Research on the Influence of Photovoltaic Grid-Connected Power System on Power Grid

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Keywords: Photovoltaic, Grid connection, Islanding effect, Electric inverters, Security, Stability, Renewable energy resource.

Abstract. The principle and features of distributed and large-scale centralized grid-connected photovoltaic power systems are described in detail and the problems due to their connection with power grid are analyzed and summarized: the power quality problems on harmonic, voltage and frequency; the islanding problem; the problems on reliability and stability; the matters of grid benefit; the problems on load characteristics, planning and dispatch, distribution automation, grid voltage, grid protection, etc, based on which, the causes of each problem are reviewed, as well as the research status and main solutions at home and abroad.

Introduction

With the rapid development of world economy, the human's growing demand for energy, as well as the traditional energy drying up, people began to look to the new clean and renewable energy, hope it can change the current energy structure, and realize sustainable development. As a kind of clean and renewable energy, solar energy is inexhaustible, cheap and pollution-free, which gives it an advantage that other new energy sources cannot match.

In recent years, with the fast development of photovoltaic power generation, photovoltaic components cost is lower, 2004 photovoltaic modules within Europe (photovoltaic (PV) grid system) cost of 5 euros per Wp, predicts 2020 would be less than 1 euro per Wp, 2030 will be less than 0.5 euro per Wp. By the end of 2007, the total installed capacity of solar cells in the world had reached 12,300 MW. In 2008, the total output of solar cells in the world amounted to 6,850 MW, and the total output of solar cells in China reached 1,780 MW. By the end of 2008, the accumulative capacity of China's photovoltaic system reached 140 MW. New photovoltaic power generation capacity worldwide in 2008, about 1GW from 10 MW and above the capacity of photovoltaic power station, China also plans in Dunhuang, Gansu province, Kunming, stone forest, construction of Qaidam basin in qinghai and other places of megawatt photovoltaic (PV) grid power station. With the construction of national megawatt and even gigawatt photovoltaic power stations, the large scale of photovoltaic power station and its network will become the main direction of future development and research.

In the problems of photovoltaic power generation research, the problem of the influence of photovoltaic power generation system on the system is an urgent problem to be solved. This paper introduces the principle and characteristics of photovoltaic grid-connected power generation, and expounds the influence of photovoltaic power generation system on multiple aspects of power grid.

The Type, Principle and Characteristics of Photovoltaic Grid-Connected Power Generation System

Classification of Photovoltaic Grid Generation System

Photovoltaic grid-connected generation system can be divided into two types: centralized photovoltaic grid-connected power generation system and distributed photovoltaic power generation system. 

84
Centralized photovoltaic (PV) grid power generation systems, that is photovoltaic (PV) grid power system, the system of energy into the grid directly, but this way cannot fully play to the vast solar widely distributed, etc.

Distributed photovoltaic (PV) grid power generation system, namely the household photovoltaic (PV) grid system, it can form roof and building photovoltaic system, through the design can reduce the construction cost and cost of photovoltaic power generation system. In a distributed photovoltaic grid-connected system, the amount of electricity that is not used during the day can be sold to the local public power network through the inverter, and when electricity is needed at night, it is purchased from the power network.

In addition, PV grid-connected power system can be divided into two categories according to the system function: one kind of “uncontrollable photovoltaic grid power generation system” for non-reserved batteries; The other category is the “controllable photovoltaic grid generation system” which includes the battery group as the energy storage link.

Nowadays, the PV grid-connected power generation system has the following two development trends: the capacity of the photovoltaic grid power station is developing in a large scale, and the performance is connected to the network friendly development.

Principle and Characteristics of PV Grid-Connected Power Generation System.

