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Design and Simulation Research on Electric Vehicle Charging Stations with Photo-voltaic Power

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Abstract

Electric vehicle (EV) is a clean transportation tool by replacing the traditional internal-combustion vehicles. Photovoltaic power generation is the trend of new energy power generation of environmental protection and green. They will be the effective choice to solve the problem of the current environmental protection, energy, and to ensure that the electric car charging station is very necessary. Photo-voltaic electric vehicle charging stations using photo-voltaic (p-v) as charging power supply, not only need to add energy to electric vehicles, as well as electric cars and electric grid interface. Therefore its construction is the key to the current industrialization of electric vehicles. In view of the photo-voltaic electric vehicle charging station, this paper proposes two feasible design schemes. And through the simulation analysis, the simulation of the operation of the charging station provides reliable support for the construction of the charging station actual.

Keywords*: electric vehicle, charging station, photovoltaic, power quality, design and simlation study*

1. Introduction

As car caused serious environmental pollution and oil crisis, since the 1990 s, the electric car research began to be taken seriously. Now many countries in the world carry out its industrialization. In order to promote the electric car, perfect supporting infrastructure is indispensable. So the constructions of electric vehicle charging station become the key problem. From October 2009, the domestic has set about building with functions of commercial operation of the electric vehicle charging station. There are several stations in Shanghai, shenzhen, xiangfan and yichun have been put into use[1-2].

Now, however, the electric car is still in the trial run stage, and the design, the construction of the electric vehicle charging stations is also very immature. Also the relevant technical standards of electric vehicle charging stations at home and abroad are very few. That has become one of the most important factors that affect the industrialization of electric vehicles[3].To promote electric vehicles, as the representative of new energy vehicles industrialization, the country issued many relevant policies, supporting the popularity of electric cars. Based on this environment, photo-voltaic power generation and electric vehicle, as the combination product of the two most important development directions in the field of new energy, the research of the construction of the photo-voltaic electric vehicle charging station becomes more imminent.

As a consequence, this article starts with the electric vehicle charging facilities specific to the electric vehicle charging stations including photo-voltaic. From two aspects: design and simulation study, the article illustrates the principles which p-v charging station design should follow. And through mat-lab simulation platform, the simulation demonstrates the proposed design of charging stations.

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2. Electric Vehicle Charging Infrastructure

At present, according to the different methods of electric vehicle charging, the electric car charging infrastructure can be divided into three types: charging pile, charging station and converter station. They correspond to three kinds of charging ways: slow charging, fast charging and fast changing.

Charging pile provides alternating current power supply for the electric vehicles with car charger. It has many characteristics, such as smaller power, smaller area, and flexible stationing. It can be installed in the parking lot, shopping plaza, and other existing location which is convenient for electric car to be parked. Charging station, which takes a large area, can take a variety of ways for electric car to be powered. There are quick charge, slow charge and change the battery. At the same time when it charged, it can be able to monitor the conditions of the charger, power battery and battery replacement equipment. A charging station is composed of many sets of charger and charging pile. The charger adopts rectifying installation charge for storage battery of electric vehicle. It has large power, wide range of the output current and voltage, so it can meet the demand of different types of electric vehicle[4]. Otherwise, a charging pile uses AC charge for the charge of electric car. A converter stations provide users services of changing the battery and battery maintenance services. The battery removal and installation equipment is the main equipment for a converter station. It has many characteristics of the specialized operation, short battery replacement time (usually 5-10 minutes), smaller occupied area than charging station and easy stationing on a large scale in the city. As we all known, the AC charging piles are the most common charging infrastructures with the biggest energy change. It also the charging and discharging equipment which combined the most close with the technology research and application of intelligent building integrated energy efficiency management. Also the charging station and converter station can be considered to be composed of every charging pile (charger). This article mainly uses charging stations for a particular study.

2.1. Factors Should Be Considered For a Charging Station

With the continuous popularization of charging car, the number of electric cars is increasing. So energy consumption of charging and discharging network which electric vehicle charging facilities formed will be very large. Thus the impact on the grid is also gradually cannot be ignored.

