ISSN: 2583-7354

International Journal of Emerging Knowledge Studies
Publisher's Home Page: https://www.ijeks.com/

Fully Open Access | Research Paper

A comprehensive review of Thomson Coil Activation Mechanisms in Electromagnetic Launchers Systems

Mr. Hiren M. Patel[1*] Dr. Jagrut J. Gadit[2]

[1]Department of Electrical Engineering, Faculty of Technology and Engineering, The Maharaja Sayajirao University of Baroda, Vadodara, Gujarat, India.

[2]Department of Electrical Engineering, Faculty of Technology and Engineering, The Maharaja Sayajirao University of Baroda, Vadodara, Gujarat, India.

DOI: https://doi.org/10.70333/ijeks-05-04-006

*Corresponding Author: hiren.m.patel-eed@msubaroda.ac.in

Article Info: - Received : 08 February 2026 | Accepted : 25 March 2026 | Published : 30 March 2026

Abstract

Electromagnetic launcher systems have gained significant attention in recent years due to their ability to accelerate projectiles without the use of chemical propellants. These systems use electromagnetic forces to convert electrical energy into kinetic energy and are widely used in defense, aerospace, and high-speed transportation applications. Fast switching and precise activation mechanisms are essential for the efficient operation of electromagnetic launch systems. The Thomson coil actuator is an ultra-fast electromagnetic repulsion actuator used for high-speed mechanical switching and pulsed power applications in electromagnetic launchers. This paper presents a comprehensive review of Thomson coil activation mechanisms used in electromagnetic launcher systems. The review covers the fundamentals of electromagnetic launchers, working principle of Thomson coil actuators, activation mechanisms, pulsed power supply topologies, coil design and optimization, performance parameters, and applications in electromagnetic launcher systems. Different activation methods such as capacitor discharge activation, inductive pulsed power activation, solid-state switching, and spark gap switching are discussed and compared. Pulsed power supply topologies including capacitor banks, inductive energy storage systems, and pulse forming networks are also reviewed. This paper also discusses coil design parameters, electromagnetic force generation, efficiency, and performance parameters of Thomson coil actuators. Recent research developments, challenges, and future research directions in Thomson coil activation mechanisms are also presented. This review will help researchers understand the working principles, activation methods, and design considerations of Thomson coil actuators used in electromagnetic launcher systems and will serve as a useful reference for future research in this field.

Keywords: *Thomson Coil Actuator, Electromagnetic Launcher, Coilgun, Railgun, Pulsed Power Supply.*

ISSN: 2583-7354

1. Introduction

Electromagnetic launch systems (EML) are advanced projectile acceleration systems that use electromagnetic forces instead of conventional chemical propellants to launch projectiles. These systems offer advantages such as high launch velocity, improved control, reduced mechanical wear, and the ability to operate without explosive materials. Electromagnetic launchers are widely studied for applications in defense systems, aerospace launch assistance, aircraft launch systems, and high-speed transportation. The main principle behind electromagnetic launchers is the conversion of electrical energy into kinetic energy using magnetic fields and current-carrying conductors.

Electromagnetic launchers are mainly classified into three major types: railgun, coilgun, and linear induction launcher. Railguns use Lorentz force generated between two conductive rails and a moving armature. Coilguns operate based on electromagnetic induction where sequentially energized coils accelerate a ferromagnetic projectile. Linear induction launchers use traveling magnetic fields to propel conductive projectiles without physical contact. Each type has its own advantages, limitations, efficiency range, and application areas.

Table 1. Comparison of Electromagnetic Launcher Types

Launcher Type	Working Principle	Advantages	Disadvantages	Applications
Railgun	Lorentz force between rails and armature	Very high velocity	Rail erosion, high current	Military, naval guns
Coilgun	Sequential coil energization	Contactless acceleration	Lower efficiency	Projectile launch, research
Linear Induction Launcher	Traveling magnetic field	Smooth acceleration	Complex design	Aircraft launch, mass drivers

The Thomson coil actuator is a high-speed electromagnetic repulsion actuator used for fast mechanical switching and triggering applications in pulsed power systems and electromagnetic launchers. It operates based on the principle of induced eddy currents and repulsive Lorentz force generated between a flat coil and a conductive plate. In electromagnetic launcher systems, Thomson coils are mainly used for ultra-fast switching, triggering pulse power circuits, and mechanical actuation where response time is in the range of microseconds to milliseconds.

Electromagnetic launchers require very fast switching systems to discharge high current pulses into the launcher coils within a very short time duration. Conventional mechanical switches are too slow for such applications. Thomson coil actuators provide a fast, reliable, and contactless switching mechanism, making them suitable for pulsed power applications, electromagnetic launch systems, and protection systems.

Although many research works have been carried out on electromagnetic launchers and Thomson coil actuators, the activation mechanisms, pulsed power supply methods, coil design optimization, and performance analysis are scattered across different research papers. Therefore, a comprehensive review is necessary to summarize the existing research, compare different activation mechanisms, and identify future research directions in Thomson coil activation mechanisms for electromagnetic launcher systems.

ISSN: 2583-7354

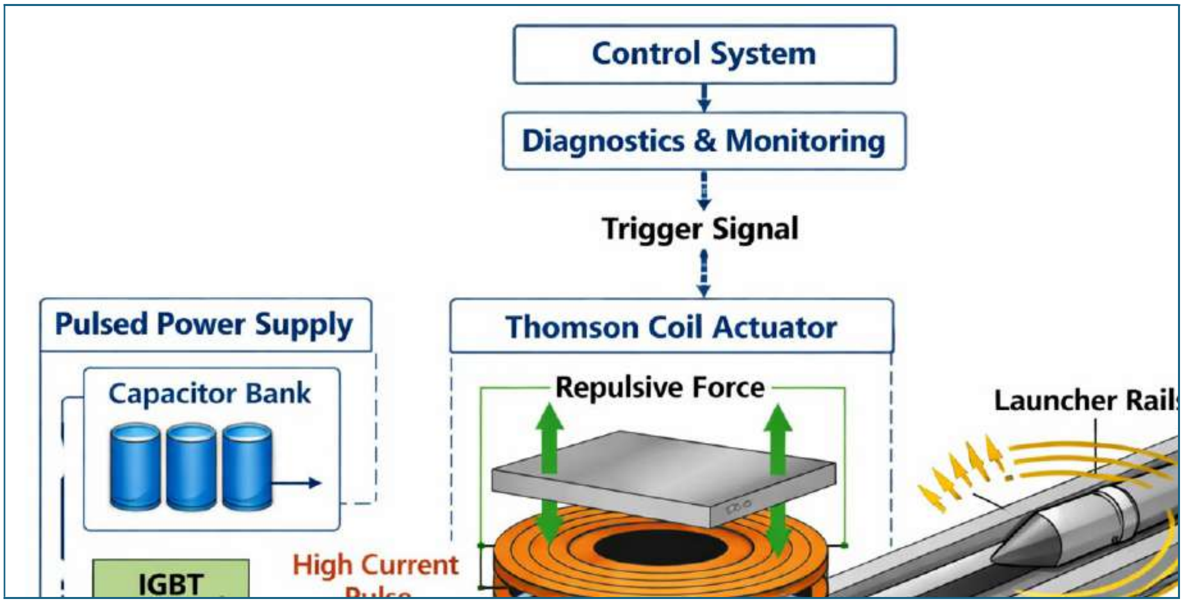

Fig. 1. Overview of Electromagnetic Launcher System with Thomson Coil

2. Scope and Objectives of the Review

2.1 Scope of the Review

This review focuses on Thomson coil activation mechanisms used in electromagnetic launcher systems, particularly in pulsed power applications and fast switching systems. The paper covers the working principle of electromagnetic launchers, the operating principle of Thomson coil actuators, activation methods, pulsed power supply topologies, coil design considerations, and performance parameters affecting system efficiency.

The review mainly includes research work related to coilgun systems, railgun triggering systems, and inductive electromagnetic launchers where Thomson coil actuators are used for ultra-fast mechanical switching and activation. The study also covers capacitor-based and inductive pulsed power supply systems used for Thomson coil activation.

This review does not focus on detailed projectile dynamics or aerodynamic analysis, but instead concentrates on electrical, electromagnetic, and actuator-based activation mechanisms used in electromagnetic launch systems.

2.2 Objectives of the Review

The main objectives of this review paper are as follows:

- To study the fundamentals of electromagnetic launcher systems.
- To explain the working principle of Thomson coil actuators.
- To review different Thomson coil activation mechanisms.
- To analyze pulsed power supply topologies used for Thomson coil activation.
- To review coil design parameters and optimization methods.
- To compare performance parameters such as force, speed, efficiency, and losses.
- To summarize recent research contributions in Thomson coil and electromagnetic launcher systems.
- To identify challenges and limitations in Thomson coil activation systems.
- To discuss future research directions in electromagnetic launch technology.

Fig. 2. Review Methodology Flowchart

3. Methodology

The methodology adopted for this review is based on a systematic literature survey of research papers related to Thomson coil actuators, electromagnetic launchers, pulsed power systems, and fast switching mechanisms. Relevant research articles were collected from major scientific databases such as IEEE Xplore, ScienceDirect, Springer, and Google Scholar using keywords including Thomson coil actuator, electromagnetic launcher, coilgun, railgun, pulsed power supply, pulse forming network, and fast mechanical switching. The collected literature includes journal articles, conference papers, patents, and technical reports that focus on electromagnetic launch technology and actuator systems.

