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Design of Robust H∞ Controller for a Realistic PMDC Motor with GA Based Performance Optimization

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Abstract

This paper proposes the robust H∞ controller design of the speed control of Permanent Magnet Direct Current (PMDC) motor. In modern robust control applications, the design of fixed structure H-loop shaping control depends on minimizing the H∞ norm of the closed loop control system. The core idea is to formulate the H∞ norm i.e., condition for the disturbance rejection and H∞ controller is designed by means of global optimization technique such as Genetic Algorithm (GA) such that it should satisfy the maximizing the disturbance rejection constraint and the PID controller design based on minimizing the integral of time weighted squared error (ITSE) performance index using another Genetic Algorithm in order to meet the desired requirements. As the results the robust H∞ controller provides good dynamic performance of system and robustness to uncertain disturbances. The robustness of the H∞ controller design is assessed and applied in controlling the speed of Permanent Magnet DC motor with the aid of computer simulation, thereby analyzing the behavior of the step response of the proposed controller and the closed loop is course tracked with perturbed parameters. This proposed model is found to be robust for arbitrary disturbances (simultaneous AC & DC) along with significant time response.

Keywords: Robust H∞ controller, Permanent Magnet Direct Current motor, Genetic Algorithm, integral of time weighted squared error (ISTE).

INTRODUCTION

A DC motor is a rotary machine that converts electrical energy into mechanical energy and based on the types, Iron cored DC motors are rotary type of electrical machine where the magnetic flux is produced by the electro magnetism effect of the coil on the ferrous laminated core [9]. The electro magnetism effect is due to the current in the electro-magnetic inducing conductor, because the core is not permanently magnetized [4]. If the poles are made up of permanent magnet in a DC motor, then it is known as Permanent Magnet Direct Current motor. These motors (brushed or brushless) are became more popular in recent years. PMDC motors are more extensive in variable speed drive and precise position control system applications. The vital role of PMDC Motor exhibits in research, Electric traction, laboratory experiments because of their ease and economical. Henceforth, the precise speed control of PMDC motor can be achieved by varying flux, resistance of armature and input voltage supplied. PMDC motor is more effective over iron cored DC motor when high efficiency and linear speed-torque curve is necessary [1]. The design of control system is the selection process of feedback gains which satisfies the desired specifications of the closed loop control system.

The PID controllers are well-known controllers over a decades and generally used in industry because of simple and reliable in nature and exhibits robustness behavior in the presence of varying dynamic characteristics of the plant in transient as well as steady-states response with its three term functionality. The Design of PID control strategy consists of three control modes viz., Proportional, Integral and Derivative modes [5]. There are so many methods where the PID controller gains can be tuned viz., Ziegler-Nichols method, Cohen-Coon method, Chiein-Hrones-Reswick (CHR) method, Wang-Juang-Chan methods etc [5].

These methods mentioned above are befitting to manual tuning by mathematically selecting the precise value of controller parameters and not acceptable to extinguish the steady state error of the process through the integral action on error and expected change in the output through the action of derivative on the error with respect to the process of set point. Therefore, these limitations of manual tuning are usually time consuming and error prone which has motivated us for automatic, continuous with improved performance for PMDC speed control applications.

MODELLING OF PMDC MOTOR

The motor armature voltage V_a is given by

$$v_a(t) = R_a i(t) + L_a \frac{d}{dt} i(t) + e_b i(t) \;\ldots..(1)$$

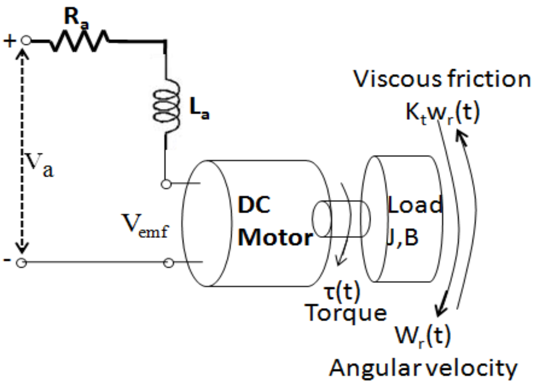

Figure 1: Equivalent circuit diagram of PMDC motor.

