

## Review of Battery Charger for V2G Application

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### Abstract

*At present, V2G(vehicle to grid) technique is received more and more attention due to developing of renewable energy sources. So, development process of EV(electric vehicle) technology is introduced in this paper and relative difficulties in V2G is analyzed. The main difficulties including the service life of battery, control strategy of current and the EVs paralleling into the grid. Battery charger is one of the key technologies of V2G. The charger consist of a filter, an AC/DC converter for grid interface and multiple bidirectional DC/DC converters for EV battery management, and a direct-current control mechanism is employed for ac system bus voltage and dc-link voltage control. Simulation results show that the AC/DC converter and the DC/DC converters have the function of electric power flowing with two-ways. Finally it points out the development direction of V2G technology.*

**Keywords:** vehicle to grid; AC/DC converter; bidirectional DC/DC converter; the strategy of control

### 1. Introduction

Nowadays, as a charging load, EVs are growing rapidly and getting market penetration in the recent years. The basic concept of V2G technology refers that the EVs feedback energy to the grid in the spare time. That is to say, these EVs in the electricity not only can absorb energy from the grid, also can feedback energy to power grid in the peaking seasons, reducing the difference of daily electricity peak-valley load.

In 1995, V2G technology was putted forward by Dr Amory Lovins, there are a lot of experts and scholars at home and abroad who continue to study the technology. In 2005, the United States at the university of Delaware Willett Kempton, PhD, and his team conducted a thorough research to the V2G project, 2009 Germany Dirk we Sauer published some articles about the influence of V2G technology in the removable storage. In the UK, university of Warwick is also researching. Currently Nissan motor company work together with the United States General Electric (GE) united team about the V2G technology research. This technology in China only a few power grids and research institutes study this technology, to the end, China and the United States signed a cooperation agreement about the technology, therefore, the technique will reach to the height of the international cooperation strategic.

A circuit topology structure of EV's charging converter based on the space vector is presented [1-3], the control strategy uses rotation vector, the main circuit of the machine adopts isolation method. The technology of PWM (pulse width modulation) and the electric-vehicle energy storage system (EVESS) are roll-outed by some researchers [4-5], it is essential to evaluate how much power can be exchange between EVESS. Compared to the traditional modulation technician, PWM modulation can obtain an advantageous performance and ideal simulation waveform. In the V2G system, the energy of the battery management system is very important [7], a methodology for maximizing the run-time of a battery driven car

varying the speed of a battery has been proposed in literature [8], so the optimal option become one of research hot spots, a multilayer AC grid including power grid layer and gradable vehicles aggregation layers is established [9]. A large number of electric grid will inevitably lead to the power grid is not stable, produce more of the harmonic and reactive power losses, but the V2G interconnection technology plays a role of peak peel [10]. Due to every user of EV in the different periods will lead to the difference of daily electricity peak valley load , at the same time, we need a kind of energy to compensation [11].

The remainder of this paper is organized as follows. The second section describes the difficulties in the battery charger of V2G technology; Section III are described and analyzed the keys of this technology and research; finally the development direction of the future EV in V2G technologies of charging and discharging.

## 2. The Difficulties of Battery Charger in V2G Technology

V2G technology is a key part between EVs and the grid, and the charger is the core technology. This charger is mainly composed by filter, AC/DC converter, bidirectional DC/DC converter and energy storage batteries; Figure 1 for the charger structure diagram in V2G.

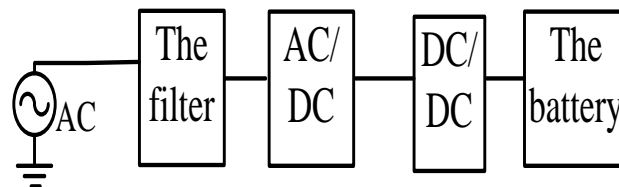


Figure 1. Structure Diagram of the Charger in V2G

Domestic research on V2G charging and discharging technology is relatively small, the reason is the V2G technology involves the research difficulties which in the aspects of the battery charging and discharging, EVs interconnect with grid, bidirectional converter control. The difficulties of V2G charging and discharging machine technology are:

(1) Charging and discharging repeatedly will affect the service life of the storage battery.

Battery is one of the main d rived energy of EVs, the life of the battery which directly affected EVs maximum mileage, and the cost of the battery directly affects the cost of a vehicle. The Literature [10] analyzed the battery charging and discharging process and battery's SOC (state of charge) through energy storage battery charging and discharging requirements.

Battery charging and discharging method has been classified into permanent current charging, constant voltage charging, charging pulse. Constant current charging used by most of the cells in series battery pack, small current charging mode for a long period of time, but the longer charging time , the more gas produced , the higher energy consummated. And constant voltage charging is simple, less gas produced, charging time is shorter, the efficiency can reach eighty percent, but the circuit is easy to up the maximum, which will cause the damage in the battery; Pulse charging is using pulse current charging and reverse current short-term discharge method to eliminate polarization.

