ISSN 2349-6193
Impact Factor (PIF): 2.243

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International Journal OF Engineering Sciences & Management Research

APLLICATION OF JAYA OPTIMIZATION TECHNIQUE TO CONTROL BLDC MOTOR

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Keywords: Brushless DC motors, PID controller, Zieglar-Nichols method, Jaya Optimization Technique, MATLAB/SIMULINK.

ABSTRACT
Brushless DC (BLDC) motors are preferred as small horse power control motors due to their high efficiency, silent operation, compact form, reliability, and low maintenance but suffer from problem on operation at variable speed so need a precise controller to be designed. Usually in these motors speed control is achieved by using proportional-integral-derivative (PID) controller being simple in structure but PID controllers require precise linear mathematical models. A new algorithms-specific variable less optimization technique has been applied and results are compared with Zieglar-Nichols based PID controller.

INTRODUCTION
Brushless DC (BLDC) motors are preferred as small horse power control motors due to their high efficiency, silent operation, compact form, reliability, and low maintenance. However, the problems are encountered in these motor for variable speed operation over last decades continuing technology development in power semiconductors, microprocessors, adjustable speed drivers control schemes and permanent-magnet brushless electric motor production have been combined to enable reliable, cost-effective solution for a broad range of adjustable speed applications. BLDC motors are a derivative of the most commonly used DC motor. The Proportional Integral Derivative (PID) controllers are applied in various fields of engineering, and these controllers are very important tools in telecommunication system. If there is a control system and stability is desired for control system, then PID could be very useful. In practice, the design of the BLDC 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 speed control design of BLDC motor.

The main provisions of this paper work is to providing the system stability and their performance using classical Zieglar-Nichols (ZN) technique and Jaya technique. Optimization techniques for PID tuning used to reduce the overshoot and rise time as compared to any other PID controller tuning algorithms, such as tuning methods. PID controller offers an improvement in the quality of the speed response. PID controllers are poorly tuned in practice with most of the tuning done manually which is difficult and time consuming. Most of these controllers use mathematical models and are sensitive to parametric variations. These controllers are robust to load disturbances. Besides, “Jaya” technique can be easily implemented.

MODELING OF DC MOTOR
Permanent magnet DC motors use mechanical commutators and brushes to achieve the commutation. However, BLDC motors adopt Hall Effect sensors in place of mechanical commutators and brushes [17]. The stators of BLDC motors are the coils, and the rotors are the permanent magnets. The stators develop the magnetic fields to make the rotor rotating.

Hall Effect sensors detect the rotor position as the commutating signals. Therefore, BLDC motors use permanent magnets instead of coils in the armature and so do not need brushes. In this paper, a three-phase and two-pole BLDC motor is studied. The speed of the BLDC motor is controlled by means of a three-phase and half-bridge pulse-width modulation (PWM) inverter. The dynamic characteristics of BLDC motors are similar to permanent magnet DC motors. The characteristic equations of BLDC motors can be represented as program. Simulink will solve these nonlinear equations numerically, and provide a simulated response of the system dynamics.

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$$v_{app}(t) = L\frac{di}{dt} + Ri(t) + v_{emf}(t)$$
$$v_{emf} = K_b.\omega(t)$$
$$T(t) = K_i.i(t)$$
$$T(t) = J\frac{d\omega(t)}{dt} + D.\omega(t)$$

Fig. 1 shows the block diagram of the BLDC motor. From the characteristic equations of the BLDC motor, the transfer function of speed model is obtained. The parameters of the motor used for simulation are as follows
The Transfer Function of Linear BLDC Motor:

