Review on Development of Smart Self-Energizing Electric Vehicle for Sustainable Mobility

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Abstract- The increasing demand for sustainable transportation has accelerated the development of electric vehicles (EVs). However, conventional EVs rely mainly on external charging infrastructure, which may lead to range limitations and charging delays. This project presents the development of a Smart Self-Energizing Electric Vehicle designed to partially recharge itself by converting kinetic energy generated during motion into electrical energy. The proposed system utilizes a flywheel-driven DC generator that captures rotational motion from the vehicle's wheel and converts it into electrical power. The generated energy is regulated using a DC-DC boost converter to maintain appropriate voltage levels and then stored in lithium-ion battery cells. An Arduino-based control system integrated with voltage and current sensors continuously monitors the charging process and battery condition. The system also includes an LCD display to show real-time electrical parameters such as voltage, current, and battery status. The stored DC power can directly supply DC loads and can also be converted into AC power using an inverter module for external devices. Additionally, the vehicle supports conventional external charging. This self-energizing design improves energy utilization, reduces range anxiety, and promotes environmentally friendly transportation.

Keywords— *Self-Energizing Electric Vehicle, Flywheel Energy Recovery, DC Generator, Boost Converter, Sustainable Mobility etc.*

I. INTRODUCTION

Electric vehicles (EVs) have become one of the most promising solutions for reducing greenhouse gas emissions and dependence on fossil fuels in the transportation sector [1]. With the growing concerns about climate change and environmental pollution, many countries are promoting the adoption of electric mobility as a sustainable alternative to conventional internal combustion engine vehicles. EVs operate using electric motors powered by rechargeable batteries, which significantly reduces carbon emissions and improves energy efficiency compared to traditional vehicles [2]. However, despite their advantages, EVs still face several limitations such as limited driving range, long charging times, and dependence on charging infrastructure.

One of the major challenges associated with electric vehicles is range anxiety, which refers to the fear that a vehicle may run out of battery power before reaching a charging station [3]. This issue becomes more critical in regions where charging infrastructure is still developing. To overcome this limitation, researchers and engineers are continuously exploring innovative technologies that can improve the efficiency and energy management of EV systems.

Energy recovery techniques are one of the most effective ways to improve the efficiency of electric vehicles. Regenerative braking systems are commonly used in EVs to convert a portion of the vehicle's kinetic energy into electrical energy during braking [4]. Although regenerative braking improves energy utilization, it only captures energy when the vehicle decelerates, leaving a significant amount of kinetic energy unused during normal motion.

To address this challenge, alternative energy recovery mechanisms such as flywheel energy storage systems have gained attention. Flywheels store energy in the form of rotational kinetic energy and can be used to capture and reuse mechanical energy that would otherwise be wasted [5]. By integrating a flywheel mechanism with a generator, it becomes possible to convert rotational motion into electrical energy and store it in a battery system. This concept can help improve the overall efficiency of EVs and extend their operational range.

The proposed Smart Self-Energizing Electric Vehicle is designed to demonstrate this concept through a prototype system. In this system, the rotational motion of the vehicle's wheel drives a flywheel through a belt mechanism. The flywheel is connected to a DC generator that converts mechanical energy into electrical energy. The generated electrical power is then regulated using a DC-DC boost converter to maintain the required voltage level before storing it in lithium-ion battery cells.

To enhance system intelligence and monitoring capability, an Arduino-based control system is integrated with voltage and current sensors. This system continuously monitors the charging process and displays real-time data on an LCD display. The stored energy can power DC loads directly and can also be converted to AC power using an inverter module. Additionally, an external charging port is provided to allow conventional charging when required.

This project demonstrates a self-energizing mechanism for electric vehicles, which combines kinetic energy recovery, smart monitoring, and dual charging capability. The proposed system contributes to improved energy efficiency, reduced dependency on external charging stations, and the promotion of sustainable transportation technologies.

II. PROBLEM IDENTIFICATION

- Conventional electric vehicles rely heavily on external charging infrastructure, which may not always be easily available in many areas.
- Frequent charging requirements increase dependency on charging stations and reduce overall convenience for EV users.
- Limited driving range of electric vehicles leads to range anxiety among users, restricting long-distance travel.
- A large amount of kinetic energy produced during vehicle motion is wasted and not effectively utilized for power generation.
- Existing regenerative braking systems recover energy only during braking, leaving unused energy during normal vehicle movement.
- Inefficient energy utilization reduces the overall efficiency and performance of electric vehicle systems.
- Lack of integrated mechanisms for continuous onboard energy generation limits the potential for self-sustaining EV operation.
- Absence of real-time monitoring and smart control systems reduces system transparency and energy management efficiency in small-scale EV prototypes.

