Research on orderly Interaction between Electric Vehicle Charge/Discharge and Power Grid

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Abstract: The development of electric vehicles can effectively solve the three problems of greenhouse gas emission, energy consumption and exhaust emission in the transport sector. The introduction of electric vehicles will bring a series of troubles about stability, safety and economic operation to the power grid because of the random and intermittency of electric vehicle charge/discharge. Based on the study about characteristics of electric vehicles including charge/discharge, charge demand and the impact of large-scale electric vehicles on the grid, an orderly interaction mechanism between electric vehicle charge-discharge facilities and power grid is put forward. From modeling and simulation for charge/discharge control management system, it can be concluded that this method can effectively utilize the charge/discharge behavior of electric vehicles to carry out grid peak load shifting.

Introduction

Climate change, energy and environmental issues are the long-term problems facing human society. With the United States expressing its return to COP15 (the Fifteenth Meeting of the Parties to the United Nations Framework Convention on Climate Change) and emerging countries represented by China and India, as well as the active implementation of energy and environmental protection strategies in major countries, the world has entered the era of truly solving the common problems of human society. The major problems in the transport sector about greenhouse gas emissions, energy consumption and exhaust emission have a direct impact on human survive and development as well. Therefore, main countries, governments, organizations, automobile manufacturers, energy suppliers and venture capital enterprise act together to promote the global automotive industry in order to upgrade the industrial structure and power system of the strategic transformation of electric vehicles, and boost the sustainable development of electric vehicle society, which can effectively address the three major problems.

Electric vehicle is not only a transportation tool, but also a special electric load. When there are a large of electric vehicles in a city, the randomness and intermittence of its charge-discharge behavior will produce a deep impact on a city's power grid, which will affect the stable operation of the grid. Based on the study of electric vehicle charge-discharge characteristics, charge demand characteristics and the impact of the grid on the majority of electric vehicle charge, this paper discusses the orderly interaction mechanism between electric vehicle charge-discharge facilities with power grid, establishes the order charge/discharge control management system and guides the charge-discharge behaviors to help grid peak load shifting.

Characteristics of electric vehicles and influence on grid

Charge curve

Electric vehicle battery whose maximum charge power of single module is 400W is taken as example, $P_{max} = 4$, and inflection point of charge curve is m=150s. The relationship between the charge instantaneous power P with the charge time t is as shown in Fig.1.

$$\begin{cases} 0.79 * 0.1048^{t} * p_{max} & (t > 1 \\ e^{-0.03*(t-150)} * p_{max} & (t \leq 1 \end{cases} \quad (1)$$

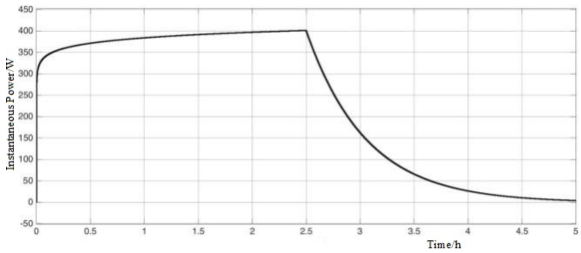


Fig.1 Function relationship between battery module charge power P with time t

In charge process, the relationship between the electricity of the module with time is obtained by integration, as shown in Fig .2.

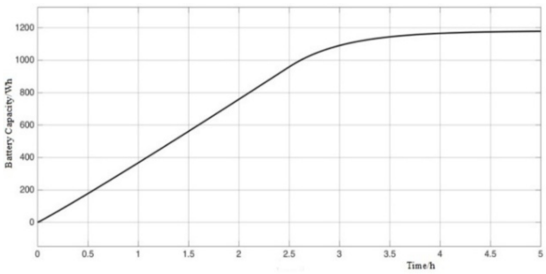


Fig.2 The function relationship between battery capacity b with time tin chargeprocessof battery module

As is shown above, two peaks of residents' electric vehicles charge are during the work and at night. And the peak charge location is near company parking lot and residential parking lot.

Influence of disorderly charge on Grid

According to " Annual Report on Beijing Transportation Development in 2011" [1]thatthe statistical data were processed and the maximum likelihood estimation method was used to make the time of arriving at company and home as normal distribution, the trend of the disorder load charge curve is[2] as shown in Fig. 3.

