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**Model of EV Battery and Charger**

*J. Bhanu Sahithya\**, *T. Mounika\*\** and *K. Sai Deepika\*\*\**

**ABSTRACT**

*In this paper, battery and charger model of electric vehicle was introduced and the characteristic of them was analyzed. Electric vehicle can reduce emissions to protect our city environment, as well as human's dependence on petrol. Therefore, it has become one of the world's common targets to develop the technology of electric vehicle. For different research needs, proper battery and charger model are recommended.*

**Keywords:** *Electric vehicle; Simulaiton; Battery model; Charger model.*

**1.0 Introduction**

At present, cherishing the earth's limited petroleum resources, protecting human survival environment, reducing the emissions of greenhouse gas, and stopping global warming trend have become the world's common topic. Car, as the product of modern social industry, bring great convenience and comfort to our life. To solve these serious problems, the auto industry must lay its direction of development on environmental protection, clean, and energy saving. The power of electric vehicle (EV) is supplied by electric power, and it generally uses the high efficiency rechargeable batteries as power source. Therefore, the electric vehicle has a lot of advantages that fuel car can't rival.

**1.1 Electric vehicle can reduce emissions**

The electric vehicle doesn't give off tail gas. Even if the power consumption will be corrected for the discharge of power plant, besides sulfur and particles, the other contaminants are also significantly reduced. And most of the power plants are built in the places that are far away from the densely populated cities, and the emissions are discharged together, so they are easy to remove.

**1.2 To reduce dependence on petrol**

The electrical energy used by electric vehicle is secondary energy, which can be converted from

wind, water, nuclear, heat, solar and so on. And many of these kinds energy are clean and renewable.

**1.3 Electric vehicle can reduce energy consumption**

The surplus electric power in the evening can be used by electric vehicle, which greatly improves the economic benefits of power equipments. Research has shown that the energy utilization efficiency of oil refined by thick and sent to the power plants to drive vehicles, is higher than refining it into gasoline to drive vehicles.

**1.4 The electric vehicle makes lower noise**

The electric vehicle motor's noise is small, even close to the high speed is the functioning of the motor won't feel uncomfortable noise, and the internal combustion engine noise is very big.

Now in the United States the "Vehicle to Grid" (V2G) concept is on the rise. V2G reflects the relationship between electric vehicles and the power grid. These vehicles' power batteries can be understood as a distributed energy storage unit of smart grid. When the battery needs to be charged, the current flows from the power grid to cars, contrarily the owners can give the battery power back to the intelligent power grid system.

The V2G bidirectional charging and discharging device based on PWM, can realize the

\*Corresponding author; Wipro Technologies, Bangalore, Karnataka, India (E-mail: Bhanusahithyareddy1907@gmail.com)

\*\*Wipro Technologies, Bangalore, Karnataka, India (E-mail: thamattam123@gmail.com)

\*\*\*Wipro Technologies, Bangalore, Karnataka, India (E-mail: karanamsaid@gmail.com)

energy interaction between power grid and the electric vehicle, and significantly inhibit harmonic interference, effectively improve the power network operation quality, as well as save energy. So it can provide a stable and efficient charging and discharging power supply for the electric vehicle battery. However the V2G model is still at the demonstration stage, and still needs study [2].

Digital simulation is a powerful tool and the model of EV is the basis. So the battery and charger model was research in this paper.

**2.0 Battery Model of Electric Vehicle**

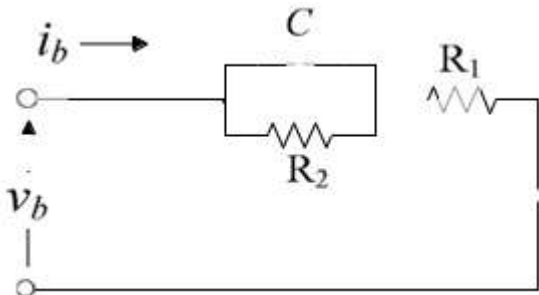
Power battery of electric vehicle is a key part of the vehicle’s power system, which is very important for vehicle’s economy and security. Battery performance model (or battery model) shows the characteristics of battery during work, which is an indispensable link in simulation of the electric vehicle system, and also is one of the difficulties in modeling the electric vehicle system.

