The Journal of Engineering

The 14th IET International Conference on AC and DC Power Transmission (ACDC 2018)

IET Journals
The Institution of Engineering and Technology

Application of micro-grid control system in smart park

eISSN 2051-3305
Received on 29th August 2018
Revised 8th September 2018
Accepted on 24th September 2018
E-First on 7th January 2019
doi: 10.1049/joe.2018.8771
www.ietdl.org

Zhang Zhaoyun[1] ✉, Zhao Wenjun[1,2], Yang Mei[3], Kang Li[1], Zhang Zhi[1], Zhao Yang[1], Liu Guozhong[1], Yao Na[1]

[1]*Dongguan University of Technology, Dong Guan, People's Republic of China*
[2]*Guangdong University of Technology, Guang Zhou, People's Republic of China*
[3]*Guangdong Power Grid Co., Ltd. Dongguan Power Supply Bureau, Dong Guan, People's Republic of China*
✉ *E-mail: 18927491998@163.com*

Abstract: Micro-grid can be used as a supplement to power supply of large power grids. Combined with smart park, users can easily manage the micro-grid. In the tourist scenic area, the local distributed new energy is mainly used to provide energy for the system. The micro-grid control system as the core of the system controls the optimal operation of the entire smart park. In order to ensure the efficient operation of the entire system, the energy management system is needed for smart control and automatic scheduling. In the grid-connected mode, the main-grid complements the system energy and charges the park energy storage device. In the island mode, the distributed energy is fully used to provide energy for the smart park system. The energy power fluctuates greatly, and the energy management system needs to schedule the micro-grid energy, energy storage system, electric vehicle load and so on, and power quality needs to be monitored. Use of micro-grid control system in the smart parking deploying photovoltaic power generation, wind power generation, charging and exchanging devices and other devices, real-time monitoring of the park of cars, charging cars automatically complete charging, automatic processing of visitor cars into and out of smart park, and improve work efficiency.

1 Introduction

With the constant increase of domestic tourism, cities all over the country have made the banner of green tourism to attract tourists. However, tourist scenic area is often built in remote areas. Access to the large grid is too expensive. Access to distributed new energy can solve the problem. New energy sources are one of the hot topics in the international competition in the 21st century. Traditional fossil fuels have a great impact on the environment, and non-renewable. New energy vehicles are gradually replacing the traditional fossil energy vehicles in the city traffic. The electric vehicle (EV) is loved by more and more people.

Parking is an essential facility near popular attractions. With the rapid development of the national economy, the self-driving rate is rising steadily. At the same time, with the extensive use of new energy vehicles, the parking lot near the scenic area must provide enough charging facilities. The parking spot in tourist scenic areas are generally more open, more conducive to the construction of photovoltaic. There are energy storage, photovoltaic, EVs, and other loads in the parking lot, and these elements are properly integrated to form a micro-grid operation.

At present, most car parks depend on manual management methods, which have low efficiency and high management expenditure. In this paper, we propose micro-grid control system in smart park, deployment of photovoltaic, energy storage, car charging, and switching facilities in the parking lot and set up as a micro-grid, supplemented by a micro-grid energy management system to complete the optimal operation of the micro-grid smart parking lot.

2 Implementation scheme of the micro-grid smart parking lot

2.1 Main function of smart parking

The parking lot that integrates photovoltaic, wind energy (optional), new energy charging facilities, and micro-grid energy management system is called the micro-grid smart parking lot [1]. The micro-grid smart parking lot mainly includes

i. Cover the PV modules in the open parking lot and install the wind power generation in the right place, vigorously develop green energy such as photovoltaic and wind energy, and it is also able to shelter a parking car from the wind and the rain.
ii. Deployment of charging facilities in the parking lot, and at the same time, the power battery of the EVs serves as the energy storage part of the micro-grid;
iii. Deploying the micro-grid control system in the parking lot to realise the stable control and the optimal control of the photovoltaic and the EVs charging.

2.2 Main function of micro-grid control system

Micro-grid control system is the core of the entire smart parking lot, its main features include

i. *Energy dispatching function of grid-connected operation*: Photovoltaic photovoltaic cells and wind power are fully used to generate power, EV battery is normally charged, and the storage battery is charged regularly to ensure the storage battery power is at a relatively high level. If the electricity of the new energy is not enough, then get electricity from the large power grid.
ii. *Energy dispatching function of off-grid operation*: When the micro-grid energy is sufficient, the EV is fully charged and the storage battery is also charged. In the case of sufficient power, some of the new photovoltaic energy is removed, so that it reaches the power balance state; when the micro-grid energy is insufficient, the energy storage device is preferentially used; when the energy storage device is lower than the set value, the diesel generator is set up when there are the diesel generator, and some non-critical loads are removed without the diesel generator, providing energy for various infrastructure and EVs in parking lots.