On the one hand, the electric car charging load has certain randomness in time and space. That may lead to increase of the peak power load, so there is the need to increase power grid capacity. Some electric power transmission and distribution network will not be able to carry their energy needs. On the other hand, the harmonic that electric vehicle charging equipment produced will also affect the power quality of local power grid. Therefore, under the broad application prospect in electric car, how to properly complete the design of the electric vehicle charging station, and how to quantitative assess the huge energy consumption affects that infrastructure network brought has become the focus of many electricity workers.

In order to make the layout of electric vehicle charging and discharging facilities more scientific and rational, so the construction of the electric vehicle charging and discharging facilities will not affect the normal operation of the power grid. It must be study deeply and thoroughly in the design and the energy consumption management.

3. Design of Photo-Voltaic Charging Station

There are several possible ways for photo-voltaic (p-v) to charge electric cars[5]. The energy distribution ways shows as followed figure 1.

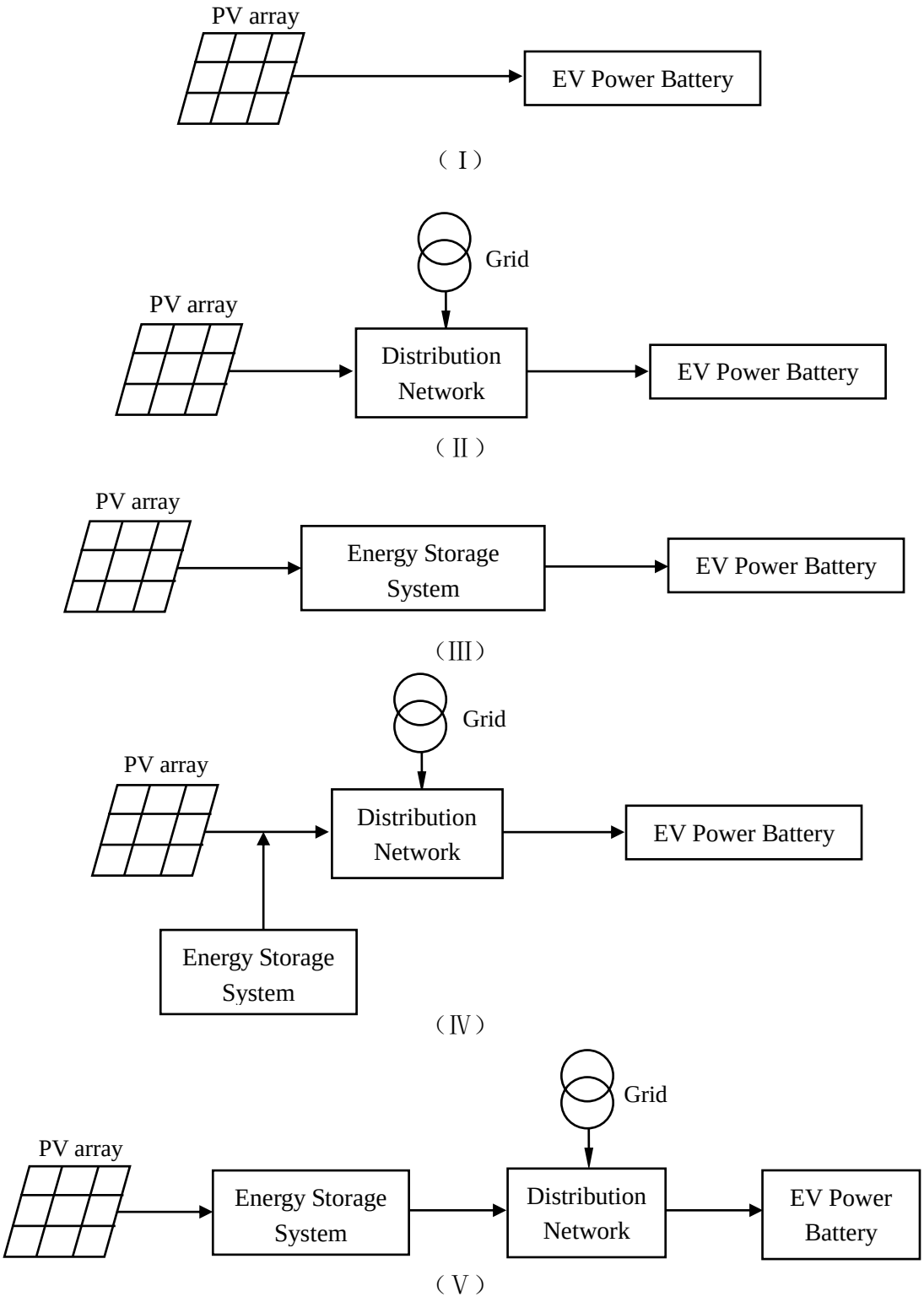

Figure 1. Modes Classification of Energy from Photovoltaic to Charging Station

This article study the charging station construction which has 250kW charging machine with photo-voltaic (p-v) power supply. In the passage, there are discussions for the design scheme of both photo-voltaic charging stations with independent photo-voltaic power

