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Control System Drive Tracking Electric Mechanisms Using PMSM Motor Based on Method Fuzzy Adaptive Sliding Mode Control

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Abstract

In this paper, the authors present a solution to improve precise control for electromechanical traction drive, using PMSM synchronous AC motor applied in industrial production based on method fuzzy adaptive sliding controls. The significant synthesis algorithm evaluates the working quality of electromechanical electric drive system tracking in industry and military; the results are simulated in Matlab - Simulink environment. That result will be the basis for evaluating and setting up control algorithms, designing tracking drive systems in the industry and military.

Keywords: *Nonlinear control, fuzzy adaptive sliding mode control, intelligent control, a system tracking electric mechanisms, position control.*

I. INTRODUCTION

In recent years, AC motor; Permanent Magnet Synchronous Motor (PMSM) are widely used in industrial and military electric drive systems. It is made into modules containing pre-existing modes; has high-quality speed control such as electric vehicles, industrial robots, medical equipment, pill filling machines in the pharmaceutical industry, etc. because of its outstanding properties (wide working speed range, ratio torque/current is large, low noise, stable, high efficiency, precise control) [1, 3, 4]. An intelligent controller is an adaptive translucent slide controller; operating efficiently over a wide speed range (from very low speed to rated speed; high speed) is an attractive choice [2, 9, 12, 20].

To apply to precise control systems with different speed levels to ensure torque, especially in areas with different speed ranges, the control system requires precision as high as the adhesion systems in the machinery of the pharmaceutical industry (pill filling machine); the requirement is "very strict" and in industry, [10, 13], there are many problems to be solved. In documents [7, 8, 10, 13], only fuzzy control methods for PMSM are proposed8.

From there, we have a block diagram showing the relationships of the elements in the mechanical part of an electric drive system, as shown in Figure 1, as shown in documents [1, 3].

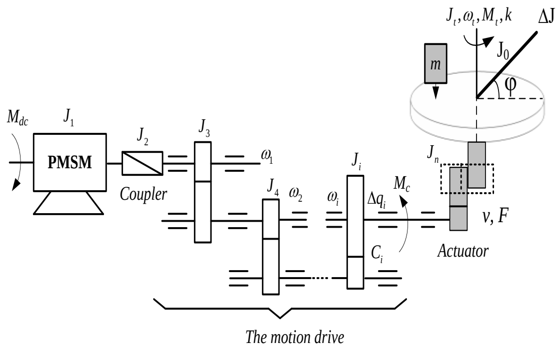

Fig 1: Dynamic diagram showing the relationships of the elements in the mechanical part of an electric drive system

To create suitable structures to ensure the system's optimization, it is necessary to give quality criteria when designing the dynamics of electric drive systems [3, 4]. This is a multi-target optimization problem, and there are many different solutions. This paper presents the research to improve precision control for PMSM synchronous AC motors used in industrial workshops, taking into account the nonlinear uncertainty factor, actuator dynamics, and transformers based on the adaptive fuzzy slip control method [10, 13, 15, 17, 21].

II. THE CONSTRUCT A MATHEMATICAL MODEL AC MOTOR PMSM

First, we consider: The mathematical model of a PMSM three-phase acting motor with the permanent magnet stator and rotor coils structure is shown as, [6].

By taking the rotor coordinates of the PMSM motor as the reference coordinate, the plane of the d-q coordinate system is represented by the following equation [6, 15, 17].

$$\begin{cases} \dot{\omega} = k_1 i_{qs} - k_2 \omega - k_3 T_L \\ \dot{i}_{qs} = -k_4 i_{qs} - k_5 \omega + k_6 V_{qs} - \omega i_{ds} \\ \dot{i}_{ds} = -k_4 i_{ds} + k_6 V_{ds} + \omega i_{qs} \end{cases} \quad (1)$$

where T_L is the load torque, ω is the rotor angular speed, i_{qs} ; i_{ds} is the d-axis stator current and the q-axis is linearized, V_{qs} is the q-axis voltage, R_s is the stator resistance, V_{ds} is the d-axis voltage, and $k_i > 0,\ i = 1 \ldots .6$, are the prices parameter value is calculated by:

$$k_1 = \frac{3}{2}\frac{1}{J}\frac{p^2}{4}\lambda_m, k_2 = \frac{B}{J}, k_3 = \frac{p}{2J}, \quad k_4 = \frac{R_s}{L_s}, k_5 = \frac{\lambda_m}{L_s}, k_6 = \frac{1}{L_s} \tag{2}$$

$$V_{qs} = R_s i_{qs} + L_q \dot{i}_{qs} + \omega L_{ds} i_{ds} + \omega\lambda_m \tag{3}$$