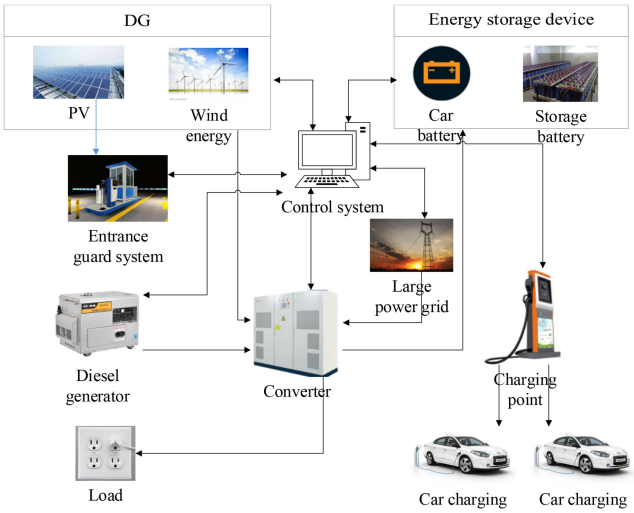

Fig. 1 *Micro-grid parking schematic diagram*

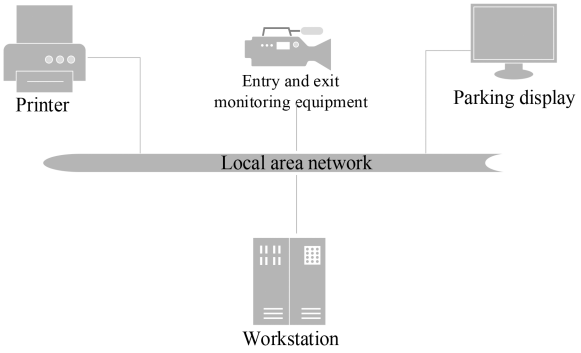

Fig. 2 *Smart parking schematic diagram*

iii. *Power quality monitoring function*: Provides real-time power quality monitoring in the micro-grid
iv. *Black start-up function*: Achieve automatic/manual start-up of micro-grids in case of collapse and enhance micro-grid self-healing capability;
v. *Grid-connected and off-grid switching function*: Combined with the requirements of voltage and frequency when grid-connected and off-grid switched in the micro-grid, safe and reliable seamless switching control;
vi. *Charge management system*: Charges include both charging costs, but also parking costs. Through RS485 and other communication interface charger information access control system, real-time monitoring of the charging post, the output power of the charging post recorded and analysis process, power off process performed after charging the energy storage device is fully charged, and print out the relevant costs; at the same time based on the time out of the parking lot parking costs, the two costs combined.

2.3 Implementation scheme of the micro-grid smart parking lot

The composition of the micro-grid smart parking lot is shown in Fig. 1, including photovoltaic, charging stations, charging posts, wind power generation, and parking facilities. Deploy the micro-grid energy management system in the parking lot to realise the stable control and optimised control of the charging EVs and photovoltaic in the parking lot. Cover the PV modules in the open parking lot and it is able to shelter a parking car from the wind and the rain.

2.3.1 Function realisation of micro-grid control system:

i. Micro-grid smart parking control system, the hardware can choose ARM chip, using Linux operating system, using C language programming to achieve [2];
ii. If it is detected that the grid-connected switch is 0 and all the voltages of the whole network are 0, it will enter the black start module to realise automatic/manual start-up of the micro-grid in case of collapse and enhance the self-healing capability of the micro-grid;
iii. If there is a manual grid-connected command input on the outside, into the grid-connected and off-grid switching function in the off-grid turn into the grid-connected;
iv. If there is a manual off-grid command input on the outside, into the grid-connected and off-grid switching function in the grid-connected turn into the off-grid;
v. If there is no external command but the grid connection switch changes from 1 to 0, into the grid-connected and off-grid switching function in the grid-connected turn into the off-grid: the voltage and frequency requirements in combination with grid-connected and off-grid switching will be achieved safely and reliably seamless switching control;
vi. If there is no external command, and the grid-connected switch is 1, then enter the grid-connected and run the energy scheduling function;
vii. If there is no external command, and the grid-connected switch is 0, then enter the off-grid and run the energy scheduling function;
viii. The following functions of the device are handled without interruption: parking management system functions, human-machine interface functions etc.

