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ORIGINAL RESEARCH ARTICLE

# Photovoltaic power generation system

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***ABSTRACT***

The potential crisis of energy and the deterioration of ecological environment make the world's cumbersome development of renewable energy including new energy, including solar energy. Traditional energy in the coal, oil and natural gas are evolved from ancient fossils, it is collectively referred to as fossil fuels. As the world's energy needs continue to increase, fossil fuels will also be depleted, it is necessary to find a new energy to replace the traditional energy. Solar energy is a clean renewable energy with mineral energy incomparable superiority. Modern society should be a conservation-oriented society, and social life should also be a life-saving energy. At the same time, Premier Wen Jiabao also proposed on June 30, 2005 and stressed the need to speed up the construction of a conservation-oriented society. And solar energy as an inexhaustible new environmentally friendly energy has become the world's energy research work in the world an important issue. Is the world in the economic situation to take a simpler, economical, environmentally friendly and reliable building heating and heating energy-saving measures. This paper summarizes the current global energy status, indicating the importance of solar power and prospects. Details of the various solar power generation methods and their advantages, and made a comparison of this power generation parameters. At the same time pointed out that the difficulties faced by solar power and solutions, as well as China's solar power of the favorable conditions and difficulties. The future of China's solar energy made a prospect.

***KEYWORDS:*** Solar energy, Power generation power plant, Solar power generation

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## 1. Introduction

With the economic development, social progress, people put forward higher and higher energy requirements, looking for new energy has become an urgent task facing the current human. There are three main types of existing energy, namely, thermal power, hydropower and nuclear power.

Thermal electricity needs to burn coal, oil and other fossil fuels. On the one hand fossil fuel reserves are limited, the less the burning, is facing the danger of depletion. It is estimated that the world's oil resources will be depleted for another 30 years. On the other hand combustion of fuel will emit CO2 and sulfur oxides, which can lead to greenhouse effects and acid rain, deteriorating the Earth's environment.

Hydropower to flood a large number of land, may lead to ecological damage, and large reservoirs once collapse, the consequences will be disastrous. In addition, a country's water resources are limited, but also affected by the season.

Nuclear power in the normal circumstances is clean, but in case of nuclear leakage, the consequences are also terrible. The accident in the former Soviet Union Chernobyl nuclear power plant has caused nine million people to suffer varying degrees of damage, and this effect has not been terminated.

These are forcing people to find new energy. New energy to meet two conditions: First, the rich will not be depleted, second, safe, clean, not threaten human and destruction of the environment. Currently found the new energy there are two, one is solar energy, the second is the fuel cell. In addition, wind power can be regarded as auxiliary new energy. Among them, the most ideal new energy is big solar energy. The main principle of solar cell power generation is the photoelectric effect of the semiconductor.

## 2. Global and China Solar Resources and Evaluation

The sun is the eternal energy of the earth, which emits about 3.8 * 1020 megawatts of energy per second in space in the form of optical radiation, of which 2.2 billion is projected onto the earth. The solar radiation outside the Earth's atmosphere is between 132.8-141.8 megawatts / cm2, and about 70% of the earth is reflected, scattered and absorbed by the atmosphere. Earth received a year of solar radiation can be as high as 1.8 * 1018 kWh, tens of thousands of times the global energy consumption.

Huge solar energy is the source of all things on earth, in addition to its 'eternal' and 'huge', but also has a 'broad', 'decentralized', 'random', 'intermittent', ' 'Cleanliness' and so on. In the oil, natural gas and nuclear mineral deposits will eventually be depleted today; full use of solar energy is clearly a double great significance of continuous energy supply and environmental protection. After the '9.11' incident in the United States, the giant grid was challenged, and the distributed energy system using solar energy was taken seriously. 'Everywhere sunshine everywhere,' the beautiful ideals will eventually be accompanied by the pursuit of green energy for people to achieve.

