Dynamic Charging Control Strategy of EV Considering Accessing of Renewable Energy

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***Abstract*—Electric Vehicle (EV) is an important part of the world's energy technology revolution and the country's renewable energy strategy. Large-scale EV charging will bring impact and challenges for the operation of power system, interaction of charging and discharging of EVs, accessing of renewable energy, security and economic of power system operation, is an important problem in development of EV and renewable energy. Stabilizing power system fluctuations caused by accessing of renewable energy and EV charging, improving absorptive capacity of power system, are serious problems. The thesis analyze the effect of large-scale random charging on power system, than the modeling of EV charging considering accessing of renewable energy is established. The dynamic charging control strategy with multi-objective is proposed. The strategy sets the optimization of regional power peak-valley difference and Stabilizing power fluctuations as the control objectives.**

***Index Terms*—Electric Vehicle, accessing of renewable energy, Monte Carlo, dynamic charging, peak load shifting.**

I. I NTRODUCTION

As the environment quality declining all over the world, people are increasingly advocating environmental-friendly living concept. EV rapidly developed in response to the country's energy conservation policy. On the other hand, the traditional fossil fuel resources are depleted, while wind and solar energy as the more promising renewable energy have been extensively researched and used[1-2].

First, it can generate the power fluctuations when wind, solar and other renewable energy grid-connected, how to stabilize the power fluctuations and increase the absorptive capacities of the grid while the large-scale renewable energy connected to the grid is the urgent solved problem. Second, the large-scale EV charging connected to the network can lead to the tense load in local areas, especially can increase the burden on the grid during peak hours, how to reduce the impact on the power grid by coordinating control of EV charging process is the worth research problem[3-4].

There are some results on the EV charging and related fields have been published. Document [5-6] built the model of the orderly charging of the EV by Monte Carlo Method, based on the performance characteristics of EV in the power consumption, than an optimization model with the target of the load shifting was established through genetic algorithm. Document [7] presented an optimized model for TOU power price time-period considering how to use ordered charging of EV to cut the peak and fill the valley of electricity power grid. Document [8] proposed a coordinated charging strategy for plug-in EV charging stations based on dynamic time-of-use (TOU) tariffs. But aforementioned documents didn't consider the Output of Regional Wind Farm and Photovoltaic Generation. Document [9-10] established a probabilistic output model of regional wind farm and photovoltaic generation, proposed an optimization model and the corresponding method.

In allusion to the cooperative control of the regional wind farm, photovoltaic (PV) generation and EV, an dynamic charging control strategy with multi objective are proposed. Firstly, a model of EV charging demand is built based on actual customer charging behaviors by Monte Carlo simulation method. Than a probabilistic output model of regional wind farm and PV generation is established and a method to assess the peak-valley difference of stochastic load curve is put forward. The correctness and rationality of the dynamic charging control strategy is verified by example.

II. THE EFFECT OF EV CHARGING AND ACCESSING OF RENEWABLE ENERGY ON THE POWER SYSTEM

2.1 The model of EV charging demand

In the case of uncontrolled, for City EV customers, probabilistic density f_{t_0} of the start charging time t_0, probabilistic density f_{t_c} of the Charging duration t_c are two important parameters:

$$f_{t_0}=\begin{cases}\dfrac{1}{\sigma_0\sqrt{2\pi}}\exp\left[-\dfrac{(x-\mu)^2}{2\sigma_0{}^2}\right] \\ (\mu_0-12)<x\le 24 \\ \dfrac{1}{\sigma_0\sqrt{2\pi}}\exp\left[-\dfrac{(x+24-\mu)^2}{2\sigma_0{}^2}\right] \\ 0<x\le(\mu_0-12)\end{cases} \tag{1}$$

Where σ_0=17.6, μ_0=3.4

$$f_{t_c}(x) = \frac{1}{x\sigma_c\sqrt{2\pi}}\exp\left[-\frac{(\ln p_c x - \ln 0.15 - \mu_c)^2}{2\sigma_c^{\ 2}}\right] \quad (2)$$

Where σ_c =3.2, μ_c =0.88

Than calculate the EV charging demand within 24 hours a day at each time point by Monte Carlo simulation method, where N =50000, charging power is the constant power P_c= 2.5 kW, a single EV charging load demand expectation curve is obtained after averaging operation of 100 times calculation, as shown Fig.1.