The research papers were selected based on their relevance to Thomson coil activation mechanisms, electromagnetic launcher systems, pulsed power supply topologies, coil design, and performance analysis. Priority was given to recent publications and highly cited papers to ensure the inclusion of significant and reliable research contributions. Papers not directly related to electromagnetic launch systems or Thomson coil actuators were excluded to maintain the focus of the review.

After collecting the literature, the selected papers were classified into major categories such as fundamentals of electromagnetic launchers, Thomson coil actuator working principle, activation mechanisms, pulsed power supply topologies, coil design and optimization, performance parameters, and applications in electromagnetic launch systems. This classification helped in organizing the review in a structured manner and allowed a comparative analysis of different activation methods and system configurations.

A comparative study was then carried out based on important parameters such as response time, force generation, efficiency, circuit complexity, cost, and reliability. The results from various research works were analyzed and summarized using tables and figures to identify the advantages, limitations, and research gaps in Thomson coil activation mechanisms. This methodology provides a structured approach to review and analyze the existing research work and to identify future research directions in Thomson coil-based electromagnetic launcher systems.

4. Fundamentals of Electromagnetic Launchers

Electromagnetic launchers are systems that use electromagnetic forces to accelerate projectiles without the use of chemical propellants. These systems convert electrical energy into kinetic energy through electromagnetic interactions such as Lorentz force and electromagnetic induction. Electromagnetic launch technology has gained significant attention due to its applications in military weapon systems, aircraft launch systems, space launch assistance, and high-speed transportation systems **(Fair, 2006; Kahlon et al., 2017).**

The basic operating principle of electromagnetic launchers is based on the Lorentz force law, which states that a current-carrying conductor placed in a magnetic field experiences a force. This principle is mainly used in railgun systems where current flows through two rails and an მოძრ armature, producing a magnetic field that generates a force to accelerate the projectile **(Fair, 2006).** In coilgun and linear induction launcher systems, the projectile is accelerated by a time-varying magnetic field generated by coils carrying high current pulses. The changing magnetic field induces currents in the projectile, which produces a magnetic force that accelerates the projectile along the launcher barrel **(Haghmaram & Shoulaie, 2004).**

Electromagnetic launchers are mainly classified into three types: railgun, coilgun, and linear induction launcher. A railgun consists of two parallel conductive rails and a moving armature, where the electromagnetic force generated by high current accelerates the projectile to very high velocities. Coilguns consist of multiple coils that are energized sequentially to create a moving magnetic field that pulls or pushes the projectile forward. Linear induction launchers operate using a traveling magnetic field that induces current in the projectile and produces thrust without direct electrical contact between the launcher and projectile **(Reelkar et al., 2020).**

Railguns are capable of achieving very high velocities and are mainly used in military applications, but they suffer from rail erosion and require very high current. Coilguns are contactless and have less mechanical wear but generally have lower efficiency due to magnetic losses and switching losses. Linear induction launchers provide smooth acceleration and reduced mechanical stress, but the system design is complex and requires precise control of the magnetic field and timing circuits **(Di et al., 2024).** Each type of electromagnetic launcher has its own advantages, limitations, and application areas depending on the required velocity, efficiency, and system complexity.

Table 2. Comparison of Railgun, Coilgun, and Induction Launcher

Parameter	**Railgun**	**Coilgun**	**Linear Induction Launcher**
Working Principle	Lorentz force	Magnetic attraction/repulsion	Traveling magnetic field
Contact	Sliding contact	Contactless	Contactless
Velocity	Very high	Medium	Medium to high
Efficiency	High	Medium	Medium
Mechanical Wear	High	Low	Low
Power Requirement	Very high	High	High
Control Complexity	Medium	High	Very high
Construction	Simple	Moderate	Complex
Applications	Military, naval guns	Projectile launch	Aircraft launch, space launch

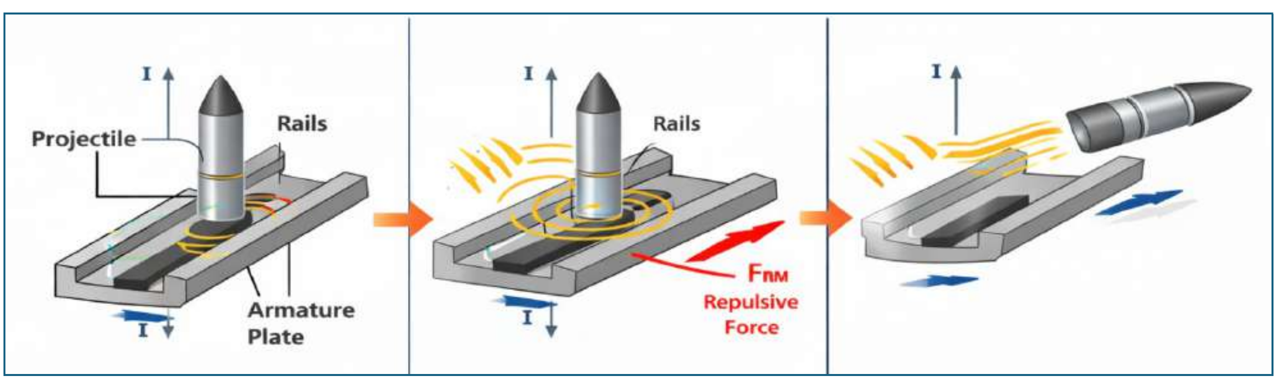

Fig. 3. Working Principle of Electromagnetic Launcher

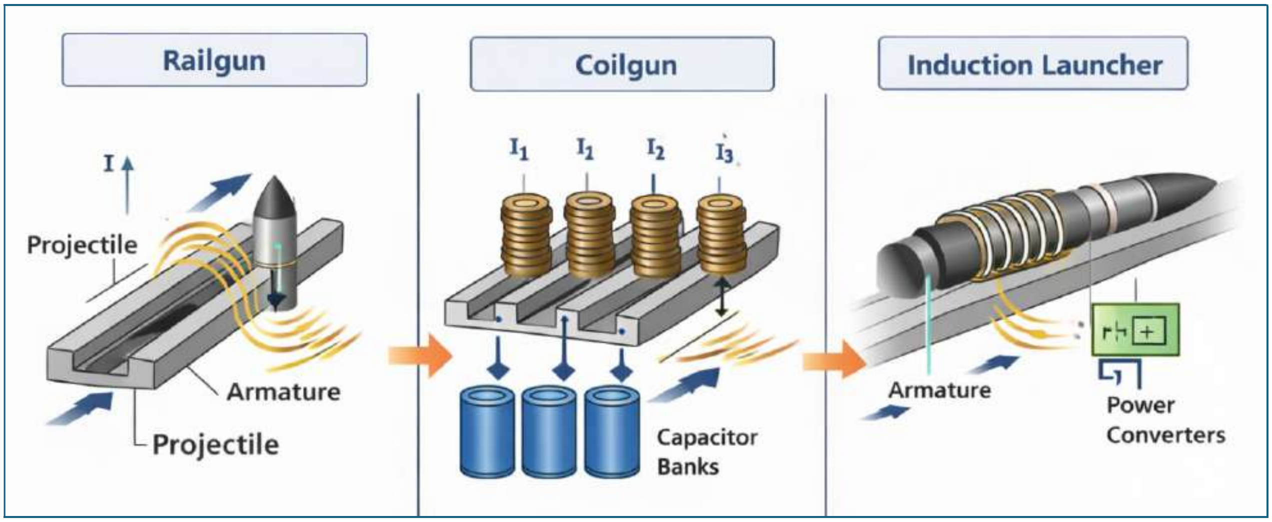

Fig. 4. Railgun, Coilgun, and Induction Launcher Comparison

5. Thomson Coil Actuator: Working Principle

The Thomson coil actuator is a high-speed electromagnetic repulsion actuator used for ultra-fast mechanical switching and triggering applications in pulsed power systems and electromagnetic launchers. The actuator operates based on the principle of electromagnetic induction and Lorentz force, where a high current pulse is passed through a flat spiral coil, producing a rapidly changing magnetic field. This changing magnetic field induces eddy currents in a nearby conductive plate, and the interaction between the coil current and induced eddy current produces a strong repulsive force that moves the conductive plate away from the coil at high speed **(Al-Dweikat et al., 2022).**

The working principle of the Thomson coil actuator is based on Lenz's law, which states that the induced current always opposes the change in magnetic flux that produced it. When a capacitor bank discharges a high current pulse through the coil, a rapidly changing magnetic field is produced. This changing magnetic field induces eddy currents in the conductive armature plate placed above the coil. The direction of the induced eddy current is opposite to the coil current, resulting in a repulsive electromagnetic force between the coil and the conductive plate. This repulsive force produces very fast mechanical motion, making the Thomson coil actuator suitable for high-speed switching applications **(Bissal et al., 2015).**