China's vast territory has a wealth of solar energy resources. It is estimated that the solar radiation energy received by our country's land surface is about 50 * 1018 kJ per year, and the total solar radiation in all parts of the country is 335 ~ 837 kJ / (cm2), the median is 586 kJ / (cm2 years). From the distribution of the total solar radiation in the whole country, Tibet, Qinghai, Xinjiang, southern Inner Mongolia, Shanxi, northern Shaanxi, Hebei, Shandong, Liaoning, western Jilin, central and southwestern Yunnan, southeastern Guangdong, southeastern Fujian The eastern part of the island and the western part of Taiwan and the southwest of the vast area of the total solar radiation is very large. Especially in the Qinghai-Tibet Plateau region, where the average altitude above 4000 meters, the atmosphere is thin and clean, transparent, low latitude, long sunshine time. For example, the city of Lhasa, known as the 'Nikko City', the average of 1961-1970, the average annual sunshine time is 3005.7h, the relative sunshine is 68%, the annual sunny day is 108.5 days, cloudy day is 98.8 days, year The average cloud cover is 4.8, the total solar radiation is 816 kJ / (cm2 years), higher than the other provinces and regions of the same latitude. The total solar radiation in Sichuan and Guizhou provinces is the smallest, especially in the Sichuan Basin, where the rain is more, the fog is more and the sunny day is less. For example, known as 'fog' is called Chengdu, the average annual sunshine hours is only 1152.2h, relative to the sunshine is 26%, the average annual sunny day is 24.7 days, cloudy day 244.6 days, the average annual cloud cover up to 8.4. Other areas of the total solar radiation is in the center.

China's main features of solar energy distribution are:

1. The high-value centers and low-value centers of solar energy are in the area of 220 ~ 350 latitude, the Qinghai-Tibet Plateau is a high-value center, and the Sichuan Basin is a low-value center.

2. The total solar radiation, the western region is higher than the eastern region, and in addition to Tibet and Xinjiang two autonomous regions, is basically lower in the south than the north.

3. Because most of the southern areas of cloud fog, in the latitude 300 ~ 400 area, the distribution of solar energy and the general solar energy with the latitude and the opposite of the law, the solar energy is not reduced with the increase in latitude, but with the increase in latitude And increase.

One, two, three areas, the annual sunshine hours greater than 2200 hours, the total solar radiation is higher than 502 kJ / cm2, is China's solar energy resources rich or rich areas, a larger area, accounting for the total area Of more than 2/3, with good use of solar energy conditions. Four or five areas, although solar energy conditions are poor, but there is still a certain value.

According to the distribution and characteristics of China's solar energy resources, China's solar energy resources can be evaluated as follows: In addition to Chongqing and its surrounding provinces (Sichuan and Guizhou), all regions of China are high solar energy resources, especially Inner Mongolia, the Qinghai-Tibet Plateau and other places solar energy resources is rich. So China is a solar energy-rich countries, has a certain advantage.

**Table 1.** China's solar energy division

| Area / Classification | Year sunshine hours | Total solar radiation year [KJ / (cm2 • a)] | Equivalent to burning standard coal (kg) | Including area | Similar to foreign regions |
|---|---|---|---|---|---|
| 1 | 3200-3300 | 670-840 | 225-285 | Northern Ningxia, northern Gansu, southeastern Xinjiang, western Qinghai, western Tibet | India and northern Pakistan |

| | | | | | |
|---|---|---|---|---|---|
| 2 | 3000-3200 | 586-670 | 200-225 | Northwestern Hebei, northern Shanxi, southern Inner Mongolia, southern Ningxia, central Gansu, eastern Qinghai, southeastern Tibet, southern Xinjiang | Jakarta, Indonesia |
| 3 | 2200-3000 | 502-586 | 170-200 | Northeast of southeast, southeastern Henan, southeastern Hebei, southeastern Shanxi, northern Xinjiang, northern Jilin, Liaoning, Yunnan, northern Shaanxi, southeastern Gansu, southern Guangdong, southern Fujian, northern Jiangsu, northern Anhui, Tianjin, Beijing, southwestern Taiwan | Washington D.C |
| 4 | 1400-2220 | 419-502 | 140-170 | Hunan, Hubei, Guangxi, Jiangxi, Zhejiang, northern Fujian, northern Guangdong, southern Shaanxi, southern Jiangsu, southern Anhui, Heilongjiang, northeastern Taiwan, | Milan, Italy |
| 5 | 1000-1400 | 335-419 | 110-140 | Sichuan, Guizhou, Chongqing | Most parts of Europe |

## 2.1. Research and Development of Photovoltaic Power Generation

In the photovoltaic power generation system, there are many factors that affect the efficiency of power generation, including the conversion efficiency of solar cells and the control of the maximum power point. At present, the following algorithms are developed in the tracking of maximum power points.

