

DESIGN OF PLC CONTROLLED LINEAR INDUCTION MOTOR

¹Ashish Bachute,²Akash Babar,³Balaji Bagal,⁴Abhay Bhagat,⁵Prof. Anupma Kamboj

¹Department of Electrical Engineering,

¹JSPM's Bhivarabai Sawant Institute of Technology and Research, Pune, India

Abstract: This paper presents a simple and fast methodology for designing a linear induction motor (LIM). A linear induction motor is an AC asynchronous linear motor that works by the same general principles as other induction motor but is very typically designed to directly produce motion in a straight line. Characteristically, linear induction motors have a finite length primary, which generates end effects, whereas with a conventional induction motor the primary is an endless loop. Their uses include magnetic levitation, linear propulsion and linear actuators. They have also been used for pumping liquid metal. Despite their name, not all linear induction motors produce linear motion some linear induction motors are employed for generating rotations of large diameters where the use of a continuous primary would be very expensive. Linear induction motors can be designed to produce thrust up to several thousands of Newton's. The winding design and supply frequency determine the speed of a linear induction motor.

Index Terms – Linear induction motor (LIM), magnetic levitation, programmable logic controller (PLC)

I. INTRODUCTION

A LIM is basically a rotating squirrel cage induction motor opened out flat. Instead of producing rotary torque from a cylindrical machine it produces linear force from a flat one. Only the shape and the way it produces motion is changed. But there are advantages: no rotary to linear converter, higher efficiency, silent operation, reduced maintenance, compact size, ease of control and installation. LIM thrusts vary from just a few to thousands of Newton, depending mainly on the size and rating. Speeds vary from zero to many meters per second and are determined by design and supply frequency. Speed can be controlled by either simple or complex systems. Stopping, starting, reversing, are all easy. Applications are many and varied, ranging from simple sliding doors to full control of a ten tone vehicle. According to construction LIMs are of five types as Short stator or short primary, short rotor or short secondary, Single sided LIM, Double sided LIM, Tubular LIM.

Since technology for motion control of electric drives became available, the use of programmable logic controllers (PLCs) with power electronics in electric machines applications has been introduced in the manufacturing automation. This use offers advantages such as lower voltage drop when turned on and the ability to control motors and other equipment with a virtually unity power factor. Many factories use PLCs in automation processes to diminish production cost and to increase quality and reliability.

The objective of this paper is to design a SLIM of specified parameters. The study included developing SLIM equations, design procedures, predicting its performance and controlling its direction using PLC.

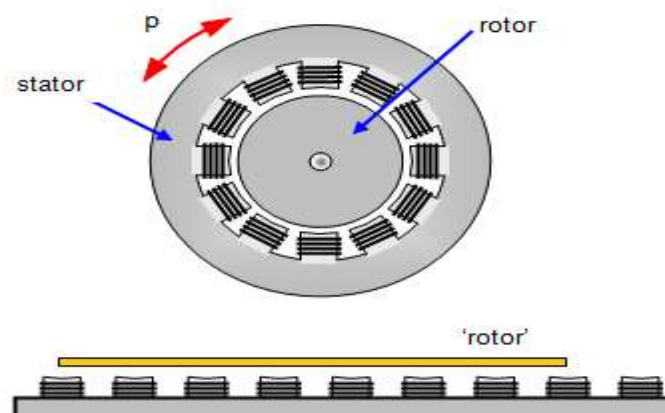


Fig.1: Single sided LIM

II. CONSTRUCTION AND WORKING OF LIM

A linear induction motor's primary typically consists of a flat magnetic core (generally laminated) with transverse slots that are often straight cut with coils laid into the slots, with each phase giving an alternating polarity so that the different phases physically overlap. The secondary is frequently a sheet of copper.

The linear motor operates on the same principle as a rotary squirrel cage induction motor. The rotary induction motor becomes a linear induction motor when the coils are laid out flat. The reaction plate in the LIM becomes the equivalent rotor. This is made from a non-magnetic highly conductive material. The air gap between the stator and rotor must typically be very small, much smaller than the allowable gap for the synchronous motor, otherwise the amount of current required for stator coils becomes unreasonable. When supplying an AC current to the coils, a travelling magnetic wave is produced. Swapping the phases reverse the direction of travel. Currents induced in the rotor by the travelling magnetic wave create a secondary magnetic field. It is not necessary to keep the field of motion synchronized by the stator coil. A linear thrust is produced with the reaction between these two fields.

III. HARDWARE DESCRIPTION

The technical specification of LIM is given in the table 3.1. We are using one PLC for the controlling of this LIM which has specification in the table 3.2.

