Electric Vehicle integration in Economic Load Dispatch with Renewable Energy Sources: A Systematic Literature Review

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Abstract. Integration of Electric vehicles (EVs) and renewable energy sources (RES) into the power systems makes the economic load dispatch (ELD) problem becomes more complex. This research shows that EVs are evolving into manageable, bidirectional energy nodes equipped to both supplying and consuming power through Vehicle-to-Grid (V2G) systems. Under operating conditions, grid stability and EV charging are affected by the uncertainty of wind and solar energy sources. This review discusses efficient grid operation and smooth power dispatch using advanced optimization techniques, such as evolutionary algorithms, hybrid metaheuristic, and artificial neural networks. Key constraints include coordinated EV-RES arrangements, smart charging systems, and multi-objective formulations. Case studies in MATLAB indicate that battery aging, infrastructure limitations, and policy support remain significant challenges. The paper concludes by emphasizing the need for collaboration among researchers, industry, and policymakers to develop integrated, flexible ELD models for effective, economical, and ecological energy management

Key Terms: Electric vehicles, Renewable Energy Sources, Economic load dispatch, Vehicle-to-Grid, Evolutionary Algorithms

1 Introduction

Electric vehicles (EVs) play an essential role in Economic Load Dispatch (ELD) by maintaining balance between demand and supply based on real-time load conditions. Vehicle-to-Grid (V2G) enables EVs to supply power to the grid during high demand periods, acting as distributed generators (DGs). Since wind and solar energy (WSE) are not always available, EVs may help to balance the resulting grid load, making it more stable. Effective use of available resources is required to balance supply and demand through the integration

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of renewable and non-renewable sources. The planning of electric vehicles in smart grids that utilize renewable energy sources through using multicriteria criteria for decision-making [1]. An integrated fuzzy PI-LADRC-based frequency regulation strategy for power systems with EV-RES integration for making the system less unstable [2]. Further demonstrated that a three-level, multi-timescale integration framework for EVs and renewable energy sources could significantly enhance the stability of the grid [3].

The latest research papers [4,5] evidently describe various hitches in the connection of EV-RES to the power systems and propose promising solutions to the corresponding hitches. In extension with the previous discussion, [6] recommended load balancing and grid-based charging situations. They ensure reduced cost and steady power predicting through EV–RES integration into the grid.

2 Economic Load Dispatch (ELD)

Subsequently add valve-point effects (VPE) to the ELD problem, it becomes highly non-linear and complex, thus requiring advanced metaheuristic techniques to solve the issue. For enhanced operational flexibility, lower generating costs, and better emissions performance in dynamic load scenarios, researchers have looked into hybrid evolutionary algorithms, nature-inspired optimization approaches, and ramp-rate–constrained formulations.

Multiple particle swarm optimization (PSO) configurations have been offered to deal with the economic load dispatch (ELD) problem facing relation to EV–RES integration, subsequently expanding research on cost-effective and efficient dispatch solutions. DELD for hybrid RES/PEV power networks [7]. The work calculates DELD using time-varying load demand, renewable generation uncertainty, and bidirectional EV charging/discharging. Simulations demonstrate that real-time EV–RES dispatch coordination lowers cost of production, smoothes demand, and increases grid flexibility. Also, standard optimization approaches were used to make the entire framework work better in an effort that is both simple and quick to compute [8].

Whale-based optimization methods are known to be extremely effective at dealing with time-varying load demand while minimizing emissions when used simultaneously for dynamic economic load dispatch (DELD) [9]. Various optimization methods have been employed to address DELD problems in order to keep the grid more stable, ensure the supply keeps going, and make the system more reliable and maintaining the real-world standards.

3 RES-EV Synergy in Economic Load Dispatch

The integration of RES and EVs with ELD is a popular innovative method to load balancing and V2G system optimization. This integration makes EVs charging during peak load times also avoid uncertainty problems caused by Wind and solar energy variations, resulting stable grid operation and optimal power dispatch. Based on optimization ELD keeps the grid more resilient by making it easier for power flow between generation and load centers. Effectively scheduling EV charging and discharging operations demonstrates that well-planned charging and discharging can significantly reduce fuel consumption and emissions.

Using predictive control techniques for planning the vehicle-to-grid (V2G) approaches appropriately improves demand flexibility, maintain grid balance, and preserve battery health [10]. Large-scale integration studies show that when electric vehicles function as active supply-side resources, that required electricity quantity can be reduced and grid integration can be simplified. Also, regulatory documents show that electric vehicles assist with the grid

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work by acting as both energy storage devices and flexible, exchangeable loads through V2G mechanisms [11].

