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Development of a position tracking drive system for controlling PMSM motor using dSPACE 1104-based variable structure

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ABSTRACT

In industrial electric drive systems, it is common to find objects that need to solve the problem of angular position control, moving the object from one position to another asymptotically with no over-correction and guarantee. calculation of maximum fast impact. This is a multi-target optimization problem with many different solutions. This paper presents a method of constructing a PMSM motor position controller with a variable structure using dSPACE 1104 card. The system consists of a position control loop with a variable structure that is an outer loop and a speed control loop degree is the inner loop. In which, the speed adjustment loop uses adaptive law to compensate for uncertain functions and build a sliding mode observation to estimate load torque, friction and noise. The results of the simulation study were verified on Matlab-Simulink environment and experimented on dSPACE 1104 card to check the correctness of the built controller algorithm. The research results in the paper are the basis for the evaluation and setting up of control algorithms, design of electric drive systems in industry and the military.

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1. INTRODUCTION

In recent years, permanent magnet synchronous AC motors (PMSM) are increasingly being used in industrial electric drive systems to replace DC motors that contain many disadvantages. The PMSM motor is made into built-in modules with many different control modes: fast working speed mode, slow working mode, and choosing suitable structure. In order to apply AC motors to position control drive systems, especially control systems that require as high a quality as industrial electric drive systems, there are many more problem to be solved, [1]-[4].

On the basis of the rotor flux vector control structure or field-oriented control (FOC), we realize that: the torque control loop through the stator current controller, the speed control loop has the advantage of dissociation controlling flux and torque generation of the motor, [3]-[5], [6]-[9]. The basic advantage of the rotor flux vector control method of AC motors is the ability to separately control the excitation current and the torque generating current similar to that of DC motors, [10]-[15]. Therefore, it gives the PMSM good control features. Therefore, the research and application of digital signal processing cards in general and dSPACE 1104 card in particular is to verify the position controller construction calculation, allowing the implementation of the transfer control algorithms in real-time [5], [6], [16], [17], [18]-[23]. Experimental system research processes with real-time is a necessary and significant new issue in industrial and civil control, [6], [24]-[26]. In [17], we studied the variable structure control system using the adaptive sliding mode control algorithm, using dSPACE

1104, but not the position control but with stopping at the speed control of the PMSM with the small motor capacity is 1,1kW. Continuing in the document [22], going to study a control system with variable structure design of sliding mode controller with experimental model only with small-capacity AC motor under 1kW, the bearing has a small capacity load. In addition, some other researches such as [16], [17], [23], [24] and in the country only stop at simulation results but have not shown experiment with position controller, or just experiment with motor position controller, small motor capacity DC, (AC motor capacity less than 1kW).

In order to create the appropriate structures to ensure optimum for the system, this paper presents the method of building a drive control system with a variable structure for a position controller using a PMSM motor, and experimented on dSPACE 1104 card to check the correctness of the built controller algorithm. On that basis to lift high quality control such as: robotic control technique, precise control for CNC metal cutting machine, process control, electropneumatic and hydraulic actuator control, etc. to saves energy for electric drive control systems, [4]-[11], [18].

2. THE SYNTHESIS OF POSITION CONTROLLER WITH VARIABLE STRUCTURE

In this part, the authors study the synthesis of the controller with the transmission system with variable structure as follows:

2.1. Object model of the tracking drive system, position control using PMSM

The working mode angle difference between input and output is very large, so the operation of the system usually goes through two stages: The stage of overcoming the movement at high speed to ensure maximum fast impact and the tracking stage, the system needs to be entered synchronization smoothly and accurately. To ensure high quality dynamics for the control process, the system should be designed so that each stage is properly structured with droper dynamic characteristics. Thus, the system will have a variable structure [3]-[6], [9], [14], [18]. Here, it is necessary to solve two problems: The problem of synthesizing the corresponding optimal structure for each stage. The problem of choosing the timing of structure transformation. The method of solving these two problems for the tracking drive system to the PMSM motor, the block diagram of the position-tracking drive system uses a PMSM motor with the control structure as shown in Figure 1 [4], [5], [10], [11], [16]. The system in Figure 1 consists of two control loops: position control loop with variable structure and speed loop, which is studied and implemented as follows.