$$V_{ds} = R_s i_{ds} + L_d \dot{i}_{ds} - \omega L_{sq} i_{qs} \tag{4}$$

$$T_e = \frac{3}{2}\frac{p}{2}\left[\lambda_m i_{qs} + (L_d - L_q) i_{ds} i_{qs}\right] \tag{5}$$

$$T_e = T_L + B\frac{2}{p}\omega + J\frac{2}{p}\dot{\omega} \tag{6}$$

The electromagnetic torque, p is the number of poles, R_s stator resistance, L_s stator inductance, J is the moment of rotor inertia, B viscosity friction coefficient, λ_m loop flux and $\omega = \dot{\theta}$; the nonlinear state evaluator then estimates θ the rotor speed ω , the motor's non-measurable component.

Another way to facilitate the calculation, on the d-q reference axis of the motor, we can write, [6]:

$$\begin{bmatrix} v_{ds}^e \\ v_{qs}^e \\ 0 \\ 0 \end{bmatrix} = \begin{bmatrix} R_s + \sigma L_s p & -\sigma L_s \omega_e & \frac{L_m}{L_r}p & -\frac{L_m}{L_r}\omega_e \\ \sigma L_s \omega_e & R_s + \sigma L_s p & \frac{L_m}{L_r}\omega_e & \frac{L_m}{L_r}p \\ -L_m\frac{R_r}{L_r} & 0 & \frac{R_r}{L_r}+p & -\omega_{sl} \\ 0 & -L_m\frac{R_r}{L_r} & \omega_{sl} & \frac{R_r}{L_r}+p \end{bmatrix} \begin{bmatrix} i_{ds}^e \\ i_{qs}^e \\ \varphi_{dr}^e \\ \varphi_{qr}^e \end{bmatrix} \tag{7}$$

$$T_e = \frac{3}{2}\frac{n}{2}\frac{L_m}{L_r}(i_{qs}^e \varphi_{dr}^e - i_{ds}^e \varphi_{dr}^e) \tag{8}$$

In the Field Oriented Control (FOC) method, the flux is oriented entirely in the d-axis set up by $\phi_{qr}^e = 0$, so we have, [1]:

$$\varphi_r^e = \varphi_{dr}^e \tag{9}$$

Then the slip angle frequency we have is:

$$\omega_{sl} = \frac{L_m}{\varphi_r^e}\left(\frac{R_r}{L_r}\right) i_{qs}^e \tag{10}$$

The electromagnetic moment is written in the following form:

$$T_e = \frac{3}{2}\frac{n}{2}\frac{L_m^2}{L_r} i_{qs}^* i_{ds}^* = K_t i_{qs}^* \tag{11}$$

in which K_t is calculated as follows:

$$K_t = \frac{3}{2}\frac{n}{2}\frac{L_m^2}{L_r} i_{ds}^* \tag{12}$$

The mathematical equation described in terms of the mechanical part of a synchronous AC motor is written as follows:

$$J_r \dot{\omega}_r(t) + B\omega_r(t) = T_e + T_L \tag{13}$$

where, J_r the torque of rotor inertia, B viscous friction coefficient, T_L the torque of load, then we replace (11) and (12) into (13) we get:

$$\dot{\omega}_r(t) = -\frac{B}{J_r}\omega_r(t) + \frac{Kt}{J_r} i_{qs}^{*e} - \frac{T_L}{J_r} = B_p\omega_r + A_p i_{qs}^{*e} + D_p T_L \tag{14}$$

where, $B_p = -B/J_r < 0; A_p = K_t / J_r > 0; D_p$, then $B_p = -1/J_r < 0.$

To obtain a mathematical model corresponding to a PMSM motor's control process, the nominal values of the parameters must be considered with regard to the influencing factors of the nonlinear components that cannot be measured and affected effects of any disturbances [12, 18, 20]. Therefore, the kinetic motor model given by (14) can be written as:

$$\dot{\omega}_r(t) = \bar{B}\omega_r(t) + \bar{A} i_{qs}^{*e} \tag{15}$$

where, $\bar{A} = \bar{K}_t / \bar{J}_r$ and $\bar{B} = -\bar{B}/J_r$ are respectively values of A_p and B_p.