2.1. Drawbacks

- Heavy dependence on external charging stations increases charging time and reduces convenience.
- Limited driving range of EVs leads to range anxiety among users.
- Regenerative braking captures only a small portion of available kinetic energy.
- A large amount of energy produced during vehicle motion is wasted.
- Absence of continuous energy harvesting systems lowers overall efficiency.
- Poor energy management may affect battery life and performance.
- Lack of real-time monitoring systems reduces user awareness of power generation and usage.

2.2. Existing system

- The existing safety systems in electric vehicles (EVs) Conventional electric vehicles rely mainly on external charging stations to recharge their batteries.
- Energy is supplied only from stored battery power, which limits the vehicle's driving range.
- Regenerative braking systems are used in some EVs to recover energy during braking.
- However, energy recovery occurs only during deceleration and not during normal vehicle motion.
- Limited charging infrastructure in many regions causes inconvenience to EV users.
- Lack of additional onboard energy generation systems reduces overall vehicle efficiency.

III. LITERATURE SURVEY

3.1. Literature Review

Zhang, Y., Li, H., and Chen, X. (2022), The study investigates the use of flywheel energy storage systems (FESS) in electric vehicles to improve energy efficiency and reduce power losses. The authors explain that flywheels can store mechanical energy in the form of rotational motion and release it when required. Compared to conventional battery systems, flywheels provide rapid charge and discharge capability and high power density. The research concludes that integrating flywheel systems with EV powertrains can significantly enhance regenerative energy recovery. However, the system requires careful design to manage rotational speed and safety. The study highlights that hybrid energy storage systems combining batteries and flywheels can improve EV performance and extend driving range.

Kumar, A., Singh, P., and Verma, R. (2021), This paper reviews various energy recovery methods used in electric vehicles, including regenerative braking, flywheel systems, and supercapacitors. The authors emphasize that energy recovery systems help improve overall vehicle efficiency by converting otherwise wasted kinetic energy into usable electrical power. The study demonstrates that combining multiple recovery technologies can significantly enhance system performance. The research also highlights the importance of power electronics, such as DC-DC converters, for efficient energy management. The authors conclude that energy recovery technologies are essential for improving EV sustainability, reducing energy losses, and minimizing dependency on frequent external charging.

Li, J., Wang, T., and Zhao, L. (2020), The authors focus on the design and performance analysis of DC-DC boost converters used in electric vehicle energy systems. The study explains how boost converters increase voltage levels from low-voltage sources such as generators or renewable energy systems. The results indicate that high-efficiency converters significantly improve power transfer and reduce energy losses during charging. The research also highlights the role of advanced control techniques in maintaining voltage stability. The authors conclude that efficient boost converter design is essential for integrating alternative energy sources such as regenerative systems or auxiliary generators into EV battery systems.

Sharma, R., Gupta, S., and Mehta, V. (2023), This research presents a smart monitoring system for electric vehicles using microcontrollers and sensor technology. The system uses voltage and current sensors to continuously monitor battery performance and energy consumption. Data is processed using an Arduino controller and displayed through an LCD interface or transmitted via IoT platforms. The study shows that real-time monitoring helps improve energy management and system reliability. The authors highlight that integrating smart monitoring systems can assist drivers in tracking battery health and energy usage. Such technologies improve user awareness and contribute to efficient operation of electric vehicle systems.

Patel, D., Shah, M., and Joshi, K. (2022), This paper explores kinetic energy recovery systems (KERS) used in electric and hybrid vehicles. The authors discuss various technologies such as regenerative braking, mechanical flywheels, and electrical storage systems. The study highlights that KERS can improve vehicle efficiency by capturing energy that would otherwise be lost as heat during braking or motion. Simulation results show that integrating kinetic energy recovery can significantly reduce energy consumption. The research also identifies challenges such as mechanical complexity and cost. Overall, the study confirms that advanced energy recovery systems are essential for improving EV performance and sustainability.

Wang, H., Liu, Q., and Chen, D. (2021), The research investigates hybrid energy storage systems that combine batteries, supercapacitors, and flywheels to improve electric vehicle performance. The authors explain that each energy storage technology has unique advantages in terms of energy density and power density. By combining these technologies, the system can achieve improved efficiency, faster charging capability, and longer battery life. The study also demonstrates that hybrid systems help stabilize power flow during acceleration and regenerative braking. The authors conclude that integrating multiple energy storage technologies provides a promising solution for next-generation electric vehicles.