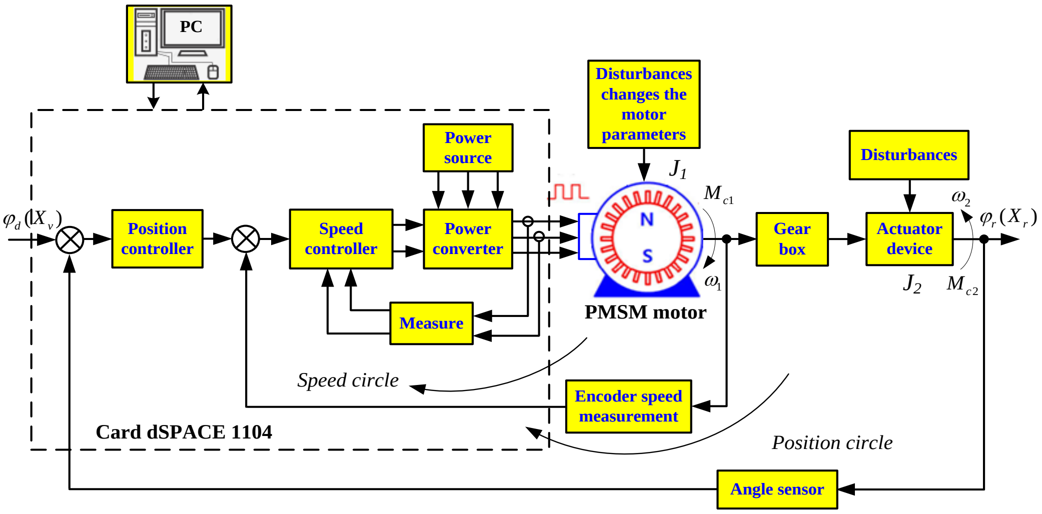


Figure 1. Diagram of position tracking drive system with variable structure

2.1. Adaptive sliding mode control-based speed control

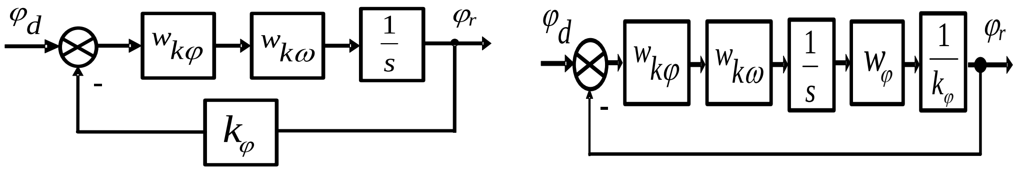
The speed control loop is designed according to the standard of modular optimum or symmetrical optimization. To ensure that the motor speed is always closely related to the set speed, when taking into account the model's nonlinear uncertainties such as: change of motor parameters, variation of friction torque, also such as when the set values and the load noise change. There are also power transformers and power converters, PMSM motors, and a number of other intelligent and auxiliary measuring devices, [6], [10], [14], [16], [18]-[20].

Research on speed control loop synthesis with nonlinear control object as shown in Figure 1, the use of traditional linear controllers such as PID has not overcome the effects of uncertain nonlinear factors and variable parameters of the model to the working quality of the system, [3], [4], [9], [13]. By synthesizing the adaptive sliding mode controller, the negative influencing factors of friction, elasticity, the quality of the drive system have been solved [6], [10], [18]. In the document [20], the authors have presented very carefully the synthesizing method of adaptive sliding mode controller for speed control loop with PMSM motor.

2.2. The position controller uses a PMSM motor based on the adaptive sliding mode speed controller

When using a dSPACE or industrial inverter for the construction of a traction drive control system, the most fundamental issue is the dynamic design of the position controllers. When the error angle is small, the position controller is built according to the design principle of multi-loop electric drive systems with dependent adjustment loops [4], [6]. When designing the position controller dynamics, we consider that the speed loop is designed according to the standard of optimum modularity or optimum symmetry. Then the current loop has the electromagnetic time constant (T_u) and the converter T_{bd} time constant is replaced by their sum of T_μ. The speed control loop is synthesized according to the modular optimization standard, [4], [6], [8]. When building an electric drive controller for a PMSM motor, one of the basic requirements is to have a closed loop control to regulate the current i_d and i_q. This allows to keep i_d = const in transient and equilibrium mode, improving energy characteristics, i_q is the current component generating torque [8]. Here, the authors synthesize the position control loop according to the Ziegler-Nichols method or the method using PID Design controller design software as in the document [4]. To design the position controller location of PI and PID.

Then the structure diagram is transformed into the diagram in Figure 2 (a), then continue to transform the block diagram we have the diagram in Figure 2 (b). In which: $w_{k\omega}$ is the speed controller transfer function, $w_{k\phi}$ is the position controller transfer function, k_ϕ is coefficent the transfer function of the measurement portion.



(a) (b)

Figure 2. These figures are; (a) Structural diagram of positional tracking drive system; (b) alteration of the structure diagram of the positional tracking drive system

Consider the system in the error zone with the setting angle of 0.1 rad. Let T_μ be the sum of the small uncompensated small time constant ($T_\mu = T_u + T_{bd}$). Because the system has quite large mechanical inertia, the time constant to be compensated is the electromechanical time constant of the system. The object of the positional loop controller has the form:

$$W_{0\phi} = W_{K\omega}.\frac{1}{s} = \frac{1/K_\omega}{a_\omega.a_I.T_\mu s+1}.\frac{1}{s} \tag{1}$$

Then the close-loop transfer function is written:

$$W_{k\omega} = \frac{1/K_\omega}{(a_\omega.a_I.T_\mu s+1)} \tag{2}$$

As shown in (2) has been approximated simply, ignore the higher order term in the transfer function denominator. Synthesis of the position controller according to the optimal modularity standard [2], [3]. The desired transfer function of the system has the following form:

$$W_{H\phi} = \frac{1/K_\phi}{a_\phi.a_\omega.a_I.T_\mu.s.(a_\omega.a_I.T_\mu s+1)} \qquad (3)$$

The position controller transfer function is:

$$W_\phi = \frac{W_{H\phi}}{W_{0\phi}} = \frac{K_\omega}{K_\phi.a_\phi a_\omega.a_I.T_\mu} = K_{d\phi} \qquad (4)$$

At this point, the close-loop transfer function the position control system is rewritten as:

$$W_{k\phi} = \frac{1/K_\phi}{a_\phi.a_\omega.a_I.T_\mu.s.(a_\omega.a_I.T_\mu s+1)+1} \qquad (5)$$

When the initial error angle is large, the system works with two stages corresponding to the large and small value of the deviation angle. The problem is how to choose the timing of control structure switching, so that the system achieves the optimum standard of fast and asymptotic action at the end position, without over-tuning [4], [19], [21]. Considering the priority condition at the stop time, when the system enters the region with a small deviation (near to the destination), then it is necessary to improve the accuracy. At the time when the transition to a closed system starts working, we have: initial speed is $\omega = \omega_{bd}$; angle error is $\Delta\phi_{bd} = \phi_d - \phi_{bd}$. When adjusting the system according to the impact reduction standard, we can choose $a_\phi = 4$, [2], [3]. Then we see that the position controller output signal is set to the speed controller. The speed controller input signal is written as:

$$U_{d\omega}\text{-}K_\omega.\omega = K_{d\varphi}.\Delta\varphi\text{-}K_\omega.\omega_k \qquad (6)$$

