SIMULATION AND IMPLEMENTATION OF CURRENT CONTROL OF BLDC MOTOR BASED ON A COMMON DC SIGNAL

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Abstract: The objective of this project is to build a simple current controlled modulation technique for brushless dc motors. In electric traction and most other applications, a wide range of speed and torque control of the electric motor is required. The dc machine fulfills these requirements, but the dc machine requires constant maintenance. But the brushless permanent magnet motors do not have brushes and so they require less maintenance only. Brushless dc motors are widely used in applications which require wide range of speed and torque control because of its low inertia, fast response, high reliability and maintenance free. This current controlled technique is based on the generation of quasi- square wave currents using only one controller for the three phases. The current control strategy uses a triangular carrier for the power transistors which is simpler and more accurate than any other options. The advantages of this technique are: a)The stator currents are completely characterized by their maximum amplitude , b) The three phases are controlled with the same dc component , and then the phase currents are kept at exactly the same magnitude I max, c) The dc link current measurement is not required .d) phase currents are kept balanced and phase over currents are eliminated

Key words : Inverter, PSIM , BLDC motor

I. INTRODUCTION:

IN ELECTRIC traction, like in other applications, a wide range in speed and torque control for the electric motor is desired. The dc machine fulfils these requirements, but this machine needs periodic maintenance. The ac machines, like induction motors, and brushless permanent magnet motors do not have brushes, and their rotors are robust because commutator and/or rings do not exist. That means very low maintenance. This also increases the power-to-weight ratio and the efficiency. For induction motors, flux control has been developed, which offers a high dynamic performance for electric traction applications. However, this control type is complex and sophisticated. The development of brushless permanent magnet machines has permitted an important simplification in the hardware for electric traction control. Today, two kinds of brushless permanent magnet machines for traction applications are the most popular: 1) permanent magnet synchronous motor (PMSM), which is fed with sinusoidal currents 2) brushless dc motor (BDCM), which is fed with quasisquare- wave currents. These two designs eliminate the rotor copper losses, giving very high peak efficiency compared with a traditional induction motor (around 95% in Nd–Fe–B machines in the range 20 to 100 kW). Besides, the power-to-weight ratio of PMSM and BDCM is higher than equivalent squirrel cage induction machines. The aforementioned characteristics and a high reliability control make this type of machine a powerful traction system for electric vehicle applications. The research introduced in this paper is guided to give a simple and efficient modulation control system, which allows to have good current waveforms. In order to fulfill these objectives, a BDCM was used because of the following advantages: 1) the quasisquare-wave armature currents are mainly characterized through their maximum amplitude values, which directly controls the machine torque; 2) the position sensor system for the shaft needs only to deliver six digital signals for commanding the transistors of the inverter; 3) the inverter performance is very much reliable, because there are natural dead times for each transistor. The first characteristic allows to design a circuit for controlling only a dc component, which represents the maximum amplitude value of the trapezoidal currents, Imax. The second and third characteristics allow to reduce the complex circuitry required by other machines, and allows the self-synchronization process for the operation of the machine. The most popular way to control BDCM for traction applications is through voltage-source current-controlled inverters. The inverter must supply a quasisquare current waveform whose magnitude, Imax, is proportional to the machine shaft torque. Then, by controlling the phase-currents, torque and speed can be adjusted.

There are two ways to control the phase-currents of a BDCM: 1) through the measurement of the phase currents, which are compared and forced to follow a quasisquare template; 2) through the measurement of the dc link current, which is used to get the magnitude of the phase-currents, Imax. In the first case, the control is complicated, because it is required to generate three, quasisquare current templates, shifted 120 for the three phases. Besides, these current templates are not easy to follow for the machine currents, because of phase-shifts and delays introduced [8]. In the second case, it is difficult to measure the dc current, because the connection between transistors and the dc capacitors in power inverters are made with flat plates to reduce leakage inductance. Then, it becomes difficult to connect a current sensor. To avoid those drawbacks, in this paper the equivalent dc current is obtained through the sensing of the armature currents. These currents are rectified, and dc component, which corresponds to amplitude I max

