Development and Engineering Application of AC Charging Pile for Energy Internet Router

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Abstract. At present, in the context of the rapid development of green new energy and environmental protection requirements, it is of great significance to build an energy Internet ecosystem based on charging network and vehicle networking platform. In this paper, the system block diagram of ac charging pile of energy Internet router is given. At the same time, based on the overall scheme design, the control strategy of the energy Internet router ac charging pile is introduced in detail. Finally, the development of the prototype is given, and a demonstration application project of the energy Internet router ac charging pile is established in shanheyuan community, Yangzhou, Jiangsu province.

1. Introduction

American futurists Jeremy Rifkin in his book "the third industrial revolution," for the first time, puts forward the concept of Energy Internet, he thinks the internet is renewable distributed energy interact with the internet as the core, the realization of distributed generation, energy storage and electric cars, large-scale use, and the widespread participate in fair trade network. In recent years, extensive studies have been conducted at home and abroad on the characteristics, key technical equipment, basic concepts and organizational structure of energy Internet, which have promoted the development of energy Internet [1-5].

As a new means of transportation, electric vehicle is also a distributed power load with energy storage function, which can not only respond to the policy requirements of energy conservation and emission reduction, but also reduce the dependence on traditional fossil energy. As an important part of Energy Internet, electric vehicle is directly related to whether the Energy Internet can be truly realized. With the continuous maturity of electric vehicle technology and rapid development of the industry, it is expected that electric vehicles will achieve absolute parity in 2020, and the use cost is far lower than that of traditional fuel vehicles [6-9]. At the same time, global installed photovoltaic capacity will continue to increase, the cost of photovoltaic power generation will continue to fall, solar energy will become the most economic form of energy, will also become an important energy source for electric vehicles. In addition, with the continuous promotion of commercial application of energy storage and the gradual popularization of 5G communication network, the energy Internet with intelligent and networked electric vehicles as an important element will usher in all-round and in-depth development [10].

In this paper, the system block diagram of ac charging pile of energy Internet router is given, and various working modes under typical working conditions are described in detail. Based on the overall scheme design, the control strategy of ac charging pile for energy Internet router is introduced in detail.
2. The overall scheme design of energy Internet router ac charging pile

The ac charging pile system framework of Energy Internet router is shown in figure 1, which includes ports: two-way ac port, photovoltaic access port, ac charging pile port and energy storage device port. The functions of each port are as follows: the two-way ac port can realize the two-way flow of energy, provide reactive power support to the power grid, and maintain the stability of the dc voltage of the energy router when connected to the grid. Off-grid operation, maintain the stability of ac voltage. Photovoltaic access port integrates photovoltaic energy into the dc system to achieve the maximum photovoltaic power tracking. The port of ac charging pile can charge electric vehicles with a capacity of 7KW or below, which can realize energy management. The energy storage device port can charge and discharge the energy storage battery, which can calm the fluctuation of photovoltaic power generation and power grid, realize energy storage at night and peak discharge, realize controllable charge and discharge function and energy management, and set charge and discharge strategies according to different characteristics of energy storage system.

Figure 1. Energy Internet router ac charging pile system framework

The following detailed introduction of energy Internet router in the typical working conditions of various working modes.

1) photovoltaic grid-connection

Under this working mode, the power grid switch is closed, and the direct current energy output by the photovoltaic array is converted into AC voltage and incorporated into the power grid to supply power to users after being inverted by DC/DC converter and DC/AC converter.

2) photovoltaic power supply after off-grid (daytime)

In this working mode, the power grid switch is disconnected. On the one hand, the photovoltaic array charges the battery, and on the other hand, it supplies power to the charging pile after the transformation of electric energy.

3) power supply by battery after off-grid (at night)

When the photovoltaic array is not working at night, the battery group will supply power to the charging pile after the transformation of electric energy.

