

Review of Global V2G Research from an Energy Technology Economics Perspective

Yueran, Ni

SHANGHAI UNIVERSITY OF ENGINEERING SCIENCE

Abstract

With the rapid growth of the global number of new energy vehicles in stocks approaching the 90 million milestone, their energy storage attribute has also expanded rapidly. The orderly charging and discharging of new energy vehicles can effectively support the operation of the new power system, further activate the value of the modern power grid, and effectively release their energy storage economic attributes. Through a comprehensive review of V2G, VPP, electricity trading and other technologies, it was summarized that the current status of technical frameworks, policy logics, market approaches and other aspects, analyzed that the core issues , including high-efficiency power converters with the wide-band gap power switches based on SiC & GaN, and so on. It is proposed that the new energy technology ecological relationship and development logic, and the methodology for new energy vehicles, new energy technologies, new energy economies and other fields under global sustainable development such as power router for energy internet.

Introduction

V2G (Vehicle-to-Grid) denotes bidirectional power exchange between EVs and power grids, with its concept originating in the 1990s. The U.S. put forward the original V2G prototype in 1995, followed by the first frequency response test in 2008. Denmark launched the world's first fully commercial V2G project in 2016. Italy rolled out the globe's largest V2G pilot with over 700 EVs in 2020 and unveiled a 25 MW ultra-fast frequency regulation V2G project in 2023, signifying its full commercial operation. Under the framework of the Paris Agreement, the global energy structure is undergoing a profound transformation. However, the inherent intermittency, variability, and uncertainty of renewable energy sources have increasingly highlighted the mismatch with the inflexible demand on the load side.

In this context, the coordinated interaction between high-penetration NEVs and the power grid—Vehicle-to-Grid (V2G)—has evolved from a technical concept into a critical enabler in building the ecosystem for new power systems.

Technology ecosystem

The new energy power system is the technical foundation of V2G. Centered on new energy sources, it adapts to the “dual high” features of high-proportion renewable energy and high-density power electronic equipment. Featuring efficient coordination of source, grid, load and storage, digital intelligence, safety, stability, eco-nomic efficiency and environmental friendliness, it realizes static and dynamic power balance in the scenario of “multiple sources and multiple power flows”. Meanwhile, by participating in market spot transactions such as peak shaving, valley filling and time shifting as virtual power plants (VPP) and other market entities, it curtails wind and solar power curtailment and improves the new energy accommodation capability of the new power system.

The V2G system consists of new energy vehicles, charging piles, power grid and electricity trading market. The technical and economic principle of the V2G energy system is illustrated in Fig.1.

Let's move to the next poster panel and look at Figure 1.

Review of Global V2G Research from an Energy Technology Economics Perspective

Yueran, Ni

SHANGHAI UNIVERSITY OF ENGINEERING SCIENCE

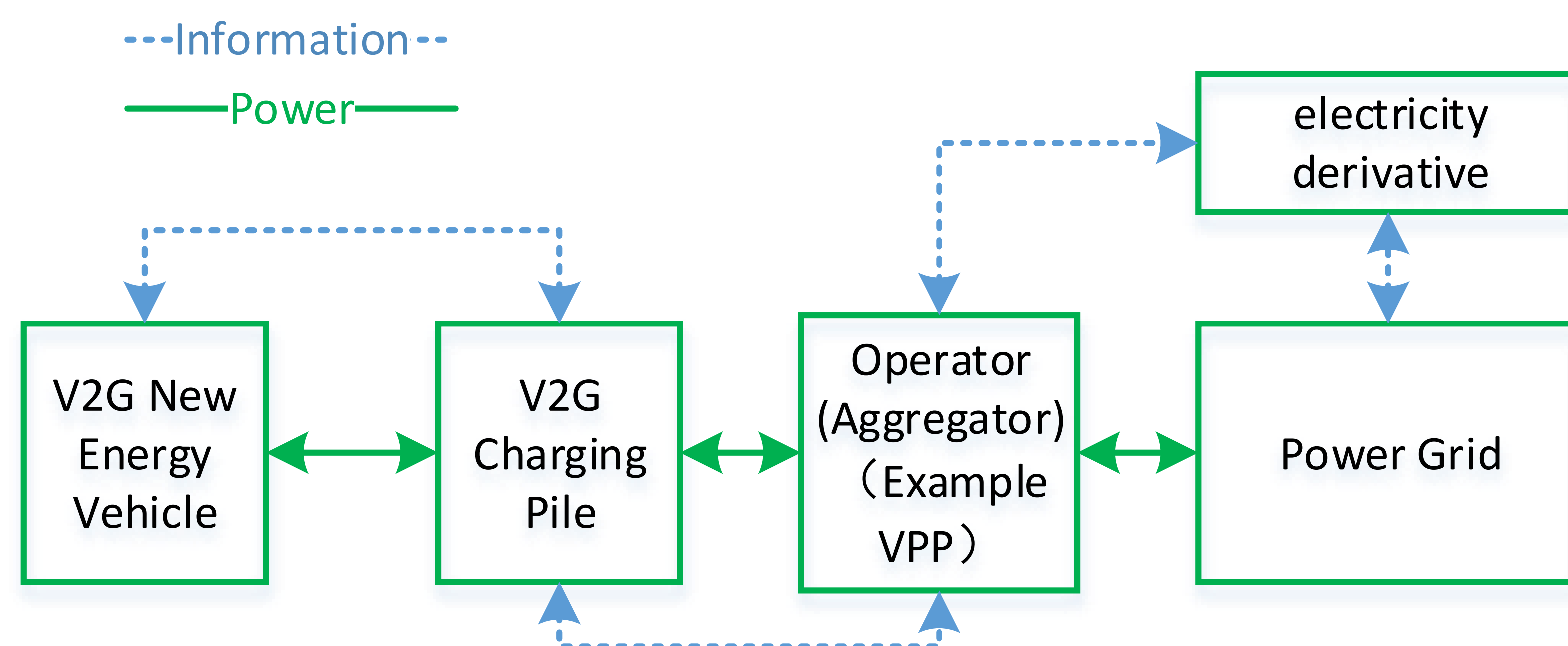


Fig. 1 V2G Energy Techno-Economic System

As shown in Figure 1, the V2G technology eco-system presents a 'bidirectional' trend, involving both energy and information, with massive data volumes for both. It can be seen that the V2G energy technology and economic system cannot do without distributed data centers and distributed computing centers.

Full Panorama of Technology Ecosystem

V2G mainly relies on six core supporting technologies: High-efficiency bidirectional power electronic technology, Battery technology, Communication technology, Blockchain technology, AI technology and Digital twin technology.

Power Market Entities and Transaction Classification

Power marketization promotes the commercial application of vehicle-to-grid (V2G) technology and realizes multi-stakeholder economic benefits. Typical V2G market participants include power grid enterprises, end users, aggregators, and virtual power plants, while major trading types cover spot trading, peak-valley regulation, frequency modulation, rotational reserve, and demand response.

Economic Benefits of V2G

V2G technology delivers multi-stakeholder economic benefits for end users, aggregators and power grids, forming a positive industrial closed-loop ecosystem. It mainly includes the following aspects: User Level, Operator (Aggregator) Level, Operator (Aggregator) Level and Power grid company level.

Existing issues

There are five core bottlenecks limiting large-scale, sustainable V2G development: policy execution, institutional incentives, technical standardization, commercial operation and infrastructure support.

Conclusion

NEV-grid integration is pivotal to global energy transition and new power system construction. Driven by technological progress, policy support, economic value exploration and ecosystem optimization, V2G technology has achieved qualitative leaps from quantitative accumulation.