From the Equivalent circuit diagram of PMDC motor [1] as shown in the Figure1, $i_a(t)$ is the current through the armature windings in Amps, e_b is back emf in volts, R_a and L_a are armature resistance in ohms and inductance in Henry respectively. According to DC motor's working principle, the back emf voltage is induced due to the movement of the armature winding in the main magnetic field

The back emf voltage generated is being proportionate to the angular speed of rotor.

$$e_b(t) = k_b \omega_r(t) \;\ldots..(2)$$

Where k_b is back emf constant in V/(rad/sec), ω_r is angular speed of rotor. The speed of the rotor (ω_r in m/sec) is expressed in terms of differential equation of motion is given by

$$T_e(t) = T_L(t) + B\omega_r(t) + J \frac{d}{dt} \omega_r(t) \;\ldots..(3)$$

Where, T_e and T_L are electromagnetic torque and load torques in N-m, J, B to be Moment of inertia in Kg-m2/rad, and frictional coefficient of motor and load in N-m/ (rad/sec). In PMDC motor, conductor experiences force which leads to electromagnetic torque, whenever armature carries current in the presence of flux. Electromagnetic torque is given by

$$T_e(t) = k_t i_a(t) \;\ldots..(4)$$

Where k_t=Torque constant in N-m/A. By considering τL= 0 and apply the Laplace Transform to the above equations from (1) to (4), then

$$V_a(s) = R * I_a(s) + L_a * sI_a(s) + E_b(s) \;\ldots..(5)$$

$$E_b(s) = k_b \omega_r(s) \;\ldots..(6)$$

$$T_e(s) = (B + sJ)\omega_r(s) \;\ldots..(7)$$

$$T_e(s) = K_t I_a(s) \;\ldots..(8)$$

Evaluate the $I_a(s)$ from equation (5),

$$I_a(s) = \frac{V_a(s) - E_b(s)}{R_a + sL_a} \;\ldots..(9)$$

Substitute equation (9) in equation (8)

$$T_e(s) = K_t \frac{V_a(s) - E_b(s)}{R_a + sL_a} \;\ldots..(10)$$

Compare equation (7) and equation (10), then

$$(R_a + sL_a)(B + sJ)\omega_r(s) = k_t * V_a(s) - k_t * E_b(s) \;\ldots..(11)$$

But we know that, $E_b(s) = k_b \omega_r(s)$.

Then substitute above equation in the equation (11)

$$((R_a + sL_a)(B + sJ) + k_t k_b) * \omega_r(s) = k_t * V_a(s)$$

This results in PMDC motor's closed loop transfer function [1] given by

$$\frac{\omega_r(s)}{V_a(s)} = \frac{k_t}{(R_a + sL_a)(B + sJ) + (k_t k_b)} \;\ldots..(12)$$

For the simplification of transfer function, let us assume that B=0

$$G(s) = \frac{\omega_r(s)}{V_a(s)} = \frac{k_t}{sJ(R_a + sL_a) + (k_t k_b)} \;\ldots..(13)$$

From equation (6), mechanical time constant (T_m) and electrical time constant (T_{ele}) are defined as

$$T_m = \frac{JR_a}{k_t k_b}$$

$$T_{ele} = \frac{L_a}{R_a}$$

The motor transfer function [10] is expressed as in term of time constants

$$\frac{\omega_r(s)}{V_a(s)} = \frac{1}{k_b(s^2 T_m T_{ele} + sT_m + 1)} \;\; ..... (14)$$

$$G(s) = \frac{\omega_r(s)}{V_a(s)} = \frac{1}{k_b(s^2 T_m T_{ele} + sT_m + 1)} \;\; .... (15)$$

Where $T_m > T_{ele}$

Design of H∞ Controller Using GA

In the conventional methods of controller design, the disturbance is considered to be in familiar form of a step or sinusoidal function. This disturbance signal being arbitrary in nature with limited amplitude [3] is taken care by using H_∞ norm. Let us consider single input-single output linear time-invariant (LTI) system with feedback control shown in Figure.2

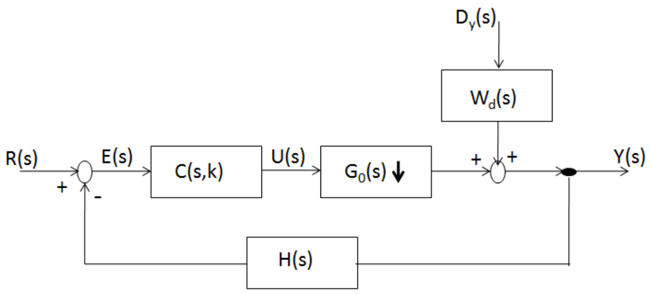

Figure 2: Control system with disturbance.

Let us consider the fixed-structure controller in the form of transfer function in rational notation i.e, C(s,k), where $k=[k_1,k_2,k_3,\ldots k_m]^T$, $k_1,k_2,k_3,\ldots k_m$ are the parameters of controller. $G_0(s)$ represents the nominal transfer function of motor/plant; $D_y(s)$ represents the external disturbance. Condition for disturbance rejection can be described by H_∞ norm as follows [6].

