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Performance Evaluation H$^\infty$ Controller in Comparison with PID, Observer Based Control and Sliding Mode Control

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ABSTRACT: An attempt has been made to analyze the performance of different controllers which have been developed thus far. Robust control methods have been applied and the, performance of H$^\infty$ controller has been evaluated with classical PI controller, sliding mode controller and observer based control technique. The parameters of permanent Magnet synchronous motor have been considered for performance evaluation is verified.

Key Words: PMSM, H$^\infty$ Controller, sliding mode controller, PI Controller.

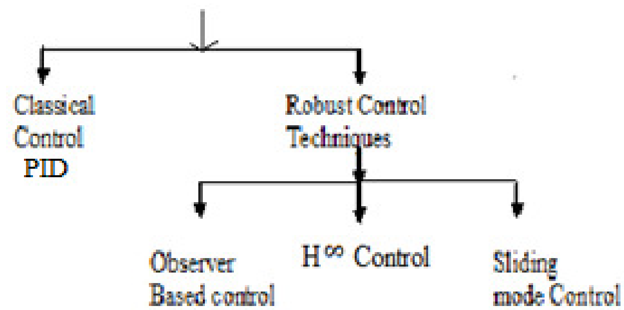
I. INTRODUCTION

In recent years due lot of advancements in mathematical controllers and very powerful software's like MATLAB, Model SIM and Lab view. The mathematically modeled controller models can be applied to practical problems and analysis can be easily done, one of the significant application of control system is to the control of acceleration and velocity in PMSM, linear DC motor, reluctance Motor, DC Motor used in wheeled mobile robot, Linear synchronous motor with parametric uncertain servo systems, and many other practical application motors [1]

A control system is a set of device that commands direct and regulates its own behavior itself or the behavior of some other system [1] [8]. The Operating mechanism of control system is examined by means of numerical modeling of the regulator actuators. Controller then, deals with the functioning of a system in interdisciplinary filed of Engineering and mathematics [6] all the modern control computational techniques have been used in design and analysis of systems.

II. CLASSIFICATION

Generally Control system can be classified as either classical control theory or modern control theory depending on the type of signal that is required to be handled. Analysis can be done in time domain and frequency domain based on the type of technique used, many stability analysis techniques used to analyze the stability.



The system can be classified as deterministic, if the behavior of system exhibits a repetitive pattern [7] Controller with Robust performance or stabilization can be developed by utilizing H$^\infty$ control technique [1]

Contemporary control techniques such as sliding mode control, feedback linearization control, adaptive control, back stepping principle and Fuzzy Logic control are employed for solving speed or position control problems in many application motor such as (Permanent Magnet Synchronous Motor)[5].

III. PID

The proportional integral derivative (PID) controller is widely used in many control applications because of its simplicity and effectiveness. Use of PID has been long lasting in the field of control Engineering the three control gain parameters, proportional gain K_P, Integral Gain K_I and derivative gain K_D, are usually fixed. The disadvantages of PID are poor capabilities of dealing with system uncertainty i.e. Parameter variation and external disturbance.

In recent years Robustness has gained more and more attention and they have been extensive Interest in self tuning the above three gains, hence PID in used as an adaptive PID to cope with external disturbance [3] A genetic algorithm was used to find the optimum tuning parameters of PID controller by taking integral of absolute error as fitting faction. SMC is used for uncertain systems[5-7]. PID do not work for non linear system. Fuzzy Logic is also used with PID.

$$u = ke + \frac{1}{1+st} \quad (1)$$

$$u = k\left(\frac{1}{1+st}\right)e = \left(k + \frac{k}{st}\right) \quad (2)$$

Here the PID Controller considered as a cascade of PI and PD actions the forward path transfer function of PD controller with plant is