4) power supply (daytime)

The daytime photovoltaic array works, which can use photovoltaic power generation and power grid to charge the battery bank on the one hand, and power the charging pile on the other hand.

5) power supply by power grid (at night)

The photovoltaic array does not work at night, but electricity is cheaper at night. The power grid can be used to charge the battery on the one hand and power the charging pile on the other.

6) power grid support

When the grid needs support in an emergency, photovoltaic arrays, batteries and car batteries supply power to the grid load at the same time.
3. Control strategy of ac charging pile of energy Internet router

Based on the overall scheme design of ac charging pile of energy Internet router mentioned above, this section introduces the control strategies of various converters in energy Internet router.

3.1. Control strategy of converter 1

The topology of converter 1 is two interlaced BOOST DCDC converters controlled by a single voltage loop. MPPT is realized by continuously adjusting the output voltage of the photovoltaic array to make it always run at the maximum power point of p-v characteristic curve. The output voltage and output current of the photovoltaic array obtained by sampling are used to obtain the reference value of the output voltage of the photovoltaic array through MPPT algorithm, and the error between it and the actual output voltage of the photovoltaic array is compared with triangular wave after PI adjustment, thus generating PWM signal. The control structure of converter 1 is shown in figure 2.

![Figure 2. Control structure diagram of converter 1](image)

3.2. Control strategy of converter 2

According to the analysis and introduction of 3.1, although the MPPT control of converter 1 makes the photovoltaic array run at the maximum power point, its output power also changes due to the constant change of external conditions such as light intensity and temperature. If the voltage of dc bus is not controlled, it will inevitably change due to energy fluctuations. When the energy output of the photovoltaic array suddenly increases, the voltage of the dc bus will rise if the energy is not sent to the power grid through the inverter in time or consumed by the load, and the high voltage will easily lead to the damage of electrolytic capacitor or switch tube due to overvoltage. On the contrary, if the energy of pv array output reduced suddenly, dc bus voltage will be lower, if too low to reach peak value of the ac voltage, is unable to realize the inverter, power grid will be through the switch tube of parallel diode reverse flow in the form of not controlled rectifier inverter, the inverter current will not be controlled, so you must to control the dc bus voltage.

Converter 2 adopts HERIC DC/AC converter, and the control block diagram is shown in figure 3. Converter uses the voltage and current double closed-loop structure of grid current control, voltage outer loop to stabilize the dc bus voltage, a given dc voltage value and the actual dc voltage PI adjustment, the error between the output as alternating current amplitude is given, with the grid voltage after units sine signal multiplication phase-locked loop to get the given value as alternating current. The current inner loop realizes the control of ac current, and the error between the given value and the actual value is compared with the triangle wave after PI adjustment to generate PWM signal.

![Figure 3. Control structure diagram of converter 2](image)
3.3. Control strategy of converter 3

Converter 3 also adopts HERIC DC/AC converter. As shown in figure 4, the converter adopts voltage type control, the outer voltage loop adopts PI adjustment to stabilize the output voltage, and the inner current loop adopts PR adjustment to improve the response speed.

![Figure 4. Control structure diagram of converter 3](image)

3.4. Control strategy of converter 4

Converter 4 adopts a two-stage structure. The front stage is Buck-Boost converter and the rear stage is LLC resonant converter, realizing the two-way flow of energy and the electrical isolation of the primary and secondary sides. The Buck-Boost converter realizes constant voltage, constant current and constant power charging and discharging, while the LLC resonant converter adopts open-loop control to realize high frequency isolation. Its control block diagram is shown in figure 5.

![Figure 5. Control structure diagram of converter 3](image)

In figure 5, the current instruction calculation module collects the voltage, current and voltage of the low-voltage side of the converter and selects the corresponding control outer ring according to the control instructions of the superior system to achieve different control objectives.

