International Journal of Education, Information Technology and Others (IJEIT), April 2026, 9 (2), 245-252
DOI: https://jurnal.peneliti.net/index.php/IJEIT/article/view/14212
p-ISSN: 2654-2528 e-ISSN: 2623-2324
Accredited by Directorate General of Strengthening for Research and Development
Available online at https://jurnal.peneliti.net/index.php/IJEIT

Analysis Review of Electromagnetic Fields in System Long Stator Linear Synchronous Motor for Improving Maglev Speed

Diyajeng Luluk Karlina

Department of Electrical Engineering Vocational Education, Faculty of Teacher and Education, University Sultan Ageng Tirtayasa, Serang, Indonesia

Received: 5 April 2026
Revised: 18 April 2026
Accepted: 28 April 2026

Abstract

This research presents an in-depth literature review regarding the role and characteristics of electromagnetic fields in the Long Stator Linear Synchronous Motor (LS-LSM) system to support the improvement of transportation maglev operational speed. The review emphasizes how magnetic flux behavior, field uniformity, and electromagnetic synchronization influence propulsion efficiency and dynamic stability in high-speed maglev operations. As the primary propulsion unit, the LS-LSM operates by synchronizing the moving magnetic field generated along the stator with the magnetic elements on the train, thereby producing a stable and continuous propulsion force. The findings indicate that the quality of the electromagnetic field, evaluated through flux density, waveform purity, and harmonic distortion reduction, significantly affects levitation stability, propulsion smoothness, and energy conversion efficiency. Electromagnetic field optimization can reduce power losses, minimize propulsion force fluctuations, and maintain propulsion performance at high speeds.

This review also identifies potential technological developments, including the use of advanced magnetic materials, improved stator designs, and intelligent control strategies capable of regulating the electromagnetic field in real time. These insights support the design of propulsion systems that are more efficient, stable, and responsive. The research concludes that improving the quality of the electromagnetic field in LS-LSM systems is a key factor in achieving higher maglev speeds, better operational stability, and greater reliability for next-generation transportation systems.

Keywords: Electromagnetic Field, LS-LSM, High-speed maglev, Propulsion system

(*) Corresponding Author: diyajeng@untirta.ac.id

How to Cite: Luluk Karlina, D. (2026). Analysis Review of Electromagnetic Fields in System Long Stator Linear Synchronous Motor for Improving Maglev Speed. *International Journal of Education, Information Technology, and Others, 9*(2), 245-252. Retrieved from https://jurnal.peneliti.net/index.php/IJEIT/article/view/14212

INTRODUCTION

Technological advancements in modern transportation continue to drive the development of high-speed mobility systems that are not only energy-efficient but also possess high levels of operational reliability and stability. One technology that demonstrates significant potential is magnetic levitation (maglev), a transportation system that utilizes electromagnetic interactions to generate levitation and propulsion forces without physical contact. The elimination of mechanical friction enables a substantial increase in operational speed while simultaneously reducing structural maintenance requirements.

In high-speed maglev technology, the Long Stator Linear Synchronous Motor (LS-LSM) functions as the primary propulsion mechanism, generating linear thrust through synchronous interaction between the stator magnetic field and the magnetic components on the vehicle. LS-LSM offers advantages such as precise flux control, uniform thrust distribution, and the ability to maintain electromagnetic synchronization under various speed conditions.

The performance of the LS-LSM is highly determined by the characteristics of the electromagnetic field generated along the stator. Factors such as magnetic flux intensity, field waveform symmetry, core and winding configuration, and harmonic effects are critical elements that determine energy conversion efficiency and thrust stability. Imperfections in electromagnetic field management can trigger power losses, thrust irregularities, and synchronization disturbances that limit the system's ability to achieve maximum operational speed. Although various studies have evaluated the design and characteristics of linear synchronous motors, the need for a deeper investigation into electromagnetic field optimization in long stator configurations remains highly relevant. Technical challenges such as minimizing cogging force, improving field waveform quality, and controlling harmonics at high speeds require further analysis to ensure stable and efficient propulsion performance.

