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Dynamo-Less Electricity Generation for Automotive

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***Abstract* - This project focuses on the development of a dynamo-less electricity generation system utilizing the concept of magnetic coupling between a primary railway axle and a secondary generator shaft. The system harnesses the rotational motion of the train's axle to generate electrical energy without any direct mechanical contact. The proposed design integrates a magnetic coupling mechanism that efficiently transfers rotational energy from the locomotive axle to the generator shaft through magnetic flux interaction, thereby eliminating frictional losses and mechanical wear typically associated with conventional dynamos. The inclusion of a variable capacitor and regulated power control unit ensures stable power generation and output quality. This device can be conveniently installed along railway bogies or locomotive axles to continuously produce auxiliary electrical power during train motion. The frictionless operation not only enhances system durability but also prevents any alteration or mechanical load on the primary drive components. Such a system is highly beneficial for railway applications, enabling sustainable and maintenance-free electricity generation for onboard systems such as lighting, sensors, and communication devices.**

Keywords: Magnetic coupling, Dynamo-less generator, Non-contact energy transfer, Railway axle power generation, Electromagnetic induction, Sustainable energy, Rotational energy harvesting.

I. INTRODUCTION

In the modern world, electricity has become an indispensable part of human life. The demand for electrical energy continues to grow exponentially with rapid industrialization, technological advancement, and lifestyle changes. Every sector—from transportation and communication to manufacturing and daily domestic activities—depends heavily on a consistent supply of electricity. However, the increasing demand has placed immense pressure on conventional energy resources, leading to their depletion and environmental degradation. Therefore, it has become crucial to explore alternative and sustainable methods of electricity generation that can meet modern energy requirements efficiently and safely.

One of the most promising approaches lies in harnessing mechanical or kinetic energy that is otherwise wasted during daily human and industrial activities. For instance, human locomotion involves significant bio-mechanical energy that remains unutilized. Studies show that an average individual takes approximately 3,000 to 5,000 steps per day, and if a fraction of that energy could be converted into electrical power, it could become a supplementary renewable energy source. Similar concepts can be extended to large-scale mechanical systems, such as **moving trains**, where rotational or vibrational energy can be harvested and converted into electricity.

The primary goal of the proposed project is to develop an **eco-friendly and self-sustaining power generation system** that can complement existing power infrastructure. The concept utilizes the continuous motion of railway axles to produce electricity without requiring an external energy input. Since trains operate throughout the day across vast networks, this method ensures a **continuous and inexhaustible power supply** as long as railway operations persist. By deploying magnetic coupling mechanisms along locomotive axles, the system efficiently transforms mechanical rotation into electrical energy while maintaining the integrity of the original setup.

Traditional power systems along railway tracks often face difficulties in providing reliable energy to signaling devices, sensors, and communication systems, particularly in remote or rural locations. Supplying electricity to such isolated railway sections generally involves installing extended power lines or using batteries, both of which can be expensive and maintenance-intensive. External grid connections are often impractical due to terrain, distance, and cost considerations. In contrast, the proposed system offers a **localized generation solution**, eliminating dependency on distant power grids and reducing infrastructure costs.

The **magnetic coupling mechanism** plays a pivotal role in this project. It employs **permanent magnets** to transfer torque between two rotating shafts—namely, the train axle (input shaft) and the generator shaft (output)—without any physical contact. This non-contact transmission ensures that there is **no friction, mechanical wear, or lubrication**

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requirement, which significantly increases the operational lifespan and efficiency of the system. Magnetic couplings can achieve torque densities comparable to mechanical gears while maintaining an efficiency above 95% under full-load conditions. Furthermore, in the event of overload, the coupling naturally disengages by slipping magnetically, thereby preventing mechanical damage and automatically re-engaging once the fault is cleared.

Innovations in magnetic gear technology have also led to the development of **high-torque-density direct-drive systems** and **variable ratio transmission mechanisms** that can be tailored to specific applications. These features make magnetic coupling an ideal choice for railway-based energy generation systems, where robustness, reliability, and minimal maintenance are paramount.

