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SIMULATION DYNAMIC MODEL OF LINEAR INDUCTION MOTOR WITH VECTOR CONTROL

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Abstract: Induction motors are most commonly used motors in the industry. Their commercial application is due to their simple construction, reliability and sturdiness. Linear induction motors (LIM) is an alternative to rotary induction motors due to the avoidance of mechanical gears. Typically, the LIM is used in devices with large loads, such as the treatment of materials under pressure and in transport systems. Management principles of LIM are similar to traditional induction motors, but its features and ways to manage more complex than traditional rotary motors. In use of vector control LIM behaves as a separately excited DC motor. This paper presents a dynamic mathematical model of a linear induction motor. A method for vector control with PI controller. The effectiveness of the proposed control scheme is verified by simulation examples.

Keywords: Linear induction motor, dynamic model, vector control, simulation results

1. INTRODUCTION

The electric motor is an electromechanical device that converts electrical energy into mechanical energy. The physical principles on which operate the electric motor is based on the relationship between the electric current and the magnetic field. The electric motors can be divided into two types: AC motors and DC motors. Induction motors are used in approximately 85% in electric industry. This is due to their simple operation, simplicity of construction and relatively low price. Usually the management of induction motors using systems without feedback as mechanisms, which are driven at a constant speed. Considering, however, the induction motor during transients open system is difficult to apply and requires the use of different type and structure "feed-back system". Most of the contemporary ways of managing AC electric drives are based on management based inverters. At the present time, efforts are focused on controls induction electric drives, leading to the concept under DC electric drives.

All mechanisms perform some movement. Mechanical movement can be categorized as: linear, rotary movements, pulse movements, translational movement and others. Mechanical actuators in electro lead to complex construction and ultimately to mechanical losses.

Linear motors are a special type of motors that convert electromagnetic forces into a rectilinear motion without additional mechanical gears. The generally the linear motors are similar to standard rotary motors, but unlike rotary motors, the stator and rotor in linear motors have an open loop system and have a linear form.

Linear motors are an alternative to traditional motors rotary engine. Usually linear motor is used in arrangements where power plants require and percussion prologue, such as materials handling and transport systems. In linear motors are provided with precision motion mechanisms without additional mechanical losses. Management of linear motors is accomplished by frequency or vector control.

The principles and methods for frequency or vector control are described in numerous references, such as [4, 7, 9]. By changing the frequency of the inverter controlling the linear motors with high pitch it can control the speed of movement of the linear motor, and also to maintain the required linear force. In [4] has shown the possibility that linear induction motor can be controlled by vector control.

In [1] is shown a method for managing magnetic levitation vehicle with the help of linear induction motors. In this control method, voltage vector of pulse-with modulation PWM.

In [1, 7, 9] is shown as a relatively simple construction management linear synchronous motors with permanent magnets. The control is performed using three controllers: backstepping adaptive controller; adaptive controller with auto-tuning and an adaptive controller perform the vector transformation, the development of which is shown in [3]. These controllers are controlled by computer. On a computer monitor are reported the transients, the load distribution of the linear motor. In [7] is shown without sensor management and time management and flow adhesion in induction motor. Yamamura in [11] intrudused the impact of the phenomenon of end effects as a feature in the operation of the linear induction motor. Sensorless control reporting the final effect is discussed in [7].

This article shows the predictive simulation mathematical model induction linear synchronous motor in the d-q coordinate system. The linear induction motor is vector controlled. Efficiency of the depicted model is verified by simulation results obtained.