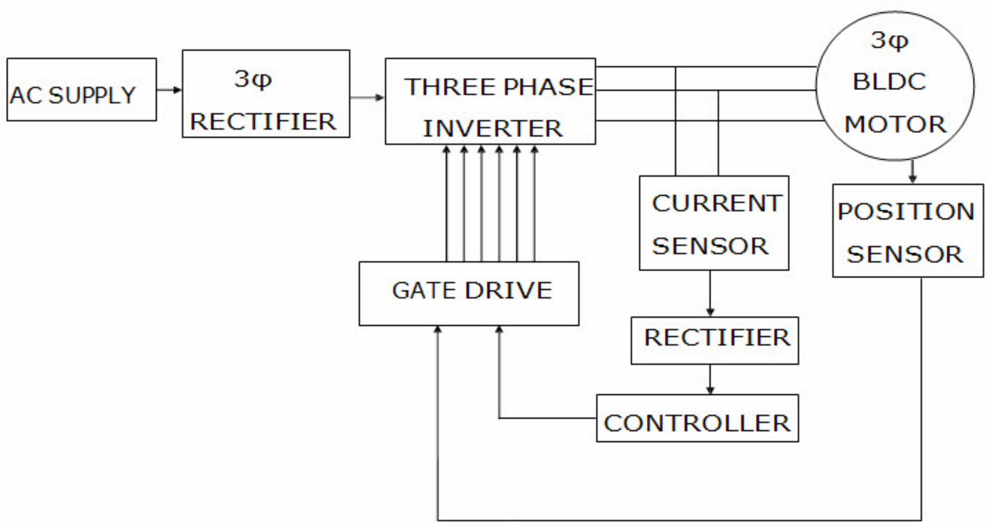


Fig 1. Basic Block Diagram

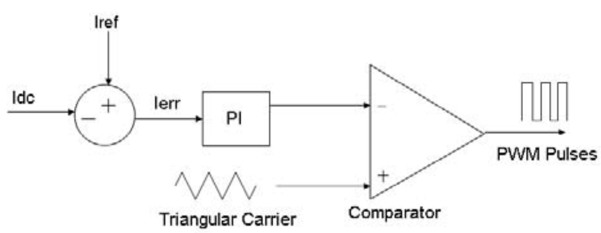


Fig 2 . Current controller block

of the original phase currents is obtained. This dc component is then used to drive the BDCM. The advantages of this strategy are: a) the stator currents are completely characterized by their maximum amplitude; b) the three phases are controlled with the same dc component, and then the phase currents are kept at exactly the same magnitude Imax; c) the dc link current measurement is not required. These characteristics allow using the triangular carrier as a current control strategy for the power transistors, which is simpler and more accurate than other modulation methods.

II. PROPOSED CONTROL SYSTEM

Fig 1. shows the simple block diagram of the proposed method .Fig. 2 current controller block in the fig 1. The operation of the system is as follows: as the motor is of the brushless dc type, the waveforms of the armature currents are quasisquare. These currents are sensed through current sensors, and converted to voltage signals. These signals are then rectified, and a dc component, with the value of the ceiling of the currents, Imax, is obtained as shown in Fig. 1. This dc signal is compared with a desired reference Iref, and from this comparison, and error signal Ierr is obtained. This error is then passed through a PI control to generate the PWM for all the six valves of the inverter, which are sequentially activated by the shaft position sensor. The torque is directly commanded by Iref. The larger the reference Iref, the higher the torque produced. The strategy becomes simple, because the control only needs to be in command of one dc current instead of three alternating waveforms. Another advantage of this strategy is that the modulation of the currents can be done using one of the simplest control strategies available: the "triangular carrier modulation strategy" which offers the following additional advantages: 1) the switching frequency becomes defined by the triangular carrier Fig. 2. Stator and rotor's MMF during step change from motor to brake operation. 2) The ability to follow the template with the proposed method becomes quite accurate when triangular carrier is used 3) the hardware implementation is very simple