Therefore, an analytical review is required to comprehensively evaluate the benefits and contributions of electromagnetic fields in LS-LSM systems toward improving maglev operational speed. This study is expected to strengthen the theoretical foundation, provide insights into more effective electromagnetic design strategies, and support the development of more reliable and sustainable magnetic levitation-based transportation technology.

LITERATURE REVIEW

1. Electromagnetic Fields in Electric Drive Systems

Electromagnetic fields are physical phenomena that arise from the interaction between electric fields and magnetic fields. When an electric current flows through a conductor, a magnetic field is generated around the surrounding area. Conversely, changes in the magnetic field can induce electric currents that produce electric fields. This mechanism describes the fundamental relationship between electric current, electric fields, and magnetic fields (M. Yang et al., 2023).

The fundamental concepts of electromagnetic fields are explained through several important laws of physics, such as Coulomb's Law, Ampere's Law, and Faraday's Law. Faraday's Law, as one of the principal foundations, states that changes in magnetic flux can induce an electric current in a conductor. This principle serves as the basis for the development of various electrical engineering devices, including generators and transformers (Maglev et al., 2017).

2. Linear Synchronous Motor

The basic principle of the Long Stator Linear Synchronous Motor (LS-LSM) is a functional extension of the conventional rotating synchronous motor that has been "unrolled" to create contactless propulsion. In a Maglev system, the guideway functions as a long-distance stator consisting of three-phase wire windings distributed along the track. When these windings are supplied with electronically controlled three-phase alternating current (AC), they generate a traveling magnetic field that moves along the guideway. Meanwhile, the motor rotor, consisting of superconducting permanent magnets or electromagnets, is mounted underneath the train(H. Yang et al., 2022). The thrust force is generated through the synchronous interaction between the traveling magnetic field in the stator and the static magnetic field in the rotor, in accordance with the Lorentz Force Law. As long as the traveling magnetic field and the rotor maintain synchronized frequency and speed, the generated thrust continuously propels the train forward, eliminating the need for wheels and mechanical friction (Kong et al., 2022).

This principle of magnetic field generation is closely related to the maglev propulsion system, particularly in the Long Stator Linear Synchronous Motor (LS-LSM). Propulsion performance and the achievement of high speeds depend on the stability and density of the magnetic flux interaction between the stator and the magnetic elements on the train. The use of permanent magnets is capable of providing strong and efficient magnetic flux because they do not produce excitation losses, allowing the system to generate more optimal thrust at high operational speeds. Therefore, improving magnetic field quality through the use of permanent magnets plays an important role in supporting the performance and operational speed of maglev systems (Divekar & Ekbote, 2019).

3. Electronic Control and Synchronization

Electronic control and synchronization mechanisms play a crucial role in ensuring that the electromagnetic field generated by the maglev system can maintain air gap stability, produce smooth propulsion forces, and sustain stable dynamic responses under various operating conditions. In electromagnetic suspension (EMS) technology, the levitation force is generated through the direct interaction between electromagnets mounted on the train frame and the ferromagnetic guideway surface. This type of levitation system is naturally unstable because even small deviations in the air gap can cause significant changes in the lifting force. Therefore, a fast feedback-based electronic control system is required to regulate the current supplied to the electromagnetic coils based on position information obtained from sensors. This control mechanism enables immediate correction of air gap fluctuations, allowing the train to remain levitated without physical contact with the guideway (Kang et al., 2018).

In contrast to EMS, the electrodynamic suspension (EDS) system generates levitation force through induced currents in conductors or superconducting coils located on the guideway. Its operating principle relies on dynamic magnetic field interactions, meaning that levitation stability is more influenced by the train's speed and the characteristics of electromagnetic induction rather than by direct current regulation as in EMS.

