STM JOURNALS

Journal of
Nuclear Engineering & Technology

https://journals.stmjournals.com/jonet

ISSN: 2277-6184 (Online)
ISSN: 2321-6514 (Print)
Volume 14, Issue 3, 2024
September–December
DOI (Journal): 10.37591/JoNET

Review JoNET

Advanced Design, Modeling and Optimization Techniques in Electric Vehicle Using Green Energy: A Review

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Abstract

In today's world, we are using conventional energy sources in a larger amount. To reduce it we must move to use an alternative source, it means replacing the diesel and petrol vehicles with an electric vehicle, which is the best option. The rapid expansion of electric vehicles (EVs) is expected to make them a major contributor to transportation. Increasing fossil fuel use has resulted in greenhouse gas emissions that are crucial for the development of a sustainable transport system. Both industrialized and developing nations will pursue long-term plans to replace gasoline-powered cars with electric or hybrid models and use renewable energy sources to produce electricity, which will expand the number of charging stations. Researchers are attempting to create clever solutions to fulfill the rising demand for EV chargers. Nevertheless, maintaining the quality of electricity and meeting peak demand on the grid has been challenging due to many EVs being used. To enhance the design and installation of charging stations, information on EV charging controls is provided in this document. This report provides a detailed analysis of the different types of EVs, global charging standards, and converter architecture for Alternating Current- Direct Current (AC-DC) and DC converters. The paper also examines the role played by energy collectors and the diffusion of EVs in integrating power generation systems with renewables.

Keywords: Electric vehicle, design, modeling, green energy, battery, charging, discharging, grid, hybrid electric vehicle

INTRODUCTION

The interconnection between the generation of electrical power and the global transportation sector is intricately linked to several pressing challenges in the current era, including the depletion of finite oil reserves, the escalating issue of climate change, and the pursuit of energy self-sufficiency. The energy sector plays a crucial role in meeting the world's primary energy demand, accounting for more than 60% of the total energy demand. However, the sector's reliance on oil for transportation and coal for electricity generation has led to increased carbon dioxide emissions [1]. To address this issue, the industry is actively pursuing the development of alternative transportation technologies, such as EVs, to reduce dependence on oil and mitigate its environmental impacts. The integration of the transportation and electricity sectors, coupled with the widespread adoption of electric vehicles (EVs) and renewable energy, presents a significant opportunity to reduce global reliance on fossil fuels and mitigate greenhouse gas emissions [2].

However, the integration of renewable energy sources into electricity systems faces several

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Received Date: October 08, 2024
Accepted Date: November 17, 2024
Published Date: November 17, 2024

Citation: Sahil Shelke, Rahul Bibave, D.B. Pardeshi. Advanced Design, Modeling and Optimization Techniques in Electric Vehicle Using Green Energy: A Review. Journal of Nuclear Engineering & Technology. 2024; 14(3): 20–28p.

challenges, including the inherent variability of wind and solar photovoltaic (PV) electricity, which does not align with changes in demand. Different strategies such as storage, transportable load, and alternative power production capacity have been developed to address this issue. EVs have the potential to support such strategies, and they are of great importance in fully integrating renewables into existing energy systems. This study aimed to explore the potential benefits and challenges associated with the integration of EVs and renewable energy sources into the transportation and electricity sectors. By examining the current state of these sectors and the barriers to integration, this review provides insights into how EVs can contribute to the transition toward a more sustainable and decarbonized energy system.

LITERATURE REVIEW

This study provides a comprehensive review of electric vehicle technology, charging methods, standards, and optimization techniques. It discusses the characteristics of hybrid and electric vehicles, discusses recent research on EV charging methods such as Battery Swap Stations, Wireless Power Transfers, and Conductive Charging, analyzes EV standards, and proposes recommendations for future research [3].

This study reviews the integration of renewable energy sources (RESs) and EVs into power systems. This highlights the importance of managing, monitoring, and controlling power systems, particularly in the emission context. This review categorizes the literature into two main groups: mathematical algorithms and heuristic algorithms [4]. The execution of a substantial portion of these algorithms was facilitated by the utilization of MATLAB/Simulink in this study, with Complex Linear Programming Expert (CPLEX) being the prevailing tool. The integration of RESs with EVs is a sustainable and efficacious approach to mitigating environmental impacts. Furthermore, this study provides opportunities for additional research in the uncharted domains. A bibliographic analysis has identified IEEE Access as a preeminent journal in terms of influence [5].