The control strategy also allows regenerative braking, which is very important in many applications, like electric vehicles, where energy can be returned to the battery pack. To brake the motor (regenerative braking) the stator magnetic field is reversed. This action is accomplished through the inversion of the signals given by the position sensor. The position sensor discriminates six positions each 360 electric degrees. During motor operation, the rotor moves clockwise. When the brake signal is applied, the stator field is reversed 180 electric degrees. This action produces an instantaneous change in the direction of the torque, making a fast reduction of the speed of the machine, which begins to return its energy to the dc link. The same strategy can be used for reversal of rotation of the machine

III. CIRCUIT DESIGN:

The drive system consists of a three-phase inverter, a BDC permanent magnet motor, and a dc power supply. The sensing system is divided in two parts: *Position Sensor System* and *Current Sensor System*. The first system is based on three hall effect cells placed inside the motor, and a magnetic disc in the rotor, with the same number of poles as the motor. The second sensing system is based on the current sensors.

The sensors are to be placed in any two of the three phases of the motor. The measurement of the currents in the three phases is not required because of the following: a) there is no neutral connection, and hence the third phase current can be obtained from the other two; b) despite the first reason is more than enough to justify the use of only two current sensors, there is another reason which could justify just one current sensor: the sensing of the current is only required to get the value of the magnitude (the phase-shift and sequence is given by the position sensor). Assuming only one current sensor, it could be possible to get information of the current during of the cycle (240).For the other 120, the PWM could be maintained with the same duty cycle until the next information of is obtained. In general conditions are safer and more accurate to have at list two current sensors. Clearly, the information of one current sensor could be used, providing that the PWM is kept with constant duty cycle during the two intervals of 60 were no information about is obtained.