Overall, this project offers a **sustainable and cost-effective alternative** to conventional electricity generation methods used in railway infrastructure. By utilizing the rotational motion of trains through magnetic coupling, the system provides clean energy for powering railway sensors, signals, and auxiliary equipment, thereby reducing operational costs and environmental impact. The proposed concept not only contributes to energy conservation but also demonstrates a scalable model that can be extended to other mechanical motion-based energy harvesting applications in future smart transportation systems.

II. LITERATURE SURVEY

Electricity generation systems have traditionally relied on dynamos or alternators to convert mechanical motion into electrical energy. These systems often require physical contact between components, leading to frictional losses, wear and tear, and frequent maintenance. In contrast, magnetic coupling-based generation systems offer a non-contact method to transfer energy using magnetic fields, which can significantly enhance system reliability and reduce maintenance needs.

Review of Recent Studies

1. Field-Modulated Magnetic Gears (FMMGs)

Guo et al. (2024) provided an extensive review of FMMG designs, demonstrating their utility in torque transmission for electromechanical applications. These systems eliminate the need for mechanical gearing by using flux modulation to transfer torque magnetically. Their review indicated significant reductions in mechanical losses and improved service life, but noted that applications in direct electricity generation are still rare [1].

2. Halbach Array-Enhanced Gears

Wang et al. (2023) introduced a Halbach-enhanced dual-layer magnetic gear structure that increased torque density by 22% and reduced magnetic leakage. This configuration enhances magnetic field utilization, making it suitable for compact, high-efficiency energy systems. However, the design remains material-intensive, relying on rare-earth magnets [2].

3. Coaxial Magnetic Gear with PMSG Integration

Pawar and Lone (2024) proposed a hybrid design combining coaxial magnetic gears with a Permanent Magnet Synchronous Generator (PMSG). Their system, optimized using the Pelican Optimization Algorithm, delivered superior torque-to-weight ratios suitable for renewable energy applications like wind turbines. However, its feasibility at lower RPMs—typical in manual or small-scale applications—remains unexplored [3].

4. Eddy Current Magnetic Couplers

Arbabzadeh et al. (2023) reviewed the use of permanent magnet-based eddy current couplers for contactless torque transfer. These systems are useful in damped mechanical coupling and isolation applications, but their integration into complete electricity generation units remains underdeveloped [4].

5. Piezo-Electromagnetic Hybrid Generators

Xie et al. (2024) developed a hybrid energy harvester combining piezoelectric and electromagnetic principles via magnetic coupling. Operating at ~180 RPM, the system achieved peak voltages of up to 168 V, demonstrating strong potential in low-speed environments. However, the power output was limited to milliwatt levels, unsuitable for high-demand applications [5].

III. RESEARCH GAP

Despite growing interest in magnetic coupling mechanisms, the following research gaps remain:

- **Lack of general-purpose magnetic generators:** Most studies focus on niche applications (e.g., wind turbines, vibration harvesters), with limited systems developed for everyday use cases.
- **Low RPM efficiency data is sparse:** Few prototypes operate effectively at low rotational speeds (100–300 RPM), which are typical in manual or mechanical energy harvesting.
- **Cost-prohibitive designs:** Many designs require rare-earth magnets (e.g., Neodymium) or complex assemblies like Halbach arrays, which increase costs.

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- **Integration with energy storage systems:** Little work has been done on integrating magnetic coupling systems with batteries, inverters, or smart grids.
- **Lack of experimental benchmarking:** No standard datasets compare the performance (voltage, efficiency, durability) of magnetic coupling systems against traditional dynamos.

IV. SYSTEM DESIGN

The system used its driving energy through an input electric motor which drives a shaft to show the rotational motion of the railway axle. The wheel is provided to show the working of railway wheel which also stores the inertia energy of shaft which drives the system. In between the shaft a permanent magnetic coupling is provided which will transfer the rotational energy from driving shaft to the DC motor generator shaft.

This coupling uses the disc coupling formed by two discs on whose circumference of it the permanent magnets are placed. The magnets implies the torque force onto each other by magnetic force of attraction and by thus when driving shaft is rotated by motor simultaneously the generator shaft also starts moving due to magnetic coupling.