A. Disturbance Rejection Constraint

By setting the reference signal R(s) = 0, nominal transfer function of the system will be $Y(s)/D_y(s)$.Then the relationship of the controlled variable Y(s) to the disturbance at the output $D_y(s)$ can be represented as follow

$$\frac{Y(s)}{D_y(s)} = \frac{1}{1 + C(s,K)G_0(s)} \;\; ..... (16)$$

The norm refers to vector-valued signals, to real functions of time, or to the variables of the Laplace transformation. Commonly used norms in automatic control are the Euclidean norm and the maximum norm. The L_2 -norm of the signal v(t) is defined by

$$\|v\|_2 = \left[\int_{-\infty}^{+\infty} (v(t))^2 \, dt\right]^{0.5} \;\; .... (17)$$

And the L_∞ norm is defined by the following:

$$\|v\|_\infty = \max_t |v(t)| \;\; .... (18)$$

The L_∞ norm of v(t)is the maximum amplitude of the signal v(t)

Applying theorem (17) to equation (16) yields:

$$\max_{dy(t)\in L_2} \frac{\| y \|_2}{\| d_y \|_2} = \left\| \frac{W_d(s)}{1 + C(s,K)G_0(s)} \right\|_\infty \;\; ....(19)$$

The disturbance rejection sets out to be the condition for maximum amplitude of the output y(t) caused due to the disturbance on the plant dy(t) and must not exceed upper bound of pre-fixed point γ i.e.

$$\max_{dy(t)\in L_2} \frac{\| y \|_2}{\| d_y \|_2} = \left\| \frac{W_d(s)}{1 + C(s,K)G_0(s)} \right\|_\infty \angle \gamma \;\; ....(20)$$

Where $\gamma \leq 1$ is a design parameter (Disturbance rejection level).

The introduction of a weighting function $W_d(s)$ consists of a low-pass filter. These Weighting functions are chosen for the problem of H_∞ optimal control to indicate the transient response target. Weighted functions simultaneously with performance index calculates the robustness and performance of the closed loop system. The range of frequency for minimization is limited by finding a Hardy space $W_d(s)$. The weighting function $W_d(s)$ with the following properties:

$$|Wd\,(jw)| = high; \;\; 0 \leq \omega \leq \omega b$$

$$= low = \epsilon \;\; ; \omega \geq \omega b$$

Where ϵ is an arbitrarily small quantity not equal to zero (for non-trivial function to be analytic in R.H.S plane, its magnitude cannot be zero on a subject of the imaginary axis of positive measure.). Now the disturbance attenuation problem can be restated as, minimize $\|W_d(s)S(s)\|$ for attenuating disturbance on the plant's output, the controller has to be designed such that

$$\|W_d(s)S(s)\|_\infty \le 1$$

Where S(s) is called the Sensitivity function and given by $S(s) = [1+C(s)\,G(s)]^{-1}$

$W_d(s)$ is in the form of

$$W_d(s) = \frac{1}{\tau s}$$

By applying the H_∞ norm, the disturbance rejection constraint tends to

$$\left\|\frac{W_d(s)}{1+C(s,K)G_0(s)}\right\|_\infty = \max_{\omega\in[0,\infty)}\left(\frac{W_d(j\omega)W_d(-j\omega)}{(1+C(j\omega,K)G_0(j\omega))(1+C(-j\omega)G_0(-j\omega))}\right)^{0.5} \quad \text{.... (21)}$$

$$\left\|\frac{W_d(s)}{1+C(s,K)G_0(s)}\right\|_\infty = \max_{\omega\in[0,\infty)}\left(\alpha(\omega,K)\right)^{0.5} \quad \text{.... (22)}$$

Where,

$$\alpha(\omega,K) = \frac{\alpha_z(\omega,K)}{\alpha_n(\omega,K)} = \frac{W_d(j\omega)W_d(-j\omega)}{(1+C(j\omega,K)G_0(j\omega))(1+C(-j\omega)G_0(-j\omega))} \quad \text{.... (23)}$$

Henceforth, the condition for disturbance rejection can be expressed in the frequency domain as

$$\max_{\omega\in[0,\infty)}\left(\alpha(\omega,K)\right)^{0.5} < \gamma \quad \text{.... (24)}$$

The function α (*ω*, k) in equation (3.9) can also be written in the following form:

$$\alpha(\omega,k) = \frac{\alpha_z(\omega,k)}{\alpha_n(\omega,k)} = \frac{\sum_{j=0}^{p}\alpha_{zj}(k)\omega^{2j}}{\sum_{i=0}^{q}\alpha_{ni}(k)\omega^{2i}} \quad \text{.... (25)}$$

The numerator and denominator polynomials α_z (*ω*,k) and α_n (*ω*,k) have even powers of ω and the coefficients α_{zj} and α_{ni} are the functions of controller vector $\mathbf{k}^*$.

