PERFORMANCE IMPROVEMENT OF BLDC MOTOR USING FUZZY LOGIC CONTROLLER

Sharmila Kumari.M, Sumathi.V, Vivekanandan S, Shobana S

Abstract- This project deals with a fuzzy controller based sensorless control of brushless DC motor. It works on "Indirect position sensing" method. Using voltage and current waveform position detection can be derived. Using voltage difference measured at the motor terminals position information can be found. Fuzzy controller is used here for precise control and to get better performance. This Controller is effectively implemented using MATLAB. The voltage and current waveform are using MATLAB. Since fuzzy controller is used no need for separate processors like i.e. FPGA or DSP. So this drive system has more advantage than the conventional sensor less control. The proposed drive system is cost effective, more flexible and robust.

Keywords- BLDC, Electro Magnetic Force, Pulse Width Modulation, Low Pass Filter, Fuzzy Logic Controller

I.INTRODUCTION

Brushless dc motor is most widely used in automotive applications specially on vehicle fuel pumps, due to its high efficiency, small size less maintenance when compared to brush dc motor [1],[2].Using hall sensor mounted on a rotor, accurate and ripple-free instantaneous torque for position information can be obtained. This results in high cost, poor reliability in vehicle applications [3],[4].To avoid the above mentioned problems, many position sensorless algorithms have been considered as potential solution[5]. The performance of the sensorless drive decreases with the phase shifter in the transient state. Also it is sensitive to the phase delay of the low pass filter (LPF) especially at high speed. Several phase shifters are used in the conventional method to compensate for phase error induced by the LPF of back-EMF are proposed [6]-[9].The position information is found by integrating the back-EMF. This method has an error accumulation problem at low speed [1],[10],[11]. The sensorless control techniques using the phase-locked loop (PLL) and the third-harmonic back-EMF are suggested [12], [13]. The motor commutation drifts away from the desired phase angle due to the conduction of the freewheel diode. Furthermore, the drift angle varies as the motor parameters, speed, and load conditions change.

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The improved sensorless controller by removing the effect of the freewheel diode conduction is suggested [14]. Access to the motor neutral point is required, which will complicate the motor structure and increase the cost. Some approaches use the zero crossing points of three-phase line-to-line voltages, so that they coincide to six commutation points [15]-[17].

Although the commutation signals can be obtained without any phase shifter, the phase delay due to the LPF could not be considered and the multiple output transitions of the comparator may occur from the high frequency ripple or noise in the back-EMFs. The zero-crossing point of the back-EMF for generating proper commutation control of the inverter is calculated by sampling the voltage of the floating phase without using current and position sensors [18], [19]. Sensorless techniques are based on back-EMF estimation. However, when a motor is at standstill or very low speed, it is well known that the back-EMF is too small to estimate a precise rotor position. Therefore, a specific start-up process in sensorless drive systems is required. The general solution to the problem is the open-loop start-up method named 'Align and go' [5], [20].

The direct back emf detection for sensorless BLDC motor is given in [21]. Analysis of BLDC motor is given in [22]. Modelling of BLDC motor is given in [23]. Feed forward speed control of Brushless DC motor with input shaping is given in [24]. A PSO-based optimization of PID controller for a Linear BLDC Motor is given in [25]. Speed Control of BLDC based on CMAC & PID controller is given in [26]. A sensorless drive system for BLDC using a Digital Phase-Locked Loop is given in[27].All the above classical methods can be implemented in well defined systems to achieve good performance of the system. To control a system an accurate mathematical model is required. The

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fuzzy logic control have characteristics that can achieve robust response to a system with uncertainty, parameter variations and load disturbance. Fuzzy Logic and Fuzzy set theory was presented by Zadeh [28]. Fuzzy a Logic Controllers have been broadly used for ill-defined, non-linear and complex systems [29], [30]. In the area of electrical drives, fuzzy logic controllers have been applied to switched reluctance motors [31], [32], induction motors [33] and PMBLDC motors [34] successfully. BLDC motors drives are used in a wide range of commercial and residential applications such as domestic appliances, heating, ventilating and air-conditioning equipment due to their highest possible efficiencies.