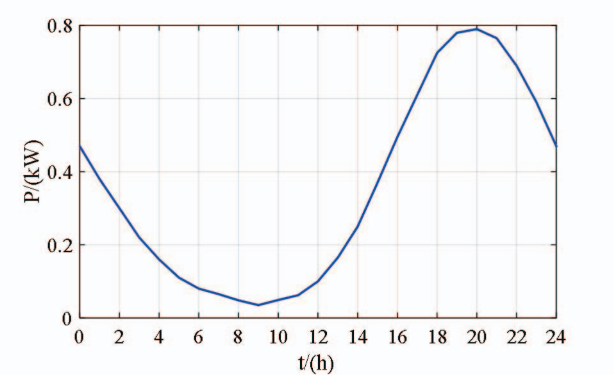


Fig.1 The charging demand of one EV

According to document [12-13], a city domestic daily load curve is proposed using a simple and pragmatic method of typical day curve forecasting. Let EV ownership of the area be 10000, permeability be 15%. Due to the random charging of EV， the change of the base daily load curve is shown in Fig.2.

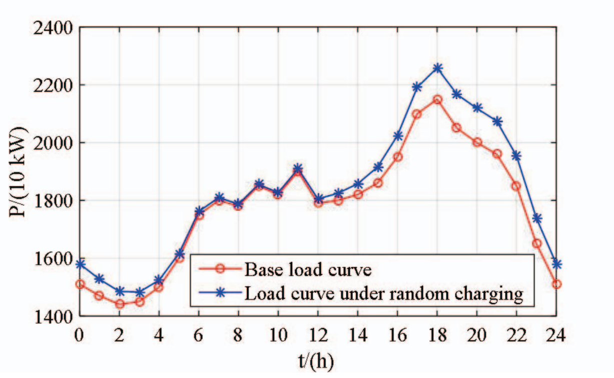


Fig.2 Load curves under random charging

The figure shows that, in the absence of any guidance and control measures, the charging peak load demand of large-scale EV appears in the vicinity of the original load peaks, it creates the peak of power load curve upward, peak-valley difference of grid load increased[14-15].

2.2 The probabilistic model of regional wind farm and PV generation

Assuming that there are n wind farms and m photovoltaic power plants, the correlation coefficient of the output of each wind power generator(PV module) in the same wind farm (photovoltaic power plant) is one; the total output of different wind farms(photovoltaic power plants) are independent, the correlation coefficient is zero.

The probabilistic density characteristic of wind speed v can be expressed using Weibull function[16]:

$$f_1(v) = \frac{\pi}{c}(\frac{v}{c})^{a-1}\exp(-(\frac{v}{c})^a) \qquad (3)$$

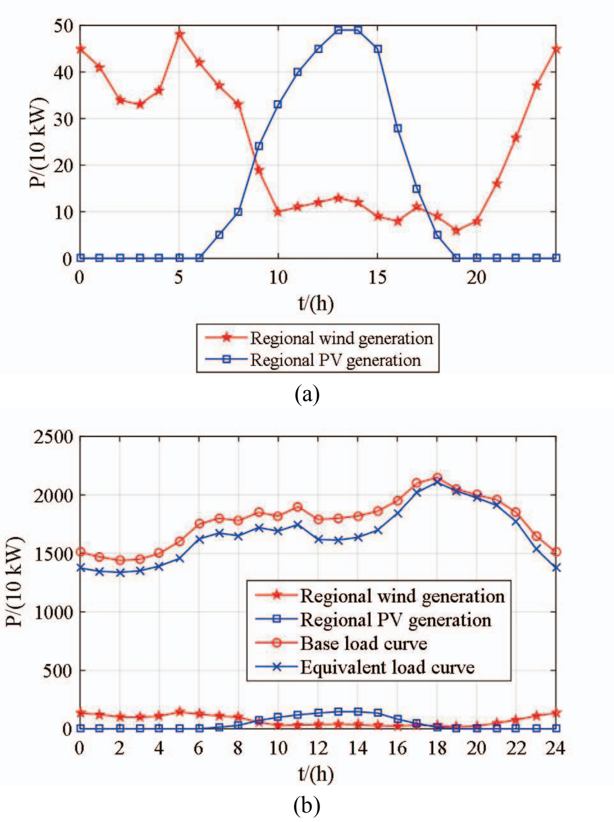
Where π is shape parameter, c is scale parameter, $a \in$ [1, N]. The output power of the wind farm is a random variable determined by a common wind speed and turbine parameters. Most output characteristics of the wind generators are shown as break curve.

Let random variable of PV system output power be x. Since the PV system output power is proportional to the light intensity, probabilistic density characteristics of x can be represented as Beta function [17].

$$f_2(x) = \frac{\Gamma(\alpha+\theta)}{\Gamma(\alpha)\Gamma(\theta)}(\frac{x}{P_{\mathrm{m}}})^{\alpha-1}(1-\frac{x}{P_{\mathrm{m}}})^{\theta-1} \qquad (4)$$

Where P_{m} is Maximum output power, α and θ are distribution parameters scale parameter.