supply and photo-voltaic grid-connected charging stations respectively. And the next section briefly makes a comparison with two kinds of solutions.

3.1. Design of Operation Independent Photo-Voltaic Charging Station

In this design, charging machine and electricity equipment such as office lighting is the main body for charging station. That basic structure is as shown below in Figure 2. As you can see, the power energy that the PV array produced can storage in the light energy storage system, and the energy stored by the storage system can guarantee the use of charging stations for 7 days.

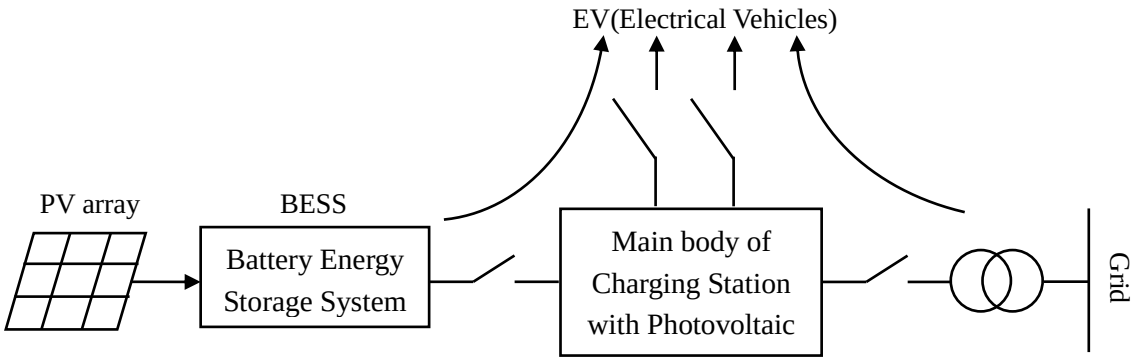

Figure 2. Design of Independent Photovoltaic Power Supply Charging Station

In the shortage of independent photovoltaic power supply, we use the charging stations grid-connected operation mode. That is to say, charging station get energy from the power grid. The main wiring structure diagram for power distribution is as shown below. Because charging station is the secondary load, here we use two 10 kV roads into line. Both High voltage side and low voltage side adopt the main wiring mode of single bus section form, through the circuit breaker QF01/02 standby. If the charging station operation situation is normal, QF01/02 is disconnected. The two way power output independent through two transformers. Each of them undertake the work of charging stations is about 50%; When any bus bar lose electricity, we can obtained the power from another bus at the same level, through the circuit breaker closing. Thus the power supply reliability of charging station connect grid mode can be improved. The measuring cabinet is installed on high voltage side of input transformer. And the harmonic suppression and reactive power compensation device are installed on the low voltage side.