EV-RES systems present complexity due to the inherent unreliability of wind and solar energy sources. However, electric vehicles can store excess energy and transmit it back to the grid through V2G, rendering the system more stable and improving dispatch quality. Electric vehicles serve as both electricity consumers and suppliers, assisting in maintaining grid balance, reducing energy consumption, minimizing pollution, and enhancing overall grid stability [12].

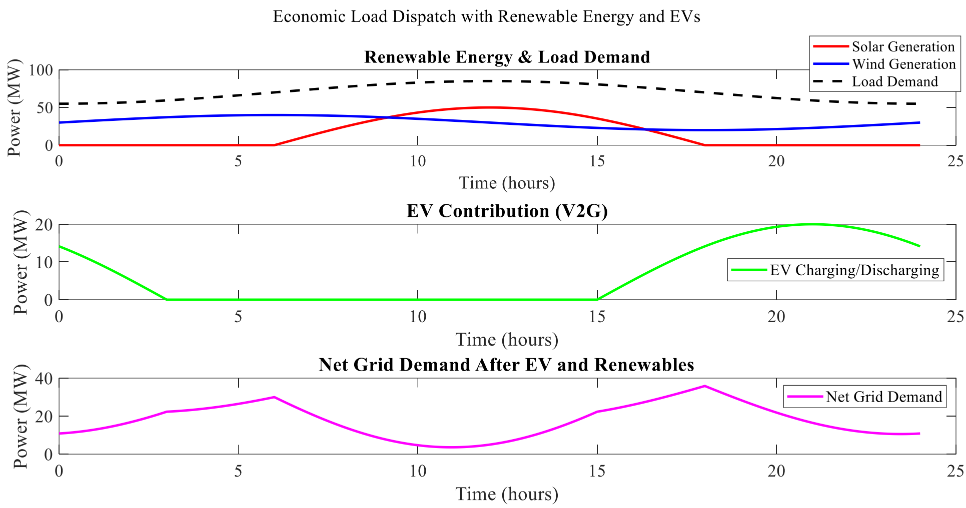

Fig. 1. EV-Driven ELD with Renewable Integration.

Figure 1 shows the effect of ELD with EV-RES, and V2G. Load is high in the evening, solar power is high in the afternoon, and wind power stays steady for long hours. EVs give power from 13:00 to 21:00 to meet high demand and charge again after 21:00 when demand is low.

This setup holds power use steady, reduces grid load, and uses more green energy. EV–RES supports ELD. RES enables low-cost ELD. Proper EV timing improves GS. Recent works (2022–2024) focus on SEVs, AC, and DL for improved V2G.

4 EV Modelling, Optimization, and Challenges

Economic load dispatch (ELD) with EV-RES integration improves grid performance, reduces costs, and provides environmental benefits. Some methods machine learning and hybrid control strategies effectively manage EV charging and usage patterns. Deep learning technologies enhance system speed and flexibility. Building-to-Vehicle (B2V) and Vehicle-to-Building (V2B) systems increase green power utilization, reduce costs, and strengthen grid operations. Aggregated EVs improve renewable energy utilization; maintain grid stability, and lower operational costs. Optimized EV charging and prioritized utilization improve efficiency when renewable energy sources fluctuate. Evolutionary computation-based methods enhance grid stability and DELD performance when RES-EV systems are combined.

Figure 2 analyses traditional ELD with RES/EVs integration and without RES/EVs, fossil fuel dependence increases costs, and conventional generators meet most variable demand.

With RES and EV integration, charging during off-peak hours and discharging during peak hours, combined with renewable energy contributions, smooths the load curve.

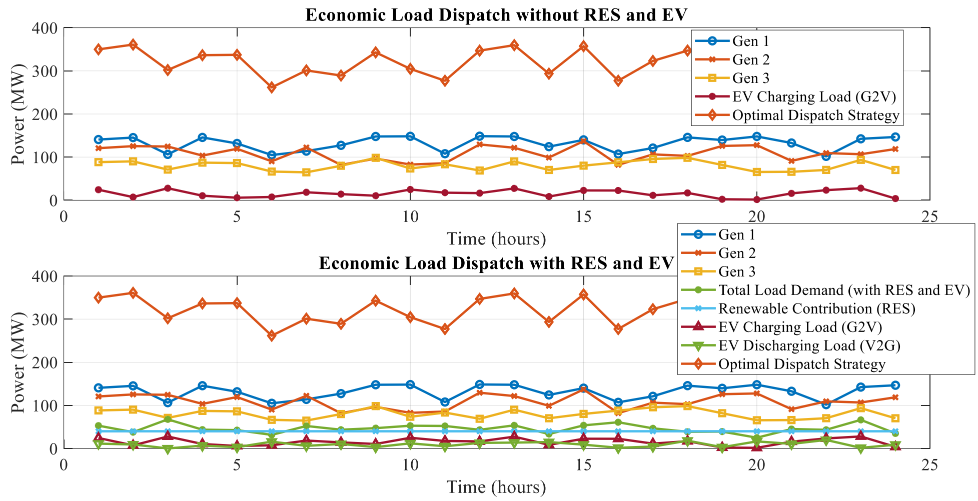

Fig. 2. EV-Driven ELD with Renewable Integration.

