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MFAC based SMC Combine Algorithm for the Stability of PMDC

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Abstract

A discrete time sliding mode control of PMDC motor can be combine with the Model Free Adaptive Control (MFAC) to reduce time, cost and difficultly of nonlinear reliable system commonly used mathematical modelling which is quite difficult to operate. As in system model it does not require any prior data but only depends upon data collected by system Inputs/Outputs. Theoretically, to increase the rate of convergence, pseudo partial derivative (PPD) must be used for MFAC control Algorithms and strict mathematical assumptions can be made to verify the stability of the system. This research proposed a MATLAB based valid control algorithm used for speed and position tracking control of PMDC linear motor. This research also compares analysis between PID and model free learning adaptive control (MFLAC) using simulations and verify the speed and position tracking of linear PMDC motor has a better control performance with robust and precise tracking.

***Keywords**: Model free adaptive control (MFAC), Sliding mode control (SMC), Model Free Learning Adaptive Control (MFLAC), Permanent Magnet DC (PMDC)*

1. Introduction

PMDC motors are currently used as adaptable speed drive systems for automotive, aerospace, automation, and industrial applications because of their low maintenance cost and high power density [1]. However, accurate functioning of these systems presents significant challenges that are associated with modeling, control, dynamical analysis, and application aspects. Moreover, nonlinearity has been observed in many classes of motor drive systems therefore uncertainties and disturbances in a nonlinear system should overcome [2].

Conventional PID control technology due to its simple principle and adaptable nature has been widely applied in various fields of process control; however, PID is highly ineffective for strongly nonlinear, time varying and control of complex systems with uncertain parameters [3, 4, 5]. On the other side, SMC has some attractive feature such as a fast response, good transient performance, insensitive to match parameters and disturbances. Hence, the SMC control approach for uncertain systems is robust and possible to control the effect of both unknown time varying parameters and disturbances. The sliding control method is successfully applied in a motor application [6, 7].

Most of the traditional control theory depends upon the system model, state space model or input-output model based control Methods [8]. As nonlinear system, modeling is time-consuming and cost effective. It is not convenient to establish a reliable system model [9]. Therefore, model free adaptive control approach is considered.

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During recent years, the MFAC method has been recommended for nonlinear SISO discrete-time systems with a well-organized structure. The comparison of MFAC algorithm with other model based adaptive algorithm shows that MFAC has numerous attractive features that make it useful in various real-world control problems. MFAC uses real time measured data from the system input/output to design a general purpose controller without any need of mathematical model or training process as required in neural network control, so the overall cost of the controller is lower [10, 11, 12]. MFAC is modest, robust and can simply be applied with minimum mathematical calculations. On considering few assumptions, stability convergence of CFDL based MFA control and PFDL based MFA control of SISO discrete time nonlinear systems are guaranteed [9]. MFAC has better results than other data driven approach such as VRFT, IFT, unfalsified control (UC) [10, 11]. Moreover, the MFAC algorithm has been successfully carried out in actual real world Process control [13, 14, 15].

In this article, the characteristics of MFAC are combined with sliding mode control algorithms. This algorithm is based on tight format linearization for a discrete time nonlinear system. The algorithm not only uses the PPD estimation of the past time, but also transforms a model based SMC in a data driven control. Thus, the modeling process of controlled system is omitted, thereby excluding the un-modeled dynamics present in the control system.

This proposed method is also compared with traditional PID and Model free learning adaptive control (MFLA) and is successfully applied to the PMDC linear motor. Stability and performance analysis were verified using Simulink.

2. MFAC

2.1. Compact Algorithm for Nonlinear Systems

The general SISO nonlinear discrete-time input/output system can be expressed as follows:

$$y(\kappa+1) = f\left(y(\kappa), y(\kappa-1), ..., y(\kappa-n_h), u(\kappa), u(\kappa-1), ..., u(\kappa-n_u)\right), \tag{1}$$

Where: $y(\kappa)$ is the output and $u(\kappa)$ is the input of the systems $, n_y, n_u$ are the unknown order of the output and input respectively, $f(...)$ is a generally unknown nonlinear function. The dynamic linearization technique is based on the assumptions in literature [16]. The discrete time nonlinear system must satisfy the assumptions in the literature [16, 17].

From equation (1) if the system satisfies the assumptions, when $\Delta u(\kappa) \neq 0$, there exists a PPD $\phi(\kappa)$, such that the equation (1) becomes the following partial form dynamic linearization.

$$\Delta y(\kappa+1) = \phi(\kappa)\Delta u(\kappa), \tag{2}$$

Where:

$\phi(\kappa) = \left[\phi_1(\kappa), ..., \phi_n(\kappa)\right], \left|\phi(\kappa)\right| \le b,$ where b is a constant.