2. DYNAMIC MODEL OF LIM

Before proceeding to the design of the controller for linear induction motor is necessary to establish a dynamic model of the engine. The most commonly used dynamic models of the linear induction motors are based on a synchronous coordinate system that is directly controlled by the frequency of the supply voltage. This approach is very similar to the modeling of three-phase induction motors, but there are some peculiarities. In the dynamic model of the linear induction motor is assumed that:

1) Only stator variables are measurable
2) No end-effect is considered
3) No friction is considered
4) Three phases of the LIM are balanced
5) It is assumed that the magnetic system is unsaturated

In the rest paper, the following symbol for various parameters and variable are used: R_s -is the active resistance of the primary winding; R_r -active resistance of the LIM; L_m -Magnetizing inductance; L_s - primary inductance; L_r -inductance of the slider; i_{sd} - d axis primary current ; i_{sq} -q axis primary current ; u_{sd} -d axis primary voltage; u_{sq} - q axis primary voltage; $T_r = \frac{L_r}{R_r}$ - secondary time constant; $\sigma = 1 - \frac{L_m^2}{L_s L_r}$ - the leakage coefficient; v_e - synchronous linear velocity; v - the slider linear velocity; h - pole pitch; λ_{sd} -d axes primary flux; λ_{sq} -q axes primary flux; λ_{rd} - d-axes secondary flux; λ_{rq} -q-axes secondary flux; $K_f = \frac{3}{2}\frac{\pi}{\tau}\frac{L_m}{L_r}$ -force constant; F_e - linear electromagnetic force; F_L - external resistance force; M - mass of the slider; D - coefficient of viscous friction.

The dynamic model of a linear induction motor is compiled on the basis of T-replacement schemes shown in Figure 1 [7,11].

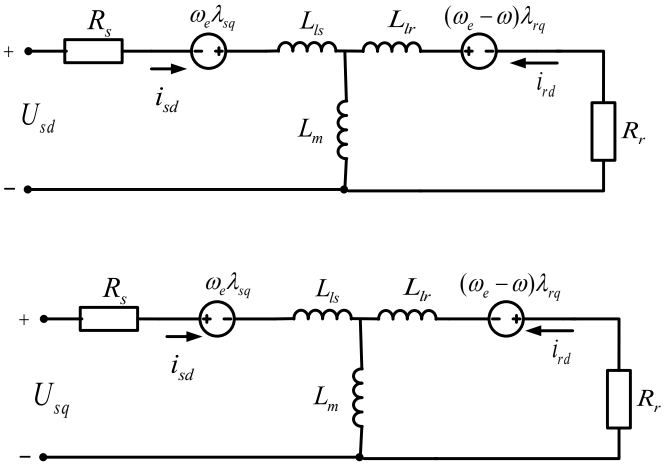

Figure 1.T substitution d-q ecvivalent circuits of the LIM excluding end effects

The relation between primary and secondary currents and fluxes in a stationary reference frame is:

$$\begin{aligned} \lambda_{sd} &= L_s i_{sd} + L_m i_{rd} \\ \lambda_{sq} &= L_s i_{sq} + L_m i_{rq} \\ \lambda_{rd} &= L_r i_{rd} + L_m i_{sd} \\ \lambda_{sd} &= L_r i_{rq} + L_m i_{sq} \end{aligned} \tag{1}$$

The three-phase supply voltage of the LIM creates an electromagnetic field which is a synchronous rotational speed, which is associated with synchronous linear velocity of the stator by the formula:

$$\omega_e = \frac{\pi}{\tau}.v_e \tag{2}$$

Where h is pole pitch, and ω_e is the frequency of the supply voltage. Supply voltage induced in the slider electromagnetic field which drives the slider with speed v. Following the concepts on induction motors, the slider speed, v, is always slightly less, i.e.:

$$\omega_{sl} = \omega_e - \omega_r = \frac{\pi}{\tau}(v_e - v) \tag{3}$$

Dynamic equations of the LIM in d-q synchronous reference frame is:

$$u_{sd} = R_s i_{sd} + \frac{d}{dt}\lambda_{sd} - \omega_e \lambda_{sq} \tag{4}$$

$$u_{sq} = R_s i_{sq} + \frac{d}{dt}\lambda_{sq} + \omega_e \lambda_{sd} \tag{5}$$