II.CONVENTIONAL SYSTEM

Sensorless control by using a hysteresis comparator method for an automotive fuel pumps application. It consists of the LPFs for suppressing the high switching frequency ripples, hysteresis comparators for generating three-phase commutation signals, and a gating signals generator for generating six PWM signals. After sensing the three-phase terminal voltages, each of the three-phase terminal voltages is fed into an LPF to suppress the high switching frequency ripple or noise. As only two phases of the BLDC motor are energized at any time, the back-EMF can be measured from its terminal voltage in the period of an open phase (60°). During the two-phases conduction period (120°), the only difference between the back-EMF and its terminal voltage is a stator impedance voltage drop, which may be considerably small compared with the dc voltage source. the zero crossing points of three-phase line-to-line voltages, so that they coincide to six commutation points. Although the commutation signals can be obtained without any phase shifter, the phase delay due to the LPF could not be considered and the multiple output transitions of the comparator may occur from the high frequency ripple or noise in the back-EMFs.

The zero-crossing point of the back-EMF for generating proper commutation control of the inverter is calculated by sampling the voltage of the floating phase without using current and position sensors. Most sensorless techniques are based on back-EMF estimation. However, when a motor is at standstill or very low speed, it is well known that the back-EMF is too small to estimate a precise rotor position. Therefore, a specific start-up process in sensorless drive systems is required. The general solution to the problem is the open-loop start-up method

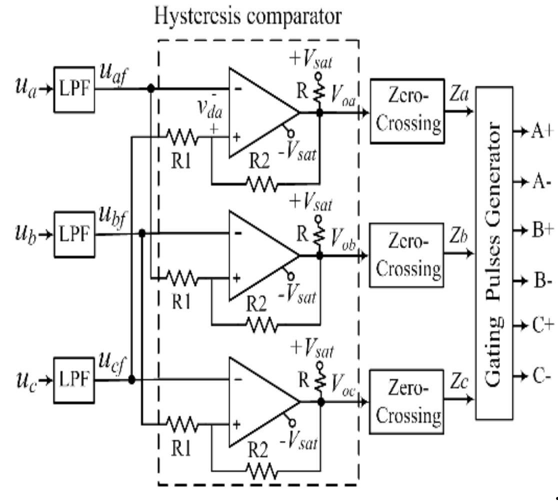

Fig.1.Block of BLDC motor using hysteresis comparator

The procedure is to excite two phases of the three-phase windings for a preset time. The permanent magnet rotor will then rotate to align to a specific position. With a known initial rotor position and a given commutation logic, an open-loop control scheme is then applied to accelerate the motor from a standstill. Although this technique can be applied to certain automotive applications, it causes a large instantaneous peak current and generates a temporary vibration. In addition, the rotor position of the BLDC motor can be identified and driven smoothly from standstill without any position sensors by utilizing the inductance variation technique. sensorless control based on a hysteresis comparator of terminal voltage and a potential start-up method with a high starting torque. the rotor position for achieving the maximum starting torque, the BLDC motor accelerates from a standstill up to a nominal speed within 1.2sec. The magnitude of the stator current for aligning the rotor position can be easily controlled by modulating the pulse width of specific switching devices.

III.PROPOSED SYSTEM

BLDC motor has characteristics like a DC motor, Where as it is controlled the same as AC motors. One electrical cycle of the motor is divided to six 600 modes that at each mode, only two phases are conducting the current. Sensorless techniques based on back-EMF and terminal voltages are the most popular due to their simplicity, ease of implementation and lower cost. Back-EMF estimation methods typically rely on the zero crossing detection of the EMF waveform.

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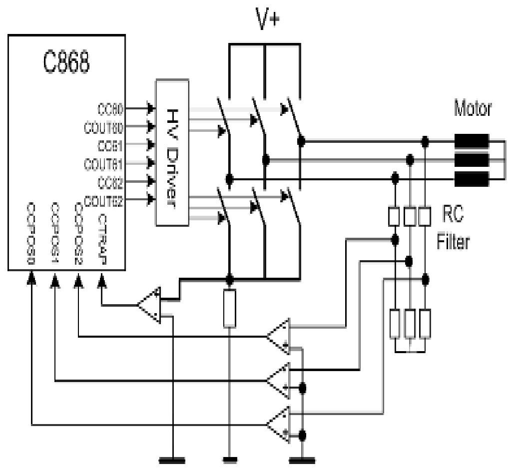