Considering the assumption of the established conditions, equation (2) can be rewritten as,

$$y(\kappa+1) = y(\kappa) + \left[\phi(\kappa)\Delta u(\kappa)\right]. \tag{3}$$

2.2. Pseudo Partial Derivative Estimation Method Based On Compact Algorithm

The existing methods for PPD estimation introduce a new parameter estimation criterion as introduced as follows:

$$J(\phi(\kappa)) = \left[\left(y^*(\kappa) - y(\kappa-1) - \phi(\kappa)\Delta u(\kappa-1) \right)^2 + \mu \left(\phi(\kappa) - \hat{\phi}(\kappa-1) \right)^2 \right], \tag{4}$$

By using equation (2), the minimization of the criterion functions gives control law algorithm and estimation algorithm $\phi(\kappa)$ is,

$$\phi(\kappa) = \left[\hat{\phi}(\kappa-1) + \left(\frac{\eta_\kappa \Delta u(\kappa-1)}{\mu + |\Delta u(\kappa-1)|^2} \right) \cdot \left(\Delta y(\kappa) - \hat{\phi}(\kappa-1)\Delta u(\kappa-1) \right) \right], \tag{5}$$

$$\hat{\phi}(\kappa) = \hat{\phi}(1), \text{ If } \left|\hat{\phi}(\kappa)\right| \le \varepsilon, \text{ or } |\Delta u(\kappa-1)| \le \varepsilon, \tag{6}$$

Where: μ is positive weighting constant, η_κ are step size constant series and $\eta_y \subset (0,2)$, $\hat{\phi}(1)$ is the initial estimation information of $\hat{\phi}(\kappa)$, ε is a positive constant.

When $\Delta u(\kappa)$ and the sampling instant values are too small, $\phi(\kappa)$ is considered to be the slow time varying parameter which can be ignored by $u(\kappa)$. The adaptive control system can be designed by, integrating equation (3), (5), (6) will introduce the equation (7).

$$y(\kappa+1) = y(\kappa) + \left[\left(\hat{\phi}(\kappa) + \delta_\phi(\kappa) \right) \Delta u(\kappa) \right], \tag{7}$$

Where: $\delta_\phi(\kappa) = \left[\phi(\kappa) - \hat{\phi}(\kappa) \right]$, is the parameter estimation error. Since $\phi(\kappa)$ is the PPD of the system, it cannot be used in practice, use $\hat{\phi}(\kappa)$ instead of the actual value of $\phi(\kappa)$, and system can only get the past value of $\hat{\phi}(\kappa)$, that is $\hat{\phi}(\kappa-1)$ and we get parameter estimation as follows:

$$\delta_\phi(\kappa) = \hat{\phi}(\kappa-1) - \hat{\phi}(\kappa-2),$$

In addition, the equation (7) can be expressed as follows:

$$y(\kappa+1) = \left(y(\kappa) + \left(\hat{\phi}(\kappa) + \hat{\phi}(\kappa-1) - \hat{\phi}(\kappa-2) \right) \Delta u(\kappa) \right). \tag{8}$$

2.3. MFLAC based Control Algorithm

The idea of the MFLAC algorithm is the same as MFAC and control design is only depending on system input and output. The dynamic linearization techniques are also based on the assumptions consider in the section 2.1.

The control algorithm for MFLAC is based on weighted one-step control input criterion function as follows:

$$J(u(k)) = \left| y^*(\kappa+1) - y(\kappa+1) \right|^2 + \lambda \left| u(\kappa) - u(\kappa-1) \right|^2 \tag{9}$$

Where λ is the weighting function and $\lambda|u(\kappa) - u(\kappa-1)|^2$ is the criterion function. Substituting equation (2) into equation (9) then differentiating equation (4) with respect to $u(k)$ and setting it is zero will result in the following control law as follows:

$$u(\kappa) = \mathrm{u}(\kappa-1) = \frac{\rho_\kappa \phi(\kappa)}{\lambda + \phi(\kappa)^2} \left(y^*(\kappa+1) - y(\kappa) \right) \tag{10}$$

In addition, the parameter estimation algorithm is as follows:

$$\hat{\phi}(\kappa) = \left[\hat{\phi}(\kappa-1) + \left(\frac{\eta_\kappa \Delta u(\kappa-1)}{\mu + |\Delta u(\kappa-1)|^2} \right) \cdot \left(\Delta y(\kappa) - \hat{\phi}(\kappa-1)\Delta u(\kappa-1) \right) \right], \tag{11}$$

For SISO nonlinear system only one parameter is needed to be adjusted and is different from the traditional adaptive control system and only depend upon the input and output of the system.