$$G_P(s) = \frac{0.129(1+sK_d)}{s^2+0.25\,s} \quad (3)$$

IV. H$^\infty$ CONTROLLER

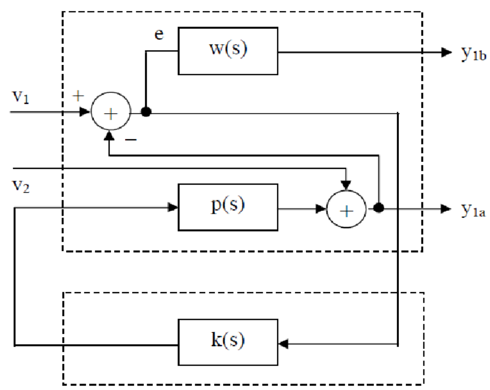
H$^\infty$ Controllers a powerful technique to design robust controller for system under consideration with uncertainties parameters change and disturbance. H$^\infty$ is kind of loop shaping method of closed loop system. So that, H$^\infty$ norm is minimized under unknown disturbance and plant uncertainties $\left\|\frac{SW_s}{TW_t}\right\|_\infty < 1$,

$$\begin{bmatrix}\phi_d\\ \phi_q\\ \phi_p\end{bmatrix} = \begin{bmatrix}L_d & 0 & 0\\ 0 & L_q & 0\\ 0 & 0 & L_p\end{bmatrix}\begin{bmatrix}I_d\\ I_q\\ I_p\end{bmatrix} \quad (4)$$

$$\begin{bmatrix}V_d\\ V_q\end{bmatrix} = \begin{bmatrix}R+L_d' & -\omega L_q\\ \omega L_d & R+L_q'\end{bmatrix} + \begin{bmatrix}0\\ \omega L_P I_P\end{bmatrix} (5)$$

It gives stable controller to satisfy the above equation Using multi-objective optimization based on genetic algorithm the fittest chromosome, say X^{fit}, is selected from the selection pool i.e. the chromosome which has the maximum fitness among all the chromosomes that are present in the selection pool.

Augmented plant



Controller

H$^\infty$ Controller Scheme

Based on the gene values of X^{fit}, the remaining chromosomes thatare present in the selection pool are modified as follows:

$$x_j^{new_k} = \begin{cases} x_j^{(k)} + \frac{1}{x_j^{(k)}} & ; if \quad x_j^{(k)} < x_j^{fit} \\ x_j^{(k)} & ; if \quad x_j^{(k)} = x_j^{fit} \\ x_j^{(k)} - \frac{1}{x_j^{(k)}} & ; if \quad x_j^{(k)} > x_j^{fit} \end{cases} \quad (6)$$

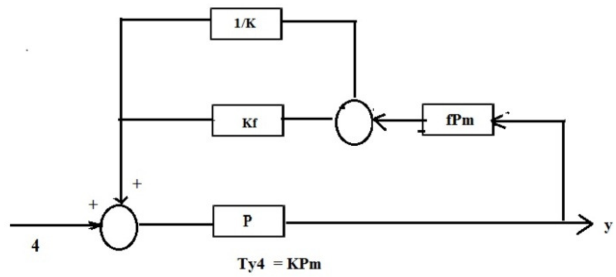
The genes of the obtained new chromosomes are modified such that the following criterion is satisfied.

$$x_j^{new} = \begin{cases} x_j^{\min} & ; if \ x_j^{new} < x_j^{\min} \\ x_j^{\max} & ; if \ x_j^{new} > x_j^{\max} \\ x_j^{new} & ; otherwise \end{cases} \quad (7)$$

V. OBSERVER BASED CONTROL

Here observed is designed to include pure list and mismatched dynamics between actual system and observer model (2) K Kaneko.

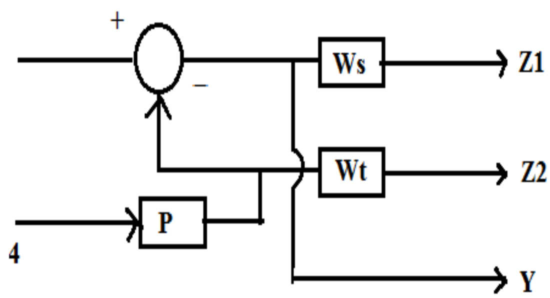
It is equivalent to assume the system dynamics as the observer model



It works well for limited frequency it is very difficult to change the low pass filter system is sensitive to measurement noise as the loop gain is very high to assume good convergence of observer.

