Speed Plus Theta Control Strategy for BLDC motor modelling for Electric Power Steering System

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Abstract: **- Now-a-days, BLDC motors are gaining popularity very rapidly. BLDC motors are highly used in industries. These motors do not use brushes for commutation, instead of that, they are electronically commutated. As compared to Brushed DC motor, Induction motor, BLDC motors have many advantages. The aim of this paper is to show how the harmonics are reduced by employing feedback in the closed loop combined simulation model as compared to an open loop simulation model. For this purpose, the performance of BLDC system is simulated. Combined Strategy employed is speed plus theta .Based on the mathematical model of BLDC motor, the models are analysed using MATLAB/SIMULINK, which can provide accurate predictions of FFT analysis of the system behaviour.**

Keywords: **BLDC, electronically commuted, MATLAB / SIMULINK, FFT analysis**

I. INTRODUCTION

BLDC motors are a type of synchronous motor. The magnetic field generated by the stator and the magnetic field generated by the rotor rotate at the same frequency in case of BLDC motor. BLDC motors do not experience the slip which is normally seen in induction motors. BLDC motors are single-phase, 2-phase and 3-phase configurations. Corresponding to its type, the stator has the same number of windings. Out of these, 3-phase motors are the most popular and widely used.

A BLDC motor is one that retains the characteristics of a dc motor eliminating the commutator and the brushes. In many cases, Brushless DC (BLDC) motors can replace conventional DC motors. There are no brushes on the rotor. They are driven by dc voltage but current commutation is done by solid state switches that mean, the commutation is done electronically. The BLDC motors are available in many different power ratings ranging from very small motors as used in hard disks to large motors in (EV s) i.e. electric vehicles [2]. BLDC motors are highly used in industries such as Aerospace, Appliances, Automotive, Consumer, Medical, Industrial, Automation Equipment and Instrumentation since it has high reliability, high power density, low maintenance requirement, lower cost and lower weight. BLDC motors have many advantages over brushed DC motors. Some of these are:

- Higher speed ranges
- Higher efficiency as compared to other motors
- Noiseless operation
- Better speed versus torque characteristics
- Long operating life
- Higher dynamic response

We are employing the SPWM technique in this simulation.

In this method the speed is controlled in a closed loop by measuring the actual speed of the motor. The error in the set speed and actual speed is calculated. A proportional plus integral (PI) controller is used to amplify the speed error and adjust the PWM duty cycle [3]. By analysing the motor speed,torque and other parameters and then imposing different control strategies on the system,a best and reliable strategy can be adopted. Here, in this paper,a simulation models of BLDC motor are built,based on mathematical analysis, the reliability and validity of this method has been proved by simulation results[3].

II. OUTLINE OF THE PROJECT

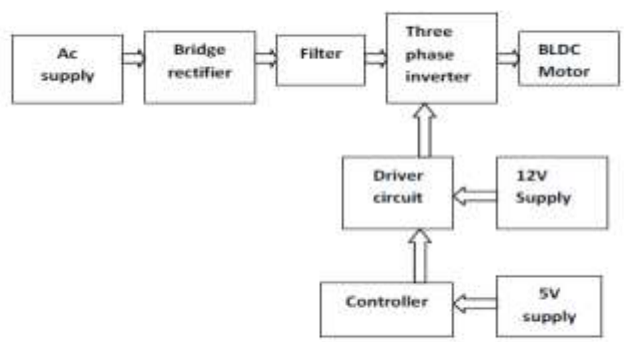

Fig. 1. Block diagram of the project

III. CIRCUIT DIAGARAM

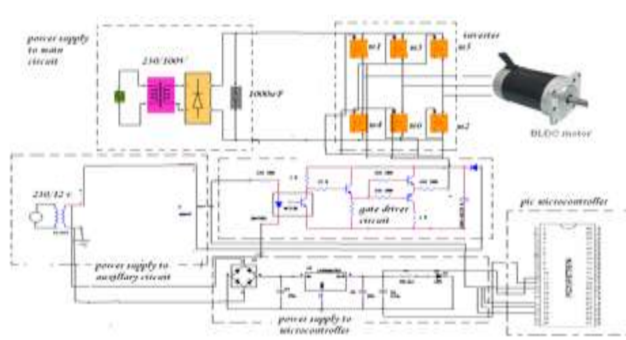

Fig. 2. Circuit Diagram

IV. HARDWARE DETAILS

An experimental set-up was constructed for implementation and further validation of the simulation results for the SPWM technique. The following section gives a brief description of overall requirements and designs for the experimental set up. The experimental set up is as shown.