(1) Constant voltage control

The PV array is a non-linear power supply. Its output characteristics can be seen as the constant current region and the constant voltage region, the two areas of the junction point is the maximum power point. Thus, at different light intensities, the PV array will have such a maximum power output point; from the power point of view can be regarded as the current operating conditions under the optimal point. As the light intensity and temperature changes will change this constant current and constant voltage region, so the maximum power point is also changing.

Generally, the open-circuit voltage of a silicon-type photovoltaic array is affected by the junction temperature. At the same light intensity, the maximum power point is also affected by the temperature. When the power output of the PV array changes with temperature, if the constant voltage tracking control strategy is still used, the output power of the array will deviate from the maximum power output Point, resulting in a relatively large power loss. In particular, in some cases, the junction temperature of the PV array is relatively obvious, resulting in the array of volt-ampere curves and the system pre-set the operating voltage may not exist in the intersection, then the system will produce oscillation.

(2) Improved constant voltage algorithm

In order to overcome the use of the occasion season, sooner or later and weather conditions and environmental temperature changes on the impact of the system, based on the constant voltage algorithm can take the following several ways to deal with compromise:

1. Manual adjustment: by manually adjusting the potentiometer according to the season given different, this method uses less, need manual maintenance.

2. According to the thermometer adjustment: in advance the specific photovoltaic array at different temperatures measured at the maximum power point voltage stored in the controller, the actual operation, the controller according to the detection of photovoltaic array temperature, through the look-up table to select the appropriate value The

3. Reference battery method: in the photovoltaic power generation system to add a PV array with the same characteristics of the smaller photovoltaic cell module to detect the open circuit voltage, according to the fixed

coefficient calculated by the current maximum power point voltage, this method can be in the approximate constant voltage Of the control costs are close to the MPPT control effect.

(3) Interference observation method

Interference observation method is one of the commonly used methods to realize MPPT. The principle is to increase or decrease the voltage at regular intervals and observe the direction of the subsequent power change to determine the next control signal. This control algorithm also generally uses power feedback, that is, the use of two sensors on the DC bus current and the voltage across the sampling. This control method, although the algorithm is simple, and easy to implement hardware, but the response is very slow, only applies to those light intensity changes are very slow occasions. In the steady state case, this algorithm will cause the actual operating point of the PV array to oscillate slightly near the maximum power point, which will cause some power loss. When the light changes rapidly, the tracking algorithm may fail and judge the wrong Tracking direction.

(4) Conducting incremental method

The conductance increment method changes the control signal by comparing the conductance increment and the instantaneous conductance of the PV array. This control algorithm also requires sampling the voltage and current of the photovoltaic array. Conductivity incremental method is accurate, fast response time, suitable for rapid changes in atmospheric conditions of the occasion. But the requirements of the hardware, especially the precise requirements of the sensor is relatively high, all parts of the system response speed requirements are faster, so the entire system hardware cost will be relatively high.

(5) Fuzzy logic control

Due to the uncertainty of solar light intensity, the change of PV array temperature, the change of load situation and the nonlinear characteristics of PV array output characteristics, there are many factors to be taken into account to realize the accurate tracking of the maximum power point of PV array. A fuzzy logic control algorithm is developed for this nonlinear system. The fuzzy logic method is used to control the MPPT of the PV system, which has good dynamic characteristics and precision, and has a very wide application prospect.

With the development of technology, in addition to the above control algorithms, we have developed a variety of algorithms including hysteresis comparison method, neural network control method, optimal gradient method, etc. These algorithms implement the basic principles of MPPT control Is similar, but the specific implementation methods are different.

