IMPROVED BRUSHLESS DC MOTOR CONTROL ALGORITHM FOR REDUCING SOURCE CURRENT HARMONICS. SIMULATION STUDY

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ABSTRACT

Recently, BLDC motors have become very popular in wide application areas. The BLDC motor does not have a mechanical commutation, and is, consequently, more reliable than the classic DC motor. In recent years, with the increasing number of nonlinear loads drawing nonsinusoidal current, power quality has become a serious problem; hence an optimal control scheme must ensure the desired motor behavior and an undistorted current waveform in the network. This paper presents a new simplified control scheme for the BLDC motor, eliminating the disadvantages of the classic control scheme, and in addition keeping the source currents waveforms near sinusoidal, according to the standards.

INTRODUCTION

Considering the wide range of different types of motors, the choice of a specific motor type for a particular application generally is determined by performance and cost. Of all these, the brushless DC (BLDC) motor is gaining widespread use in various consumer and industrial applications. The BLDC motor features high efficiency and good controllability due to their linear speed/torque characteristics, giving predictable speed regulation.

A BLDC motor is a rotating electric machine where the stator is a classic 3-phase wound stator, like that of an induction motor, and the rotor has surface-mounted permanent magnets. When the wound stator is energized by a 3-phase alternating current, it creates a rotating magnetic flux that causes the rotor to rotate synchronously with it.

In a BLDC motor, the position of the rotor (and hence its permanent magnetic field) is sensed with respect to the stator coils (phases), and the supply current is switched electronically (commutated) to the appropriate phases. BLDC motor control systems often incorporate either internal or external position sensors to sense the actual rotor position. Alternatively, the rotor position can be detected without sensors by measuring the back-EMF in each stator winding (Cyan Technology 2007).

The BLDC motor is driven by trapezoidal currents coupled with the given rotor position. They offer longer life and less maintenance than conventional brushed DC motors. Some other advantages over brushed DC motors and induction motors are: better speed versus torque characteristics, noiseless operation and higher speed ranges. In addition, the ratio of torque delivered to the size of the motor is higher, making them useful in applications where space and weight are critical factors.

In recent years, with the increasing number of nonlinear loads drawing nonsinusoidal currents, power quality distortion has become a serious problem in electrical power systems due to the increasing harmonics disturbance. These harmonics currents causes adverse effects in power systems such as overheating, perturbation of sensitive control and communication equipment, capacitor blowing, motor vibration, excessive neutral currents, resonances with the grid and low power factor (Maswood el al. 2002). Hence an optimal control scheme must ensure the desired motor behavior and an undistorted current waveform in the network.

This paper presents a new simplified control scheme for the BLDC motor, which eliminates the disadvantages of the classical control scheme, and in addition, also keeps the network current waveform sinusoidal. The new scheme is simulated using Matlab SimPowerSystems.

CLASSICAL BLDC CONTROL SCHEME

The classical BLDC control scheme is shown in figure 1. Typically it contains two power electronics bridges – first one is an uncontrolled rectifier with diodes and the second one is a three phase controlled PWM inverter. Usually, between the two bridges is a capacitor (King et al. 2008).

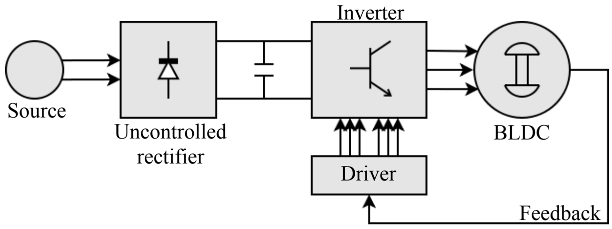

Figure 1: Classical BLDC Control Scheme

The torque and the speed of the BLDC motor depend on the magnetic field of the windings, consequently on the

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currents. Thus, for maintaining the torque and the speed constant at a desired value, one need to measure the current through the motor and generates the command for the PWM inverter. But, because of the uncontrolled rectifier, this type of control scheme draws from the network a nonsinusoidal current, thus distorting the current waveform, as seen in figure 2. The total harmonic distortion is 144.95%.