Table 3.1: Specification of LIM:

Rated output power	3HP/2.2kW
Rated voltage	400V AC
No. of phase	3
No. of poles	4
Frequency	50Hz
Type of connection	Star/Delta

Table 3.2: Specification of PLC:

Manufacturing company	Allen Bradley
Input power supply	24V DC
Memory	10K
Digital Input	24V/12V DC
Digital output	24v (Relay) 0.7-1.5 Amp
Serial port	RS232C
Operating temperature	-20°C to +60°C
Programming software	Rslogix 500 or above version

IV. DESIGN AND CALCULATION

Firstly we choose the specification of LIM which is given in the table 3.1. We have been used all formulas which related to the LIM and induction motor.

4.1 Calculation of Main Dimensions

For calculation of main dimensions firstly calculated the output power of the motor in kW from following question.

$$\text{Output in KW} = 3 * \text{HP} / 1000 \quad (1)$$

Where; HP is the rating of motor in horse power. After that have been calculated the KVA input of motor by using equation

$$Q = \text{HP} * 0.746 / \eta * \cos\phi \quad (2)$$

Where; Q: KVA input of motor, η : efficiency which is assumed from standard data sheet is 0.81, $\cos\phi$: power factor of motor which is also assumed from standard data sheet is 0.81.

$$D^2 L = Q / (Co * ns) \quad (3)$$

Where; D: diameter of stator bore in meter, L: length of stator core in meter, Co: output coefficient, for calculation of Co we used following formula

$$Co = 11 * kw * Bav * ac * 10^{-3} \quad (4)$$

Where; kw: winding factor, Bav : specific magnetic loading, ac: specific electrical loading. For the separation of the product D^2L , we consider the ratio of core length to pole pitch (L/τ), For cheap design, ratio L/τ should be between 1.5 to 2. From the equation of D^2L and L/τ we get values of D and L.

4.2 Stator Design and Selection of Conductor Size

It is most important to find the flux per pole from following equation

$$\Phi m = Bav * \tau * L \quad (5)$$

In above equation Φm is flux per pole. Next step is calculation of stator turn per phase.

$$Ts = Es / (4.44 * f * \Phi m * Kw) \quad (6)$$

Where; Es is input voltage of motor, f : frequency of input voltage and other remaining terms mentioned above. After that the selection of conductor size which is most important part of designing of motor. For this we have been calculated the line and phase current.

$$Is = (Kw * 1000) / (3 * Es * n * \cos\phi) \quad (7)$$

$$I_{sL} = \sqrt{3} * I_s \quad (8)$$

In the above equation I_s is phase current and I_{sL} is line current of motor. From these calculation selected the size of copper conductor which is used for the winding of motor. Remaining calculation part is as same as the design of induction motor.

V. CONTROLLING OF LIM BY USING PLC

In industry PLCs are mostly used for controlling of various machines. We can control the LIM by using PLC. In this project we used Allen Bradley Company's PLC. A PLC is a microprocessor-based control system, designed for automation processes in industrial environments. It uses a programmable memory for the internal storage of user-orientated instructions for implementing specific functions such as arithmetic, counting, logic, sequencing, and timing. A PLC can be programmed to sense, activate, and control industrial equipment and, therefore, incorporates a number of I/O points, which allow electrical signals to be interfaced. Input devices and output devices of the process are connected to the PLC and the control program is entered into the PLC memory.

In Fig. 2, the block diagram of the experimental system is illustrated.