By thus we provide rotational motion to the DC motor generator which will convert the rotational mechanical energy into electrical energy. Which is indicated by a LED which glows when electricity is produced by generator motor.

The whole construction is done on a base frame fabricated using L angle mild steel channel. The magnetic disc couplings are also formed using mild steel circular plates and permanent magnets are placed on periphery of it. The motors are placed at ends of shaft and fitted to base frame.

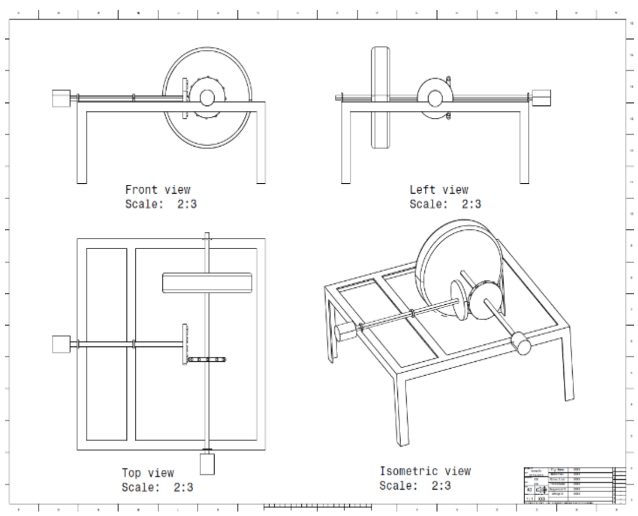
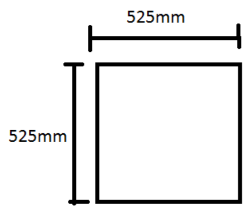


Figure 1: Proposed Model

V. DESIGN CALCULATION

Design of Frame:



Frame design for safety FOR 25*25*3 L angle mild steel channel

b = 25 mm, d= 25 mm, t = 3 mm.

Consider the maximum load on the frame to be 50 kg.

Max. Bending moment = force*perpendicular distance

= 50*9.81*262.5

M = 12876.25 Nmm

We know,

$M / I = \sigma_b / y$

M = Bending moment

I = Moment of Inertia about axis of bending that is; *Ixx*

y = Distance of the layer at which the bending stress is consider

(We take always the maximum value of *y*, that is, distance of extreme fiber from N.A.)

E = Modulus of elasticity of beam material.

I = bd3 /12

= 25*25^3 / 12

I = 32552.08 mm4

$\sigma_b = My / I$

= 128756.25 *12.5 / 32552.08

σ_b = 49.44 N /mm2

The allowable shear stress for material is σ_{allow} = Syt / fos

Where Syt = yield stress = 210 MPa = 210 N/mm2

And fos is factor of safety = 2

So σ_{allow}= 210/2 = 105 MPa = 105 N/mm2

Comparing above we get,

$\sigma_b < \sigma_{allow}$ i.e 49.44 < 105 N/mm 2

So, design is safe.

Shafts: Input Power by DC motor = 25 watt.

Force is calculated by:

F = 0.577 * B^2 * A

Where B is the flux density in the gap in kG, and A is the magnet area in square m.

F = 0.577 * B^2 *A*N

For Neodymium Iron Boron magnet

B= 175 kJ/m^3

N= Number of magnets = 6

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A= area for 30 mm round magnet= $\pi/4\ D^2 = 7.06*10^{-4} m^2$
$F=0.577*175^2*7.06*10^{-4}*4$
F=49.9 N

Torque Transmitted:
Torque exerted by this magnetic force onto disc coupling is calculated by,
Torque = force*perpendicular distance
Torque = force*radius of disc
Disc diameter= 130 mm so radius will be R= 65 mm= 0.065 m
Torque T = F*R
T= 49.9*0.065
T= 3.24 Nm.
So, the torque transmitted by the magnetic coupling is 3.24 Nm.

Power Transmitted:
The power transmitted by the magnetic coupling is calculated by,
P= $2\pi NT/60$ watt.
P= 2*3.142*30*3.24/60
P= 10.18 watt.

