

eHighway

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Abstract: *The de-carbonization of heavy-duty road transport is a critical challenge due to its high energy demand and dependence on fossil fuels. Electrified Road Systems (ERS), such as the eHighway, enable e-trucks to draw power from overhead lines while in motion, significantly improving energy efficiency and reducing emissions. However, continuous power availability remains a key concern, particularly during renewable energy intermittency and battery discharge conditions. This work proposes an enhanced eHighway power architecture that integrates solar generation with a dual-battery system consisting of a running battery and a standby battery. During normal operation, solar energy and grid supply power the overhead catenary and charge the running battery of the vehicle. This ensures continuous vehicle operation without performance degradation. The study shows that the integration of solar-assisted charging and dual-battery redundancy improves reliability while maintaining the high efficiency of ERS compared to battery-only and hydrogen-based solutions*

Keywords: Dynamic pantographs, Renewable Energy Sources, Electric vehicles

I. INTRODUCTION

Road transportation is one of the major contributors to global greenhouse gas emissions and environmental pollution due to its heavy dependence on fossil fuels. The increasing demand for transportation and the depletion of conventional energy resources have created the need for sustainable and energy-efficient transportation systems. Electrification of road transport has emerged as a promising solution to reduce carbon emissions and improve energy efficiency in modern transportation systems^[1]. Electric vehicles (EVs) are considered an important step toward sustainable mobility; however, the limited energy density of batteries and the long charging time remain significant challenges for long-distance transportation. Large batteries increase the cost, weight, and charging time of vehicles, which can reduce efficiency and cargo capacity^[2]. To overcome these limitations, Electric Road Systems (ERS) or E-Highways have been proposed as an innovative transportation concept. In this system, electrical energy is transferred directly from the road infrastructure to the vehicle while it is in motion. This dynamic power transfer allows vehicles to operate with smaller batteries and reduces the need for frequent charging stops^[3]. Electric road technology can be implemented using different energy transfer methods such as conductive rails embedded in the road, inductive wireless charging systems, or overhead power lines similar to those used in electric railways. These systems enable continuous power supply to vehicles and support the development of cleaner and more efficient transportation networks^[4].

II. LITERATURE REVIEW

Several researchers have explored the concept of electrified road transportation systems as a solution to the limitations of conventional vehicles and battery-powered electric vehicles. Studies on Electric Road Systems have shown that electrifying highways can significantly reduce greenhouse gas emissions and dependence on fossil fuels in the transportation sector. Electrified roads enable dynamic power transfer from the road infrastructure to the vehicle, allowing vehicles to receive electrical energy while driving and reducing need for large onboard batteries^[1]. Research has also highlighted that the limited energy density of batteries remains one of the major challenges in electric vehicles. Increasing battery capacity increases vehicle weight, cost, and charging time, making long-distance travel less efficient. Electric road systems address this issue by supplying energy continuously from the road to the vehicle, enabling smaller battery sizes and improved vehicle performance^[2]. Different energy transfer mechanisms for electrified roads



have also been investigated. These include conductive power transfer through rails embedded in the road, inductive wireless power transfer systems, and overhead catenary systems similar to those used in trolley buses and electric trains. Among these methods, overhead power supply systems using pantographs have been widely studied for heavy transportation due to their reliability and efficiency^[3]. Recent research also discusses the integration of advanced technologies such as smart energy metering, communication systems, and control modules to monitor energy consumption and improve system efficiency in electric road transportation systems. These technologies help in accurate billing, energy monitoring, and better management of electric vehicle infrastructure^[4]. Overall, the existing literature demonstrates that electrified road systems have strong potential to transform modern transportation by enabling continuous power supply to vehicles, reducing environmental impact, and improving the efficiency of electric mobility.

III. SYSTEM ARCHITECTURE

The proposed system integrates renewable energy generation, electrical power distribution, and vehicle energy management into a unified electrified transportation framework. The primary objective of the system is to enable electric vehicles to operate continuously using power supplied directly from highway infrastructure. In the proposed architecture, solar panels are installed along the highway infrastructure to generate renewable electrical energy. The generated solar power is stored in energy storage systems and also supplied directly to the highway power distribution network. During periods when solar energy generation is insufficient, electrical power from the conventional grid supply is used to maintain stable system operation. The electrical energy is transmitted through overhead catenary lines installed above the highway lanes. Vehicles equipped with pantograph collectors establish contact with these lines while travelling and receive electrical energy directly from the power distribution network. This energy is used to power the vehicle motor and charge onboard batteries simultaneously. A dual battery architecture is incorporated into the vehicle system to improve reliability. The primary battery supplies power to the vehicle motor during normal operation, while a secondary standby battery serves as a backup source. When the primary battery becomes discharged or when power supply from the overhead line is temporarily interrupted, the standby battery automatically supplies power to ensure uninterrupted vehicle movement. The microcontroller acts as the central control unit that reads inputs from buttons and sensors and controls the motors, relay, L293D driver and LCD to operate the electrical highway system. The Arduino NANO used in this prototype is used to receive the signals from the voltage sensor if the primary battery dead or degrades below a limit. This architecture ensures efficient utilization of renewable energy while maintaining consistent power supply for electric vehicles.