$$0 = R_r i_{rd} + \frac{d}{dt}\lambda_{rd} - \omega_{sl} \lambda_{rq} \tag{6}$$

$$0 = R_r i_{rq} + \frac{d}{dt}\lambda_{rq} + \omega_{sl} \lambda_{rd} \tag{7}$$

The complete dynamic model of LIM is than optained by combining the above equations, and given in by [18,19],

$$\frac{di_{sq}}{dt} = \frac{1}{\sigma L_s} u_{sq} - \left(\frac{R_s}{\sigma L_s} + \frac{1-\sigma}{\sigma T_r} \right) i_{sq} - \frac{\pi}{h} v_e i_{sd} - \frac{L_m \pi}{\sigma L_s L_r h} v \lambda_{rd} + \frac{L_m}{\sigma L_s L_r T_r} \lambda_{rq} \tag{8}$$

$$\frac{di_{sd}}{dt} = \frac{1}{\sigma L_s} u_{sd} - \left(\frac{R_s}{\sigma L_s} + \frac{1-\sigma}{\sigma T_r} \right) i_{sd} + \frac{\pi}{h} v_e i_{sq} + \frac{L_m \pi}{\sigma L_s L_r h} v \lambda_{rq} + \frac{L_m}{\sigma L_s L_r T_r} \lambda_{rd} \tag{9}$$

$$\frac{d\lambda_{rq}}{dt} = \frac{L_m}{T_r} i_{sq} - \frac{\pi}{h}(v_e - v)\lambda_{rd} - \frac{1}{T_r}\lambda_{rq} \tag{10}$$

$$\frac{d\lambda_{rd}}{dt} = \frac{L_m}{T_r} i_{sd} + \frac{\pi}{h}(v_e - v)\lambda_{rq} - \frac{1}{T_r}\lambda_{rd} \tag{11}$$

The motion of the slider is described by the equation of electrical drive based on the second law of the Newton, i.e.:

$$F_e = M\frac{dv}{dt} + Dv + F_L , \tag{12}$$

where

$$F_e = K_f \left(\lambda_{rd} i_{sq} - \lambda_{rq} i_{sd} \right) \tag{13}$$

is electromagnetic force of the slider.

3. VECTOR CONTROL

The principles of control of LIM were similar to those used in conventional rotating induction motors, but in contrast to them. The control of the characteristics in the LIM are complicated.

The vector control of the LIM is obtained if $\lambda_{rq} = 0$ и $\frac{d\lambda_{rq}}{dt} = 0$ for all time. Thereby it can control the frequency of the supply voltage, which is a good way of change of the supply voltage. Equations satisfying in vector control are:

$$U_{sd} = R_s I_{sd} - \sigma L_s \omega_e I_{sq} \tag{14}$$

$$U_{sq} = R_s I_{sq} + L_s \omega_e I_{sd} \tag{15}$$

$$\omega_e = \frac{\pi}{h} v + \frac{R_r}{L_r}\frac{I_{sq}}{I_{sq}} \tag{16}$$

The complete of the closed loop system of the vector of LIM is shown in figure 2.

