

AUTOMOTIVE MATERIALS & SUSTAINABILITY (ACHA6012)

Vehicle to Grid Technology

BEng Motorsport Engineering

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ABSTRACT

In a world where it is necessary to increase the use of renewable energies to reduce pollution and combat climate change, it is necessary to have electricity storage systems to combat the weak point of renewables: their variability.

Faced with this challenge, there is a technology called V2G (Vehicle-to-Grid) that allows the electric car to be used as a device to store energy, allowing the flow to run in both directions: from the car to the electricity grid and from the grid to the car.

A critical analysis is carried to discuss the implementation of this technology and its implications in the immediate and long term.

INTRODUCTION

1. THE ELECTRIC CARS

The electric car market is on the rise, every year the number of manufacturers and the variety of models available on the market is wider. For this reason, electric vehicles are a key element in the development and energy transition of the current energy models and technologies.

1.1 Types of electric vehicles

There is few electric vehicle types:

- Battery electric vehicles (BEVs)
- Plug-in hybrid electric vehicles (PHEV)
- Non-plug-in hybrid electric vehicles (HEV)
- Extended range electric vehicles (REX)
- Fuel cell electric vehicles (FCV)



FIGURE 1. DIFFERENT POWERTRAINS (SKODA, 2019)

The greatest potential for the integration of electric vehicles in the energy network electrical power lies in the BEV, PHEV and FCV. These are considered the most effective way to reduce dependence on fossil fuels and thereby reduce greenhouse gas emissions greenhouse. With the use of V2G technology, electric vehicles can catch electricity from the grid and return it.

1.2 Batteries

The main battery technologies are:

- Lead acid (Pb-acid)
- Nickel-hydrate metal (Ni-MH)
- Lithium ion (Li-ion)

Lead-acid batteries, mostly used in combustion cars, they have a lower energy density, shorter service life and, in addition, they have the problem of the memory effect when loaded (if they don't get completely charged after each use, they will potentially only charge up to the last highest charge), which are very important factors in functionality and profitability of this type of vehicle. Therefore, this type of battery is not suitable for electric vehicles.

Ni-MH and specially Li-ion are the ones getting the best results. On the one hand, Ni-MH batteries have properties intermediates between lead-acid and Li-ion, the cost is much lower than lithium batteries in terms of the final battery pack production, but they have probabilities to have weak-cell syndrome (some or all the cells of the battery pack no longer hold power). (Anon., 2021)

On the other hand, Lithium-ion batteries have a high specific energy, better energy density and longer service life, which makes the cost of such batteries and electric cars the integrate have a very high initial cost, it can also handle heave input and output voltage, making it the best option for electric vehicles. In addition to improving profitability for the integration of V2X systems. (C. Iclodean, 2017)

Some of the characteristics of these 3 types of batteries are show in the table 1.

Type	Specific Energy (Wh/kg)	Specific Power (W/kg)	Life cycles
Pb-acid	30-45	200-300	400-600
Ni-MH	60-120	150-400	600-1200
Li-Ion	90-160	250-450	1200-2000

TABLE 1. CHARACTERISTICS OF PB-ACID, NI-MH & LI-ION BATTERIES (ANON., 2021)

Table 2 compares the reliability of the cell and the battery of an electric vehicle typical, with the batteries being configured in series to reach the voltage level of 312 V.

Type	Cell voltage (V)	Number of cells	Battery Voltage (V)	Cell Reliability (%)	Battery reliability (%)
Pb-acid	2	126	312	98.45	85.55
Ni-MH	1.25	250	312.5	97.53	77.9
Li-Ion	3.6	87	313.5	99.14	91.69

TABLE 2. COMPARISON OF SOME OF THE CHARACTERISTICS (ANON., 2021)

2 Smart Grids

A smart grid or Smart Grid is an electrical network that uses digital technologies and other advanced technologies to monitor and manage the transport of electricity from all generation sources to meet the different electricity demands of the users. (Edvard, 2012)

Smart grids have smart meters, which replace the traditional ones in homes and businesses, that can collect data and establish bidirectional communication on supply and demand between producers, network operators and consumers. Thus, it is possible to operate in the most efficient way possible, minimizing costs and environmental impacts. Taking advantage of data information and treating them. For example, power generation plants can better predict and respond to peak demand periods.

The smart grid improves flexibility while maximizing the reliability, efficiency, and stability of the electrical system, this will improve the integration of new generation methods of more intermittent electricity such as renewable energies, and new tensions in the network with electric vehicles.

