers

The DRV832x family of devices is an integrated gate driver for three-phase applications. The devices provide three half-bridge gate drivers, each capable of driving high-side and low-side N-channel power MOSFETs. The DRV8323 generates the correct gate drive voltage using an integrated charge pump for high-side MOSFETs and a linear regulator for the low-side MOSFETs. The Smart Gate Drive architecture supports peak gate drive currents up to 1-A source and 2-A. The DRV832x can operate from a single power supply and supports a wide input supply range of 6 to 60V for the gate driver and 4 to 60V for the optional buck regulator.

The 6x, 3x, 1x and independent input PWM modes allow for simple interfacing to controller circuits. The configuration settings for the gate driver and device are highly configurable through the Spi or hardware (H/W) interface. The DRV8323 integrate three low-side current sense amplifiers that allow bidirectional current sensing on all three phases of the drive stage.

A low-power sleep mode is provide to achieve low quiescent current draw by shutting down most the internal circuitry. Internal protection functions are provided for undervoltage lockout, charge pump fault, MOSFET overcurrent, MOSFET short circuit, gate driver fault, and overtemperature. Fault conditons are indicated on the nFAULT pin with detalis through the device registers for SPI device variants present in fig. 5

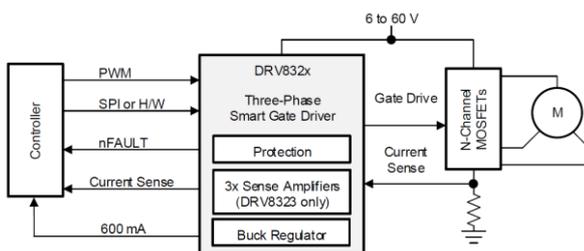


Fig.5 Simplified schematic

For the use of these modules and the realization of the controller I chose the MathLab application with the extension from Simulink.

Simulink is a MATLAB-based graphical programming environment for modeling, simulating and analyzing multidomain

dynamical systems. Its primary interface is a graphical block diagramming tool and a customizable set of block libraries. It offers tight integration with the rest of the MATLAB environment and can either drive MATLAB or be scripted from it. Simulink is widely used in automatic control and digital signal processing for multidomain simulation and model-based design.

MathWorks and other third-party hardware and software products can be used with Simulink. For example, Stateflow extends Simulink with a design environment for developing state machines and flow charts.

MathWorks claims that, coupled with another of their products, Simulink can automatically generate C source code for real-time implementation of systems. As the efficiency and flexibility of the code improves, this is becoming more widely adopted for production systems, in addition to being a tool for embedded system design work because of its flexibility and capacity for quick iteration. Embedded Coder creates code efficient enough for use in embedded systems.

Simulink Real-Time (formerly known as xPC Target), together with x86-based real-time systems, is an environment for simulating and testing Simulink and Stateflow models in real-time on the physical system. Another MathWorks product also supports specific embedded targets. When used with other generic products, Simulink and Stateflow can automatically generate synthesizable VHDL and Verilog.

Simulink Verification and Validation enables systematic verification and validation of models through modeling style checking, requirements traceability and model coverage analysis. Simulink Design Verifier uses formal methods to identify design errors like integer overflow, division by zero and dead logic, and generates test case scenarios for model checking within the Simulink environment.

We created through block diagrams in Simulink the application on which the whole operation will run, where the graphs will be based, based on which the operating

algorithms will be modified. Figure 6 shows the total block diagram where they are virtually all connected to each other in order to function and what we want to result as operations.

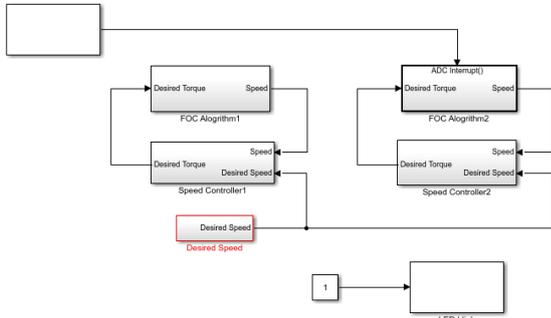


Fig.6 Block diagram

In Fig. 6 each block has subdivisions, which contain parts of running programs to achieve the desired results. The FOC algorithm for speed control 1 is also shown in figure 7. It is shown from 3 PWMs that are generated and a unit that determines the speed.

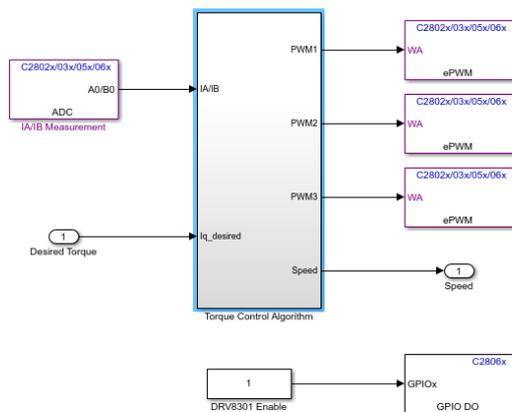


Fig.7 FOC Algorithm

An important characteristic of this approach is that as the frequency of motor rotation increases, so does the challenge of maintaining the desired current. This is because the current loop is affected by the rotation frequency. Lag in the current loop, insignificant at low rotation speeds, generates increasing amounts of unwanted torque at higher rotation speeds, resulting in a reduction of available torque.

The control scheme for FOC, figure 7, differs in that the current loop occurs de-referenced from the motor's rotation. That is, independent of the motor's rotation. In the FOC approach, there are two current loops, one for the quadrature torque and another for the unwanted torque. The quadrature torque loop is driven with the user's desired torque from the servo controller. The unwanted loop is driven with an input command of zero, so as to minimize the unwanted direct torque component.

3. CONCLUSIONS

In conclusion, the use of BLDC motors without Hall sensors makes it easier to use the motors, but also a more precise control. Removing Hall sensors from engine components can make any BLDC engine controllable at adjustable speeds, and with the use of these Texas instrument drivers torque can be adjusted even at low speeds, which is a global impediment.

4. REFERENCES

- [1].Magnetic Field and Lines of Force, <https://www.askiitians.com/iit-jee-magnetism/magnetic-field/>
- [2].<https://www.ti.com/tool/LAUNCHXL-F28069M#tech-docs>
- [3].DRV832x 6 to 60-V Three-Phase Smart Gate Driver datasheet <https://www.ti.com/product/DRV8323>
- [4].<https://www.digikey.com/en/articles/controlling-sensorless-blcdc-motors-via-back-emf>
- [5].<https://www.mathworks.com/help/mcb/gsr/un-three-phase-AC-motors-open-loop-control-calibrate-adc-offset.html>
- [6].https://www.ti.com/lit/ds/symlink/drv8323.pdf?ts=1605094315393&ref_url=https%253A%252F%252Fwww.google.com%252F
- [7].<https://www.mathworks.com/matlabcentral/fileexchange/49109-dual-motor-control-with-ti-launchxl-f28069m-launchpad>