B. *Designing of Optimal Controller*

The sufficient condition to be considered is the constraint for disturbance rejection; thereby, it contributes no idea about the tracking of set point of the control system. The computation of controller vector **k,** is obtained by minimization of the performance index. Let the nominal H_2 performance index ITSE [6], is represented as

$$I = \int_0^\infty t.(e(t))^2\,dt \quad \text{.... (26)}$$

By the product of the Parseval theorem, it can be shown that the integral above can be determined. Let

$$f(t) = t^n.e(t) \quad \text{.... (27)}$$

$$g(t) = e(t) \quad \text{.... (28)}$$

Applying Laplace transformation to equation (27)

$$L[f(t)] = \left[-\frac{d}{ds}\right]^n E(s)$$

Using the Parseval Theorem, the integral 'I' can be represented in the frequency domain as follows.

$$\int_0^\infty f(t).g(t).dt = \frac{1}{2\pi}\int_{-j\infty}^{+j\infty} F(s).G(s).ds \quad \text{... (29)}$$

$$f(t) = t.e(t) \quad \text{... (30)}$$

$$g(t) = e(t) \quad \text{... (31)}$$

$$I = \frac{-1}{2\pi j}\int_{-j\infty}^{+j\infty}\frac{d}{ds}\left(E(s)\right).E(-s)ds \quad \text{... (32)}$$

The error signal E(s) can be expressed in rationalized function form as

$$E(s) = \frac{D(s)}{A(s)} = \frac{\sum_{j=0}^{m} d_j s^{m-j}}{\sum_{i=0}^{n} a_i s^{n-i}} \quad \text{... (33)}$$

Introducing E(s) from Equation (33) into Equation (32) results in the following:

$$I = -\frac{1}{2\pi j}\int_{-j\infty}^{+j\infty}\frac{d}{ds}\left\{\frac{\sum_{j=0}^{m} d_j s^{m-j}}{\sum_{i=0}^{n} a_i s^{n-i}}\right\}.\frac{\left(\sum_{j=0}^{m} d_j(-s)^{m-j}\right)}{\left(\sum_{i=0}^{n} a_i(-s)^{n-i}\right)}ds \quad \text{... (34)}$$

Equation (34) can be solved analytically by means of the Residue Theorem. If the control system is stable, then the value of I_n is always positive. For unstable control systems, the value of I_n is not computable. Because the coefficients a_i with i=0…n and d_j with j=0…m contains the controller parameters, the calculation of suitable controller parameters can be carried out by minimization of $I_n(\mathbf{k^*})$.

While designing the disturbance rejection controller of optimal form with fixed structure, both the disturbance rejection and tracking behavior are considered. The design of the controller has to be expressed as a constrained optimization problem, i.e.

$$\min_K I_n(K)$$

Subjected to

$$\max_\omega \left(\alpha(\omega, K)\right)^{0.5} < \gamma \quad \dots (35)$$

While designing the optimal robust disturbance rejection controller with fixed structure, the disturbance rejection and tracking behavior along with robust stability constraint are considered. The design of the controller then has to be expressed as a constrained optimization problem, i.e.

$$\min_K I_n(K)$$

Subjected to

$$\max_\omega \left(\alpha(\omega, K)\right)^{0.5} < 1 \quad \dots (36)$$

The optimization problem mainly consists of the minimizing the performance index i.e. $I_n(\mathbf{k^*})$ which is subject to the disturbance rejection constraint [6] and/or robust stability constraint as shown in the figure 3. The objective of the optimization is to identify the vector of the parameters $\mathbf{k^*}$ such that the value of the performance index $I_n(\mathbf{k^*})$ is minimum to satisfy the condition for the disturbance rejection.

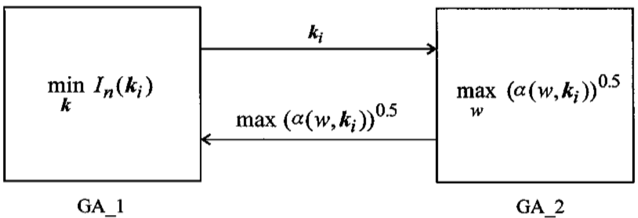

Figure 3: Representation of H_∞ controller by GA

Table 1: ITSE performance index by GA parameters

Parameter	Value/type
GA-1's Population size	100
GA-2's Population size	50
GA-1's max generation	100
GA-2's max generation	50
Type of selection	Tournament
Type of crossover	Arithmetic
Crossover parameter	0.5
Probabilities of crossover (p_{c1}, p_{c2})	0.35
Type of mutation	Uniform
Probabilities of mutation (p_{m1}, p_{m2})	0.02
Parameter bounds	[0, 30]

The penalty constants were taken as M_1=100 and M_2=1, 00,000.