Fig.2. Circuit of BLDC motor using fuzzy

The technique of estimating back-EMF by sensing the terminal voltages. The neutral point will not be stable during PWM switching. Low pass filters have been used to eliminate the higher harmonics and to convert the terminal voltages. Delay is introduced in the sensed signal due to heavy filtering, which also varies with the operating speed. The line voltage difference is measured and given to the zero crossing detectors. Several other add-on toolsets can be incorporated for developing the specialized applications, the fuzzy logic, and PID toolkits are used in the present application.

ce/e	NL	NM	NS	ZE	PS	PM	PL
NL	NL	NL	NL	NL	NM	NS	ZE
NM	NL	NL	NM	NM	NS	ZE	PS
NS	NL	NM	NS	NS	ZE	PS	PM
ZE	NL	NM	NS	ZE	PS	PM	PL
PS	NM	NS	ZE	PS	PS	PM	PL
PM	NS	ZE	PS	PM	PM	PL	PL
PL	ZE	PS	PM	PL	PL	PL	PL

Fig. 3: Rule-base editor for fuzzy logic controller.

In fifth stacked sequence gives the frequency at which the pwm pulses is to be produced and the actual speed information. The e(k), ce(k) are the conditions given as input to the FLC. Depending on these conditions, a particular rule in the rule-base is fired then FLC gives out the control signal u(k). The control signal produces the corresponding pwm pulses which amplified using the driver. Three driver ICs are used to amplify the gate pulses. The results are also displayed in MATLAB easily. IF e(k) is PL and ce(k) is NL, THEN cu(k) is ZE.

IV.EXPERIMENTAL SETUP

The block diagram of sensorless BLDC MOTOR using fuzzy logic controllers is shown in the figure. As shown in the figure DC supply is given to the inverter.

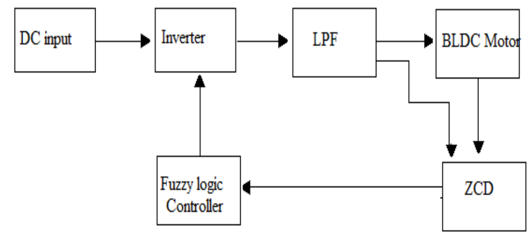

Fig.4. Block diagram of BLDC motor using FLC

BLDC motor has characteristics like a DC motor, Where as it is controlled the same as AC motors. The trapezoidal back-EMF, current profiles, and Hall-sensor signals of the three-phase BLDC motor. One electrical cycle of the motor is divided to six 60° modes that at each mode, only two phases are conducting the current. Three phase bridge inverter fabricated using n – channel MOSFET is operated in 120 degree mode to provide square wave current excitation to the stator winding. Low pass filters have been used to eliminate the higher harmonics and to convert the terminal voltages into sine waveform signals. Delay is introduced in the sensed signal due to heavy filtering, which also varies with the operating speed. Sensorless techniques based on back-EMF and terminal voltages are the most popular due to their simplicity, ease of implementation and lower cost. Back-EMF estimation methods typically relay on the zero crossing detection of the EMF. The technique of estimating back-EMF by sensing the terminal voltages with respect to a virtual neutral point. The neutral point will not be stable during PWM switching. PI controller is used as a speed controller for recovering the actual motor speed to the reference. The reference and the measured speed are the input signals to the PI controller. The Fuzzy logic controller signal produces the corresponding PWM pulses and the actual speed information.

V.SIMULATION RESULT

In the system simulink model as shown in the figure 5 in BLDC Motor using Fuzzy logic controllers. The speed PI controller determines the PWM duty ratio. After reading the states of the three-phase commutation signals, the six gating signals are calculated by using logic equations. The

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pulse width of the upper three switches in the inverter is modulated with PWM duty ratio, and the six PWM signals are generated for driving the inverter as shown in figure7. The inverter output is 3 phase voltage see the figure8 and the harmonics are reduced output as shown in the figure9. Then the motor output is shown in figure6. But in the system simulink model as shown in the figure6. It consists of fuzzy logic controller. The PWM pulse is to produce and the actual speed information. The two controlled voltages are filtered by LPF as shown in the figure9. The speed waveform and the pulses are displayed as shown in the figure6. The start-up current at the same angle is higher under the heavy load condition. In conclusion, when the start-up technique proposed by this paper is applied, it is able to start up the BLDC motor with the low current and the possibility for the start-up failure may be reduced. Figure6 shows the experimental results for responses of the reference and rotor speeds, reference voltage, and a-phase current in order to verify the start-up technique.