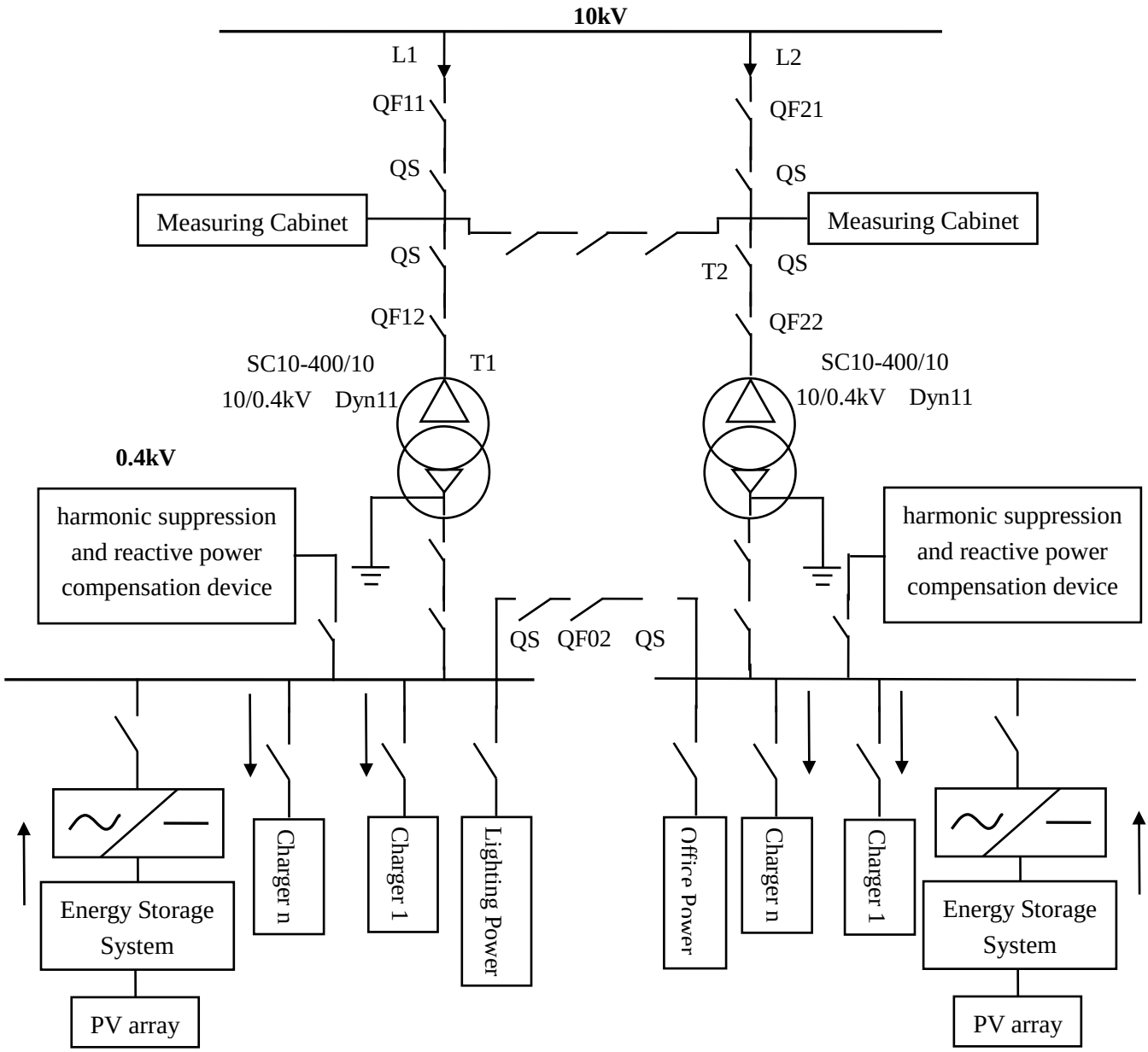

Figure 3. Main Wiring Structure Diagram for Power Distribution of Charging Station with Independent Photovoltaic Power Supply

3.2. Design of Grid-Connected Photo-Voltaic Charging Station

Using this scheme, PV array are attached to 0.4 kV bus bars by inverter. The basic structure design scheme of charging stations is as shown in figure 4 below.

As you can see, the energy charging stations provided for PV comes from the 0.4 kV bus bars. During the daytime, power energy of PV array flow to bus bars. At night or cloudy weather, the voltage of bus bars is mainly supported by power grid. Here energy storage system can be seen as power supply, and it complete energy supplement through PV array at ordinary times. When the power of PV array is insufficient or can't provide sufficient energy by night or rainy weather, and the power grid happened to power failure due to the fault, 0.4 kV bus bars voltage was maintained by the energy storage system. Obviously, as long as keep 0.4 kV bus bars voltage, can guarantee the stable operation of

the charging station.

