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DESIGN CONTROL AND MODELING OFTHREEPHASEBLDCMOTOR APPLICATIONSUSINGPID

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ABSTRACT: The research paper is to develop a complete model of the BLDC motor and to design controller for its position control. PID controllers used for many control problems because of its simple structure, implementation. In practical, we often do not get the optimum performance with the conventionally tuned PID controllers. The efficiency of this method is compared with that of traditional method. I predict results showed that PID control tuned by GA somewhat efficient closed loop response for position control of BLDC motor. The modeling, control and simulation of the BLDC motor have been done using the software.

Keywords: Brushless DC motor, PID control, Pulse Width Modulation.

I. INTRODUCTION

BLDC motors are very popular in does a switch need high performance because of their smaller volume, high force, and simple system structure. In practice, the design of the BLDCM drive involves a complex process such as modeling, control scheme selection, simulation and parameters tuning etc. An expert knowledge of the system is required for tuning the controller parameters of servo system to get the optimal performance. Recently, various modern control solutions are proposed for the optimal control design of BLDC motor [1] [2]. However, these methods are complex in nature and require excessive computation. In contrast, PID control provides a simple and yet effective solution to many control problems [3]. In this paper, extensive modeling of a BLDC motor and GA-based PID scheme is proposed for its position control. The paper is organized in the following manner. Section 2 describes mathematical modeling and the driving circuitry of BLDC motor, section 3 explains the design of PID controller using Ziegler-Nichol's (ZN) method, section 4 gives brief overview of GA, section 5 briefly illustrate the design of PID controller using GA method, section 6 presents the comparison between the results obtained by the GA and ZN.

II. MATHEMATICALMODELING

The Y-connected, 3-phase motor with 8-pole permanent magnetic rotor is driven by a standard three phase power convertor. The motor specifications are given in Table I.

Number of Poles	8
Stator resistance	0.0905 ohms
Stator inductance	0.115 mH
Rated Torque	50 Nm
Band width	6-8 Hz
Supply voltage	28V

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Nominal current	11 A
Sampling period	10µs
Friction constant	0.0001 Kg-m s/rad
Motor moment of inertia	0.000018395 Kg-ms^2/rad

Fig.1shows the basic building blocks of BLDC motor and its Driving circuitry. Driving circuit consists of Reference Current Generator, PID controller, PWM current controller and MOSFET based three phase Power Converter.

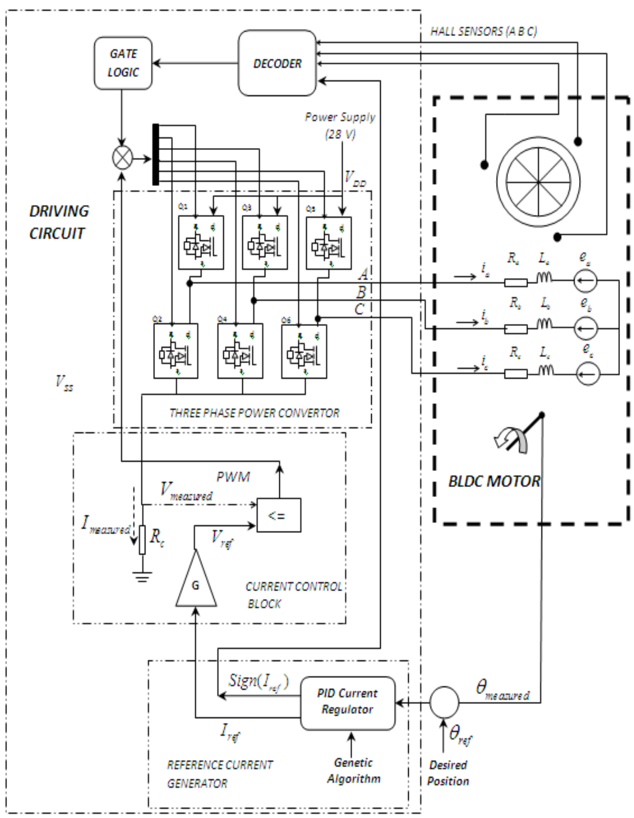

Fig.1Block diagram of BLDC motor

Fig. 2 shows the complete Simulink model of three phase BLDC motor with its controlling and driving circuitry. The detailed description of the major blocks of BLDC motor is mentioned below.