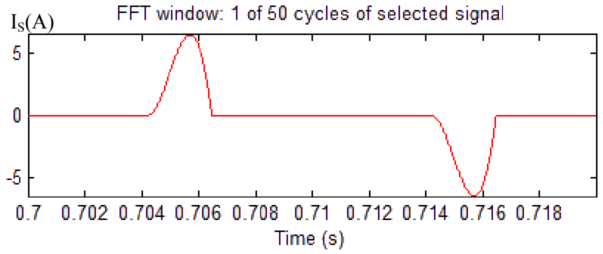

Figure 2: Source Current Waveform

PROPOSED BLDC CONTROL SCHEME

Figure 3 shows the proposed BLDC control scheme. The scheme contains two controlled power bridges, one PWM controlled inverter and one PWM controlled rectifier.

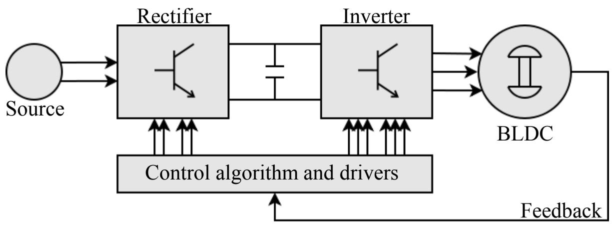

Figure 3: Proposed BLDC Control Scheme

The advantages of the proposed control scheme over the classical scheme are due to the introduction of the controlled rectifier over the uncontrolled rectifier, and are as follows:

- the current waveform of the source is kept near sinusoidal, due the controlled rectifier, in the range of the imposed (IEEE STD. 519-1992);
- the DC voltage on the capacitor is filtered and kept constant to the reference value provided by the regulated speed error;
- a quick response to load variations;
- robustness against uncertainties in component values and operations conditions;

The speed and the torque of the BLDC motor depend on the currents in the stator windings. To control the speed or the torque of the BLDC motor is sufficient to control the voltage of the inverter, possible by commanding the rectifier.

Figure 4 shows the Matlab Simulink model of the proposed BLDC control scheme, according to figure 3. The power supply is a single phase 220V/50Hz source and the BLDC motor has three phases, with the back EMF waveform sinusoidal and rotor type with salient poles. The mechanical input of the BLDC motor is the torque, set to 1 N·m. The reference of the system is the desired speed, ω^*, first set at 2000 r/min, then after 0.5s is set to 3000 r/min.

The inverter provides the commutation for the creation of the rotation field. For proper operation is necessary to keep the angle between the stator and rotor flux close to 90^0, thus the stator flux vector must be changed at a certain rotor position. The rotor position is sensed with Hall sensors, which generates three signals comprising six states, according to figure 5 (Musil 2006).

Using the correspondence between each of the Hall sensor states and stator flux vectors, a truth table can be assigned to control the each of the IGBT of the inverter, as shown in table 1.

Table 1: Truth Table for Inverter Command

Ha	Hb	Hc	Q1	Q2	Q3	Q4	Q5	Q6
0	0	1	0	0	0	1	1	0
0	1	0	0	1	1	0	0	0
0	1	1	0	1	0	0	1	0
1	0	0	1	0	0	0	0	1
1	0	1	1	0	0	1	0	0
1	1	0	0	0	1	0	0	1