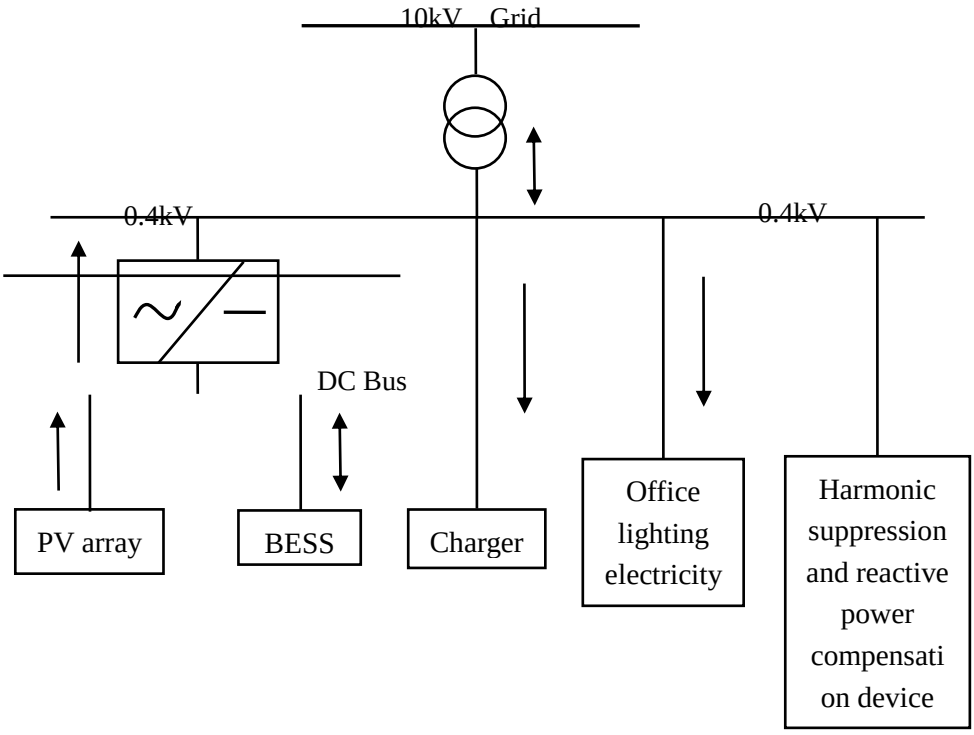

Figure 4. Design of Grid-Connected Photo-Voltaic Charging Station

The main distribution wiring structure is as shown in the figure 5 below. Both two photovoltaic (p-v) grid-connected inverters are connected to grid by 0.4 kV interconnections. Charging stations with 1 road 10kV power lines are used to meet the power of lighting, office and charging equipment; Metering device and harmonic and reactive power control device on the low voltage side of transformer are installed as the same design scheme with the former.

It is important to note that charging station capacity of 10 kV line in the figure must be greater than all the charging station equipment required for capacity. In this passage, we need that is greater than the sum of the total power of chargers and office lighting power. In addition, there should also have a certain margin in input transformer capacity S_N[6-7]. Charging station is generally regarded as the secondary load, but the distribution of main wiring only used 1 road 10 kV power supply into line, this is considering the plan charging station can be through the two way grid power, photovoltaic power supply and equipped with UPS power supply, to ensure its reliability.

For charging station with independent photo-voltaic power supply, it can be applied to area that is far away from the grid, or regional power grid connection is not convenient when it do not pick up the grid. Since in the city zone, charging station with independent photo-voltaic power supply is not economic. Because photo-voltaic battery energy storage system is expensive, and its use cycle is very short, if only consider the cost, that makes this plan theory is far from economic than charging station with p-v power grid connected operation.

For charging station with photo-voltaic (p-v) power grid connected, its construction is more economic, relative to the charging station with independent photo-voltaic power supply scheme. The battery energy storage system used as UPS here, hence its energy storage requirements on capacity is much lower. The charging stations using photo-voltaic (p-v) power grid connected operation scheme can also take advantage of the difference

between the mains electricity price and photo-voltaic feed-in tariff to make up the high cost of photo-voltaic power generation due to the current technology. As a result, at the existing technical conditions, this scheme-charging station with photo-voltaic (p-v) power grid connected is more worth considering, relative to the charging station with independent photo-voltaic power supply scheme.