All the active power output of wind farms and PV power plants are m + n random variables, according to the assumption, because of the additive characteristics between the semi independent variables, then the wind power and PV active power output curves can be obtained. And the equivalent daily load $P_{\mathrm{equ}} = P_0 - P_{\mathrm{W}} - P_{\mathrm{PV}}$ of the regional daily load curves with the wind and PV, as shown Fig.3.



(a)

(b)

Fig.3 Equivalent load curves under regional wind farm and PV generation

When the wind, PV and EV random charging can reduce load rate of the equivalent grid load curve, and increase the valley to peak rate, resulting in utilization of conventional power units decrease and peaking capacity requirements increase.

III. THE MULTI-OBJECTIVE DYNAMIC CHARGING CONTROL STRATEGY OF EV CONSIDERING ACCESSING OF RENEWABLE ENERGY

3.1 Overview of the EV multi-objective dynamic charging control strategy

Wind power and PV generation can bring the negative effects to the regional grid, the main cause is the random and uncertainty characteristics of the load, at the same time, and the EV load demand can increase the grid valley to peak. Therefore, considering the two negative factors of the grids, based on the wind and PV power output stochastic model and EV load model, according to the evaluation method of the valley to peak load curves, taken the optimization of the regional grid and the fluctuations of wind and PV energy grid- connected as the charging control strategy purpose, and develop the TOU of the EVs as the guide strategy, then the purpose of the wind and PV power cooperative control can be achieved.

3.2 Flowchart of the EV multi-objective dynamic charging control strategy

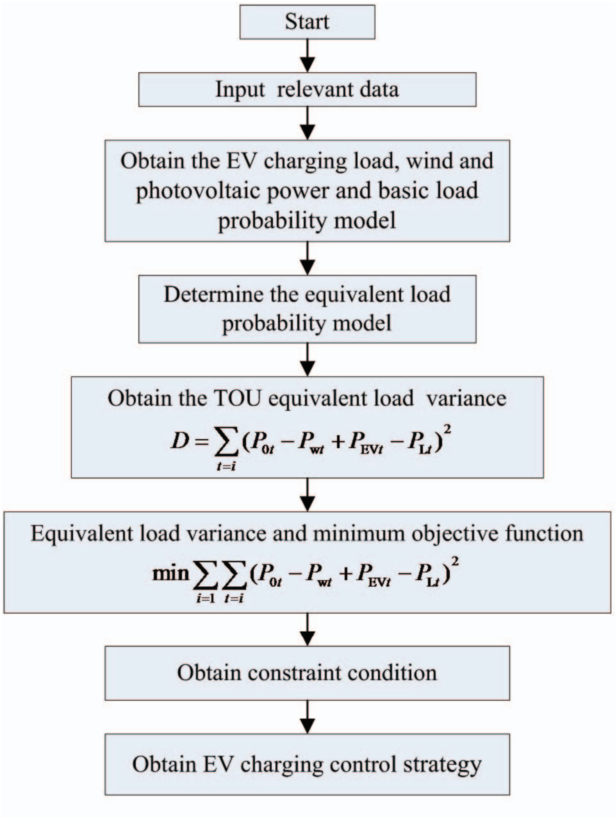


Fig.4 Flowchart of the EV dynamic charging control strategy

IV. CASE STUDY

Base on the daily load curve and wind, PV historical data of one domestic typical city, and the wind power plant and PV power plant data is supposed. Accordance with the parameters assumptions above, multi-target programming dynamic charging control strategy flowchart used by MATLAB toolbox, and the optimization results are obtained as shown in Fig.5.

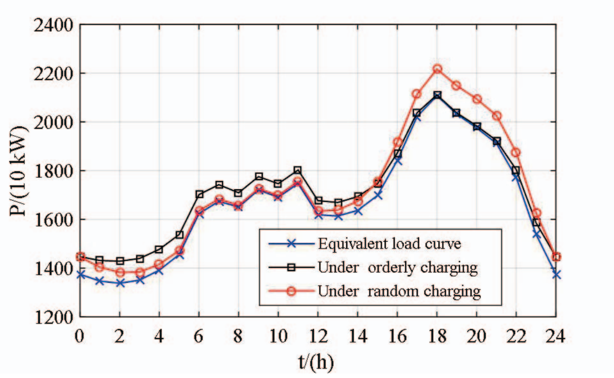


Fig.5 Load curves under orderly charging

During the equivalent load "valley" period, through the EV load regulated can increase the comprehensive load, and play the role of "valley" effect. The optimized load curve tends to be more flat as shown in the figure. Therefore, the optimal results can be concluded that, after the development of multi-objective dynamic control strategy for EVs, the control results can affect the load curves when the wind and PV connected to grid, and the grid valley to peak of the random load is effectively reduced as the data shown.