2.1 Main characteristics smart grids

Some of the main characteristics that smart grids offer are:

- **Direct participation of consumers:** Smart grids allow consumers to have knowledge and control over their consumption, electricity prices and incentives, helping to balance supply/demand and ensuring reliability.
- **It adapts to any form of generation and storage:** With the growing variety of distributed energy resources, smart grids are capable to implement them into the system.
- Provides the right power depending on the needs: Not all customers need the same power, different degrees of power are supplied by the smart grid.
- **Optimization and operational efficiency:** Smart grids can be used at higher loads with the continuous control and classification of their capacities. Through maintenance conditions, they improve the efficiency at the precise moment and use system control devices to reduce losses and eliminate congestion.
- **Robust to riots, attacks, and natural disasters:** If there is a problem in the system, the electrical network isolates the faulty elements and operates with normality.

3. V2X Concept

Prior to understand and learn about the V2G technologies, it important to know about the term “vehicle-to-everything” (V2X). The term refers to technologies that use the power from EVs batteries for any application outside the vehicle.

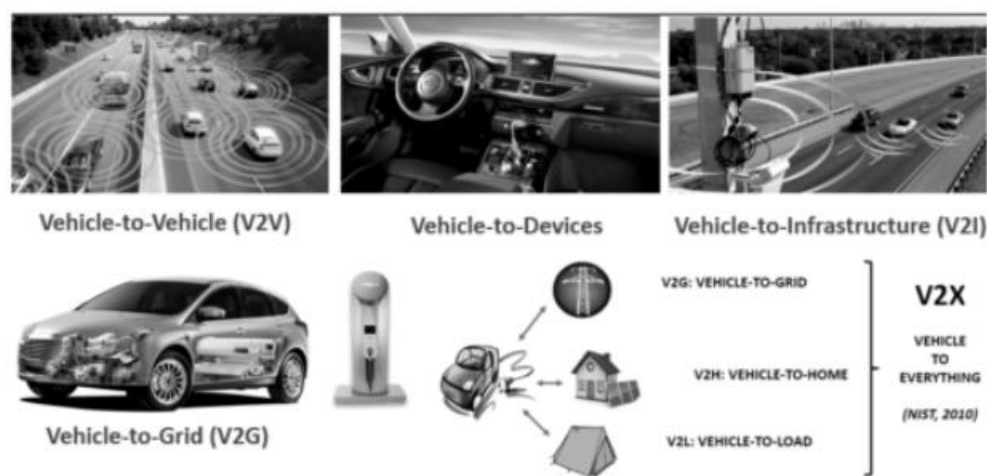


FIGURE 2. V2X CONCEPT

3.1 V2G (Vehicle to Grid)

Vehicle-to-grid (V2G) is an innovative technology based on bidirectional charge management, which transforms electric vehicles into large mobile batteries with wheels that intelligently interact with the grid.

In practical terms, vehicles draw energy to recharge during periods of lower consumption and return energy to the grid when demand is high, thus helping to balance supply and demand and avoid

blackouts. In other words, they provide services that make the network more flexible increasing stability and security.

To implement the V2G technology, some elements are necessary (Chunhua, 2013):

- Smart Grid to balance supply/demand and ensuring reliability.
- Control or logical unit (smart V2G charge), necessary for the network operator to determine the available capacity, request ancillary services or vehicle power.
- Special connector that allows the connection of the vehicle to the network and the exchange of electric power.
- On-board vehicle smart meter to measure accurately how much power or service the vehicle has provided to the grid.

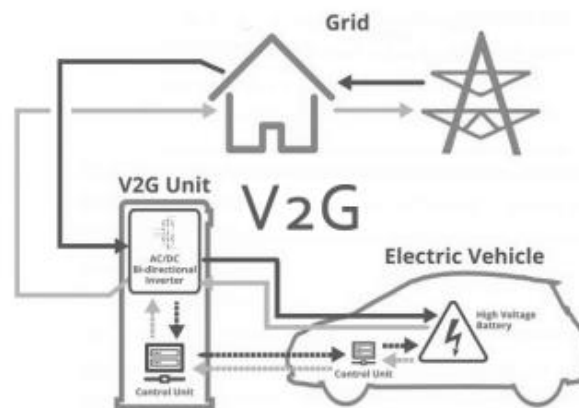


FIGURE 3. V2G DIAGRAM (CASSIDY, 2019)

An example diagram of V2G operation is shown. The EV is connected to a bi-directional charging station, which serves the home or the grid. With this, the electric vehicle can supply power to the house or the grid. There is a control and monitoring unit to provide an accurate input to the battery by comparing the reference signal built into the car and the outputs of the power converter.

In order to bring the mains voltage level to the appropriate battery level or vice versa, a bi-directional inverter is used for AC / DC or DC / AC conversion. These operations are carried out depending on the amount of energy in the battery and the charging strategy that is established.

3.2 V2G & renewable energy

One of the well-known benefits of V2G technology is the ability to complement with renewable energy sources, especially wind and solar generation. Giving the possibility of solving one of the main problems by renewable energy sources.

