Wheel Integrated Energy Recovery System for Electric Vehicles Using Dynamo

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How to Cite this Article:

PUGAZHENTHI, , A, S. & K, S. (2026). Wheel Integrated Energy Recovery System for Electric Vehicles Using Dynamo. International Journal of Creative and Open Research in Engineering and Management, <i>02</i>(05). https://doi.org/10.55041/ijcope.v2i5.215

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ABSTRACT

The rapid increase in electric vehicles (EV) has created a need for better energy efficiency and longer driving range. This project proposes a Wheel Integrated Energy Recovery System using a dynamo to convert unused mechanical energy from wheel rotation into electrical energy.

In this system, the rotation of the vehicle's wheel drives a small dynamo, generating alternating current (AC). This is converted into direct current (DC) using a rectifier and then regulated before storing it in the battery. The generated energy can support small electrical loads or assist in battery charging.To avoid performance loss, a control or clutch mechanism is used to reduce unnecessary drag.

The design is simple, affordable, and can be used in both new EV and existing vehicles.Although the energy produced is limited, it helps improve overall efficiency and reduces reliance on external charging. This method can also work alongside other technologies like regenerative braking and solar power, contributing to a more sustainable transportation system.

Keywords— WIERS, Dynamo, PMSG, Regenerative Energy, $LiFePO_4$ Battery,

BMS, DC-DC Converter, Sustainable Mobility

I. INTRODUCTION

The rapid growth of Battery Electric Vehicles (BEV) reflects the global shift toward sustainable transportation. However, challenges such as range anxiety and limited charging infrastructure still affect their widespread adoption.During vehicle operation, energy is continuously lost due to air resistance, friction, and heat. Although regenerative braking helps recover some energy, it only works during braking, leaving a significant amount of energy unused during steady driving.

One key observation is that the wheel axle rotates continuously whenever the vehicle is in motion, making it a reliable source of mechanical energy. This energy can be converted into electrical power using a generator.To address this, the Wheel Integrated Energy Recovery System (WIERS) is proposed. It uses an axle-connected Permanent Magnet Synchronous Generator (PMSG) to generate electricity continuously and can be integrated into existing EVs without major design changes, improving overall efficiency.

In this design, the vehicle's rotating wheels drive a compact dynamo, generating alternating current (AC). The AC is then converted to direct current (DC) via a rectifier, regulated, and stored in the battery. This recovered energy can supplement small electrical loads or contribute to battery charging, thereby enhancing the vehicle's efficiency.

To prevent performance losses, a control or clutch mechanism is incorporated to minimize unnecessary drag on the wheels. The system's straightforward and cost-effective design makes it suitable for both new EVs and retrofitting existing vehicles.

While the amount of energy generated may be modest, this approach improves overall efficiency and reduces dependence on external charging infrastructure. Furthermore, the system can complement other technologies, such as regenerative braking and solar power, fostering a more sustainable and integrated transportation ecosystem.

II. LITERATURE REVIEW

Regenerative braking is the go-to method for energy recovery in electric vehicles. Toyota Prius rolled it out first, and it's still widely used. The system grabs kinetic energy when you hit the brakes and turns it back into electricity. It works pretty well, but only when you're slowing down. If you're cruising at a steady speed, it basically just sits there doing nothing.

Piezoelectric energy harvesting sounds futuristic—it tries to pull power from how your tires deform as you drive. Trouble is, it generates barely any electricity, and keeping the electrical connections stable inside spinning tires is a headache. So, for now, it doesn't really make sense for real-world use.

Electromagnetic shock absorbers are another idea. They reclaim some energy when your car's suspension moves, especially on bumpy roads. On smooth highways, though, they don't do much. Plus, installing these systems means reworking the car's whole suspension. Take Audi's eROT concept, for example—lots of promise, but not exactly plug-and-play.

In-wheel hub motors—think Protean Electric—push efficiency even further and give you more control over each wheel. The downside? They add a lot of weight right where you don't want it (at the wheels), and the wheel assembly needs a total overhaul. That makes it tough to use them on cars that are already built.

Flywheel Energy Storage Systems work a bit differently. They capture mechanical energy while braking, then let it loose when you need an extra boost. The catch is, flywheels add their own set of problems, like complicated gyroscopic forces and the need for pretty specific conditions to work well. So, while they can bump up efficiency, they're not a simple add-on.