3. MFA Based Adaptive SMC Algorithm

The discrete sliding mode function is given below:

$$s(\kappa) = e(\kappa) + c \cdot e(\kappa - 1), \tag{12}$$

Where: where c must satisfy the Hurwitz condition $c > 0$. And tracking error $e(\kappa)$ which is well-defined as,

$$e(\kappa) = y^*(\kappa) - y(\kappa), \tag{13}$$

Where: $y^*(\kappa)$ is the desired tracking trajectory, $y(\kappa)$ is the system output. By using discrete exponential reaching law,

$$s(\kappa+1) = (1-q)s(\kappa) - \varepsilon \cdot sgn(s(\kappa)) \ , \tag{14}$$

$\varepsilon > 0$, $0 < q < 1$,

From equation (12) and (14) the equivalent derived equation is

$$e(\kappa+1) = (1-q)\cdot s(\kappa) - \varepsilon \cdot sgn(s(\kappa)) - c \cdot e(\kappa), \tag{15}$$

Let $\beta 1 = e(\kappa+1) = (1-q)\cdot s(\kappa) - \varepsilon \cdot sgn(s(\kappa)) - c\cdot e(\kappa)$,

By using equation (15) tracking error becomes

$$\left(y^*(\kappa+1) - y(\kappa+1)\right) = \beta 1, \tag{16}$$

By solving equation, (8) and (16) produce the following result:

$$\Delta u(\kappa) = \left(\left(\frac{1}{\hat{\phi}(\kappa) + \left(\hat{\phi}(\kappa-1) - \hat{\phi}(\kappa-2)\right)} \right) \cdot \left(y^*(\kappa+1) - y(\kappa) - \beta 1\right) \right), \tag{17}$$

Combining $\Theta(k) = \left(\dfrac{1}{\hat{\phi}(\kappa) + \left(\hat{\phi}(\kappa-1) - \hat{\phi}(\kappa-2)\right)} \right)$,

Put the value of $\beta 1$ and then Equation (12) and (17) establish the following control law:

$$u(\kappa) = \left(u(\kappa-1) + \Theta(\kappa) \times \left(y^*(\kappa+1) - y(\kappa) - \beta 2 + \varepsilon \cdot sgn\left(e(\kappa) + c\cdot e(\kappa-1)\right)\right)\right), \tag{18}$$

Where $\beta 2 = (1-c-q)\cdot e(\kappa) - c(1+q)\cdot e(\kappa-1)$

Since $\Theta(\kappa)$ is linear convergence slow varying parameter may not be able to satisfy the necessity of the controlled system, therefore, the equation (18) can be improved in the following expression:

$$u(\kappa) = \left(u(\kappa-1) + \tilde{\Theta}(\kappa) \times \left[\mathrm{y}^*(\kappa+1) - y(\kappa) - \beta 2 + \varepsilon \cdot sgn\left(e(\kappa) + c \cdot e(\kappa-1)\right)\right]\right), \tag{19}$$

Where

$$\tilde{\Theta}(\kappa) = \left(\frac{\rho_\kappa \cdot \left(\hat{\phi}(\kappa) + \left(\hat{\phi}(\kappa-1) - \hat{\phi}(\kappa-2)\right)\right)}{\lambda + \left|\hat{\phi}(\kappa) + \left(\hat{\phi}(\kappa-1) - \hat{\phi}(\kappa-2)\right)\right|^2} \right),$$

Equation (19) is the MFA based SMC control law converges exponentially that will result in a reduction of time of regulation and it causes no effect on stability. Where λ is the weighting factor, ρ_κ is the step sequence, and $\rho_\kappa \subset (0,2)$. By solving equation, (19) and (12) result in stable polynomials c that ranges from $0 < c < \min\left\{\frac{1-q}{2-q}, \frac{-1+\sqrt{4q^2-8q+5}}{2(1-q)}\right\}$.

Analysis shows that: $\tilde{\Theta}(\kappa)$ is Quadratic convergence and $\hat{\phi}(\kappa-1)$, $\hat{\phi}(\kappa-2)$ values are present in the control law, thus MFA based adaptive SMC is greatly improved. It can be seen that the equation (19) has discontinuous $sgn()$ function. This function will establish a high frequency chattering at sliding mode surface. This high frequency will reduce the performance of the control system and can not be applied to actual control system. To eliminate the high frequency chattering replace $f\left(s(\kappa)\right) = \frac{s(\kappa)}{\left|s(\kappa)\right| + \Delta}$ with $sgn()$ function in equation (19) [18-19]. By replacing the above function, it will convert discontinuous function of continuous signal that will result in a reduction of chattering effect.

The new control algorithm becomes the following equation.

$$u(\kappa) = \left(u(\kappa-1) + \tilde{\Theta}(\kappa) \times \left[\mathrm{y}^*(\kappa+1) - y(\kappa) - \beta 2 + \varepsilon \cdot f\left(e(\kappa) + c \cdot e(\kappa-1)\right)\right]\right), \tag{20}$$

Where $f\left(e(\kappa) + c \cdot e(\kappa-1)\right) = \left(\frac{e(\kappa) + \mathrm{c} \cdot \mathrm{e(k-1)}}{\left|e(\kappa) + \mathrm{c} \cdot \mathrm{e(k-1)}\right| + \Delta}\right)$

Integrating equation (5), (6), (20) will result in MFA based SMC control Algorithm. It can be seen from the above equation that MFA based SMC controller design use PPD value and only uses the input/output information about the system.

