SOLAR PHOTOVOLTAIC

Chen Wang

Yuefeng Lu

Bachelor's Thesis

Degree Programme in Industrial Management

___. ___. _____ _____

Bachelor's degree (UAS)

SAVONIA UNIVERSITY OF APPLIED SCIENCES

THESIS
Abstract

Field of Study Technology, Communication and Transport			
Degree Programme Degree Programme in Industrial Engineering and Management			
Author(s) Chen Wang, Yuefeng Lu			
Title of Thesis SOLAR PHOTOVOLTAIC			
Date	12-04-2016	Pages/Appendices	35
Principal lecturer Harri Heikura， Olli-Pekka Kähkönen			
Client Organisation Savonia University of Applied Sciences			

Abstract

In the 21st century, human demand for new energy sources is urgent, because the traditional fossil energy is unable to meet human needs, and the fossil resource will make pollution, in this situation, solar energy gradually into the vision of scientists. As science advances, humans can already extensive use of solar energy to generate electricity.

Solar energy is an inexhaustible and clean energy. In the global energy crisis, environmental pollution is the growing problem of today. The use of solar energy research is to alleviate the energy crisis, protect the environment and ensure sustainable economic development of great significance. Solar industry is divided into solar thermal industry and solar photovoltaic industry; solar thermal industry's main products are solar water heaters. Scientists have made great process in study of solar power. Humans can do solar photovoltaic in the desert. Solar radiation on Earth is very large. About 40 minutes of solar radiation on Earth, it can suffice the consumption of the energy for all human for one year.

Nowadays, human built many solar photovoltaic plants to generate electricity, and many people are seting solar cells on the roof to generate electricity for their daily consumption. All these prove that solar energy has become increasingly popular. The Governments of China, The USA and some other countries also support the use of solar power, thus reducing the consumption of non-renewable resources and protect the environment.

Keywords
new energy, solar power, solar photovoltaic, inexhaustible energy, clean energy

ONTENTS

1 INTRODUCTION

Nowadays, humans are facing the energy depletion crisis. Non-renewable resources are less and less, and most of the energy is accompanied by pollution. With the deterioration of the living environment and the growing of the demand of the energy, humans must find and use some new energy, such like wind, tidal, solar and so on. And the most popular new energy is solar power.

There are many ways to use solar power, and this thesis is about how to use solar power to produce electricity. This thesis will introduce the principle of solar photovoltaic, the composition and operation of the solar photovoltaic system, the maintenance of solar photovoltaic system and the background of the use of solar power in the world.

1.1 TARGET OF THE THESIS

Solar energy generally refers to solar radiation energy. The main form of use of solar energy has photothermal conversion of solar energy, photovoltaic and photochemical conversion. Broadly, solar power is the resources of many energy, for example, the wind power, chemical energy, potential energy of water and other are all converted by the solar power. Some main methods of using solar power are such as solar cells, photoelectric conversion by the energy contained in sunlight into electricity; solar water heaters, the use of solar heat for heating water, and the use of hot water generation. Solar energy is quite clean, no pollution and the rate of using is high, and no shortage of this statement, which determines all the advantages of its irreplaceable role in the turnover of energy.

Along with social progress and social development, the development of new energy sources is more and more imperative, and solar photovoltaic power generation as a new renewable energy needs more and more investment in research and application.

Since the 1980s, solar photovoltaic power generation is one of the fastest growing technology industries. Its power generation account is about eighty percent of the world's photovoltaic generating capacity in Japan, the EU and the United States.

With the deterioration of our living environment, and energy depletion, humans had to develop new energy sources. Solar power is clean, if it can be used in reasonable way. Human society will achieve progress in leaps and bounds, and will be no burden for the environment.

One thing should be noticed is that energy depletion and environmental pollution is imminent. Mankind must make a decision; they should reduce dependence on traditional fossil fuels, and reduce greenhouse gas emissions for the sake of the future of mankind.

2 BACKGROUND

Why humans need new energy? Why humans need solar power? Here are some reasons, to explain the background of the use of solar power of the world.

2.1 NEW ENERGY TECHNOLOGY

New energy technology is one of the five areas of the world economic development with the most decisive force in the 21st century. Solar energy is a clean, efficient and everlasting new energy. In the new reality, governments will use solar energy resources as a national sustainable development strategy. The photovoltaic power generation is safe and reliable, has no noise, no pollution, is less constrained, has low failure rate, easy maintenance, etc. In the vast and cold western part of China, under the conditions of the varied and scattered terrain, it has many effects. In those areas, the Realistic conditions are relatively poor, and the economy situation is not good too. It can be facilitated to establish large-scale solar photovoltaic power stations on those varied land, and can supply the electrical energy to the people who live there for their daily lives.

