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Coordination Dispatch of Electric Vehicles Charging/Discharging and Renewable Energy Resources Power in Microgrid

Xiuli Jiang , Jinkuan Wang , Yinghua Han* , Qiang Zhao

Northeastern University, Shengyang 110819 , China
** Corresponding authors: yhhan723@126.com,*

Abstract

A large number of distributed powers access to the distribution network have a multifaceted impact on the power grid, while microgrid is an effective way to solve the impact of distributed generation on the power grid. In microgrid, the proportion of renewable energy is large, while it's output is random. Besides, electric vehicles(EVs) play an important role in microgrid and a high penetration level of EVs could bring about a large impact on microgrid. Therefore, considering the coordination between renewable energy sources and EVs, a optimization model is proposed in this paper. In the optimization model, the minimum variance of equivalent load as the objective function, considering the electric vehicle driving behavior and electric vehicle capacity constraints, EVs charging/discharging power in each scheduling period is obtained. Simulation result shows the effectiveness of the model. The results show that charging/discharging of EVs can be dispatched to reduce the equivalent load and increase absorptive capacity of renewable energy.

*Keywords:*electric vehicles, charging/discharging, microgrid, vehicle to grid(V2G)， renewable energy generation

1.Introduction

The microgrid is a footprint power system that is typically located at the down stream of the distribution system. The benefit is the supply of the load by local generation. Mostly microgrids consist of the distributed generation from distributed energy resource(DERs). The DERs like wind and solar resources are inherently volatile in nature. The lulls and gusts in the wind, and clouds and other environmental effects across the photovoltaic(PV) panel, cause their output power to be always fluctuating.

EVs also play an important role in microgrid besides the primary transportation[1]. The charging in electric vehicles bring certain impact on power grid. V2G(vehicle-to-gird) technology can achieve two-way flow of energy,

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increasing the interaction between the user and the power grid. The user is no longer just a consumer of energy, but also can be an energy provider. V2G can be applied to any network of vehicles. Because most of the cars are parked at an average of 95% of the time, their batteries are able to flow to the power grid. Therefore, microgrid can be eased considerably by V2G technology.

There have been a lot of domestic and foreign scholars who have done much researches in charging/discharging of EV now. To give priority to the use of renewable energy in electric vehicle swapping station , multi-objective optimization model of the electric vehicle power plant with wind and wind power generation unit is established [2]. Collaborative scheduling model of electric vehicles and wind energy is bulit in order to reduce "abandon wind" phenomenon but don't consider V2G technology[3]. The hierarchical and zonal dispatching architecture is adopted and a new bilevel optimization model is presented for coordinating the charging/discharging schedules of the EVs in order to reduce the peak valley difference [4]. The operation and arbitration modes of electric vehicle battery swapping stations(EVBSS) are analyzed on the basis of time-of-use(TOU) pricing mechanism, then the benefit function is obtained [5]. The authors build a mathematical model of discharging strategy and use the multi-swarm cooperative partical swarm optimization to achieve the daily dispatching strategy optimization [6]. The charging/discharging strategy of "minimum charge minimum fluctuation" considering battery charge and discharge life loss is established. The goal of this method is to reduce the operating costs of charging/discharging agents, and to minimize the load fluctuation of charge and discharge based on satisfying the user's requirement in [7]. Two-layer smart charge-discharge strategies for EVs considering wind generation and users' satisfaction is proposed in [8].

In this article, the wind energy and solar energy power generation models are established according to the local wind speed, light intensity. Secondly, electric vehicle model is bulit through the electric vehicle driving behavior rules. Coordination dispatch model of electric vehicles charging/discharging and renewable energy resources power is proposed to minimum variance of equivalent load. Electric vehicle charging/discharging can increase the utilization of renewable energy.

2. System Model

In the paper, we consider a charging/discharging of EVs system model in microgrid, as shown in Fig. 1 according to [9]. Through the common coupling (PCC), the microgrid and main grid are connected together. The microgrid is made up of base load, renewable distributed energy resources, the control center and other generators and EVs.