RESEARCH METHOD

This research applies a literature review method as the primary approach to evaluate the benefits and characteristics of electromagnetic fields in the Long Stator Linear Synchronous Motor (LSLSM) propulsion system in an effort to improve the operational speed of maglev trains. This method was conducted through the processes of searching, selecting, and critically reviewing various relevant scientific sources, including reputable journal articles, conference proceedings, textbooks, technical standards, and recent research reports related to maglev technology, linear synchronous motors, and electromagnetic design.

The literature review was carried out in three main stages. The first stage was the identification and collection of references, which involved searching for sources through scientific databases such as IEEE Xplore, ScienceDirect, SpringerLink, and Google Scholar using keywords related to LS-LSM, electromagnetic fields, maglev propulsion systems, and speed optimization in maglev trains. The selection of literature considered topic relevance, publication recency, and publication quality.

The second stage involved literature analysis and synthesis, in which each source was examined to identify fundamental concepts, electromagnetic models, design parameters, and empirical findings related to LS-LSM performance. This process included comparing various methods, optimization strategies, and testing results reported in previous research.

The third stage was the formulation of the review results, which aimed to integrate the information into a more comprehensive understanding of the influence of electromagnetic fields on thrust efficiency, levitation stability, and speed enhancement in maglev systems. This synthesis was then used to identify research gaps and formulate directions for future technological development. This study did not conduct direct experiments; however, it provides an in-depth analysis based on previously published findings.

RESULTS AND DISCUSSION

Electromagnetic Field Characteristics in LS-LSM (Long Stator Linear Synchronous Motor)

In the Long-Stator Linear Synchronous Motor (LS-LSM) system used in electromagnetic suspension (EMS) maglev trains, the magnetic field responsible for levitation force and the field responsible for propulsion force do not operate independently. Both interact with each other, meaning that levitation and propulsion responses must be considered as a unified dynamic system. During the levitation process, the electromagnets on the train interact with the ferromagnetic guideway to maintain a stable air gap. To preserve this distance, the excitation current in the levitation coils is continuously adjusted according to changes in the train's position (Khadijah et al., 2024). Any variation in this current alters the local magnetic field distribution around the stator. At the same time, the LS-LSM generates propulsion force by controlling the three-phase current in the stator so that it remains synchronized with the moving position of the train. The propulsion force strongly depends on the shape and stability of the magnetic field within the air gap. When the levitation current changes, the magnetic field pattern in the same region also changes, thereby indirectly affecting the magnitude of the propulsion force.

As a result of this interdependence, the control system must be capable of coordinating levitation current adjustments with propulsion requirements. The interaction between the two is particularly evident during transient conditions, such as when the train accelerates rapidly, decelerates, or passes through stator segment boundaries, where magnetic field variations can cause fluctuations in propulsion force and instability in the air gap. If these magnetic field interactions are not properly controlled, they may lead to increased vibration, variations in lateral force, and reduced efficiency at high speeds (Kurniasari et al., 2024). Therefore, the design and control of LS-LSM systems must take into account the coupling between levitation and propulsion in order to ensure stable, safe, and optimal maglev operation at high speeds.

Influence of Electromagnetic Fields on Propulsion Force Efficiency

Electromagnetic fields in maglev propulsion systems play a vital role in determining the magnitude and effectiveness of the propulsion force generated along the guideway. The propulsion force arises from the interaction between the magnetic field produced by the stator on the track and the magnetic field on the train. The efficiency of the propulsion force is therefore highly dependent on the quality of the generation, distribution, and control of these electromagnetic fields (Liu et al., 2025).

First, magnetic flux intensity is a parameter that directly affects the magnitude of the propulsion force. A high magnetic flux can support an increase in propulsion force, but maximum efficiency can only be achieved when it operates within an optimal working range. If the flux intensity becomes excessively high, the excitation current increases, resulting in copper losses, core losses, and heat accumulation in the stator windings. The energy dissipated as heat reduces energy conversion efficiency, since not all electrical power is converted into propulsion force.

Second, synchronization between the stator magnetic field wave and the position of the magnets on the train plays a crucial role in determining propulsion stability and efficiency. In a linear synchronous motor, the maximum propulsion force is achieved when the stator field wave remains in phase with the magnetic field on the train. Any phase mismatch reduces the propulsion force, requiring the system to supply additional current to maintain performance, which in turn decreases efficiency.