To deal with non-measurable components, they must be considered; compute and add to the dynamic model of the PMSM engine the corresponding real-time values. Therefore, in equation (14), we consider to calculate the non-measurable components of the engine structure model in the drive system then written as follows:

$$\dot{\omega}_r(t) = (\bar{B} + \Delta B)\omega_r(t) + (\bar{A} + \Delta A) i_{qs}^{*e} + D_p T_L + \delta = \bar{B}\omega_r(t) + \bar{A} i_{qs}^{*e} + L(t) \tag{16}$$

where, $L(t) = \Delta B\omega_r(t) + A i_{qs}^{*e} + D_p T_L + \delta.$

In the above equation, the unknown component is represented by ΔA and ΔB; typical for systems containing uncertainty, including variable parameters and nonlinear estimated errors are not measured. Besides, these components are since the structure and dynamics of the system do not change, so for simplicity of analysis, calculate; estimate the parameters; in this paper's framework, the above parameters are assumed to be constant, so we write as δ . The equation above is called unknown components, but the limit is $|L(t)| < m$, where m is a positive constant.

III. THE STUDY PROPOSES A FUZZY ADAPTIVE SLIDING MODE CONTROLLER FOR THE DRIVE CONTROL SYSTEM

A. The basis sliding controller normal

Let From the conventional slide controller, and there are many advantages in the synthesis of nonlinear systems [10, 17, 21]; due to invariants with disturbances affecting systems and unspecified components; the system size is reduced when sliding modes appear on the slip surface, the principles of motion division, analysis principles can be applied to bring large-sized systems to small-sized subsystems more controllable and observable. Here we consider the change in speed adjustment error, and then the component $e(t)$ is calculated $e(t)=\omega_r(t)-\omega_r^*(t)$, so that in sliding mode in space can be written as:

$$S(t)=h(Ce(t)+\dot{e}(t)) \quad (17)$$

Where *C* and *h* are positive constants, replace (16) in (17), the first derivative of *S(t)* over time we will get:

$$\dot{S}(t)=h\left(C\dot{e}(t)+\bar{B}\dot{\omega}_r(t)+\bar{A}u(t)+\dot{L}(t)-\ddot{\omega}_r^*(t)\right) \quad (18)$$

where, $u(t)=i_{qs}^{e}(t)$.

By giving $\dot{S}(t)=0$, and $\dot{L}(t)=0$, then the desired performance according to the system dynamics model (equivalent control) is written as, [8, 10, 17, 14]:

$$u_{eq}(t)=-(\bar{A})^{-1}\left[(C+\bar{B})\dot{e}(t)+\bar{B}\dot{\omega}_r^*(t)-\ddot{\omega}_r^*(t)\right] \quad (19)$$

To achieve the appropriate performance, the actuator kinetics always work stably based on the sliding surface $S(t)$. Then discontinuous component $u_r(t)$ is written as:

$$u_r(t)=-(\bar{A}h)^{-1}k(t)\text{sign}(S(t)) \quad (20)$$

where, $k(t)>0$ and the function "sign" is the functional functions defined as follows:

$$\text{sign}(S(t))=\begin{cases}1, \text{ neá } S(t)>0\\ -1, \text{ neá } S(t)<0\end{cases} \quad (21)$$

Therefore, the performance of the controller is always qualitative, considering uncertain components and unchanged system dynamics, which can then be written as:

$$u(t)=u_{eq}(t)+u_r(t) \quad (22)$$

$$i_{qs}=\frac{1}{\tau}\int_0^t u(t)dt \quad (23)$$

where A is an integral positive constant. According to the control design, the Lyapunov (CLF) control function is selected in the form:

$$V(t)=\frac{1}{2}S^2(t) \quad (24)$$

Stability conditions represent the stability obtained from the Lyapunov function's stability theorem [2, 9, 10, 20].

$$\dot{V}(t)=S(t).\dot{S}(t)\le\eta\left|S(t)\right| \quad (25)$$

where η is a perfectly positive constant? From the expressions (18), (19), and (22), (25) can be rewritten to the following expression:

$$\dot{V}(t)=S(t).\dot{S}(t)=-S(t)h\bar{A}u_r(t)+hS(t)\dot{L}(t)$$

$$\dot{V}(t)\le-k\left|S(t)\right|+h\left|S(t)\right|\left|\dot{L}(t)\right| \quad (26)$$

$$\dot{V}(t)\le-\left|S(t)\right|(k(t)-hm)$$

Compare equations (25) and equation (26) considering $\left|\dot{L}(t)\right|<m$, then the stability of the system is guaranteed according to the following equation:

$$k(t)\ge hm+\eta \quad (27)$$

When η it is large, there always happens a "Chattering" phenomenon inlet control around the slip surface. Chattering can be alleviated by replacing the discontinuous function sign with a continuous function approximately $s/(|s|+\mu)$ where μ is a positive constant. We know that the controller's characteristic will approximate the original controller [10], [12].