$$\frac{\omega(s)}{v_{app}(s)} = \frac{K_t}{LJ.s^2 + (RJ + LD)s + K_t.K_s}$$

$$\frac{\omega(s)}{v_{app}(s)} = \frac{275577.36}{s^2 + 417.7s + 39490.17}$$

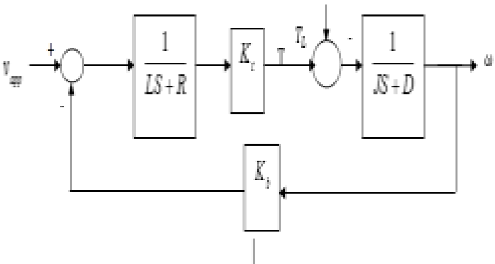

Fig. 1 The block diagram of BLDC motor

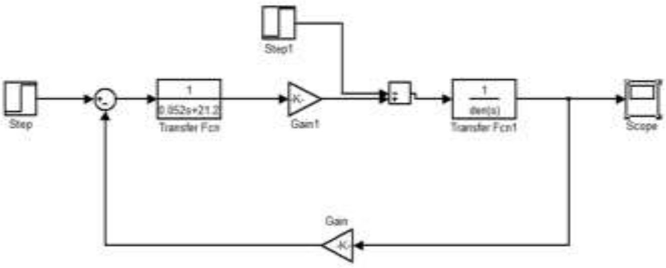

Fig. 2 The Simulation diagram of linear BLDC motor

Overall transfer function of BLDC Motor without PID controller is

$$\frac{C(s)}{R(s)} = \frac{G(s)}{1 + G(s)H(s)}$$

Fig.3 The Simulation Model of BLDC Motor without PID Controller
Result of Linear BLDC Motor system without PID Controller

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Impact Factor (PIF): 2.243

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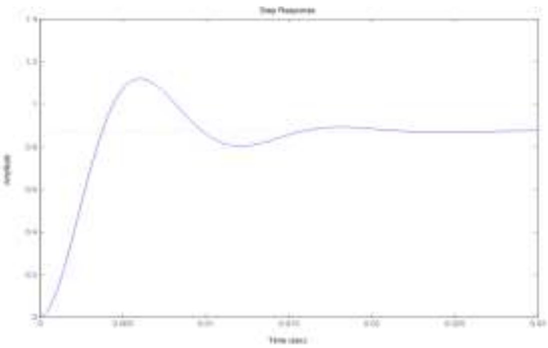

Fig.4 The Step Response of BLDC Motor without PID Controller.

SELECTION OF COMPENSATOR

The compensators can be any among four type P, PI, PD and PID out of which we have to choose according our requirement based on the following features:

- Steady State Error
- Maximum Overshoot
- Rise Time
- Settling Time

► **Proportional controller:**

With the increase in proportional gain system steady state error and rise time reduces. But with the proportional gain steady state error can be reduced much but completely cannot be eliminated. Besides reduction in steady state error increase in proportional gain increases the system's maximum overshoot. It improves the dynamics of the system and reduce settling time with larger bandwidth but the system become more susceptible to noise. Large value of K (proportional gain) may leads to system instability.

► **Proportional plus Integral (PI):**

Integral term is principally wont to eliminate the steady state error however at the price of the reduced speed of the system. Proportional term used is employed to compensate the lag created by integral term however overall system lags its earlier speed. Conjointly it will boost the oscillations and system maximum overshoot.

► **Proportional plus Derivative (PD):**

It is principally wont to boost the dynamics of the system and increase the soundness of the system. The spin off management isn't used alone attributable to the matter of amplifying the noise. It has terribly less impact on the steady state error of the system.

► **Proportional plus Integral plus Derivative (PID):**

PID has quick dynamics, zero steady state error and no oscillations with high stability. It's advantage is that it is applied to system of any order. Spinoff gain additionally to PI is to extend the speed of response and reduce overshoot and oscillations. There are very less innumerable standardization ways offered together with on-line standardization together with repetitious procedures, offline standardization exploitation the pen and pencil. Consistent with the benefits offered by PID over alternative we tend to choose PID and here we tend to apply 2 ways to tune the parameters of PID parameters.