The Thomson coil actuator mainly consists of a flat spiral coil, a conductive armature plate (usually made of aluminum or copper), an insulating support structure, and a pulsed power supply such as a capacitor bank. When the capacitor bank is discharged through the coil, a high current pulse flows through the coil for a very short duration, typically in the range of microseconds to milliseconds. The resulting electromagnetic repulsion force moves the armature plate at very high speed, which can be used to operate mechanical switches or triggering mechanisms in pulsed power systems **(Al-Dweikat et al., 2022).**

The main advantage of the Thomson coil actuator is its very fast response time, high force generation, contactless operation, and low mechanical wear compared to conventional mechanical actuators such as spring actuators, solenoid actuators, and motor-driven actuators. However, the Thomson coil actuator requires a high current pulse and a pulsed power supply system, which increases system complexity. Due to its fast response time and high force output, the Thomson coil actuator is widely used in electromagnetic launch systems, fast circuit breakers, pulsed power switching, and electromagnetic forming applications **(Stroehla et al., 2021).**

ISSN: 2583-7354

Table 3. Thomson Coil vs Conventional Actuators

Parameter	Thomson Coil Actuator	Solenoid Actuator	Spring Actuator	Motor Actuator
Working Principle	Electromagnetic repulsion	Electromagnetic attraction	Mechanical spring force	Motor rotation
Response Time	Very fast (μs–ms)	Medium	Slow	Slow
Contact	Contactless	Contact	Contact	Contact
Force Output	High	Medium	Low	Medium
Wear and Tear	Low	Medium	High	High
Power Requirement	High	Medium	Low	Medium
Control	Pulse power	Simple	Simple	Complex
Applications	Fast switching, pulsed power	Relays	Mechanical systems	Automation

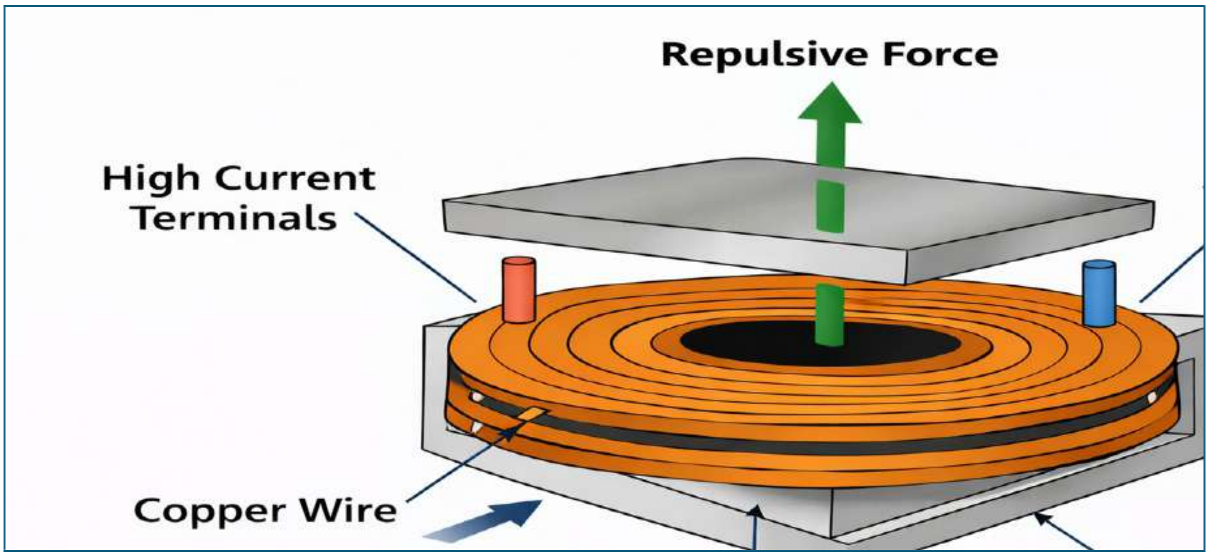

Fig. 5. Structure of Thomson Coil Actuator

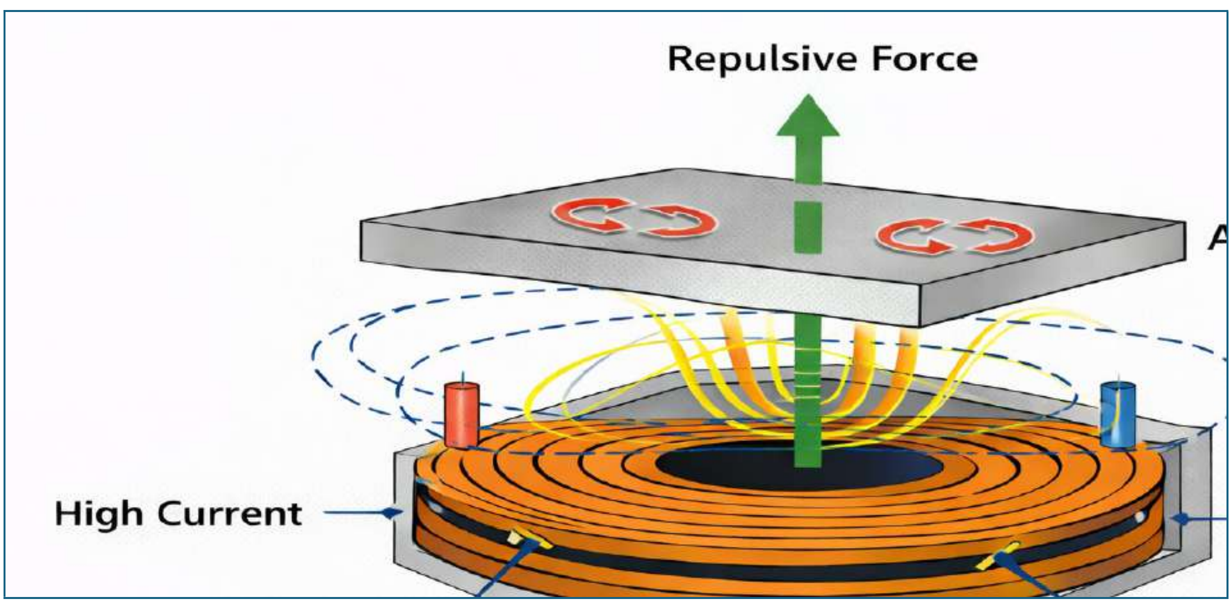

Fig. 6. Thomson Coil Repulsion Principle

ISSN: 2583-7354

6. Thomson Coil Activation Mechanisms

The activation mechanism of a Thomson coil actuator is an important part of the system because it determines the speed of operation, force generation, and overall system efficiency. The Thomson coil actuator requires a high current pulse for a very short duration, which is usually supplied by a pulsed power system such as a capacitor bank or inductive energy storage system. The activation circuit is designed to discharge stored electrical energy into the coil rapidly in order to produce a strong magnetic field and induced eddy current in the armature plate, resulting in a repulsive force **(Al-Dweikat et al., 2022).**

One of the most commonly used activation methods for Thomson coil actuators is capacitor discharge activation. In this method, electrical energy is stored in a capacitor bank and then discharged through the Thomson coil using a high-speed switching device such as a thyristor, IGBT, MOSFET, or spark gap switch. The capacitor discharge produces a high current pulse with very short rise time, which is suitable for Thomson coil operation. This method is widely used because of its simple circuit design, high current capability, and fast response time **(Bissal et al., 2015).**

Another activation method is inductive pulsed power activation, where energy is stored in an inductor and then rapidly released into the Thomson coil through a switching circuit. Inductive energy storage systems are capable of delivering very high current pulses and are used in high-power electromagnetic launch systems. However, the circuit design is more complex compared to capacitor discharge systems and requires additional components such as opening switches and protection circuits **(Liebfried, 2017).**

Solid-state switching activation is also used in Thomson coil systems, where semiconductor devices such as IGBT, MOSFET, and thyristors are used to control the discharge of current into the coil. Solid-state switches provide precise control over switching time, improved reliability, and repeatable operation. However, they may have current limitations compared to spark gap switches and require proper protection circuits **(Al-Dweikat et al., 2022).**

In some high-power applications, spark gap switching is used as an activation method because it can handle very high voltage and current. Spark gap switches are commonly used in pulsed power and electromagnetic launcher systems due to their high current handling capability and fast switching speed. However, spark gap switches have disadvantages such as electrode wear and less precise control compared to solid-state switches **(Liebfried, 2017).**

Therefore, the selection of Thomson coil activation method depends on parameters such as current requirement, response time, circuit complexity, cost, and reliability. Capacitor discharge activation with solid-state switching is the most commonly used method for Thomson coil actuators in electromagnetic launcher applications.