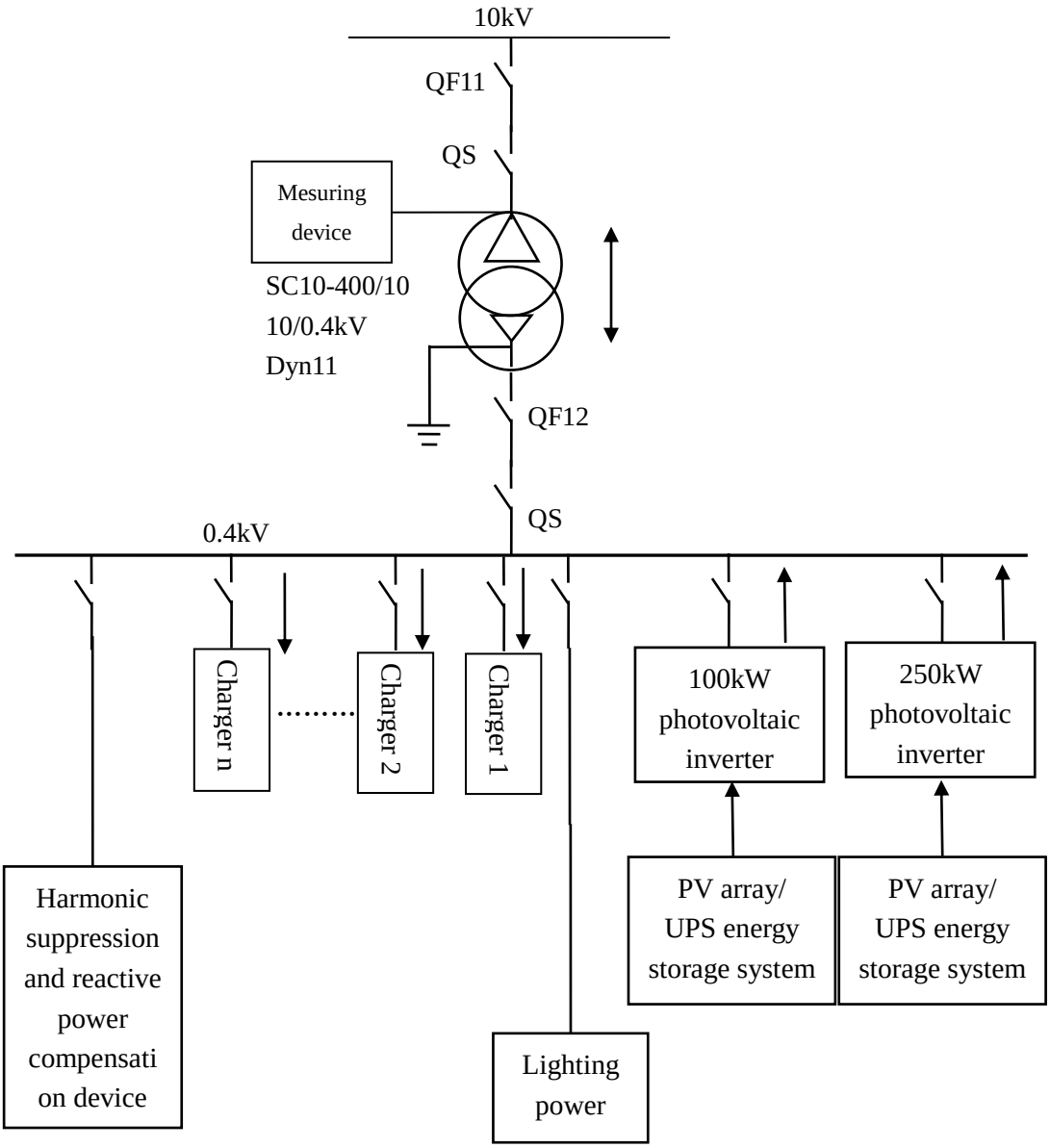

Figure 5. Main Wiring Structure Diagram for Power Distribution of Charging Station with Photo-Voltaic (P-V) Power Grid Connected Power Supply

Regardless of the design scheme we use, large areas of the charging station construction is the key problem if electric cars want to be widely promoted. Both two kinds of charging station design scheme of the above discussion cost very high compared with the charging station construction with pure ordinary mains operation, due to the limitations of current technology. But in sense of integration of charging stations and photo-voltaic power, the study of charging station with photo-voltaic (p-v) power supply for electric vehicle is significantly important in accordance with the low carbon economy

development direction. In other words, the study is very practical from a long-term point of view.