The battery model can be divided into four kinds, namely, the electrochemical model, the hot model, the coupled model, and the performance model. Based on the need of electric vehicle simulation, the researchers designed three kinds of equivalent circuit model as following.

**2.1 Thevenin equivalent circuit model**

Thevenin equivalent circuit model (as shown in figure 1) is the most representative of equivalent circuit model, which is the foundation of other complex equivalent circuit model [3].

**Figure 1: Thevenin Equivalent Circuit Model**



In the model, the capacitance C and resistance R2 (to describe the potential) are in parallel, and then connect to the voltage source VOC (to describe open voltage), and resistance R1 (battery resistance). With the battery working conditions and internal

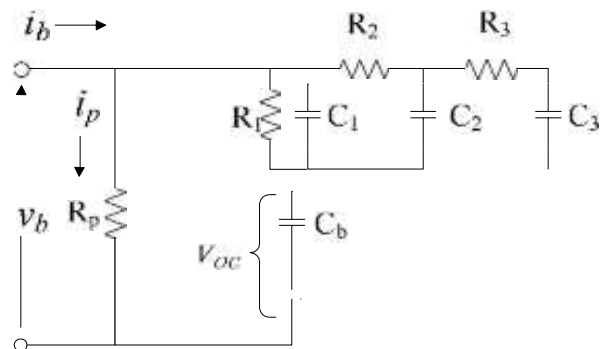
state changing, Thevenin equivalent circuit model’s parameters don’t change, so the accuracy of this model is poor.

**2.2 Improved thevenin equivalent circuit model**

The linear equivalent circuit model [3] is shown in figure 2. The model is the improvement of the Thevenin equivalent circuit model. The open voltage VOC is the voltage sum of the source voltage EO and the capacitance Cb. Then it connects to a circuit network which is composed of three capacitances C1, C2, C3, and three resistances R1, R2, R3 (describe the potential), and all of these components in parallel is a self-discharge resistance.

Rp. The parameters in this model can not be affected by temperature and other factors.

**Figure 2: Improved Thevenin Equivalent Circuit Model**



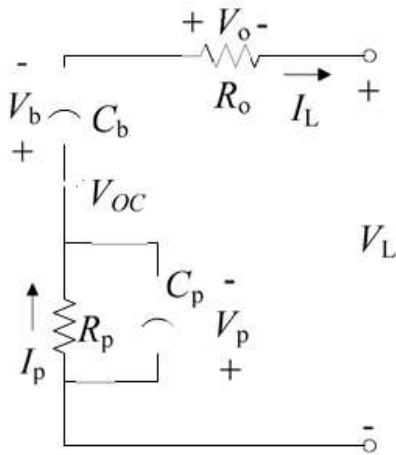
**2.3 PNGV model**

The nonlinear model of EV power battery was shown in fig.3. The components in this circuit are mostly not constant, they are affected by voltage, temperature or SOC, and so this model is closer to the actual battery. Among all this kind of model, PNGV is the most representative one. Its physical meaning is clear, and the test of model parameter identification is easy to perform [4]. At the same time, it is a high precision model. Therefore, it is the often used at present.

In the model, VOC means the open voltage of the battery; Ro stands for internal resistance; Rp is polarization resistance; capacitance Cp and Rp is in parallel; tisa constant describes the polarization time (t = CpRp); IL refers to load current; Ip is for the current on the polarization resistance; UL is for load voltage; capacitance Cb is used to describe change process of open voltage when the load current

accumulating with time. Based on the circuit principle the state equation of PNGV model is shown as follows.

**Figure 3: Structure of PNGV Circuit Model**



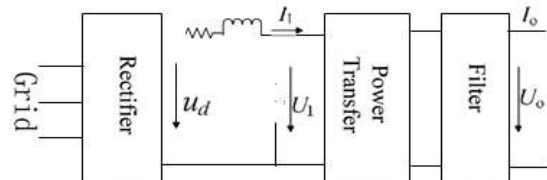
### 3.0 Charger Model of Electric Vehicle

The charging machine is one of the main equipment of the electric vehicle charging station. Charging machine is a kind of power electronic equipment, which is composed of rectifier, DC-DC converter and so on. The capacity of one charging machine is affected by many factors, such as the kind and charging characteristics of battery, the type and working characteristics of charging machine, or the charging method and charging control strategies of battery. Currently, the high frequency charger is very popular.