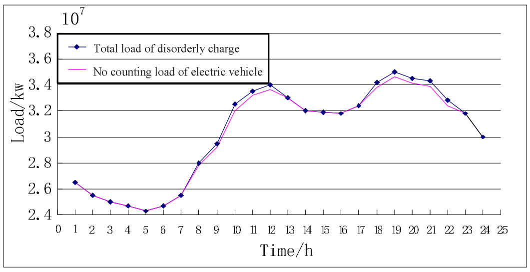


Fig.3 Load curve of electric vehicles' disorderly charge in 2012

Taking the load curve of district and the charge behavior of residential parking lot as the research object, the load curve of Yangjiaping district in Chongqing in 2016 was intercepted[3]. After being smoothedthrough formula fitting, the district load curve without introducing the load of the electric vehicle can be obtainedas a function for simulation as shown in Fig 4.

$$y = -0.0026x^5+0.1543x^4-3.2606x^3 + 29.478x^2 - -98.191x + 214.24 \quad (2)$$

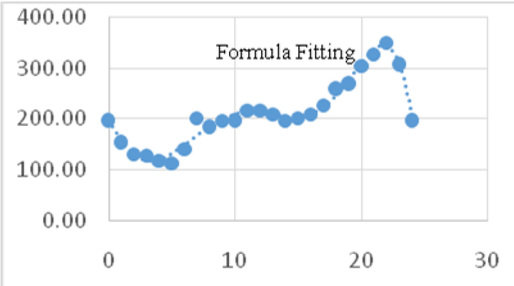


Fig.4 Load curve fitting of a district in Yangjiaping, Chongqing

As a district parking lot, the charge peak of the electric vehicle during the day outside does notbe considered but the state of disorder. Electric vehicle charge peak is in the evening, and the maximum load ofcharge is10%, 20% thedistrict maximum load. Then the modelis shown as as shown in Fig .5and Fig.6.

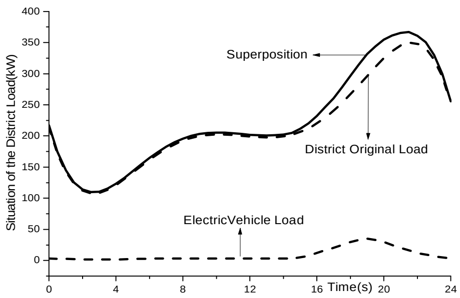


Fig.5 Impact on the power grid configuring 10% electric charge disorderly

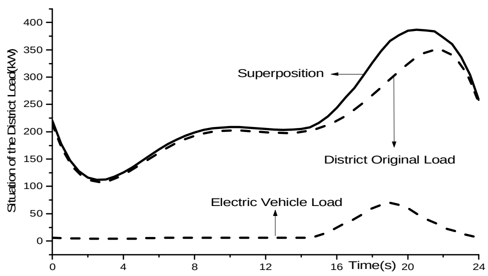


Fig.6 Impact on the power grid configuring 20% electric vehicle vehicle charge disorderly

As shown above, most of the electric vehicles in the district are family cars which need to be charged after work, and the charge curve shows that the first 3 hours of charging pure into high power,while the late 3 hours gets gradually declining power. Meanwhile,the charge curve of electric vehicle can be got with the normal distribution law of large-scale charge under disorder state being considered. After superimposing the load with it, conclusions come that the peak load of the district is about 1 hour ahead of time, and the grid burden of night peak will increase.

Modeling and simulation

Foundation of modeling

(1) Taking peak load shifting as target.

Peak clipping: the user is not recommended to charge in the peak load of the grid; sufficient battery can send their power to the fixed loadin manner of off-grid (low cost)and inverter at the peak vertex, which can reduce the burden on the grid.Valley filling: users may be encouraged to charge in manner of reducing the electricity price in the time of power grid trough.

(2) To facilitate the user as the principle

Electric vehicle is same as ordinary cars. It is the most important to ensure that the user can utilize it easily and orderly charge-discharge mechanism[5]. The user can be provided a reference about performing a charge-discharge operation after given the charge-discharge signals, which need to take into account the load status of the grid and all kinds of electric vehicle battery power, and carry out overall planning.