When controlling according to angle deviation:

$$K_{d\varphi}.\Delta\varphi\text{-}K_\omega.\omega_k = 0;\ K_{d\varphi}.\Delta\varphi = K_\omega.\omega_k \qquad (7)$$

According to (7), the acceleration during elimination of the $\Delta\varphi$ deviation angle can be determined as follows:

$$\frac{d\omega_k}{dt} = \frac{K_{d\phi}}{K_\omega}.\frac{d}{dt}.(\phi_d - \phi') = \frac{K_{d\phi}}{K_\omega}[-\frac{d(K_\phi.\phi)}{dt}] = \frac{K_{d\phi}}{K_\omega}[-K_\phi\frac{d(\phi)}{dt}] = \frac{-K_{d\phi}}{K_\omega}.K_\phi.\omega \qquad (8)$$

Thus, the maximum slower acceleration of motion in the electric drive system is, the higher the initial speed is (7). This acceleration increases when the initial angle deviation $\Delta\varphi_{bd}$ increases, then the system moves to the closed system into the synchronous working position, so the armature current reaching the maximum value also increases.

$$I_{max} = \frac{1}{C}.\left[J_\Sigma(\frac{d\omega}{dt})max + M_C\right] \qquad (9)$$

If I_{max} value calculated by the expression (9) needs to ensure the condition that limits the current $I_{max} \leq I_{cf}$ and the system is then linear. If the initial values $\Delta\varphi_{bd}$ and ω_{bd} are large then the following condition always exists:

$$I_{max} > I_{cf}(I_{restrict}) \qquad (10)$$

Regulator ω will switch to the saturation phase of the following characteristic:

$$U_{dI} = U_d.I_{max} = K_I.I_{cf} = const \qquad (11)$$

Then the system works as an open circuit with maximum current $I_{max} = I_{cf}$. Since the brake acceleration corresponding to the allowable brake torque is less than the value required for a quiet, precise stop, this matter has been taken into account as above. So, at the end of the process there will be a phenomenon of overregulation. Thus, the optimal position adjustment loop with the proportional regulator when $W_\phi = K_{\phi d}$ will be performed with the need to limit the initial value of the error of angle and speed ($\Delta\varphi_{bd}$, ω_{bd}), at the time when the system. The system goes into the working phase with the closed loop system structure to enter the synchronization. Then the maximum torque control current has not reached the permissible limit value

[1], [2], [4], [7], [18], [26]. According to (8) and (9), the allowable value of the speed at the moment of maximum torque control current will be determined:

$$\omega_{maxcf} = \frac{K_{\omega}.\varepsilon_{Tmax}}{K_{\varphi d}.K_{\varphi}} = \frac{K_{\omega}}{K_{\varphi d}.K_{\varphi}} - \frac{C.I_{cf}+M_C}{\beta_C.T_M} = \frac{K_{\omega}}{K_{\varphi d}.K_{\varphi}} - \frac{C.I_{cf}+M_C}{\beta_C.T_M} \tag{12}$$

Here the value β_C is the mechanical stiffness; The component I_{cf} is the limited permissible current. If we assume that the time for the current to increase to Imax is $t_{max} = 2a_I.T_{\mu}$ then we have:

$$\omega_{maxcf} = \omega_{bdcf} - \frac{\varepsilon_{Tmax}.t_{max}}{2} = \omega_{bdcf} - a_I \varepsilon \mu_{Tmax} \tag{13}$$

So, the initial allowable rate ω_{bdcf} is calculated as:

$$\begin{aligned} \omega_{bdcf} &= \omega_{\max cf} + a_I.\varepsilon_{T\max}.T_{\mu} = \frac{K_{\omega}}{K_{\varphi_d}.K_{\varphi}}\varepsilon_{\max} + a_I.\varepsilon_{T\max}.T_{\mu} \\ &= \frac{K_{\omega}}{K_{\varphi_d}.K_{\varphi}}.\frac{C.I_{cf}+M_c}{\beta_c.T_M}.\left(1+\frac{K_{d\varphi}.K_{\varphi}.a_I.T_{\mu}}{K_{\omega}}\right) = \frac{a_{\varphi}.a_{\omega}.a_I.T_{\mu}}{\beta_c.T_M}.(C.I_{cf}+M_c).\left(1+\frac{1}{a_{\varphi}.a_{\omega}}\right) \end{aligned} \tag{14}$$

Expression (14) is the basis for selecting the initial speed for the correct synchronous attachment phase. From (14) we see that the torque of resistance increases the value of the initial allowable speed, so when calculating, it is necessary to choose the smallest M_C with M_C changes in the wide limit. Consider the system when rotating at a given angle. The system starts to operate when the first condition is zero. The system includes the following motion phases: Gia tốc đến tốc độ ω_{max} ($\Delta\varphi$), motion with maximum speed allowed, precisely stop. The greater the initial set angle acceleration, the greater the starting current. When ω_{max} is larger, the maximum current when braking is greater. The dynamic properties of the position control system are preserved only when the current value $I_{max} < I_{cf}$, the control system is linear. In order to avoid over-tuning when braking at maximum initial speed, the position regulator gain gain can be selected according to (7), then we consider the rated speed of the drive system as the initial speed and give the values $|\varepsilon_{tb}| = \varepsilon_{hmax} = const$, [2], [4], [9], [15].