► **Block diagram of optimal PID control for the BLDC motor**

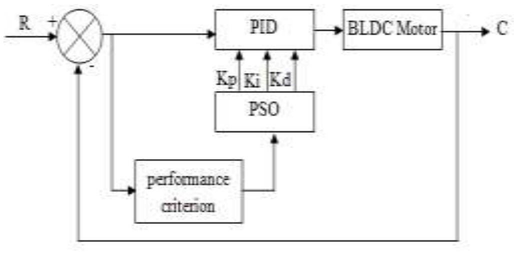

Fig. 5 optimal PSO-PID control for BLDC Motor

► **Transfer Function of PID Compensator**

Consider the continuous-time PID Controller transfer function as shown below,

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$$G_c(s) = K_p + \frac{K_i}{s} + K_d s = Kp(1 + \frac{1}{T_i s} + T_d s)$$

Various control techniques are: Fuzzy logic controller, Artificial Neural Network (ANN), PID controller, PI controller, sliding mode controller. For control over steady state and transient errors the two control strategies discussed so far should be combined to get proportional-integral derivative (PID) control. Hence the control signal is a linear combination of the error, the integral of the error, and the time rate of change of the error. The PID controller contains all the control components (proportional, derivative, and integral). All three gain constants are adjustable. In order to get acceptable performance the constants K_P, K_d and K_i can be adjusted. This adjustment process is called tuning the controller. Increasing K_P and K_i tend to reduce errors but may not be capable of producing adequate stability. The PID controller provides both an acceptable degree of error reduction and an acceptable stability and damping.

CONTROLLER PARAMETERS ESTIMATION USING ZIEGLER-NICHOLS METHOD

The step response start oscillating for variable Kp = 1.8, with oscillation period of T_u = 8.94ms. Now as per Ziegler-Nichols method.

$K_p = 0.6K_u = 0.6*1.8 = 1.08$,
$K_i = 2*Kp/Tu = 241.6$
$K_d = Kp*0.125*Tu = 1.2*10^{-3}$

With these values of PID parameters there were not much improvement, than after various trial and error methods manual tuning with the help of matlab better values of PID parameters are found

$K_p = 2.08$
$K_i = 241.6$
$K_d = 8*10^{-3}$

Using these values of PID parameters the step response of BLDC motor are obtained as:
Result of Linear BLDC Motor system with PID Controller based on ZN method

Table: 1
Step Response Characteristics of BLDC Motor with PID Controller.

Rise Time	**0.0013**
Settling Time	**0.0058**
Overshoot	**0.2678**
Steady state Error	**0.0**

INTRODUCTION TO "JAYA" TECHNIQUES

This algorithm is based on the concept that the solution obtained for a given problem should move towards the best solution and should avoid the worst solution. This algorithm requires only the common control parameters and does not require any algorithm-specific control parameters.

Let $f(x)$ is the objective function to be minimized (or maximized). At any iteration i, assume that there are 'm' number of design variables (i.e. j=1,2,…,m), 'n' number of candidate solutions (i.e. population size, k=1,2,…,n). Let the best candidate *best* obtains the best value of $f(x)$ (i.e. $f(x)$best) in the entire candidate solutions and the worst candidate *worst* obtains the worst value of $f(x)$ (i.e. $f(x)$worst) in the entire candidate solutions. If $X_{j,k,i}$is the value of the jth variable for the kth candidate during the ith iteration, then
this value is modified as per the following eq.

$$X'_{j,k,i} = X_{j,k,i} + r_{1,j,i}(X_{j,best,i} - |X_{j,k,i}|) - r_{2,j,i}(X_{j,worst,i} - |X_{j,k,i}|)$$

where, $X_{j,best,i}$is the value of the variable j for the *best* candidate and $X_{j,worst,i}$is the value of the variable j for the *worst* candidate. $X'_{j,k,i}$is the updated value of $X_{j,k,i}$ and $r_{1,j,i}$ and $r_{2,j,i}$ are the two random numbers for the jth variable during the ith iteration in the range [0, 1]. The term "$r_{1,j,i}$ ($(X_{j,best,i} - |X_{j,k,i}|)$" indicates the tendency of the solution to move closer to the best solution and the term "$-r_{2,j,i}(X_{j,worst,i} - |X_{j,k,i}|)$" indicates

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the tendency of the solution to avoid the worst solution. $X'j,k,i$is accepted if it gives better function value. All the accepted function values at the end of iteration are maintained and these values become the input to the next iteration.