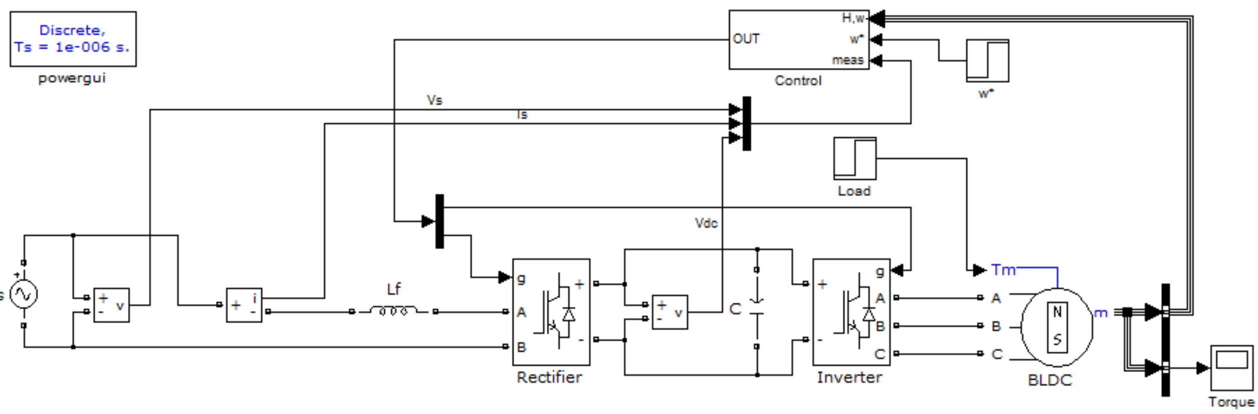

Figure 4: Matlab Simulink Model of the Proposed BLDC Control Scheme

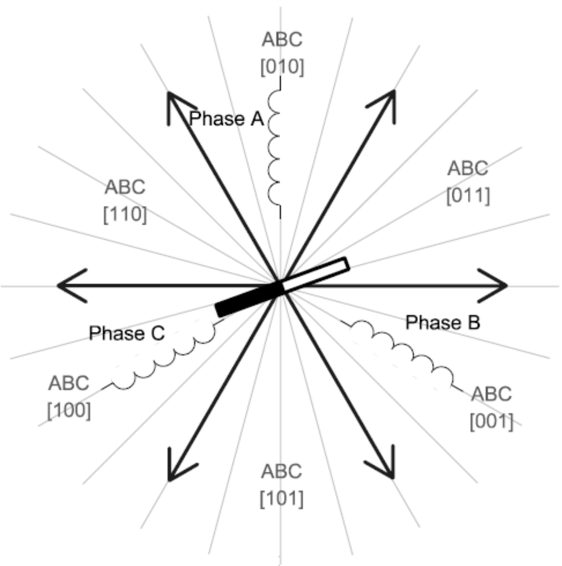

Figure 5: Stator Flux Vectors and Hall Sensors Output

While commutation ensures proper rotor rotation of the BLDC motor, the motor speed depends on the amplitude of the applied voltage. The amplitude of the applied voltage is adjusted by the controlled rectifier. The required speed and voltage are controlled by two PI controllers. The difference between the actual and required speed (and voltage) is the input of the PI controller. Using the difference, the PI controller control the duty cycle of PWM pulses fed to the controlled rectifier, corresponding to the voltage amplitude required to keep the desired speed. In addition, it needs to keep the source current harmonics free. The proposed control algorithm is presented in figure 6.

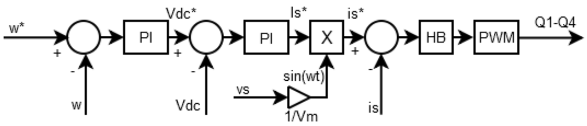

Figure 6: Proposed Algorithm for BLDC Control

SIMULATION RESULTS

The overall model of the proposed BLDC control is presented in figure 4 and the results were obtained using Matlab Simulink SimPowerSystems. The parameters of the chosen BLDC is seen in table 2.

Table 2: Motor parameters

Nominal voltage	220 V/50 Hz
Number of phases	3
Rotor type	Salient-pole
Back EMF waveform	Sinusoidal
Stator resistance	18.5 Ω
Inductances Ld and Lq	0.02682 H
Number of pole pairs	4

Figure 7 shows the reference and the obtained speed using the proposed BLDC control, under two reference speeds, 2000r/min and 3000r/min. It can be seen that the actual speed follows its reference speed very good, with a transient of 0.1s for the first reference, and with a transient of 0.05s for the second reference, thus proving the proposed BLDC control algorithm is very effective.

