Electrified Highway for Heavy Vehicles Using Catenary System

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***Abstract*—This paper addresses the urgent need for the transportation industry to move away from dependency on non-renewable energy sources by providing a thorough analysis of current developments in the electric vehicle (EV) sector. Alternative forms of transportation must be investigated and put into practice since traditional vehicles emit dangerous compounds continuously, which contributes significantly to environmental pollution. The Electric Highway, a cutting-edge technology that is transforming conventional transportation networks, is one encouraging option. By integrating electrical road infrastructure, the Electric Highway enables cars to take electricity straight from the grid by means of dynamic pantographs that are fixed to overhead transmission lines. With the help of this innovative method, EVs can now charge their batteries while driving, greatly minimizing the need for frequent stops to refuel. Vehicles can easily refuel by utilizing the infrastructure of the Electric Highway, which improves driver convenience and efficiency. This study examines the features and advantages of electric vehicles (EVs) as well as their inherent limits and the pressing need for sustainable transportation alternatives. We can ensure the continuous mobility and functionality of modern civilization while paving the way for a greener, more ecologically sensitive future by supporting initiatives like the Electric Highway.**

Keywords—Electric vehicle, Electric Highway, alternative transportation, sustainable infrastructure, dynamic pantograph, overhead transmission lines, environmental conservation.

I. Introduction

The introduction of electric vehicles (EVs), which provide a greener and more sustainable form of transportation, has completely changed the automotive industry. But even with all of its advantages, EVs have disadvantages, especially when it comes to large cars meant for long distance driving. Longer charging periods and the requirement for higher battery capacities are two of these difficulties [3,5,10].This study offers a novel way to address these restrictions and lessen the drawbacks of electric heavy vehicles. The creation of a functional model modeled after the catenary system used in electric trains is the suggested remedy. This method allows the vehicle's motor to run efficiently by delivering power to it via a pantograph that collects power from overhead transmission cables [2]. Power lines can be utilized to provide instantaneous battery charging for trucks, including hybrid models [2]. The pantograph automatically initiates a connection when sensors installed in the trucks identify the existence of an electric contact line. If these sensors are not present, drivers can manually move the pantograph to make contact with the electrical line. The energy that is delivered ensures that the car runs continuously by recharging the battery and powering the electric motors. Furthermore, the vehicle can smoothly transition to battery power when it is not linked to a power connection.

II. Literature Survey

Electric Heavy Vehicle Transportation Highway (By Catenary System) by Suvash Dhavarkar, Suraj Sontakke, Vipul Shinde, and Nilam Ghuge (2022): This paper describes a proposed system for electric heavy vehicles that uses a catenary system to provide power. The authors argue that this system is an effective and environmentally friendly solution for long-distance transportation of heavy vehicles.

Study on E-Highway - Future of Road Transportation by K. Chandra Mouli, N. Pannirselvam, V. Anitha, and D. V. V. Nagasai Pardhu (January 2019): This paper discusses the concept of e-highways and their potential benefits, including reducing CO2 emissions and improving fuel efficiency. The authors also describe the technology behind e-highways, including the use of catenary systems and pantographs.

E-Highway Electrified Heavy Duty Road Transport by Patrik Akerman (2016): This paper focuses on the use of e-highways to reduce carbon dioxide emissions from heavy duty trucks. The author discusses different options for providing power to electric trucks, including on-board storage and external power supply. The paper also mentions that e-highway systems can be integrated with hybrid and fully electric vehicles.

III. Proposed System

By effortlessly transmitting electrical energy to electric cars (EVs) while they are in motion, the Electric Road System (ERS) is a cutting-edge technology that has the potential to completely transform the transportation industry. This will increase EVs' energy efficiency and decrease their dependency on conventional fuel sources. This novel idea, as seen in Figure 10, highlights the possibility of dynamic power transfers from the road to the car, as several research have clarified [1,9,12]. Dynamic power transfer, which is the foundation of the ERS, is the process by which energy is transferred from the road infrastructure to the moving vehicle using a variety of power transfer methods [1, 6]. We use the same Catenary System technology as electric trains in this study, but with a Two-Line AC System (230 AC). As seen in Figure 7, the energy is gathered using a pantograph and then rectified to create 12 volts DC.

The vehicle's battery is subsequently charged with this electrical power, enabling propulsion (Figure 1) [2,7]. One significant benefit of this technology is that it can use lower capacity batteries, such the 12V7AH lead-acid battery (Figure 8), which reduces the overall weight and starting cost of the vehicle. Moreover, the method increases the range of large trucks and dramatically reduces the amount of time that electric cars must wait for static charging. The vehicle smoothly transitions to battery power to continue operating in the case of a Pantograph disconnection or blockages to the overhead system. Three essential requirements define the ERS's operational model:-

1. The car runs and charges the battery at the same time while the power supply is on [6,9].
2. The vehicle smoothly switches to battery power for continuing operation in the event of a power outage.
3. The battery is charged while at standstill to guarantee maximum preparedness for further operation [9].