In addition, the uniformity of the magnetic field distribution along the guideway also affects propulsion quality. A non-uniform magnetic field produces fluctuating propulsion forces, causing vibrations and disturbing the dynamic stability of the train. Stabilization efforts to compensate for these irregularities require additional energy. In contrast, a uniform magnetic field distribution generates smooth and constant propulsion force, allowing energy to be utilized more efficiently. At high speeds, the increasing operating frequency of the magnetic field leads to greater eddy current and hysteresis losses in ferromagnetic materials. These losses reduce effective energy that can be converted into propulsion force because part of the energy is dissipated as heat. If not properly compensated, the propulsion force tends to decrease at high speeds due to the reduction in electromagnetic efficiency.

Optimization of propulsion efficiency can be achieved through proper current control and waveform shaping. Current with a clean sinusoidal waveform and minimal harmonic distortion produces a stable and efficient magnetic field while also reducing magnetic leakage. This allows a greater portion of electromagnetic energy to be directly converted into effective propulsion force. Overall, the propulsion efficiency of a maglev system depends on the system’s ability to generate electromagnetic fields that are strong, stable, uniformly distributed, and associated with minimal losses. The better the quality and control of the magnetic field, the greater the proportion of electrical energy that can be converted into effective propulsion.

Impact of Electromagnetic Fields on Increasing Maglev Speed

Electromagnetic fields play a central role in determining the ability of maglev trains to achieve high speeds. In the Linear Synchronous Motor (LS-LSM) system, electromagnetic fields function not only as levitation elements but also as the primary source of propulsion force(Abidin & Pradipta, 2022). The quality and stability of these fields directly affect how effectively electrical energy is converted into the train’s acceleration and traveling speed.

First, strong and well-controlled electromagnetic fields are capable of increasing propulsion force, allowing the train to accelerate more rapidly. Stable magnetic fields produce smoother and more consistent thrust, enabling energy to be utilized optimally to increase speed without significant energy losses caused by oscillations or force irregularities.

Second, the ability of the system to achieve high speeds greatly depends on the phase alignment between the stator magnetic field and the magnetic field on the train. When the electromagnetic fields are properly synchronized, the generated propulsion force reaches its maximum condition. In contrast, a lack of synchronization leads to reduced propulsion force and energy waste, making it difficult to achieve maximum speed.

Furthermore, a uniform magnetic field distribution along the guideway has a positive impact on the dynamic stability of the train. Non-uniform magnetic fields can trigger fluctuations in propulsion force and vibrations at high speeds. With a uniform magnetic field, the train can move more smoothly and stably while maintaining high speeds without requiring additional energy for vibration damping. During high-speed operation, the increased frequency of the magnetic field also gives rise to electromagnetic losses such as hysteresis and eddy currents. These losses reduce the effectiveness of the propulsion force because part of the energy is converted into heat. Therefore, the efficiency of the electromagnetic field must be maintained to prevent a decline in propulsion performance at high speeds.

In addition, proper current control and clean waveform generation further enhance propulsion capability. Current waveforms with minimal distortion produce more efficient magnetic fields and reduce magnetic leakage, thereby increasing effective propulsion force and supporting the achievement of higher speeds. Overall, the increase in maglev speed is strongly influenced by the system’s ability to manage electromagnetic fields efficiently, stably, and accurately. The better the quality of the generated magnetic field, the greater the train’s capacity to operate at high speeds safely and energy-efficiently.

Implications for Development of Maglev Technology

The results of the analysis regarding the characteristics and benefits of electromagnetic fields in the Long Stator Linear Synchronous Motor (LS-LSM) system provide several important implications for the future development of maglev technology. The optimization of magnetic flux distribution and the improvement of magnetic field synchronization quality have been shown to contribute significantly to enhancing propulsion efficiency and operational stability at high speeds. These findings confirm that precise electromagnetic control is a key element in improving maglev propulsion performance.

