New energy vehicles taking into account user needs participate in the FM model

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Abstract—In this paper, a new energy vehicle participation FM model considering user needs is established and verified by simulation. It has been proved that the model can guarantee user travel needs. The new energy vehicle participation FM model is divided into three parts: energy storage calculation, power constraint and energy constraint. Energy storage calculation is to model and analyse the available energy of new energy vehicles participating in FM, and get the variation of participating FM capacity in a day considering the user SOC demand. Power constraint is the charge and discharge power constraint of new energy vehicles, which is the necessary condition to ensure that new energy vehicles do not violate the technical conditions of new energy vehicles and ensure that the energy constraint of user demand participates in frequency modulation.

1. Introduction
The power distribution strategy is to study the power regulation signal of the new energy vehicle cluster agents through what strategy to allocate to each new energy vehicles, in this process are new energy vehicle users as the center, agents only on the basis of user needs to rationalize the distribution of frequency modulation power.

The basic needs of new energy vehicle users include three aspects: driving distance, charging price and security. Of these, mileage has the highest priority when electricity prices are currently lower than oil prices. The second is safety, including charging safety and driving safety, the latter is already under the category of road traffic safety and will not be discussed here. The last thing that needs to be considered is the electricity price of charging, because electricity has a huge price advantage, so the electricity price of charging needs to be considered in the lowest priority\cite{1}.

2. Construction and Geometrical Dimensions of Specimens

2.1. Controlled energy storage calculation of new energy vehicles
Under the dealer mechanism, the available energy storage of new energy vehicles at any time of the day can be expressed using the formula\cite{1}:

\[ E_{\text{control}}(t) = E_0 + E_{\text{control-in}}(t) - E_{\text{plug-out}}(t) - E_{\text{LFC}}(t) \]  

(E\text{\textsubscript{0}} is the initial energy storage of a controlled new energy vehicle\cite{2}, and \(E_{\text{control-in}}(t)\) is the amount of energy storage increase caused by a new energy vehicle becoming controlled. They are calculated as follows:}
\[ E_0 = \frac{SOC, N_0 E_{ev}}{1000} \]  \hspace{1cm} (2)

\[ E_{control-in}(t) = \frac{SOC, N_{plug-in} E_{ev}}{1000} \]  \hspace{1cm} (3)

\( E_{plug-out}(t) \) is the amount of energy storage that is reduced when a new energy vehicle is disconnected from the grid. This method adopts the \( SOC \) control strategy in literature [3], so that the new energy vehicle battery \( SOC \) in a controlled state can be approximated to the average \( SOC \) of all controlled new energy vehicles. Therefore, the calculation of \( E_{plug-out}(t) \) can be calculated using the formula (4):

\[ E_{plug-out}(t) = \frac{N_{plug-out}(t)}{N_0 + N_{control-in}(t)} (E_0 + E_{control-in}(t) - E_{LFC}(t)) \]  \hspace{1cm} (4)

\( E_{LFC}(t) \) is a \( t_0 \) to \( t \) time period, controlled new energy vehicles participate in the system FM caused by the amount of energy storage changes, calculated as follows:

\[ E_{LFC}(t) = \frac{1}{3600} \int_{t_0}^{t} P_{LFC}(\tau) d\tau \]  \hspace{1cm} (5)

\( P_{LFC}(\tau) \) is the FM power distribution obtained by the secondary dealer, and its positive and negative numbers are specified as follows: discharge is positive. All controlled new energy vehicles \( SOC \) calculation formula is:

\[ SOC_{control}(t) = \frac{E_{control}(t)}{E_{sum}(t)} \]  \hspace{1cm} (6)

\( E_{sum}(t) \) represents the total capacity of controllable new energy vehicles in the area controlled by the sub-dealer and is calculated as follows:

\[ E_{sum} = \frac{N_e(t) E_{ev}}{1000} \]  \hspace{1cm} (7)

In summary, the total energy storage model can be obtained shown in Fig.1.

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2.2. Power and energy constraints

Controlled new energy vehicles participating in power system FM have battery \( SOC \) that fluctuate in the range of [80%, 90%], and their total energy storage is correspondingly \( (E_{\text{min}}(t), E_{\text{max}}(t)) \) range fluctuations[3]. The upper and lower limits of total energy storage are calculated as follows:
\[ E_{c_{\text{min}}} = \frac{SOC_{\text{min}} N_c(t) P_{ev}}{1000} \]  
\[ E_{c_{\text{max}}} = \frac{SOC_{\text{max}} N_c(t) P_{ev}}{1000} \]

SOC_{\text{min}} and SOC_{\text{max}} are 80% and 90%, respectively. In addition to energy constraints, new energy vehicle clusters need to consider power constraints. Controlled new energy vehicle cluster charge and discharge power limit \( P_{\text{limit}}(t) \):

\[ P_{\text{limit}}(t) = \frac{N_c(t) P_{ev}}{1000} \]

\( P_{ev} \) is the charge and discharge power of a single controllable new energy vehicle in a secondary dealer, with a positive discharge\[4\].

