The Review of the Impact of Large Scale Photovoltaic Power Generation on Power System

Tao WANG †, Peng QIU†, Meng-qi LIU, Yun-he SUN and Yue ZHANG
Jinzhou Power Supply Company of Liaoning Province of State Grid,
Jinzhou, Liaoning, China
Northeast Dianli University, Jilin, China

Human concerns energy security and worries environmental deterioration, which makes full use of renewable energy, become a global consensus. Such solar, wind as the representative of the large-scale grid connected power generation with renewable energy has become an irresistible trend of development of new power system, has deep influence on power system, and the academe and engineering give great attention. The purpose of the paper is review of domestic and foreign large-scale photovoltaic research present situation, which is aim to explore the factors on affecting the interaction between solar power generation and power system, refine the academic and engineering problems, and sort out the next step development ideas. From the power system planning, simulation, scheduling and control of angle, this paper lays emphasis on discusses in the modeling and simulation of large-scale PV systems, effects of large-scale photovoltaic (PV) accessed to the dynamic and steady state characteristics and the key technology of large-scale photovoltaic delivery and consumptive analysis.

Keywords: Electric Power System, Photovoltaic Power Generation, Planning, Review, Solar Energy.

1. Introduction

In recent years, the global economy faces the double pressure of resources and environment, the world also increases emphasis on the development of new energy. Especially in the electric power industry, the traditional electricity generation is mainly by thermal power generation and water power generation, which makes coal resources increasingly exhaust. The pollution situation of water resources gradually seriously, how to change the traditional way of high energy consuming power is the research direction of the electric power enterprise, which is highly noticed. Many countries have made large-scale development and utilization of solar power generation, wind power decision-making and planning, a new era of new energy power generation as a sign of the new era is coming.

In recent years, photovoltaic power generation develops rapidly, photovoltaic component cost is lower and lower, the cost of PV (photovoltaic grid connected system) is 5 €/Wp in the scope of Europe in 2004, It can be expected
that by 2020 the cost will be less than 1 €/Wp, by 2030 it will be less than 0.5 €/Wp [1]. As of the end of 2007, the world solar energy battery cumulative installed capacity had reached 12300 MW. In 2008 world solar battery output reached 6850MW, China’s solar cell production reached 17.8 MW; by the end of 2008, the cumulative installed capacity of China’s photovoltaic system reached 140 MW. In 2008, in the whole world new photovoltaic power generation installed capacity, about 1 GW was from photovoltaic power plants of 10 MW capacity and above, China also planned to construct MW level photovoltaic power station in Dunhuang, Gansu Province, Shilin, Yunnan Province, Qaidam Basin in Qinghai Province and other places.

As photovoltaic power system installed capacity accounted for the proportion is more and more big, its effects on planning, simulation, scheduling and control of power system, which also causes great concern to people [2]. PV generation shows two patterns of coexistence on the size of dispersed development, connection to the low voltage, local consume and large-scale development, connection to high voltage grid, long-distance high-voltage send consume, which impacts on the power system in terms of the depth and breadth will be far-reaching, the heat of engineering and academic circles of home and abroad research are also not decreased. The achievements often occur.

The purpose of this paper is that from multiple perspectives, summarizing large-scale solar power generation and power system of interaction with the research status and achievements from home and abroad. This provides reference to deeper research.

2. Modeling and Simulation of Large Scale Photovoltaic System

2.1. Photovoltaic Cells and Array Model

The model is based on single diode model, according to the principle of Kirchhoff it establishes the mathematical expression of the model of photovoltaic cells and on the basis of it, the theoretical formulas are simplified, using technical parameters of short-circuit current ISC, open circuit voltage UOC, current I’m of the maximum power point, the maximum power point voltage Um, we can get suitable engineering calculation of mathematical expressions, which are provided by photovoltaic battery suppliers. Model of the PV array can be obtained according to the corresponding model of photovoltaic cells and the relationship of the serial and parallel
between each other, the key of the model established is to calculate multiple peak value of P-V characteristics caused by PV modules of photovoltaic array difference, which is important for the photovoltaic array cluster modeling.

2.2. Converter and Inner Loop Control Model

Currently the main converter has both inside and outside and double loop control structure, outer loop is mainly responsible for input voltage control and transforms it into the referenced current for the inner loop control, then determines the grid strategy and external characteristic; Inner Loop of the input current mainly bases current reference value generated with the outer loop control, through the control link as well as with circulator conversion it can realize the current smoothly into the net [3].

In order to simplify the controller design, we usually use feed forward decoupling control strategy to realize converter for electromechanical transient model of d, q-axis voltage, current decoupling in the dq0 coordinates, and add the control link to the inner loop. The time constants of the inner loop control are very small (under millisecond), in consideration of meeting the calculation step of simulation software, converter with inner control should be simplified. Converter with inner control electromechanical transient model and the simplified model diagram are shown in Figure1 and 2.

![Figure 1. Inverter and inner control loop model.](image)
2.3. Dynamic Model of Photovoltaic Power Generation System

When the dynamic model is established, it needs to use the equations to establish various each component of state equation in power system, and make inverter and MPPT control transform into the state equation, and then make the two simultaneous equations to construct the equations and a photovoltaic power generation system model [4]. According to research needs, it can also choose other modeling method [5], such as the equivalent two port network model, simplified equivalent circuit model and the controlled source model.

3. Influences for Large Scale Photovoltaic Accessed on the System Characteristics

3.1. Influences for Active Frequency Characteristics

Photovoltaic power generation has the characteristics including external output shorthand volatility, static power, and non-rotary inertia, different features and off grid phenomenon more frequent of low voltage ride through (LVRT) during in loop device grid process.