The main drawback is because, in this type of system, it is not possible to adapt the generation to the demand (it is not possible to control the generation of these). This causes intermittence in the renewable generation that must be controlled by the network operators and represents a great challenge. (Briones, 2012)

The role that V2G would play would be as a complement to renewable generation, since the control and regulation function of electric vehicles connected to the grid can be used to smooth out unexpected fluctuations in the production of photovoltaic or wind energy.

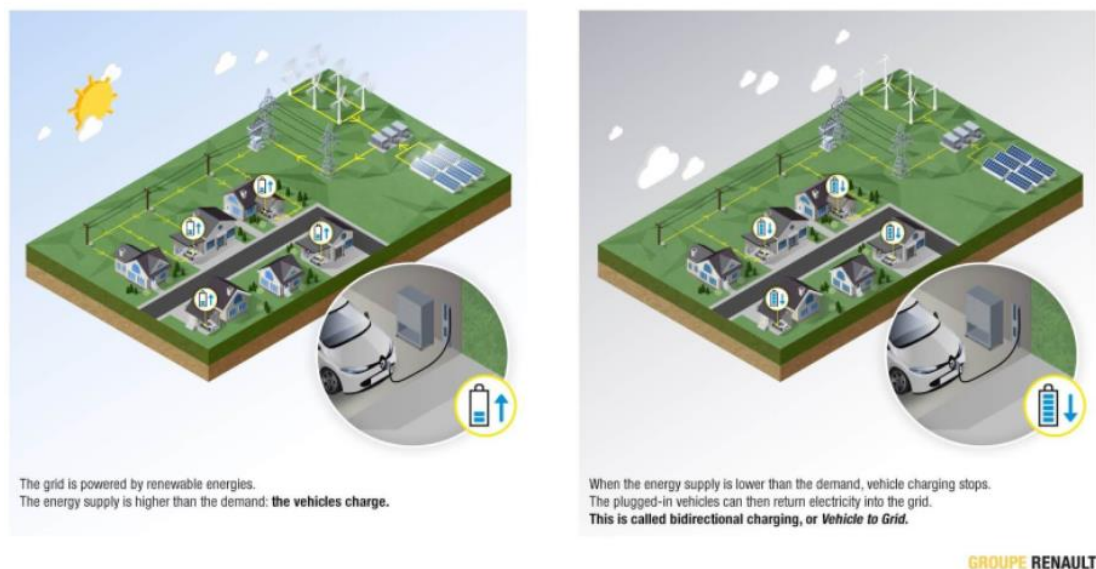


FIGURE 4. V2G & RENEWABLE ENERGIES (RENAULT, 2019)

ANALYSIS

4. Analysis on the risks & benefits of V2G

Based on all the knowledge acquired, an analysis can be carried out on the risks and benefits of using V2G technology in the immediate and the implications in the future for domestic, company and factory applications.

4.1 Risks V2G

To analyse the V2G technology the risks have been grouped into 4 different groups:

- Legal risks: Collects the risks related to the legislation that could affect V2G technology.

Legal Risks	
Risks	Description
Juridical uncertainty	The changes and instability of fiscal regulations in the medium-long term could create problems or delays and affects investments and technology growth.
Lack of market regulation	V2G is a technology that is still in development phase and testing projects. The lack of participants and regulations can cause the technology to not work efficiently, with quality, safely and continuously

Lack of standardization of the technological components and electric for Evs	The technological and electrical elements of V2G lack technological standards that allow an easy choice of them and that guarantee correct operation, reliability, and safety.
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- Technical risks: The risks that have an impact in the system (low reliability, availability, or optimization) due to technology maturity and unforeseen failures due to factors not considered that lead to a loss in efficiency and performance. (Vadi, 2019)

Technical Risks	
Risks	Description
Degradation of batteries	When batteries are used to satisfy the services offered by V2G, there is extra wear and tear that shortens their useful life. Other factors such as uncoordinated charging and discharging of the vehicle, and a poor quality of supply from the network contribute to increasing the wear and tear of the batteries. All of this leads to more frequent replacements and new investments.
Failures in subsystems of the EV	The different elements of the electric vehicle and the link with the V2G charging station are also affected by the continuous use of this technology, which may cause alterations in its behaviour and its useful life.
System failures charges produced by a lack of standardization in chargers	Different vehicle manufacturers have chosen to develop their standard chargers stopping universal access to any charger in any place due to incompatibility of connection and vehicles. This generates more problems such as failure in the communication between the vehicle and the network (supply not guaranteed) that the elements of the vehicle's electrical system are compromised, or that the loading/unloading strategy is not correctly carried out to maximize the benefits and cause additional network losses.
Component performance lower than expected	The energy conversion and transfer processes are not yet optimized, leading to higher component losses and consequently poor performance due to ineffective use of resources.