This study reviews the literature on EVs and renewable energy integration, focusing on their potential to decrease carbon emissions in the transportation and power generation sectors. The text explores the various aspects related to EVs, encompassing their economic, environmental, and grid implications [6]. This emphasizes the potential of EVs to effectively mitigate the surplus renewable energy generated within the electric systems. Furthermore, this paper sheds light on the extensive research conducted on the interaction between wind energy and EVs, surpassing the studies conducted on solar photovoltaics and EVs. Ultimately, the text concludes by offering valuable recommendations for future research in this field.

OVERVIEW OF ELECTRIC VEHICLES

Electric vehicles, commonly known as EVs, are propelled by one or more electric motors that are powered by a battery [7]. This battery served as a storage unit for electric power. The utilization of electricity in EVs ensures that they are free from pollution and has a positive impact on the environment. The incorporation of lithium-ion batteries in these vehicles makes them suitable for long-term use. These batteries can be charged using different sources such as solar panels, electric power stations, or alternative energy sources. The efficiency of EVs on the road is attributed to the presence of various components that work together harmoniously [8]. Each EV component of an electric vehicle plays a crucial role in its overall performance. The details of EVs are shown in Figure 1.

Working of Battery

Batteries that store electrical energy to power motors are the main power sources for electric cars. The battery capacity of an EV directly affects its travel distance. Longer travel distances are possible with batteries of higher capacities [9]. However, increasing the number of batteries to extend the range is not the best course of action because doing so increases the weight and requires more space, which affects the fuel economy and energy efficiency of the vehicle.

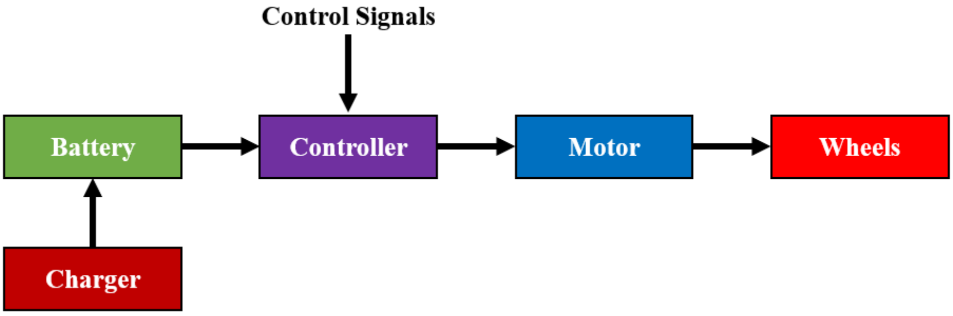

Figure 1. Block diagram of major components used in electric vehicles.

It is advisable to utilize lightweight, compact batteries with a large electrical storage capacity to increase the driving distance. Recent developments in lithium-ion battery technology have increased the energy storage capacity and discharge rate of these batteries. These batteries are ideal for EVs because they are small and have a long lifespan [10].

Working of Controller and Control Signals

The controller was designed to gather data from a range of sensors, including those measuring throttle position, motor speed, battery management, and regenerative braking. Additionally, the system is responsible for controlling the motor and managing its performance [11].

Working of Motor

Owing to its high initial torque, which enables the creation of a significant electric pull at varying loads, the series DC Motor is regarded as the most feasible option for propulsion in EVs. This type of motor can further function as a generator to charge batteries. Brushless DC motors are frequently employed as traction motors in the automotive industry because of their many advantages, including straightforward design, wide speed range, small weight, and silent operation. The induction motor is a different choice for traction motors [12]. This machine boasts a regenerative system and powerful starting torque for different loads. However, they are prone to breakage at low speeds. However, it is crucial to remember the use of an expensive, high-efficiency AC driver topology.

METHODOLOGY

Advanced design, modeling, and optimization techniques are of utmost importance in the advancement of EVs that are fueled by environmentally friendly energy sources. These techniques are indispensable for enhancing the effectiveness, functionality, and eco-friendliness of the EVs. In this regard, this discourse aims to delve into the three fundamental facets of advanced design, modeling, and optimization for EVs that utilize green energy.