Singh, N., Sharma, P., and Yadav, R. (2020), This study reviews the integration of renewable and alternative energy sources into electric vehicle systems. The authors analyze different methods of generating supplementary energy during vehicle operation. The research shows that incorporating additional energy generation mechanisms can reduce dependence on external charging infrastructure. The paper also discusses the importance of efficient power management systems to ensure stable operation. The authors conclude that integrating renewable energy technologies and energy recovery mechanisms can significantly improve the sustainability of electric transportation systems.

Brown, T., Smith, J., and Wilson, K. (2023), This paper focuses on advanced energy management systems used in modern electric vehicles. The authors examine how intelligent control algorithms and power electronics can optimize energy distribution between batteries, motors, and auxiliary systems. The research highlights the importance of real-time monitoring and control in improving EV efficiency. Simulation results demonstrate that optimized energy management can increase vehicle range and reduce energy losses. The study concludes that advanced control systems are critical for improving the performance and reliability of electric vehicles.

Gupta, A., Jain, R., and Bansal, S. (2021), The study presents a smart charging and monitoring system designed to improve electric vehicle battery management. The system integrates sensors, microcontrollers, and power electronics to monitor battery voltage, current, and temperature. The research shows that smart monitoring systems can prevent battery overcharging and improve operational safety. The authors also emphasize the importance of user-friendly interfaces that provide real-time information about energy consumption. The study concludes that intelligent monitoring and charging technologies are essential for improving battery life and enhancing the reliability of EV systems.

Lee, S., Park, J., and Kim, H. (2022), This research investigates the potential of mechanical energy harvesting systems in transportation applications. The authors analyze how rotational motion and vibration from vehicles can be converted into electrical energy using generators and mechanical mechanisms. Experimental results demonstrate that energy harvesting technologies can provide supplementary power for onboard electronic systems. The study suggests that integrating mechanical energy harvesting devices into EV designs can improve energy efficiency. The authors conclude that such systems can play an important role in the development of self-sustaining and energy-efficient transportation technologies.

3.2. Literature Summary

Recent studies on electric vehicles (EVs) emphasize improving energy efficiency and extending driving range through advanced energy recovery and storage technologies. Researchers have explored various methods such as regenerative braking, flywheel energy storage systems, and hybrid energy storage systems combining batteries and supercapacitors. Flywheel systems have been identified as effective for storing rotational kinetic energy and releasing it when required, offering high power density and rapid energy transfer. Several studies also highlight the importance of DC-DC converters for efficient voltage regulation and energy transfer to battery systems. In addition, smart monitoring technologies using microcontrollers, sensors, and IoT platforms have been widely adopted to monitor battery health, power flow, and system performance in real time. Despite these advancements, most current research focuses mainly on large-scale EV systems and regenerative braking technologies. Limited attention has been given to small-scale prototype systems that demonstrate continuous kinetic energy harvesting during vehicle motion using simple mechanical mechanisms such as flywheel-driven generators.

3.3. Research Gap

Although many studies have explored energy recovery systems in electric vehicles, most existing solutions rely primarily on regenerative braking to capture kinetic energy during deceleration. This approach limits energy recovery since a large portion of kinetic energy generated during normal vehicle motion remains unused. Additionally, many advanced energy recovery technologies require complex control systems, high-cost components, or sophisticated power management strategies, making them difficult to implement in low-cost prototype models. There is also limited research on integrating simple mechanical systems such as flywheel-driven generators with smart monitoring and energy storage systems in small-scale EV prototypes. Furthermore, existing studies often focus on improving battery technologies rather than developing alternative onboard energy generation mechanisms. Therefore, there is a need for a practical and cost-effective system that can demonstrate continuous kinetic energy harvesting during vehicle motion, along with real-time monitoring and dual charging capabilities, to improve overall energy efficiency and reduce dependency on external charging sources.

