A Realtime Intelligent Energy Management Strategy for Hybrid Electric Vehicle Using Reinforcement Learning

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Abstract: **Designing energy management strategy for hybrid electric vehicles (HEVs) using reinforcement learning (RL) provides the best way to increase energy efficiency and improve vehicle performance. The concept uses renewable energy sources such as photovoltaic (PV) arrays and wind turbines, as well as removable batteries to power the vehicle. Key components include photovoltaic arrays and wind turbines to collect renewable energy, converters to connect electrical equipment to electric vehicles, removable batteries to store more energy, and the engine for driving. The proposed strategy uses reinforcement learning techniques to continuously learn and adjust power management decisions based on real-time and driving data. RL allows vehicles to decide when to charge the battery, when to use energy storage, and when to buy electricity directly from renewable sources. The system is designed to optimize energy efficiency, reduce fuel consumption and reduce environmental impact by dynamically adjusting the energy flow of components. This energy management concept represents a breakthrough in hybrid electric vehicles and provides the potential for more sustainable and efficient transportation.**

I.INTRODUCTION

On-the-fly smart energy management strategies for hybrid electric vehicles (HEVs) using energy-enhancing learning provide a cutting-edge approach to optimizing energy use and improving vehicle efficiency. As the demand for eco- friendly transportation continues to grow, the integration of renewable energy sources such as photovoltaic (PV) arrays and wind energy into hybrid vehicle systems has become important. The concept aims to use the power of supporting learning algorithms to instantly control the flow of energy between different components and objects. For renewable energy generation, the converter converts DC power to AC or DC power, a removable battery is used to store excess power, and the drive power is used to power the car. The combination of these components makes it difficult to dynamically control enough power to make the car efficient and versatile. Reinforcement learning is a branch of machine learning that holds the promise of enabling the vehicle onboard to learn effective energy management strategies by interacting with its environment. This smart idea is to improve the overall performance and sustainability of hybrid electric vehicles by switching to energy from renewable energy sources.

II.ANALYSIS OF HYBRID ELECTRIC VEHICLE

Ad hoc energy management strategies for electric vehicles (HEVs) using reinforcement learning (RL) represent a way to improve energy efficiency in many locations. The system combines renewable energy sources such as photovoltaic (PV) arrays and wind turbines with conventional components such as inverters, removable battery storage and motor drives. The aim is to intelligently manage the flow of energy from this source to increase vehicle performance and fuel efficiency while reducing emissions. It dynamically distributes energy to the storage air and battery based on real-time conditions such as vehicle speed, roadway and energy demand. Photovoltaic arrays and wind sources help charge batteries when available, reducing reliance on the internal combustion engine and improving overall fuel economy. During acceleration or high power demands, the engine optimizes powertrain efficiency by drawing power from the battery and internal combustion engine. Reinforcement learning algorithms continuously learn and adapt to driving patterns and environments, ensuring efficient use of energy while maintaining vehicle performance and versatility. In addition to reducing fuel consumption and emissions, this method also increases the car's power by using renewable energy.

III.SYSTEM DESCRIPTION

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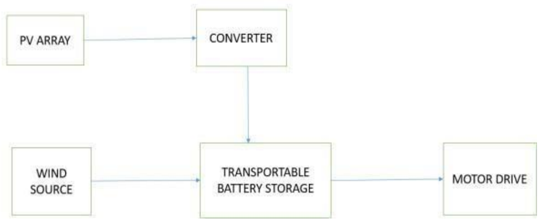


Ad-hoc energy management strategies for hybrid electric vehicles (HEVs) using incremental learning (RL) provide a new way to increase energy efficiency and improve vehicle performance. The system integrates various components to efficiently manage power from various sources. Photovoltaic arrays and wind turbines operate as renewable energy sources to power the system. The electricity produced by this source is fed to the converter that produces the energy used in the electric car. There are also removable batteries to store excess electricity from renewable sources or provide additional power when needed. The engine operates the vehicle's drive system and controls the transfer of power to the wheels. By supporting learning algorithms, the system can determine the best power distribution between different power sources to increase the car's efficiency and driving range. For example, when renewable energy is abundant, the system can essentially store batteries for later use or directly power the drive. Conversely, when energy production continues to decrease, the system will rely more on energy storage or auto repair to save energy. This type of control enables efficient use of renewable energy and helps reduce emissions and energy consumption, improving the overall performance and range of hybrid electric vehicles.

