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LEVITATION OF LINEAR INDUCTION MOTOR

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Abstract:
In 1890, initial implication to linear induction apparatus started, just a mere couple of years following the disclosure of the rotary induction concept. Fundamentally, the notion underlying the linear mechanism involves imaging a rotating apparatus sliced in a radial plane and subsequently "unfolded," culminating in a primary constituent composed of a solitary succession of copper coils arranged in there place within a core crafted from laminated steel. There exists an explication of the disparities between rotary and linear motors, alongside an elucidation of the gradual integration of linear motors. Essential advancements in linear machinery from the 1950s are deliberated upon. An induction engine has the capability to energize XV capsules within pneumatic capsule pipeline technology. Various optimal configurations for a unilateral linear induction motor (ULIM) were implemented. The proposed analogous circuit of ULIM considers the terminal effects, half occupied slots, iron saturation, and skin effect phenomenon. By employing the intricate power equivalence amidst the primary and secondary facets and the dummy electrical potential method, multiple coefficients within the circuit were derived, encompassing the longitudinal terminal effect coefficients Kr(s) and Kx(s), the lateral terminal edge effect coefficients Cr(s) and Cx(s), and the skin phenomenon coefficient K. To further heighten operational efficiency and diminish primary mass, a multitude of ULIM optimal design restriction equations are provided. The outcome strives to introduce a novel lift notion employing innovative construction methodologies. These encompass the skin phenomenon coefficient K, the lateral terminal edge effect coefficients Cr(s) and Cx(s), and the longitudinal terminal effect coefficients Kr(s) and Kx(s). To further curtail primary mass and enhance operational efficiency, several ULIM optimal design restriction equations are furnished. By utilizing a distinct construction methodology and integrating the system with a counterbalance, it enhances comfort and reliability while reducing expenses, with the aim of instigating a pioneering lift concept.

I. INTRODUCTION:

In contrast to a rotary induction motor (RIM), the SLIM demonstrates superiority due to its ability to exert greater force on the secondary without mechanical contacts, accelerate or decelerate more rapidly, minimize wheel wear, reduce turn radius, and provide a more adaptable road line. The linear induction motor (LIM) possesses inherent characteristics such as longitudinal end-effect, transversal edge-effect, and normal force resulting from its cut-open magnetic circuit. Additionally, it features partially occupied slots in the primary ends. Consequently, developing an accurate equivalent circuit model for LIM poses greater challenges compared to RIM. Despite the exploration and development of various SLIM analysis methodologies in recent years, effective design techniques for SLIM remain elusive for several reasons: difficulty in choosing between electric and magnetic loading via load distribution, complicating the calculation "The linear induction motor (LIM) stands out for its distinct features, such as its impact on the ends and edges, and its ability to generate force without physical contact. This is due to the innovative design of its magnetic circuit, featuring specialized slots at the ends. Understanding and accurately modeling the LIM presents a unique challenge compared to conventional induction motors, given its intricate characteristics.

In the realm of converting rotary motion to linear motion, traditional methods often involve intricate mechanical systems comprising gears and axles. However, these conventional setups often incur inefficiencies and high maintenance costs due to friction and wear. The utilization of an electric motor capable of producing linear motion directly offers a novel solution, promising cost savings and heightened reliability, particularly within transportation sectors.

for controlling mover position in linear induction motors (LIMs). Keywords: linear induction motor, squirrel cage induction motor, electromagnetic energy, laminations, magnetic core.