4. Stability Analysis

4.1. The Existence and Reachability of the Discrete-Time Sliding Mode

The extension of the discrete system is expressed in the form of a continuous system.

$$\left[s(\kappa+1) - s(\kappa)\right] s(\kappa) < 0, \tag{21}$$

The condition in equation (21) is a necessary condition for the existence of the SMC but it is not a sufficient condition to assure the stability of the plant. Consider a Lyapunov function

$$V(\kappa) > 0 = \frac{1}{2} s(\kappa)^2, \tag{22}$$

Such that

$$\Delta V(\kappa) = s^2(\kappa+1) - s^2(\kappa) < 0 \ , \ s(\kappa) \neq 0 \ ,$$

When $s(\kappa) = 0$ belongs to the global asymptotic stability of the equilibrium surface and any arbitrary initial position will tend to switch surface $s(\kappa)$, so consider the condition $s^2(\kappa+1) < s^2(\kappa)$. At sampling time T, the stability of the system need to satisfy the condition in equation (23).

$$\begin{bmatrix} \left[S(\kappa+1) - s(\kappa)\right] sgn\left(s(\kappa)\right) < 0 \ , \\ \left[S(\kappa+1) + s(\kappa)\right] sgn\left(s(\kappa)\right) > 0 \end{bmatrix}, \tag{23}$$

4.2. Stability Verification

To verify the stability of the algorithm, transform the equation (14) that result in discrete exponential reaching law, which is given as follows:

$$\begin{bmatrix} \left[\left(s(\kappa+1)-s(\kappa)\right)\cdot sgn\left(s(\kappa)\right)\right]= \\ \left[\left(-q\cdot s(\kappa)-\varepsilon\cdot \mathrm{sgn}\left(s(\kappa)\right)-s(\kappa)\right)\cdot sgn\left(s(\kappa)\right)-(q+1)\left(\frac{s^2(\kappa)}{|s(\kappa)|}\right)-\varepsilon\cdot\left(\frac{s^2(\kappa)}{|s(\kappa)|^2}\right)\right]= \\ \left[-(q+1)\cdot|s(\kappa)|-\varepsilon\right]<0 \end{bmatrix} \quad (24)$$

$$\begin{bmatrix} \left[\left(s(\kappa+1)+s(\kappa)\right)sgn\left(s(\kappa)\right)\right]= \\ \left[\left[-q\cdot s(\kappa)-\varepsilon\cdot sgn\left(s(\kappa)\right)+s(\kappa)\right]\cdot sgn\left(s(\kappa)\right)\cdot(1-q)\left(\frac{s^2(\kappa)}{|s(\kappa)|}\right)-\varepsilon\cdot\left(\frac{s^2(\kappa)}{|s(\kappa)|^2}\right)\right]=\left[(1-q)\cdot|s(\kappa)|-\varepsilon\right]>0 \end{bmatrix} \quad (25)$$

Thus, the MFA based SMC approach law exists. Moreover, the reaching condition of discrete SMC and the design of the control system is stable.

5. Simulation Study and Result Discussion

Linear motors are popular for applications that needs high speed and high precision because of its simple mechanical construction. The motor position and speed control need high velocity and precision that makes the control approach very difficult. However, in the process operation, the motor equipped with the load, environment parameters and the speed of the motor is nonlinear, so it is very difficult to construct the model parameters in the dynamic process of motor speed regulation. In this paper, an MFA sliding mode control is adopted to track the desired trajectory of a given speed and the position of a PMDC linear motor [20]. Nonlinear model of PMDC linear motor is shown as.

$$\dot{x}=v$$
$$\dot{v}=\frac{u-f_f-f_r}{m}+W(t) \quad (26)$$

Where: f_f is the friction force (N), f_r is the ripple force (N), u is drag force(N), m is the mass with load(kg), $W(t)$ is noise interference, x is a linear motor position (m), v is a linear motor speed (m/s).

Friction force and ripple force are given as below,

$$\begin{Bmatrix} f_f=(f_c+(f_s-f_c)e^{-(\dot{x}/\dot{x}_s)\theta}+f_v\dot{x})\mathrm{sgn}(\dot{x}) \\ f_r=b_0\sin(\omega_0 x) \end{Bmatrix} \quad (27)$$

Where: f_s is the level of static friction force, f_c is a minimum coulomb friction force , $\dot{x}_s$ is a lubrication parameter measured experimentally, f_v is an experimentally measured load parameters (N), θ is an additional empirical parameter, b_0 is a pulsation amplitude thrust, ω_0 is a thrust pulsation angular velocity (rad/s).

