

USING THE PROGRAMMABLE LOGIC CONTROLLER IN POSITION CONTROL OF PERMANENT MAGNET SYNCHRONOUS LINEAR MOTOR WITH HYSTERESIS CURRENT CONTROLLERS

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SUMMARY

Nowadays, linear motors are widely used in industry such as tool machines, CNC (Computer Numerical Control) machines, process control systems because they make linear motions without gears, hence using linear motors in these fields will decrease the cost and increase both the reliability and the durability of the system. One of the most common linear motors used in industry is the permanent magnet synchronous linear motor. The most important control of permanent magnet synchronous linear motors is the precise position control. In this paper, a programmable logic controller is applied in exact position control of the permanent magnet synchronous linear motor with hysteresis current controllers which are simple current controllers used widely in industry. The quality of the control system is quite good and is proved by experiments

Key words: permanent magnet synchronous linear motor; Programmable Logic Control; exact position control; optimal velocity and running time

CONSTRUCTIONAL DIAGRAM OF CONTROL SYSTEM

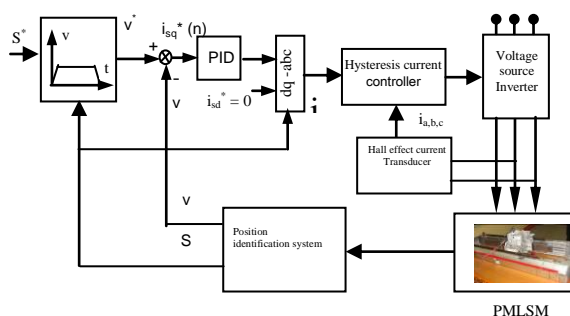


Figure 1. *Block diagram of control system*

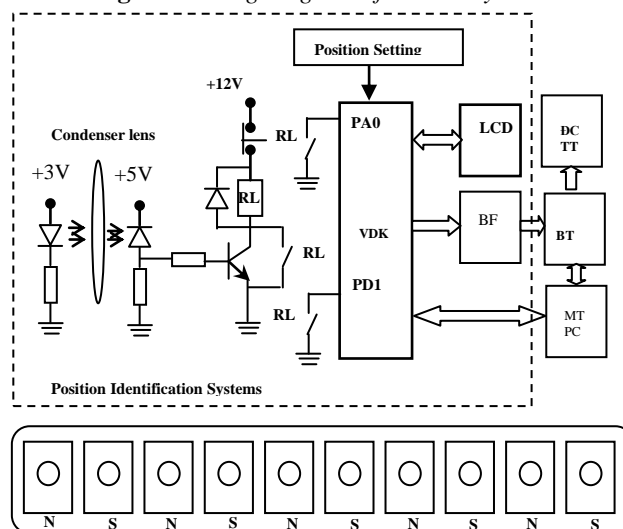


Figure 2. *Position identification system*

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Meanings of symbols in figure 2:

RL: Relay; VDK: Microcontroller; LCD: Liquid Crystal Display ;MTPC: Personal Computer; DCTT: Permanent Magnet Synchronous Linear Motor; BF: Output Buffer; BT: Block of PLC and Inverter

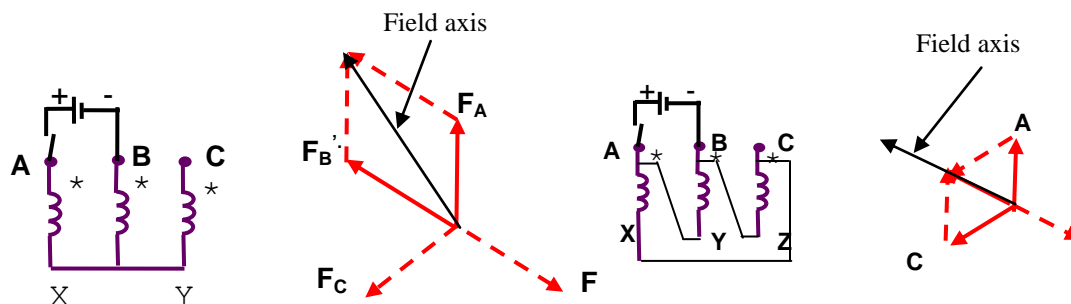


Figure 3. The armature magnetic field axis position in star connection and triangular connection of three phase windings.