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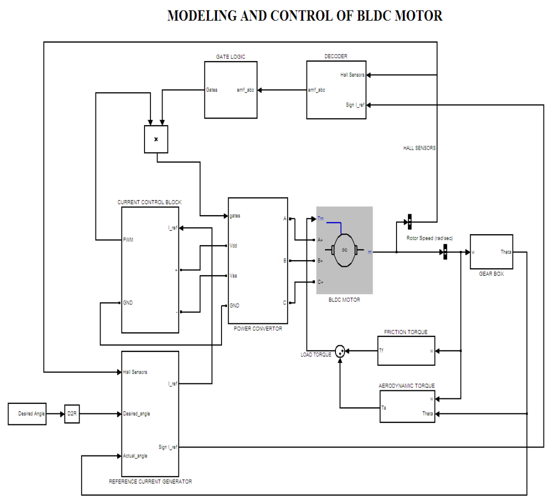

Fig.2Simulink model of BLDC motor

A. ELECTRICALSUBSYSTEM

The electrical part of DC brushless motor and relationship between currents, voltage, and back electromotive force and rotor velocity is deriving using Kirchhoff's voltage law [6]:

$$r_a = R_a i_a + I_a \frac{di_a}{dt} + M_{ab}\frac{di_b}{dt} + M_{ac}\frac{di_c}{dt} + a_a$$

$$r_b = R_b i_b + I_b \frac{di_b}{dt} + M_{ba}\frac{di_a}{dt} + M_{bc}\frac{di_c}{dt} + a_b \quad (1)$$

$$r_c = R_c i_c + I_c \frac{di_c}{dt} + M_{ca}\frac{di_a}{dt} + M_{cb}\frac{di_b}{dt} + a_c$$

B. MECHANICAL SUBSYSTEM

A mathematical relationship between the shaft angular velocity and voltage input to the DC brushless motor is derived using Newton's law of motion [6].

$$I\frac{d\omega_r}{dt} = T_e - T_m - F\omega_r \quad (2)$$

The angular position is obtained from an integration of the angular velocity.

$$\theta_r = \omega_r dt \quad (3)$$

Generated electromagnetic torque for this3-phaseBLDC motor is dependent on the current, speed and back-EMF waveforms, so the instantaneous electromagnetic Torque can be represented as:

$$T_{em} = \frac{1}{\omega_m}(e_a i_a + e_b i_b + e_c i_c) \quad (4)$$

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C. DESCRIPTION OF DRIVING CIRCUITRY

Driving circuitry consist soft three phase power convertors as shown in Fig.3, which utilize six power transistors to energize two BLDC motor phases concurrently. The rotor position, which determines the switching sequence of the MOSFET transistors, is detected by means of 3-Hall sensors mounted on the stator.

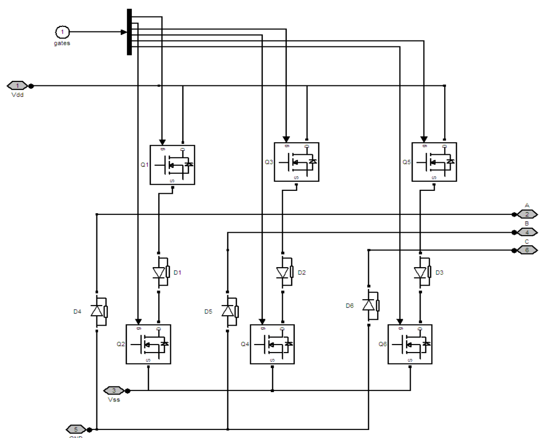

Fig.3 Three phase power convertor

By using Hall sensor information and the sign of reference current (produced by Reference current generator), Decoder block generates signal vector back EMF. The basic idea of running motor in opposite direction is by giving opposite current. Based on that, we have Table.4 and Table.5 for calculating back EMF for clockwise and anticlockwise direction of motion as shown below:

Hall Sensor A	Hall Sensor B	Hall Sensor C	EMF A	EMF B	EMF C
0	0	1	0	-1	1
0	1	0	-1	1	0
0	1	1	-1	0	1
1	0	0	1	0	-1
1	0	1	1	-1	0
1	1	0	0	1	-1

Table.1 Clockwise rotation

Hall Sensor A	Hall Sensor B	Hall Sensor C	EMF A	EMF B	EMF C
0	0	1	0	1	-1
0	1	0	1	-1	0
0	1	1	1	0	-1
1	0	0	-1	0	1
1	0	1	-1	1	0
1	1	0	0	-1	1

Table.2 Anticlockwise rotation

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The gate logic to transform electromagnetic forces to the 6 signal on the gates is given below:

EMF A	EMF B	EMF C	Q1	Q2	Q3	Q4	Q5	Q6
0	0	0	0	0	0	0	0	0
0	1	1	0	0	0	1	1	0
0	1	0	0	0	1	0	0	1
-1	0	1	0	1	0	0	1	0
1	0	-1	1	0	0	0	0	1
1	-1	0	1	0	0	1	0	0

Table.3 Gate logic

In Reference current generator block as shown in Fig.7, PID controller attempts to minimize the difference between desired angle and the actual measured angle by taking a corrective action to generate reference current signal direction of rotation is based on the sign of that reference current.

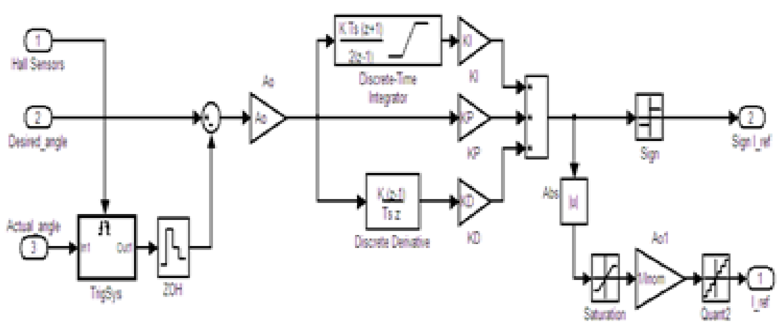

Fig.4 Reference current generator block

In current control block shown in Fig.8, the reference current from current generator is transformed to reference voltage signal by using Ohm's law ($V_{ref}=I_{ref}R$).This reference voltage is then compared with the measured voltage across control resistance R_C, where $R_C=0.01\Omega$..When the measured voltage is less than the reference voltage, control signal is set to one for $t=2T_S$, where T_S is sampling time. In other case control signal is set to zero. In this way a pulse width modulated (PWM) signal having fixed frequency with variable duty cycle is obtained. This PWM signal is then multiplied with the output from gate logic to drive three phase Power Convertor.

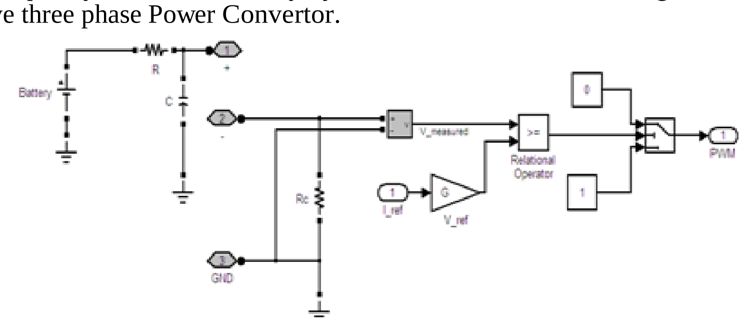

Fig.5 Current control block

III. DESIGN OF PID CONTROLLER USING ZIEGLER-NICHOLS METHOD

The gain tuning of PID is done by increasing the proportional gain until the system oscillates; that gain is K_u.At this instant, time interval is measured between peaks to get T_u. Table V gives approximate values for the controller gains.