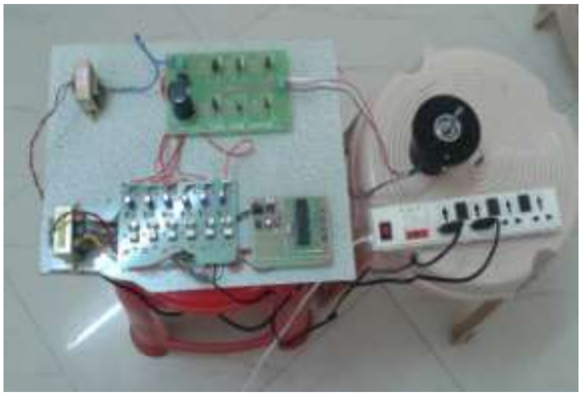

Fig. 3. Experimental set up

In this circuit, we are utilizing the energy source of 230 V,50 Hz and stepping down, rectifying,filtering and regulating the voltage. In this circuit, the transformer of 230V/0-12V is used to perform the step down operation,where, a230V AC appears as 12 V AC across the secondary winding.Current rating of transformer used is 1 A. Apart from stepping down AC voltages; it gives isolation between the power source and power supply circuitries.

1. Driver circuit components.

The driver circuit is used to amplify the pulses. It consists of three main components.

- Optocoupler: It is also known as Optoisolator.It is used to isolate the voltages between the main circuit and the microcontroller circuit. The pulses are provided to MOSFET switch using microcontroller circuit. This circuit produces a waveform of 5 V DC. This pulse is supplied to MOSFET switch which is supplied by 12 V AC, as the source and destination voltages are different,they have to be isolated, which is done by using Optocoupler. We are using MCT2E 1K,100Ω Optocoupler here.
- Buffer IC CD 4050: The CD 4050 Bc hex buffers are monolithic complementary MOS(CMOS) integrated circuits constructed with N and P channel enhancement mode transistors. It is used for impedance matching.
- Transistors.CK100 and 2N2222 (known as Quad 2), these 2 main type of transistors are present in Driver circuit,which is connected in Darlington pair. Transistor is used to amplify the signal pulses coming from microcontroller circuit.

2. Microcontroller:

To perform various operations and conversions required to switch control and monitor the devices, a processor is needed. In this project circuit, a microcontroller is used because requires to generate a clock. A PIC 16F877A microcontroller is used here. This PIC16F877A CMOS FLASH based 8 bit microcontroller is upward compatible with PIC16C5x, PIC12Cxxx and PIC16C7x devices. It is 40 pin, features 200 ns instructions executions, 256 bytes of EEPROM data memory, self programming, an ICD,2 comparators,8 channels of 10 bit Analog to Digital (A/D) convertor.

3. Diode Rectifier IN 4007:

The diode Rectifier is used in main circuit. Usually, all power electronics circuits are provided with a diode rectifier. This helps to convert the 12 V AC voltage to DC voltage. They are connected at the output of input filters.

4. MOSFET switch IRFP250N:

In this Project, the MOSFET switches are connected to main circuit. Here, there are 2 types of switches, namely, main switch Sm and auxiliary switch Sa. Here, 6 switches are used, among those, 3 are Sm and 3 are Sa. The pulses to these switches are given using microcontroller PIC16F877A through a driver circuit. In PIC16F877A, the pulse of 5V is generated which is sent to driver circuit. This signal is amplified to about 12 V DC, that is sent to MOSFET switches, Sm andSa respectively.