## 3. Classification of photovoltaic power generation systems

Photovoltaic power generation system is the use of solar cells directly into solar energy into the power generation system, its main components are solar cells, batteries, controllers and inverters. Its characteristics are high reliability, long life, no pollution of the environment, independent power generation and grid operation, by the national business organizations of all ages, with

Broad prospects are for development. According to its system configuration can be divided into stand-alone (stand-alone) grid (grid-alone) 2 kinds. According to their use of different places, can be divided into two major categories of space applications and ground applications, the ground can be used as a separate power supply, wind turbines or diesel engines can also be mixed with power generation system, but also with the grid connection, to the grid electricity. At present the application of a wide range of photovoltaic power generation system is mainly used as a ground independent power supply. The usual independent photovoltaic power generation system is mainly composed of solar cells, batteries, controllers, solar controllers and blocking diodes.

### 3.1. Photovoltaic power generation components:

1. Photovoltaic battery square: the role of the square is the direct conversion of solar radiation into electrical energy, the supply of load. Generally by a number of solar modules in a certain way to connect and coupled with the appropriate bracket and junction box.

2. Battery: battery is a solar cell array energy storage device, its role is to send a sunny square in the excess energy stored in the evening or rainy days for the use of load. In the photovoltaic power generation system, the battery in the floating charge and discharge state, the amount of summer sunshine, in addition to the supply of electricity, but also on the battery charge; in the winter sunshine less, this part of the stored energy gradually released, in this seasonal cycle On the basis of the need to add a much smaller day cycle, the day square to the battery charge, (while the matrix also to the load of electricity), the night the load power all by the battery supply. Therefore, the requirements of the battery self-discharge are small, and the charging efficiency is high, but also considers the price and ease of use and other

factors. Commonly used batteries are lead-acid batteries and silicone batteries, requiring higher occasions are also more expensive nickel-cadmium batteries.

3. Controller: in different types of photovoltaic power generation system controller is different, its function and the complexity of the great difference, according to the requirements of the power generation system and the importance to determine. The controller is mainly composed of electronic components, instruments, relays, switches and other components. In a simple solar cell, battery system, the role of the controller is to protect the battery, to avoid overcharge, over discharge. If the PV power plant and power supply, the controller will need to automatically monitor, control, regulation, conversion and other functions. If the load is AC, the load and the battery should also be equipped with an inverter, the role of the inverter is the square and the battery to provide low-voltage direct current into 220 volts AC power supply, the use of load.

4. Blocking diode: also known as anti-charge diode or isolation diode, its role is to use the diode's one-way conductivity to prevent no sunshine when the battery through the solar cell discharge. The requirement for blocking diodes is that the operating current must be greater than the maximum output current of the square, and the reverse withstand voltage is higher than the voltage of the battery pack. In the square array work, blocking the two ends of a certain voltage drop, the silicon diode is usually 0.6V ~ 0.8V; Schottky or germanium tube about 0.3V.

5. Sun tracking control system: the sun's lighting angle is changing at all times, in order to effectively ensure that the solar panels can always be on the sun, power generation efficiency to achieve the best condition.

## 4. Grid-connected power generation principle and structure

Grid-connected solar photovoltaic power generation refers to the way solar photovoltaic power generation is connected to the national grid's power generation, becoming a supplement to the grid, typically characterized by the need for batteries. Grid-connected solar power generation system consists of photovoltaic modules (square), photovoltaic grid-connected inverter power device. PV modules (solar array) will be converted into direct current solar energy, through the grid inverter power supply will be converted into DC power with the same frequency in the same phase AC power into the grid. Grid-connected inverter power supply is the core equipment of photovoltaic grid-connected power generation system.

### 4.1. Analysis of Volt - ampere Characteristics of Grid - Connected Solar PV Array

Where Iph is the photocurrent current and is proportional to the area of the photovoltaic cell and the intensity of the incident light. The ambient temperature rises, the value rises slightly.

ID is dark current; no light under the basic behavior of photovoltaic cells is similar to a common diode. Refers to the photovoltaic cells in the absence of light and the external voltage under the P-N junction itself generated by the total diffusion current changes.

IL is the load current output by the PV cell.

Uoe is the open circuit voltage of the battery. It is proportional to the logarithm of the intensity of incident light. And the ambient temperature is inversely proportional to the size of the battery has nothing to do.