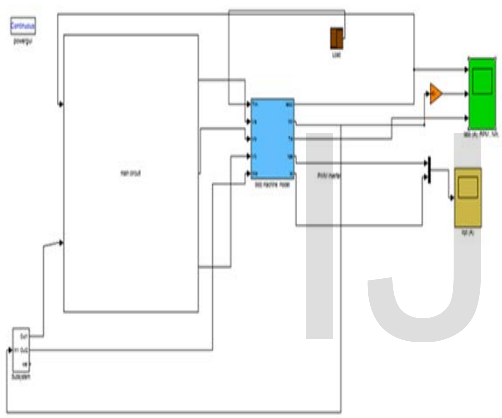

Fig.5.Software configuration

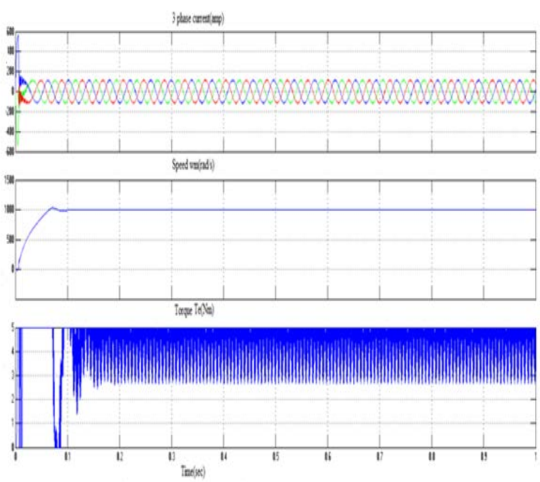

Fig.6.Rotor current, speed, torque signals of the BLDC motor

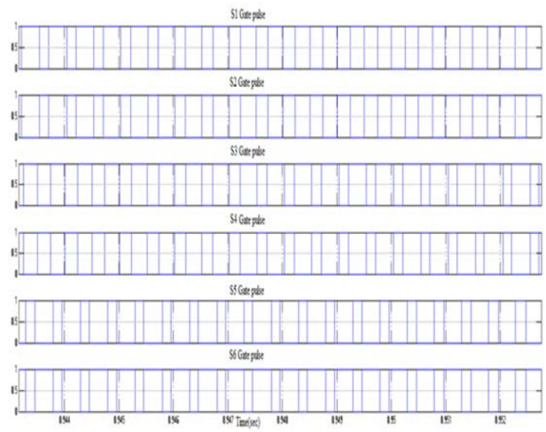

Fig.7.Result of gate pulse

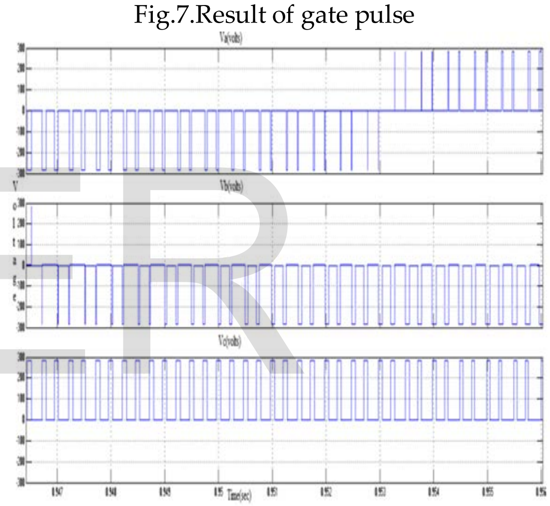

Fig.8.Result of inverter output voltage

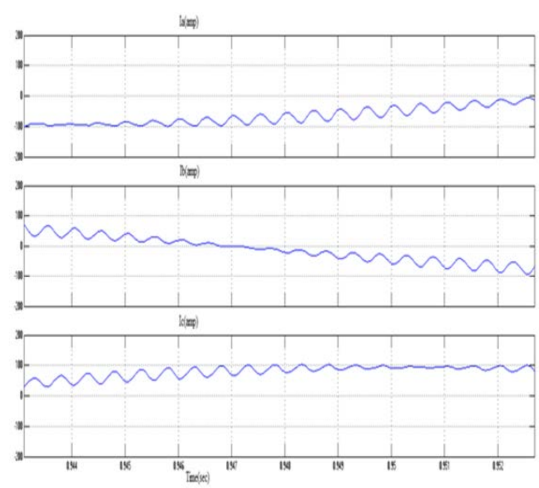

Fig.9.Result of LPF

VI.CONCLUSION

This project presents a sensorless control based on a fuzzy logic controller of a terminal voltage and a potential start- up method with a high starting torque for an automotive fuel pump application. After aligning the rotor position for achieving the maximum starting torque, the BLDC motor accelerates from a standstill up to a nominal speed within 0.07sec.The magnitude of the stator current for aligning the rotor position can be easily controlled by modulating the pulse width of specific switching devices. Through the experimental results, it can be seen that the proposed sensorless and start-up techniques are ideally suited for the automotive fuel pump application.

VII.REFERENCES

[1] J. Shao, "An improved microprocessor-based sensorless brushless DC (BLDC) motor drive for automotive applications," *IEEE Trans. Ind. Appl.*,vol.42, no.5, pp.1216-1221, Sep./Oct. 2006.

[2] J. Gao and Y. Hu, "Direct self-control for BLDC motor drives based on three-dimensional coordinate system," *IEEE Trans. Ind. Electron.*, vol.57, no.8, pp.2836-2844, Aug. 2010.

[3] J. Fang, X. Zhou, and G. Liu, "Instantaneous torque control of small inductance brushless DC motor," *IEEE Trans. Power Electron.*, vol.27, no.12, pp.4952-4964, Dec. 2012.

[4] J. Fang, X. Zhou, and G. Liu, "Precise accelerated torque control for small inductance brushless DC motor," *IEEE Trans. Power Electron.*, vol.28, no.3, pp.1400-1412, Mar. 2013.

[5] N. Matsui, "Sensorless PM brushless dc motor drives, " *IEEE Trans. Ind.Electron.*, vol.43, no.2, pp. 300-308, Apr. 1996.