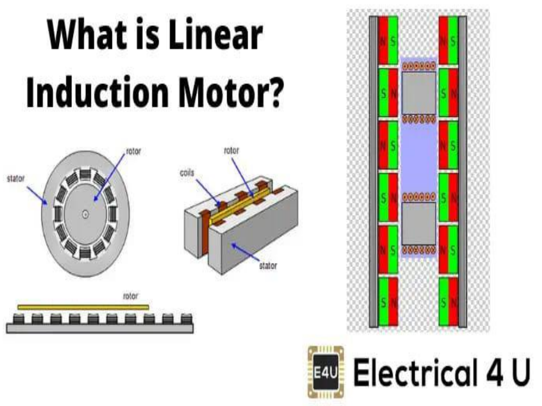


Fig1: Block Diagram

I. HISTORY:The inception of linear electric motors traces back to the 1840s, with early experiments conducted by Charles Wheatstone in London. However, it was not until later advancements by visionaries like François Arago and Walter Baily in understanding magnetic fields and induction motors that the technology began to materialize.. It seems that Nikola Tesla and Galileo Ferraris independently devised viable alternating current induction motors, with the latter subsequently showcasing a functional motor prototype in 1887 and the former in 1885 ,groundbreaking contributions of figures like Tesla and Westinghouse in the late 19th century accelerated the adoption of induction motors, significantly shaping the landscape of electrical engineering., an employee at Westinghouse, was assigned to aid Tesla before assuming responsibility for the company's induction motor advancement. Mikhail Dolivo-Dobrovolsky, a steadfast advocate for three-phase progression, devised the three-limb transformer in 1890 and the squirrel aluminium cage-rotor induction motor in 1889. The initiation of three-phase induction motor development was undertaken by the General Electric Company (GE) in 1891. In 1896, Westinghouse and General Electric entered into a mutual licensing agreement for a brief secondary with a smaller conducting plate. Brief primaries are typically interwoven sequentially, whereas short secondary is wave winding which are connected in parallel ,motors utilize electromagnetic induction to rotate a shaft or rotor, converting electrical energy into mechanical energy. Electromagnetic induction refers to the generation of an electrical voltage across a conductor placed in a varying field. The electromotive force (EMF) induced along a closed circuit is directly proportional to the rate of changing flux linkages, as per Faraday's Law. This essentially implies that whenever there is the change in the emf depends upon the flux linkages cut by the rotor will flow through any closed loop of the conductor. This principle remains valid irrespective of the magnitude of the field alteration or the manner in which the conductor interacts with it.

A. The squirrel cage motor represents the most fundamental variant of induction motors.The most popular industrial AC motors are squirrel cage motors; when powered by a steady AC supply, they are.

B. The squirrel-cage rotor was subsequently dubbed the bar-winding rotor design only machines with continuous speed.

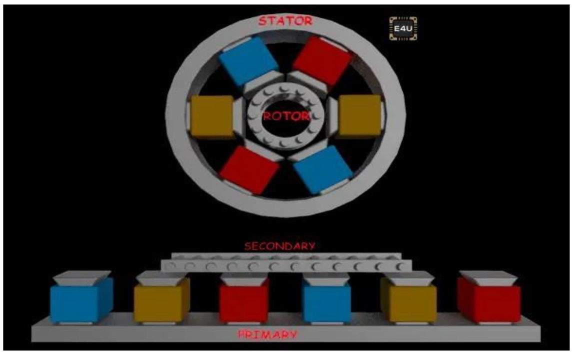


Figure 2 Showing the sectional cutting view od the induction motor.

Linear induction machine :

Induction motors harness the power of magnetic fields to drive motion, leveraging electromagnetic induction principles pioneered by luminaries such as Faraday.

With its core composed of coils and a secondary component crafted from aluminum and iron, the linear electric motor has emerged as a game-changer across various industries, offering unparalleled efficiency and safety compared to conventional mechanical systems.

In the pursuit of enhanced precision and control, ongoing experiments are exploring novel methods to manipulate voltage and frequency in linear motors. The concept of synchronous speed, dictated by factors such as pole count and electrical frequency, underscores the dynamic nature of these innovative propulsion systems."