Table 4. Comparison of Activation Methods

Activation Method	Energy Storage	Switching Device	Advantages	Disadvantages	Applications
Capacitor Discharge	Capacitor	Thyristor / IGBT / MOSFET	Simple, fast response	High current stress	Thomson coil, coilgun
Inductive Pulsed Power	Inductor	Opening switch	Very high current	Complex circuit	Railgun, launcher
Solid-State Switching	Capacitor	IGBT / MOSFET	Precise control	Current limitation	Fast switching
Spark Gap Switching	Capacitor	Spark gap	Very high current	Electrode wear	Pulsed power

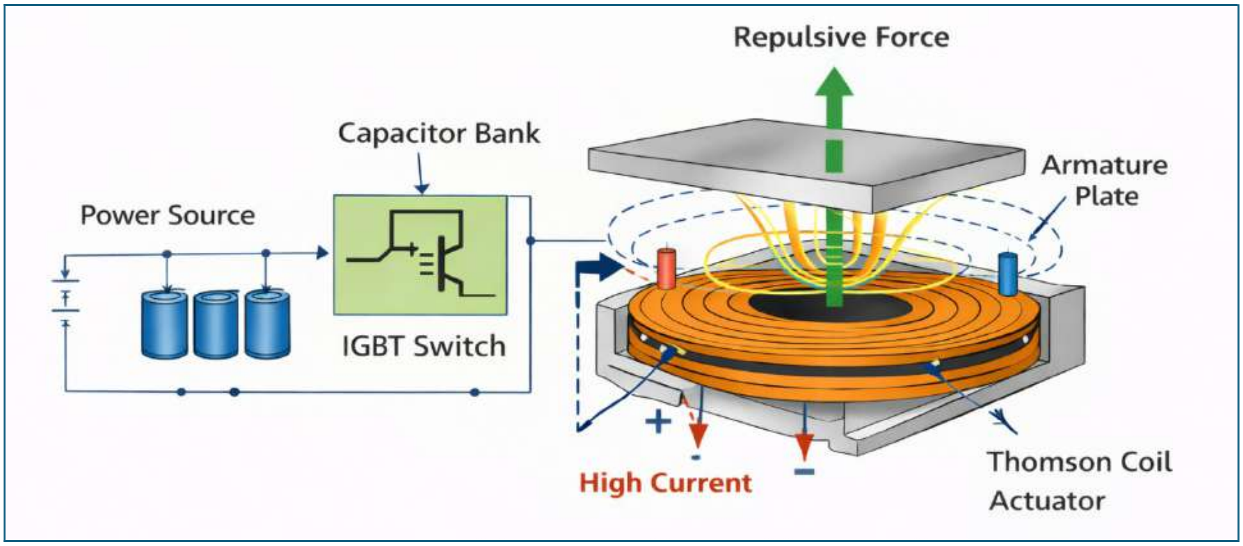

Fig. 7. Thomson Coil Activation Circuit

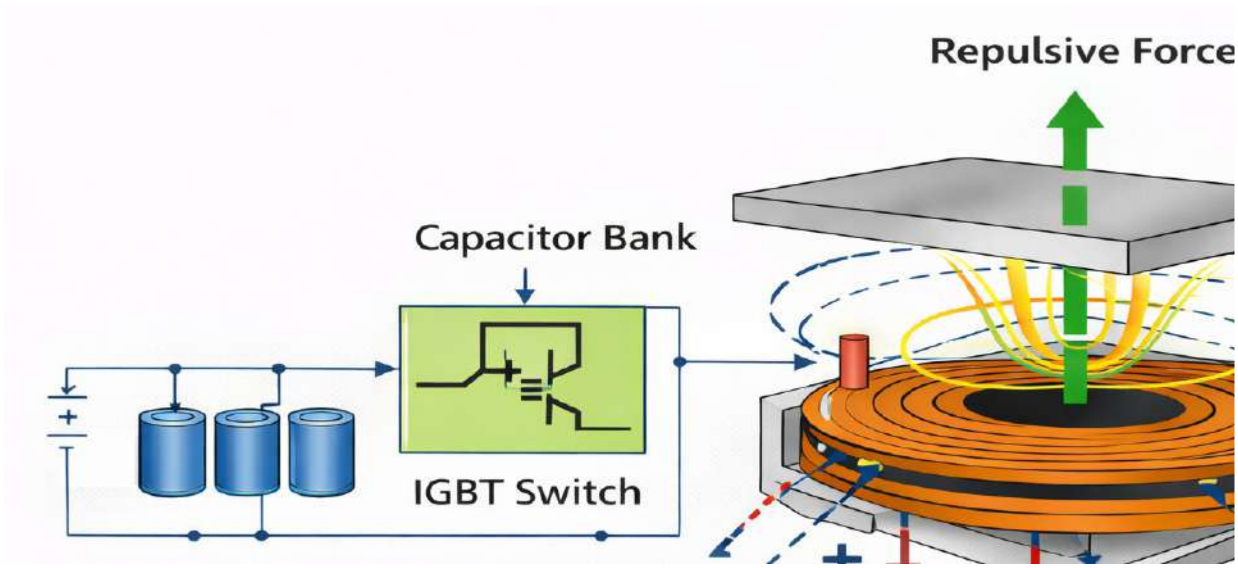

Fig. 8. Capacitor Discharge Activation Method

7. Pulsed Power Supply Topologies

Pulsed power supply systems are an essential part of Thomson coil actuators and electromagnetic launcher systems because they provide the high current pulse required for actuator operation and projectile acceleration. The main function of a pulsed power supply is to store electrical energy over a relatively long time and release it in a very short time in the form of a high-power pulse. These systems are widely used in electromagnetic launchers, pulsed power applications, and fast switching systems **(Ceylan et al., 2019).**

One of the most commonly used pulsed power supply topologies is the capacitor-based pulsed power supply. In this system, electrical energy is stored in capacitor banks and then discharged rapidly through the load using a high-speed switch. Capacitor-based systems are widely used in Thomson coil activation due to their simple design, high discharge current capability, and fast response time. The current pulse waveform depends on the capacitance, inductance, and resistance of the circuit, and it is typically an underdamped RLC discharge waveform **(Ceylan et al., 2019).**

Another pulsed power supply topology is inductive pulsed power supply, where energy is stored in an inductor and then rapidly released into the load through an opening switch. Inductive pulsed power systems are capable of delivering very high current pulses and are used in high-power electromagnetic launch systems such as railguns. However, these systems require complex switching circuits and protection components (Liebfried, 2017).

Pulse Forming Network (PFN) is another important pulsed power topology used to generate controlled pulse shapes and pulse duration. PFN consists of a network of capacitors and inductors arranged in stages to produce a rectangular or flat-top current pulse. PFN is commonly used in electromagnetic launch systems where controlled pulse shaping is required to improve system efficiency and performance (Huenefeldt et al., 2005).

In recent years, advanced pulsed power systems such as compulsators, battery-based pulsed power supplies, and superconducting magnetic energy storage (SMES) systems have been studied for electromagnetic launcher applications. These systems are capable of delivering very high power pulses and improving overall system efficiency, but they increase system complexity and cost (Liebfried, 2017).

Therefore, the selection of pulsed power supply topology depends on energy requirement, pulse duration, current magnitude, system efficiency, and cost. Capacitor-based pulsed power supplies are commonly used for Thomson coil activation, while inductive and PFN systems are used in large electromagnetic launcher systems.

Table 5. Comparison of Pulsed Power Supply Topologies

Power Supply Type	Energy Storage	Pulse Shape	Advantages	Disadvantages	Applications
Capacitor Bank	Capacitor	Exponential	Simple, fast discharge	High current stress	Thomson coil, coilgun
Inductive Storage	Inductor	Sharp pulse	Very high current	Complex circuit	Railgun
Pulse Forming Network	L–C network	Rectangular	Controlled pulse	Complex design	Launcher systems
Compulsator	Rotating machine	Controlled	High power	Expensive	Military launch
Battery-Based	Battery	Long pulse	Portable	Low peak current	Small launcher

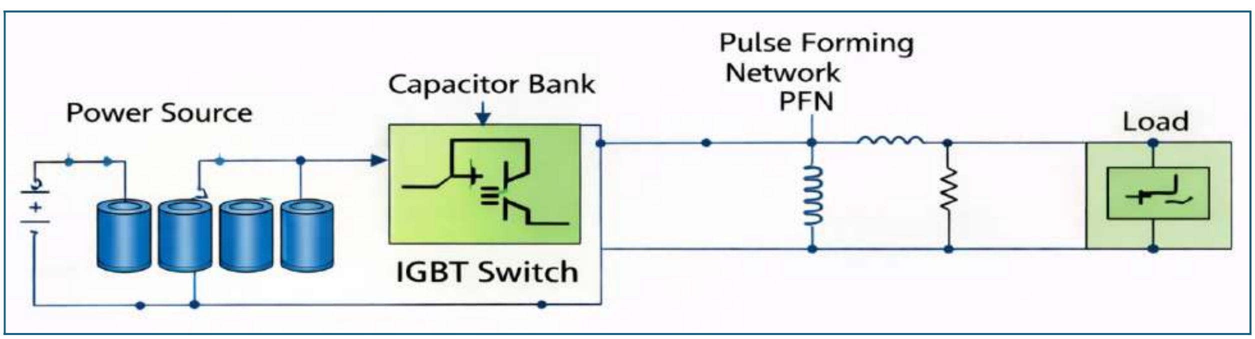

Fig. 9. Capacitor-Based Pulsed Power Supply

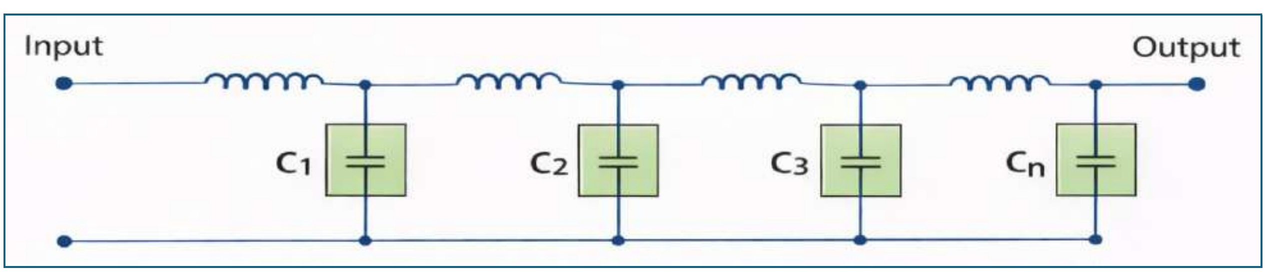

Fig. 10. Pulse Forming Network (PFN)