(2) Control strategy of the battery charger in V2G technology

V2G bidirectional charger not only achieve the energy flow and ensure current sinusoidal on the net side, but also guarantee that the reasonable to the storage battery charging and discharging. Converter strategy is divided into the control of

linear and nonlinear control [7], linear control with cyclic control, namely voltage type control. The control structure is simple, strong anti-jamming capability, but the response speed is slow, and it need additional circuit to limit the output current; Two loops control, the introduction of the output voltage and inductance current as feedback amount two states at the same time, it belongs to the current mode control, when the duty cycle is greater than 0.5, harmonic oscillation will be generated, so it is necessary to join the compensation slope for eliminate.

In the battery charger, the control strategies of AC/DC converter and DC/DC converter are independent with each other, AC/DC converter control system is responsible for the control of AC/DC side active power and reactive power flowing, to ensure the net side current sinusoidal and maintain bus capacitor charging and discharging while it is being recharged that the voltage of Cdc is constant at both ends. DC/DC converter control system is to reach the effect of voltage modulation.

(3) The influence of the EVs parallel into the grid.

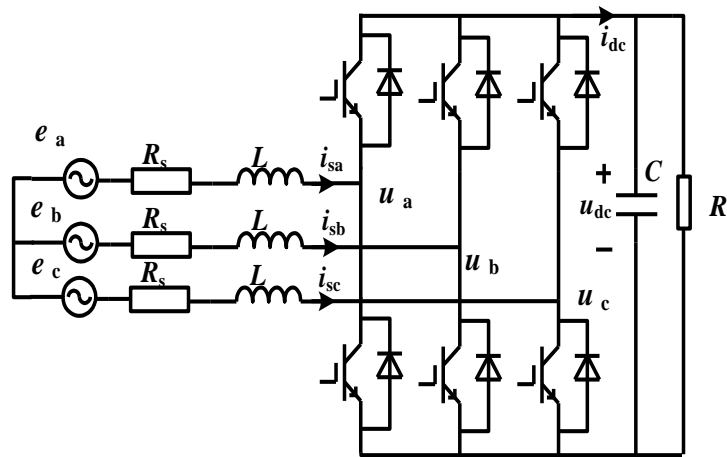
Sometimes, if the vehicles participate into the grid randomly, it may cause the charging and discharging control chaos. In this case it cannot have been expected peak "cut" and it's possible to appear on "peak", instead of the impact of power grid. Battery charge and discharge frequently on the depth and disordered, it will inevitably lead to battery life reduce and damage the interests of the electric car users. Finally users are reluctant to participate in the interaction of V2G technology. The literature [12] analyzed that the influence of V2G into to power grid, including harmonic analysis. The literature [13] through the analysis of the root mean square and the standard deviation curve to study the peak shaving and valley filling on the V2G technology of grid system.

### **3. The Key Technologies of the Battery Charger of V2G**

The key technologies of the battery charger are aimed at the difficulties of the technology research. As mentioned above, charger need to complete the function of energy flow in two-ways, it will inevitably produce harmonic pollution, and cause enormous influence to power grid, and even affect the normal operation of the power grid. Therefore, in the key technology of the battery charger in V2G mainly has two aspects: AC/DC converter and bidirectional DC/DC converter.

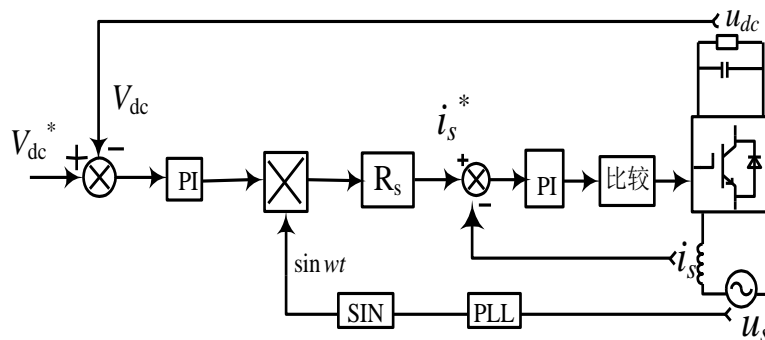
#### **3.1 AC/DC Converter**

The realization of the V2G technology requires the input side rectifier current sinusoidal, unit power operation, the dc output voltage constant and to realize two-ways flow of energy. At present, most of the research topology based on two-ways energy flow is AC/DC voltage source PWM rectifier circuit. Rectifier converter topology structure as shown in Figure2.