RL is the battery external load resistance.

Rs is a string drop resistance. Generally less than 1 Euro. Mainly by the battery

Body resistance: surface resistance, electrode conductor resistance, electrode and silicon surface contact resistance and metal conductor resistance and other components.

Rsh for the bypass resistance, as thousands of ohms. It is mainly caused by the surface of the pool dirty and semiconductor crystal defects caused by the leakage current corresponding to the P-N junction leakage resistance and the battery edge of the leakage resistance and other components.

Rs and Rsh are photovoltaic cells inherent resistance, equivalent to the internal resistance of photovoltaic cells. An ideal photovoltaic cell and due to the small series of Rs, parallel Rsh is very large, so the ideal circuit calculation, they are negligible. S The ideal equivalent circuit is only connected to a constant current source of Iph in parallel with a diode.

In addition, the equivalent circuit of photovoltaic cells should also contain N junctions formed by junction capacitance and other distributed capacitance. Since the photovoltaic cells are DC standby, there is usually no high frequency AC component, so these capacitors are also negligible.

By the above definition, you can list the equivalent of the equivalent circuit in the photovoltaiccell is as follows:

$$I_D = I_0(\exp\frac{qU_D}{AkT} - 1)$$

$$I_L = I_{ph} - I_D - \frac{U_D}{R_{sh}} = I_{ph} - I_0[\exp(\frac{q(U_{oc} + I_L R_s)}{AkT}) - 1] - \frac{U_D}{R_{sh}}$$

$$I_{sc} = I_0[\exp\frac{qU_{oc}}{AkT} - 1]$$

$$U_{oc} = \frac{AkT}{q}\ln(\frac{I_{sc}}{I_0} + 1)$$

Where Io is the P-N saturation current of the equivalent diode inside the photovoltaic cell. It is related to the performance of the battery itself, anti-photovoltaic cells on the photo generated carriers of the largest composite capacity. Generally constant, will not be affected by the intensity of light. Isc is the battery's short current. UD is the terminal voltage of the equivalent diode. Q is the electron charge. K is the Boltzmann constant, and T is the absolute temperature. A is the curve constant of the P-N junction.

The curve has a corresponding maximum power output point. The left side of the maximum power point is called the battery showing the characteristics of the current source, the output voltage drops quickly, and the output current is almost constant: on the right side shows the characteristics of the voltage source, the output current increases quickly, the voltage changes slowly.

The photovoltaic cell output characteristics have a non-linear characteristic, and its output is affected by light intensity, ambient temperature and load conditions. In a certain light intensity and ambient temperature, the photovoltaic cells can work at different output voltage, but only in a certain output voltage, the photovoltaic cell output power to reach the maximum, then the photovoltaic cell operating point reached Maximum power point (maxpowerpoint, MPP).

## 4.2. Requirements for grid inverters

Inverter to be connected with the grid must meet the grid power quality, to prevent the island effect and safety isolation grounding three requirements.

In order to avoid the photovoltaic grid-connected power system on the public grid pollution, the inverter should output a small sine wave distortion. One of the main factors that affect the distortion of the waveform is the switching frequency of the inverter. In the numerical control inverter system using high-speed DSP and other new processors, can significantly improve the grid inverter switching frequency performance, it has become one of the widely used technology of the system; the same time, the choice of inverter main power components Vital. Small-capacity low-voltage system uses more power field-effect transistor (MOSFET), it has a low on-state voltage drop and high switching frequency; but MOsFET with the voltage rise of its on-state resistance increases, Capacitive systems generally use insulated gate bipolar transistors (IGBTs); and in very large capacity systems, the general use of thyristor (GTO) as a power component.

According to IEEE 2000-929 [7] and UL1741 [8] standards, all grid-connected inverter must have anti-islanding function. Isolated island effect is when the grid due to electrical failure, misuse or natural factors such as interruption of power supply, the photovoltaic grid-connected power generation system failed to detect the power outages and cut off the grid, so that photovoltaic power generation system and the surrounding load to form a Power companies cannot grasp the self-powered island. The key to the anti-islanding effect is the detection of power offsets. In order to ensure safe and reliable operation of the grid and inverter, the effective isolation of the inverter and the grid and the inverter grounding technology is also very important.