Ideal tracking design speed and position of the linear motor is given as follows:

$$\begin{Bmatrix} x^*(\tau)=x_0+\left(x_0-x_f\right)\left(15\tau^4-6\tau^5-10\tau^3\right) \\ v^*(\tau)=\left(x^0-x_f\right)\left(60\tau^3-30\tau^4-30\tau^2\right) \end{Bmatrix} \quad (28)$$

Where: $\tau=t/\left(t_f-t_0\right)$, x_0 *and* x_f are initial position and the final position respectively. The system simulation parameters for linear motor control parameters are given as follows:

$\varepsilon=10^{-5}$,

$\eta_k=15\times10^{-3}$, $\rho=10$, $\lambda=10^{-5}$, $\mu=10^{-3}$, $q=0.5$, $c=0.22$, $T=10^{-4}$, $u(1)=12, u(2)=12$,

$x(1),\ldots,x(3)=0,\quad y(1).....y(3)=0,\quad \phi(1)=\phi(2)=2$

Parameters of the PMDC linear Motor are:

$\mathrm{m}=0.69\,\mathrm{kg},\ \ \mathrm{f_c}=10\,\mathrm{N},\ \ \mathrm{f_s}=20\,\mathrm{N},\ \ \mathrm{w_0}=314\,\mathrm{rad/s},\ \ \mathrm{x_s}=0.10,\ \ \mathrm{b_0}=8.50,\ \ \mathrm{q}=1$

The general block diagram of the whole process is shown in Figure (1).

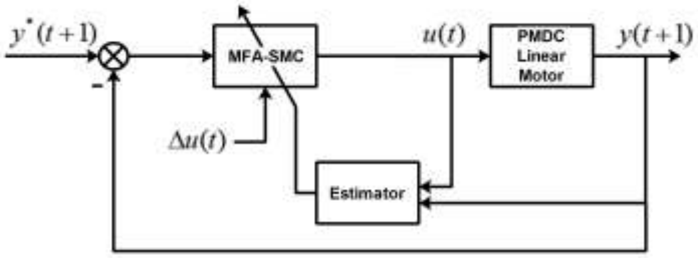

Figure 1. General Block Diagram of Proposed Algorithm

The purpose of this study to show the comparison between the PID, Model Free learning adaptive control (MFLAC) and MFA based SMC algorithm under load disturbance. As the proposed algorithm is data driven, hence the mathematical model of the motor is used only to collect the input/output data of the system for verification of the algorithm. The all algorithms were simulated in Matlab on personal computer.

5.1. Using Traditional fixed Structure PID Algorithm:

The following cases are considered for permanent magnet linear motors speed and position tracking that are used with fixed structure PID. PID parameter was tuned to get maximum performance of the controller.

Simulation Case 1: when load $f_v\ =5N$

Speed and position performance curve with 5N load using PID are shown Figure (2) and Figure (3) respectively. Maximum Speed and position error seen using PID with 5N load are approximately $0.25m/s$ and $2.5\times10^{-3}m$ respectively. It can be seen in the figures That the performance is very poor.

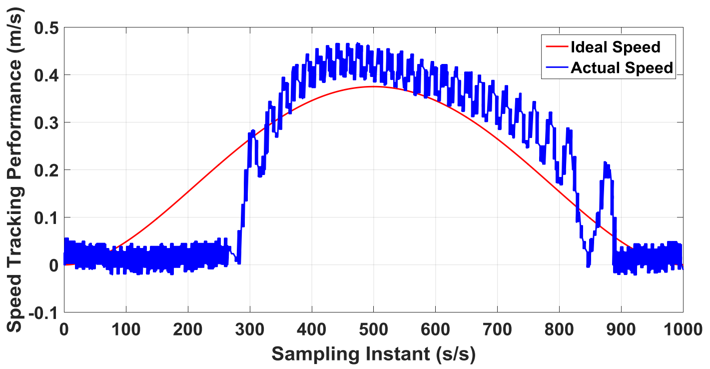

Figure 2. Speed Tracking Performance Curve (m/s)

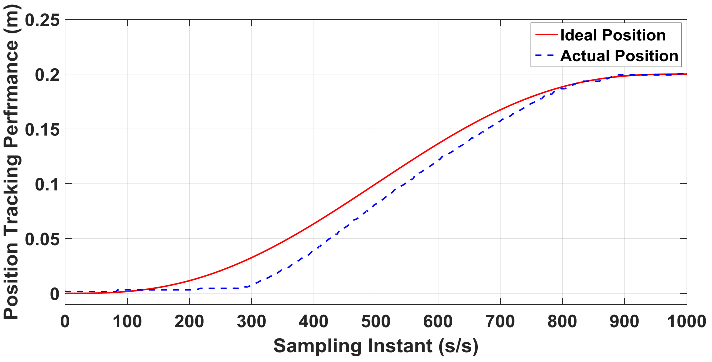

Figure 3. Position Tracking Performance Curve (m)

Simulation Case 2: when load $f_v = 50N$

Speed and position performance curve with 50N load using PID are shown Figure (4) and Figure (5) respectively. Maximum speed and position error are seen using PID with 50N load are approximately $0.31m/s$ and 2.7×10^{-3} respectively.it can be seen that on load change the speed error is too high and position is fluctuating around the reference position signal.