We have: $\frac{\Delta\phi}{K_{\phi}} = \frac{\omega_{dm}^2}{2\varepsilon_{hmax}}$ (15)

Replace (15) with (7) we get:

$$K_{d\phi} = \frac{2.K_{\omega}.\varepsilon_{hmax}}{K_{\phi}.\omega_{dm}} \tag{16}$$

When the component $\Delta\varphi$ is large ($\Delta\varphi_{dmax}$: deviation at the start of the brake state), it is necessary to choose $K_{d\varphi}$ according to the condition (16). When the component $\Delta\varphi$ is small, we choose $K_{d\varphi}$ inversely propo-rtional to the speed:

$$K_{d\phi} = \frac{K_{\omega}.\varepsilon_{Tmax}}{K_{\phi}.\omega} \tag{17}$$

Calculate and simplify, we obtain the position controller transfer function is:

$$W_{\phi} = K_{d\phi} + \frac{K_{d\phi}}{2a_{\phi}T_{\omega}s} \tag{18}$$

As shown in (18) is the integral rate controller. When synthesizing the PI position controller, we can calculate according to the Ziegler-Nichols method or the method using the specialized software PID Design in [4] to calculate and select the appropriate parameters. Then with the necessary values for simulation and experimentation of the controller are: $a_{\phi}= 0{,}2$; $\mathrm{K}_{\omega} = 0{,}002$; $T_{\omega} = 0{,}079$. At this point, we can calculate the components K_P and K_I as: $K_P = 2850$; $K_I = 8100$. Then the control structure transformation is done as a function of state parameters (speed and angle deviation) of the system [8], [9], [10], [19].

3. RESULTS AND DISCUSSION

In this section, the results of system simulation research on the basis of Matlab Simulink and experiment with hardware dSPACE 1104 on the console are performed by the authors. From there evaluate the research results and discussion analysis.

3.1. The simulation researches

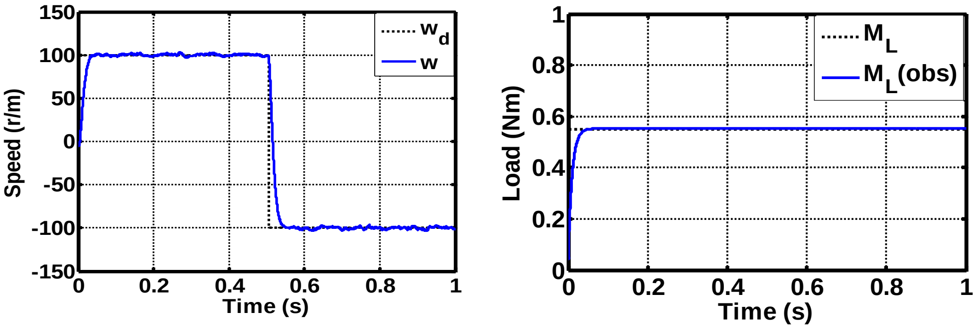
After studying the calculation, building the position controller, based on the parameters calculated and selected above. The simulation parameters: PMSM motor, symbol 1FK708-2AF71-1EA0 of the company Siemens denoted by YF C037579101001, used to simulate and experiment, including: Power P = 2,1 kW; rated speed 3000 rpm; voltage U = 315 V; rated current I = 4,4A; number of poles 2p = 8; static torque M_0 = 8,0 Nm; Rated torque M_{dm} = 6,8Nm; viscosity friction coefficient B = 0.0001 N.m.s /rad; moment of inertia J = 14200 kgcm²; max permissible speed 6000 rpm; encoder AM 2048 S/R; net weight of the motor is 10,3 kg. Develop a simulation program on Matlab-Simulink software to simulate, evaluate the results to verify the validity of the research method.

Survey and evaluate the quality indicators of the system, when the impact is a ladder function. The simulation is performed with different large and small values of input amount (preset angle). Research on the effects of regulator parameters on system quality (fast impact calculation and asymptotic ability without oscillation to the end position). Select adjuster parameters to achieve the desired value [2]-[5], [8], [9]. Investigate the integrated adjustment tracking system with more control channels according to the input content direction, and select the channel coefficient. Designing the integrated controller to improve the quality of the tracking drive system, when there is an additional content-directed control channel. To ensure that the system is infallible when the input signal changes at a constant speed. With the speed controller in the inner loop, it is possible to expand the control channel according to the interference torque [4], [9].

The control system built as above works when converting the structure with different deviation values and is simulated as some of the following cases:

- **Case 1:** Simulated with a speed control loop using PMSM motor, with the dSPACE 1104 card of electromechanical tracking drive system. In this case, as shown in [20], when simulating at high speed (thousands Rpm), the system can always respond. But the problem authors want to point out here is that for variable architecture using dSPACE 1104 card, the speed controller of the tracking drive system works at very slow speed with is essential. Therefore, in this case, the authors have studied simulations at low speeds to simulate and evaluate the working ability, the system's response during the start-up and braking process, when the speed changes, the load torque have not any change (the load torque is constant).

  When the set speed ω_d is 100 rpm, corresponding to the set speed of 20.9 rad/s and the time to reach the equilibrium value t_1 = 0.035s to t_2 = 0.5s, the reverse speed drops to -20.9 rad/s Figures 3 (a) and (b) shows that the estimated load torque stably providing enough information about the load for the controller. Response current i_{sq}, although changing at the time t_1 = 0.035s and t_2 = 0.5s but still reaching an equilibrium value of about 0.5A Figure 4 (a); i_{sd} fluctuates about 0.25A, Figure 4 (b); in case 1. It can be seen that the estimated speed is always closely related to the set value both in the changing speed mode and in the steady state. Moreover, in transient mode, the response of the observer also responds to the relatively fast time.