**Figure 2. Rectifier Converter Topology Structure**

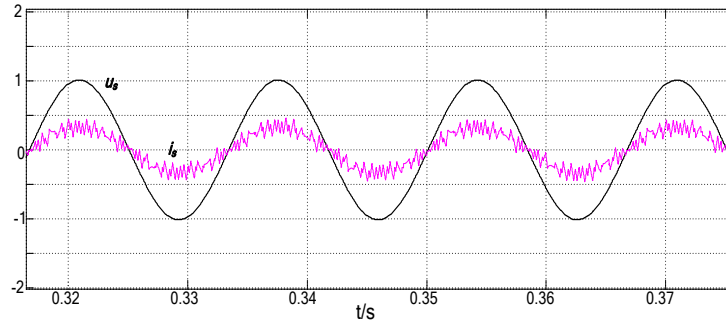
Circuit uses IGBT switch tube, with a diode in parallel, to realize the two-way synchronous rectifier and energy flow. PWM rectifier control strategy of the converter is mostly adopts linear control, literature [9] put forward the various control methods and analyze their advantages and disadvantages of the rectifier, and finally, comprehending the above research, this paper adopts a synchronous rotating coordinates based on the current decoupling control strategy, in order to obtain a stable output voltage and the least amount of harmonic pollution. Bidirectional AC/DC converter control structure diagram as shown in Figure3.



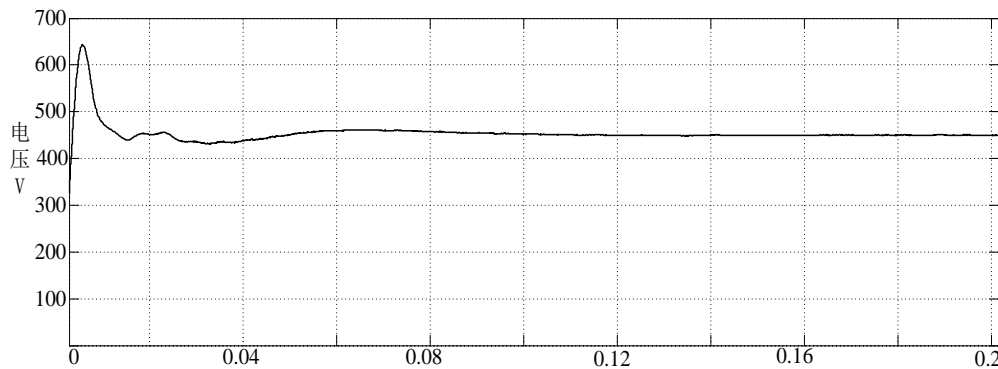
**Figure 3. AC/DC Converter Control Structure Diagram**

We established a simulation mode of the battery charger in Matlab/simulink, the simulation result of rectifier is shown in Figure4 and Figure5.

From the diagram, the phase of voltage and current at the side of power grid is no difference, so the transmission power factor of the charger is 1, the dc-link voltage is consistent with the given voltage value.



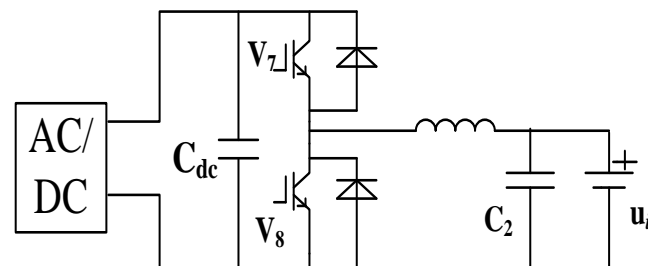
**Figure 4. The Waveform of Voltage and Current in the Grid**



**Figure 5. The Waveform of the Dc-Link Voltage**

### 3.2. Bidirectional DC/DC Converter

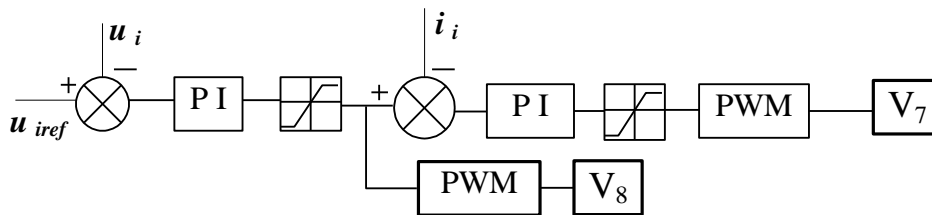
The range of battery voltage is larger, if the battery is connected to the motor directly, that may make the motor driven performance deterioration. Now it is necessary to access bidirectional DC/DC converter between the motor and battery. The literature[7] put forward two single-phase DC/DC converter in parallel for implementing two-ways of energy flow, but two uni-direction DC/DC in parallel will lead to the system become complicated inevitably, and reduce stability of the system. Ultimately, V2G system will do not conform to the requirement of vehicle production. Half bridge of bi-direction DC/DC converter topology was proposed [4], as shown in Figure6.