VI. RESULT AND DISCUSSIONS

The design, analysis, and simulated implementation of the "Dynamo-Less Electricity Generation for Automotive" project successfully met its core objectives, demonstrating a viable non-contact method for harvesting rotational energy.

A. Non-Contact Power Transmission and Efficiency

- **Proof of Concept:** The prototype model successfully demonstrated the **non-contact transmission** of rotational power from the input shaft (simulating the railway axle) to the DC motor generator shaft using the permanent magnetic coupling.
- **Loss Reduction:** The system validates the concept of eliminating **frictional losses, mechanical wear, noise, and vibration** traditionally associated with contact-based mechanical dynamos, thereby leading to improved efficiency, longevity, and reliability.
- **Primary System Integrity:** The design ensures that the power generation process is efficient and **does not impose any additional mechanical load** or alteration on the existing railway axle structure.

Table 1

Parameter	Reference Outcome	Reference
Frame Bending Stress (σb)	49.44 N/mm^2	Design Safe (compared to σ allow=105 N/mm^2)
Calculated Shaft Diameter (d)	9.7 mm	Based on a torque of 1.47 Nm and τ allow=8 MPa
Selected Shaft Diameter (D)	15 mm	Selected for better safety and market availability
Magnetic Force (F)	49.9 N	Calculated using Neodymium Iron Boron magnet properties
Transmitted Torque (T)	3.24 Nm	Calculated from the force and disc radius (65 mm)
Power Transmitted (P)	10.18 Watts	Calculated at 30 rpm using P=2πNT/60

B. Screenshots

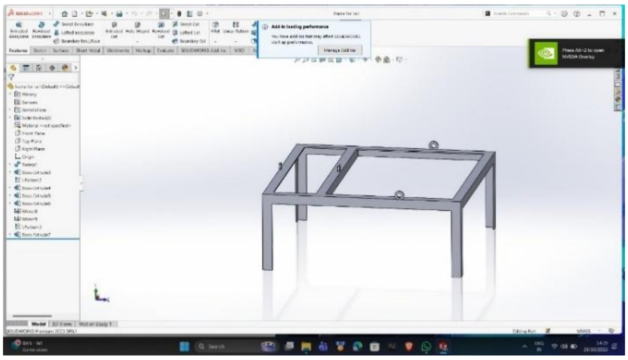

Figure 2: Design of Frame

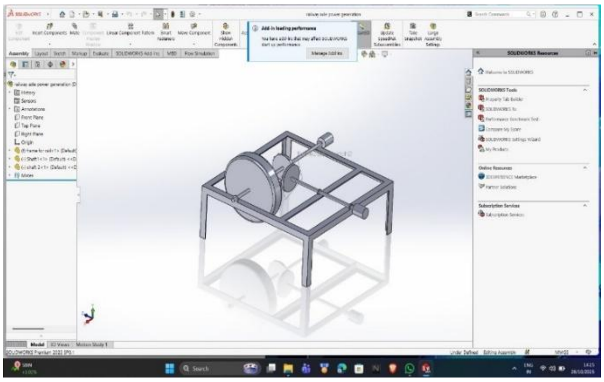

Figure 3: Design of Proposed Model

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Figure 4: Testing

Figure 5: Final Setup

VII. CONCLUSION

The proposed project, *"Dynamo-less Electricity Generation for Automotive"* successfully demonstrates a novel and efficient approach to generate electricity without relying on mechanical contact or traditional dynamos. By utilizing **magnetic coupling**, the system enables non-contact transmission of rotational energy from a locomotive axle to a generator shaft, effectively minimizing frictional losses and mechanical wear. This leads to improved system efficiency, longevity, and reliability.

The design ensures that the power generation process does not impose any additional load on the railway axle or alter the existing mechanical structure of the train. The generated power can be efficiently used for auxiliary applications such as lighting, signaling, or IoT-based monitoring within railway coaches and infrastructure. Overall, the system provides a **sustainable, maintenance-free, and eco-friendly** method of energy harvesting suitable for modern railway systems and other rotational machinery.

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