V. BLDC MOTOR SPEED CONTROL

A BLDC motor is driven by voltage strokes coupled by rotor position and the rotor position is measured using Hall sensors. We can control the speed of the motor,by varying the speed of the motor.When using PWM outputs for controlling the six switches of the three-phase bridge, variation of the motor voltage can be obtained by varying the duty cycle of the PWM signal. The speed and torque of the motor depend on the strength of the magnetic field which is generated by the energized windings of the motor. The magnetic field in the windings depend on the current through them. Hence adjusting the rotor voltage and current will change motor speed[4].

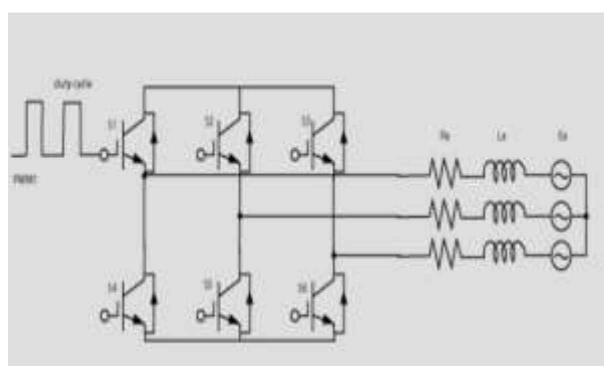

Fig. 4. PWM Speed control

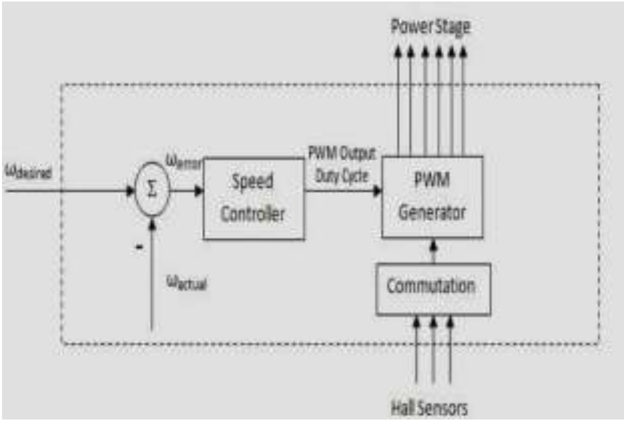

Fig. 5. Schematic of speed controller

VI. SIMULINK MODEL OF BLDC MOTOR

Here, we are considering two models: open loop model and the closed loop model with speed feedback of BLDC motor.In both the models ,we are using six MOSFET s as a three phase inverter,to which the BLDC motor is connected.In case of closed loop structure,speed feedback is given to the pulse generator along with a reference speed of 1500 rpm. Here the pulses are generated. The error signal is given to the MOSFET switches and then these signals are passed over to the BLDC motor.

Open loop model is as shown;

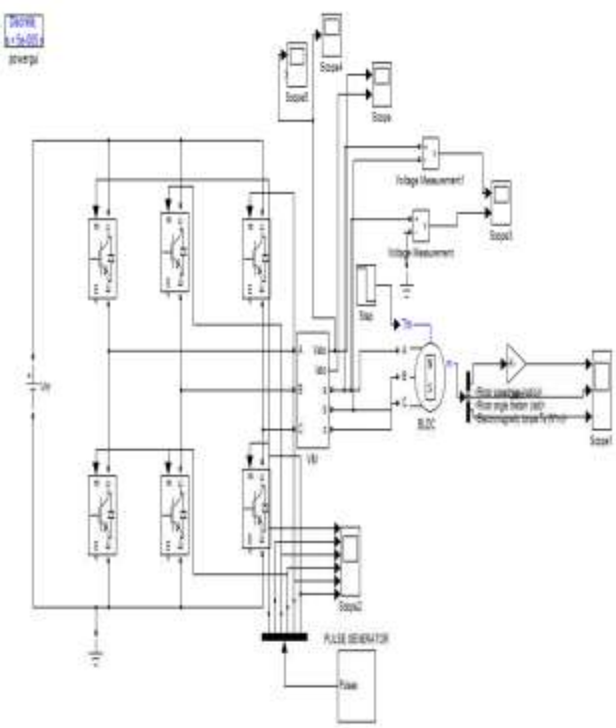

Fig. 6. Open loop model with no feedback.