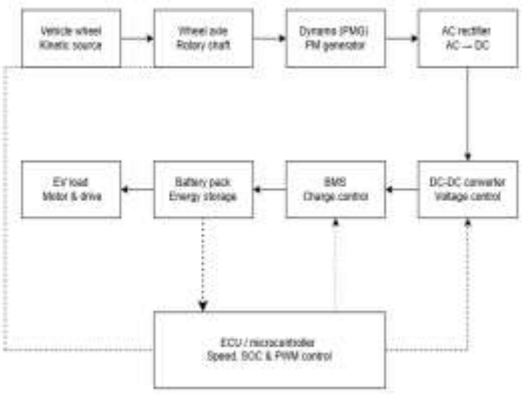
III. PROPOSED SYSTEM

The proposed system, Wheel Integrated Energy Recovery System (WIERS), is designed to continuously generate electrical energy from the rotation of vehicle wheels. Unlike conventional methods that work only during braking, this system captures energy throughout the entire motion of the vehicle.

In this setup, a Permanent Magnet Synchronous Generator (PMSG) or dynamo is mechanically coupled to the wheel axle. As the wheel rotates, the generator produces alternating current (AC), which is then converted into direct current (DC) using a rectifier. The DC output is regulated through a DC-DC buck converter and safely stored in a $LiFePO_4$ battery, managed by a Battery Management System (BMS).

To ensure that vehicle performance is not affected, a control or clutch mechanism is incorporated to engage or disengage the generator when required, thereby minimizing additional drag. The system is compact, lightweight, and designed for easy integration without major modifications to the vehicle structure.

Overall, the proposed WIERS provides a continuous, efficient, and cost-effective solution for energy recovery, improving battery utilization and supporting sustainable electric vehicle operation.



IV. SYSTEM ARCHITECTURE

The Wheel Integrated Energy Recovery System, or WIERS, is basically a compact unit that fits right into a vehicle's wheel assembly and catches energy as the wheels turn. It's built from three main pieces: mechanical parts, electrical components, and a control system, all talking to each other to squeeze out as much electricity as possible from every rotation.

Here's how it plays out: mechanically, the wheel's axle connects to a dynamo or a Permanent Magnet Synchronous Generator (PMSG). When the car's in motion, that rolling axle spins the generator and cranks out AC power. There's a clutch or some type of control to switch the generator on or off, so it doesn't add extra drag when it's not needed and keeps the car running smoothly.

On the electrical side, the AC from the generator heads straight to a rectifier, turning it into DC power. Then, a DC-DC buck converter steps in to smooth out the voltage and make it safe for charging. That clean, dependable power goes straight into a $LiFePO_4$ battery for storage.The control system is anchored by a Battery Management System, or BMS. This section keeps a close eye on battery stats like voltage, current, and temperature. It protects the battery from being overcharged or drained too much and generally keeps everything working at top performance.

All in all, WIERS gives you steady energy recovery without bogging down the vehicle. It's small, efficient, and slots easily into new electric cars or retrofits in older ones.

V. WORKING METHODOLOGY

The Wheel Integrated Energy Recovery System, or WIERS, captures the constant spin of a vehicle's wheels and turns it into electricity. As the car moves, the wheel axle connects to a dynamo or Permanent Magnet Synchronous Generator (PMSG), generating AC power.

Next, a rectifier changes this AC into steady DC, and a DC-DC buck converter keeps the voltage stable. The system stores this power in a $LiFePO_4$ battery, which can later take some strain off the main battery or run extra electronics.

A Battery Management System (BMS) watches over the battery's voltage, current, and temperature, making sure everything stays safe. To avoid slowing the car down, the system also uses a clutch or similar mechanism. That way, it recovers energy efficiently without hurting your ride's performance.

VI. ENERGY CALCULATION

1.Mechanical Power Generation

$$P = T \cdot \omega$$

This equation explains how the spinning wheel turns mechanical energy into power. T stands for torque—the force twisting the generator's shaft. ω is the wheel's angular speed. Basically, more torque or faster spinning equals more power.

2. Angular Speed of Wheel

$\omega = v / r$

This connects how fast the vehicle moves with how quickly the wheel spins. Here, v is the vehicle's speed, and r is the wheel's radius. If you drive faster, the wheels spin quicker, which means more energy is generated.

3. Electrical Power Output

$P = V \cdot I$

Here's how you figure out the power the generator actually produces. V is voltage, and I is current. This tells you how much usable electricity is available—what you can actually store.

4. Energy Generated

$E = P \cdot t$

This shows how much energy builds up over time. P is power, t is time. Let the system run longer, and you store more energy in the battery.

5. System Efficiency

$\eta = P_{out} / P_{in}$

Efficiency is all about how much input energy ends up as useful power coming out. Some goes to waste—lost as heat, friction, and other messy stuff.

6. Overall Efficiency of WIERS

$\eta_{total} = \eta_{gen} \times \eta_{rect} \times \eta_{conv}$

Now, for the big picture: the system's total efficiency includes every step—generator, rectifier, converter. How well these parts work together decides how much energy you'll actually get. If one lags, your real usable energy drops.