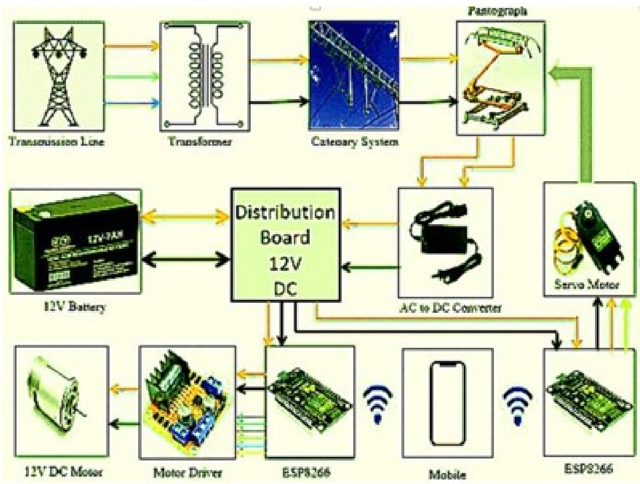

Fig. 1. Wiring Diagram

IV. Methodology

The electrical infrastructure of our project starts with the power supply supplying 230V AC to the overhead transmission line. Current passes through to the rectifier after the pantograph connects to the transmission line. There, it is converted from AC to DC to make it compatible with the vehicle's motor [2,7]. Meanwhile, this current is also used to charge the car's battery, allowing it to work in two ways: it runs on the power that is provided while the battery is being recharged [6,10]. A changeover switch is used to make sure that operational transitions go smoothly. The car seamlessly transitions to battery power when the overhead supply is turned off, allowing for continuous driving [6]. The Rover Controller provides operational control of the vehicle and is managed by software that may be accessed through a mobile application. The vehicle's wheel movements can be precisely controlled via the mobile application, which also offers left, right, and forward direction adjustments. In addition, the mobile application's specialized software controls the pantograph's movements, including its raising and lowering mechanisms. The truck is equipped with indicators to improve operating awareness. These indicators ensure that the operational state of the pantograph link is clearly visible by providing visual indications about its status. Furthermore, a battery indicator is integrated, providing instantaneous voltage readings to determine the battery's state of charge. This is especially helpful while the pantograph is operating or when using battery power exclusively.

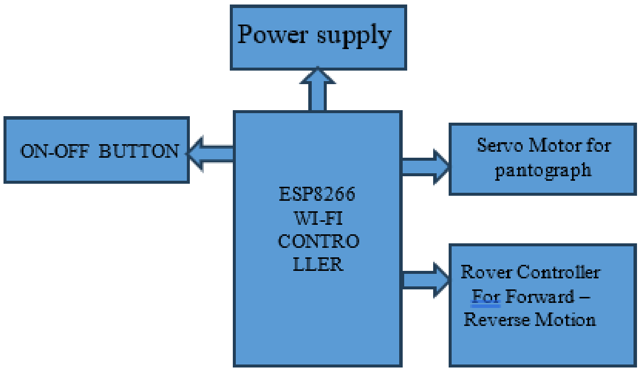

Fig. 2. Block Diagram

V. Components Description

1. Power Supply

In order to power the motor and the Arduino that controls the pantograph, the power supply energizes the E-Vehicle. As soon as the pantograph is connected to the overhead line, the battery starts to recharge, which keeps the car running continuously.

Fig. 3. 12V-7AH Lead Acid Rechargeable Battery

2. Battery Percentage Indicator

The Battery Percentage Indicator gives customers vital information about the power state of their system or device by showing the voltage rating and charge level of the battery.

Fig. 4. Battery Percentage Indicator

3. Rover Controller

With the aid of the Rover Controller, robots can move in any direction—forward, backward, left, or right. It serves as an interface to control the robot's movement and make sure it travels in the intended directions. Figure 6 shows the pin connections between the Rover Controller and ESP8266, illustrating the smooth integration for effective control.