VII. SIMULATION RESULTS

From the designed circuit parameters, the MATLAB simulation is done and results are as shown here. Speed is set at 1500 rpm. The speed regulations are obtained at set speed and the simulation results are as shown.

1. Simulation results for open loop

For speed, angle theta and electromagnetic torque, the waveforms are;

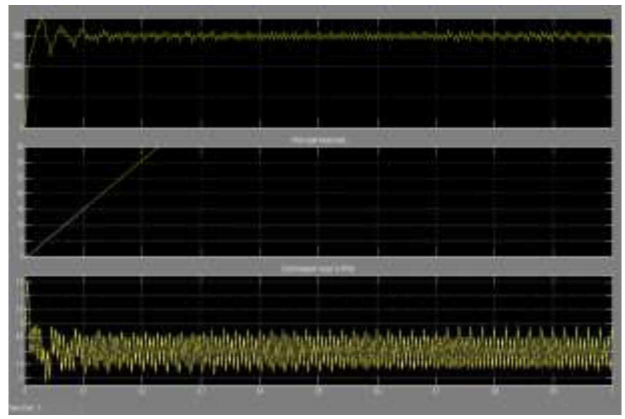

Fig. 7. Output waveforms for speed, theta and Electromagnetic torque respectively.

Voltage and current waveforms:

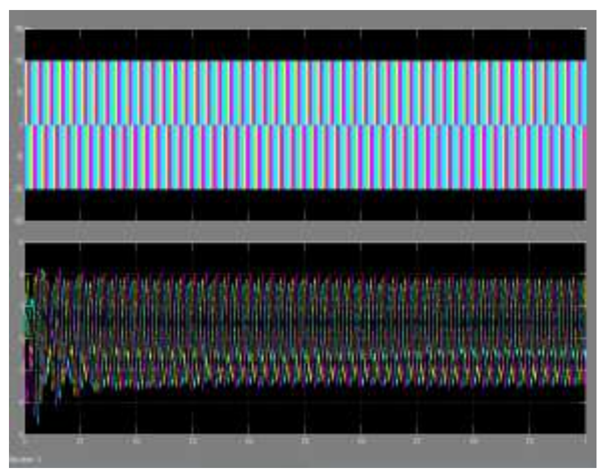

Fig. 8. Output waveforms for voltage & current.

VIII. MODELING WITH SPEED & THETA FEEDBACK

The work can also be compiled as;

Now the same BLDC motor is used for modelling. Here speed feedback is combined with theta feedback, both are compared, and then the resultant pulses are given to the gate terminal of the MOSFET switches and the results are analysed.

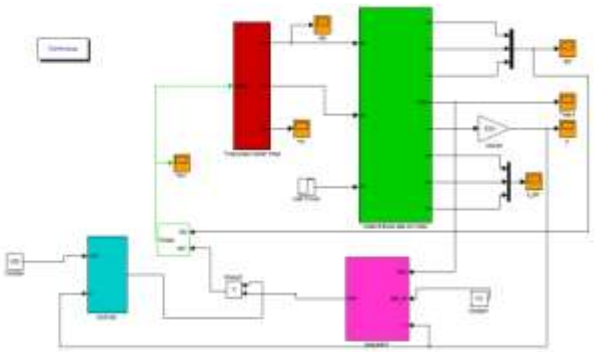

Fig. 9. Simulink model of BLDC Motor

The simulation results are

For three phase current, the waveform is as shown:

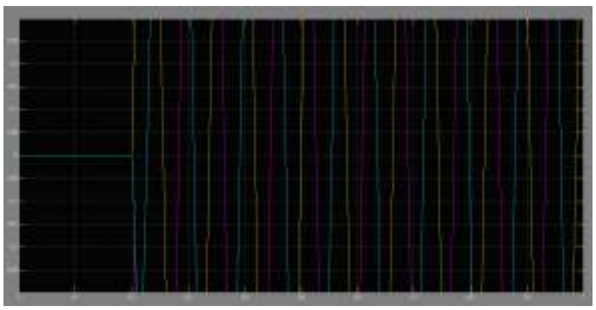

Fig. 10. Output Waveform for three phase currents

For theta

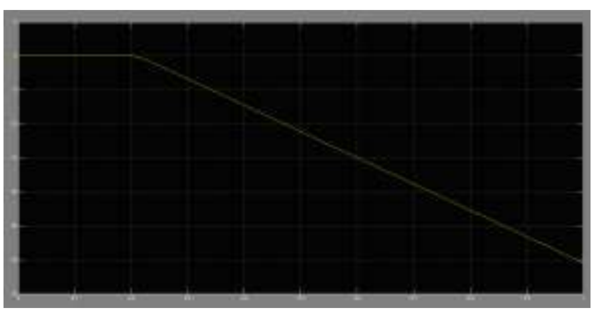

Fig. 11.Output waveform for theta

For speed

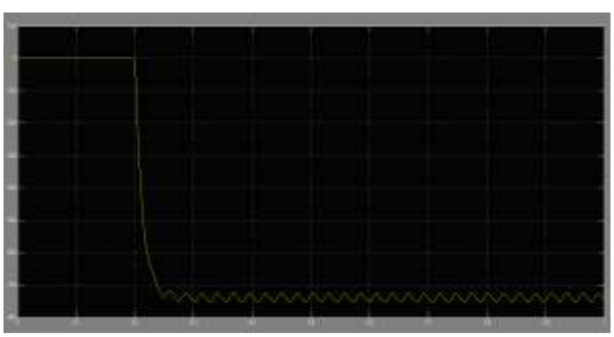

Fig.12.Output waveform for speed

For three phase EMF

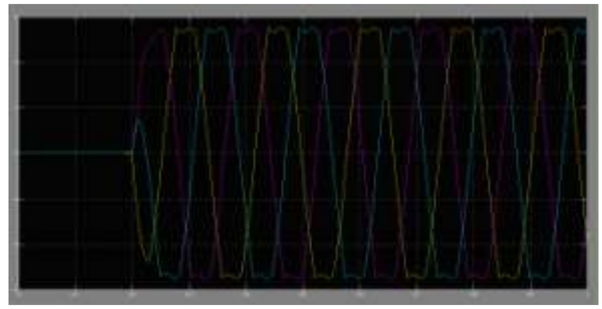

Fig. 12.Output waveform for EMF a, b and c

For Voltage

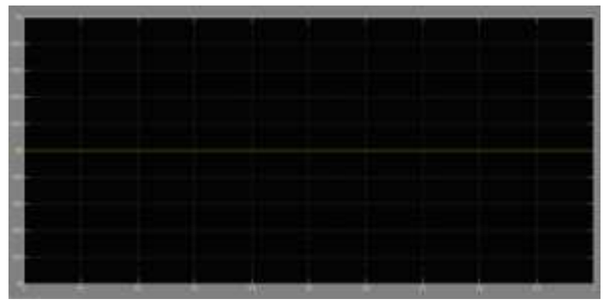

Fig. 13. Output Waveform for voltage

IX. COMPARATIVE ANALYSIS OF THE RESULTS WITH AND WITHOUT SPEED FEEDBACK

1. THD Comparison

Parameters	Without Feedback	With Speed Feedback
Speed	170%	159.01%
Theta	80.24%	80.33%
Electromagnetic Torque	456.61%	516.48%
Voltage	92.98%	93.21%
Current	34.46%	29.42%

Table 1.THD Comparison

2. Fundamental Frequency comparison

Parameters	Without Feedback	With Speed Feedback
Speed	37.29	32.43
Theta	1.001	0.997
Electromagnetic Torque	0.1127	0.1029
Voltage	68.5	68.61
Current	2.862	2.822

Table 2 Fundamental Frequency comparison

X. CONCLUSION

It can be concluded that by using closed loop speed control strategy, the harmonic can be reduced to a certain extend as compared to without any feedback in open loop. So we have introduced a combined spped plus theta feedback strategy. The modelling procedure proposed here in this paper helps in simulation of various types of BLDC motors. The fruitful simulation results show that such a modelling is very useful in studying the drive system before taking of the dedicated controller design.

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