POSITION IDENTIFICATION SYSTEM

The position identification system consists of photodiodes which are put along the length of moving distance of the linear motor. The distance between two photodiodes which are next to each other is 2 centimeters, that distance is equal to the pole pitch of the linear motor. The part which generates the light is the LED which is located on the moving part of the linear motor. The position of the linear motor is specified by the light received from the LED (Light – Emitting Diode) through photodiodes

The microcontroller system receives the voltage signals from photodiodes and the setting position (the desired position of the linear motor), in cooperation with the Programmable Logic Control (PLC) system, generates the optimal runtime, the optimal linear motor velocity which are corresponding to the moving distance that is specified by the microcontroller system.

THE SOLUTION IMPROVING THE ACCURACY OF SPECIFYING THE POSITION OF THE LINEAR MOTOR

To have the smallest quantity of photodiodes and input ports of the microcontroller, as well as the high accuracy of specifying the position of the linear motor, the following solution is used:

- Step 1: Apply the DC voltage pulse to two phase terminals A and B of the linear motor to put the moving part of the motor in the standard position. In this position, the LED is face to face with the photodiode which is put along the length of moving distance of the linear motor.

When a DC voltage pulse is applied to the armature windings as above figures, according the push- attraction rule of the magnet, the armature magnetic field axis position is located in the middle of the opposite pole of permanent magnets on the stator part.

- Step 2: Supply voltage for the LED and run the system.

THE PROGRAMMABLE LOGIC CONTROL (PLC) SYSTEM

PLC system receives input signals from output terminals of the microcontroller system, generates the optimal runtime, the optimal linear motor velocity which are corresponding to the moving distance that is specified by the microcontroller system.

SPECIFYING THE OPTIMAL VELOCITY AND RUNNING TIME FOR THE LINEAR MOTOR

In controlling the position of the linear motor, the characteristic of the desired velocity has the form in figure 4.

Where, $\operatorname{tg} \alpha = a_{\max}$; a_{\max} is determined by the velocity controller

The moving distance of the linear motor: $S = v \cdot t = S_{ABCD}$ This is the area of the trapezium ABCD: $S = a_{\max} t_1^2 + a_{\max} t_1 t_2$. The optimization problem has objective function : $F = 2t_1 + t_2 \rightarrow \min$ and constraints: $t_1, t_2 \geq 0$; $S = a_m t_1^2 + a_m t_1 t_2$; $S \geq 0$;
 $v = a_{\max} t_1 \leq v_{\max}$. After solving the optimization problem, we have the optimal

velocity: $v_{tu} = a_m t_1 = a_m \sqrt{\frac{s}{a_m}} = \sqrt{a_m s}$ and

the optimal time:

$$F_m = 2t_1 + t_2 = 2 \cdot \sqrt{\frac{s}{a_m}} + \frac{s - a_m \frac{s}{a_m}}{s \cdot \sqrt{\frac{s}{a_m}}} = 2 \cdot \sqrt{\frac{s}{a_m}}$$

CONTROL ALGORITHM

The control algorithm of the position controller is described in figure 5

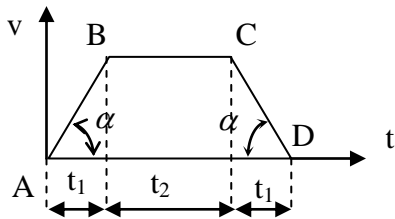


Figure 4. The characteristic of the desired velocity in controlling the position of the linear motor