(a) (b)

Figure 3. The Speed controller simulation; (a) set speed ω_d and actual speed ω of the motor; (b) the set torque M_L and estimated torque M_L (observer) in case 1

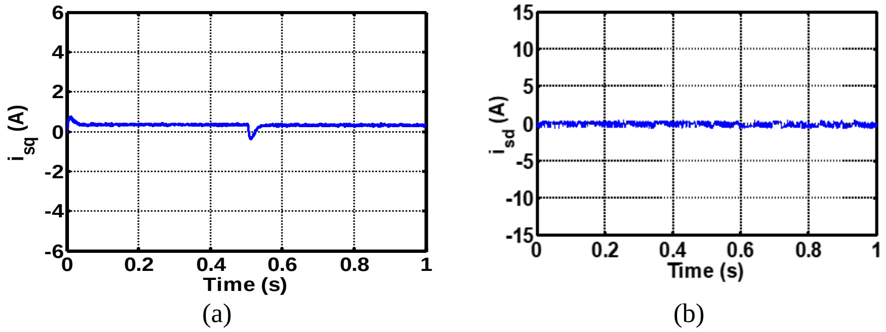


Figure 4. Response current values; (a) i_{sq}; (b) i_{sd} in case 1

- **Case 2:** Study the effect of the time of structure transformation: the system works at the wrong angle when converting the structure with the optimal value which is the given amount of the ladder function Xv = 0.1 rad, when the torque of the load constant M_c = 5Nm. The simulation results show that the angular input and output response has time to reach the equilibrium value of 0.1s as shown in Figure 5 (a), the output is always tracking to the input amount, the current value i_{sq} in Figure 5 (b), in case 2 shows the correct process system work. We have the following results:

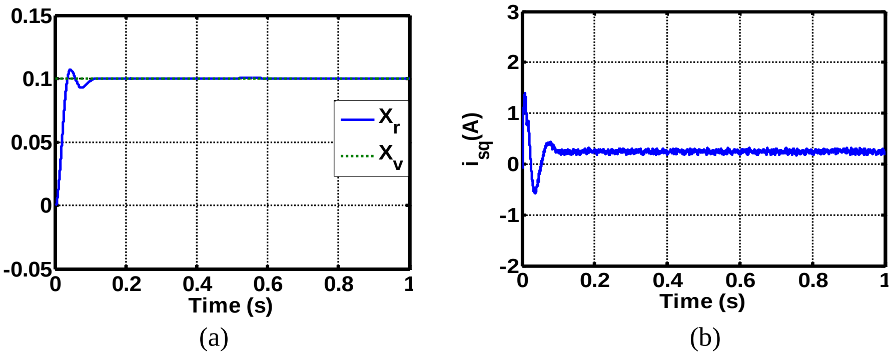


Figure 5. The controller input and output responses: (a) at an angle of 0.1 rad; (b) i_{sq} value in case 2

- **Case 3:** Study the reaction of the system, when the applied angle is a function of variable speed variation according to the law of function $X_v = V_t$, (V = 1 rad/s) constant load moment M_c = 5Nm, as shown in Figure 6 (a). The value of current i_{sq} shows the correct working process, according to the response of the position controller in Figure 6 (b) in case 3.

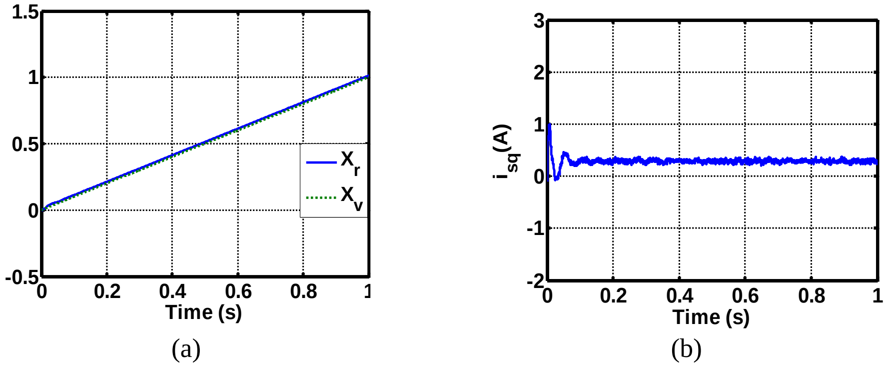
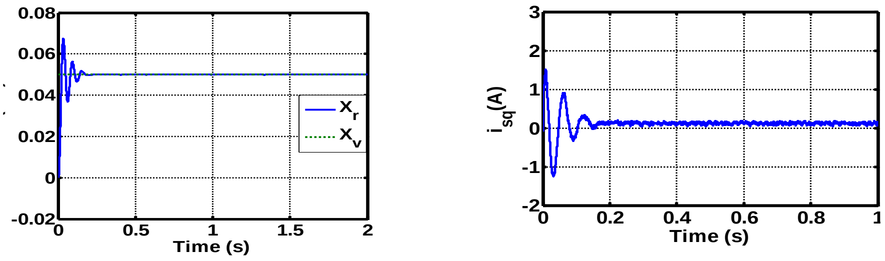


Figure 6. Response to the position controller; (a) at an angle of 1 rad; (b) i_{sq} value in case 3

- **Case 4:** The set angle to the baby X_v = 0.05 rad, the system works with the output of the system that changes during the transition, the system's oscillation process has the number of oscillations=2 times; transient time t_{qd} = 0.16s; The output still closely follows the amount in the equilibrium process. We have the result in Figures 7 (a) and 7 (b), in case 4.



(a) (b)

Figure 7. Response controller inputs and outputs; (a) at an angle of 0.05 rad; (b) value of line i_{sq} case 4

Observing the simulation results, it shows that the choice of the time of structure transformation greatly affects the dynamic quality of the electric drive system: the error angle when converting the structure (set angle is large, 0,1 rad; 0,5 rad or small set angle of 0,06 rad), and constant speed input. Here the position controller is considered, there is always the change of the angle applied to the system with many different cases. This shows that the stability of the controller against uncertain nonlinear component effects, the system works stably. The controller ensures stability with changing set speed, setting angle of system to work stably for the system, [1], [2], [4]. The output (X_r) is always tracking by the input (X_v) amount in the balancing process, the system works stably.