Implementation Steps of the "JAYA" For Finding PID Parameters

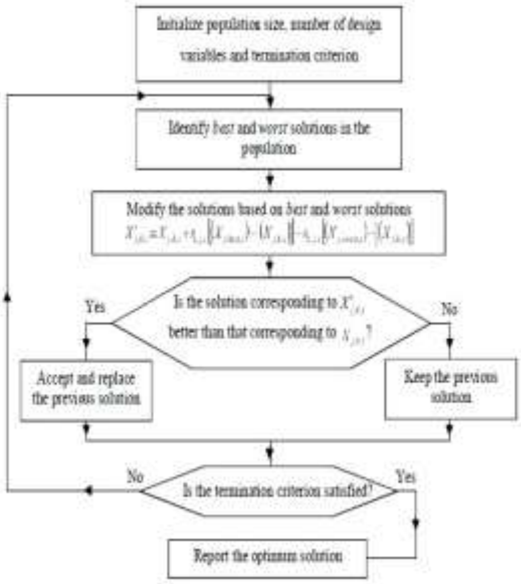

Fig. 6 Flow chart of Jaya Algorithm

After one iteration variables are modified according to equation 4.1. In next step function value obtained in previous iteration are compared with newly obtained value and then best and worst are selected from all of them. This way top M best variables are again modified according to equation 4.1. This process is repeated again and again till an acceptable level of solution is not obtained or terminated after maximum allowable iterations are completed. Details of "JAYA" can be referred in section 3. Following method is taken to apply "JAYA" algorithm for PID tuning of BLDC Motor.

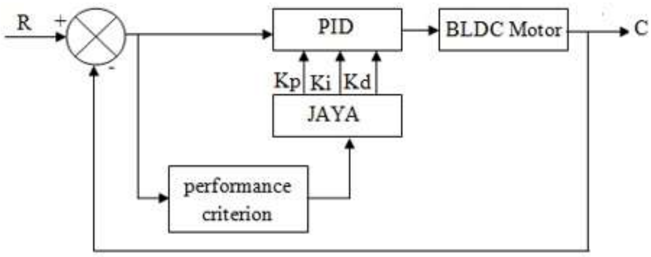

Fig.6 "JAYA"-PID Control for BLDC Motor.

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Flowchart of "JAYA"-PID controller is shown in Figure

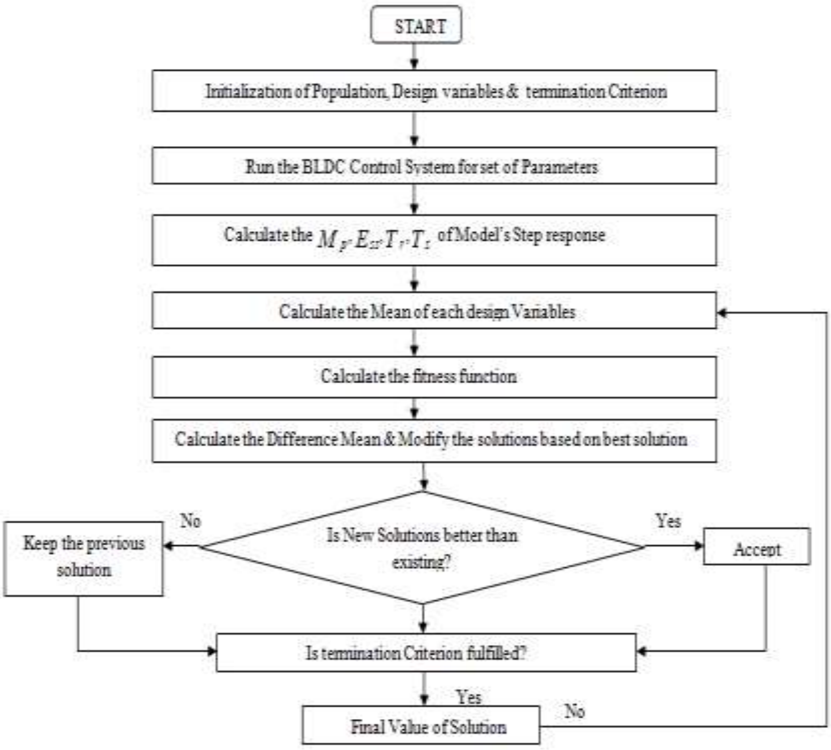

Fig.4.3 Flowchart of "JAYA"-PID Control System

"JAYA" BASED SIMULATION & RESULTS

Transfer Function of BLDC motor without technique

$$\frac{\omega(s)}{v_{app}(s)} = \frac{K_t}{LJ.s^2 + (LD + RJ)s + K_t K_s}$$

$$\frac{C(s)}{R(s)} = \frac{\omega(s)}{v_{app}(s)} = \frac{275577.36}{s^2 + 417.7s + 39490.17}$$