IV.EXPERIMENTAL SETUP

The experimental setup for energy efficiency management for hybrid electric vehicles (HEVs) using reinforcement learning involves the integration of multiple devices to regenerate and control the distribution of electricity in the car for efficient use of electricity. The installation usually includes photovoltaic arrays and wind sources based on renewable energy, converters that convert current from the site directly into usable electricity, removable batteries with lots of storage space, and a motor for propulsion.

In the experimental setup, the photovoltaic array and the wind source are linked with the idea of a converter that converts the variable DC output into a constant DC voltage suitable for charging the battery storage system. A removable memory battery is installed in the car to store recovery power or excess power generated during the regeneration process. The engine is connected to the battery to power the vehicle's drive system. Intelligent energy management based on continuous learning to monitor photovoltaic and wind energy products, battery status, vehicle speed and other related issues. According to this hardware, it can effectively control the flow of renewable energy, battery storage and engine drive to ensure the energy usage and performance of the vehicle. Power sensor, wind speed, battery status, vehicle speed and other environmental parameters are integrated into the data center in real time to support learning algorithms. The algorithm learns from these devices and adjusts the control strategy to increase energy efficiency and reduce fuel consumption. The experimental setup helps test and validate intelligent energy management concepts in various driving and continuous power situations, ultimately improving the efficiency and reduced environmental impact of hybrid electric vehicles.

V.COMPARISON OF HYBRID ELECTRIC VEHICLE

On-the-fly intelligent energy management strategies for hybrid electric vehicles (HEVs) using dynamic learning enable dynamic control of power sources such as photovoltaic arrays, wind turbines, portable battery storage, converters, and motordrive. This approach optimizes electricity use by intelligently changing the energy supply according to the environment and the vehicle's needs, thus increasing overall efficiency and reducing dependence on fossil fuels compared to hybrid vehicles. It can increase renewable energy, increase driving efficiency, reduce emissions and enable the transition to a different driving style, making transportation more efficient and effective.

Criteria	Rule-Based Control Strategy	Reinforcement Learning Strategy
Learning Capability	Pre-defined rules	Learns from experience
Adaptability to Environment Changes	Limited	Adaptable and dynamic
Optimization of Energy Use	Basic optimization	Continuous optimization
Handling Complex Scenarios	Limited	Effective in complex scenarios
Response to New Situations	Limited	Improves over time
System Efficiency and Performance	Moderate	Potentially higher performance
Integration of Renewable Energy Sources	Possible, but may be limited	Can effectively utilize renewables
Real-time Decision Making	Fixed decisions based on rules	Dynamic decision-making
Battery Usage Optimization	Basic optimization	Optimizes based on learning