8. Coil Design and Optimization

Coil design is one of the most important factors affecting the performance of Thomson coil actuators and electromagnetic launcher systems. The coil parameters such as number of turns, coil thickness, inner and outer diameter, conductor material, and spacing between turns significantly influence the magnetic field strength, inductance, resistance, and force generated by the actuator. Proper coil design is necessary to achieve high electromagnetic force, fast response time, and high system efficiency **(Sijoy & Chaturvedi, 2008).**

The electromagnetic force generated in a Thomson coil actuator depends on the rate of change of current and magnetic field produced by the coil. Increasing the number of turns increases the magnetic field strength but also increases the coil inductance and resistance, which may reduce the peak current and slow down the response time. Therefore, coil design involves a trade-off between magnetic field strength and current rise time **(Al-Dweikat et al., 2022).**

The selection of conductor material also affects coil performance. Copper is commonly used due to its high electrical conductivity, which reduces resistive losses and improves efficiency. Aluminum is sometimes used because of its low weight and cost, but it has higher resistance compared to copper. The coil geometry, such as flat spiral coil, helical coil, or multi-layer coil, also affects the magnetic field distribution and force generation **(Yang et al., 2017).**

Thermal effects are another important consideration in coil design because high current pulses produce significant heat due to resistive losses. Proper insulation, cooling methods, and coil spacing are required to prevent coil damage and improve system reliability. Mechanical strength is also important because the coil experiences strong electromagnetic forces during operation **(Sijoy & Chaturvedi, 2008).**

Optimization techniques such as finite element analysis (FEA), genetic algorithms, and Taguchi optimization methods are used by researchers to optimize coil parameters for maximum force, efficiency, and minimum losses. These optimization methods help in selecting optimal coil dimensions, number of turns, and conductor size for Thomson coil actuators and electromagnetic launcher systems **(Le et al., 2018).**

Table 6. Coil Design Parameters and Their Effects

Coil Parameter	Effect on System	Advantage	Disadvantage
Number of Turns	Increases magnetic field and inductance	Higher force	Slower current rise
Wire Diameter	Reduces resistance	Higher current	Increases coil size
Coil Radius	Affects magnetic field distribution	Better field uniformity	Larger size
Coil Thickness	Increases magnetic flux	Higher force	Increases inductance
Coil Material	Affects resistance and heating	Copper has low resistance	Aluminum has higher resistance
Turn Spacing	Reduces heating	Better cooling	Reduces magnetic field

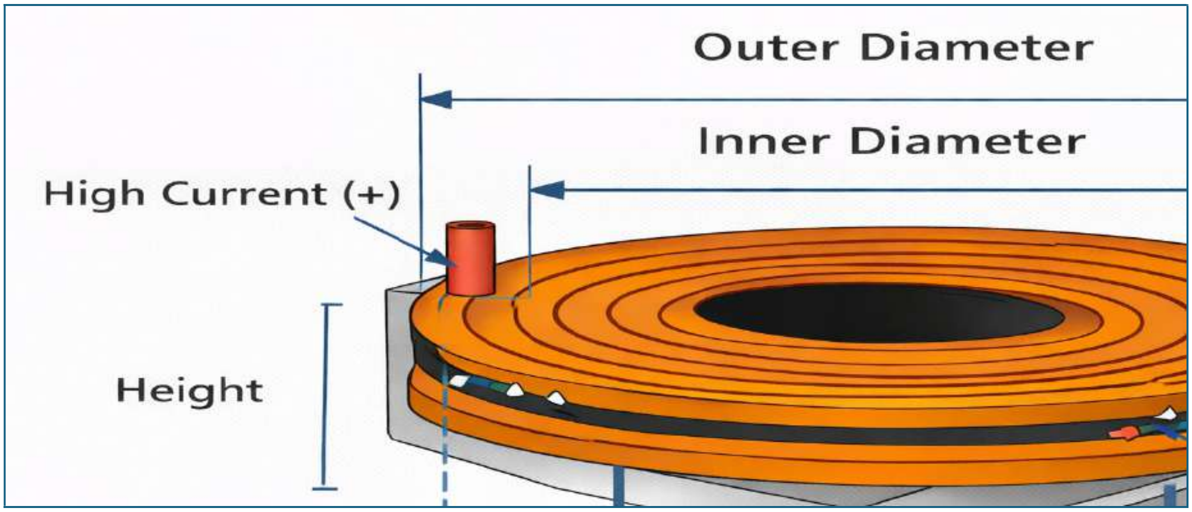

Fig. 11. Thomson Coil Geometry

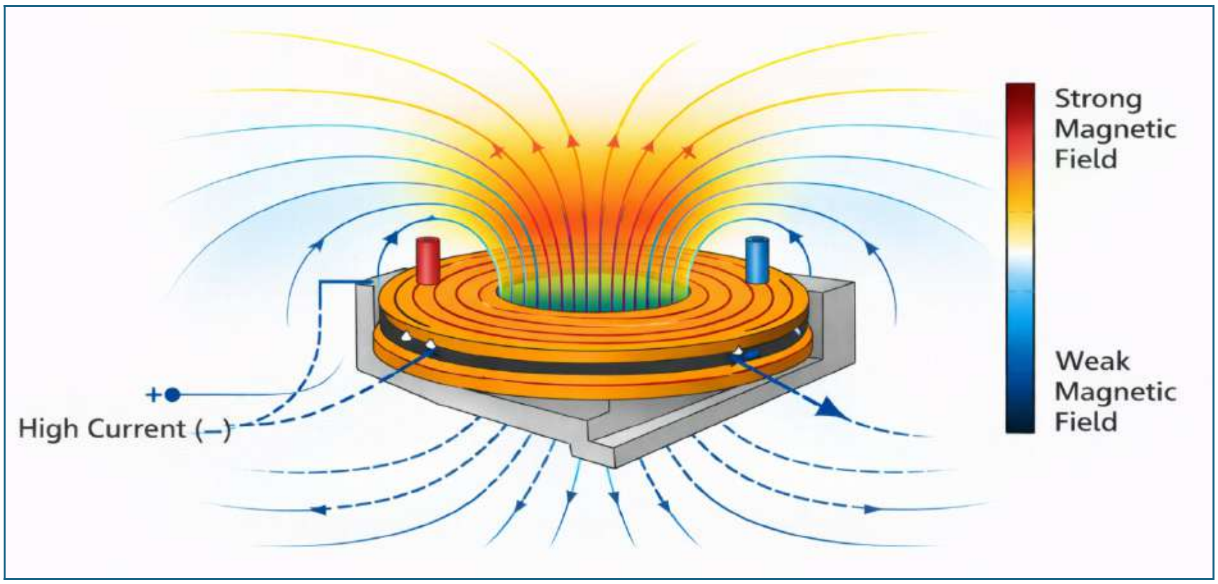

Fig. 12. Magnetic Field Distribution of Coil

9. Performance Parameters and Efficiency

The performance of a Thomson coil actuator in electromagnetic launcher systems is evaluated based on several important parameters such as force generation, response time, velocity of the moving plate, input energy, output mechanical energy, and overall efficiency. These parameters determine the effectiveness of the Thomson coil actuator in fast switching and electromagnetic launch applications. The electromagnetic force generated by the Thomson coil depends on the coil current, magnetic field strength, and induced eddy current in the armature plate **(Al-Dweikat et al., 2022).**

One of the most important performance parameters is response time, which refers to the time taken by the actuator to move the armature plate after the current pulse is applied. Thomson coil actuators have very fast response time compared to conventional actuators, typically in the range of microseconds to milliseconds, making them suitable for pulsed power switching applications **(Bissal et al., 2015).**

Efficiency is another important parameter and is defined as the ratio of mechanical output energy to electrical input energy. Losses in Thomson coil actuators occur due to resistive losses in the coil, eddy current losses in the conductive plate, magnetic losses, and mechanical losses. These losses reduce the overall efficiency of the actuator system **(Stroehla et al., 2021).**

The force generated by the Thomson coil actuator increases with increasing current and decreasing distance between the coil and armature plate. However, very high current may cause excessive heating and mechanical stress in the coil. Therefore, proper design and optimization are required to achieve high force and high efficiency without damaging the system (Al-Dweikat et al., 2022).