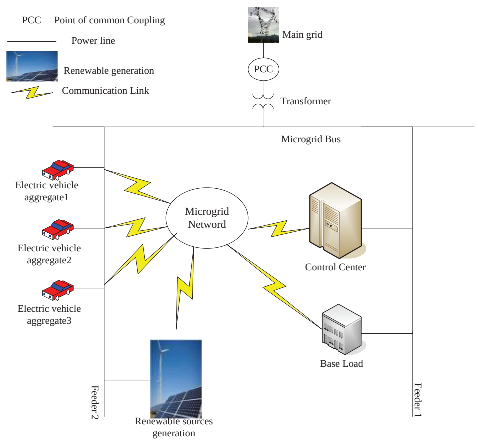

Fig. 1. system model for charging/discharging EVs in a microgrid

The wind turbines and solar panels generate renewable resources. Base load refers to the load which excludes electric vehicle load. Through the communication network, the control center obtains data and transmits commands to or from other devices in microgrid . There are three EVs aggregates in the microgrid in this paper. The core idea of hierarchical partition scheduling is to layer the power system according to the voltage level, and then the level of the power distribution system is divided into several regions according to the region. For each area, the microgrid system dispatching mechanism or aggregate is responsible for the coordination of electric vehicles.

3. Optimal Scheduling Model

The power fluctuation of wind power and light is not controlled, and the space of wind power capacity of the grid is improved by controlling the normal power supply. Electric vehicle power battery as the dispersion type of energy storage device, if the load of EVs can be guided reasonably, it can not only cut the peak and fill valley but also consume excess renewable energy sources. Renewable energy accessed to microgrid and electric vehicles charging increase the peak valley difference. Therefore, the objective of the optimization should decrease the equivalent load peak valley difference.

3.1 Wind Generation Model

There are three important concepts: cut-out wind speed, rated wind speed , cut-in wind speed . Cut-in wind speed is the wind turbine's speed, when the cut-in wind speed is less than actual wind speed, the wind turbine begins to work . A large number of experiments show that the characteristics of the wind turbine power generation equation are as follows[10]:

$$P_{WT} = \begin{cases} 0 & 0 \le V \le V_i \\ P_{rated} \dfrac{V - V_i}{V_r - V_i} & V_i \le V \le V_r \\ P_{rated} & V_r \le V \le V_c \\ 0 & V_c \le V \end{cases} \tag{1}$$

where V represents the actual wind speed, V_c represents the cut-out wind speed, V_r represents the rated wind speed, V_i is cut-in wind speed, P_{rated} represents wind turbine rated power, P_{WT} is real power of the fan.

3.2 Solar Generation Model

Nonlinearity is the characteristic of photovoltaic power generation.Various factors, such as weather, environment temperature, sunshine intensity and other meteorological conditions affect the output power. The output of photovoltaic cells is:

$$P_{PV} = \frac{GP_{STC}\left[1 + k_T\left(T - T_{STC}\right)\right]}{G_{STC}} \tag{2}$$

where P_{PV} is the output power of photovoltaic cells, G is the light intensity, T is photovoltaic cell operating temperature, G_{STC} is light intensity, T_{STC} is ambient temperature, P_{STC} is maximum texting power, k_T is the power temperature coefficient. Standard test conditions: ambient temperature is 25 degrees Celsius, light intensity is $1000 W / m^2$.

3.3 Driving Behavior of Electric Vehicles

Cars are in suspended state more than 90% of the time one day. Fig. 2. shows that the car is in a stopped state probability in a day. One day in more than 90% of the time the car is in suspended state.