- Social/ethical risks: Risks that may create unfavourable conditions, or present a threat, that affect social welfare, sustainable development, project progress or the environment.

Social/Ethical Risks	
Risks	Description
Loss of privacy	V2G introduces a new security threat in the communication between the network operator and the electric vehicle, this implies continuous access to the data of our vehicle, which may lead to access to sensitive information or a malicious attack causing damage to the vehicle.
Increase in the social gap	V2G technology requires certain requirements for its implementation, such as a design and construction of the houses of users with a social position and average income, with which the integration of V2G can widen this social difference among the population, widening the difference in the quality of life between those who have access to V2G and those who do not.
Negative impact on the environment	Extra battery degradation causes the frequency of battery replacement to increase. Most of the batteries are lithium-ion and adequate techniques for their recycling have not been developed, in addition to the fact that there is no proper management of recycling these batteries.
Lithium extraction/mining & human conditions	Due to the high demand for batteries, more lithium needs to be mined to supply the demand. "Lithium production has required moving large amounts of dirt and rocks, and consuming millions of gallons of water to extract this precious resource. The process has often unsettled local ecosystems, threatened endangered species and disrupted nearby communities". Also, the mining conditions are not the best, most of the resource is mined in poor countries where there is child labour, and they work without even the most basic protective equipment. This high demand could create more unethical conditions.

- Economic risks: Uncertainty due to economic changes in the sector such as: the appearance of new competitors, new technologies or variation in demand or services that can lead to not achieving the expected economic objectives.

Economic Risks	
Risks	Description
Less benefits than expected for network users and operators	Only simulated results of the use of V2G are available or some projects limited to certain behaviour. Relying on this information could generate some discrepancies under real conditions.
High initial investment	The integration of this technology entails high financial investments due to the construction of support infrastructure for this technology.
High price spare parts	V2G causes additional usage for components involved, causing more wear and tear, which means that these must be replaced in advance and reinvest. These spare parts could have higher prices due to the technology being recent.

4.1 Benefits V2G

To analyse the V2G technology the risks have been grouped into 3 different groups:

- Social benefits: The benefits that imply an improvement in social and environmental well-being.

Social Benefits	
Benefits	Description
Helps raise awareness of responsible consumption	The opportunities offered by V2G can mean a change in the behaviour, or the thinking of the population to show interest in electric vehicles and the way of using energy.
It helps to achieve the EU's energy and climate framework targets for 2030.	The integration of V2G favours the achievement of the goals and objectives proposed by the European Union on the political objectives in the framework on climate and energy for 2030. Among them, the reduction by 40% of greenhouse gas emissions, a 32% share of renewable energy use and a 32.5% improvement in energy efficiency.
Positive impact on the environment	The use of V2G allows the use of EV as a source of generation, which would lead to helping to reduce the carbon footprint, damage to health and favouring the energy transition
Increase employment	V2G would mean the need for new figures in the electricity market and new producers of the components that make up this technology, which would lead to the hiring of new workers for the sector

- Technical benefits: Which are related to the operational and functional benefits of V2G integration. (Steward, 2017)

Technical Benefits	
Benefits	Description
Support for renewable energies	V2G provides a solution to the problem of the intermittency of renewable energy sources, such as the wind or the sun, which depend on the load and serve as a technology for storing excess energy for use at peak hours. This technology is also highly complemented by renewable energies in the home and can serve as support or energy backup even in emergency situations such as blackouts or natural disasters.
Offers auxiliary services	This technology increases quality, reliability, and sustainability by reducing frequency regulation and harmonic distortion. In addition, the use of EVs as a rotation reserve reduces the size of the generators, reducing their wear, tear, and costs.

- Economic benefits: Which are related to the operational and functional benefits of V2G integration.

Economic Benefits	
Benefits	Description
Economic savings for EV owners	The user can receive an income with the use of V2G and the provision of services. In addition to other additional savings such as fuel when purchasing an electric vehicle. This energy also offers freedom when deciding how to handle our electricity.
Economic savings for entities	This technology offers the possibility of keeping the electricity supply stable, safe, and continuous at a lower cost than conventional methods.
New business model	With the arrival of this technology, a new opportunity opens for a new business model. For example, V2G equipment manufacturer.

Conclusion

Looking at the risks and benefits of this technology, there is still much progress to be made to make it viable. Still, V2G has the potential to be something feasible going forward, driving innovation and freedom in many users, as well as pushing the creation of more renewable energy.

Now, diesel oil and gasoline are paid at the price set by the oil companies and electricity from the houses at the price set by the electricity companies. This technology can be a great change in the future because, every person who has an electric car, and has a bidirectional charge, could be, within their possibilities, the owner of the consumption of their electrical energy.

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