Top of Form

power becomes evident. Precisely timed power phases applied to the three coils, set at 120° angles, ensure smooth rotation of the shaft without interruptions. The accompanying illustrations offer a clearer depiction of this process. Typically, electric motors drive rolls for transporting laminated products. The adhesion of laminated materials to the moving rolls is facilitated by the electric motor's rotation.the only factor influencing the acting moving force, which lowers the rolling speed. The bars will slide on the rolls because the consequent strong inertial forces will prevent a significant acceleration. The laminated product could serve as the moving body of a linearasynchronous motor, which could provide a solution to this issue. The trials were carried out in a variety of realistic ways. In order to obtain a suitable model design that could be applied to the tests, the system underwent various conditions and adjustments. By adjusting the LIM's air gap, magnetic gap, secondary material composition, electrical and magnetic circuit breakages, primary and secondary misalignment, and other parameters, as well as by utilizing alternative supplies and controls, the experimental data were acquired. With the use of a three phase auto transformer and a VVVF drive, the tests For achieving direct voltage control, frequency modulation, and variable voltage, variable frequency control or V/f control, successful experiments were conducted. Graphing the data acquired from the motor's secondary winding under closed or shorted conditions by an external impedance was performed. Similar to the currents induced in transformer secondary windings, the rotating magnetic flux induces currents in the rotor windings. Consequently, the magnetic fields generated by these currents in the rotor windings counteract the stator field within the rotor.

SYNCHRONOUS SPEED:

The rotational speed of the magnetic field in the stator of an AC motor, referred to as synchronous speed or Ns, is measured in revolutions per minute. Ns = 120*f/p, where p represents the number of magnetic poles and f denotes the motor supply frequency in Hz. In essence, for 50 Hz and 60 Hz supply systems, where p equals 6, Ns equals 1,000 RPM and 1,200 RPM, respectively, for a six-pole, three-phase motor with three pole pairs spaced 120° apart.

Slip, denoted as s, represents the comparison for both synchronuous and operational speeds at the same frequency, expressed in rpm, percent,as it is frequency,expressed in rpm,percentage or a a ratio of synchronous or as a ratio of synchronous speed. Therefore, S = (Ns - Nr)/Ns. The rotor's mechanical speed aligns with the stator's electrical speed. slip just changes the torque which is null at Ns and very high at rotor stationary. A minimal slip results in substantial current flow in the rotor and high torque due to the low resistance of short-circuited rotor windings. Slip varies at full rated load; it exceeds 5% for small or specialized motors and falls below 1% for large motors. Differences in speed when mechanically coupling motors of varying sizes may lead to load-sharing challenges. Employing variable frequency drives (VFDs) often provides the optimal solution for mitigating slip.

PRINCIPLES: The motive force in the electric motor generates a linear magnetic field by using the winding conductors. In accordance with Lenz's law, any conductor placed within this field—whether a loop, coil, or mere sheet of metal—will experience induced eddy currents, giving rise to an opposing magnetic field. As the magnetic field interacts with the metal, the repulsion between the two opposing fields engenders motion: $Ns = 2fs/p$, where p denotes the number of poles, fs is the supply frequency in Hz, and Ns is the synchronous speed in frequency of the magnetic field. The frequency of the linear magnetic field pattern is: $Vs = 2\pi fsT$, where T represents the pole pitch, and Vs denotes the linear velocity of the traveling field in meters per second.

For a slip of s in a linear motor, the secondary speed is determined by: $Vr = (1 - s)Vs$.

THRUST

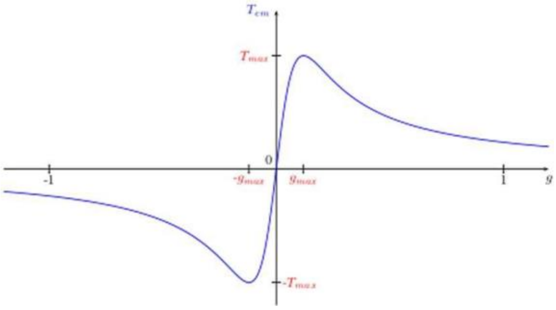


Figure 3 depicts the propulsion produced in relation to slip.