- Integration of EVs with green energy sources
- Optimization of energy conservation process and energy management

Integration of EVs with Green Energy Sources

The transportation sector is currently undergoing a major transformation, as the global community addresses the environmental impact of conventional fossil fuels. EVs have emerged as practical and eco-friendly substitutes for traditional gasoline- and diesel-powered cars, gaining widespread popularity. Moreover, these EVs are powered by RESs, such as solar panels and wind turbines, which are paving the way for a cleaner and more sustainable future.

Solar Power

Solar energy is widely popular owing to its positive impact on the environment and cost-effectiveness. Solar panels can convert solar energy into electricity by harnessing the energy from the sun. Incorporating solar power into the EV charging infrastructure shows great potential for reducing greenhouse gas emissions and minimizing the environmental impact of EVs. Integrating solar energy with EVs involves the installation of solar panels to capture sunlight and convert it into electricity. This renewable energy source can then be utilized to charge EVs, reducing the dependence on grid electricity, and minimizing the carbon footprint. By employing appropriate charging equipment and the capability to store excess solar energy in batteries, EVs can be conveniently charged even during overcast days or at night.

The utilization of smart technology and monitoring systems ensures the efficient utilization of solar-generated power. By remaining connected to the grid, you have the flexibility to draw energy as required and potentially contribute any surplus energy back to the grid, thus earning credits. This approach, which is both environmentally friendly and cost-effective, aligns with the growing trend of sustainable transportation and energy practices, offering a cleaner and more sustainable method to power EVs.

Wind Power

Wind turbines capture the kinetic energy of wind and transform it into electricity, which is a valuable addition to solar power in the pursuit of sustainable energy sources for charging EVs. Integrating wind energy with EVs involves the utilization of wind power to generate clean electricity. Wind turbines, whether in large-scale installations or smaller residential systems, can be employed to harness wind energy. This electricity can then be utilized to charge EVs, offering an environmentally friendly and sustainable power source.

The variability of wind energy can be effectively managed by integrating it with energy storage solutions such as batteries to ensure consistent charging capabilities, even during periods of low wind activity [13]. This innovative approach not only contributes to reducing carbon emissions but also aligns with the broader objectives of sustainable transportation and renewable energy, making it a promising avenue for powering EVs with renewable wind energy.

In recent times, challenges have arisen in electric energy networks owing to the involvement of the transportation sector in utilizing electric facilities. As shown in Figure 2, EVs have substantial advantages for power systems, in addition to these difficulties. EV network integration is crucial for battery charging. The integration of EVs into the power grid holds significant potential for managing peak demand, supplying reactive power, reducing harmonics, and facilitating other processes [14].

While integrating green energy sources for EVs, challenges such as initial cost, geographical location, and storage of energy remain for a long time. Without this type of problem, we can solve it without any issues.

Optimization of Energy Conservation Process and Energy Management

As the world works towards reducing reliance on fossil fuels and addressing climate change, the significance of green energy sources such as solar, wind, and hydropower cannot be emphasized enough. Generating green energy is a crucial step in the right direction; however, it is equally important to maximize its utilization. This is where optimizing the energy conversion process and implementing advanced energy management systems are essential [15].

Solar Power Optimization

Solar panels have become increasingly popular for harnessing solar power. The optimization of solar energy conversion includes the following: This involves a solar tracking system and smart inverter techniques.

a. *Solar tracking system:* A solar tracking system is a system that tracks the sun’s movement throughout the day, at the position where it is always aligned for maximum energy captured [16].
b. *Smart inverter:* High-efficiency inverters convert DC electricity from solar panels into AC electricity for homes and businesses, thereby reducing energy losses.