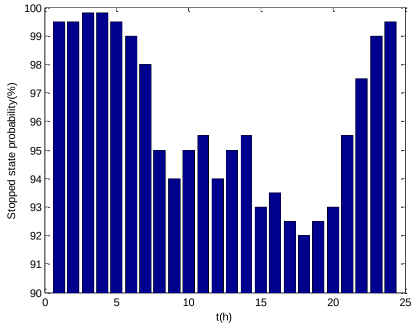

Figure 2. probability of a vehicle to be parked

Electric vehicles and traditional cars have suspended the same probability distribution. Because every time there are a high proportion of electric vehicle in a suspended state, which makes the electric vehicle scheduling to stabilize renewable energy power generation output fluctuations is possible.

3.4 The Objective Function

The equivalent load mean variance is:

$$\min F = \sum_{t=1}^{24} \left(p_{dt} + p_{ev,t} - P_{WT} - P_{PV} - p_{av} \right)^2 \tag{3}$$

where p_{dt} is power grid load in the t th period of time, $p_{ev,t}$ represents each electric vehicle agglomerations charging/discharging power in the t th period of time, P_{WT} represents output of wind power generator in the t th time, P_{PV} is solar energy photovoltaic pow in the t th period of time, p_{av} represents equivalent load average.
The average value of the equivalent load is

$$Pp_{av} = \frac{1}{T} \sum_{t=1}^{T} (p_{dt} + p_{ev,t} - P_{WT} - P_{PV}) \tag{4}$$

where $T = 24$.

3.5 Constraints

Stopping probability of electric vehicles is $G_{park}(t)$. Assuming that there are N electric vehicles in the each electric vehicle aggregate area, the number of electric vehicles can be scheduled at the time of T is $N_{avi}(t)$, then the number of electric vehicles that are driving is $N_{dch}(t) = N - N_{avi}(t)$ in the t th time period. Total energy consumption for each electric vehicle aggregate is $P_{trip}(t)\Delta t = N_{dch}(t) - E(P_{dch}(t))\Delta t$. Power consumption per hour of electric vehicle assembly is $E(P_{dch}(t))\Delta t = E(h_c(t))E(v_e)\Delta t / \eta_e$. $E(h_c(t))$ is electricity consumption per kilometer of EV. $E(v_e)$ is the average speed of mathematical expectation of EV. Δt is time interval. η_e is motor energy conversion efficiency.

- Charging /discharging equality constraints for electric vehicle aggregate

$$S(t+1) = S(t) + \eta p_{ev,t} - P_{trip}(t)\Delta t \tag{5}$$

where $S(t+1)$ is electric vehicle aggregate electricity in the $(t+1)$th period of time . $S(t)$ is electric vehicle aggregate electricity in the t th period of time, η represents efficiency of electric vehicle charging/discharging to grid.

- Charging /discharging capacity in a scheduling period is equal for electric vehicle aggregate

$$\sum_{t=1}^{T} \eta p_{ev,t} = 0 \tag{6}$$

- There is an upper limit on the power of charging/discharging in the electric vehicles at each time of the microgrid

$$-N_{avi}(t)p \le p_{ev,t} \le N_{avi}(t)p \tag{7}$$

where p is charging/discharging power of an electric vehicle.

- Battery safety

$$S_{\min} \le S(t) \le S_{\max} \tag{8}$$

$$S_{\max} = NC_{EV} \tag{9}$$

$$S_{\min} = 20\% NC_{EV} \tag{10}$$

where $S_{\max}$ and $S_{\min}$ represent the upper and lower limits of electric vehicle aggregate storage battery respectively , C_{EV} is capacity of an electric vehicle, N is the number of one electric vehicle aggregate.

- Charging/ discharging power dynamic climb

The charging/discharging power fluctuation range is not more than 20% of the maximum charging/discharging power.

$$-\Delta_{ci} \le p_{ev,t} - p_{ev,t-1} \le \Delta_{ci} \tag{11}$$

where fluctuation range of charging/discharging of aggregate is $\Delta_{ci} = 20\% Np$.