Furthermore, a deeper understanding of electromagnetic field dynamics enables the design of systems capable of minimizing power losses, reducing harmonic distortion, and suppressing force ripple that may disrupt levitation stability. This creates opportunities for the development of more adaptive stator architectures, more efficient coil designs, and control algorithms that are more responsive to changes in load and speed conditions. From a systems engineering perspective, other implications include the potential application of advanced magnetic materials, improvements in power circuit topology, and the integration of artificial intelligence-based control systems to predict and correct magnetic field irregularities in real time. These approaches can lead to more stable propulsion performance, lower energy consumption, and more optimal acceleration capability.

CONCLUSION

The results of this research indicate that the electromagnetic field characteristics in the Long Stator Linear Synchronous Motor (LS-LSM) are the primary factors determining the effectiveness of propulsion force, levitation stability, and the capability of maglev systems to consistently achieve high speeds. The analyzed literature suggests that parameters such as magnetic flux density, field profile uniformity, electromagnetic phase alignment, and harmonic control greatly influence the quality of energy conversion into propulsion force. Improvements in electromagnetic field generation have been proven to reduce power losses, minimize propulsion force variations, and enhance the dynamic response of the system, enabling maglev operations to become more efficient, stable, and safe at various speed levels. In addition, the implementation of more efficient stator designs, the use of advanced magnetic materials, and the application of adaptive electronic control techniques provide significant opportunities for the development of next-generation maglev technology. Overall, this study confirms that improving the quality of electromagnetic fields in LS-LSM systems is an essential prerequisite for achieving high-speed performance, more optimal energy efficiency, and greater reliability of magnetic levitation transportation systems in the future.

BIBLIOGRAPHY

Abidin, A. S., & Pradipta, A. (2022). *Sistem Kendali Prototype Kereta Maglev Untuk Mengatur Pergerakan Menggunakan Nodemcu Esp8266*. *6*(1).

Divekar, P. S., & Ekbote, T. (2019). *Design and Analysis of Maglev Trains*. *8*(7), 1444–1449.

Kang, J., Wang, S., Liu, Y., & He, C. (2018). *A METHOD OF THRUST RIPPLE SUPPRESSION FOR*. *4*(2), 30–44. https://doi.org/10.17816/transsyst20184230-44

Khadijah, S., Inu, A., & Sri, P. (2024). *Mapping of Electromagnetic Field Radiation Intensity in the JL Base Transceiver Station (BTS) Area . Kenangan 05 and the Impact of Health in Society*. *9*(1), 76–80. https://doi.org/10.31572/inotera.Vol9.Iss1.2024.ID295

Kong, F., Yin, S., & Sun, C. (2022). *Sustainable Energy & Fuels Design and optimization of a maglev electromagnetic – triboelectric hybrid energy* *converter for supplying power to intelligent*. 800–814. https://doi.org/10.1039/d1se01582f

Kurniasari, S., Akuba, K. R., & Paputungan, D. T. (2024). *ELECTROMAGNETIC RADIATION OF EXTREMELY LOW FREQUENCY (ELF)*. 97–101.

Liu, D., Wu, D., Xu, J., Li, Y., Gul, M. Z., & Ni, F. (2025). *Machine Learning in Maglev Transportation Systems : Review and Prospects*. 1–31.

Maglev, H., Stator, L., Jo, J., Lee, J., Han, Y., Lee, C., & Lee, K. (2017). *Development of Propulsion Inverter Control System Synchronous Motor*. https://doi.org/10.3390/en10020170

Yang, H., Li, Y., & Lu, Q. (2022). *Performance Simulation of Long-Stator Linear Synchronous Motor for High-Speed Maglev Train under Three-Phase Short-Circuit Fault*.

Yang, M., Sun, Y., Xu, J., & Sun, B. (2023). *Finite Element Analysis and Electromagnetic Field Optimization of Linear Synchronous Motor in High-Speed Maglev Systems*. 117–130.