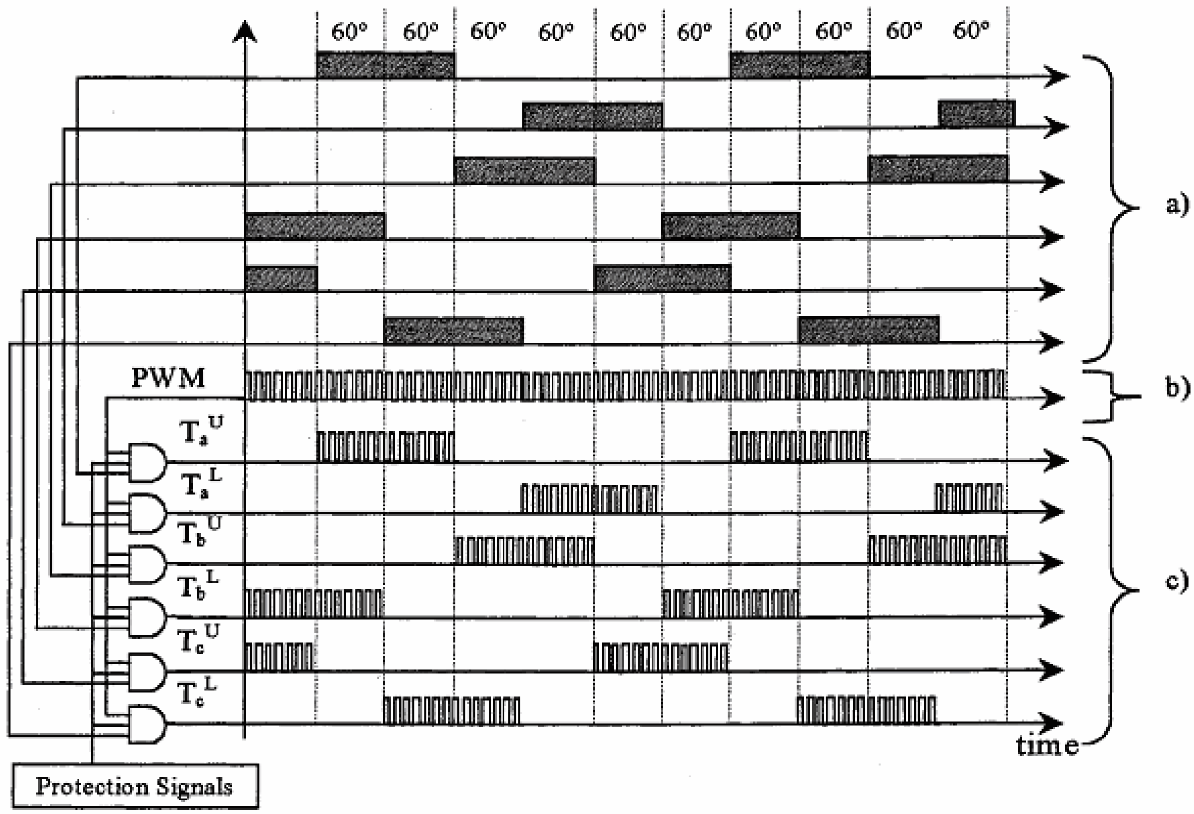


Fig. 3. Digital operation of the position sensor: (a) position sensor signals, (b) PWM signal, and (c) gating signals for the

However, the information with two sensors is complete and redundant as shown in the same Fig. 1. As it was already mentioned, the utilization of one current sensor at the dc link is not possible, because the power inverter was implemented using flat cooper plates between transistors and electrolytic capacitors. This is the common way to construct power inverters, because otherwise the leakage inductance between dc link and transistors becomes very large, producing dangerous over voltages that could destroy the power transistors.

The Control Circuit of the Fig. 1 has sub blocks of analog and digital electronic circuits (comparators, PI controller, and adder devices). As it was already mentioned, the dc signal is obtained from signal rectification of the phase currents. This rectification system uses germanium diodes to reduce the nonlinearity problem introduced by the fixed voltage drop of the diodes used in the rectifier. However, this problem becomes noticeable only when the current is smaller than 3% of the nominal value of (120 A). Then, it does not become a serious problem in the operation of the proposed method. The current is compared with a desired reference, and from this comparison, and error signal Ierr is obtained. This error signal is then processed with a PI control. The output of the PI control is compared with a triangular waveform of fixed amplitude and frequency, which gives a common and unique pulse width modulation for the three phases of the motor. This unique PWM pattern, and the information given by the position sensor, generates the modulation signals for each transistor. The PWM controls the magnitude, and the position sensor discriminates when the PWM has to be applied to each of the six transistors, creating the correct sequence for the rotation of the machine. The Fig 3 shows the digital operation of the position sensor.

IV. CURRENT CONTROLLER DESIGN

The tuning of the current controller starts with the determination of the amplitude and frequency of the triangular carrier, and the gains of the PI control. To get a PWM signal operating at the carrier frequency, the control should be adjusted to keep the reference current moving around the reference. The Fig. 5 shows the way the stator currents are controlled, through the feedback signal. The PWM based on the triangular carrier method has to set a commutation frequency lower than (or equal to) the carrier. In other words, the slope of the PI control must not exceed the slope of the carrier. To make the simulations, the software power electronics simulator (PSIM) developed by Powersim Technologies Inc., was used.