Photovoltaic array requirements for inverters

As the sunshine intensity and ambient temperature will affect the power output of the PV array, it must be adjusted by the inverter to make the PV array output voltage close to the maximum power point output voltage to ensure that the PV array at maximum power point to obtain the maximum energy. Commonly used maximum power point tracking

(MPPT) methods are: constant voltage tracking method, 'up the mountain' method, interference observation method and incremental conductivity method

### 4.3. PV array operating point tracking control

PV array operating point of the control is mainly constant voltage control (CVT) and MPPT these two ways. The following are the same as the '

CVT is to determine the system power point by stabilizing the voltage at the PV array to a certain value. Its advantages are simple control, good system stability. However, when the temperature change is large, the PVR operating point in the CVT mode will deviate from the maximum power point r1. The following are the same as the'

MPPT is the most widely used PV array power point control strategy. It realizes the working state of the system in real time, tracking the maximum working point of the array, thus realizing the maximum power output r1 of the system. It is a kind of self-seeking way, dynamic performance is better, but the stability is not as good as CVT. The common methods are 'uphill' method, interference observation method, conductance increment method, the concrete realization see the literature.

### 4.4. Inverter detection and control of islanding effect

In fact, in addition to the basic protection function, it should also have the special function of anti-islanding effect. From the safety of electricity and the quality of power, the islanding effect is not allowed to occur. When the island occurs, it is necessary to quickly and accurately cut off the grid-connected inverter, which leads to the research on the detection and control of the islanding effect.

The detection of islanding is generally divided into passive and active. Passive detection is the use of grid monitoring status (such as voltage, frequency, phase, etc.) as a basis for judging whether the power grid failure. If the load in the grid is exactly the same as the inverter output, the passive method will not detect the occurrence of the island. The active detection method is to generate the interference signal through the power inverter to observe whether the power grid is affected as the basis of judgment, such as pulse current injection method, output power change detection method, active frequency offset method and sliding mode frequency offset method. Wait.

They are in the actual grid inverter have been applied, but there are also their own shortcomings. When the voltage amplitude and frequency range is less than a certain value, the frequency offset method cannot detect the islanding effect, that is, there is a 'detection blind spot.' Output power change detection method does not exist 'detection blind spot', but the photovoltaic grid system Strength and other effects, the photovoltaic output power at any time in the fluctuations in the inverter to join the active power perturbation, will reduce the efficiency of photovoltaic arrays and inverter systems. In order to solve this problem, photovoltaic grid-connected active and reactive power integrated control method Is often raised.

With the further application of photovoltaic grid-connected power generation system, when a number of inverter at the same time grid, the inverter output changes are very large, resulting in the above method may be invalid. Therefore, the study of multi-inverter grid-connected communication, collaborative control has become its islanding effect detection and control of the research trend cited.

## 5. Principle and structure of independent photovoltaic system

During the daytime, under the lighting conditions, the solar cell components produce a certain electromotive force, through the series of parallel and parallel components to form a solar cell array, making the square array voltage to the system input voltage requirements. And then through the charge and discharge controller to charge the battery, the energy conversion from the light energy stored up. In the evening, the battery pack directly to the DC load power supply, or for the inverter to provide input power, through the role of the inverter, the DC into AC power for the use of AC load.

### 5.1. Design of stand-alone PV system

Stand-alone photovoltaic power generation system consists of solar photovoltaic arrays, battery packs. Controller, inverter and AC power distribution equipment. The system structure is shown in Fig. The PV array converts solar energy directly into electrical energy, and when it is sunny, it powers the electrical equipment and charges the battery pack. In the rainy days, at night when the sun is insufficient, the battery discharge, for the use of equipment to provide electricity Chong. The controller automatically monitors the working status of the PV array and makes corresponding adjustments to ensure that it works in the optimal power state, and also fully controls the charging and discharging of the

whole system. The inverter converts DC to AC power through the AC power supply. The whole system has overvoltage protection, overload protection, battery charging automatic adjustment and other functions.

System control to DSP as the core and is through the sensor on the whole working state and work environment to monitor.

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