VI. SLIDING MODE CONTROL

The sliding mode control is based on variable structure systems in characterized by its change to control structure. The system in sliding mode is constrained to the pre-described switching hyper plane. The control structure is altered depending on the side of hyper plane to let the system approach to it and then the system sliding mode is identical to the hyper plane. It is based on LQG Design (3) U+Kin V.I. and K.S. Young



Plant structure using sliding mode control.

The analysis of the above mathematical computation is discussed in table 1

Table 1: Performance Comparison.

Specification	Nominal plant	Plant with PID Control	Plant with sliding mode controller	Plant with observer based controller	Plant with H^{∞} control
Rise time(t_r)	11 sec	5.8 sec	5.0 sec	4.3 sec	3.52 sec
Settling time(t_s)	37 sec	10.6 sec	9.0 sec	7.40 sec	5.10 sec
Peak overshoot(M_p)	25.28 %	21.3%	15.5%	8.4%	1.10%
Steady state eror(e_{ss})	0.1	zero	zero	zero	zero

VII. RESULTS

The step response performance of H^{∞} compared to other robust control techniques is much better as shown in figure 1. Combined performance is shown in figure 2.Velocity response in figure 3.

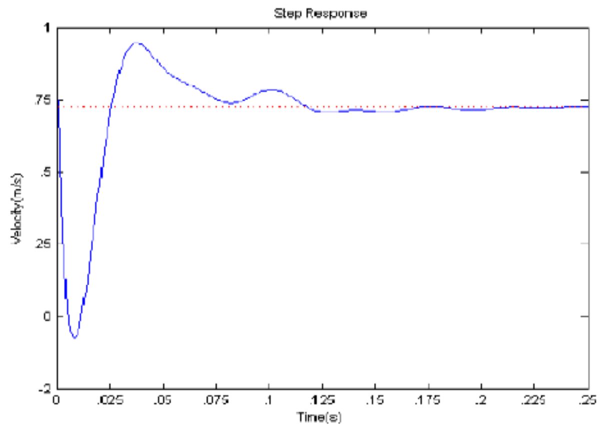


Fig. 1.

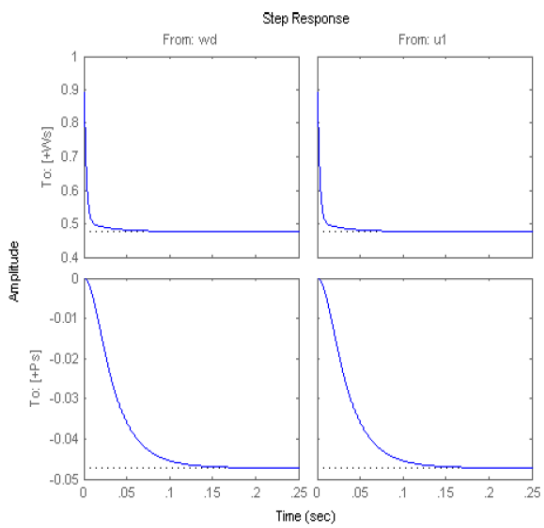


Fig. 2.

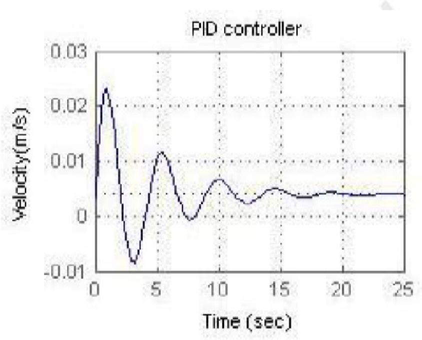


Fig. 3.

CONCLUSION

Based on the above results the Robust H^{∞} and conventional PID when compared with the other Robust control techniques mentioned in the above table-1 the time response for unit step input are obtained and the performance based on time domain specifications were observed. The transient response characteristics depend on close loop poles of the system.

The performance of H^{∞} is better compare to sliding mode control and observer based control $^{\text{the}}$ table 1 provides the comparison of performance specifications of feedback loops comprising PID, H^{∞} control the responses are as shown in fig 1 and 2.

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