VII.HARDWARE IMPLEMENTATION

The Wheel Integrated Energy Recovery System (WIERS) hardware brings together mechanical and electrical parts right inside the vehicle's wheel assembly. A dynamo or Permanent Magnet Synchronous Generator (PMSG) connects straight to the wheel axle, harnessing the spinning motion and turning it into electricity.

Once that AC power comes out of the generator, it runs through a rectifier and turns into DC. A DC-DC buck converter keeps the voltage right where it needs to be for charging. All the energy then goes into a $LiFePO_4$ battery. A Battery Management System (BMS) keeps an eye on the battery, making sure everything runs safely.

There are extra bits, too—sensors for voltage, current, and temperature, plus a clutch or some sort of engagement system to improve efficiency and cut down on drag. Altogether, the hardware stays compact and efficient, fitting neatly into new electric vehicles or retrofitting into older ones.

VIII.SOFTWAREIMPLEMENTATION

This software handles monitoring, control, and safety for the whole system. A micro controller—like an Arduino or something similar—gathers data from sensors and keeps everything running smoothly.

The control algorithm keeps an eye on things like battery voltage, current, and temperature through the BMS. It uses that data to manage charging and make sure nothing goes out of bounds. It also manages when to turn the generator on or off, depending on what's happening.

On the software side, you've got the basics: grabbing data, controlling voltage, spotting faults, and showing the system status. You can even add IOT functions, so you get live updates and can dig into performance stats any time.

IX. PERFORMANCE ANALYSIS

Parameter	20 km/h	40 km/h	60 km/h	80 km/h
Rotor speed (RPM)	158	315	473	630
AC output voltage (V, rms)	6.2	12.8	19.4	26.1

DC output after rectifier (V)	5.8	12.1	18.3	24.5
Output current (A)	0.45	0.92	1.38	1.85
Power generated (W)	2.61	11.13	25.25	45.33
Overall system efficiency (%)	71.2	78.4	83.1	86.7

We looked at how the Wheel Integrated Energy Recovery System (WIERS) performs as the vehicle speeds up, from 20 km/h all the way to 80 km/h. As you'd expect, when the car goes faster, the rotor spins quicker. This boosts the generator's output, so both the AC and the DC voltages climb steadily.

When you're only going 20 km/h, WIERS doesn't produce much—voltage, current, power, all on the low side. You only get about 2.61 W out of it. But things pick up as the speed hits 40 and 60 km/h. There's a real jump in how much electricity the system puts out. At 80 km/h, the system really hits its stride and manages about 45.33 W, with stronger current and higher voltage.

You also see a noticeable bump in efficiency. At 20 km/h, efficiency sits at 71.2%. Push the speed up, and that efficiency goes up too—all the way to 86.7% at top speed. That happens because there's less wasted energy and the generator, plus the power electronics, just work better when they're spinning faster.

So, WIERS does its best when you're cruising at moderate to high speeds—exactly what you want for highway driving. Sure, it doesn't do much at slower speeds, but it still helps recover energy and makes the vehicle as a whole more efficient.

X. ADVANTAGES

- Continuous energy generation during motion
- Improves overall vehicle efficiency
- Reduces load on main battery
- Increases driving range
- Simple and low-cost system
- Easy to integrate (retrofit-friendly)
- Works effectively at higher speeds
- Supports sustainable transportation

XI. FUTURE SCOPE

The future scope of the Wheel Integrated Energy Recovery System (WIERS) lies in improving efficiency and expanding its capabilities through advanced technologies. Integration with AI-based control systems can help optimize energy generation by intelligently managing the engagement of the generator based on driving conditions. The use of high-efficiency generators and lightweight materials can further enhance performance while reducing system losses.

Additionally, the system can be combined with other energy recovery methods such as solar panels and regenerative braking to create a hybrid energy solution. Real-time monitoring through IOT or mobile applications can provide better control, performance tracking, and predictive maintenance.

In the long term, WIERS can be scaled for different types of electric vehicles, including two-wheelers, cars, and buses. With further development and optimization, the system has strong potential for commercial implementation, contributing to more efficient and sustainable transportation.

XII. CONCLUSION

The Wheel Integrated Energy Recovery System (WIERS) presents a simple and effective approach to improve energy efficiency in electric vehicles. By converting continuous wheel rotation into electrical energy, the system utilizes energy that would otherwise be wasted during normal driving conditions.

The proposed design is compact, cost-effective, and easy to integrate into both new and existing vehicles without major modifications. It works alongside existing technologies like regenerative braking to enhance overall energy utilization and support auxiliary loads.

Although the power generated is relatively small, it contributes to reducing battery dependency and improving driving range. Overall, WIERS offers a practical and scalable solution for promoting sustainable and energy-efficient transportation in the future.

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