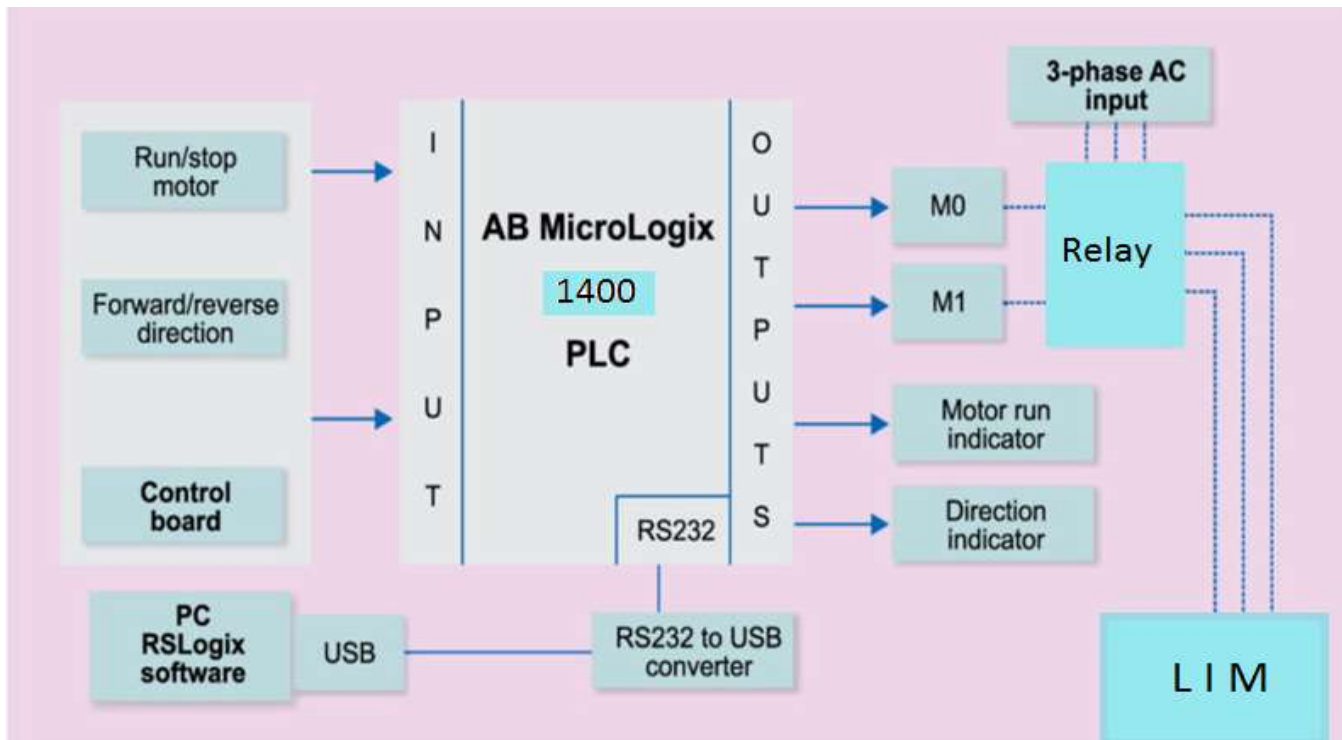


Fig 2: Block diagram of controlling of LIM

The programming method used is the ladder diagram method. The PLC system provides a design environment in the form of software tools running on a host computer terminal which allows ladder diagrams to be developed, verified, tested, and diagnosed. First the high-level program is written in ladder diagrams. Then, the ladder diagram is converted into binary instruction codes so that they can be stored in random-access memory (RAM) or erasable programmable read-only memory (EPROM). Each successive instruction is decoded and executed by the CPU. The function of the CPU is to control the operation of memory and I/O devices and to process data according to the program. Each input and output connection point on a PLC has an address used to identify the I/O bit. The method for the direct representation of data associated with the inputs, outputs, and memory is based on the fact that the PLC memory is organized into three regions: input image memory (I), output image memory (Q), and internal memory (M). For communication between PLC and PC RS232 port is used. By using electromagnetic relay we controlled the forward-reverse direction, start-stop of motor.

VI. ADVANTAGES

1. Direct electromagnetic force.
2. Economical and cheap maintenance.
3. Easy expansion for any linear motion of system topology.
4. Exact positioning in closed loop systems.
5. Possibility to provide inductor and winding separate cooling.
6. All electro-mechanical controlled systems used for an induction motors can be adopted for a LIM without any bigger changes.

VII. DISADVANTAGES

1. Power factor and efficiency are less than that of rotary motors because of a ratio of large air gap between and pole pitch.
2. The longitudinal end effect reduces power factor and efficiency .it can be reduced with special motor design methods.
3. Extra vibration with distortion can be noticed because of uncompensated normal force.

VIII. FUTURE SCOPE

In future we can control the speed of LIM and can be used for various applications. This LIM can also be used in direction as well as speed control using various power electronic devises like VFD, etc. Apart from Aluminum and Copper, new materials can be experimented for conducting layer of reaction plate to explore better efficiency of LIM.

IX. CONCLUSION

This paper presents simple methodology of designing of LIM. Different types of windings gives different output results. The controlling of LIM by using PLC is very reliable, fast and efficient. The controlling of LIM by PLC proves its high accuracy in speed regulation. The obtained efficiency by using PLC control is increased as compared to the other systems.

REFERENCES

- [1] Amir Zare Bazghaleh, Mohammad Reza Naghashan, and Mohammad Reza Meshkatoddini, "Optimum Design of Single-Sided Linear Induction Motors for Improved Motor Performance" IEEE Transactions on Magnetics, Vol. 46, No. 11, November 2010
- [2] Bekaddour Benatia Mostefal, Bekkouche Benaissa, Merahi Amir, Medles Karim, "A Fast and Simple Method for Designing a Linear Induction Motor (LIM)" Journal of Electrical Engineering www.jee.ro
- [3] Maria G. Ioannides, Senior Member, IEEE, "Design and Implementation of PLC-Based Monitoring Control System for Induction Motor" IEEE Transactions on Energy Conversion, Vol. 19, No. 3, September 2004
- [4] A Text Book of "Electrical Machine Design" by A. K. Sawhney.

