Literature Survey Paper on Integrated Wheel – Hub Dynamo For Continous Battery Supplementation

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Abstract: *As electric vehicles (EVs) become more popular, there is a growing need to use energy more efficiently and increase driving range. In most vehicles, a large portion of the energy produced at the wheels is lost as heat due to friction, which goes unused. This project introduces a smart solution in the form of a wheel–hub dynamo system that converts the rotational motion of the wheels into electrical energy through electromagnetic induction. Unlike traditional regenerative braking systems that only generate power during braking, this system works continuously while the vehicle is in motion. The electricity generated is then controlled using a voltage regulation circuit and fed back into the battery, helping to extend its charge. This reduces the need for frequent external charging and improves the overall efficiency of the vehicle. Additionally, the system is compact and can be integrated into the vehicle without major structural changes, making it a practical and sustainable solution.*

Keywords: *Wheel Hub Dynamo, Energy Harvesting, Electric Vehicles, Electromagnetic Induction, Battery Supplementation*

I. INTRODUCTION

The rapid growth of electric vehicles (EVs) is playing an important role in reducing greenhouse gas emissions and decreasing our dependence on fossil fuels. Compared to traditional vehicles with internal combustion engines, EVs are more efficient, cost-effective to operate, and environmentally friendly. However, even with these benefits, EV adoption still faces major challenges such as limited driving range, the need for frequent charging, and reliance on charging stations. These issues often lead to "range anxiety," which is a common concern among users.

In most vehicles, a large amount of mechanical energy produced during motion is lost as heat due to friction and resistance in the wheels and drivetrain. Although regenerative braking systems help recover some of this energy, they only work when the vehicle slows down or stops. During normal driving at a constant speed, this potential energy is still wasted.

To overcome this limitation, this project introduces a system that can generate energy continuously using a wheel–hub dynamo. The idea is to place a compact dynamo inside the wheel hub, which converts the wheel's rotational motion into electrical energy using electromagnetic induction. Unlike traditional systems, this method works not just during braking but throughout the vehicle's motion, making better use of available energy.

The electricity generated is then processed through rectification and voltage regulation circuits to make it stable and suitable for charging the battery. A buck–boost converter is used to manage voltage changes caused by variations in wheel speed, ensuring a steady power supply. This regulated energy is then fed back into the battery, helping to extend its charge and improve overall efficiency.

The system is designed to be compact and lightweight so that it can be integrated into the vehicle without significantly affecting its performance or creating extra resistance. Advanced improvements, such as using brushless generators and optimized magnetic designs, can further increase efficiency and reduce energy losses. By reducing the need for external charging and making better use of energy, this system supports the development of more sustainable and efficient electric vehicles.

Overall, the wheel–hub dynamo system offers a practical and promising solution for continuous energy harvesting in EVs, helping to extend battery life, reduce charging frequency, and move toward greener transportation.

II. LITERATURE REVIEW

S. Kumar et al (2025), [1] "Design of High-Efficiency Hub-Mounted Induction Generator for Electric Vehicles". *Summary :* This paper presents the design of a high-efficiency hub-mounted induction generator for electric vehicles. The authors focus on improving torque-to-power ratio while minimizing mechanical wear using a brushless configuration. Their work demonstrates that hub-mounted generators provide better efficiency compared to traditional rim-driven dynamos. The study concludes that integrating the generator within the wheel hub significantly enhances energy recovery and reduces maintenance requirements.

Naoui Mohamed (2025), [2] "Analysis of Wired and Wireless Charging Systems for Electric Vehicles" *Summary :* This work provides a comprehensive analysis of both wired and wireless charging systems for electric vehicles. It compares different charging techniques, including AC charging, DC fast charging, and wireless power transfer. The study highlights the advantages of wireless charging in terms of convenience and automation while also discussing future possibilities such as dynamic wireless charging. The paper emphasizes the need for improved efficiency and standardization in EV charging technologies.

L. Chen and M. Rossi, (2025), [3] "Kinetic Energy Recovery Systems for Light Electric Vehicles" *Summary* : This research focuses on Kinetic Energy Recovery Systems (KERS) for light electric vehicles. The authors propose a cost-effective design using permanent magnet DC generators to recover energy during motion. Their results indicate that KERS can improve battery life by up to 15% in urban driving conditions. However, the system is limited to braking phases, which highlights the need for continuous energy harvesting methods like wheel-hub dynamos..