Photovoltaic power generation process will produce large amplitude frequent random fluctuations, which will cause impact to the balance of the system, affect primary and secondary frequency modulation of the system, have a fundamental effect on the system active power economic dispatch operation characteristics; at the same time backup system optimization strategy will have to make timely adjustments and changes because of large-scale photovoltaic power generation access; In addition, with the access of the photovoltaic power generation scale increases and replacing the conventional power supply, which deteriorates the
ability of system to deal with the power vacancy and power fluctuation, and under the extreme conditions even the frequency rapidly changes, the frequency drop rate and depth may trigger low frequency load shedding, high frequency cutting machine control and the serious operational problems of protection action [6-8].

3.2. Influences for Reactive Power Voltage Characteristics

Large-scale and long-range photovoltaic power generation transmission easily affects and disturbs the reactive power balance of local power grid, and then causes large fluctuation to the bus along the voltage.

At the same time, all of the actual local grid voltages have relatively weak ability to support, so in the process of transmission it is easy to appear phenomenon of voltage instability. Because accessed large-scale photovoltaic power generation not only changes the original radial grid structure of local power grid system, but also changes the power structure of the local power grid system, which affects the distribution of power flow, and has fundamental influence on the distribution network voltage quality.

3.3. Influences on the Stability of Power Angle

After large-scale photovoltaic power accesses system, stochastic volatility and no rotary inertia properties of system are both affected, effective inertia of the system has to become smaller, so the system power angle stability changes, its specific change direction and magnitude depend on the topological structure, power grid operation mode, power control technology of power grid and position and access of the scale factors of accessed photovoltaic power generation. Connection of the photovoltaic power can improve and may also deteriorate the angle stability of power grid work [7,9-11], which must combine with the specific scene simulation and determine by simulation analysis.

Power angle instability mainly is the oscillatory instability. Because the fluctuation of the PV output changes the characteristics of the operating system, and grid connected inverter has different control strategies compared with conventional machine, so the damping of the system will change under the influence of the outside world and then changes system original electromechanical oscillation mode, which brings new band range of oscillation.
4. Key Technology of Large-scale PV Transmission and Consumption

4.1. New Transmission Technology of Large-scale PV Transmissions

In order to increase fluctuation power controllability of like the long channel PV transmission, controllable high resistance, Dynamic Reactive Power Compensation SVC and Thyristor Controlled Series Compensation (TCSC) are installed along the channel. AC transmission technology of collecting various FACTS devices enhanced the system receptiveness of intermittent new energy like PV.

Recently, the novel HVDC technology has been further developed [12]. VSC-HVDC utilizes full-controlled switching devices, which is restricted by capacity restrictions of switching devices. So currently, VSC-HVDC cannot replace the traditional HVDC in the long-distance, high-capacity transmission fields, and its voltage levels and transmission capacity need to be further improved. However, in the large-scale distributed PV grids and regions, renewable energy consumption area is a useful complement to the traditional HVDC.

4.2. Planning and Design Technology of PV Power Plant

Planning and design of PV power plant include the following contents: 1) the installation location; 2) the installed capacity; 3) the investment time; 4) the number of PV module and inverter module; 5) the installation angle of the PV module; 6) the optimal combination of PV module and inverter; 7) the station connection mode; 8) the penetrating power of PV power plant; 9) the confidence capacity; 10) the economic evaluation, etc. Therein, the capacity planning of PV power plant includes independent PV system, hybrid PV/diesel system, hybrid PV/wind power system and hybrid PV/diesel/wind power system, etc. The main methods for solving such problems are intuitive category method, Artificial Intelligence Optimization Algorithm, etc. Optimization method is mainly based on system reliability analysis. Considering the randomness of the PV and the load, it can be directly calculated for the power plant planning capacity by fitting the function expression of relationship between system reliability and PV power plant planning capacity, which can also set up the system investment costs of the project life cycle and the operation maintenance costs. Moreover, it can replace the cost economic model and optimize solving.
4.3. **Integrated Planning Technology of Promoting PV Consumption**

The layout of large-scale PV power plant has impact on the grid planning. In terms of Grid planning, for large-scale PV centralized grid connected, when the scale of PV power generation is smaller, it would transport electricity into the load center of the province through extra high voltage (EHV) and high voltage transmission, so the construction of the province's EHV power grid needs to be strengthened synchronously. With the increasing PV power generation scale, when the electricity was fed into the regional power grid and consume, it would need to strengthen regional power grid interconnection across provinces. In order to improve the utilization efficiency of the transmission channels, it needs to coordinate all kinds of power like hydropower, wind power and thermal power to achieve coordinated operation and transmission.

For large-scale distributed PV grid, adjusting the structure designed of the distribution network has been an urgent problem, and how to reasonably plan smart distribution network which contains PV system for has become an important factor. Meanwhile, the PV distribution and capacity should also be coordinated with the distribution network. With the increase of urban PV power generation roof and building integrated photovoltaic (BIPV), the planning of urban power grids should allow sufficient leeway.

5. **Conclusions**

This paper summarized and generalized research status from three aspects: 1) modeling and simulation of large-scale PV system, 2) the impact on the system dynamic and steady-state characteristics by large-scale PV accessing, 3) large-scale PV transmission and consumption. Of course, there are still some elements, such as security monitoring of large-scale PV power plant, which cannot be included in the limited space but is worth to continue to discuss.

**References**