2.3.2 Function realisation of smart parking lot: The composition of the micro-grid smart parking lot is shown in Fig. 2.

i. Cover the PV modules in the open parking lot and install the wind power generation in the proper place to shelter the parked cars. The location of tourist attractions is relatively remote, parking lot can occupy a larger area, so it is suitable for the plane parking system [3, 4].
ii. When the vehicle enters the parking lot identification area, the licence plate recognition technology is used to identify the licence plate, and the vehicle information is stored in the management workstation. After receiving the vehicle identification information, the workstation controls the entrance controller to turn on the automatic gate to allow the vehicle to enter.
iii. Parking detector full time detection of the smart parking lot spaces, and the information stored in the management workstation, the workstation will be real-time feedback on the parking space information on the display, the parking space is divided into ordinary parking space and charging parking space, which is for vehicle owners reference.
iv. After the charging car is connected to the charging post, through RS485 and other communication interface charger information access control system, real-time monitoring of the charging post, the output power of the charging post recorded and analysis process, power off process performed after charging the energy storage device is fully charged.
v. The sensor controls to turn on the automatic gate to allow the vehicle to exit after the sensor successfully identifies the licence plate. General car parking fees based on time to enter and exit, and new energy vehicles need to pay the charging and parking management fees.

3 Optimisation control strategy of the micro-grid smart parking lot

Since the power quality of distributed new energy generation (such as wind and solar power generation) and EV charging in smart parking lots is characterised by randomness and volatility, the main objective of the smart parking optimisation control system is to suppress these randomness and volatility. Specifically, in the micro-grid grid-connected state, the power line fluctuations between the micro-grid and the grid are suppressed and the micro-grid access is improved; in the off-grid state of the micro-grid,

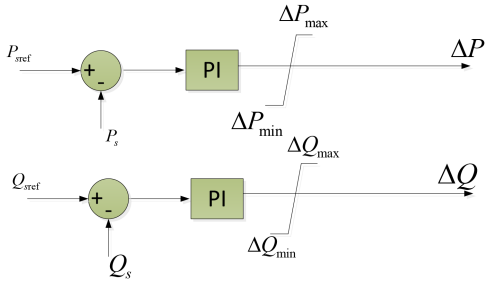

Fig. 3 *Schematic diagram of reference power calculation*

stable voltage and frequency control of the micro-grid is achieved. Improve the micro-grid's ability to operate independently. Controllable objects in smart parking include

i. Energy storage device (contains EV charging section), and its energy storage and energy release rate charge and discharge can be adjusted, it is also the primary control target in smart parking;
ii. *Exchange power with the grid*: In grid-connected state, the exchange power with the grid is an important adjustment parameter, and a reasonable grid exchange power can be determined based on the current renewable energy and the use of EVs.
iii. Non-essential loads such as redundant lighting systems/air conditioning systems. Especially in off-grid conditions, non-essential loads can be removed. Only the removal of part of the non-important load can maintain the energy balance in the off-grid state. It is necessary to remove the non-important load first.
iv. *Charging piles*: Charging piles are more important loads, and the power supply is needed to ensure that the vehicle can leave the parking lot in the case of electricity. However, the charging speed can be appropriately slowed down, and when the charged car power reaches 50% and the cruising range can reach a certain distance, the car can be stopped from being charged. Of course, this requires intelligent modification of the charging pile control module.

According to classification of smart parking operation status, optimisation control strategies mainly include grid-connected control strategy and off-grid control strategy.

3.1 Grid-connected optimisation control strategy

The goal of optimising the grid-connected is to suppress the power line fluctuations of the micro-grid and the grid, and improve the friendliness of the micro-grid access. At the same time, the difference in peak-to-valley electricity prices is fully utilised to improve economic efficiency. Specifically, the exchange power at night can be set large to ensure that all energy storage devices are fully charged; and at peak electricity prices, the exchange power is minimised.

In grid-connected operation mode, all devices in the smart parking lot (including the EV battery) are in *PQ* operation mode.