C. H_∞ Controller Using GA for PMDC Motor

Genetic Algorithm is based upon the concepts of natural selection and genetic modification [8]. Two Genetic Algorithms is employed in this paper to obtain the results of constrained optimization problem. First Genetic Algorithm (GA-1) is formulated to minimize the performance index I_n(k) and the controller parameter is optimized within the specified search domain. Second Genetic Algorithm (GA-2) is used to design the H_∞ control such that the disturbance rejection constraint α(ω,sk) is maximized, which has to be initialized with variable frequency ω. The optimal controller parameters are transferred to the GA-2 so that the disturbance rejection constraint during fixed generations is maximized. If the maximum value of disturbance rejection constraint is less than γ, it indicates that H_∞ controller design is satisfactory. When the maximum value of disturbance rejection constraint is larger than γ, again search process for controller parameters will be started until controller parameters satisfies the disturbance rejection constraint. Performance index by GA parameters with respect to ISTE is shown in Table 1 [6]. Genetic Algorithm consists of three operators; tournament selection, arithmetic crossover, and mutation. The design of H_∞ controller by Genetic Algorithm process is represented in the figure 4 [6].

i). Selection: The process of selection is to pick the fittest individual from a population to further go into next generation. Tournament selection then compares the fitness of each individual in consecutive individuals and decides which individual goes on to the next population. During the tournament selection, the part individuals in the population are arbitrarily selected into a subpopulation therefore by competition the fittest individual in each subpopulation is identified.

ii). Crossover: This process includes the selective copies to be inserted in the newest population. Also by exchanging the genetic material between the individuals the finest individual emerges as the result. Further these Two individuals are chosen and thereby crossed. Resulting the offspring which replaces the parents in the new population.

iii). Mutation: Mutation is the random occasional alteration of the information contained in the chromosome. By itself, mutation is random but when it is combined with crossover, it acts to improvise the GA performance by preventing premature loss of genetic information from the GA population [8]. This process is achieved with the probability p_m and probability of this process which is fixed before the optimization. For each term, a random number between zero and one is founds, which is then compared with the mutation probability.

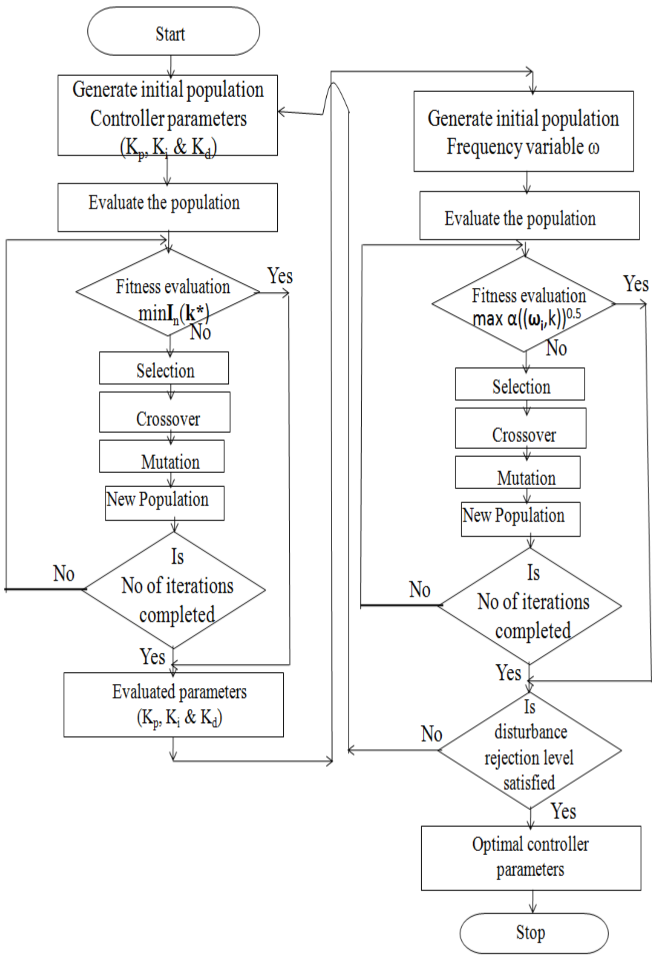

Figure 4: Flow chart of design of H∞ controller by GA.