4. Simulation Result and Analysis

EV parameters are shown in Table 1. The measured data of wind speed and light intensity in this area shown in Fig. 3.(a) and (b). From wind power and solar power output model, we can get the power as shown in Fig. 4.(a) and (b). The total rated capacity of the wind turbine is 450kW, the speed of rated wind is 12m/s, the speed rated wind is 2.5m/s, the speed of cut-out is 25m/s. The maximum power output of PV array is 300kW under standard test conditions. Assuming that the region has three electric vehicle aggregates, each aggregate has 50, 100, 150 electric vehicles. The initial capacity of each electric vehicle aggregates is sixty percent of the total capacity.

Table 1.Parameter of EVs.

Parameter	Value
C_{EV} (kWh)	21.6
p (kW)	3
W_{100} (kWh/100km)	13.9
v_e (km/h)	40
SOC_{max} / SOC_{min} (%)	100/20
η	0.8
η_e	0.672

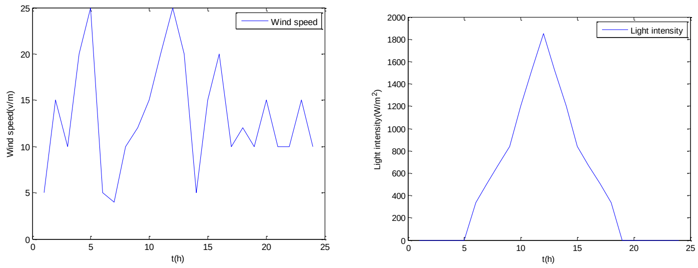

Fig. 3. (a) wind speed curve; (b)light intensity curve

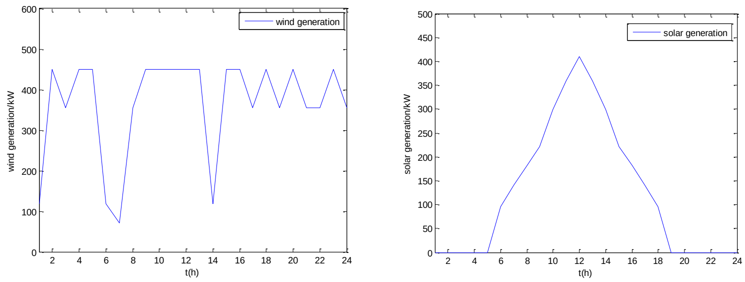

Fig. 4. (a)wind generation curve; (b) solar generation curve

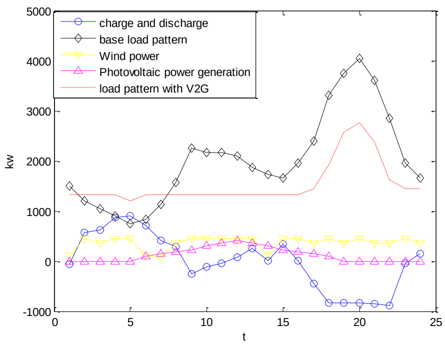

Fig. 5. The equivalent load curve

Fig.5. contains wind power, photovoltaic power generation, base load, charging/discharging power of EVs, the equivalent load. The optimal charging and discharging of electric vehicles can restraint the load fluctuations , and reduce the peak load curve in Figure 7. It is clear that EVs play an important role of valley filling and peak shaving for load pattern in microgrid. The waste of renewable energy generation can be decreased through the charging/discharging of electric vehicles

5. Conclusion

A collaborative scheduling model of renewable energy sources and electric vehicles is proposed in this paper. Firstly, electric vehicle model is established by the driving rules. Then, wind power generation model and photovoltaic power overall output model are established. In order to minimize the variance of equivalent load, a cooperative scheduling model is founded. The simulation results show that the difference between the valley and the peak of the equivalent load can be reduced through the EVs charging/discharging . The charging/discharging of EVs can increase renewable energy consumption and reduce the generation of abandoned wind and abandoned light phenomenon in renewable energy rich regions.

6. Acknowledgements

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