V. SIMULATION RESULTS

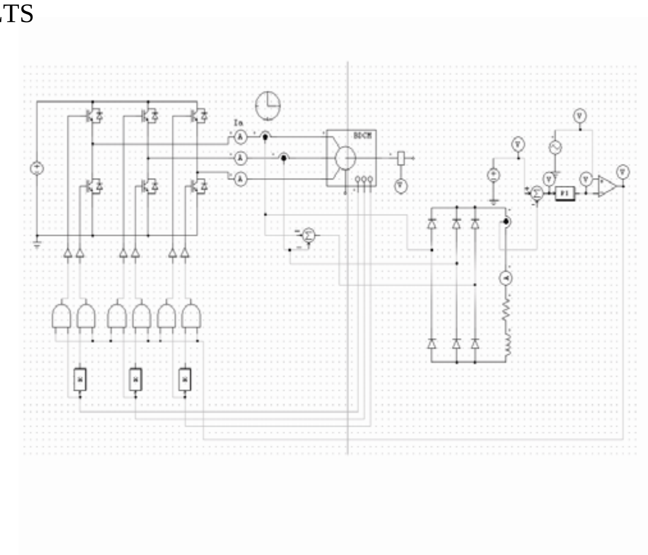


Fig 4. Simulated Circuit diagram for the proposed method using PSIM

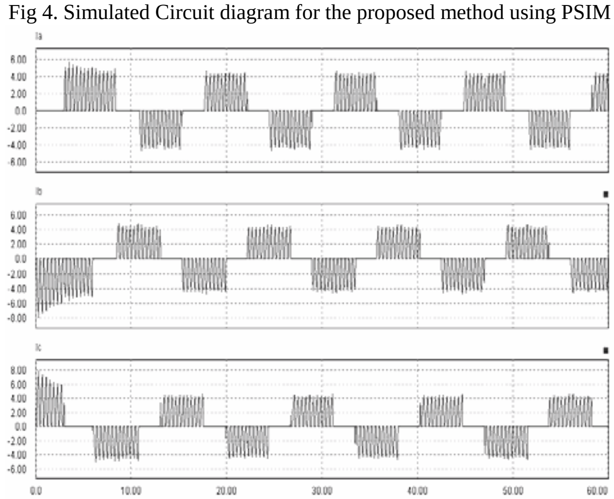


Fig 5. Phase current Waveforms

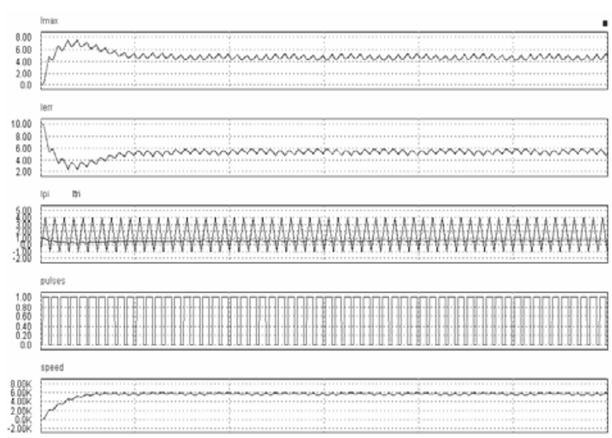


Fig 6. Generation of controlled pulses and speed waveform

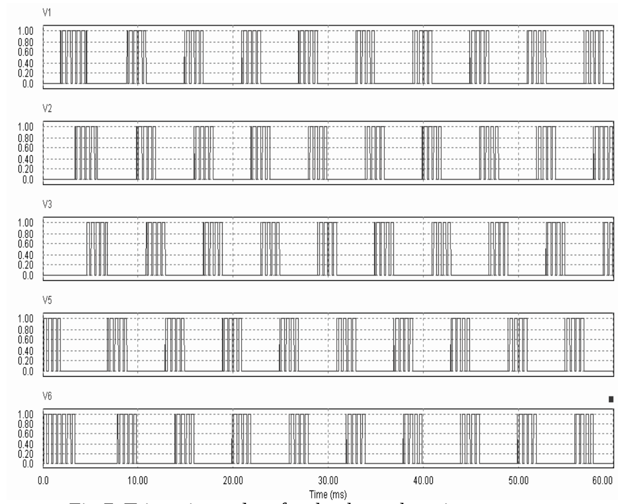


Fig 7. Triggering pulses for the three phase inverter

The simulation of the proposed control technique is done using PSIM. Fig 4. shows the closed loop simulated circuit diagram. The BLDC motor is given supply through a three phase inverter. The motor currents are sensed, rectified and then dc component is compared with a reference value, and the error in current is then processed using a PI controller. The controlled error is then compared with a triangular wave to generate the controlled PWM pulses. These pulses are then ANDed with the position sensor signals and then given to the three phase inverter switches. Fig 5 and 6 represents various simulated waveforms. Fig 7 shows the six triggering pulses for the three phase inverter.

VI HARDWARE IMPLEMENTATION:

The proposed method of control is implemented with a BLDC motor of supply voltage of 24 V. The three phase inverter is constructed using MOSFET switches. The gating signal required for these switches is given through the rotor position sensor. The output waveforms are given below. The fig8 shows the Hall Effect sensor output. The fig 9 shows the output voltage waveform of the BLDC motor. Fig 10. Shows the comparison of the PI controller output and fig 11. Shows the generation of PWM pulses, which will be then combined with the Hall Effect sensor output to generate the triggering pulses for the three phase inverter.