The battery is conventionally charged by constant current or constant voltage with small current. Once discharged, the battery should be recharged immediately (no more than 24 hours). The charging current is as low as about 15A, while the charging time commonly last from 4 to 6 hours. Compared to other charging method (such as fast charging), it has many advantages: the costs of machine and installation are low; making full use of the power at off-peak time to reduce the cost of charging; the charging efficiency can be improved and the life of the battery can be extended. The disadvantage is that the charging time is too long in case of emergency. The working principle of charging machine is as follows. Firstly, the inputting three-phase alternating current is rectified by rectifying circuit. Then through filter circuits, it provides direct current for high-frequency DC-DC

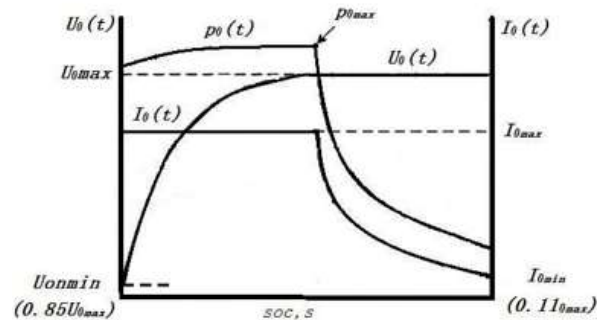
power transfer circuits. Lastly, the output of power transfer circuits goes through the filter circuits, to charge the vehicle battery. The principle block diagram is shown in figure 4.

**Figure 4: The General Structure of High-Frequency Charger Block Diagram**



Currently, the two stage charging method is usually applied in the charging method and its control strategies [5], which means cc/cv(constant current and limited voltage in the first half period, constant voltage and limited current in the second half period).When taking CC/CV charging methods, in a complete charge cycle, the typical curve of the output current  $I_o(t)$ , voltage  $V_o(t)$  of charger, and the output power  $P_o(t)$  are shown in figure 5, in which  $U_{omax}$  and  $I_{omax}$  are the basic parameters according to battery types and charging characteristics.

**Figure 5: Typical Curve of Charger Parameters in a Charging Process**



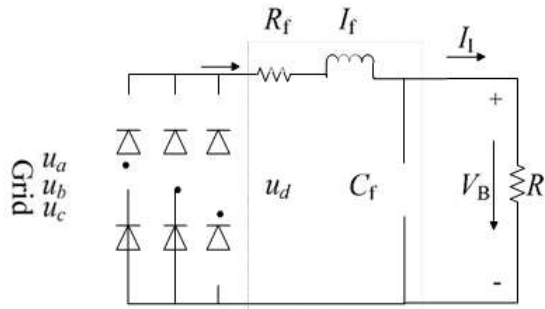
In this figure, from charging period beginning, the output power of the charger increased gradually, and then arrived at the peak, finally gradually decreased.

### 3.1 Charger model of 6 pulse commutator

Conventional charging time of a charging machine generally lasts about 300 minutes. In this process, the output voltage and current keep changing. But when we consider it in a very short

time, such as “ds”, the output current  $I_o$  and voltage  $V_o$  can be thought as constant. That is, in ds, a nonlinear resistor  $R$  can be used to simulate the input impedance of high- frequency power transfer [1]. The approximate equivalent model is shown in Figure 6.

**Figure 6: Efficiency Measurement Model of Uncontrolled Rectifier EV Charger**



In this figure, the uncontrolled rectifier takes place of the rectifier equipment, including 6 uncontrolled diodes, which is the equivalent model of 6 pulse uncontrolled rectifier charger. It changes three-phase alternating current to direct current, to provide power supply for electric vehicle battery.

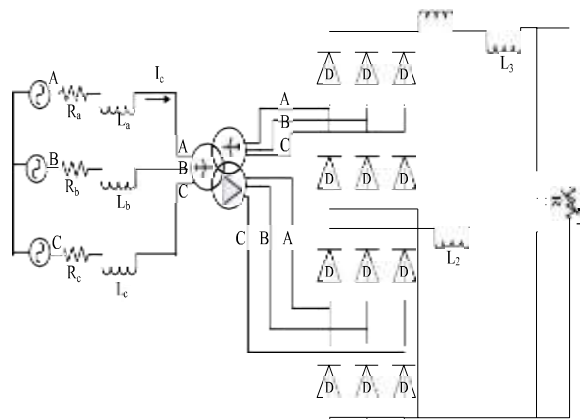
**3.2 Chager model of 12 pulse commutator**

If the rectifier is composed of 12 diodes, the model can be called the 12 pulse rectifier. The circuit can be divided into parallel and serial. But when the rectifier is applied to the charger, we need to control the voltage of the rectifier on the DC side at a low level, considering the input voltage of the power transfer can't be too high. So the 12 pulse rectifier circuit should use parallel connection circuit.