[6] K. Y. Cheng and Y. Y. Tzou, "Design of a sensorless commutation IC for BLDC motors," *IEEE Trans. Power Electron.*, vol.18, no.6,pp.1365-1375, Nov. 2003.

[7] Y. Wu, Z. Deng, X. Wang, X. Ling, and X. Cao, "Position sensorless control based on coordinate transformation for brushless DC motor drives," *IEEE Trans. Power Electron.*, vol.25, no.9, pp.2365-2371, Sept.2010.

[8] G. J. Su and J. W. McKeever, "Low-cost sensorless control of brushless DC motors with improved speed range," *IEEE Trans. Power Electron.*,vol.19, no.2, pp.296-302, Mar. 2004.

[9] D. H. Jung and I. J. Ha, "Low-cost sensorless control of brushless DC motors using a frequency-independent phase shifter," *IEEE Trans. Power Electron.*, vol.15, no.4, pp.744-752, July, 2000.

[10]R. C. Becerra, T. M. Jahns, and M. Ehsani, "Four-quadrant sensorless brushless ECM drive," *in Proc. IEEE- APEC'91 Conf.*, 1991, pp.202-209.

[11] T. M. Jahn, R. C. Becerra, and M. Ehsani, "Integrated current regulation for a brushless ECM drive," *IEEE Trans. Power Electron.*, vol.6, no.1,pp.118-126, Jan. 1991.

[12] J. X. Shen, Z. Q. Zhu, and D. Howe, "Sensorless flux weakening control of permanent-magnet brushless machines using third-harmonic back-EMF," *IEEE Trans. Ind. Appl.*, vol.40, no.6, pp.1629-1636, Nov./Dec. 2004.

[13] M. Fraq and D. Ishak, "A new scheme sensorless control of BLDC motor using software PLL and third harmonic back-EMF," *in Proc.IEEE-ISIEA 2009*, pp.861-865.

[14] J. X. Shen. and S. Iwasaki, "Sensorless control of ultrahigh-speed PM brushless motor using PLL and third harmonic back EMF," *IEEE Trans. Ind. Electron.*, vol.53, no.2, pp.421-427, Apr. 2006.

[15] P. Damodharan and K. Vasudevan, "Sensorless brushless DC motor drive based on the zero-crossing detection of back electromotive force (EMF) from the line voltage difference," *IEEE Trans. Energy Convers.*,vol.25, no.3, pp. 661-668, Sept. 2010.