Fig.2 Considers the participatory FM model for the user needs of new energy vehicles

Fig In Fig.2, \( E_{control} \) is compared with \( E_{c_{\text{max}}} \) and \( E_{c_{\text{min}}} \), respectively, to limit FM power within controlled energy constraints\[5\]. When the SOC currently meets the \( SOC_{\text{min}} \leq SOC \leq SOC_{\text{max}} \), the total energy storage meets \( E_{c_{\text{min}}} (t) \leq E_{control} (t) \leq E_{c_{\text{max}}} (t) \). The \( K_1 < 0, K_2 > 0 \) is the corresponding K1, and the model can adjust the power up or down with the LFC signal under this control\[6\]. Suppose that the controlled vehicle gradually rises up the SOC under LFC signal and reaches \( SOC_{max} \), at which point the controlled new energy vehicle \( E_c (t) \). The upper limit \( E_{c_{\text{max}}} (t) \) is also reached as it rises. Then on the way \( K_1 = 0, K_2 > 0 \), there are charge-discharge power constraints on the K1 road, which restrict the new energy vehicles to only discharge when participating in FM\[7\]. Similarly, when the SOC reaches the lower limit of \( SOC_{\text{min}} \), limiting the participation of new energy vehicles in FM can only be charged.

In summary, considering the power and energy constraints of new energy vehicles, the SOC of new energy vehicles participating in FM can be limited to a certain range, in order to meet the user's driving needs\[8\].

2.3. Simulation research

Based on what we know, set the load power distribution signal for Fig.3. Set up 100 cars in secondary dealers with a starting SOC of 85%, a charging power of 3kW and a capacity of 15kWh. Calculate changes in the controlled quantity of new energy vehicles, \( SOC \), and total energy storage under the one-day dealer mechanism. The following results are obtained:
Fig. 3 Load power distribution signal

Fig. 4 Controlled New Energy Vehicle SOC in Sub-Dealers

Fig. 4 shows the average curve of changes in the $SOC$ of a controlled new energy vehicle in a control area over the course of a day.

Fig. 5 Total energy storage for controlled new energy vehicles in one day
3. Conclusion
As can be seen from the final results, the total energy storage of new energy vehicles does not exceed its upper and lower limits in the equivalent model of new energy vehicles used, which means that the $SOC$ of new energy vehicles controlled by each sub-agent is also within the limits of constraints, and ultimately ensures the travel needs of users.

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References
[1] Shimizu K, Masuta T, Ota Y, et al. (2010) Load Frequency Control In Power System Using Vehicle-To-Grid System Considering The Customer Convenience Of Electric Vehicles[C]. Power System Technology (POWERCON), 2010 International Conference on. 2010:1-8.
[2] Han X, Ouyang M, Lu L, et al. (2014) A comparative study of commercial lithium ion battery cycle life in electrical vehicle: Aging mechanism identification[J]. Journal of Power Sources, 2014, 251(2):38–54.
[3] Shimizu K, Masuta T, Ota Y, et al. (2012) SOC Synchronization Control Method of Electric Vehicles Considering Customers' Convenience for Suppression of System Frequency Fluctuation[J]. Ieej Transactions on Power & Energy, 2012, 132(1):57-64. [4] Thompson, J.N. (1984) Insect Diversity and the Trophic Structure of Communities. In: Ecological Entomology. New York. pp. 165-178.
[4] LI Yi ran, ZHANG Shu, XIAO Xian yong, et al. (2021) Charging and discharging scheduling strategy of EVs considering demands of supply side and demand side under V2G mode [J]. Electric Power Automation Equipment, 2021, 41 (3):129-135, 143.
[5] ZHONG Q, NGUYEN P L, MA Z Y, et al. (2014) Self-synchronized synchronverters: inverters without a dedicated synchronization unit [J]. IEEE Transactions on Power Electronics, 2014, 29 (2):617-630.
[6] LI Xiaomeng, JIA Hongjie, MU Yunfei, et al. (2020) Coordinated frequency control based on electric vehicles and heat pumps considering time-delay [J]. Electric Power Automation Equipment, 2020, 40 (4):88-95, 110.
[7] MEI Zhe, ZHAN Hongxia, YANG Xiaohua, et al. (2020) Optimal operating strategy of distribution network based on coordination of electric vehicle and distributed energy resource considering current protection [J]. Electric Power Automation Equipment, 2020, 40(2):89-102, 181.
[8] LU Sheng jian. (2018) Charge/discharge and auxiliary frequency modulation control strategy of electric vehicle based on virtual synchronous machine [D]. Beijing: North China Electric Power University, 2018.