To make the output instantaneous voltage of the two rectifier bridges in the 12 pulse rectifier stagger 30° in phase, a three winding transformer is used in the power system of the two rectifier bridges. One of the two windings on secondary side is connected in "Y", another is connected in "triangle", so the output voltage of the later one is 30° ahead compared to the former. As the two transformer windings stagger 30° in phase, and the instantaneous output voltages of the two rectifiers in parallel are not equal, a rectifier shuts off because of back pressure, we need add a reactor to ensure that the two rectifier conduct at the same time [6].

When the 12 pulse uncontrolled rectifier and the 6 pulse uncontrolled rectifier are at the same system, they have same voltage on DC side, so the value of each point of nonlinear resistance  $R$  is same, so as control strategies. In conclusion, the simulation topology of 12-plus rectification charger access system is shown in Figure 7.

**Figure 7: Simulation Topology of 12-plus Rectification Charger Access System**



When running the model, we can measure the electric parameters of each point, such as harmonic current, power factor, efficiency and so on.

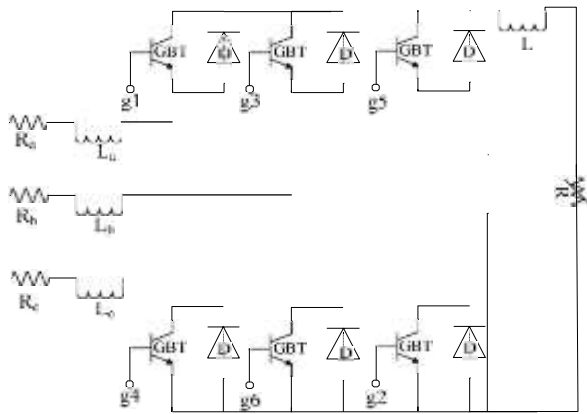
**3.3 Chager model of PWM commutator**

The conventional rectifier part often uses uncontrolled diodes or controlled thyristor to compose rectify circuit, which will inject much resonant wave into grid, bringing pollution to grid. As a kind of device connecting power grid and power transfer device, electric car charger's rectification device uses PWM technology. The main purpose is to achieve the control of the unit power factor in the rectifier, and the key is to control the grid current [6]. On one hand, by controlling voltage of PWM rectifier on the alternating side, we can control current on the grid side indirectly. On the other hand, the current on the grid side can also be controlled directly by close-loop controlling strategy. The simulation model of PWM rectification charger is established as Figure 8.

The PWM rectifier charging machine's main circuit use three-phase voltage source PWM commutator consisting of IGBT and diode. The control circuit uses the 2-loop control strategy, namely, the voltage outer loop and the current inner

loop. The main role of inductance on alternating side is to isolate the voltage on grid side and alternating voltage of rectifier, and filter out the PWM rectifier's harmonic current, in order to make the rectifier's current waveform keep good while transferring reactive power to grid. The main purpose of capacitance on alternating side are to buffer the energy transfer between rectifier bridge's alternating side and the DC load side, to stabilize voltage on DC side of VSR, and to suppress harmonic voltage on DC side. Besides, the power switch tube must inverse parallel a diode, to cushion the reactive power in PWM process.

**Figure 8: Simulation Model of PWM Rectification Charger**



#### 4.0 Summary

In this paper, battery and charger model of electric vehicle were introduced. Comparing with

Thevenin equivalent circuit model and improved Thevenin equivalent circuit model, the PNGV circuit model has more advantages. The physical meaning of PNGV model is clear, and the test of model parameter identification is easy to perform. At the same time, it is a high precision model. So the PNGV model was recommended as the battery model of EV. Three kinds of charger model were introduced and the characteristic was analyzed separately. The PWM commutator model is essential for V2G simulation.

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