Control logic relationship

(1)Grid information:the time of sharp, peak, flat and valley can be dynamically imported through the grid interface, or manually input through the interface.User1_gird_state, User2_gird_stateand User3_gird_state represent their own grid information status of the region where user own is located.

(2) The battery power information is expressed as a percentage and divided into five sections. Each section can derive dynamic terminal control logic through logic analysis with the grid information as shown inTab.1.

Tab.1 Terminal Control Logic (Battery Charge and Discharge orderly)

Grid StateTerminal Control LogicBattery State	b<15	15=< b< 50	50=< b<85	85=< b<100	b=100
Tip （user1_gird_state = 1）	1203110	1203110	1302110	1302110	1103021
Peak （user1_gird_state = 2）	2203111	2203110	2203110	2302110	2103021
Flat （user1_gird_state = 3）	3203111	3203111	3203111	3203111	3102031
Valley （user1_gird_state = 4）	4203111	4203111	4203111	4203111	4102031

(3) Terminal control logic

1)battery charge code:1; switch state: In OFF: 0—turning off charge

In ON: 1—turning on charge

2) battery discharge code: 2; switch state: Out OFF: 0—turning off discharge

Out ON: 1—turning on discharge

3) power supply code: 3; switch state: Gird OFF: 0—turning off supply

Gird ON: 1—turning on supply

Power supply sequencing are arranged by the order such as 1302110. Over where 1 is user 1; 30 is that the gird stops power supply: 3 is power supply, 0 is turning off supply; 21 is turn on discharging: 2 is battery discharging, 1 is turn on discharging; 10 is turning off charging: 1 is battery charging, 0 is turning off charging. It means that the battery state (capacity) 85 = <b <100 and the inverter discharge when the grid is at the tip load.

Modeling and Simulation

Modeling and simulation in MATLAB/SUMLINK.

(1) Modeling of battery module

The initial battery capacity can be set and the loss coefficient is set to 0.95 when charging. For example, the battery measured 400W when charging power was 420W from the line side. The loss coefficient is set to 0.9 when inverting. For example, it can save the grid load360W when a single battery module in verted to release the electric power 400W.

Charging process: The modeling function is defined with Eq. (1) and we can obtain the relationship between time and battery capacity, time and charging power. Inverter discharging process: Considering constant power discharge and the maximum discharge power of each sub-module is 400W,what the maximum charging load accounts for 10% and 20% of the district's maximum load (350KW) can be modeled respectively. When 10% electric vehicles are configured, 88 batteries whose maximum-module charging power is 400W; when configuring 20%, 176 batteries are needed.When simulating, zero-point battery capacity is divided into four groups to set and the result is as follows in Tab.2.

Tab.2 0 point initial value setting of battery module

	Configuring 10% of district's load peak			
The battery module number	22	22	22	22
The initial value of battery capacity	20	50	70	90
	Configuring 20% of district's load peak			
The battery module number	44	44	44	44
The initial value of battery capacity	20	50	70	90

Driving electricity for electric vehicles: setting from 8:00 to 22:00, 20% of electric vehiclesare selected randomly every two hours and reduced by 10% of the capacity every time. The time of electric vehicles return the parking stall: setting 8:00 to 18:00, 20% of electric vehiclesselected randomly are in the parking install and from 18:00 to 8:00 the second day, 95% of electric vehicles selected randomly are in the parking install.

(2)The grid data is modeled according to the expression (1).

(3)The control module is modeled according to Table II.

In order to reduce the step pulse on the grid caused by the sudden charge and discharge of a large number of batteries, batch input mode is applied on the program control[6]. For example, when 88 battery sub-modules are collected, the power is low enough to charge, and at this point all in the grid trough. At this moment, control system will be charged by the speeding of putting into a sub-module every 5 seconds, whose principle is that the lower power sub-module will be charged preferentially to ensure the gliding property of the grid load curve as shown in Fig .7.