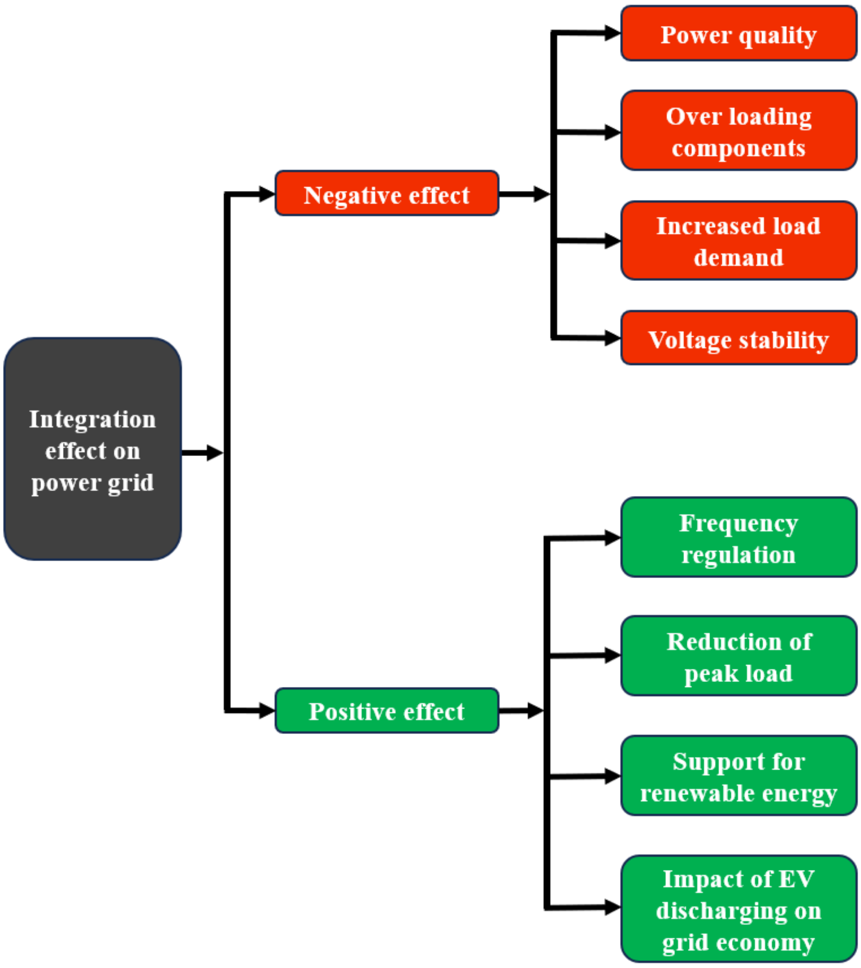

Figure 2. Various effects of integration of EV on the power grid.

Wind Power Optimization

Wind turbines are another cornerstone of renewable energy research. The following will help optimize the wind energy conversion. This involves turbine placement and blade design techniques.

a. *Turbine placement:* To maximize the energy output, it is crucial to position wind turbines in areas with consistent and strong winds [17].
b. *Blade design:* Wind turbine efficiency can be enhanced using advanced blade designs that incorporate aerodynamic shapes and lightweight materials.

Smart Grids

Smart grids are systems that use advanced technologies to manage the generation, distribution, and consumption of electricity. These intelligent and digitally connected grids were designed to optimize energy use. This involves demand response and energy storage integration techniques.

a. *Demand response:* Smart grids allow utilities to effectively balance supply and demand by responding in real-time to changes in energy demand.
b. *Energy storage integration:* Energy storage solutions, such as batteries, can be incorporated into smart grids to save surplus energy for future utilization [18].

Industrial Energy Management

Industrial energy management is a holistic method for enhancing energy utilization in manufacturing and industrial facilities. This involves energy audits and Internet of Things (IoT) automation.

1. *Energy audits techniques:* Energy audits can help find ways to save energy by identifying inefficiencies.

2. *IoT automation:* IoT and automation can optimize energy consumption by controlling the machinery and lighting.

CHALLENGES/PROBLEMS IN THE DESIGN, OPTIMIZATION, AND MODELING OF ELECTRIC VEHICLE

Several challenges and problems must be addressed to enhance the performance, efficiency, and adoption of EVs. These challenges include designing, optimizing, and modeling EVs.

Battery Charging Speed

The charging speed of the Sahil Shelke Battery is a major challenge for EVs. Current charging speeds are relatively slow, especially when compared to refueling a gasoline-powered car. This can be a significant barrier to EV adoption, as it makes EVs less convenient for drivers who need to make long trips or who do not have access to home charging [19].

Driving Range

The driving range refers to the maximum distance that an EV can travel on a single battery charge. This is a significant consideration for individuals contemplating the purchase of an EV, as it may impose limitations on long journeys or for those without access to home charging facilities.

Vehicle Cost

The adoption of EVs is hindered by their high cost, which is a major barrier. In comparison to gasoline-powered cars, EVs are generally costly, and their initial cost can pose a significant challenge for numerous consumers [20].

Materials and Recycling

The materials used to make EVs are made of different types of materials. Some materials such as batteries are harmful to the environment.