**Figure 6. Half Bridge of Bi-Direction DC/DC Converter Topology**

For achieving the two-ways flow of energy, bidirectional DC/DC converter topology is composed by two unidirectional DC/DC converters in parallel and a set of reverse switch and diode device. The control strategy of bidirectional DC/DC converter is the closed loop, the charging and discharging work mode control

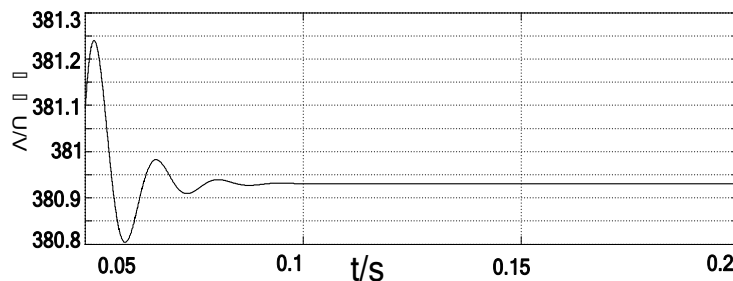
strategies are disparate, Figure7 for the charging and discharging mode of the DC/DC control block diagram



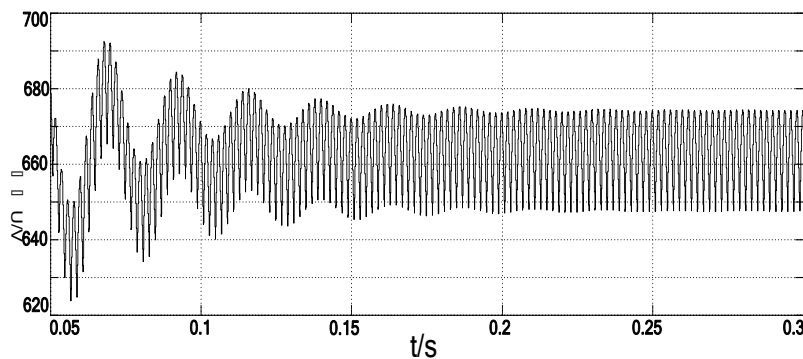
**Figure 7. The DC/DC Control Block Diagram**

The simulation result of his part is shown in the Figure 8 and Figure 9, this DC/DC converter can complete the function of electric power flowing with two-ways, that is to say, the circuit is able to charge or discharge.

When the DC/DC converter is charging, the converter is regarded as a buck circuit; the output voltage is reduced comparing with the DC-link voltage.



**Figure 8. The DC/DC Converter is Charging**



**Figure 9. The DC/DC Converter is Discharging**

In the Figure9, the converter is regarded as a boost circuit. Although the output voltage can reach steady state and as a booster, the output citric is still need to continue to modify parameters for achieving more ideal effect.

#### 4. The Direction and Prospect of V2G Technology Development

Since 2001, our country put forward to the study policy of three horizontal and three vertical layout, so the country invested a huge sum of money to research in terms of pure electric vehicles, fuel cell vehicles and hybrid. At present, the V2G technology is still in the primary stage of practical application. The international organization has posted EVs charging and discharging system standards (IEC

standard), but which remains to be further perfected. Charging and discharging behaviors in V2G technology are uncertain and random in charging time, charging place, and driving or not, so the speed of study on V2G technology is slow. Research of V2G technology at home and abroad mainly is a topological structure, as well as the load of charging process and the nature of battery system research. Performance of battery which is good or bad determines the V2G charging and discharging functions. Research of V2G technology in the future is major in the control strategy s and discharging process control. In addition to, research of intelligent energy management system will be an important direction of future research. Contrary

World energy is becoming insufficient gradually, so the use of EV is also changed more and more widely. The battery charger is the important part of V2G technology of EVs. The core of the technology in the future will be more and more studies in the aspect of intelligence, we will make better use of the EVs, for the environment, energy, even the power system.

## 5. Conclusion

This article described the V2G technology development and the key technology of battery charger in detail; we understand the difficulties of the V2G charging and discharging technology, and through the technical problems to study the key technology of V2G control strategy and its charging and discharging process. Simulation results show that the AC/DC converter and the DC/DC converters have the function of eclectic power flowing with two-ways. All of the EVs research at home and abroad spends a lot of money and talents for the future to make more contribution on the research of this aspect, to make the V2G charging and discharging system more intelligent and more convenient application. Ultimately, it can bring more economic benefit for the society.

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