The power supplied to the stationary part windings, as mentioned earlier, is used to compensate for rotor copper losses and to generate useful linear thrust force is shifted to the rotating part. The mechanical active power generated by the rotor, represented in terms of equivalent circuit elements, equals the power transferred from the stationary part to the rotating part across the air medium, minus the variable losses in the rotor. Comparable to an linear induction motor with resistance rotor starter, the LIM generates force during normal operation that is directly proportional to the voltage product of voltage and diminishes as difference between synchronous speed and rotor speed is reduced.

Levitation

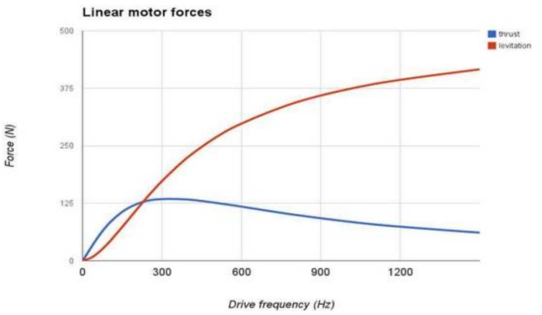


Figure 4 illustrates the curves for levitation and propulsion forces of a linear induction motor.

In contrast to a rotational machine, a dynamic levitating force is demonstrated, which starts at zero slip and increases in both directions to maintain a nearly constant force/gap ratio. This phenomenon is observed in single-sided motors, but the presence of an iron back plate on the output often inhibits levitation by creating an attraction force that exceeds the necessary lifting force.

Similar operational principles to those of other induction motors govern the behavior of a linear induction machine (LIM), an Alternate Current asynchronous linear machine primarily designed to induce motion directly along a straight path. While the primary of a conventional induction machine is configured in an infinite cycle, the finite length primary of a linear induction machine introduces end-effect. Despite their name, not all linear induction machine are employed for linear motions. Some are utilized to generate large diameter rotations, a scenario where employing a continuous primary would be prohibitively costly.

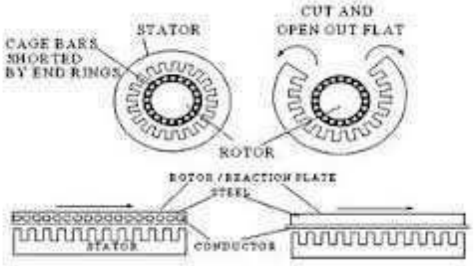


Figure 5.sectional Cutting and opening a IM to a LIM

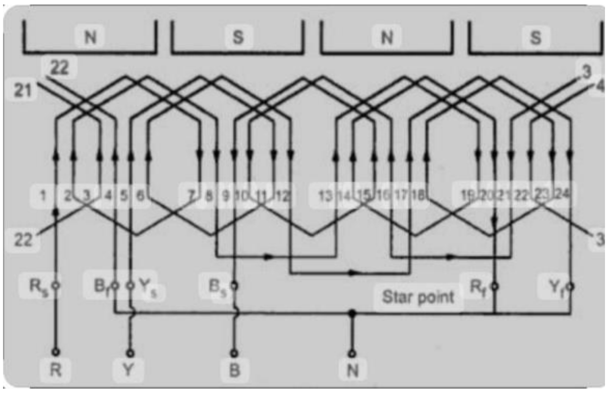
The connection between propulsion and other variable factors is the central focus of this manuscript. In the vertical direction, the perpendicular force is at a right angle to the stator. Undesirable forces, known as sideways forces, emerge in SLIMs due to the orientation of the stator. These forces become more notable during high-frequency operations (60 Hz), underscoring the need for their consideration. A minor sideways force can be nullified using a pair of roller for support. The standard analogous circuit depicted in Fig. 1 can be employed for the study of linear induction machine with minimal terminal effects. The constituent components of the circuit are determined based on SINGLE PHASE LINEAR INDUCTION MOTOR parameters. It is feasible to ascertain the propulsion and effectiveness of SLIM performances. The exact analogous circuit of a LIM is illustrated in Fig. 1. This circuit operates phase by phase. Since a practical air gap magnetic flux density yields moderate flux densities in the core and therefore relatively moderate core losses, the core losses are disregarded. Skin effect is the floe of electrons on the surface of the conductor of secondary side. Consequently, the equivalent rotor inductance is very small so that it is negligible. The remaining significant properties are depicted in Fig. 1 and elaborated upon below. The force created by the stator in the rotor exhibits a analogues linear motion modifiable by terminal effects. Unlike a circular or aZhao, Wei. "Study on the control strategy of linear induction motor for maglev vehicle." Master's thesis,BeijingJiaotongUniversity, 2017.