SIMULATION RESULTS AND DISCUSSIONS

In order to assess the dynamic behavior and robustness of designed H∞ controller according to the above procedure, simulations are made by considering model of PMDC motor Maxon RE 35 (catalogue number 273754) [2]. The parameters of Maxon RE 35 PMDC motor are tabulated in Table 2.

Table 2: Parameters of PMDC motor [Maxon RE 35]

Parameter	**Symbol**	**Values**	**Units**
Armature Resistance	Ra	2.07	Ω
Armature Inductance	Lm	$6.2*10^{-4}$	H
Moment of Inertia	J	$7.2*10^{-6}$	Kg-m2
Torque Constant	Kt	0.052	Nm/A
Back Emf const	Kb	0.052	Vs/rad
Coefficient of viscous friction	Kf or B	$4.8*10^{-5}$	Nms/rad

The closed loop transfer function of PMDC motor is given by

$$G(s)=\frac{\omega_r}{V_a}(s)=\frac{19.23}{0.000001651s^2+0.005512s+1} \quad \ldots (37)$$

Weighting function Wd(s) is chosen as [6]

$$W_d(s)=\frac{1}{50s+1} \quad \ldots (38)$$

The controller C(s) can be described in the form of transfer function follows:

$$C(s)=k_p+\frac{k_i}{s}+k_d s \quad \ldots (39)$$

$$C(s)=\frac{k_d s^2+k_p s+k_i}{s} \quad \ldots (40)$$

The limits of parameters are [0, 1]. Then vector **k** of the controller parameters is represented by:

$$k=\begin{bmatrix}k_p & k_i & k_d\end{bmatrix}^T \quad \ldots (41)$$

The error signal E(s) is given by

$$E(s) = \frac{R(s)}{1 + C(s)G_0(s)} \quad \dots (42)$$

By introducing C(s), R(s) and G(s):

$$E(S) = \frac{d_0 s^2 + d_1 s + d_2}{a_0 s^3 + a_1 s^2 + a_2 s + a_3} \quad \dots (43)$$

Where

$$d_0 = a_0 = 0.000001651, d_1 = 0.005512, d_2 = 1,$$
$$a_1 = 0.005512 + 19.23K_3, a_2 = 1 + 19.23K_1, a_2 = 19.23K_2$$

The Integral Time-weighted Squared Error (ITSE) performance index for a speed control of PMDC motor is given by

$$I_3(k) = \frac{d_2^2}{4a_3^2} - \frac{d_0 d_1 + d_1 d_2 \frac{a_1}{a_3}}{2(a_1 a_2 - a_0 a_3)} + \frac{d_0^2(a_2^2 + a_1 a_3) + (d_1^2 - 2d_0 d_2)(a_0 a_2 + a_1^2) + \frac{d_2^2}{a_3}(a_0^2 a_3 + a_1^2)}{2(a_1 a_2 - a_0 a_3)^2}$$

The disturbance attenuation constraint is given by

$$\max_{w \in [0,\infty)} \left(\frac{\alpha_z(\omega,k)}{\alpha_n(\omega,k)} \right)^{0.5} < \gamma$$

Therefore,

$$\frac{W(s)}{1 + C(s)G_0(s)} = \frac{ps^3 + qs^2 + rs}{as^4 + bs^3 + cs^2 + ds + e} \quad \dots (45)$$

$$p = 0.000001651, q = 0.005512, r = 1$$
$$a = 0.00008255, b = 0.275601651 + 961.5k_3,$$
$$c = 15.005512 + 961.5k_1 + 19.23k_3,$$
$$d = 1 + 961.5k_2 + 19.23k_1, e = 19.23k_2$$
$$\alpha_z(\omega, k) = r^2\omega^2 + (q^2 - 2rp)\omega^4 + p^2\omega^8 \quad \dots (46)$$

$$\alpha_n(\omega, k) = a^2\omega^8 + (b^2 - 2ac)\omega^6 + (c^2 + 2ae - 2bd)\omega^4 + (d^2 - 2ce)\omega^2 + e^2 \quad \dots. (47)$$

The step input is applied for PMDC motor and the corresponding step response of the motor without controller is shown in Figure 5 and Figure 6.