IV. METHODOLOGY

A prototype model of the proposed e-Highway system was developed to demonstrate the feasibility of electrified road transportation. The prototype consists of a miniature electrified road section, a small electric vehicle model, power supply circuitry, and energy management components. The power supply system includes a solar energy derived from solar panel and regulated it to the requires level and Battery sources of the vehicle. Electrical power is transmitted through conductive overhead lines installed above the model highway. The vehicle model is equipped with a pantograph mechanism that collects electrical energy from the overhead line and transfers it to the vehicle motor. The motor converts electrical energy into mechanical motion, allowing the vehicle to move along the highway track. The battery management system monitors the energy levels of the running battery and standby battery to ensure proper energy distribution. The microcontroller acts as the central control unit that reads inputs from buttons and sensors and controls the motors, relay, and L293D Driver, LCD to operate the electrical highway system. The microcontroller used here transmits the signals to the L293D driver to operate the motor for the movement of the pantograph and the microcontroller also sends signals to the relay for the operation of the vehicle. The Arduino NANO used here receives signals from the voltage sensor if the primary battery voltage drops below a certain level and operates the relay. The prototype successfully demonstrates the capability of electrified highways to supply electrical power to moving vehicles.



V. RESULTS AND DISCUSSION

The developed eHighway prototype demonstrates the feasibility of supplying electrical energy to electric vehicles while they are in motion. The proposed model, solar panels generate electrical energy which is regulated and supplied to the overhead catenary system. Electric vehicles equipped with pantograph collectors can draw power directly from the overhead line while travelling on the electrified lane. At the same time, the vehicle's running battery is charged through the supplied electrical energy. A standby battery is incorporated into the system to enhance reliability. If the running battery becomes discharged or if there is a temporary interruption in solar generation, the standby battery automatically supplies power to maintain vehicle operation. This dual-battery arrangement ensures uninterrupted performance and prevents sudden power loss. The prototype results indicate that integrating renewable energy with electrified road infrastructure can significantly improve system efficiency and sustainability. Compared with traditional battery-only electric vehicles, the proposed approach reduces dependency on large battery packs and minimizes charging downtime. However, large-scale implementation of this system requires addressing several technical considerations, including infrastructure installation cost, efficient power transfer mechanisms, and safety standards for overhead electrical systems.



Fig. 1. eHighway

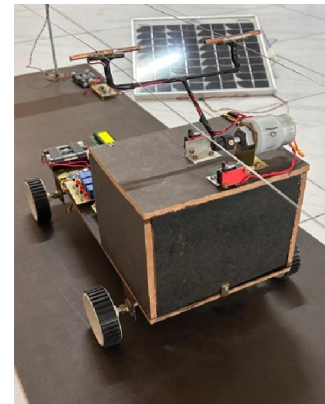


Fig. 2. Prototype of e-truck

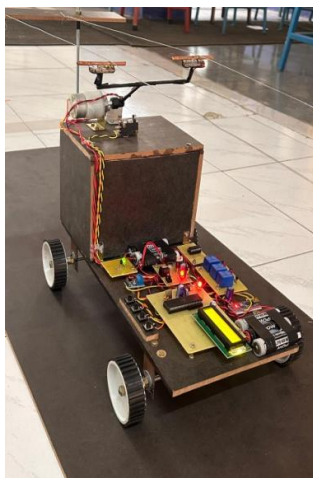


Fig. 3. e-truck connected to overhead line

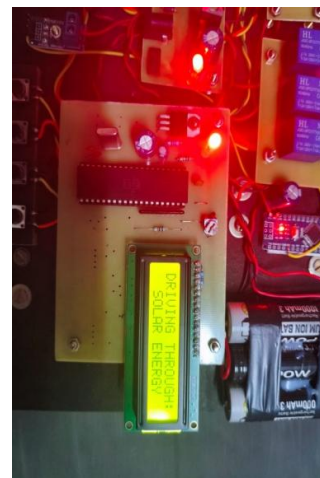


Fig. 4. Status of Energy Source being used



VI. CONCLUSION

The electrification of road transportation is essential for reducing environmental pollution and dependence on fossil fuels. The proposed eHighway system offers an effective solution by enabling electric vehicles to receive power dynamically while travelling. This presents a solar-assisted electrified highway architecture that incorporates a dual-battery system to enhance operational reliability. The integration of solar energy helps reduce the reliance on conventional grid power, while the standby battery ensures continuous operation even during fluctuations in power supply. The results demonstrate that electrified road systems can significantly improve energy efficiency and reduce emissions from heavy-duty transportation. With further technological advancements and infrastructure development, eHighway systems have the potential to become a practical and sustainable solution for future transportation networks.

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