Technical Reports:

Korea Institute of Science and Technology. "Advancements in Linear Induction Motor for Maglev Transport: Technical Report", 2019. When the secondary component is abbreviated, the behavior closely resembles that of a rotary apparatus, provided it possesses two poles or more. However, if the primary component is abbreviated, there is a decrease in propulsion at low slip rates. Conventional induction motors can operate with a nearly synchronous field under light load circumstances; however, linear motors cannot operate under similar conditions due to the presence of end effects. This leads to significantly higher losses in linear motors due to the end effects.

II. BASIC PRINCIPLES OF LIM OPERATION:

A rotary induction motor and a LIM both operate on the same basis. Basically, you can create a linear induction motor by simply opening and flattening a revolving squirrel cage induction motor. Instead of a cylindrical machine creating rotary torque, this flat structure generates a linear force. It is possible to construct LIMs to generate pushes up to several thousand Newton’s. A LIM's speed is determined by its supply frequency and winding architecture. The fundamental workings of a standard rotor squirrel-cage induction machine are comparable to those of a LIM. The major components of the three phase induction machine is stationary winding part and rotating rotor part with a balanced polyphase winding that is evenly distributed throughout the stator's peripheral slots. A uniform speed of 2ω/p is generated by the stator,this generates the sine wave in the air medium. The number of poles (p) and the angula momentum (ω) are based to the frequency f. A voltage is induced in the rotor by the speed of the rotor conductors and the magnetic field. The rotor will experience a current flow as a result of this generated voltage, creating a magnetic field. The torque created by the relation between the stator produced magnetic field and the rotor of the field. The squirrel cage would remain unchanged if it were relocated by a constant sheet of conducting.



APPLICATIONS:

The transportation industry is one where a LIM is heavily utilized. Typically, the car has a short primary and the track has a longsecondarylike

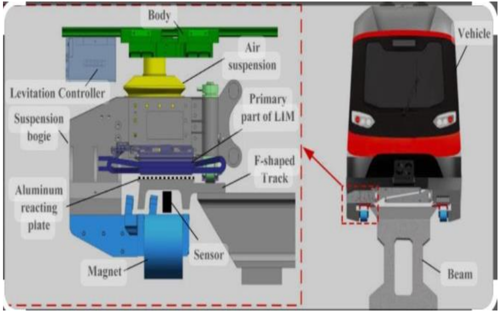


Fig. (f) depicts a transportation test vehicle that makes use of such a LIM.

Additional uses for a LIM include sliding door closers, curtain pullers, material handling, and the pumping of liquid metal.

II. CONCLUSION:

In conclusion, this research represents a significant step forward in the optimization of LIM control processes for industrial applications. By leveraging the synergistic effects of voltage amplitude and source frequency manipulation, the proposed methodology enables the timely attainment of steady-state conditions, thereby enhancing operational efficiency and productivity. The integration of multiplexer blocks within the simulation model further enhances the versatility and adaptability of the control system, paving the way for continued advancements in the field of linear induction motor technology.Books: Boldea, Ion and Syed, A.Nasar. “Linear Motion Electromagnetic Systems.” CRC Press, 2000.

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