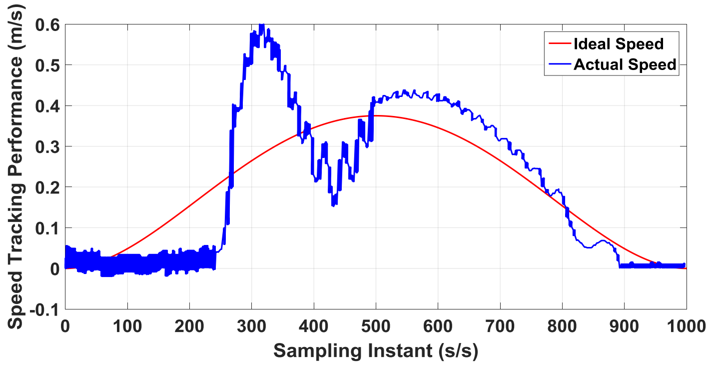

Figure 4. Speed Tracking Performance Curve (m/s)

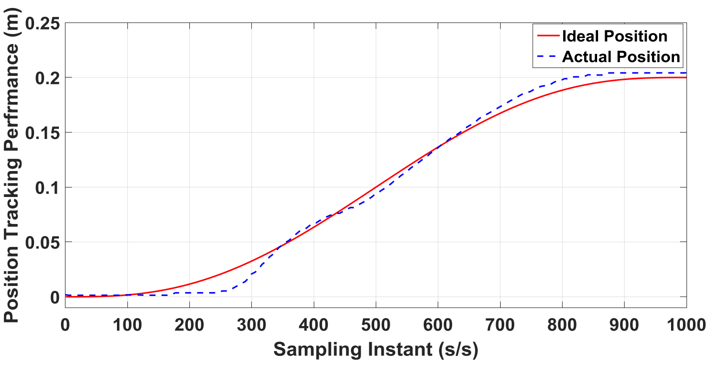

Figure 5. Position Tracking Performance Curve (m)

5.2. Using MFLAC Algorithm

The following cases are considered for permanent magnet linear motors speed and position tracking with Model free learning adaptive control (MFLAC) Algorithm.

Simulation Case 1: when load $f_v = 5N$

Speed and position performance curve with 5N load using MFLAC are shown Figure (6) and Figure (7) respectively. Maximum error speed and position error are seen using MFLAC with 5N load are approximately $0.22 m/s$ and $1.9\times10^{-3} m$ respectively.

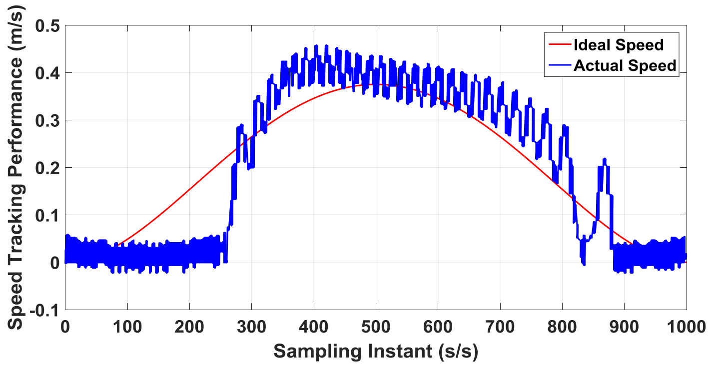

Figure 6. Speed Tracking Performance Curve (M/S)

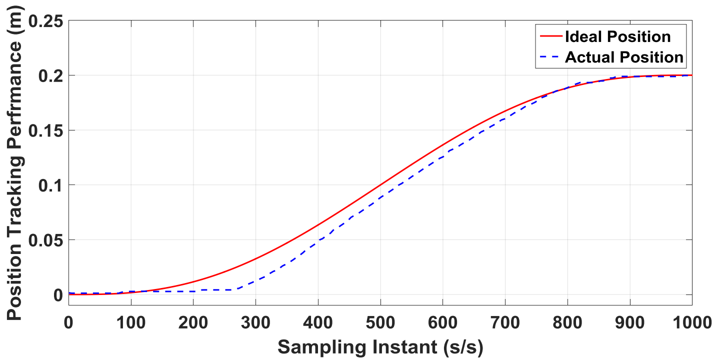

Figure 7. Position Tracking Performance Curve (m)

Simulation Case 2: when load $f_v = 50N$

Speed and position performance curve with 50N load using MFLAC are shown Figure (8) and Figure (9) respectively. Maximum speed and position error using MFLAC with 50N load are approximately $0.24 m/s$ and $2.3\times10^{-3} m$ respectively. Comparative analysis of PID and MFLAC shows that MFLAC has a better speed performance and position tracking.