IV. METHODOLOGY

4.1. Proposed System

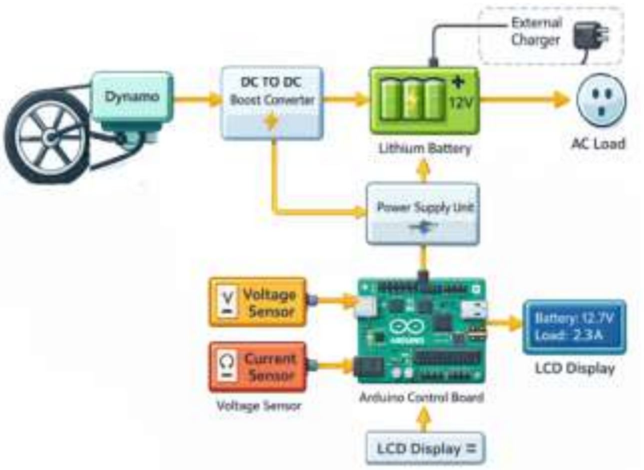

Figure 1. Proposed System

Working Principle:

- When the electric vehicle moves, the rotation of the rear wheel generates mechanical kinetic energy.
- The rotating wheel is connected to a flywheel mechanism through a belt drive system.
- As the wheel rotates, the belt transfers motion to the flywheel, allowing it to store rotational energy.
- The flywheel is mechanically coupled to a DC generator (dynamo).
- The rotation of the flywheel drives the DC generator, converting mechanical energy into electrical energy.
- The generated electrical power is initially low and may vary depending on wheel speed.
- Therefore, the generated voltage is passed through a DC–DC boost converter.
- The boost converter increases and stabilizes the voltage to a suitable level for battery charging.
- The regulated electrical energy is stored in a 12V lithium battery for later use.
- A power supply unit distributes power to different electronic components of the system.
- Voltage and current sensors continuously monitor battery voltage and charging current.
- The Arduino controller processes the sensor data and manages system monitoring.
- Real-time information such as voltage, current, and battery status is displayed on an LCD screen.
- The stored DC power can supply DC loads directly.
- An inverter module converts DC power into AC power for external AC loads.

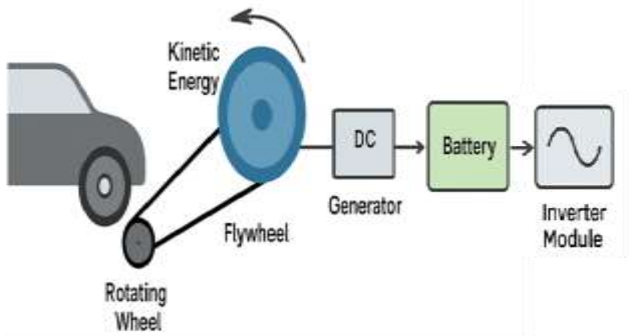

Figure 2. Functional Diagram

4.2. Hardware Used

- Flywheel Assembly: Stores rotational kinetic energy generated from the wheel motion and helps maintain continuous rotation for power generation.
- DC Generator (Dynamo): Converts mechanical energy from the rotating flywheel into electrical energy in the form of DC voltage.
- DC-DC Boost Converter: Increases the low voltage produced by the generator to a suitable level required for battery charging.
- Lithium Battery (12V, 2Ah): Stores the generated electrical energy and supplies power to different loads and system components.
- Arduino Controller: Acts as the main control unit for monitoring voltage, current, and system status.
- Voltage Sensor: Measures battery voltage and sends the data to the Arduino controller.

- Current Sensor: Monitors the charging and load current in the system.
- LCD Display: Displays real-time system parameters such as voltage, current, and battery status.
- Inverter Module: Converts stored DC power into AC power for AC loads.

4.3. Software Used

- Arduino IDE: Used to write, compile, and upload programs to the Arduino microcontroller for system control and monitoring.
- Embedded C Programming: The Arduino is programmed using Embedded C language to process sensor inputs and control system functions.
- Serial Communication: Used for communication between Arduino and connected modules such as sensors and LCD display.
- Sensor Data Processing: Software algorithms read voltage and current sensor signals and convert them into digital values.
- Display Programming: The Arduino program updates real-time system information on the LCD display.
- Power Monitoring Logic: The software continuously monitors battery charging conditions and system performance.
- Debugging and Testing Tools: Arduino IDE serial monitor is used to test sensor outputs and verify correct system operation.
- Control Algorithms: Basic control logic ensures accurate monitoring and efficient energy management in the system.

V. ADVANTAGES

- Utilizes otherwise wasted kinetic energy generated during vehicle motion.
- Improves overall energy efficiency of the electric vehicle system.
- Reduces dependency on external charging stations.
- Provides real-time monitoring of voltage, current, and battery status.
- Supports both DC and AC loads through inverter integration.
- Promotes sustainable and eco-friendly transportation technology.