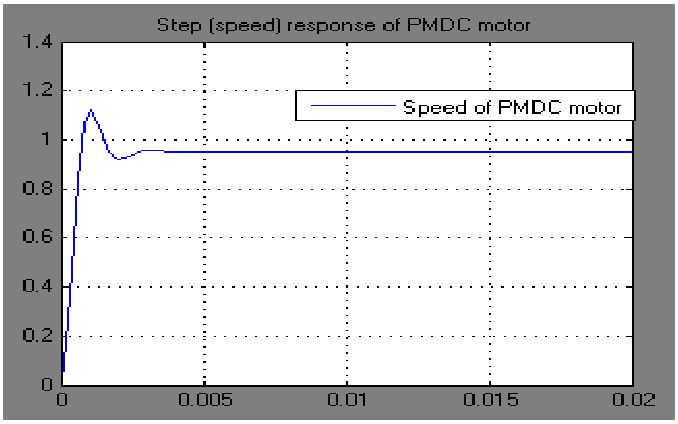

Figure 5: Step (speed) response of PMDC motor

The step input is applied for PMDC motor and the corresponding step response of the motor without controller is shown in Figure 5. The step response of speed control of PMDC motor without controller exhibits little bit maximum peak overshoots and the settling time is almost infinity. Therefore, H_∞ controller is necessary to stabilize the speed of motor.

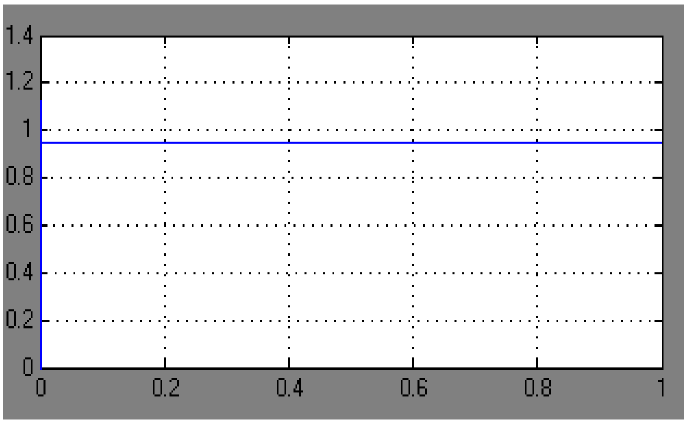

Figure 6: Step response of speed control of PMDC motor

Now, the designed H_∞ controller is incorporated to the speed control of PMDC motor and the controller performance can be evaluated in terms of unit step response of speed control of motor even though in presence of arbitrary disturbance. Initially, H_∞ controller is adopted in speed control of PMDC motor to stabilize speed of the PMDC motor as well as to exhibits better dynamic behavior such as nullification of peak overshoot and get less settling time. Then, in the presence of internal or external disturbance, the same optimal H_∞ controller is able to minimize the effect of disturbance on speed of the PMDC motor. In the process of design of H_∞ controller using Genetic algorithm, the plots of performance index minimization for evaluation of controller parameters and disturbance attenuation maximization verses no of iterations are shown in Figure 8 and Figure 9. The optimal control parameters are kp=0.01,ki=0.9, kd=2x10-9 .The unit step responses of speed control of motor along with H_∞ controller in presence and absence of disturbances as shown in Figure 7.

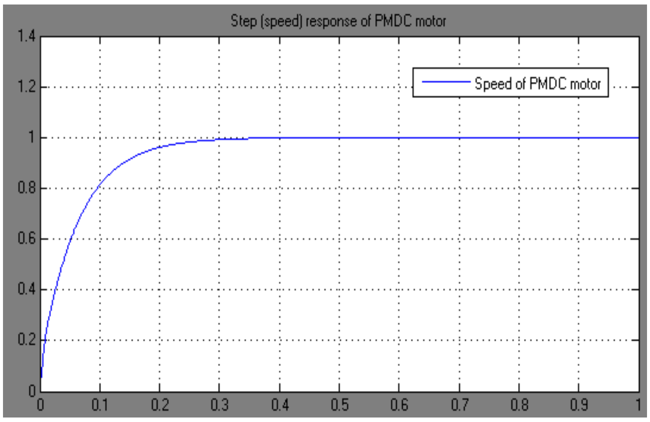

Figure 7: Step (speed) response of PMDC motor with controller

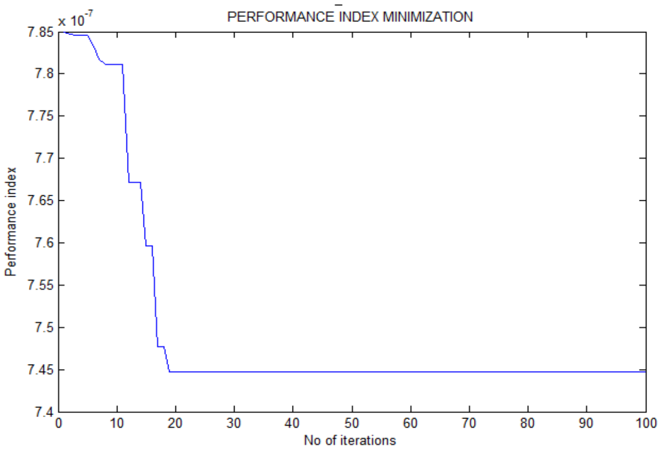

Figure 8: Performance index minimization (I_{min})