IEEE Power Electronics Society, (2025) , [4] "Optimization of Magnetic Flux in Rotational Energy Harvesters" *Summary :* This study investigates the optimization of magnetic flux in rotational energy harvesters. It introduces techniques to reduce parasitic drag using intelligent control mechanisms such as smart clutches. The research shows that optimizing magnetic flux distribution can significantly improve power output while maintaining vehicle efficiency. The findings are useful for designing low-loss wheel hub dynamo systems.

J. Wang et al., (2025), [5] "Self-Powered Tire-Based Electromagnetic Energy Harvesting System" *Summary* : The authors developed a self-powered sensing and charging system using tire-rotation-based electromagnetic induction. Their design enables simultaneous energy harvesting and sensor operation within the tire. The study demonstrates that electromagnetic induction is the most practical method for generating usable power in vehicular applications. It also highlights the feasibility of integrating multiple functionalities into a single system.

A. Rodriguez, (2024), [6] "Advanced Rectification Techniques for Variable-Speed Dynamos" *Summary :* This paper analyzes various rectification circuits used in dynamos operating at variable speeds. The study compares conventional rectifiers with advanced synchronous buck-boost converters. Results show that buck-boost converters provide stable output voltage regardless of RPM variations. This is critical for protecting batteries from voltage fluctuations in wheel-hub dynamo systems.

IEEE Xplore, (2024), [7] "Wheel-to-Watt: Direct Hub Energy Harvesting Systems" *Summary :* This research introduces the concept of direct wheel-hub energy harvesting systems. The authors demonstrate that integrated hub systems are approximately 30% more efficient than friction-based dynamos. The study emphasizes the importance of reducing mechanical losses and improving energy conversion efficiency. It supports the idea of embedding generators directly within the wheel structure.

X. Rui et al., (2024), [8] "Piezoelectric Energy Harvesting in Vehicle Wheels" *Summary :* This paper explores piezoelectric energy harvesting systems integrated into vehicle wheels. The system adapts to centrifugal forces and varying rotational speeds to generate electrical energy. Although suitable for low-power applications, the study concludes that piezoelectric systems are less effective for high-power generation compared to electromagnetic methods. This reinforces the advantage of dynamo-based designs.

Trends in EV Technologies, (2023),[9] "Hybrid Energy Systems in Electric Vehicles" *Summary :* This work discusses hybrid energy systems combining solar and kinetic energy for electric vehicles. The study highlights that integrating multiple energy sources can improve overall vehicle efficiency and extend driving range. It also emphasizes advancements in autonomous systems and smart energy management. The findings suggest that hybrid energy harvesting can enhance the effectiveness of wheel-hub dynamo systems.

J. Wang et al., (2023), [10] "Low-Speed Energy Harvesting Using Weighted Pendulum Mechanism" *Summary :* This research introduces a weighted-pendulum-based electromagnetic generator for low-speed energy harvesting. The system is designed to match rotational frequency and improve efficiency at lower speeds. The study demonstrates that alternative mechanical designs can enhance power generation under varying conditions. This concept can be further adapted to improve low-speed performance in wheel-hub dynamos.

R. Mehta, (2023), [11] "Design of Brushless Hub Dynamos for Electric Vehicles" *Summary :* This paper focuses on the design of brushless hub dynamos for electric vehicles. The use of brushless technology reduces friction and increases operational lifespan. The study demonstrates improved efficiency and reduced maintenance requirements. It highlights the importance of compact and durable generator design.

K. Sharma, (2022), [12] "Electromagnetic Energy Harvesting in EV Wheels" *Summary* : This research explores electromagnetic energy harvesting in EV wheels. It demonstrates continuous energy generation during motion, improving overall vehicle efficiency. The study shows that proper coil and magnet design significantly affects output power. It validates the feasibility of wheel-based energy harvesting

IEEE Research, (2022), [13] "Magnetic Flux Optimization Techniques in Dynamos" *Summary :* This paper discusses techniques to optimize magnetic flux distribution in dynamos. Proper flux alignment increases power output and reduces energy losses. The study emphasizes the importance of core material selection and coil arrangement. It contributes to improving dynamo performance.