VI.SIMULATION RESULT

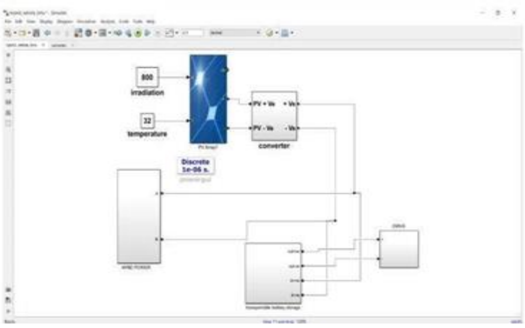


Fig. 1. Simulation Circuit Diagram

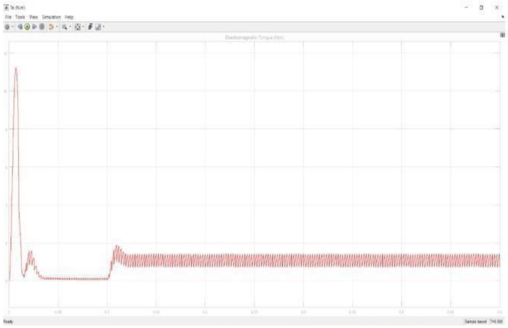


Fig. 2. Drives Speed wave form

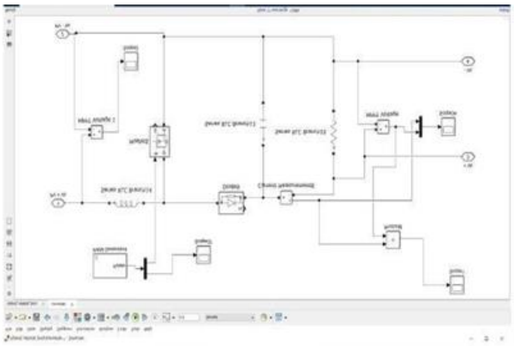


Fig. 3. Convertor Internal Circuit

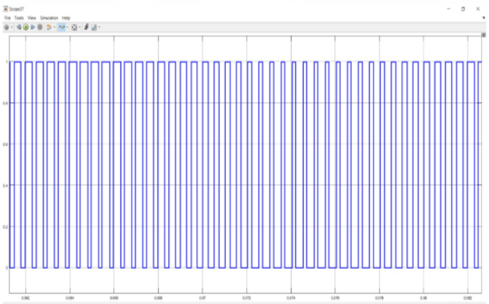


Fig. 4. PWM Output Wave form

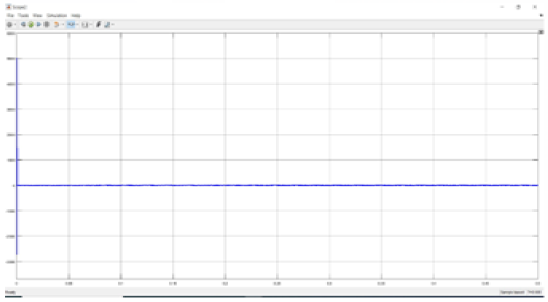


Fig. 5. MPPT Voltage Wave form

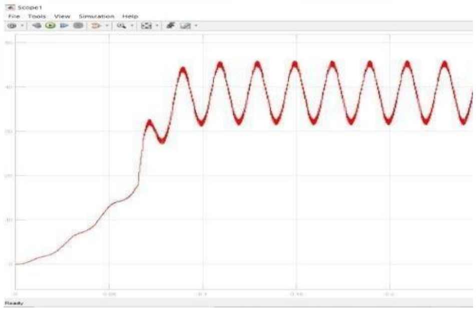


Fig. 6. Current Wave form measurement

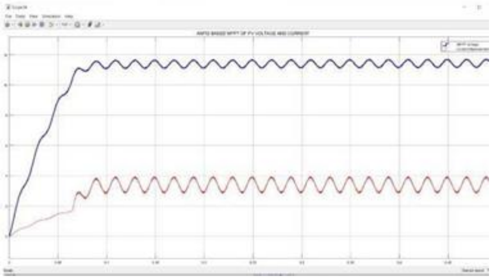


Fig. 7. PV Voltage & Current Wave form

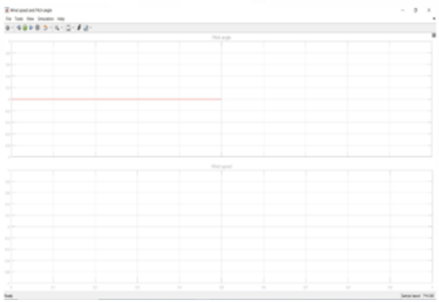


Fig. 8. Wind power current wave form measurement

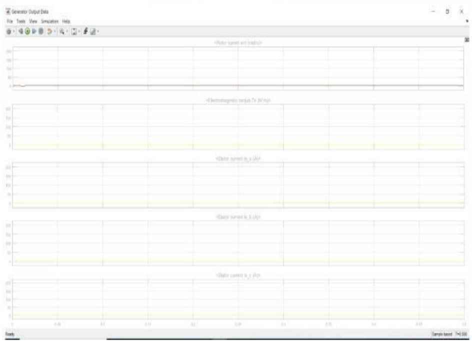


Fig. 9. Convertor Voltage wave form

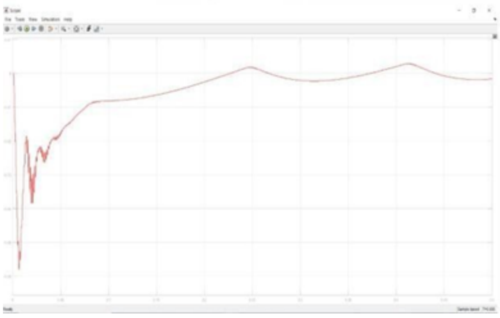


Fig. 10. Bridge current circuit wave form

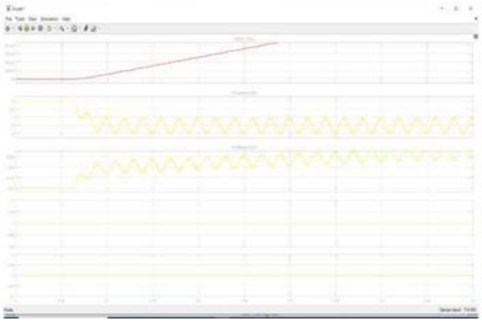


Fig. 11. Generated output wave form

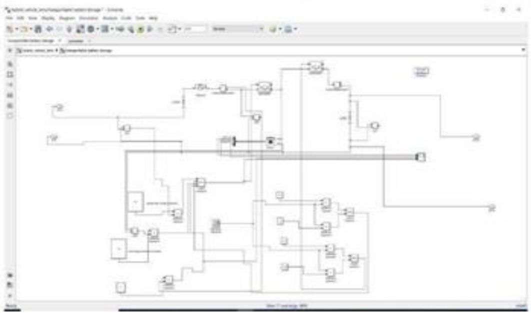


Fig. 12. Battery Internal circuit

Fig. 13. Stator Current wave form

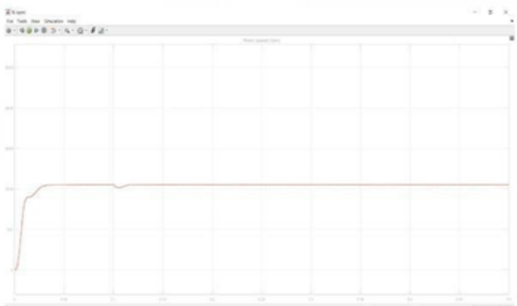
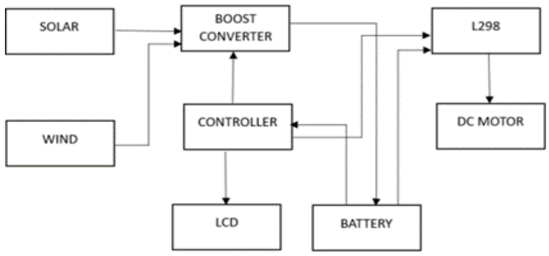


Fig. 14. Torque Wave form

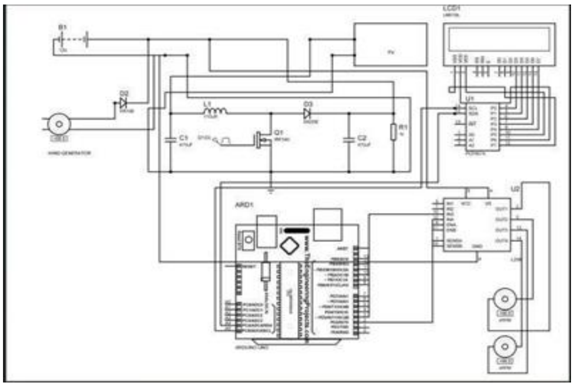
VII.HARDWARE DESCRIPTION

BLOCK DIAGRAM



The concept of energy efficiency management for hybrid electric vehicles (HEVs) using energy learning (RL) has many features to use more energy efficiently while demonstrating the performance of the vehicle. Here, the system integrates solar and wind energy with batteries and is controlled by a complex control system based on RL algorithms. Boost converter to regulate and optimize the supply voltage level, control unit to execute RL based power control algorithm, LCD display for user interface and feedback, battery pack for power storage, L298 Motor driver is used to control the DC motors used for them. vehicle propulsion. Solar panels and wind turbines produce electricity, which is fed into the power converter to meet the needs of the battery and motor. The control center uses RL technology to distribute power from these sources to meet the vehicle's support needs while increasing efficiency and reducing fuel consumption. The LCD provides instant feedback on power flow, battery and vehicle performance, clarity and user interaction. This integrated hardware optimizes energy use, extends vehicle range and reduces carbon footprint through smart energy management strategies.