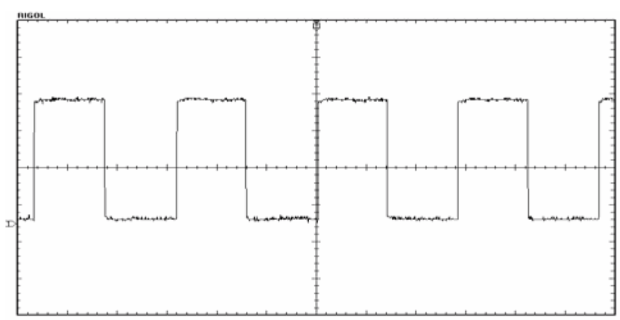


Fig 8.Hall Effect sensor corresponding to

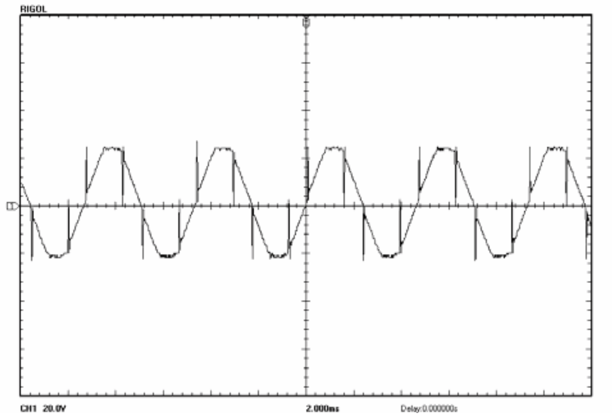


Fig 9 . Output voltage of BLDC motor

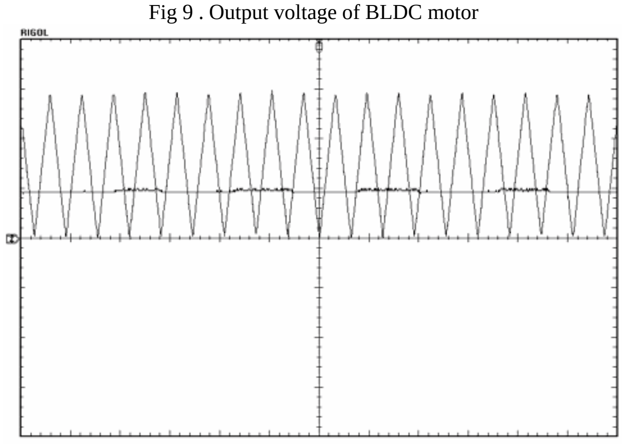
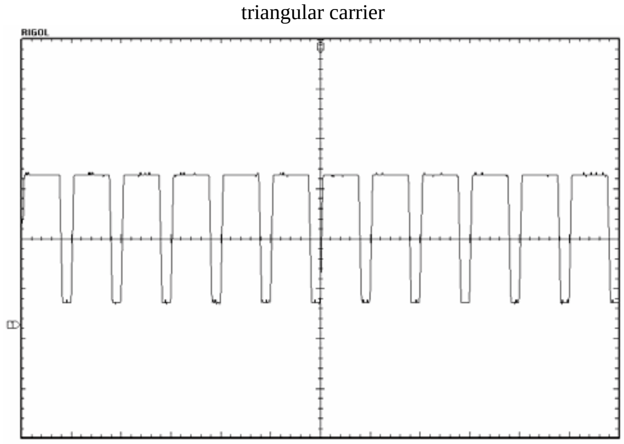


Fig 10. Comparison of PI output and triangular carrier



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VI. CONCLUSION

A different control strategy for brushless dc machines has been presented. It is based on the generation of quasisquare currents using only one current controller for the three phases. The advantages of this strategy are a) very simple control scheme; b) phase currents are kept balanced; c) current is controlled through a dc component, and hence phase over currents are eliminated. These characteristics allow to use the triangular carrier as a current control strategy for the power transistors, which is simpler and more accurate than other options. This control strategy has been compared with conventional techniques to show the excellent characteristic of this modulation technique.

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