Controller	K_p	T_i	T_d
PID	$0.6 \times K_u$	$T_u/2$	$T_u/2$

Table.4 The Ziegler-Nichols rules (frequency response method)

From the above algorithm the step response of the system is shown in below Figure:

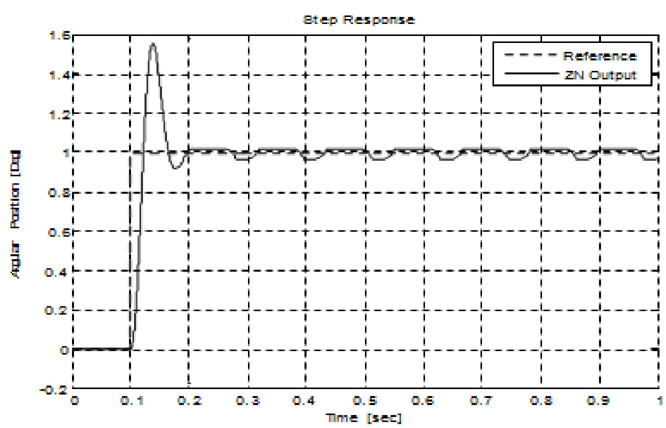

Fig.6 Step response

Below analysis depicts that the system response is not optimum. In order to achieve better performance, GA approach is used to find the optimal value so PID gains.

	Ziegler Nichols Method
K_p	2400
T_i	0.02
T_d	0.005
Overshoot	54%
Rise Time	0.03 sec
Settling Time	0.09ec

Table.5 Controller performance

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$$Fitness\ value = \frac{1}{Performance\ Index} \tag{6}$$

D. TERMINATIONCRITERIA

Termination of algorithm takes place when the value of the fitness function for the best point in the current population is less than or equal to fitness limit and the change in the value of fitness function is less than function tolerance. The best member of the population was selected and plotted in the graph. The variation of the PID parameters Kp, T_i and T_d are below. It is evident from the results that the best particle has an excellent convergence before reaching generation limit. The plot of the error, which is based on IAE criterion for all iterations, is shown in figures below;