4. Simulation of Photo-Voltaic Power Charging Station

The electric car charger using power electronic technology is a typical high power nonlinear device, so the vigorous promotion of electric car charger will seriously affect the power quality of power grid. Thus this is an important problem which must be considered by the construction of charging station. Before construction of electric vehicle charging station, it is necessary for engineers to analyze and simulate the impact charging station and its operation made on the grid. At the same time, engineers need to know that whether charging station construction requirements meet the national standard. So the results of analysis and simulations can provide the reference for the construction of charging stations, for whether the charger stations need to configure appropriate governance such as harmonic suppression and reactive power compensation device.

The article aim at the simulation study of photo-voltaic electric vehicle charging station, illustrating mainly from the PV array, charger and charging station three aspects. Then it states how to use Matlab or PSCAD simulation software to model and analyze.

4.1. PV Array

For any given temperature and radiation parameters, PV array model equation can be determined according to I-V curve of the PV cells. PV array modeling process is as shown in the figure below.

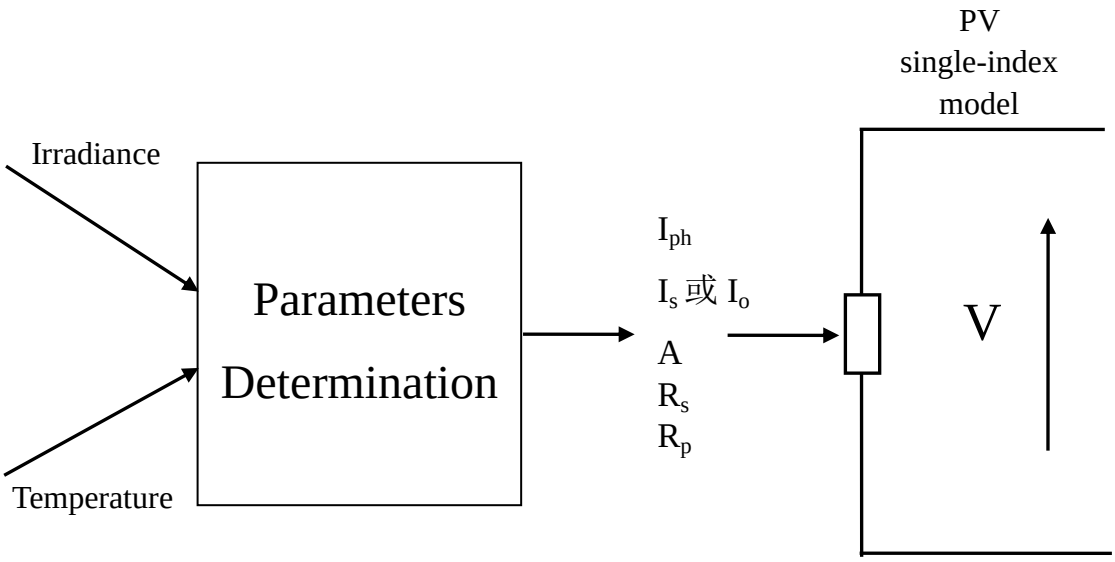

Figure 6. PV Modeling Procedure

PV array model can be represented as ASUPVD model[8]. That is, when the PV array output voltage is V, the corresponding current output I can be repressed as follows:

$$\mathrm{I} = \mathrm{I}_{\mathrm{sc}}(1 - C_1(\mathrm{e}^{\frac{V-DV}{C_2 V_{OC}}} - 1)) + DI \tag{1}$$

其中：

$$\mathrm{C}_1 = (1 - \mathrm{I}_{\mathrm{m}}/\mathrm{I}_{\mathrm{sc}})\mathrm{e}^{-\frac{\mathrm{V}_{\mathrm{m}}}{\mathrm{C}_2 V_{oc}}} \tag{2}$$

$$C_2 = (V_m/V_{oc} - 1)/\ln(1 - I_m/I_{sc}) \quad (3)$$

$$DI = a \cdot \frac{R}{R_{ref}} \cdot DT + (\frac{R}{R_{ref}} - 1)I_{sc} \quad (4)$$

$$DV = -bDT - R_s DI \quad (5)$$

$$DT = T_c - T_{re} \quad (6)$$

T_{ref} and R_{ref}: light and temperature reference value, generally take 1 kW/m^2, 25 ℃;

a and b: current and voltage temperature coefficient respectively under reference radiation (Amps / ℃, V / ℃);

I_{sc}, V_{oc}: short circuit current and open circuit voltage respectively;

I_m, V_m: Current and voltage of maximum power point respectively.