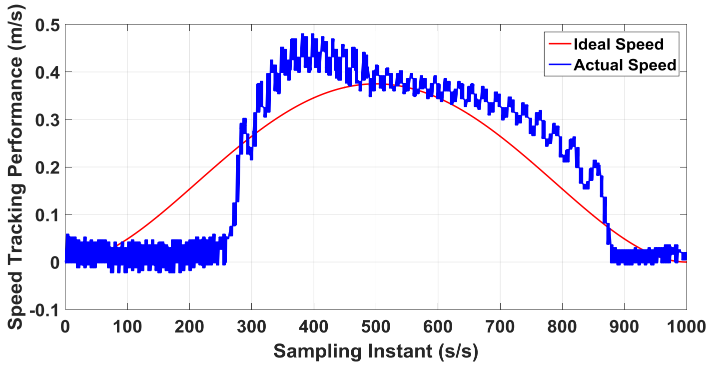

Figure 8. Speed Tracking Performance Curve m/s)

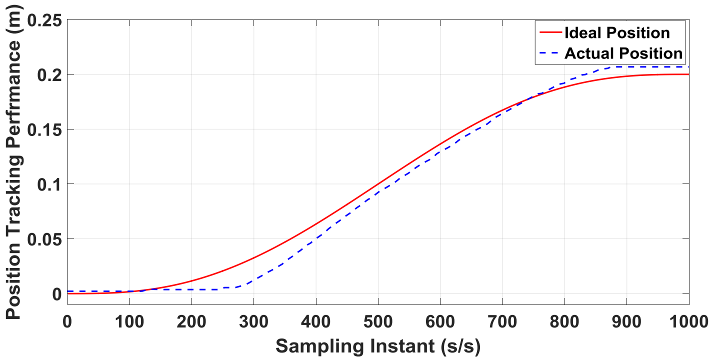

Figure 9. Position Tracking Performance Curve (m)

5.3. Using MFA-SMC Algorithm

The following cases are considered for permanent magnet linear motors speed and position tracking with MFA based SMC (MFA-SMC) Algorithm.

Simulation Case 1: when load $f_v = 5N$

Speed and position performance curve with 5N load using MFA-SMC is shown Figure (10) and Figure (11) respectively. Maximum speed and position error are seen using MFA-SMC with 5N load are approximately $0.11 m/s$ and $1.1 \times 10^{-3} m$ respectively. The result shows that new algorithm has better results than PID and MFLAC.

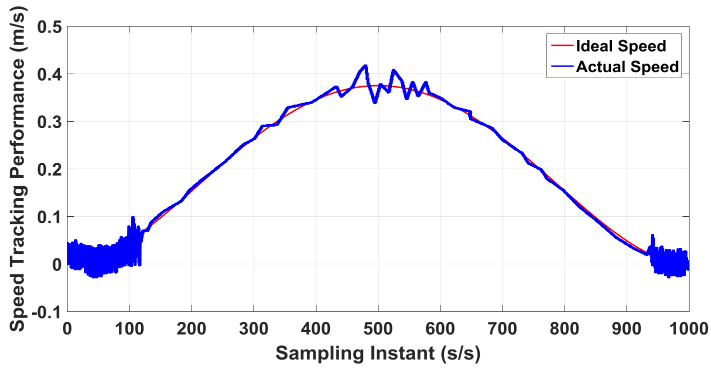

Figure 10. Speed Tracking Performance Curve (m/s)

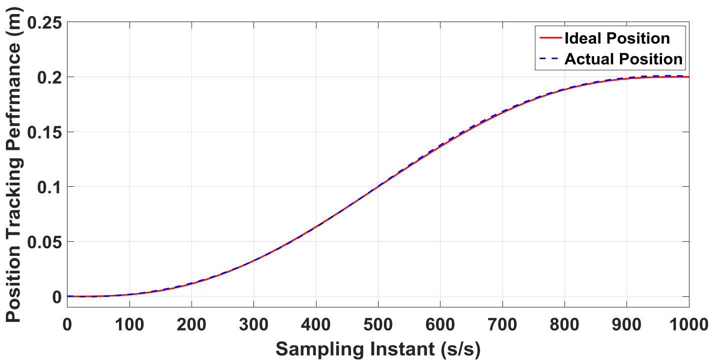

Figure 11. Position Tracking Performance Curve (m)

Simulation Case 2: when load $f_v = 50N$

Speed and position performance curve with 50N load using MFA-SMC is shown Figure (10) and Figure (11) respectively. Maximum speed and position error using MFA-SMC with 50N load are approximately $0.15m/s$ and $1.5\times10^{-3}m$ respectively.