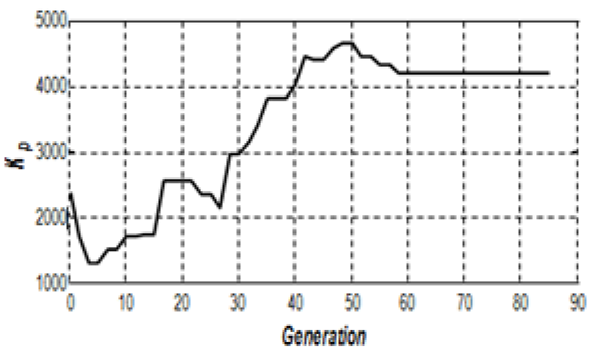

Fig.7 K_p Convergence

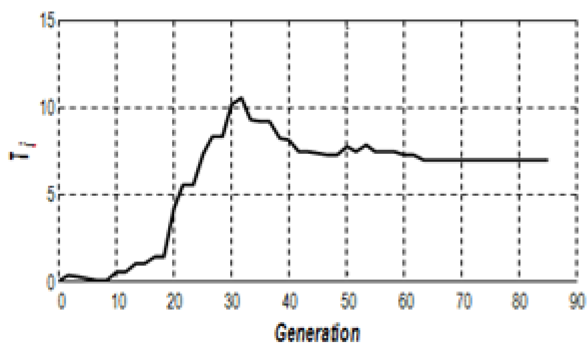

Fig.8 T_i Convergence

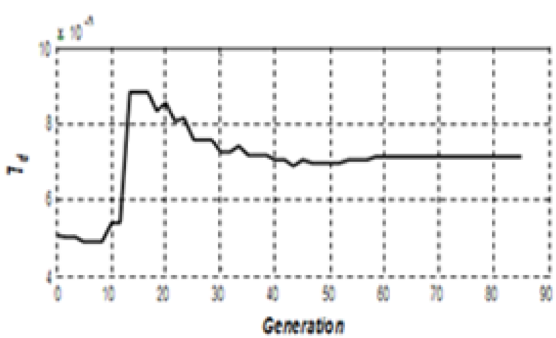

Fig.9 T_d Convergence

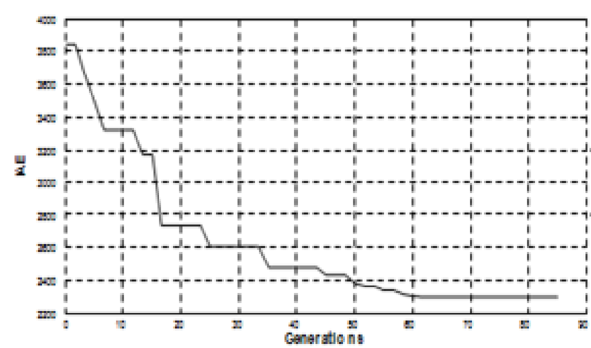

Fig.10 IAE Convergence

PID parameters acquired after GA optimization are listed below:

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K_p	T_i	T_d
4200	7	0.0071429

Table.7 PID parameters

VI.SIMULATIONRESULTSAND COMPARISON

With optimized PID gains using GA, the step response of the controlled system is shown in below along with the response obtained from ZN method:

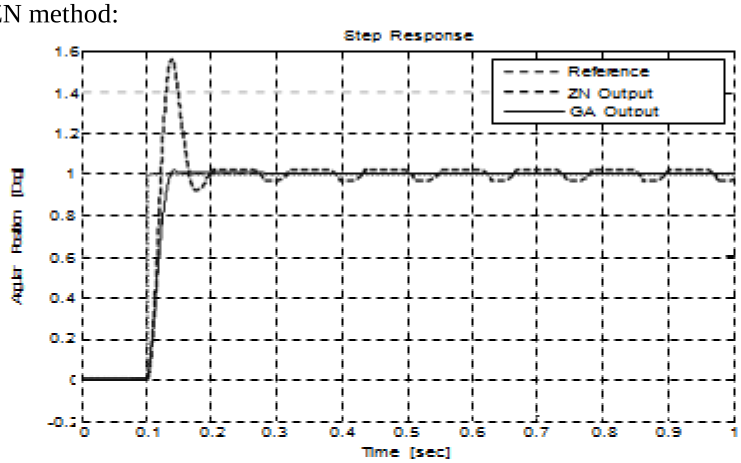

Fig.11 Performance comparison

It is apparent from the above step response that the controller performance with GA optimized gains is quite efficient as compared to the response obtained from ZN method. The comparison of results in term of rise time, settling time and over shoot are listed in table below:

PERFORMANCE COMPARISON TABLE:

	Ziegler Nichols Method	Genetic Algorithm Method
K_p	2400	4200
T_i	0.02	7
T_d	0.005	0.007142
Overshoot	54%	Less than1%
Rise Time	0.03 sec	0.03 sec
Settling Time	0.09 sec	0.051 sec

Apart from step response, various simulations are carried out in which sinusoidal and square waves having various amplitude and frequencies are applied. Performance comparison of GA optimized controller with the controller tuned by ZN method from various simulations are shown in below Figures:

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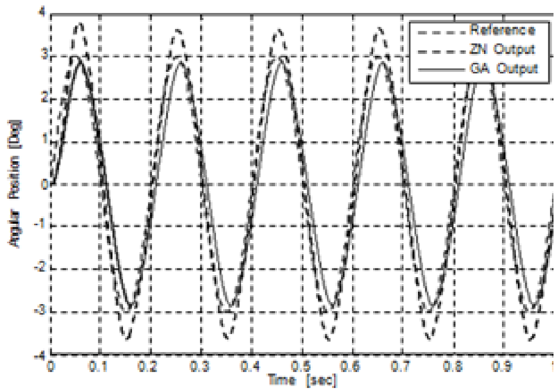

Fig.12 Sinusoidal response 3deg at 5 Hz

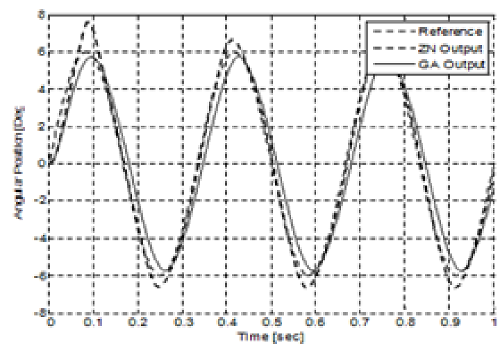

Fig.13 Sinusoidal response 6 deg at 3 Hz

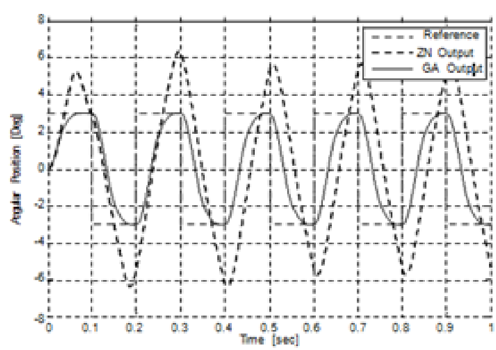

Fig.14 Square wave response 3 deg at 5 Hz

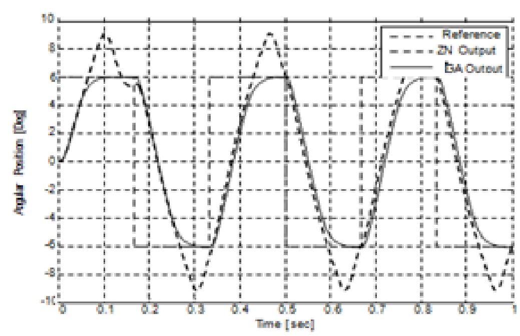

Fig.15 Square wave response 6 deg at 3 Hz

It is clear from above Figures that the controller designed with ZN method has high over shoots as was observed in the step response, while the controller with GA optimized gains precisely follows the input signal. Above Figures depict that the response of ZN method appears sinusoidal against square wave input. There as on is that the controller was still in its transient state when the next pulse is arrived. On the other hand GA based controller achieved its steady state before the next pulse arrived due to its low settling time.

VII. CONCLUSION

In this research paper, modeling of three phase BLDC motor and its optimized PID position control are designed. Comparative study is carried out in which the response of GA based controller is compared with the controller designed using ZN method. It is obvious from review simulation results that the controller performance with GA optimized gains is much more efficient than the ZN method in terms of rise time, settling time, over shoot and set point tracking. However ZN method is good for providing the starting values of PID gains for GA optimization.

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BIOGRAPHY

Mr.S.Sathish Kumar is working as an Assistant professor in Electrical and Electronics Engineering Department at Jansons Institute of Technology, Coimbatore. He has finished B.E. in 2003 and M.E. (Applied Electronics) in 2005 under Anna University, Chennai. He has published 12 papers in National Conference, 5 papers in International Conference and 5 papers in International Journal.

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