B. The fuzzy adaptive sliding mode controller for the drive control system

Construct a based on fuzzy adaptive sliding mode control technique to ensure that the engine speed always follows the set speed when considering the model's uncertainty factors, such as changes in engine parameters. Variability changes the friction moment, moment of inertia, other uncertain nonlinear components, etc. When set values and load noise change. Besides, to improve the controller's quality, in the rotor flux-based control, an update of the rotor's angular position must always be provided for the conversion of the coordinate system. Then, a nonlinear state evaluator, to accurately estimate the rotor position and speed, taking into account the effect of the parameter; and non-measurable components in both low and high-speed regions are used to provide information to the controller [8, 19].

The system block diagram is shown in figure 2. The fuzzy adaptive sliding mode controller (TMTN) is shown above. The TMTN controller is used as a speed controller, providing information such as the torque component of the current stator i_{qs}^{*e} is selected as the output component. On the d-coordinate system, the flux component of the current stator i_{ds}^{*e} is set as a constant value component corresponding to rated conditions. The d-q coordinate system's current values are compared with the current values on the corresponding actual DQ axis and processed through two separate PI controllers to provide the components. Axis voltage d-q at the output. Chattering can be eliminated by smoothing out the control interruption within a limit close to the slip surface. In practice, the inner sign function (20) will be replaced by the function "sat," as defined below

$$\text{sat}\left(\frac{S}{\psi}\right)=\begin{cases}\text{sign}(S), \; khi\left|S\right|>\left|\psi\right|\\ \dfrac{S}{\psi}, \; khi\left|S\right|\le\left|\psi\right|\end{cases} \quad (28)$$

In which, A is defined as the thickness of the border layer on the slip surface. Then the control adjacent to (20) is then changed to the expression:

$$u_r(t)=-(\bar{A}h)^{-1}k(t)\text{sat}(S(t)/\psi) \quad (29)$$

Block diagram of an electric drive control system used in industrial production is shown in figure 2:

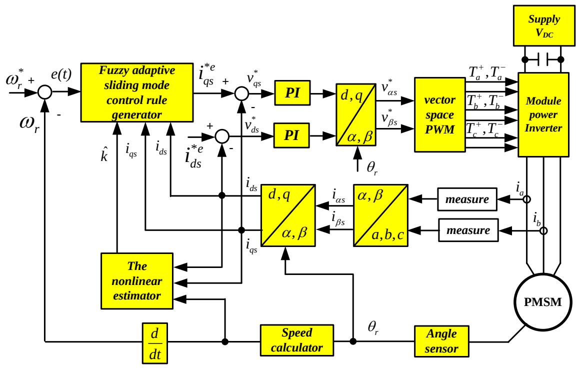

Fig 2: The structure block diagram of the control drive system using a PMSM motor based on a fuzzy adaptive sliding mode control method

By applying the above control problem, the control process's efficiency can be unsuitable because chattering still exists, resulting in the controller working process unstable. To solve these problems, then the saturation function is replaced by a fuzzy system that acts like a saturation function, which reduces the nonlinear uncertainties. The proposed fuzzy control system is considered a variable structure; then, *S(t)* is changed to *ΔS(t)* and is considered the output control variable u_{TMTN}. . Therefore, the fuzzy control system is represented as follows:

$$u_{TMTN} = TMTN(S(t), \Delta S(t)) \qquad (30)$$

The approach and control effects are then defined as follows:

$$u_r(t) = -(\bar{A}h)^{-1} k(t) u_{TMTN} \qquad (31)$$

$$u(t) = u_{eq} - (\bar{A}h)^{-1} k(t) u_{TMTN} \qquad (32)$$

Because the object does not have an ideal integral, the authors choose a fuzzy controller according to PI law. According to [7, 12, 13], we built the TMTN controller structure on the Matlab Simulink, as shown in Figure 3.

The approach and control effects are then defined as follows:

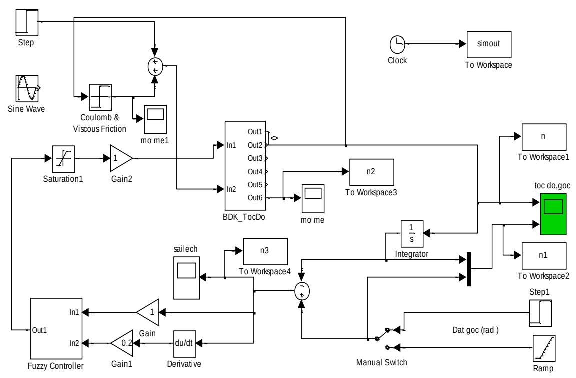

Fig 3: The system diagram using fuzzy adaptive sliding mode controller to control PMSM motor on MatLab Simulink

The fuzzy controller consists of two input signals: *S(t)* deviation, deviation derivative Δ*S(t)*, and one output signal u_{TMTN}. The structure of the fuzzy map is illustrated in Figure 4.