Take Asupvd model as the research object to build the SIMULINK simulation model of PV arrays. Among them, the input R, T is the surface of the PV array illumination intensity and the current environment temperature respectively. The input of I_{in} is the current moment for PV array output current; Output V_{om}, I_{om} respectively is the voltage and current value of PV array current moment MPPT point. They have the MPPT algorithm to calculate in real time; Output V_o is the actual output voltage of PV array.

4.2. Charging Set

H_f charger general structure diagram is as follows. Among them, three-phase alternating current (ac) U_a, U_b, U_c are obtained through transformer from the three-phase grid. They can provide power for charger. High frequency DC to DC converter frequency is more than 20 kHz. Here, as well as having isolation effect, it can reduce the volume of equipment such as transformer and filter. At the meantime, it can also improve the filtering effect and efficiency of charger.

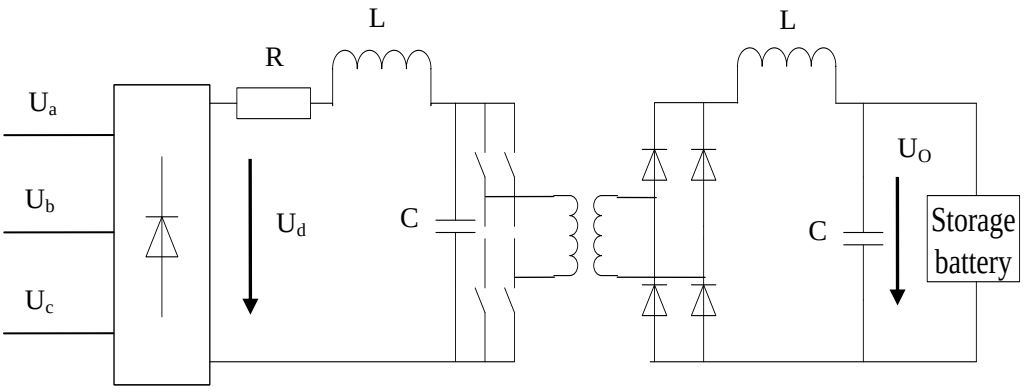

Figure 7. H_f Charger General Structure Diagram

In essence, the electric car charger is high-power switching power supply. In the middle of it, a high frequency power conversion section is the key to the charger simulation. In the simulation, it is important to set the frequency of the given high frequency power transformation model, such as 20 kHz for simulation.

Because that the high frequency charger model under the environment of matlab/ simulink is a large amount of calculation, thus it is inconvenient to directly simulate high frequency charger, in order to study the influence of the charging station on grid power quality[9]. Our country's power grid voltage frequency is 50 Hz, and the time charging machine needed for charging power frequency cycle is very long relative to the line cycle time. As a result, in a certain time period, the charger can be regarded as a constant power output. Therefore, a nonlinear resistor $R_{charger}$ can be used approximate as the equivalent input impedance of high-frequency power conversion circuit.

The matlab/simulink simulation model of Charger, therefore, is consist of a three-phase controlled rectifier, LC filter circuit and the equivalent input resistance $R_{charger}$ of high frequency conversion circuit.

During actual construction of Electric vehicle charging stations, it may choose different models of charging machine equipment. And different needs and will require different charging mode and different charging station construction scale. All these will obviously result in different harmonic pollution for different charging stations to the grid[10]. Considering these factors, engineers can establish charging stations Simulink/Matlab simulation model and calculate the impact on power grid power quality.

5. Conclusion

Electric vehicle charging stations not only need to add energy to electric vehicles, as well as act electric cars and grid interface. So the electric car charging station construction is the key to the current industrialization of electric vehicles. Based on two direction the photovoltaic and electric vehicle charging station, the article takes the electric vehicle charging stations with photovoltaic power supply as example to discuss the design, simulation and analysis of the charging station. In the paper, it introduces the basic design scheme of two kinds of charging stations, and points out that it is very important to simulate the charging station operation through the Matlab/ Simulink software in advance. That will make a lot of sense before construction of the charging station actual, making the charging station more useful, planning and reasonable.

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