Other important performance parameters include displacement of the armature plate, velocity of the moving plate, peak current, pulse duration, and energy transfer efficiency. These parameters are used to evaluate and compare the performance of different Thomson coil activation systems and pulsed power supply configurations.

Table 7. Performance Parameters of Thomson Coil

Parameter	Description	Effect on Performance
Peak Current	Maximum current through coil	Higher current → Higher force
Response Time	Time taken to move plate	Faster switching
Electromagnetic Force	Force between coil and plate	Determines actuator speed
Displacement	Movement of armature plate	Determines switch operation
Velocity	Speed of armature plate	Faster operation
Input Energy	Electrical energy supplied	Affects force and motion
Output Energy	Mechanical energy produced	Used to calculate efficiency
Efficiency	Output/Input energy	Overall system performance
Temperature Rise	Heating of coil	Affects reliability
Pulse Duration	Time of current pulse	Affects force and displacement

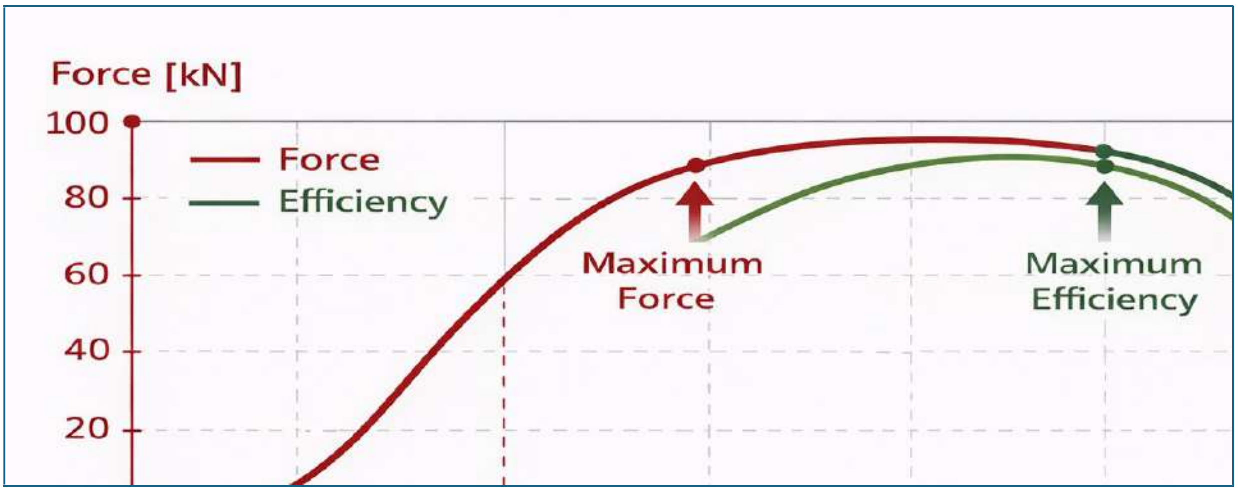

Fig. 13. Force vs Current and Efficiency Characteristics

10. Applications in Electromagnetic Launcher Systems

Thomson coil actuators are widely used in electromagnetic launcher systems due to their fast response time, high force generation, and contactless operation. In electromagnetic launch applications, very fast switching is required to discharge pulsed power into the launcher coils at precise time intervals. Thomson coil actuators are used as fast mechanical switches and triggering devices in pulsed power circuits of electromagnetic launchers (Al-Dweikat et al., 2022).

One of the major applications of Thomson coil actuators is in coilgun systems, where multiple coils are energized sequentially to accelerate the projectile. Thomson coil actuators are used to trigger high-current switches in multi-stage coilgun systems, ensuring proper timing and synchronization of coil energization. Proper switching timing improves projectile acceleration and overall system efficiency (Zhang et al., 2019). In railgun systems, Thomson coil actuators are used in pulsed power switching systems and protection circuits. Railguns require very high current pulses, and Thomson coil actuators can be used for triggering high-current switches and circuit breakers in railgun pulsed power systems (Liebfried, 2017).

Thomson coil actuators are also used in inductive electromagnetic launchers and linear induction launch systems where fast switching is required to generate traveling magnetic fields. In addition, Thomson coil actuators are used in fast circuit breakers, pulsed power switching, electromagnetic forming, and high-speed mechanical actuation systems (Stroehla et al., 2021).

The main advantage of using Thomson coil actuators in electromagnetic launcher systems is the ultra-fast response time, high reliability, and reduced mechanical contact wear. However, these actuators require pulsed power supply systems and high current pulses, which increases system complexity and cost.

Table 8. Applications of Thomson Coil in Launcher Systems

Application Area	Role of Thomson Coil	Advantage
Coilgun	Triggering coil switching	Fast switching
Railgun	Pulsed power switching	High current capability
Induction Launcher	Triggering traveling field coils	Precise timing
Circuit Breakers	Fast mechanical switching	Arc reduction
Pulsed Power Systems	High-speed switching	Reliable operation
Electromagnetic Forming	Metal forming actuation	Contactless force

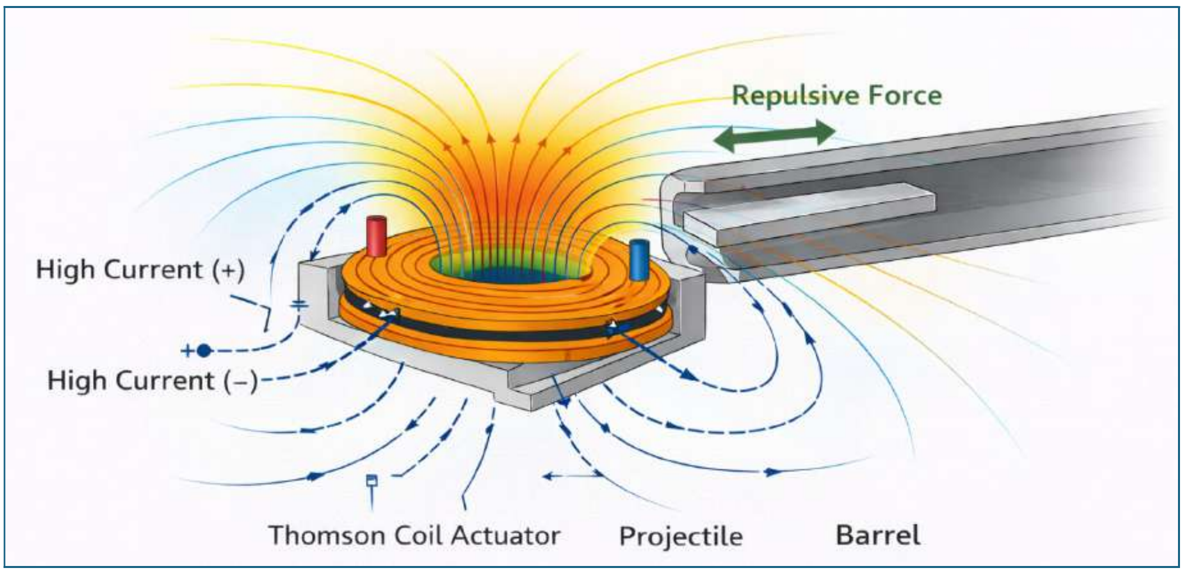

Fig. 14. Thomson Coil Application in Electromagnetic Launcher

11. Recent Research and Developments

Recent research in Thomson coil actuators and electromagnetic launcher systems has mainly focused on improving actuator efficiency, reducing losses, improving pulsed power supply systems, and optimizing coil design. Researchers have worked on multi-stage coilgun systems, improved coil geometry, and advanced pulsed power circuits to increase projectile velocity and system efficiency. Modern electromagnetic launcher systems use advanced pulse forming networks, solid-state switching devices, and optimized coil structures to improve performance and reliability (Zhang et al., 2019).

Recent studies have also focused on improving inductive pulsed power supply systems and energy recovery systems to improve overall system efficiency. Superconducting magnetic energy storage (SMES), battery-based pulsed power supplies, and compulsator-based power supplies are being developed for high-power electromagnetic launcher applications (Liebfried, 2017).

In Thomson coil actuator research, recent developments include multi-layer flat coils, improved armature plate design, better insulation materials, and thermal management techniques to increase actuator life and performance. Researchers are also using finite element analysis and optimization algorithms to improve coil design and force generation **(Al-Dweikat et al., 2022).**

Another important area of research is the development of high-speed solid-state switching devices such as IGBT and MOSFET-based pulsed power circuits for Thomson coil activation. These switching devices provide precise control, repeatability, and improved system reliability compared to traditional spark gap switches.

12. Challenges and Limitations

Despite the advantages of Thomson coil actuators and electromagnetic launch systems, there are several challenges and limitations that affect system performance. One of the major challenges is the requirement of very high current pulses, which requires large pulsed power supply systems and increases system cost and size. High current also produces significant heating in the coil, which may cause insulation failure and coil damage.

Another major limitation is the efficiency of electromagnetic launch systems. A significant amount of energy is lost in the form of resistive losses, eddy current losses, switching losses, and mechanical losses. These losses reduce overall system efficiency and require proper cooling and optimization techniques.