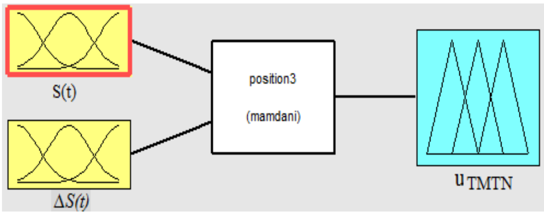

Fig 4: The fuzzy controller structure

The fuzzy controller consists of two input signals: *S(t)* deviation, deviation derivative Δ*S(t)*, and one output signal u_{TMTN}. The structure of the fuzzy map is illustrated in Figure 4.

The fuzzy rule table is built as table 1. Input relation; fuzzy controller output, as shown in Figure 5, Figure 6, Figure 7.

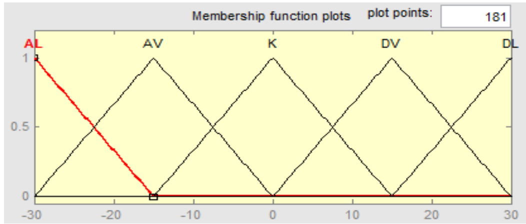

Fig 5: The blurring input S(t)

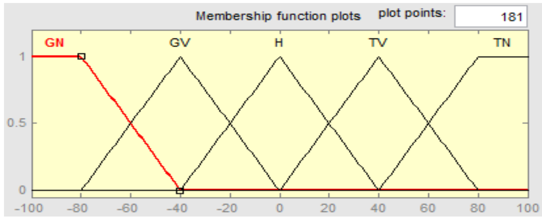

Fig 6: The blurring input ΔS(t)

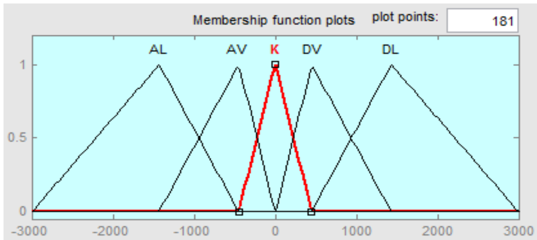

Fig 7: The blurring output u_{TMTN}

Then we have a fuzzy rule table is built as table 1.

TABLE I. The fuzzy rule table

u_{TMTN}		*S(t)*				
		AL	AV	K	DV	DL
Δ*S(t)*	GN	AL	AN	AV	K	DV
	GV	AL	AV	AV	K	DV
	H	AL	AV	K	DV	DL
	TV	AV	K	DV	DV	DL
	TN	AV	K	DV	DL	DL

Then it is necessary to minimize the *L(t)* component at (26). It is necessary to estimate the component *k(t)* using the corresponding adaptive law presented in [3], to update the calculation, to ensure the conditions for the concept maps to work well in sliding mode. Then, *k(t)* is estimated to reduce the control errors at (32). At this time, the controller works stably following Lyapunov's stability theorem. Therefore, to achieve the mentioned objectives, *k(t)* is taken as:

$$\dot{k}(t) = \lambda_k \left|S(t)\right| \quad (32)$$

$$u(t) = u_{eq} - (\bar{A}h)^{-1} k(t) u_{TMTN} \quad (33)$$

where λ_k is a positive constant? In practice, the component acts as an adaptive filter to minimize control errors.

The consider candidate Lyapunov function after (34), k may be the estimated value of *k(t)*.

$$V(t) = \frac{1}{2} S(t)^2 + \frac{1}{2\lambda_k}(k(t) - \hat{k})^2 \quad (34)$$

Replace (18) and (34) to (25) to get $\left|S(t)\right| < \psi(t)$ as follows:

$$\dot{V}(t) = S(t)h\left(\bar{A}u_r(t) + \dot{L}(t)\right) + \frac{1}{\lambda_k}\left(k(t) - \hat{k}\right)\dot{k}(t)$$

$$= S(t)h\left(-\bar{A}k(t)(h\bar{A})^{-1}\operatorname{sgn}(S) + \dot{L}(t)\right) + \frac{1}{\lambda_k}\left(k(t) - \hat{k}\right)\dot{k}(t)$$

$$= -S(t)k(t)\operatorname{sgn}(S) + hS(t)\dot{L}(t) + \frac{1}{\lambda_k}\left(k(t) - \hat{k}\right)\dot{k}(t). \quad (35)$$