To bring down on operational costs and system losses, multi-objective ELD frameworks that combine EVs and RES have been designed. Researchers have also looked into hybrid modelling methods to improve the way EVs retain energy and the way effectively they deliver electricity to the grid. In this case, in-depth research has looked into better ways to coordinate EVs and RES in ELD formulations [13].

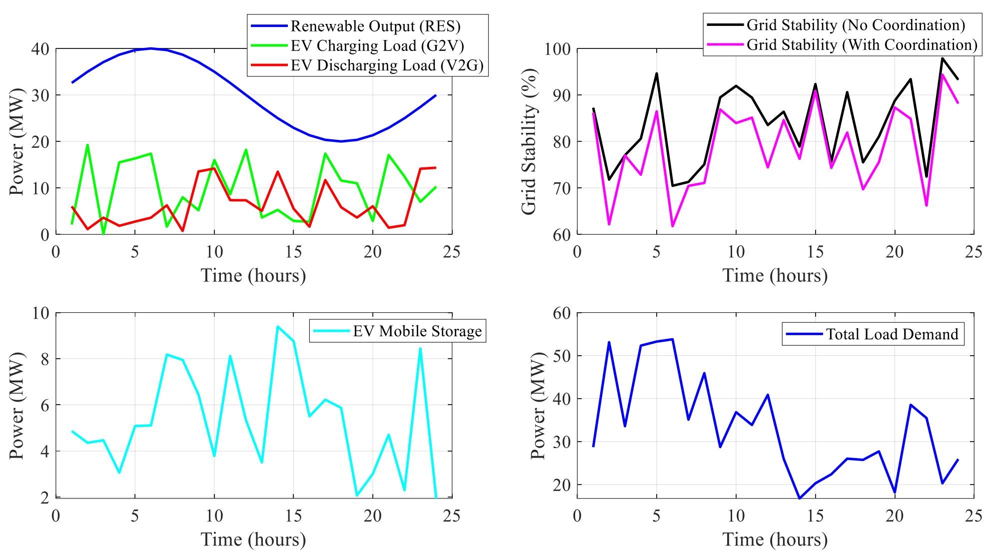

Fig. 3. EV and RES Integration in ELD Systems Challenges.

Recent work (2022-2024) examines machine learning-based integrated energy management, EV charging optimization, and B2V/V2G technologies for enhanced system control. Figure 3 presents four subplots highlighting key ELD challenges and solutions using EV-RES integration.

The first subplot shows how much renewable energy is produced, EV charging (G2V), and V2G power supply throughout a day. It shows that EVs charge when there is too much renewable energy and discharge when there is too much demand. Studies confirm that synchronized EV–RES scheduling alleviates grid congestion and enhances efficiency [14].

The second subplot illustrates the differing impacts of synchronized versus unsynchronized EV charging on grid stability. Unsynchronized charging during grid instability intensifies frequency variations, whereas synchronized charging maintains stable performance. Research indicates that uncoordinated charging significantly destabilizes the grid, particularly with high RES penetration. Advance planning ensures EV operations align with grid requirements, thereby enhancing reliability. The third subplot depicts EVs as mobile storage units that accommodate fluctuating system demands. The fourth subplot shows how RES and EVs flatten the load curve, thereby reducing reliance on fossil fuels.

5 Conclusion

In Economic Load Dispatch (ELD) problem by incorporating Plug-in electric vehicles (EVs) and renewable energy sources (RES) which make it more dynamic and complex. Key economic and technological challenges include the shortage of charging stations, high infrastructure costs, battery degradation over time, RES unpredictability, and grid instability. These problems may resolve by making better dispatch scheduling, making more synchronized power flow in both directions. To forecast the demand for EVs and generation of renewable energy by using the advanced optimization methods. MATLAB-based research and simulations demonstrate that integrating EVs and RES reduces peak demand, smooths load variations, and minimizes fossil fuel consumption. Policy measures—such as investments in smart grids, standardized V2G protocols, and dynamic pricing—are essential to promote widespread adoption. In the future, we need to concentrate on integrated planning that includes technology, money, and rules, as well as strong infrastructure and best battery management. These measures ensure that EV-RES-compatible ELD systems are sustainable, efficient, and cost-effective.

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