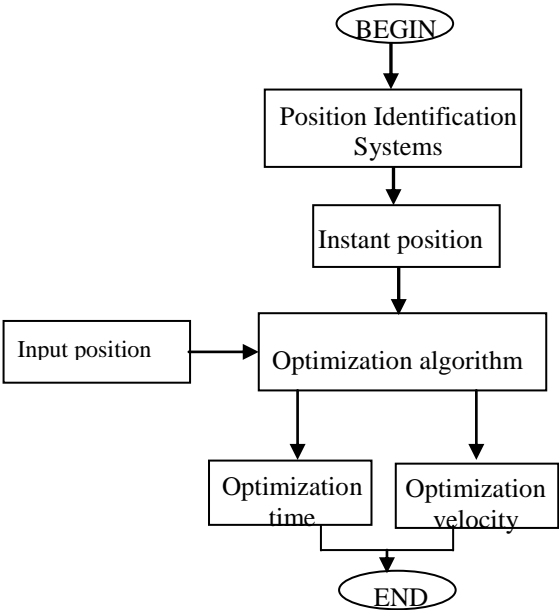


Figure 5. The control algorithm of the position controller

THE RESULTS OF THE EXPERIMENT

Basing on the experimental system described in figure 6, the experiment is done and the results are described in following figures.



Figure 6. The experimental system

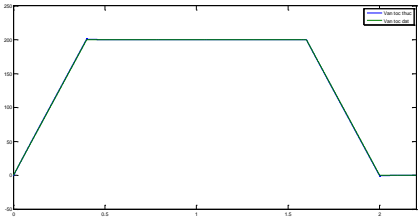


Figure 7. The referent velocity and the real velocity

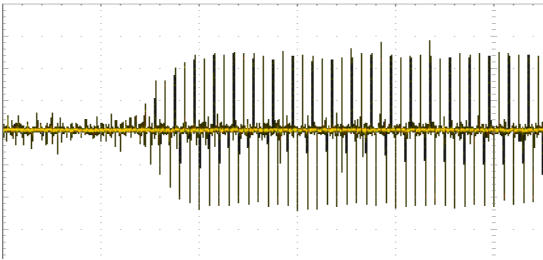


Figure 8. The real current of the motor when the velocity changes from 0 to the optimal value

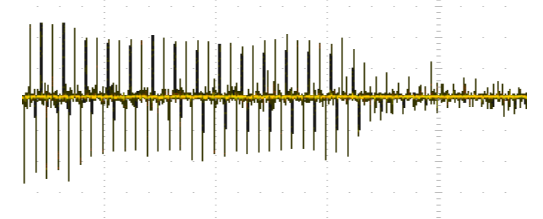


Figure 9. The real current of the motor when the velocity changes from the optimal value to 0

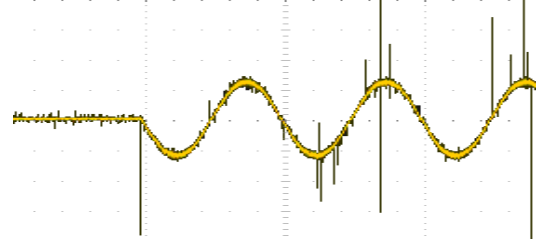


Figure 10. The real current of the converter (converting the voltage from the AC form to the DC form) when the velocity changes from 0 to the optimal value

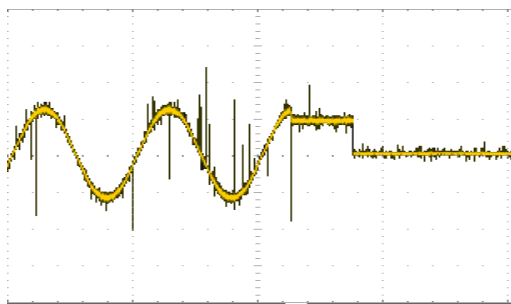


Figure 11. The real current of the converter (converting the voltage from the AC form to the DC form) when the velocity changes from the optimal value to 0