Substituting (33) into (35) and transforming (25) yields:

$$\dot{V}(t) \le \left|k(t) - k - \hat{k}\right|\left|S(t)\right| + h\left|\dot{L}(t)\right|\left|S(t)\right| + \left|k(t) - \hat{k}\right|\left|S(t)\right|$$

$$< -\left|k(t) - \hat{k}\right|\left|S(t)\right| - \hat{k}\left|S(t)\right| + hm\left|S(t)\right| + \left|k(t) - \hat{k}\right|\left|S(t)\right|$$

$$< (-\hat{k} + hm)\left|S(t)\right|. \quad (36)$$

Comparing (25) and (36), we get:

$$\dot{V}(t) < (-\hat{k} + hm)\left|S(t)\right| \le \eta\left|S(t)\right| \quad (37)$$

Therefore, a component k can be selected such that the value $-k + mh + \eta$ remains negative. In other words, for the proposed stable working process of the TMTN controller, we choose $-k \ge +mh + \eta$. In this paper, by applying the proposed TMTN controller and the designed fuzzy rules and the conditions mentioned, the system's stability condition at (25) will be satisfied. Thus the operating stability of the system is guaranteed.

Factors of friction torque, elasticity, gap, etc., always exist in electromechanical drive systems, including motor and working mechanisms. This is a typical nonlinear component, and traditional controllers have not yet overcome their impact on the system's working quality. By improving the above fuzzy adaptive sliding mode controller's quality, the effects of the above nonlinearity factors on the drive system's quality have been resolved [7, 8]. Synthesized controller for proposed nonlinear quantity object; made the system operate smoothly and overcome nonlinear characteristics, especially always making the system asymptotically stable.

Parameters V_P, V_I is selected based on the experimental method Zeigler - Nichols. After selecting parameters V_P, V_I, we can calculate parameters V_P and d. However, due to the experimental design, to improve the quality of control: the transient time is short, and the over-adjustment is small, it is necessary to adjust two more parameters, V_P and d. The found correction parameters are: V_P = 0.01; d = 0.99 (with T = 0.002). After choosing the calculation, the PI controller's quality: K_P = 0.3; K_I = 0.0001. There are also methods of using PID Design map design software, as shown in the document [3, 9, 12, 14], etc., to design the controller.

IV. THE SIMULATION RESULTS AND DISCUSSION

A. The simulation results

After studying the calculation, the fuzzy adaptive sliding mode controller algorithm will build a simulation program on Matlab - Simulink software to conduct the simulation and evaluate the results too, verify the algorithm's correctness. The diagram is shown in Figure 3.

The simulation parameters: PMSM synchronous AC motor includes: Power P = 0.45KW; rated speed 3000 rpm; rated voltage U = 220V; number of poles p = 4; viscosity friction coefficient B = 0.0001 N.m.s / rad; Moment of inertia J = 1,5.10^{-4} Kgm^2.

Perform controller algorithm simulation in MATLAB - SIMULINK environment is surveyed with simulation results in the following cases:

Case 1: A simulation study evaluates the system's working capacity and reaction during the start-up and braking process; when the speed changes, the load torque is constant 0.53Nm. We have the following simulation results:

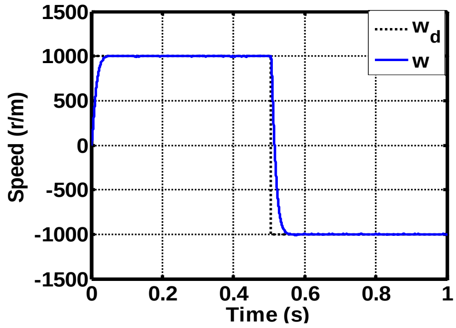

Fig 8: The set speed ω_d and actual speed ω of case 1

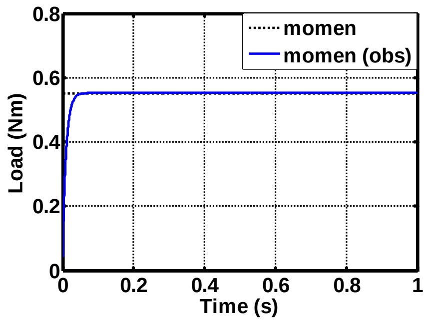

Fig 9: The torque set and estimated torque in case 1

In this case, the response is that the current i_s, although changing at the time t_1 = 0.035s and t_2 = 0.5s, still reaches an equilibrium value of about 0.5A; i_{sd} fluctuates around 0.25A.