The specific control logic is

i. Using artificial intelligence or pre-setting the reference value of exchange power in different periods of time.
ii. The system measures the exchange power *P*s and *Q*s of the grid in real time, and then calculated the difference between the reference values of the given exchange power. ΔPs = Pref-*P*s, and calculate the current system's overall power deviation reference value, as shown in Fig. 3.
iii. The calculated ΔP and ΔQ are decomposed according to the operating equipment, and the reference value of the output power of each equipment is calculated. If the battery load permits, the fluctuation will be borne by the battery as much as possible.
iv. The energy storage part controls the inverter according to the *PQ* control logic. The specific control logic is as follows:

When the storage system is under *PQ* control mode, the double loop control is used, which includes power outer-loop control and current inner-loop control.

v. At the same time through the evaluation of the current system, properly adjust the parameter values of the power exchange with the grid to form a complete closed-loop.

3.2 Off-grid optimisation control strategy

The goal of optimal control of the micro-grid when it is off-grid is to achieve stable voltage and frequency control and improve the microgrid's ability to operate independently. In order to make the smart parking system on the off-grid stable and reliable, in the off-grid operation mode, the master-slave control mode is adopted; the energy storage (including the EV battery) in the smart parking lot is divided into three parts. The first part is the basic energy storage, this part runs in the VF mode of operation. The second part is the already filled emergency power exchange car storage battery, this part is disconnected from the grid and does not participate in the operation and regulation of the micro-grid. The third part is the other battery that is not used as an emergency battery. As part of an energy storage system, participate in grid regulation. All other equipment except energy storage continues to work in the *PQ* mode.

The specific control logic is

i. The energy storage system is in the VF control mode, which establishes a stable voltage support and frequency support for the intelligent parking lot;
ii. Real-time measurement of the status of the power grid system and control of the grid according to the status. When the following conditions occur, partial load reduction is required. Specific control strategies include

    a. When the system frequency is always <50 Hz, then reducing the non-important load in sequence in a predetermined order;
    b. When the system voltage is always lower than the given value, then reducing the non-important load in sequence in a predetermined order;
    c. If the output power of the energy storage system reaches the limit, then reducing the non-important load in sequence in a predetermined order;
    d. According to the estimated operating time, when the time supported by the energy storage system alone is less than the pre-set value, then reducing the non-important load in sequence in a predetermined order;
    e. In the above case, reducing the non-essential load cannot meet the requirements. Slow down the charging speed of EVs and shut down the charging of EVs that have been charged up to 50% capacity.
    f. When only 20% of the total energy storage system capacity is left, only the power source of the system must be retained and one charging gun are kept to ensure operation under emergency conditions.

iii. When the power provided by renewable energy is greater than the demand for electricity, the charging current of the battery is increased to fill the battery as soon as possible; if enough power is available, the renewable energy inverter will be used to reduce the output of new energy. To ensure the stability of the power grid.

4 Conclusions

The micro-grid smart parking lot proposed in this paper is easy to manage and improve the travelling efficiency of vehicle owners. It makes full use of distributed new energy sources and reduces the dependence on the large power grid in the tourist scenic spots. The main functions of this type of micro-grid smart parking lot include

i. Deployment of photovoltaic modules over the parking lot or over the buildings to develop green energies; meanwhile, the

photovoltaic modules on the parking lot shelter the cars and improve the reliability of parking.

ii. The use of storage battery EVs as a micro-grid energy storage component to reduce the cost of micro-grid, to achieve optimal scheduling of micro-grid and improve the utilisation of new energy;

iii. Make full use of the existing parking lot to solve the problem of charging of EVs and promote the application of EVs;

iv. To achieve intelligent energy management and achieve a good interaction between intelligent parking lots and power grids;

v. To change the society and make the city more and more green and smarter, bring opportunities to urban infrastructure, energy, transportation, and environment.

Based on the advantages of the micro-grid smart parking lot, the micro-grid smart parking lot will be well developed.

5 Acknowledgments

This work was supported in part by Technology Foundation of China (grant no. 2017A010104023). The authors would like to thank National Key Research and Development Program and Guangdong Science and Technology Foundation for the financial support to carry out this research work.

6 References

[1] Xinfa, Y., Jian, S., Zhipeng, L.*, et al.*: 'Overview on micro-grid technology', *Proc. CSEE.*, 2014, **1**, (1), pp. 57–70

[2] Hongju, J.I.: 'Parking lot management system based on ARM', *Control Autom.*, 2010, **26**, (4), pp. 110–111

[3] Chengguang, Z.: '*Application of intelligent parking management system*' (China Academic Journal Electronic Publishing House, Tianjin, China, 2009), pp. 136–139

[4] Qingna, Y., Youmou, L., Mao, G.E.: 'Design and implementation of management system intelligent parking lot', *Academic Forum.*, 2011, **1**, pp. 72–75