Mechanical stress and electromagnetic forces acting on the coil and armature plate can also cause mechanical failure if the system is not properly designed. In railgun systems, rail erosion and armature wear are major issues. In coilgun systems, synchronization and timing of coil switching is a major challenge.

The complexity of pulsed power circuits, switching devices, and control systems is another limitation in electromagnetic launcher systems. Proper insulation, cooling, and protection circuits are required to ensure safe and reliable operation.

13. Future Research Directions

Future research in Thomson coil activation mechanisms and electromagnetic launcher systems will focus on improving efficiency, reducing system size, and improving switching speed. Advanced pulsed power technologies such as superconducting magnetic energy storage, improved pulse forming networks, and hybrid pulsed power systems are expected to improve system performance.

Research is also required in advanced coil materials, improved insulation materials, and cooling techniques to reduce thermal effects and improve coil life. Optimization techniques such as artificial intelligence, machine learning, and advanced numerical simulation methods can be used to optimize coil design and activation circuits.

Another important research area is the development of compact and portable electromagnetic launcher systems for aerospace and defense applications. High-speed solid-state switching devices and digital control systems will play an important role in future Thomson coil activation systems.

14. Conclusion

This paper presented a comprehensive review of Thomson coil activation mechanisms used in electromagnetic launcher systems. The review covered the fundamentals of electromagnetic launchers, working principle of Thomson coil actuators, activation mechanisms, pulsed power supply topologies, coil design and optimization, performance parameters, and applications in electromagnetic launcher systems. A comparative analysis of different activation methods and pulsed power supply systems was presented to identify the advantages and limitations of each method.

The study shows that Thomson coil actuators are highly suitable for fast switching and pulsed power applications due to their fast response time, high force generation, and contactless operation. Capacitor-based pulsed power supply with solid-state switching is the most commonly used activation method for Thomson coil actuators. Coil design parameters such as number of turns, coil geometry, and conductor material significantly affect actuator performance and efficiency.

Although electromagnetic launcher systems and Thomson coil actuators offer many advantages, there are still challenges such as high current requirement, heating, efficiency losses, and system complexity. Future research should focus on improving pulsed power supply systems, coil design optimization, thermal management, and high-speed switching devices to improve overall system performance and efficiency.

References

Al-Dweikat, M., Cui, J., Sun, S., Yang, M., Zhang, G., &Geng, Y. (2022). A review on Thomson coil actuators in fast mechanical switching. *Actuators, 11*(6), 154.https://doi.org/10.3390/act11060154

Bissal, A., Eriksson, A., Magnusson, J., &Engdahl, G. (2015).Hybrid multi-physics modeling of an ultra-fast electro-mechanical actuator.*Actuators, 4*(4), 314–335. https://doi.org/10.3390/act4040314

Ceylan, D., Pourkeivannour, S., &Keysan, O. (2019). A comparative study of capacitive and inductive pulsed power supply topologies for electromagnetic launcher applications. In *2019 International Aegean Conference on Electrical Machines and Power Electronics (ACEMP) & 2019 International Conference on Optimization of Electrical and Electronic Equipment (OPTIM)*.https://doi.org/10.1109/ACEMP-OPTIM44294.2019.9007196

Deng, H., Wang, Y., Fan, G., Liang, L., & Yan, Z. (2019). Design and test of a single-stage double-layer multipole field electromagnetic launcher with rotational performance. *IEEE Access, 7*, 112008–112014. https://doi.org/10.1109/ACCESS.2019.2935111

Di, W., Xiao, Z., Jince, W., &Kuang, S. (2024). Research status and application prospects of coil-type electromagnetic launch technology. In *Annual Conference of China Electrotechnical Society* (pp. 506–530).Springer.https://doi.org/10.1007/978-981-97-1072-0_48

Dong, L., Lin, F., Fu, Q., Wei, Y., & Li, S. (2020). Research on structure design of multipole field reconnection electromagnetic launch mode drive coil. *IEEE Transactions on Plasma Science, 48*(1), 305–310. https://doi.org/10.1109/TPS.2019.2960175

Engel, T. G. (2007). Solid projectile helical coil electromagnetic launcher.*IEEE Transactions on Plasma Science, 35*(3), 622–626. https://doi.org/10.1109/TPS.2007.896770

Engel, T. G., Nunnally, W. C., &Neri, J. M. (2005). High-efficiency, medium-caliber helical coil electromagnetic launcher.*IEEE Transactions on Magnetics, 41*(11), 4299–4301. https://doi.org/10.1109/TMAG.2005.854968

Engel, T. G., Nunnally, W. C., &Neri, J. M. (2004a). Development of a medium-bore high-efficiency helical coil electromagnetic launcher.*IEEE Transactions on Plasma Science, 32*(5), 1893–1895. https://doi.org/10.1109/TPS.2004.835487

Engel, T. G., Nunnally, W. C., &Neri, J. M. (2004b). Research progress in the development of a high-efficiency, medium caliber helical coil electromagnetic launcher.In *Proceedings of the 12th Symposium on Electromagnetic Launch Technology*.https://doi.org/10.1109/ELT.2004.1398045

Fair, H. D. (2006).Progress in electromagnetic launch science and technology.*IEEE Transactions on Magnetics, 43*(1), 93–98. https://doi.org/10.1109/TMAG.2006.887596

Fan, G., Wang, Y., Nie, X., Hu, Y., Chen, W., & Yan, Z. (2017).Investigation of gyroscopic stabilization for single-stage saddle sextupole field electromagnetic launcher.*IEEE Transactions on Plasma Science, 45*(7), 1656–1662. https://doi.org/10.1109/TPS.2017.2709330

Fatangde, Y., Biradar, S., Bahmne, A., Yadav, S., &Yadav, A. (2019). Electromagnetic coil gun launcher system. *International Journal of Innovative Research in Science, Engineering and Technology, 8*(3).

Gallant, J., Vancaeyzeele, T., Lauwens, B., Wild, B., Alouahabi, F., & Schneider, M. (2014). Design considerations for an electromagnetic railgun firing intelligent bursts to be used against anti-ship missiles. In *International Symposium on Electromagnetic Launch Technology*.https://doi.org/10.1109/TPS.2015.2416774

Ghanchi, V., &Badgujar, K. P. (2026). Coil guns: A review on various design aspects and potential research areas. *Sādhanā, 51*(1), 26.https://doi.org/10.1007/s12046-025-02744-8

Gherman, L., Pearsica, M., Strimbu, C., & Constantinescu, C. G. (2010). Induction coilgun based on E-shaped design. *IEEE Transactions on Plasma Science, 39*(2), 725–729. https://doi.org/10.1109/TPS.2010.2091650

Gong, C., Yu, X., & Liu, X. (2014). Study on the system efficiency of the synchronously triggered capacitive pulsed-power supply in the electromagnetic railgun system. In *International Symposium on Electromagnetic Launch Technology*.https://doi.org/10.1109/EML.2014.6920637

Haghmaram, R., &Shoulaie, A. (2004).Literature review of theory and technology of air-core tubular linear induction motors (electromagnetic launcher applications).In *International Universities Power Engineering Conference* (Vol. 2, pp. 517–522).

Huenefeldt, S. M., Engel, T. G., &Nunnally, W. C. (2005). A 750 kJ computer-controlled sequentially fired pulse forming network for a helical coil electromagnetic launcher. In *IEEE Pulsed Power Conference*.https://doi.org/10.1109/PPC.2005.300569

Hu, Y., Wang, Y., Yan, Z., Jiang, M., & Liang, L. (2018). Experiment and analysis on the new structure of the coilgun with stepped coil winding. *IEEE Transactions on Plasma Science, 46*(6), 2170–2174.https://doi.org/10.1109/TPS.2018.2837089

Kahlon, A. S., Gupta, T., Dahiya, P., &Chaturvedi, S. K. (2017). A brief review on electromagnetic aircraft launch system. *International Journal of Mechanical and Production Engineering, 5*(6).

Khatibzadeh, A., &Besmi, M. R. (2013). Improve dimension of projectile for increasing efficiency of electromagnetic launcher. In *IEEE Power Electronics, Drives and Systems Technologies Conference*.

Kim, K. B., Zabar, Z., Levi, E., &Birenbaum, L. (1995).In-bore projectile dynamics in the linear induction launcher (LIL), Part II: Balloting, spinning, and nutation.*IEEE Transactions on Magnetics, 31*(1), 489–492. https://doi.org/10.1109/20.364644

Lee, S. J., Kim, J. H., & Kim, S.-H.(2016). Design and experiments of multi-stage coil gun system.*Journal of Vibroengineering, 18*(4), 2354–2363.https://doi.org/10.21595/jve.2016.16882

Le, D. V., Go, B. S., Song, M. G., Park, M., & Yu, I. K. (2018). Design of an electromagnetic induction coilgun using the Taguchi method.*IEEE Transactions on Plasma Science, 46*(10), 3612–3618. https://doi.org/10.1109/TPS.2018.2847401

Liebfried, O. (2017). Review of inductive pulsed power generators for railguns. *IEEE Transactions on Plasma Science, 45*(7), 1109–1115. https://doi.org/10.1109/TPS.2017.2686648

Liu, W., Cao, Y., Zhang, Y., Wang, J., & Yang, D. (2011).Parameters optimization of synchronous induction coilgun based on ant colony algorithm.*IEEE Transactions on Plasma Science, 39*(1), 100–104. https://doi.org/10.1109/TPS.2010.2076315

Lu, F. (2020a). Investigation of synchronous induction coilgun with stepped coil launcher and stepped armature. *IEEE Transactions on Plasma Science, 48*(4), 1190–1194. https://doi.org/10.1109/TPS.2020.2982296

Lu, F. (2020b). Research on energy recovery of inductive pulsed power supplies based on SMES.In *IEEE International Conference on Applied Superconductivity and Electromagnetic Devices*.https://doi.org/10.1109/ASEMD49065.2020.9276234

Musolino, A., Rizzo, R., &Tripodi, E. (2013).Travelling wave multipole field electromagnetic launcher: An SOVP analytical model.*IEEE Transactions on Plasma Science, 41*(5), 1201–1208. https://doi.org/10.1109/TPS.2013.2246192

Pokryvailo, A., Kanter, M., Kaplan, Z., &Maron, V. (1998). Design and testing of a 5 MW battery-based inductive power supply. *IEEE Transactions on Plasma Science, 26*(5), 1444–1453.