Photovoltaic power generation is one of the main forms of solar energy utilization. Solar cell industry has formed a certain scale. The research work in laboratory of new solar cells has flourished already in the whole world. In recent years, China has gotten a rapid development of solar photovoltaic generation industry. The account of silicon solar cells reached 27% of the world in 2007, the productivity was the number one in the world.

The technology of solar photocoltaic is developing rapidly. The efficiency of solar cells gets higher and higher. The efficiency of monocrystalline silicon solar cells has reached 24.7% in 2007, but in 1950s, the efficiency was just 6%. That is a huge progress, and the efficiency of business solar cells has reached 16-22%. The polysilicon business solar cells' efficiency has reached 15-18%. While in the continuous development of crystaline silicon, amorphous silicon, CdTe, CuInGaSe and other thin-film solar cell technology has had rapid development also, and has a certain proportion. (Siyu Wang 2012.04.22.)

Here is a picture of distribution area of energy of the world:

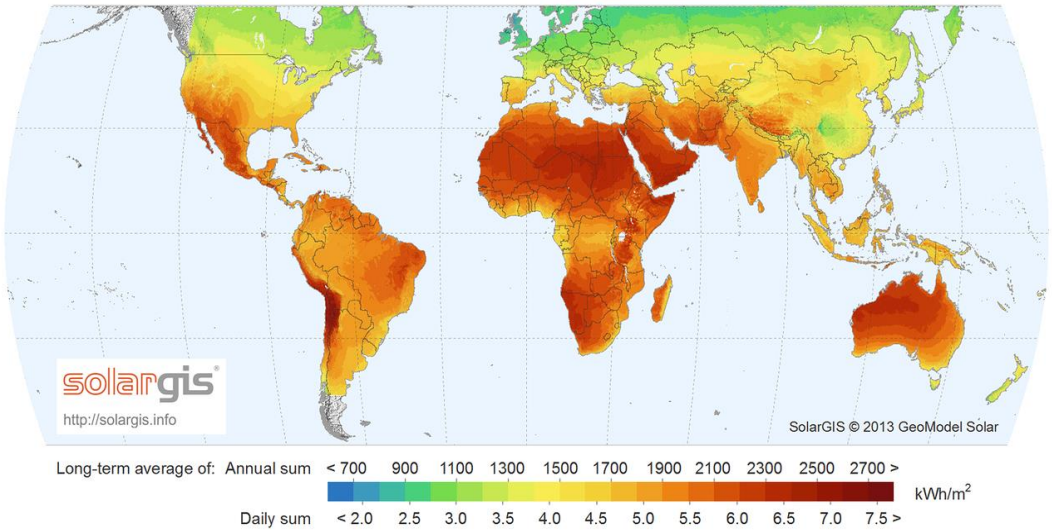

Figure 1. Distribution area of energy of the world (Cho Hyun Seok 2015.03)

The distribution area of energy of the world is also needed to know. As seen in the Figure 1, there are some colors in the picture. The red areas have enough solar energy resource, but in those light color areas, solar energy is not good for solar photovoltaic.

The value of radiant power emitted into space by the sun is $3.8*10^{23}$ kW[1], and only one of 2 billion kilo-watt of that energy can reach the atmosphere of the Earth. Meanwhile, the 30% of the power which reached the atmosphere would be reflected, and 23% would be absorbed by atmosphere. Only 47% can reach the surface of the Earth, the power is $8.0*10^{13}$ kW. It means that the power from the sun in 1 second is equivalent to burn five million tons of coal.
The consumption of the energy by total global human annual is just about 40 minutes of sun light power exposure to the Earth's surface.

The best areas of solar radiation intensity and duration of sunshine in the world include North Africa, Middle East, Mexico and the southwestern United States, southern Europe, Australia, South Africa, South America, East and West Coast and western regions of China and so on. (Siyu Wang 2012.04.22.)

3 PRINCIPLE OF SOLAR PHOTOVOLTAIC

With the progress of science, the first thing that has to be known is the principle of solar photovoltaic power generation. Then the humans can use solar power.

[1] kW = kilo-watt

Figure 2. Solar power (Devarajan Srinivasan 2015.10.20)

3.1 PHOTOVOLTAIC EFFECT

Photovoltaic power generation is a technology by using photovoltaic effect of the interface of semiconductor and changing light energy directly into electrical energy. Solar cells are the most important key element of this technology. After a series of solar cells encapsulated protection, it could form a large area solar cell module, coupled with the power controller and other components to form a photovoltaic system device.

