(#55) Dynamic Peak Load Management with Vehicle-to-Grid Technology

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Abstract

The rapid increase in electricity demand has led to innovative peak demand control processes, notably Vehicle-to-Grid (V2G) technology. V2G enables electric vehicles (EVs) to both draw power from and release stored energy back to the grid, making EVs mobile energy storage units. Traditional peak load management strategies are insufficient for modern energy demands, requiring comprehensive methodologies for effective dynamic peak load management using EVs in island mode microgrids. Integrating renewable energy sources enhances grid stability and sustainability. V2G technology's bidirectional power exchange allows EVs to balance demand and supply while supporting grid stability. This research focuses on maximizing efficiency, managing peak load demand, and improving grid stability with V2G technology, transforming EVs into energy management assets. By using EV batteries to meet peak demand, reduce fossil fuel-based power plant expenses, and lower generation costs, the study aims to optimize energy utilization and island-mode microgrid stability in a simulated city under various conditions.

Keywords: *Vehicle-to- Micro Grid (V2MG) technology, Electrical vehicles (EVs), dynamic peak load management, renewable energy integration, grid infrastructure*

Introduction

The rapid increase in electricity demand has led to innovative peak demand control processes, notably Vehicle-to-Grid (V2G) technology. V2G enables electric vehicles (EVs) to both draw power from and release stored energy back to the grid, making EVs mobile energy storage units [1]. Traditional peak load management strategies such as time of use pricing [2], load shaping methods [3], and curtailment programs [4] are insufficient for modern energy demands, requiring comprehensive methodologies for effective dynamic peak load management using EVs in island mode microgrids. Integrating renewable energy sources with electrical vehicles having V2G technology enhances grid

flexibility [5] and power quality [6]. V2G technology's bidirectional power exchange allows EVs to balance demand and supply while supporting grid stability. This research focuses on maximizing efficiency, managing peak load demand, and improving grid stability with V2G technology, transforming EVs into energy management assets. By using EV batteries to meet peak demand, reduce fossil fuel-based power plant expenses, and lower generation costs, the study aims to optimize energy utilization and island-mode microgrid stability in a simulated city under various conditions.

Methodology

The methodology adopted in this research included both simulation and algorithms. Data Collection had been done on demand in the microgrid and supply of energy from the renewable energy sources. In addition, EV usage patterns were monitored to collect data on the state of charge (SOC), availability of EVs, charging and discharging patterns of EVs, and driving schedules. The Load profiles were taken from the CEBcare website. Then, the values were scaled down for the analysis Identification of the microgrid components such as renewable energy sources (solar, wind), energy storage systems (batteries), and electric vehicles (EVs) equipped with V2G technology had been important. Next, a centralized control system had been developed for monitoring and managing energy flow within the microgrid [7]. Then, optimization algorithms had been developed to dynamically manage the charging and discharging cycles of EVs. The goal of this research had been to shift the EV charging during the off-peak periods and discharge stored energy during peak periods to manage the dynamic load. In the implementation, control strategies were used for dynamic peak load management to prioritize critical loads such as hospitals and supply energy stably during peak demand periods. Robust communication protocols had been established between the control system, EVs, and other renewable systems of the microgrid for seamless data exchange and coordination. Simulation models were created to test the effectiveness of the developed algorithms and control strategies under various scenarios in a controlled environment to validate the performance of the system and make the necessary adjustments. The performance of the microgrid, such as energy efficiency, cost savings, and system reliability, had been tested and analysed with the collected data to evaluate the effectiveness of the dynamic peak load management system. Next, the results had been

compared with baseline scenarios without V2G technology. By using data analysis, simulation, and algorithm formation, the research had targeted finding better solutions for integrating more renewable energy sources and implementing V2G technology for dynamic peak load management.

Results

The main focus of this research had been to effectively implement the dynamic peak load management with V2G technology within the simulated city context to install grid stability and maximize renewable energy utilization [5]. The result of the research included load shifting, energy efficiency, cost saving, system reliability, and behavioural changes in the EV owners. It had paved the way to a sustainable energy solution for dynamic peak load demand for simulated city by integrating V2G technology [8] into the island mode microgrid. The regulatory and economic challenges had limited the V2G technology integration to the island mode microgrid. As well, it had been impossible to conduct all real-world operating conditions and scenarios such as changes in the peak load duration and the peak load value in a simulated city to identify the productiveness of V2G technology.

Discussion

The information collected from the research indicate that the integration of V2G technology microgrid can manage the peak load effectively [9]. This system encourages the renewable energy future and reduces the carbon footprint. However, the findings identify some limitations of this project as regulatory support, advanced grid management system, and consumer support to promote V2G integration. The EV usage in dynamic peak load management is economical and sustainable instead of expensive infrastructure.

Conclusion

This research shows that V2G technology integration has a big impact on the dynamic peak load management. Due to the bidirectional flow of energy of the EVs, it can be flexible to supply power to the grid when needed. Then it enhances the grid stability and promotes renewable energy sources integration into the system. However, the study demonstrates both the capabilities and the challenges of V2G integration in island mode microgrid.

Directions for future research

Future research should focus on large-scale pilot projects as well as real-world data to find out the V2G integration impact. Studying consumer behaviour patterns, tariff structures that promote V2G integration, advancement in battery technology, and smart grid systems are also new perspectives to focus on in this research.

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