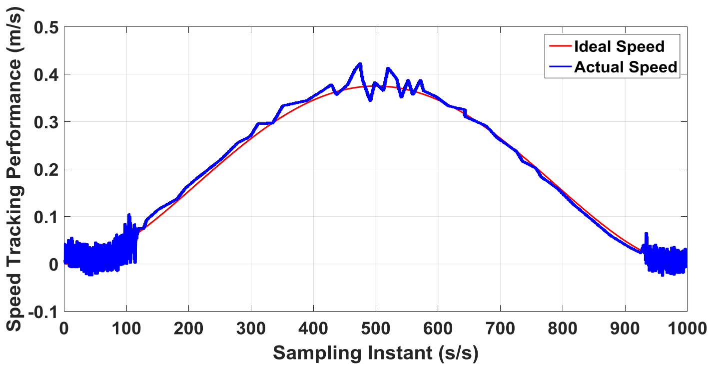

Figure 12. Speed Tracking Performance Curve (m/s)

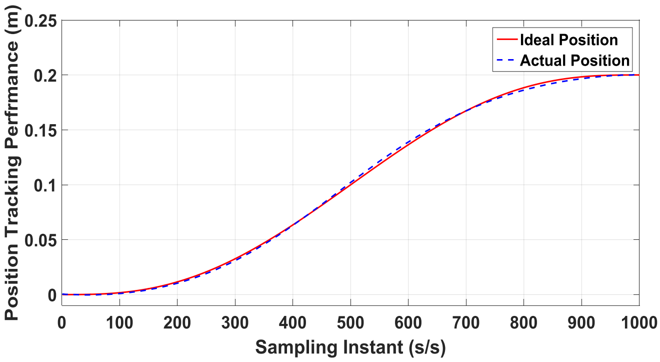

Figure 13. Position Tracking Performance Curve (m)

Comparison analysis of the speed tracking using PID, MFLAC and MFA-SMC with load ($f_v = 5N$) is shown in Figure (14) and Figure (15) with load ($f_v = 50N$)

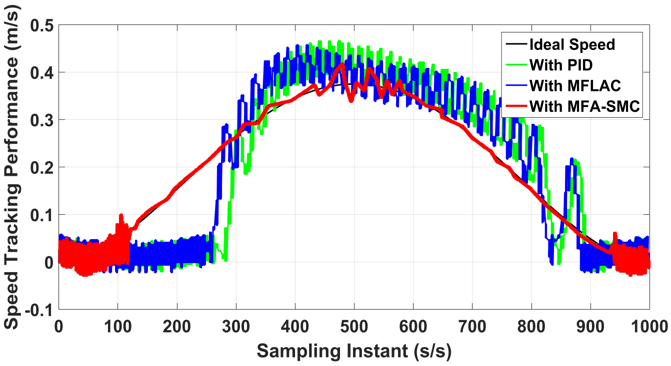

Figure 14. Speed Tacking Comparison with Load ($f_v = 5N$)

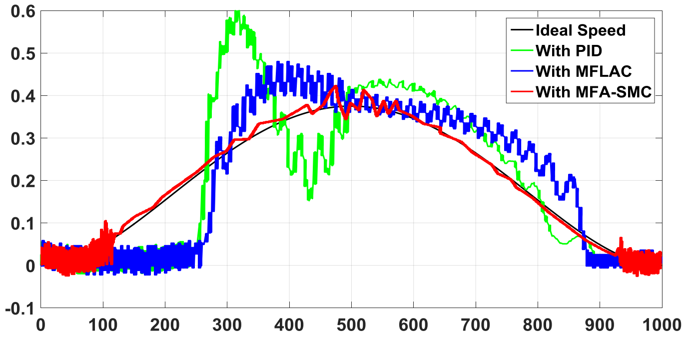

Figure 15. Speed Tacking Comparison with Load $(f_v = 50N)$

It can be seen in a view of above simulation results that PID based Control is not effective and tuning of parameter are inconvenient and controller performance is sensitive to PID parameter. However, MFLAC based control is more effective and convenient because of its simple parameter tuning method. The MFLAC and MFA-SMC based design controller are data driven. Compared to PID and MFLAC algorithm, the simulation result shows that the improved MFA based SMS algorithm has strong control performance and it offers robustness to any change in system load. The proposed model MFA-SMC control algorithm is effective and it is asymptotically stable.

6. Conclusion

In this article, the MFA based sliding mode control algorithm is investigated for the PMDC linear motor. The proposed algorithm includes past pseudo partial derivative (PPD) data, thereby eliminating the need of complex mathematical modeling procedure and only uses input/output data to control the system. Strict mathematical derivation proves the stability of the proposed algorithm. The comparative analysis of simulated results, verify that the proposed MFA-SMC algorithm can achieve better performance in term of speed, position and stability over a traditional PID and Model free learning adaptive control.

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