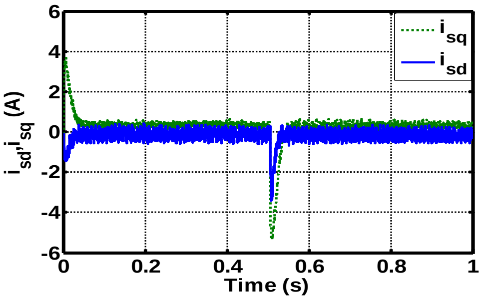

Fig 10: The response current i_{sq} and current i_{sd} case 1

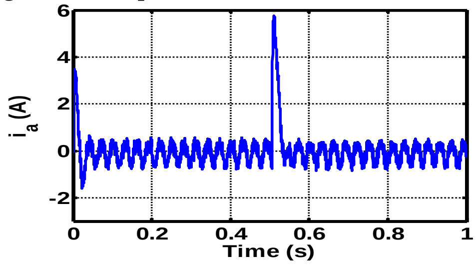

Fig 11: The current response i_a in case 1

Case 2: A simulation study to evaluate the working ability of the system when the speed changes with the amplitude of 1000 rpm to -1000 rpm, the load moment changes in the form of a sinusoid, the torque of the load is 0.5Nm

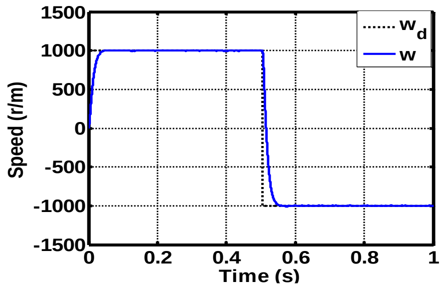

Fig 12: The set speed ω_d and the actual speed ω of the case

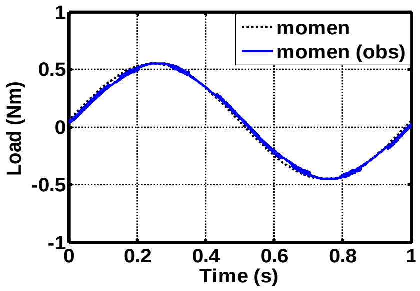

Fig 13: The torque set and estimated torque in case 2

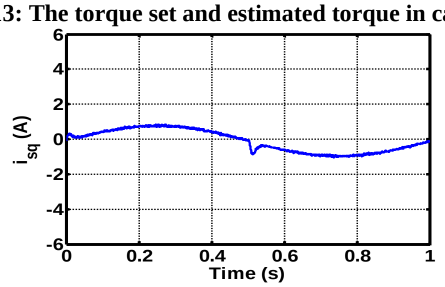

Fig 14: The response current i_{sq} in case 2

Case 3: A simulation study to evaluate the system's working ability with the full model, taking into account the actual mechanical part of the working structure. Simulate engine speed with an amplitude of 50 rpm and working mechanism speed of 0.5 rpm. Input is a constant load moment, and we have the following result:

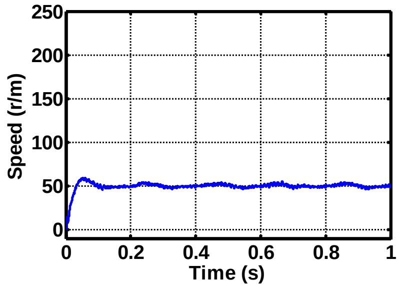

Fig 15: The set speed ω_d and actual motor speed ω in case 3

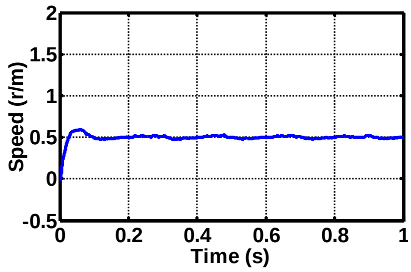

Fig 16: The setting speed ω_d and actual speed ω of the working device in case 3

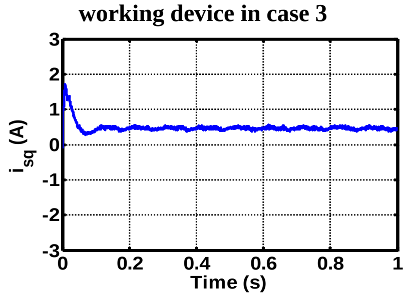

Fig 17: The response current i_{sq} in case 3

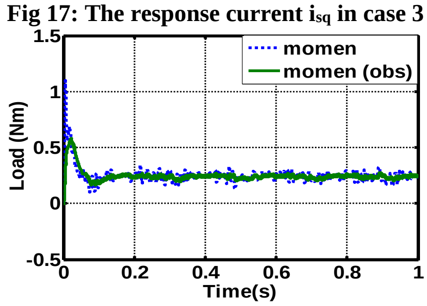

Fig 18: The torque set and estimated torque in case 3

Case 4: Studying the reaction of the system when the applied angle changes according to the function $X_v = V.t$, (V = 1rad / s) constant load torque Mc = 0.5Nm.