Ram, R., & Thomas, M. J. (2020). Experimental and computational studies on the efficiency of an induction coil gun. *IEEE Transactions on Plasma Science, 48*(10), 3392–3400. https://doi.org/10.1109/TPS.2020.3007551

Ram, R., & Thomas, M. J. (2022).A novel technique to arrest the armature capture effect in an induction coilgun. *IEEE Transactions on Plasma Science, 50*(10), 3334–3340. https://doi.org/10.1109/TPS.2022.3160202

Ram, R., & Thomas, M. J. (2023a).Launching studies with a four-stage induction coil gun. In *IEEE Pulsed Power Conference*.https://doi.org/10.1109/PPC47928.2023.10310938

Ram, R., & Thomas, M. J. (2023b). Study on the performance of sleeve projectiles launched using a four-stage induction coilgun. *IEEE Transactions on Plasma Science, 51*(10), 2885–2893. https://doi.org/10.1109/TPS.2023.3297668

Reelkar, S. S., Patil, U. V., Khatavkar, V. V., Mehta, H., &Alset, U. (2020). Electromagnetic launcher: Review of various structures. *International Journal of Engineering Research and Technology, 9*(5), 505–508.

Ren, S., Feng, G., Zhang, P., Li, T., & Zhao, X. (2022).Method of calculating inductance gradient for complex electromagnetic rail launcher.*Electronics, 11*(18), 2912.https://doi.org/10.3390/electronics11182912

Sijoy, C. D., &Chaturvedi, S. (2008). Calculation of accurate resistance and inductance for complex magnetic coils using the finite-difference time-domain technique.*IEEE Transactions on Plasma Science, 36*(1), 226–233. https://doi.org/10.1109/TPS.2007.913925

Stone, P. (2023). Coilgun electromagnetic piston. In *IEEE Pulsed Power Conference*.https://doi.org/10.1109/PPC47928.2023.10310703

Stroehla, T., Dahlmann, M., &Sattel, T. (2021).Electromagnetic actuators. In *ACTUATOR 2021; International Conference on New Actuator Systems and Applications* (pp. 1–6).

Sutton, G. P., &Biblarz, O. (2016).*Rocket propulsion elements* (9th ed., pp. 244–342).John Wiley & Sons.

Tanner, P., Loebach, J., Cook, J., &Hallen, H. D. (2001).A pulsed jumping ring apparatus for demonstration of Lenz's law.*American Journal of Physics, 69*(8), 911–916. https://doi.org/10.1119/1.1371919

Timpson, E., & Hartman, S. (2021). *Electromagnetic rifle with spin-stabilized projectile* (U.S. Patent No. 10,907,928).U.S. Patent and Trademark Office.

Timpson, E., & Hartman, S. (2018). *Electromagnetic driver with helical rails to impart rotation* (U.S. Patent No. 10,976,129).U.S. Patent and Trademark Office.

Tunceroglu, C., Hasirci, U., Maden, D., &Balikci, A. (2020). The experimental test results of a two-section linear induction launcher. *IEEE Transactions on Plasma Science, 48*(11), 4041–4047. https://doi.org/10.1109/TPS.2020.3020704

Wang, R., Liao, M., Feng, Z., Duan, X., Xie, D., & Han, X. (2024).A novel inductive gradient calculation method for electromagnetic rail launcher and its optimization.*IEEE Transactions on Plasma Science, 52*(6), 2304–2312.https://doi.org/10.1109/TPS.2024.3418216

Wang, S. H., Chen, S. Z., Li, X., & Liu, J. H. (2020). Test on the linear induction launcher with a new type of 3-phase helical coil. *Journal of Physics: Conference Series, 1507*, 102007.https://doi.org/10.1088/1742-6596/1507/10/102007

Wan, X., Yang, S., Li, Q., & Li, B. (2023). Time-varying inductance gradient in rails based on geometric mean distance.*IEEE Transactions on Plasma Science, 51*(1), 220–226. https://doi.org/10.1109/TPS.2022.3229539

Xue, X., Shu, T., Yang, Z., &Feng, G. (2016).Toroidal field electromagnetic launcher.*IEEE Transactions on Plasma Science, 44*(10), 2393–2398.

https://doi.org/10.1109/TPS.2016.2605142

Yang, D., Liu, Z., Shu, T., & Yang, L. (2017). Design and testing of a coil-unit barrel for helical coil electromagnetic launcher. *AIP Advances,* 7(8), 085105.https://doi.org/10.1063/1.4997335

Yang, D., Liu, Z., Shu, T., Yang, L., Ouyang, J., &Shen, Z. (2017).An improved genetic algorithm for multiobjective optimization of helical coil electromagnetic launchers.*IEEE Transactions on Plasma Science, 45*(12), 3229–3235. https://doi.org/10.1109/TPS.2017.2773639

Zhang, T., Guo, W., Lin, F., Cao, B., Dong, Z., Ren, R., Huang, K., & Su, Z. (2013). Experimental results from a 4-stage synchronous induction coilgun. *IEEE Transactions on Plasma Science, 41*(5), 1187–1193. https://doi.org/10.1109/TPS.2013.2256144

Zhang, T., Guo, W., Liu, Y., Su, Z., Zhang, H., Fan, W., & Huang, K. (2020). Study on the characteristics of magnetic-field arrangement of synchronous induction coil gun. *IEEE Transactions on Plasma Science, 48*(6), 2316–2323.https://doi.org/10.1109/TPS.2020.2990254

Zhang, T., Guo, W., Su, Z., Cao, B., Ren, R., Li, M., Ge, X., & Li, J. (2015). Design and evaluation of the driving coil on induction coilgun. *IEEE Transactions on Plasma Science, 43*(5), 1220–1225. https://doi.org/10.1109/TPS.2015.2409813

Zhang, Y., Gong, Y., Xiong, M., Bao, Q., Niu, X., & Li, X. (2019).Research on driving circuit improvement of coil gun.*IEEE Transactions on Plasma Science, 47*(5), 2222–2227.https://doi.org/10.1109/TPS.2019.2905044

Zhang, Y., Ruan, J., Niu, X., Tan, T., & Wen, W. (2015). Optimization analysis study of a multi-stage SICG based on OED. *IEEE Transactions on Dielectrics and Electrical Insulation, 22*(4), 2073–2080. https://doi.org/10.1109/TDEI.2015.004945

Zhang, Y., Xiong, M., Gong, Y., Xiao, G., Niu, X., & Huang, D. (2019). Study on multi-segment asynchronous induction coilgun launcher. *IEEE Transactions on Plasma Science, 47*(10), 4700–4707. https://doi.org/10.1109/TPS.2019.2936003

Zhao, B., Li, H., Wang, L., Jian, L., & Liu, X. (2020). A new modular XRAM-like inductive high-current pulse generator circuit topology. *IEEE Access, 8,* 210158–210166. https://doi.org/10.1109/ACCESS.2020.3038451

Zhu, B., Lu, J., Wang, J., &Xiong, S. (2017). A compulsator driven reluctance coilgun-type electromagnetic launcher.*IEEE Transactions on Plasma Science, 45*(7), 1663–1669. https://doi.org/10.1109/TPS.2017.2700022

Zhu, Y., Wang, Y., Chen, W., Yan, Z., & Li, H. (2012). Analysis and evaluation of three-stage twisty octapole field electromagnetic launcher. *IEEE Transactions on Plasma Science, 40*(5), 1399–1406. https://doi.org/10.1109/TPS.2012.2188530

Zhu, Y., Wang, Y., Yan, Z., Dong, L., Xie, X., & Li, H. (2010).Multipole field electromagnetic launcher.*IEEE Transactions on Magnetics, 46*(7), 2622–2627.https://doi.org/10.1109/TMAG.2010.2044416

Cite this article as: Mr. Hiren M. Patel and Dr. Jagrut J. Gadit., (2026). A comprehensive review of Thomson Coil Activation Mechanisms in Electromagnetic Launchers Systems. International Journal of Emerging Knowledge Studies. 5(3), pp. 400–418. https://doi.org/10.70333/ijeks-05-04-006