Photovoltaic power generation is based on semiconductor photovoltaic effect, which converts solar radiation directly into electricity. The direct current generated by the photovoltaic cell array is converted to the required alternating current by the inverter, and connected directly or through the transformer to the power grid. Photovoltaic system is generally composed of photovoltaic panel, controller, energy storage device and inverter. FIG. 1 shows the structure of a typical photovoltaic power generation system [7]. FIG. 2 shows the equivalent simplification circuit of the photovoltaic power station [8]. In the figure, I_p is the photoelectric current; I_PV is the output current of PV array; C_PV is the output side filter capacitance of PV array; U_PV is the dc voltage of the filter capacitor; L_AC is the ac side filter inductance for inverter. R_AC is the equivalent resistance of filter inductance; C_AC is the ac side filter capacitor for inverter. I_AC is the ac side output current of inverter; U_AC is the voltage of the filter capacitor; N is transformer ratio; L_S is the equivalent inductance from the transformer to the grid-connected node; The R_S is the equivalent resistance of the transformer to the grid-connected node; I_S is for photovoltaic power station to inject and network current; The amplitude is US, and the phase angle is Φ_S.

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**Figure 1. Photovoltaic power system structure.**

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**Figure 2. Simplified equivalent circuit of grid-connected photovoltaic power system.**
Photovoltaic power generation system generally has the following characteristics.

a. Random volatility. As a kind of typical renewable clean energy, environment temperature and solar illumination intensity and the influence of weather conditions on the photovoltaic power generation system is very strong, leading to the greatest characteristic of photovoltaic power generation systems, stochastic volatility. Figure 3 shows the active power curve output of a photovoltaic power generation system.

b. The main existing photovoltaic (PV) grid inverter control method for voltage source current control, namely the input side is voltage source, the output for the current source control, by controlling the output current to track and node voltage, achieve the goal of interconnection.

c. The correlation between the protection function and load condition of the anti-isolated island of grid-connected inverter. Since the existing photovoltaic power generation capacity is small compared with the load ratio, the voltage and frequency will rapidly decrease after the loss of the market power, and the anti-island equipment can be detected accurately.

In addition to the general characteristics of photovoltaic grid-connected system, there are some notable features of the two important forms of photovoltaic grid generation.

The characteristics of distributed photovoltaic grid generation system are as follows:

a. The electricity generated by the distributed photovoltaic grid-connected generation system is directly distributed to the user's load, and the excess or insufficient power is regulated by the distribution network connected to it;

b. The general access voltage level of distributed photovoltaic grid-connected power generation system is 0.4kv.

c. Distributed photovoltaic (PV) grid power generation system can also with other new energy in the form of micro network connected to the power grid and power grid are integrated support, this is improve the size of the photovoltaic (PV) grid power generation system is an important technical way.

The characteristics of centralized photovoltaic grid system are as follows.

a. Compared with the distributed photovoltaic power generation system, centralized photovoltaic grid-connected power generation system can easily perform reactive power and voltage control, and it is also easier to participate in the power grid frequency regulation.

b. The access voltage level of the centralized large-scale photovoltaic power generation system is generally 10 kV, but some larger photovoltaic power stations will be connected to higher voltage levels.

c. The input of secondary equipment is increased. If a large number of photovoltaic power generation systems are connected to the power grid, the protection and automation equipment shall be installed or replaced. The reverse trend caused by photovoltaic power supply requires a new voltage control strategy.

The Influence of Photovoltaic Power Grid on Power Grid.

Since photovoltaic power generation is very different from traditional thermal power generation and hydropower generation in terms of inherent characteristics and receptivity, the following problems are usually generated in parallel network.
Power Quality Problem.

Since the photovoltaic grid-connected power system can only provide active power, the reactive power of the load may affect the power supply quality of the end of the grid, and the corresponding reactive power compensation equipment should be added. In addition, the photovoltaic power generation system is affected by the solar radiation changes of the day and night, and has the characteristics of intermittence and instability, thus the generation power will also be intermittent and unstable.\cite{9} for unified power quality conditioner for dc side without energy storage device is not usually to compensate the power load, and the sun day and night alternate changes in photovoltaic (PV) grid power generation device can only intermittent work, thus affecting the equipment efficiency and the shortage of the normal operation of power system, this paper proposes a new structure and control strategy for unified power quality conditioner, the system can also achieve comprehensive governance, photovoltaic (PV) grid power generation and power quality of power compensation.