3.2. The experimental research

The objective of the experimental process is to demonstrate that the built-in position controller not only works well in the Matlab Simulink simulation but also works well in real time. This is a new scientific issue that brings many practical meanings in the industry today.

The system is experimentally implemented as follows: The general structure of the PMSM motor control position controller using dSPACE 1104 device as shown in Figure 9 (a); and experimental table as shown in Figure 9 (b). The parameters of the PMSM motors used in the experiment are the same as those of the motors used in the simulation, DC motor used to generate loads, symbol DOLIN-SH.198V with voltage U = 190V, I =13,5A, n=175 rpm. In which the current and speed feedback signals of the motor are fed into dSPACE 1104 via digital analog converter channels. The actual values of the current, speed and angular position are calculated by the processing card. The actual values of current, speed and position are fed into the programmed regulators for comparison with the set value. The interface is designed on Matlab-Simulink software, Control Desk software is used to monitor; data collection and control objects on the computer. With the structure of the system as shown in Figure 8, (K_φ position controller; K_ω speed; current K_i; power amplifier and PWM control signal modulator; PMSM AC motor and DC motor used to generate loads; angle measuring sensor (position); ADC: analog-digital converter.

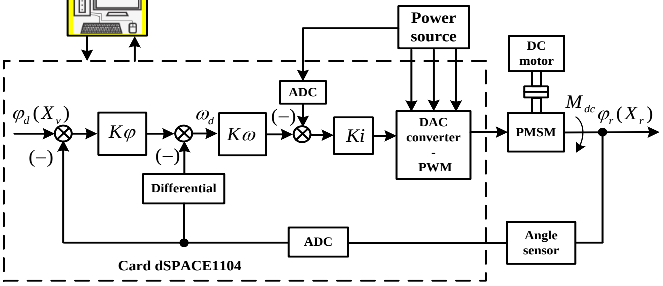
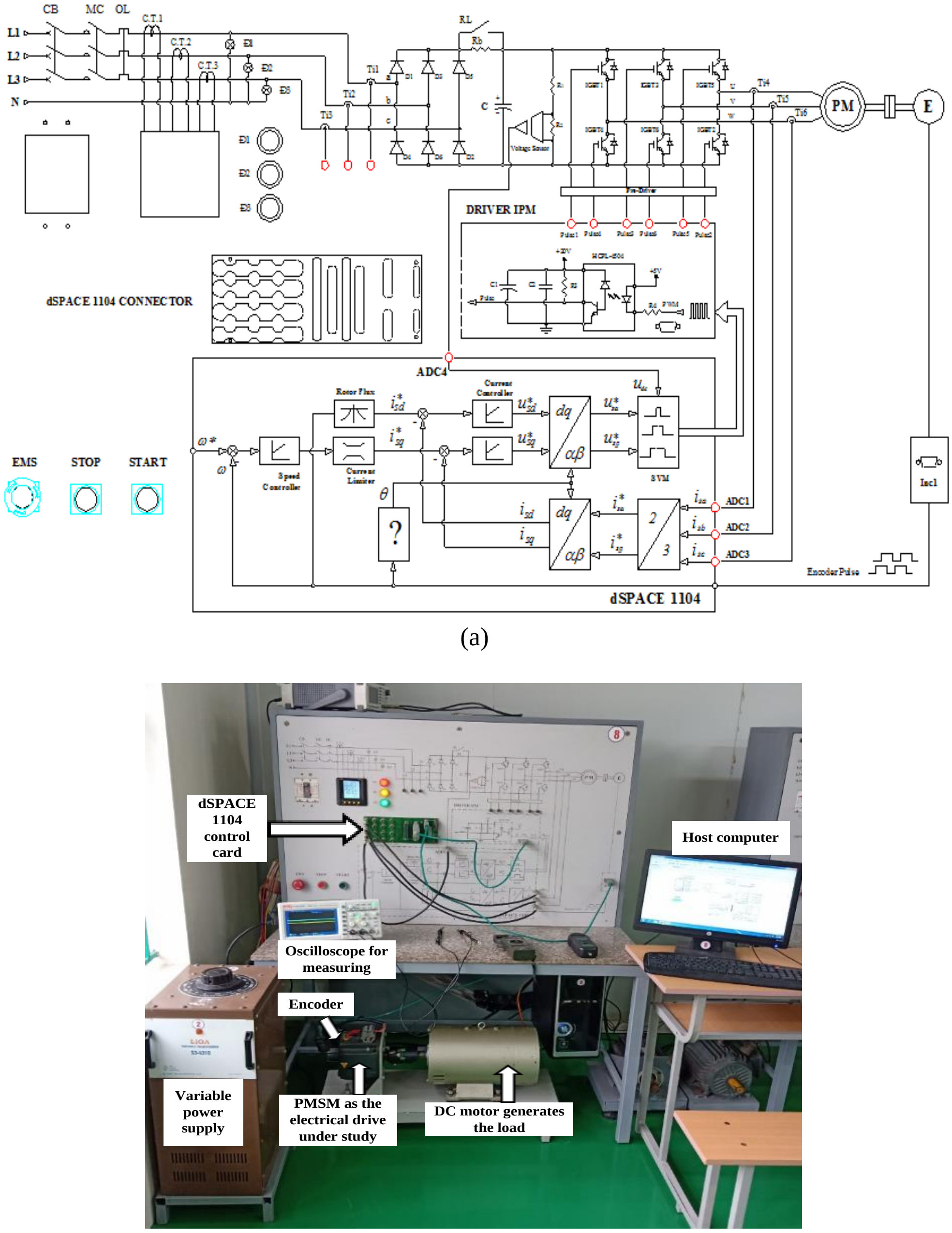


Figure 8. The structure diagram of PMSM motor position control system using dSPACE 1104 device



(a)