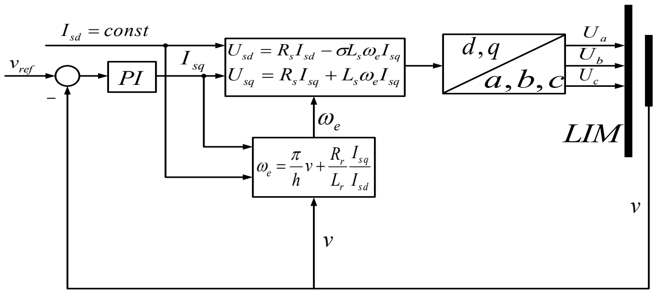

Figure 2. LIM vector control with PI controller

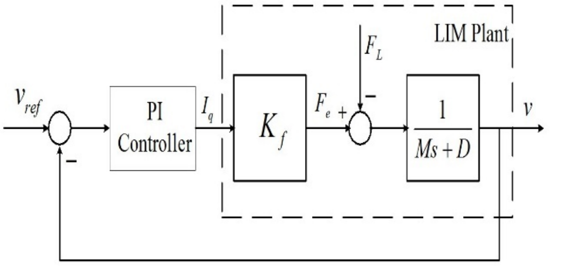

Figure 3. Vector control of LIM with PI regulator

The control shown in figure 2 uses two current I_{sd} and I_{sq}. The current I_{sd} is assumed constant, however can also be controlled separately to maintain a desired flux level in tha motor. The amount of current I_{sq} is proportional to the load on the motor and is adjusted using the PI controller, shown in Figure3.

4. SIMULATION

For the verification research model is used the engineering simulation program SIMULIK.

In the simulation, the following data of the linear induction motor are:

R_s=5.3685Ω; R_r=3.5315 Ω; L_m=0.02419 H, L_s=0.02846 H;
L_r=0.02846 H; h=0.027 m; M=2.78 kg; D=36.0455; U_a= 180 V

The PI regulator which is used in vector control for adjusting the current I_{sq} has the following values $K_P = 35$ and $K_I = 75$.

The load, which is loaded in the slider, is 50 times greater than the mass of the slider.

In the simulation it is assumed that the slider is loaded in the first 1 sec., after that it run without load.

In Figure 4 shows the speed slider with vector control, and PI controller. It should be noted that, in the vector control the speed of the slider is maintained after removal of the load, which can be seen from figure 4.

In Figure 5 is seen that the flux λ_{rq} is zero in this type of control. In Figure6 is seen electromagnetic linear force of the slider.

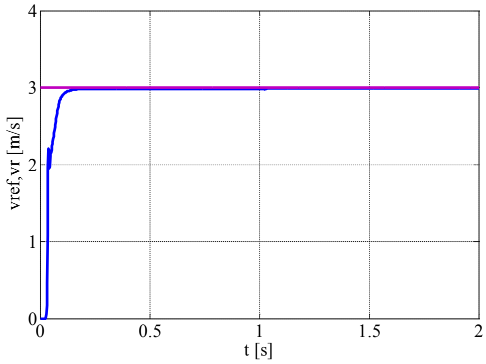

Figure 4. Speed slider with load and vector control

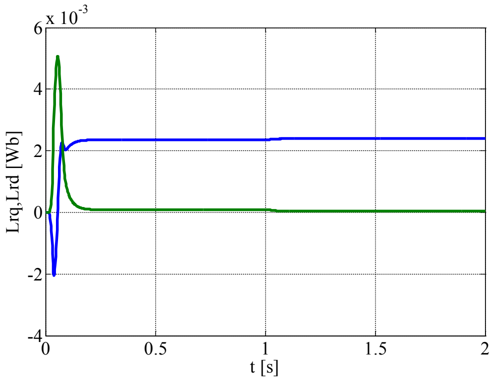

Figure 5. Fluxes λ_{rd}, λ_{rq} in vector control

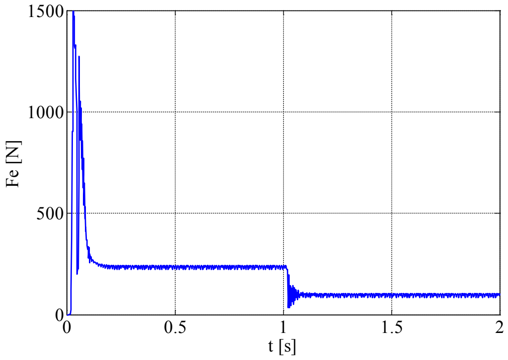

Figure 6. The electromagnetic force F_e with vector control

5. CONCLUSIONS

This article presents a dynamic model of a linear induction motor. Simulation experiment carried out on the dynamic model LIM with vector control and PI controller that achieves the desired speed of movement of the secondary element (slider).

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