Safety

Safety issues in EVs are of paramount concern, primarily because of high-voltage electrical systems and the unique nature of electric propulsion. A significant safety problem involves the risk of electric shock during accidents or when handling damaged EVs [21].

PROBABLE SOLUTIONS TO THE CHALLENGES

Battery Charging Speed

- Expanding the availability of fast charging stations with increased power output is crucial.
- To make it easier for different EV models to access fast charging infrastructure, it is important to ensure that charging stations support multiple charging protocols, such as CCS, CHAdeMO, and Tesla's Supercharger.
- Standardizing and widely implementing plug-and-charge technology can accelerate the charging process by eliminating user input requirements. This technology enables seamless and secure authentication and payment [22].
- The utilization of high-power DC fast chargers can substantially decrease the charging duration, thereby enhancing the feasibility of long-distance journeys.

Driving Range

- To enhance the vehicle's battery pack, it is necessary to improve battery technology to increase the energy density without adding much weight. This results in more power for acceleration and the ability to sustain higher speeds for longer periods.
- The aerodynamics of the vehicle can be improved to reduce air resistance, resulting in better efficiency at higher speeds. This can be achieved by conducting wind tunnel testing and incorporating innovative design features [23].

- Sahil Shelke Using dual-motor or AWD (All-wheel drive) setups can evenly distribute power to all wheels, enhancing grip and acceleration, and ultimately boosting driving speed.
- Improving the efficiency of an electric motor can result in increased torque and acceleration, allowing for faster driving speeds. This can be achieved using advanced motor designs, materials, and cooling systems.

Vehicle Cost

- One of the most expensive components of an EV, the battery, is being worked heavily to lower its cost per kilowatt-hour (kWh). This can be achieved by boosting economies of scale, improving battery chemistry, and streamlining production methods [24].
- Utilizing lightweight components such as aluminum and carbon fiber can improve vehicle performance, reduce weight, and potentially reduce manufacturing costs.
- Increased accessibility to the charging network can help EVs become more appealing and reduce range anxiety, which may compensate for their higher initial cost.
- EV production can be scaled up to achieve cost savings through economies of scale. This is particularly important for the battery and assembly of vehicles.

Materials and Recycling

- Research and exploration of alternative materials that have less impact on the environment for EV components. For example, by substituting cobalt and certain rare earth metals in batteries with less rare and environmentally damaging materials, the ecological footprint can be decreased [25].
- The lifespan of retired EV batteries that are no longer suitable for use in vehicles can be increased by repurposing them for stationary energy storage applications.
- Design batteries with recyclability. Using modular battery packs with standardized connectors can make it easier to disassemble and replace individual battery modules, thereby simplifying the recycling process.
- Increased consumer understanding of the value of recycling EV parts and batteries at the end of their useful lives. Provide advice on ethical recycling and disposal practices for EV parts.

Safety in Electric Vehicles

- Make sure to mark EVs with warning signs and color coding to show the presence of electrical parts. This will help first responders easily identify any dangers during rescue operations.
- Provide detailed emergency response guides for each EV that outline procedures for safely handling accidents and fires involving electric vehicles. These guides should be easily accessible to first responders and should include critical safety information.
- Implement battery management systems with safety features, such as quick disconnection during emergencies (e.g., collisions) and thermal management to prevent overheating.

RESULT AND DISCUSSION

With the rise in EV usage, there is a growing demand for the analysis and development of charging technology and the utilization of green energy sources. Furthermore, it is anticipated that advancements in grid integration and technological innovations, such as smart charging infrastructure and coordinated charging systems for EVs, will be implemented to maximize efficiency. This study offers a comprehensive and up-to-date review of EV technologies, encompassing the integration of green energy with EV techniques to optimize charging strategies. This paper also highlights the limitations of current technologies and suggests areas for further research. This study primarily focused on standards and technologies, thus limiting the extensive exploration of manufacturing aspects.

CONCLUSION

The integration of EVs that are powered by eco-friendly energy sources is a crucial step toward a sustainable future. The use of state-of-the-art design, optimization, and modeling techniques, as shown in this thorough analysis, offers promising prospects for increasing the efficiency, range, and environmental benefits of EVs. By addressing current challenges and adopting new technology, we can accelerate the transition to a transportation system that is more ecologically sensitive and friendly.

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