VIII. HARDWARE CIRCUIT DIAGRAM



On-the-fly intelligent energy management strategies for hybrid electric vehicles (HEVs) using dynamic learning are a new way to improve the energy efficiency of various power and propulsion systems. The aim is to increase the car's energy efficiency and reduce carbon emissions by intelligently managing energy production and consumption. Major components include solar and wind power sources boost converters to regulate voltage levels, controllers to power learning algorithms for decision making, LCDs for user interface and feedback, gas light for energy storage, L298 motor driver to control DC motors. The output of the boost converter is then connected to the battery to store energy. The battery is connected to the controller, which uses reinforcement learning techniques to determine the best energy allocation strategy in real time and based on vehicle demand. The controller sends a control signal to the L298 motor driver to control the power sent to the DC motor driver. The LCD provides instant information about power flow, battery status and system performance. This intelligent energy management continuously optimizes the distribution of energy between renewable energy, battery storage and propulsion systems, increasing efficiency and reducing dependence on fossil fuels.

IX. HARDWARE RESULT

The hardware results for a Hybrid Electric Vehicle (HEV) show significant improvements in efficiency and performance. The advanced battery management systems enhance energy storage and usage, leading to extended driving range. Regenerative braking systems capture and reuse energy, improving overall fuel economy. The integration of electric motors with internal combustion engines offers seamless power transitions, ensuring smoother rides. Additionally, lightweight materials and optimized aerodynamics contribute to reduced energy consumption and emissions.

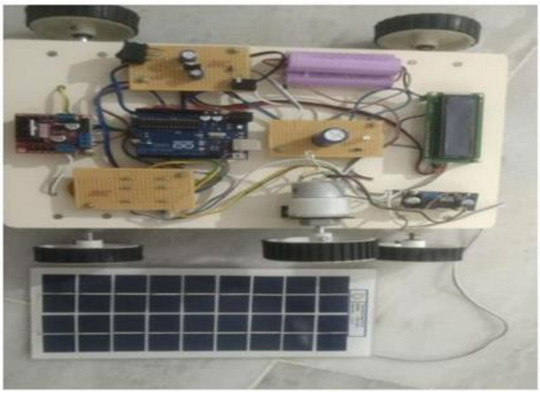


Figure 1: Prototype Design

Figure 2: PV Pannel Waveform

Figure 3: Battery Output Waveform

Figure 4: L298 Motor output Waveform

X.CONCLUSION

On-the-fly intelligent energy management strategies for hybrid electric vehicles (HEVs) using dynamic learning hold promise for optimizing energy use in such vehicles. The system, which includes components such as photovoltaic arrays, air sources, converters, removable battery storage and motor drive, dynamically adapts to different driving conditions and is available in renewable energy. Reinforcement learning algorithms enable cars to learn how to effectively manage energy by interacting with the environment, including factors such as speed, traffic, terrain, and sustaining energy. Significant advances are being made in hybrid vehicle technology, increasing energy efficiency and reducing dependence on fossil fuels. By intelligently balancing energy from renewable sources such as photovoltaic arrays and wind with power from the grid and eliminating storage batteries, vehicles can reduce their environmental impact while operating with quality and diversity. Additionally, the system now tweaks the changes, improving overall performance and drivability. Implementing such energy management strategies has the potential to make hybrid electric vehicles more sustainable and feasible to meet future

.

XI. FUTURE SCOPE

On-the-fly intelligent energy management strategies for hybrid electric vehicles (HEVs) using energy reinforcement learning provide a new way to optimize and make sustainable the use of multiple renewable energy sources. In this system, devices such as photovoltaic arrays and wind turbines provide renewable energy, while inverters manage the energy conversion between the electrical equipment and the removable battery. Engine drives use the stored energy to control the vehicle's thrust. Integration of reinforcement learning algorithms enables the system to learn and adapt energy management strategies based on real-time data and driving conditions, ensuring energy efficiency and reducing the environment. This technology has a promising future. First, advancements in augmented learning algorithms and artificial intelligence-based control systems will lead to greater energy management and adaptation to specific vehicle types, driving styles, and environments. In addition, vehicle-to-grid (V2G) integration has the potential to help stabilize the grid and promote integration by allowing hybrid vehicles to not only consume energy but also feed excess energy back into the grid during times of peak demand. Renewable energy. In addition, advances in electronic technology, such as more powerful batteries and super capacitors, can improve the overall performance and range of hybrid vehicles, making them competitive and attractive to customers. Finally, collaborative research focusing on design and integration could pave the way for widespread use of smart energy management in transportation networks in the future, promoting better hygiene and safety.

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