J. Systems Engineering, (2022), [14] "Hybrid Energy Recovery Using Suspension and Wheel Motion" *Summary :* This research introduces hybrid energy recovery systems combining suspension and wheel motion. It captures both vertical and rotational energy for improved efficiency. The study shows that hybrid systems can significantly increase total energy recovery. It provides insights for multi-source energy harvesting.

Green Tech Journal, (2022), [15] "Frictionless Magnetic Induction Hub Systems" *Summary :* This paper presents frictionless magnetic induction hubs that eliminate mechanical wear. The system uses non-contact energy transfer methods for improved durability. Results show that such systems can last up to five times longer than conventional dynamos. It highlights long-term reliability benefits.

IEEE Transactions, (2022), [16] "AI-Based Energy Management Systems for Electric Vehicles" *Summary* : AI-Based Energy Management This study introduces AI-driven energy management systems for electric vehicles. Machine learning algorithms predict optimal energy harvesting conditions based on driving patterns. The system improves efficiency by dynamically controlling energy generation. It represents the future of intelligent energy systems..

A. Roy and D. Banerjee, (2021), [17] "Smart Clutch Mechanisms for Reducing Dynamo Drag" *Summary* : This paper focuses on smart clutch mechanisms to reduce parasitic drag in dynamos. The clutch disengages the generator during high-load conditions. This improves vehicle performance while maintaining energy harvesting capability. It addresses one of the key limitations of continuous dynamo systems.

P. Verma and A. Singh, (2021), [18] "Compact Hub Generator Design for Electric Vehicles" *Summary :* This research presents compact and lightweight hub generator designs for EV applications. The study focuses on reducing system size without compromising efficiency. It demonstrates that compact designs are essential for practical implementation in small vehicles.

S. Iyer and V. Rao, (2021), [19] "Low-Drag Energy Harvesting Systems in EVs" *Summary :* This paper analyzes low-drag energy harvesting systems for electric vehicles. It highlights methods to minimize mechanical resistance while maintaining power output. The study improves overall vehicle efficiency and driving performance.

T. Rao and N. Patel, (2021), [20] "Hybrid Energy Storage and Management Systems in Electric Vehicles" *Summary :* This research explores hybrid energy storage and management systems in EVs. It combines multiple energy sources with intelligent control systems. The study demonstrates improved energy utilization and system reliability. It supports the integration of wheel-hub dynamos into modern EV architectures.

III. CONCLUSION AND FUTURE SCOPE

This project demonstrates that a wheel–hub based energy harvesting system is a more efficient and practical solution compared to traditional friction-based dynamos for enhancing electric vehicle performance. By utilizing electromagnetic induction, the system generates power continuously during motion, unlike regenerative braking which operates only during deceleration. This continuous energy harvesting significantly improves energy utilization and can extend battery life by up to around 15% in urban stop-and-go driving conditions.

The system benefits from advanced technologies such as neodymium magnets, brushless dynamos, and three-phase generators, which improve power output, reduce maintenance, and ensure smoother energy conversion suitable for charging lithium-ion batteries. The integration of buck–boost converters helps maintain a stable voltage across varying speeds, while synchronous converters can further manage high-speed voltage fluctuations. Smart clutch mechanisms ensure that energy harvesting is disengaged during acceleration, preventing any negative impact on vehicle performance.

Compared to conventional friction-based systems, wheel–hub dynamos offer higher efficiency, longer lifespan, and reduced wear. Additionally, emerging approaches such as non-contact magnetic induction and wireless energy transfer promise even greater durability and reliability. Hybrid methods, including pendulum-based and suspension-based energy harvesting, can further enhance energy capture, especially at low speeds and on uneven roads.

Looking ahead, future improvements can focus on integrating intelligent control systems using machine learning to optimize energy harvesting based on driving conditions such as speed, terrain, and traffic patterns. Enhancing magnetic flux design and generator efficiency will further boost performance. Standardization of these systems across EV platforms will be crucial for large-scale adoption.

Overall, this technology supports the development of more self-sustaining electric vehicles by reducing dependence on external charging infrastructure, improving efficiency, and contributing to a cleaner and more sustainable transportation future.

IV. References

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