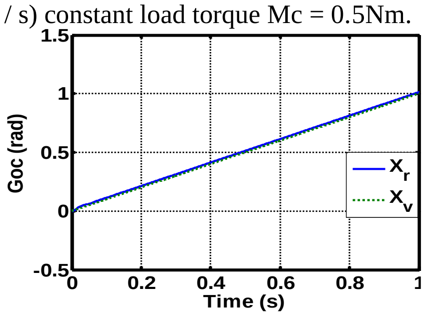

Fig 19: The response angle controller in/out in case 4

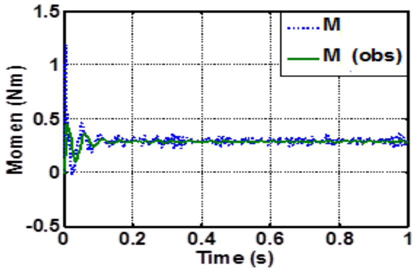

Fig 20: The response in/out according to the torque of the controller in case 4

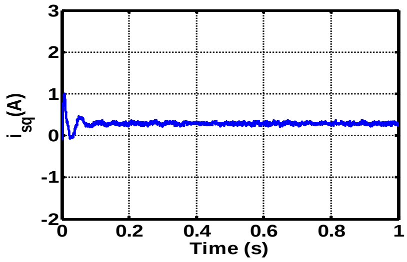

Fig 21: The response current i_{sq} in case 4

Case 5: When the system works with a given angle of input as the step function X_v = 0.05 rad, When there is the influence of friction torque on the motor shaft and the friction torque on the load side, we The results are as follows:

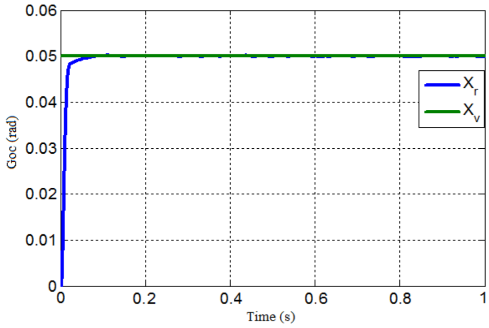

Fig 22: The response angle controller in/out in case 5

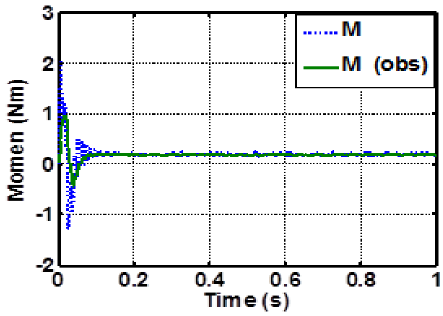

Fig 23: The response in/out according to the torque of the controller in case 5

B. The discussion

Observing the results shows that when using the adaptive fuzzy sliding controller studied above, we see the stability; the stability of the control rule against the effects of an undetermined component will change the transition time, increasing the quick impact of the drive system; then the algorithm still works stably; The output is closely related to the amount in the balancing process, the response of the system works stably. It can be seen that the estimator of the nonlinear components always closely follows the set value both in the speed changing mode and in the steady-state. This problem is evident in cases 1, case 2, case 3, and in the case of the angular position control, which is case 4 and case 5. These two cases are with Xv because of the angular position, and the control quantity at the output X_r is the received control quantity. Furthermore, in the transient mode, the controller's response is also for the response to time rather quickly.

In this paper, the research on using TMTN controller aims to produce algorithms to apply to some industrial and military traction control systems today such as robot control systems, precise control systems for pill packing machines in the pharmaceutical industry, control systems for CNC cutting machines, weapons attachment systems in the military, etc. The results are calculated and constructed; synthetic; to demonstrate the algorithm's effectiveness, improve the working quality for the grip system.

V. CONCLUSIONS

The tracking drive systems for industrial and military control objects require very high reliability and accuracy, and replacement of old control systems is necessary and urgent in traction systems. Electromechanical is being used many in practice. The paper presented the new asymptotic approach, researching building a fuzzy sliding controller adaptive for the industrial traction drive system. Theoretical and simulation studies show that the above control algorithm achieves good quality and more stable operation. This problem has proven the algorithm's correctness, and the results of this research can be completely applied in practice for today's industrial and military electric drive systems.

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