Table 4.1
"JAYA" Selection Parameters

No of design variable	3
No. of random solution	10
No. of iteration	100

Step response of "JAYA"-PID controller

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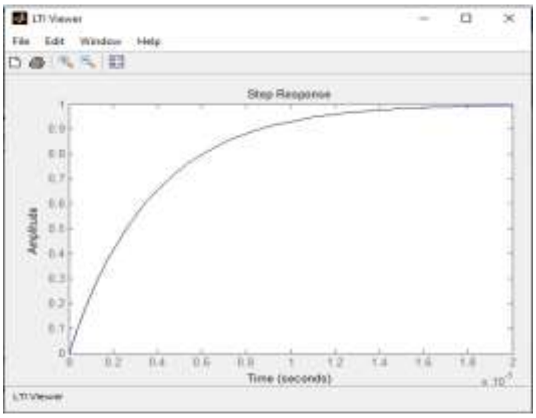

Fig.4.4 Step response of BLDC motor with "JAYA" tuned PID controller

Table 4.2
Performance of "JAYA"-PID Controller

[P I D]	[596.6356, 25.7278, 0.9649]
Rise Time(ms)	8.2441e-06
Max Overshoot (%)	0
Steady State error	0.3000
Settling time	1.4588e-05

In this chapter, Jaya optimization ("JAYA") method is used for tuning of PID controller for speed control of a BLDC motor. According to simulation results, the use of intelligence techniques gave results in better static characteristics for output response.

It is obtained through simulation of BLDC motor, the results of the proposed method for PID controller tuning can perform an efficient search for the optimal PID controller. This method is improving the dynamic performance of the system in a better way. A BLDC motor is a second order system, its Simulation is done using MATLAB 2014 and step response is obtained. The simulation results and performance characteristics of "JAYA" technique are found much better than classical approach error and trial method beside this technique is much simpler to apply and does not require specific parameters to be choose. "JAYA" technique may be able to obtain a better set of PID controller parameters to get a faster response if some more step of iteration are done. The results obtained by this technique may be of same accuracy competitively compared to other techniques but its ease of apply and less computation requirement make it much better.

CONCLUSIONS

In this dissertation, an optimization method named "JAYA" is used for determination of PID controller parameters. Every tuning algorithm has its algorithm-specific parameters which require a tedious computational effort resulting in improper tuning. Considering this aspect, the "JAYA" algorithm has been applied for speed control of BLDC motor which does not require any algorithm-specific control parameters. It requires only common controlling parameters like population size and number of generations for its working. "JAYA" is a population based method. In this optimization algorithm random solution are considered as population solution for different design variables and these solution result is analogous to the 'fitness' value of the optimization problem. In the entire population the best solution is considered as the leader.

"JAYA" is not a parameter-less algorithm. It is clearly explained that "JAYA" is an algorithm-specific parameter-less algorithm Common control parameters are common in any of the optimization algorithms while algorithm-specific parameters are specific to their algorithm and different algorithms have different specific parameters to be controlled. The results show that the proposed controller can perform an efficient search for the optimal PID controller. This method can improve the dynamic Performance of the system in a better way.

ISSN 2349-6193
Impact Factor (PIF): 2.243

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For implementation of any other optimization technique we require a proper adjustment of parameters like the number of iterations, inertia weight factor, velocity constant, and population size while implementation of "JAYA" require adjustment in only two control parameters viz. number of solution candidate, number of iteration and by observation we observed that the amount of overshoot and rise time are decreased sufficiently in "JAYA".

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