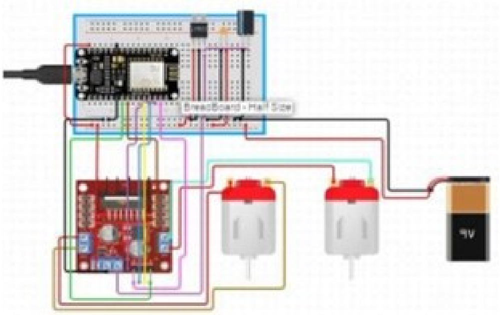

Fig. 5. Rover controller

4. *ESP8266 Microcontroller*

- Microcontroller: Tensilica 32-bit RISC CPU Xtensa LX106
- 3.3V is the operating voltage.
- Voltage input: 7–12V
- 16 digital I/O pins (DIO); 1 analog input pin (ADC); 1 UART; 1 SPI; 1 I2C; and 4 MB of flash memory
- 64 KB SRAM; 80 MHz clock speed; USB-TTL integrated with CP2102 for smooth Plug and Play operation. • PCB Antenna: Small module designed to fit into IoT projects smoothly, improving range and connectivity.

Fig. 6. ESP2866 Microcontroller

5. *Servo Motor*

The Tower Pro MG996R Digital Metal Gear High Torque Servo Motor is now available. Its sturdy metal gears allow it to generate a powerful 11 kg/cm torque for accurate motion control. It has been improved for more seamless functioning and comes with a 30-meter cable and a 3-pin 'S' type connector. It works with well-known collector brands including as GWS, Cirrus, Corona, Berg, Spektrum, and Hitec. Perfect for a wide range of uses, including robotics and RC cars.

Fig. 7. Servo Motor

6. *Pantograph*

Overhead Line Current Collection Pantograph System is an essential part of electric vehicles is the pantograph system, which makes it possible to gather current from overhead transmission lines effectively and use it to power the electric motor. In contrast to conventional techniques that depend on complicated connections or intermediate devices, the pantograph connects directly with the overhead line, guaranteeing a dependable and smooth transfer of electrical energy.

Fig. 8. Sample Pantograph

7. *Solar Charge Controller*

In order to maximize battery life, the Solar Charge Controller controls how solar panels are used to charge batteries. This ensures safe and effective charging. It serves as an essential bridge between the batteries and the solar panels, minimizing overcharging and maximizing power conversion.

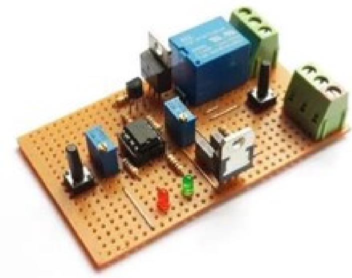

Fig. 9. Solar Charge Controller

8. *Switching Mode Power Supply*

A Switching Power Supply (SPS) efficiently converts electrical power by rapidly switching the input voltage on and off, regulating the output voltage. It's commonly used in electronic devices due to its compact size, high efficiency, and ability to handle varying input voltages.

Fig. 10. Converter

VI. Result

Successful demonstrations of the vehicle's operational capabilities show that our suggested methodology has produced promising results. By taking use of the current flowing overhead, the car runs smoothly and charges its battery at the same time. To offer unambiguous insight into the vehicle's operating mode and differentiate between battery-powered and direct supply operation, key indicators have been integrated. To reduce the possibility of interaction between AC and DC equipment, severe safety measures have been put in place, guaranteeing operational dependability and safety. As a result, transporting large vehicles over long distances is made easier, and longer charging intervals are not required. This highlights the effectiveness and feasibility of our strategy in improving the sustainability and accessibility of long-distance heavy vehicle transportation.

Fig. 11. Actual Model

VII. CONCLUSION

With its concrete advantages, the Electric Highway framework is a significant step forward in both reducing the amount of dangerous greenhouse gases released into the atmosphere and boosting the economy. This cutting-edge infrastructure has two benefits: it runs silently and is twice as efficient as conventional gasoline-powered engines, which highlights its environmental credentials in the transportation industry. Additionally, because the Electric Highway Catenary System uses less electricity than non-renewable gasoline-based transportation, its operating costs are significantly cheaper. The opening of the world's first electrified road in Sweden represents a critical turning point for environmentally friendly transportation and shows how such infrastructure has the power to completely transform the car sector. Similar to this, the global acceptance of electrification in transportation is highlighted by Germany's installation of electric roads on its motorway network, which are intended to refuel hybrid trucks while they are in motion. One unique characteristic of the Electric Highway Catenary System is its capacity to dynamically change lanes, a feature not found in other rail technology. Additionally, the system's fault detection and recovery are simplified, providing higher reliability than their rail equivalents. Moreover, the system performs better in bad weather than rail technology, which is vulnerable to surface water buildup. This is especially true during monsoons. The fundamental idea behind the e-highway system is to increase the effectiveness of electric trucks and at the same time support the US economy by lowering its dependency on fossil fuels. To sum up, the introduction of electric heavy vehicles signals the beginning of a new phase in sustainable transportation. They allow for longer travel lengths and significantly shorter charging times, which will help us move toward a more environmentally friendly and efficient future.

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