The current achievable instructions are: maintain dc bus voltage constant, constant voltage charging, constant current charging and discharging, constant power charging and discharging. When the dc bus voltage needs to be controlled, the current given value of inductance is calculated through the voltage loop on the side of the dc bus. When constant voltage charging is required, the voltage loop on the side of the battery is put into action to calculate the given value of inductive current. When constant current charge and discharge is required, the command value of charge and discharge current given by the upper computer controller or the preset current value is directly transferred to the current loop. When constant power charge and discharge is required, the corresponding charge and discharge flow under the given power of the upper computer controller is calculated. The charging and discharge control process of the battery group is as follows:

1) When charging, the front-stage buck-boost DC/DC converter works in BUCK mode. By adjusting the duty cycle of the front-stage buck-boost DC/DC converter, the input voltage of the LLC
resonant converter can be directly controlled. The latter stage LLC resonant converter operates in the open loop mode with a resonant frequency slightly higher than the switching frequency. The PI regulator can realize constant current control of the output charging current, and the output signal of the regulator is used to adjust duty cycle of the former buck-boost DC/DC converter.

2) During discharge, the battery voltage goes through the reverse boost of LLC resonant converter and limits the maximum battery discharge current. The former BUCK-BOOST converter operates in BOOST mode, boosting the bus voltage, and the discharge current is determined by the overall power consumption of the circuit.

4. Prototype development and engineering application

Based on the above overall scheme design and control strategy, an energy Internet router ac charging pile prototype is developed. The prototype is equipped with a two-way ac port of 7kVA, a 5kW photovoltaic access port, a 5kW energy storage port and a 7kW one-way ac charging port, with a total of four ports. The connection port of the network side is a two-way 7kVA PWM rectifier, and the ac output port is a 7kVA/220V single-phase port, for ac charging of the power supply motor vehicle. The relevant technical parameters are as follows:

**Table 1. Ac input requirements**

| Parameter                  | Requirement                        |
|----------------------------|------------------------------------|
| Ac input voltage           | 180～270VAC (Single phase effective value) |
| Ac input frequency         | 45～55Hz                            |
| The power factor           | advance 0.8~ lag 0.8                |
| Voltage THD                | ≤5%                                |

**Table 2. Energy storage battery side requirements**

| Parameter                  | Requirement                        |
|----------------------------|------------------------------------|
| The battery type           | Lead-acid or lithium batteries     |
| The rated voltage          | 48V DC                             |
| Maximum discharge power (W)| 4600                               |
| Maximum charging power (W) | 4600 (Can be set)                  |
| Battery capacity (Ah)      | ≥100 (Configure as required)       |

**Table 3. Photovoltaic interface side requirements**

| Parameter                  | Requirement                        |
|----------------------------|------------------------------------|
| Rated dc power (W)         | 5000                               |
| Maximum dc voltage (V)     | 580                                |
| MPPT Voltage range (V)     | 125～550                            |
| Start the voltage (V)      | 150                                |
| Maximum dc current (A)     | 11                                 |

**Figure 6. Energy Internet router ac charging pile prototype**

The prototype of ac charging pile of energy Internet router is shown in figure 6. At present, shanheyuan community in Yangzhou, Jiangsu province has started the construction of energy Internet
router ac charging pile demonstration project. Figure 7 shows the situation of the demonstration site and the appearance of the ac charging pile device of the on-site Energy Internet router.

![Demonstration Site and Energy Internet Router AC Charging Pile](image)

**Figure 7.** External view of demonstration project and Energy Internet router ac charging pile

5. Conclusion

Firstly, this paper analyzes the significance of building an energy Internet ecosystem based on charging network and Internet of vehicles under the background of the rapid development of green new energy and environmental protection requirements. Then the system block diagram of ac charging pile of energy Internet router is given. At the same time, based on the overall scheme design, the control strategy of the energy Internet router ac charging pile is introduced in detail. At last, the specific parameters of the prototype are given, and the demonstration project application of the energy Internet router ac charging pile in shanheyuan community, Yangzhou, Jiangsu province is demonstrated.

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