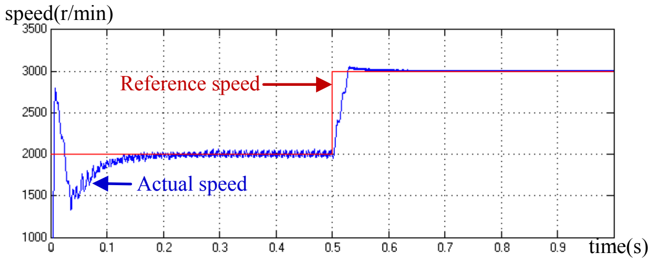

Figure 7: Reference and Actual Speed

Figure 8 shows the DC capacitor reference and actual voltage. Once the transient is over, the DC capacitor voltage is recovered to its reference value. It can be seen that its value follows up its reference, thus the objective of the proposed BLDC controller is achieved.

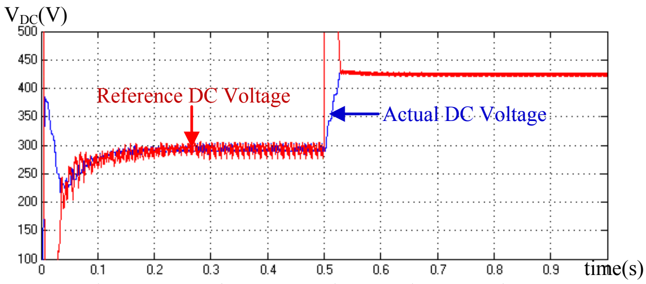

Figure 8: Reference and Actual DC Voltage

Figure 9 shows the simulation results of the source current obtained using the proposed BLDC control algorithm.

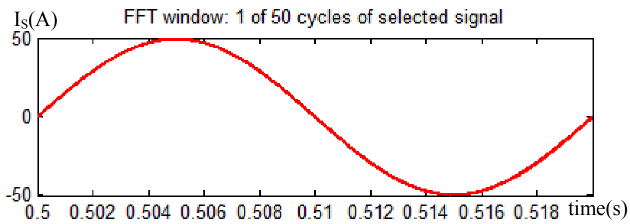

Figure 9: Source Current Waveform

Figure 10 shows the harmonic analysis of the source current. By using the proposed BLDC control algorithm, the source current has a total harmonic distortion of only 1.06%, thus meeting the limit of the harmonic standard of (IEEE STD. 519-1992).

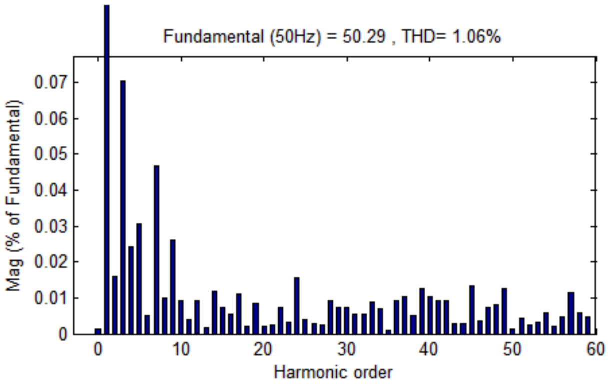

Figure 10: Harmonic Analysis of the Source Current

CONCLUSION

From the simulation results, it can be seen that the proposed BLDC control algorithm is a good alternative over the conventional BLDC control scheme, because not only that the motor operates as desired, but also the source current waveform is kept sinusoidal and with a harmonic distortion less than 5% according to the standards.

Still, this algorithm can be improved, by using it in threephased systems, so that the controlled rectifier can also provide the reactive power to the motor. In addition, it can act as a filter to the network, because it can balance unbalanced threephase systems.

REFERENCES

Cyan Technology, 2007, "3-Phase PMSM Control with Sensor Feedback – Version 1.0"

King K., Proctor R., Xu H. and Jani Y., 2008,"MCU Performance for Various Control Algorithms of BLDC Motors", Renesas Technology America, Inc.

IEEE STD. 519-1992, "IEEE Recommended Practices and Requirements for Harmonic Control in Electric Power Systems", *IEEE Industry Applications Society/Power Engineering Society*.

Maswood A. and Haque M.H., 2002, "Harmonics, Sources, Effects and Mitigation Techniques", *Second International Conference on Electrical and Computer Engineering.*

Musil J. 2006, "3-Phase BLDC Drive Using Variable DC Links Six-Step Inverter – Design Reference Manual", *Freescale Czech Systems Laboratories.*

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