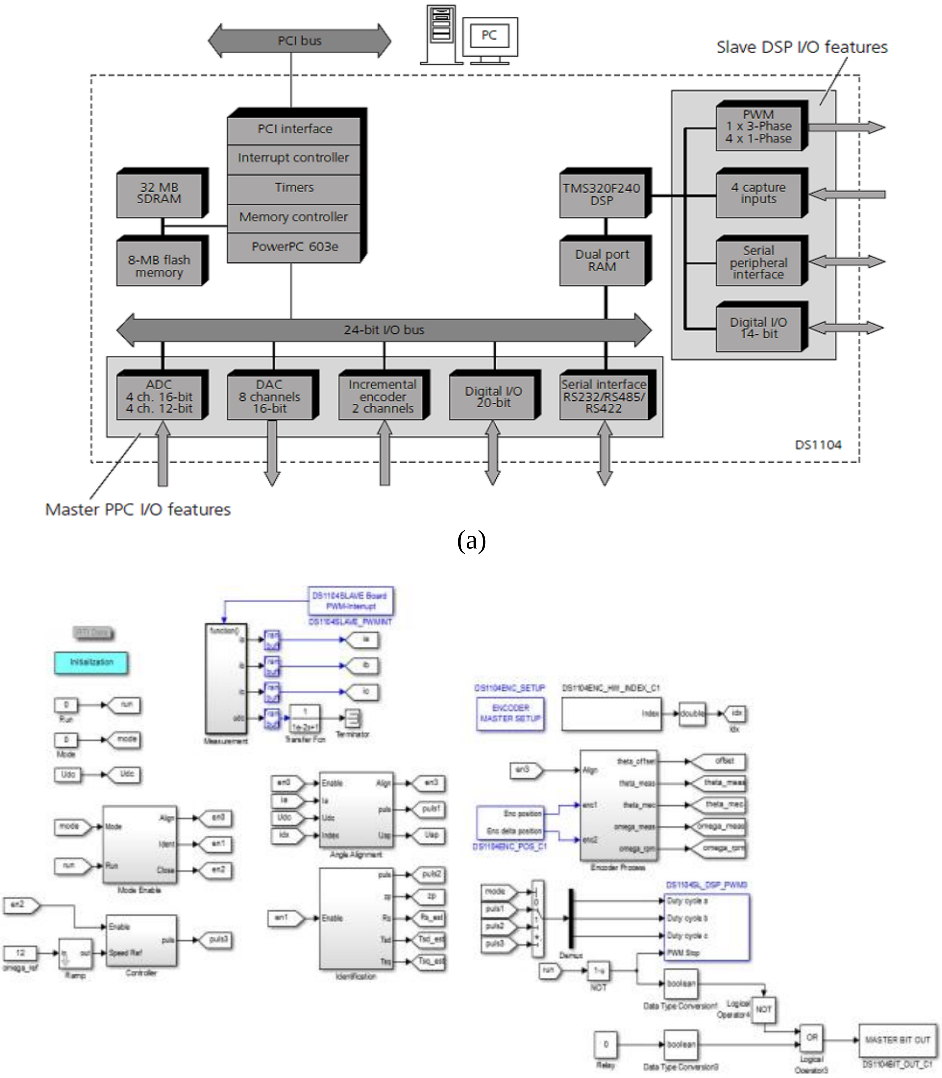
(b)

Figure 9. Structure diagram of PMSM motor position control system experimental table using dSPACE 1104 device; (a) structure and control diagrams; (b) the experimental table system using dSPACE 1104

The hardware device dSPACE 1104 is a digital control device manufactured by German firm DSP, based on a floating-point DSP digital signal processor, this is the third generation DSP. This DSP belongs to the TMS320Cxx family of Texas Instruments (USA). The dSPACE 1104 is specially designed to develop high-speed multivariable digital controllers for real-time simulation. Diagram of Dspace 1104 device block, [6] as shown in Figure 10 (a), [26]. The Simulink program data acquisition input/output data of object in Figure 10 (b).

The experimental model of the applied article is “Experimental research table of controlling position of PMSM motor with variable structure” Figure 10 (b) includes: Hardware dSPACE 1104, high-configuration embedded computer: Mainboard H110A; Processor/Intel G4400 Chip (3M Cache, 4.50 GHz); Ram 8G; DDR4 2133 MHz; RX graphics card, installed with the included driver of Dspace card, synchronous AC motor with the same parameters as simulated part, motor with high resolution encoder; extraction time t=10^{-3}s, the positional controller parameters are selectively calculated, [4]. K_ω=8561;

K_φ=2,381; K_i=6,851; combining software dedicated Matlab R2020; software to program algorithms in C and CCS languages (code composer studio); there are also power source systems, measuring equipment, oscilloscopes, and other switching protection devices.

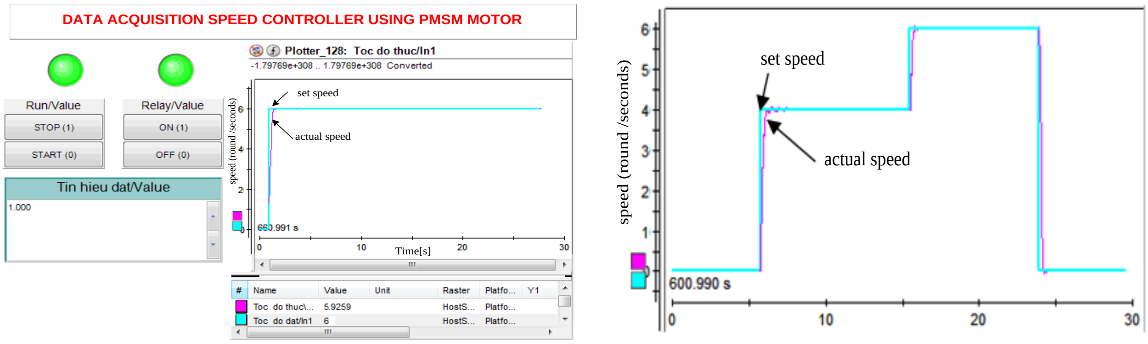


(a)

(b)

Figure 10. These figures are; (a) diagram of Dspace 1104 device block as shown; (b) simulink program data acquisition input/output data of object

- **Case 1:** This program is compiled and loaded into the dSPACE 1104 device to control the PMSM motor in real time, with the motor data as given in the simulation. The results of data collection on the Control Desk are shown in Figure 11 (a), Figure 11 (b), with the adaptive sliding speed controller, the real speed always closely follows the set value in the balancing process. Experimental results with the variable structure (structure change time always meets the preset value), controlled according to the adaptive rule for the system.