Island Effect Problem.

Photovoltaic (PV) grid power system islanding refers to the power grid lines connected to the photovoltaic power generation systems, accident occurs due to a failure or a power outage overhaul to jump, photovoltaic (PV) grid power generation systems continue to load power supply, thus forming a power supply company cannot grasp the self-power island. The island effect can cause serious harm to the distribution network system and the client.

Reliability and Stability Problems.

The power supply reliability and stability of the system will be affected by the following aspects:

a. As mentioned above, the fluctuation and randomness of power generation of photovoltaic power generation system will cause instability of output power, which will influence the reliability of power supply to a certain extent.

b. The site selection, configuration capacity and connection mode of photovoltaic power station, as well as the removal of fault photovoltaic cell components will also affect the reliability of the system;

c. With the large amount of photovoltaic power generation system in operation, the proportion of power generation capacity is increasing, which may cause the dynamic stability of the system.

Conclusion

Photovoltaic power generation as an important form of new energy has a very good development prospect. But photovoltaic (PV) grid power generation will cause power quality, stability and reliability of the grid system, power grid, and photovoltaic system brought about by the island effect and influence on the distribution network, which is mainly caused by random output characteristics of photovoltaic power generation. Two important forms for photovoltaic (PV) grid power generation system (distributed photovoltaic (PV) grid power generation system with centralized photovoltaic (PV) grid power generation systems), after the power grid of reflected by the different in the above problems, this paper was expounded. In the future research, it is necessary to further analyze these differences and propose more effective solutions to make photovoltaic power generation more secure, stable and efficient.

References

[1] Nowak S, Aulich H, Bal J L, et al. The European photovoltaic technology platform [C] // Conference Record of the 2006 IEEE 4th World Conference on Photovoltaic Energy Conversion. Hawaii, USA: IEEE, 2006: 2485-2489.

[2] Jiangqian. Analysis and prospect of solar pv industry in China. [EB / OL] .(2009—08—10). http: //www.ocn.com.cn / market / 200908 /taiyangneng101136.html.
[3] Zhao Zhengming, Liu Jianzheng. Solar photovoltaic power generation and its application [M]. Beijing: science press, 2005:5.

[4] Wang Changgui. Overview of PV grid power generation system [J]. Solar Energy, 2008 (2): 14-17. Wang Changgui. The review of the grid-connected photovoltaic power system (volume one) [J]. Solar Energy, 2008 (2): 14-17.

[5] Yan shi. Research on the grid system based on photovoltaic power generation [D]. Chengdu: southwest jiaotong university, 2009. Yan Shizhi. The research on energy and grid-connected system [D]. Chengdu: Southwest Jiaotong University, 2009.

[6] The king of the ring, Wu Xin. 3 kW photovoltaic (PV) grid inverter development [C] // eighth PV Conference Proceedings. In shenzhen, China: [publisher unknown], 2006:6-10. Wang huan, WU Xin. The development of 3 kW photovoltaic grid - connected makes // [C] The 8th PV Conference Proceedings. Shenzhen, China: [s.n.], 2006:6-10.

[7] Chen yun. Research on grid connection between wind power generation and photovoltaic power generation [D]. Shanghai: Shanghai Jiaotong University, 2009. In addition, the company has a large number of people in the world. Liu Wei,

[8] Peng Dong Bu Guang Quan, etc. Photovoltaic intelligent distribution network after the access to the system problem review [J]. Power grid Technology, 2009 (19): 1-6. Liu Wei, Peng Dong, Bu Guangquan, et al. A survey on the system the problems in smart distribution network with the grid - connected photovoltaic generation [J]. Power system Technology, 2009 (19): 1-6.

[9] Varma R K, Salama M, Seethapathy R, et al. The Large-scale photovoltaic solar power integration in transmission and distribution networks [C] // IEEE power & Energy Society General Meeting 2009, Calgary, AB, Canada: IEEE, 2009:1.