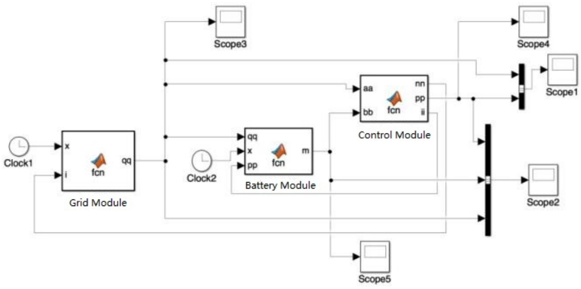
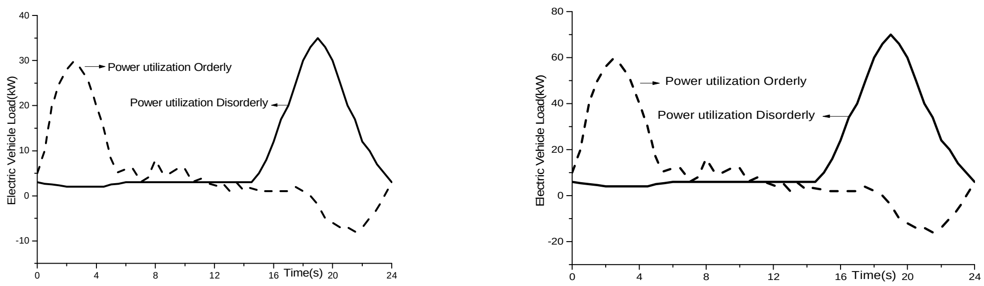


Fig.7MATLAB modeling of electric vehicle charging and discharging orderly

Simulation verification and result analysis

After introducingthe electric vehicle load, orderly and disorderly are compared as shown in Fig .8.



(a) configuring 10% electric vehicles (b) configuring 20% electric vehicles

Fig.8. Comparison of charging and discharging load of theelectric vehicle orderly and disorderly

After introducing the electric vehicle load, in the two cases of controlling orderly and disorderly, the grid load curve is compared as shown in Fig .9.

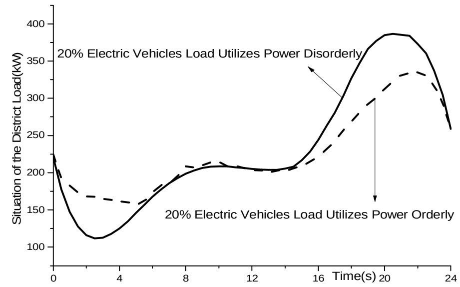


Fig.9. Comparison of the district load whenthe electric vehicle charge and discharge orderly and disorderly

When in the orderly control state, the influence on the district load pre and post introducingthe electric vehicle load as shown in Fig .10.

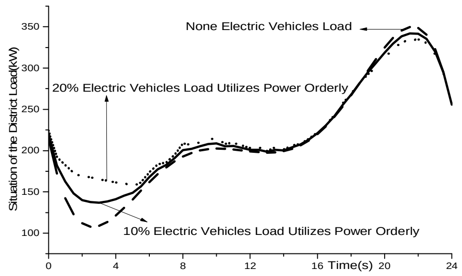


Fig.10. Comparison of district load between non electric vehicles area and electric vehicles in an orderly state

Simulation conclusion:

Orderly control can play a certain role in the peak load shifting especially in the valley filling.Comparing the peak load shifting trend according to the simulation battery capacity configuration were 10%, 20%,we can know that it is still not completely eliminating the valley and peak by configuring 20% electric vehicles of the district maximum load capacity. If increasing the electric vehicle capacity configuration, the effect will be better.

Conclusions

Based on the study of charging and discharging characteristics of electric vehicles, charging demand characteristics and theimpactof disordered charging of large-scale electric vehicles on the grid, an orderly interaction mechanism between electric vehicle charge-discharge facilities and the grid is proposed. The simulation results show that the method can effectively utilize the charging and discharging behavior of electric vehicle to finish the peak load shifting.The concrete implementation of this method needs the support of the following several aspects.

The effect of the peak load shifting will be better when ensuring more than 20% district maximum load of electric vehicle battery capacity are configured. Need to build battery capacity detection, charging vehicles' automatic switching charge and discharge, inverter module and control module.Need to introduce a reasonable electricity charge reward mechanism to encourage electric vehicle users to interact with the grid within a reasonable time segment.

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