#	Name	Value	Unit	Raster	Platfo...	Y1
🟪	Toc do thuc\...	5.9259		HostS...	Platfo...	
🟦	Toc do dat/In1	6		HostS...	Platfo...	

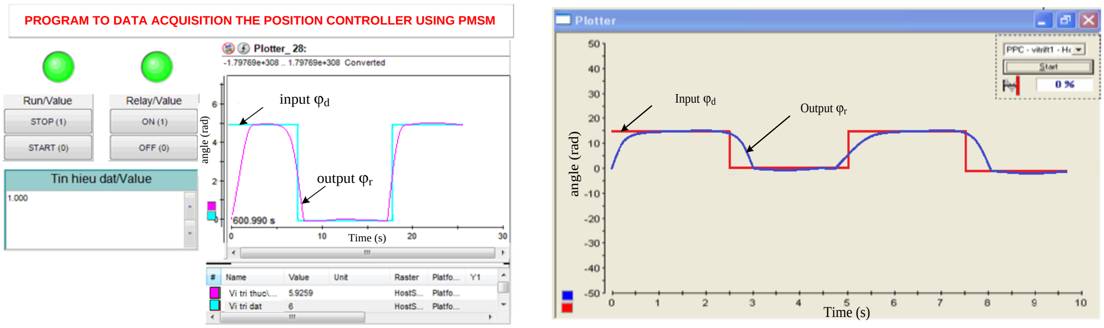
(a) (b)

Figure 11. Experimenting with speed controllers; (a) responding data acquisition with PMSM motor speed did not change; (b) responding to data acquisition with variable PMSM motor speed

Observing experimental results with the speed controller using PMSM motor via dSPACE 1104 card and Control Desk software shows that using the adaptive sliding mode controller [20] brings good quality work out adhering to the amount in the balance process, reaching the quality target of 10ms transient time and no over-adjustment. Moreover, the speed controller is designed to keep the motor speed constant when speed is changed and the torque is changed (increase or decrease), the response of the controller is always stable. Compare the results with the studies in [15], and in [13], [18], the results of the paper are better with the simulation with the time to reach a smaller equilibrium value (0.04s), to satisfy the controller of the experimental part always works well with the large capacity motor many times (more than 10 times) This is one of the proven good results for the controller that has been designed.

- **Case 2:** This program is compiled and loaded into the dSPACE 1104 device to control the PMSM motor in real time, with the motor parameter data as given in the simulation. The results of data collection on the Control Desk are shown in Figure 12 (a), the actual angle value is always close to the initial set angle value of 5 rad in the equilibrium process.

The results of control studies in real time with the position controller are collected on the Control Desk when the angle signal is set to 15 rad, the output is close to the input amount in the equilibrium process as shown in Figure 12 (b).



#	Name	Value	Unit	Raster	Platfo...	Y1
🟪	Vi tri thuc\...	5.9259		HostS...	Platfo...	
🟦	Vi tri dat	6		HostS...	Platfo...	

(a) (b)

Figure 12. (a) responding data acquisition position controller using PMSM motor; (b) actual control on Control Desk with position controller when the set angle value is 15 rad

Observing experimental results with the position controller with variable structure, shows that the control system building using dSPACE 1104 card has brought good working quality, output is always close to the amount in balanced stable working process.

Specifically, the time to reach an equilibrium value of 0.07s in a total response time of 10 seconds (as shown in Figure 12 (b). Moreover, the position controller is built capable of keeping the motor speed constant when the intake and drag torque is changed, the controller response is always stable, this is a scientific problem, completely applicable to practical industrial production. Compare results with studies in

[16], and in previous studies such as: in [17], the results of the paper are better than the simulation with time to reach equilibrium value smaller than (0.8s), in [22] the oscillating current is greater than 0.25A (Figures 14 (b) and 5 (b) of [22]). Therefore, the controller output response, with the experimental part in the article, always works well with motors with a capacity many times larger than previous studies. Therefore, the position controller has partly achieved the quality assurance target to satisfy the need of controlling high precision industrial machines such as metal cutting machines, industrial robots, to do increase labor productivity, reduce product costs to meet market demand with the lowest cost.

4. CONCLUSION

The position control system using PMSM motor with variable structure used in electric drive system for precision control objects in industry and military requires very high reliability and accuracy. The replacement of the old control systems is necessary and urgent in the electromechanical traction systems that are being used a lot in practice today. This article presented a new approach, which can be practically applied to today's industrial traction drive systems such as robot control systems, precision control systems for pill filling machines in the industry pharmacy, CNC metal cutting machine control system, weapon attachment system, electropneumatic and hydraulic actuator control system. Based on the synthesizing method of controller according to dark standards modularity and variable structure. The results show that the correct control laws are the basis for use in calculating the design of position controllers for industrial and military grip systems. Compared with previous studies, only stop at simulation and experimental results with small capacity motors. Therefore, this new research problem has been deployed and applied in practical industrial production with high quality control. Further development direction can be considered for the case: synthesizing angular close drive system with variable structure for objects directly controlling torque: using using Brushless DC motor-BLDC, and Switched Reluctance Motor-SRM.

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