V. CONCLUSION

Based on the regional wind farm and PV power output probability model and two-stage peak-valley price model, the multi-objective dynamic charging control strategy is used to guide the large-scale electric vehicle ordered charging, and then the fluctuations of the large-scale wind and photovoltaic power generation grid-connected is stabilized, thus the purposes of optimization grid valley to peak are achieved. As the scale of the wind, solar and other renewable energy grid-connected and the application of the EVs expanding, the load characteristics of the power grid can be improved by the ordered charging, and the optimization of the regional grid valley to peak is feasible.

REFERENCES

[1] Song Yonghua, Yang Xia, Lu Zongxiang. Integration of plug-in hybrid and electric vehicles: experience from China[C]//Proceedings of 2010 IEEE Power Engineering Society General Meeting, Minneapolis, MN, USA: 2010:1-5.

[2] Ferdowsi M.. Vehicle Fleet as a distributed energy storage system for the power grid[C]//Proceedings of 2009 IEEE Power Engineering Society General Meeting, Calgary, AB, Canada: 2009: 1-2.

[3] Hu Zechun, Song Yonghua, Xu Zhiwei, et al. Impacts and utilization of electric vehicles integration into power systems[J]. Proceedings of the CSEE, 2012, 32(4):1-10.

[4] Peterson S. B., Whitacre J. F., Apt J.. The economics of

using plug-in hybrid electric vehicle battery packs for grid storage[J]. Journal of Power Sources, 2010, 195(8): 2377-2384.

[5] Ma Z., Callaway D. S., Hiskens I. A.. Decentralized charging control of large populations of plug-in electric vehicles[J]. IEEE Trans. on Control Systems Technology, 2013, 21(1): 67-78.

[6] Li Haoyang. Electric Vehicle Ordered Charging based on the demand side response. Tianjin: Tianjin University, 2012.

[7] Ge Shaoyun, Huang Liu, Liu Hong, et al. Optimization of peak-valley TOU power price time-period in ordered charging mode of electric vehicle[J]. Power System Protection and Control, 2012, 40(10): 1-5.

[8] XU Zhiwei, HU Zechun, SONG Yonghua, et al. Coordinated Charging Strategy for PEV Charging Stations Based on Dynamic Time-of-use Tariffs. Proceedings of the CSEE, 2014, 34(22): 3638-3646.

[9] Yu Dayang, Song Shuguang, Zhang Bo, et al. Synergistic dispatch of PEVs charging and wind power in Chinese regional power grids[J]. Automation of Electric Power Systems, 2011, 35(14): 24-28.

[10] Liu Haojun. Cooperative Control Model and Method of the Regional Wind Farm, Photovoltaic Generation and Electric Vehicles. Proceedings of the CSU-EPSA, 2015, 12: 12-17.

[11] Tian Liting, Shi Shuanglong, Jia Zhuo, et al. A statistical model for charging power demand of electric vehicles[J]. Power System Technology, 2010, 34(11):126-130.

[12] Xiao Jianhua, Wang Ruifeng, Wen Chunnan. A Simple Method of Typical Day Load Curve Forecasting. Ji lin Electric Power, 2006, 34(2):14-17.

[13] Wang Chengshan, Zheng Haifeng, Xie Yinghua, et al. Probabilistic power flow containing distributed generation in distribution system[J]. Automation of Electric Power Systems, 2005, 29(24):39-44.

[14] Bradley T, Quinn C. Analysis of plug-in hybrid electric vehicle utility factors. Journal of Power Sources. 2010, 195:5399-5408.

[15] Hubner M, Zhao L. Impact of large-scale electric vehicle application on the power supply[C]//Electrical Power & Energy Conference. Montreal: IEEE, 2009: 1-6.

[16] Shi Dongyuan, Cai Defu, Chen Jinfu, et al. Probabilistic load flow calculation based on Cumulant method considering correlation between input variables[J]. Proceedings of the CSEE, 2012, 32(28): 104-113.

[17] KARAKI I.S., CHEDID R.B., RAMADAN R. P.. Probabilistic performance assessment of autonomous solar-wind energy conversion systems[J]. IEEE Trans on Energy Conversion, 1999, 14(3): 766-772.

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