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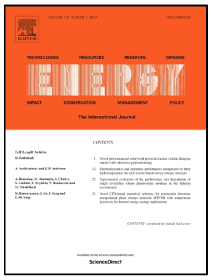

Black-Scholes option pricing strategy and coordination for designing vehicle-to-grid reserve contracts

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Black-Scholes option pricing strategy and coordination for designing vehicle-to-grid reserve contracts

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Abstract: Based on the risk-neutral trading characteristics of the vehicle-to-grid reserve market, this paper establishes an option pricing strategy for a grid company, and builds two electricity reserve models for an electric vehicle user before and after options implementation. Then, feedback equilibrium strategies and optimal profits are compared between a Stackelberg game and a cooperative game. The results demonstrate that simply using protective market pricing mechanism to determine the contract price places all of the vehicle-to-grid market's trading risk onto the grid company, so that opportunistic behavior cannot be prevented in bad market conditions. To address this, the grid company can buy options to mitigate the risk of price fluctuations; the cooperation system can be further enhanced through a "Black-Scholes option pricing + reserve cooperation + deposit" joint contract, which achieves Pareto improvements of the expected profits on both sides of the channel. Finally, the analytical relations among the vehicle-to-grid reserve's cooperation coefficient, trade deposit, and electricity contract price in equilibrium are derived, and the feasibility of the proposed models and theoretical analyses is verified by three numerical examples.

Keywords: Vehicle-to-grid reserve; electricity contract price; reserve capacity; Black-Scholes option pricing model; coordination contract

1. Introduction

The rapid development of automobile industry has accelerated oil resource depletion. At the same time, automobile exhaust has created serious air pollution and contributed to the global greenhouse effect. These large-scale problems make it crucial for automotive technology to progress towards fuel diversification and electrification. Based on advantages like energy efficiency and low emissions, electric vehicles (EVs) that employ vehicle batteries as a full or partial power supply have become the main development direction for energy conservation and environmental protection in international vehicle development [1]. Countries all over the world are strategically targeting the development of EVs as an important investment to promote energy security and transform into low carbon economies. However, power grids exhibit inefficiencies like high costs and excessive energy waste, which result from daily load demand fluctuations[2]; combating these inefficiencies requires the imposition of voltage and frequency regulations, which in turn increase grid operation costs[3]. On the other hand, renewable energy systems based on solar and wind power are increasingly being connected to the grid [4]. The vehicle-to-grid (V2G) concept was proposed to address these interconnected problems. The core idea behind V2G is to use the electricity storage capacity of a large number of EVs as a buffer between the grid and renewable energy sources. When the grid's load is too high, EVs feed their stored energy to the grid; when the grid's load is low, EVs store the excess electricity

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