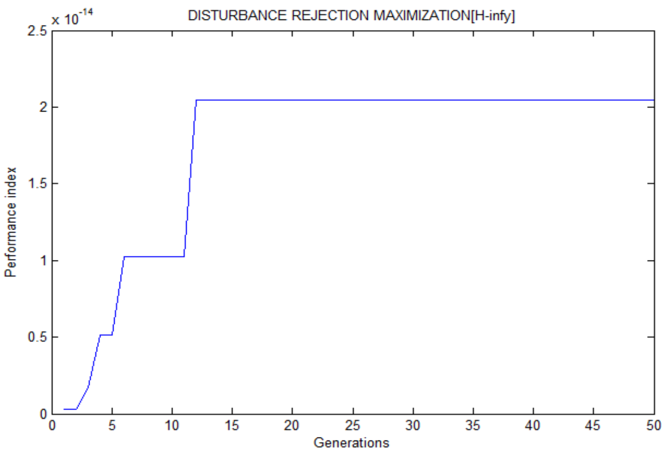

Figure 9: Disturbance attenuation maximization

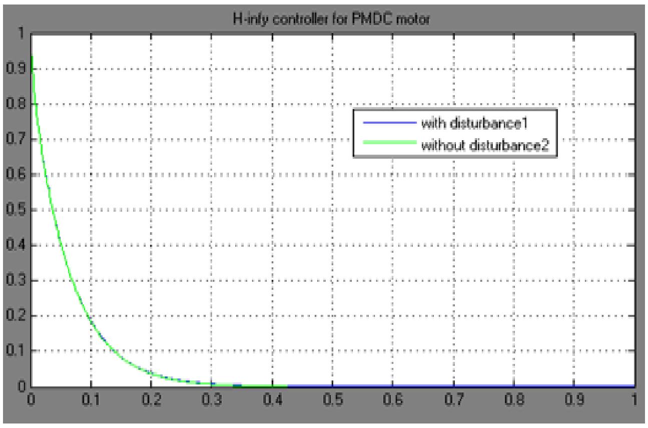

Figure10: Error response(speed) of PMDC motor with controller

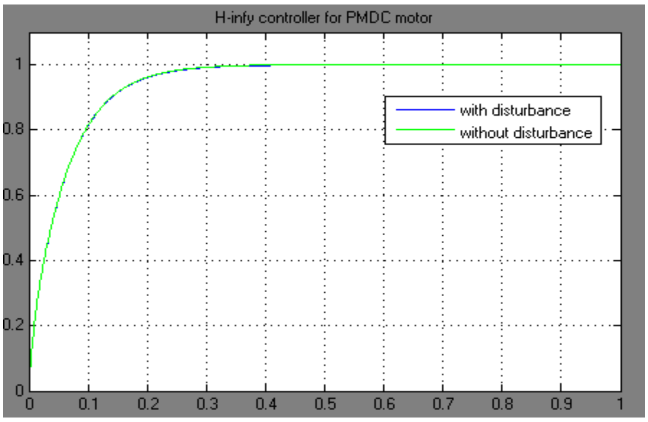

Figure 11: Step response (speed) of PMDC motor with and without controller

In Figure 5 and Figure 6, settling time of motor is almost ∞ which implies, the speed of PMDC motor is not up to rated speed. Whenever the H_∞ controller is incorporated into the system then the PMDC motor can reach its rated speed within 3.5 seconds only, which is shown in Figure 11. If any external or internal disturbance is included in the motor, the disturbance has an effect in the speed of the motor but here, H_∞ controller able to minimize the effect by disturbance on the speed of PMDC motor as shown in Figure10.

CONCLUSION

The design technique of H_∞ controller by Genetic algorithm for speed control of PMDC motor works effectively with good dynamic behavior of motor's speed. In the absence of the controller, the settling time is almost infinity and exhibits peak overshoot. When H_∞ controller incorporated to the plant results with lower settling time and there exhibits no overshoots. The optimal H_∞ controller can provide the robustness to the speed of PMDC motor even in the presence of arbitrary disturbance. Henceforth, it is concluded that the dynamic performance of speed control of PMDC motor with arbitrary disturbance to the motor presents almost no difference, as compared with zero disturbance case. Therefore, the optimal H_∞ controller can provide the robustness to the motor's performance.

Further developments in the design technique are possible in many ways. This idea can also be further applicable to the precise position control of motor as futuristic idea when the input arbitrary disturbances are taken into accountability.

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