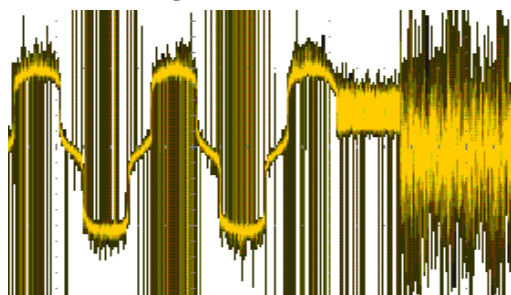


Figure 3.10. The real voltage of the motor when the velocity changes from the optimal value to 0

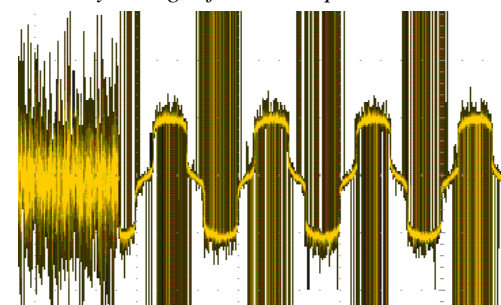


Figure 3.11. The real voltage of the motor when the velocity changes from 0 to the optimal value

CONCLUSION

The results of the experiments show that, the control quality of the system is quite good, the accuracy of controlling the position of the motor is guaranteed by the accuracy of the velocity loop and the current loop of the control system. That is expressed by the

experimental result in figure 7 where the real velocity follows the referent velocity very closely. The difference percentage in velocity is under 0.1%. The results of the experiments in figures 8 and 9 show that, when the velocity of the motor increases from 0 to the desired value, the current magnitude and frequency increase correlatively, that is similar to the opposite process. The results of the experiments in figures 10 and 11 show that, when the velocity of the motor increases from 0 to the desired value, the current magnitude following into the converter increase correlatively, but the frequency is constant and equal to the frequency of the source voltage, that is similar to the opposite process. The results of the experiments in figures 12 and 13 show that, when the velocity of the motor increases from 0 to the desired value, the motor voltage magnitude and frequency increase correlatively, that is similar to the opposite process.

In conclusion, the proposed system has met the requirements of the position control in practice such as CNC machines, robots.

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TÓM TẮT

**SỬ DỤNG BỘ ĐIỀU KHIỂN LOGIC LẬP TRÌNH ĐƯỢC (PLC)
TRONG ĐIỀU KHIỂN VỊ TRÍ ĐỘNG CƠ TUYẾN TÍNH LOẠI ĐỒNG BỘ
KÍCH THÍCH VĨNH CỬU VỚI BỘ ĐIỀU KHIỂN DÒNG HYSTERESIS****Cao Xuân Tuyền****Trường Đại học Kỹ thuật Công nghiệp – ĐH Thái Nguyên*

Hiện nay, các động cơ tuyến tính đang được ứng dụng rộng rãi trong công nghiệp, như trong các máy công cụ, các máy CNC, trong các hệ thống điều khiển quá trình do tính ưu việt của nó là không phải sử dụng thêm hệ thống bánh răng trục vít để chuyển từ chuyển động quay của trục động cơ thành chuyển động thẳng, do đó việc sử dụng động cơ tuyến tính trong các lĩnh vực này sẽ giảm giá thành, nâng cao độ tin cậy và tuổi thọ của hệ thống. Một trong số các động cơ tuyến tính được sử dụng phổ biến trong công nghiệp là động cơ tuyến tính đồng bộ kích thích vĩnh cửu. Một vấn đề quan trọng trong điều khiển loại động cơ này là điều khiển chính xác vị trí của động cơ. Trong khuôn khổ của bài báo này, tác giả trình bày việc áp dụng hệ thống PLC, vi điều khiển trong việc điều khiển chính xác vị trí động cơ tuyến tính trong hệ thống chuyển động thẳng với bộ điều khiển dòng kiểu hysteresis. Chất lượng bộ điều khiển là rất tốt và được chứng minh bằng thực nghiệm.

Từ khóa: Động cơ tuyến tính đồng bộ kích thích vĩnh cửu; bộ điều khiển logic lập trình được; điều khiển vị trí chính xác; vận tốc tối ưu; thời gian chạy tối ưu.

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