VI. APPLICATION

- Used in prototype electric vehicles for energy recovery demonstrations.
- Suitable for research on flywheel-based energy harvesting systems.
- Can be applied in hybrid electric vehicle energy management systems.
- Useful in educational laboratories for studying EV technologies.
- Can power small onboard electronic devices in vehicles.
- Supports development of sustainable and smart transportation systems.

VII. CONCLUSION

The review of existing studies on electric vehicles and energy recovery systems highlights the growing importance of improving energy efficiency and sustainability in modern transportation. Electric vehicles offer a promising alternative to conventional fuel-based vehicles; however, challenges such as limited driving range, dependency on charging infrastructure, and inefficient utilization of kinetic energy still remain. Various research works have explored technologies such as regenerative braking, flywheel energy storage systems, hybrid energy storage systems, and intelligent energy management techniques to address these challenges.

Among these approaches, flywheel-based energy storage and recovery systems show significant potential for capturing and reusing mechanical energy generated during vehicle motion. Additionally, advancements in power electronics, including DC-DC boost converters and inverter modules, have improved the efficiency of energy conversion and storage. Smart monitoring systems using microcontrollers and sensors further enhance system performance by providing real-time information about voltage, current, and battery status.

Overall, the reviewed literature indicates that integrating kinetic energy recovery mechanisms with intelligent control and monitoring systems can significantly improve the efficiency, reliability, and sustainability of electric vehicles, contributing to the development of greener transportation technologies.

REFERENCES

[1] Y. Zhang, H. Li, and X. Chen, "Flywheel energy storage systems for electric vehicles," *Renewable and Sustainable Energy Reviews*, vol. 135, pp. 110–118, 2022.
[2] A. Kumar, P. Singh, and R. Verma, "Energy recovery techniques in electric vehicles," *IEEE Transactions on Transportation Electrification*, vol. 7, no. 3, pp. 1452–1460, 2021.
[3] J. Li, T. Wang, and L. Zhao, "Design and analysis of DC–DC boost converters for electric vehicle applications," *IEEE Access*, vol. 8, pp. 203456–203468, 2020.
[4] R. Sharma, S. Gupta, and V. Mehta, "Smart monitoring systems for electric vehicles using IoT and Arduino," *International Journal of Intelligent Transportation Systems Research*, vol. 21, no. 2, pp. 145–153, 2023.
[5] D. Patel, M. Shah, and K. Joshi, "Kinetic energy recovery systems in electric vehicles," *Journal of Cleaner Production*, vol. 314, pp. 127–135, 2022.
[6] H. Wang, Q. Liu, and D. Chen, "Hybrid energy storage systems for electric vehicles," *Applied Energy*, vol. 292, pp. 116–124, 2021.
[7] N. Singh, P. Sharma, and R. Yadav, "Renewable energy integration in electric vehicle systems," *Energy Reports*, vol. 6, pp. 1023–1032, 2020.
[8] T. Brown, J. Smith, and K. Wilson, "Advances in electric vehicle energy management systems," *Energy Conversion and Management*, vol. 268, pp. 115–123, 2023.

[9] A. Gupta, R. Jain, and S. Bansal, "Design of smart electric vehicle charging and monitoring systems," *International Journal of Energy Research*, vol. 45, no. 9, pp. 13421–13430, 2021.

[10] S. Lee, J. Park, and H. Kim, "Mechanical energy harvesting in electric transportation systems," *Sustainable Energy Technologies and Assessments*, vol. 52, pp. 102–110, 2022

[11] A. Kumar, "Regenerative Braking Systems in Electric Vehicles: A Review," *International Journal of Automotive Technology*, vol. 23, no. 2, pp. 150–159, 2022.

[12] X. Li and Y. Chen, "Energy Harvesting Mechanisms for Electric Vehicles," *Renewable and Sustainable Energy Reviews*, vol. 145, p. 111081, 2021.

[13] P. Singh and S. Verma, "Design of Gear-Based Kinetic Energy Recovery System for EVs," *Journal of Mechanical Engineering Research*, vol. 12, no. 4, pp. 55–62, 2023.

[14] J. Wang and M. Zhang, "Smart Battery Management for Hybrid Electric Vehicles," *IEEE Access*, vol. 10, pp. 45678–45685, 2022.

[15] D. Patel and K. Joshi, "Integration of Boost Converters in EV Power Systems," *Journal of Power Electronics and Drives*, vol. 8, no. 1, pp. 22–29, 2023.