If light shines on the solar cells and is absorbed by the interface of semiconductor, the photon which is with enough energy can stimulate electron from the covalent between P-type and N-type silicon to produce electron–hole. Before the complex of electron and electron-hole which is near the interface layer of semiconductor, it will be separated from each other by the electric field of the space charge. The electron will move into the N region which is with positive electricity, and the electron-hole will move into the region which is with negatively electricity. With the charge separation of the interface layer of semiconductor, it will produce a voltage between P region and N region. For crystalline silicon solar cells, a typical value of open-circuit voltage is 0.5 ~ 0.6V. The more electron-hole produced at the interface of semiconductor, the electric current will be larger. The more solar energy absorbed by the interface of semiconductor and the bigger of the area of solar cells, the electric current will be larger when the system work. (Ned Haluzan on 2012.11.05.)

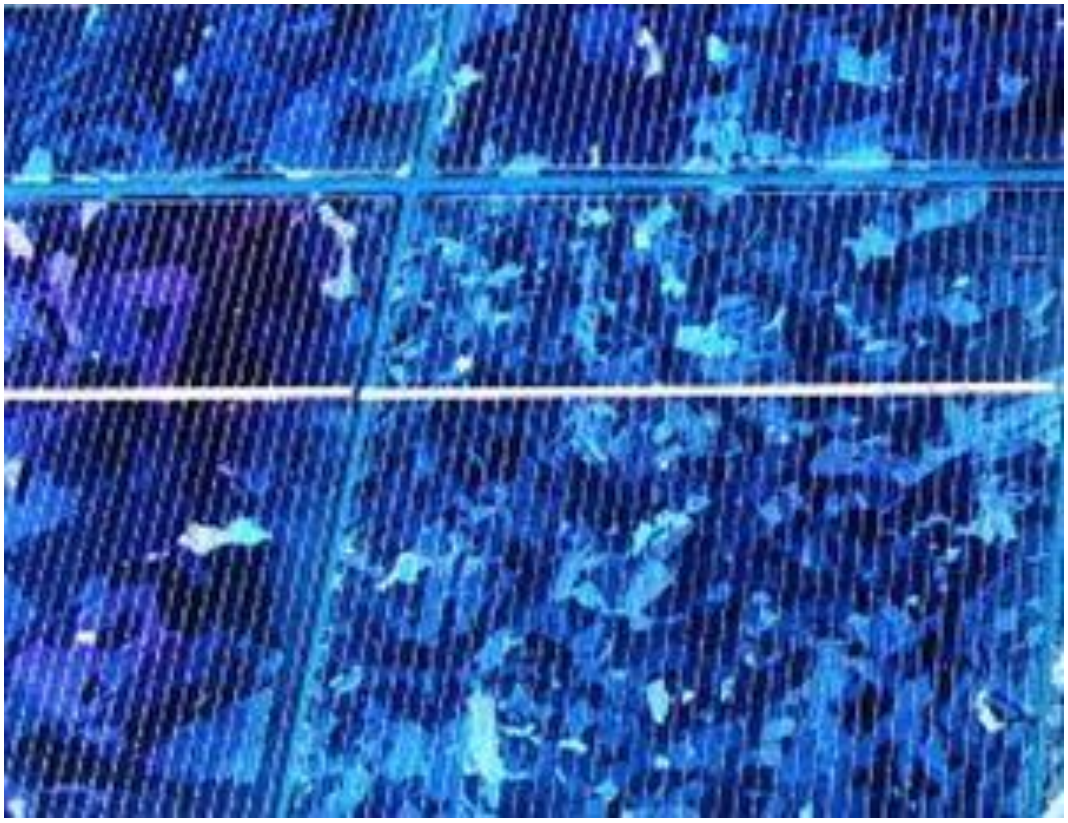

Figure 3. Solar cells absorb photons. (Ned Haluzan on 2012.11.05.)

3.2 PRINCIPLE

Solar energy is a type of radiated energy. It can be changed into electrical energy by using energy converters. The converter is a solar cell. It will produce new electron-hole pairs when light shines on the P-N knot of the semiconductor, under the function of electric field in the P-N knot, the electron-hole will flow to P zone from N zone, and the electrons flow to N zone from P zone, and produce electric current after connected to the circuit.

There are two types of solar photovoltaic, types light-heat-electricity and direct light-electricity type. (Kineavy 2014.05.01)

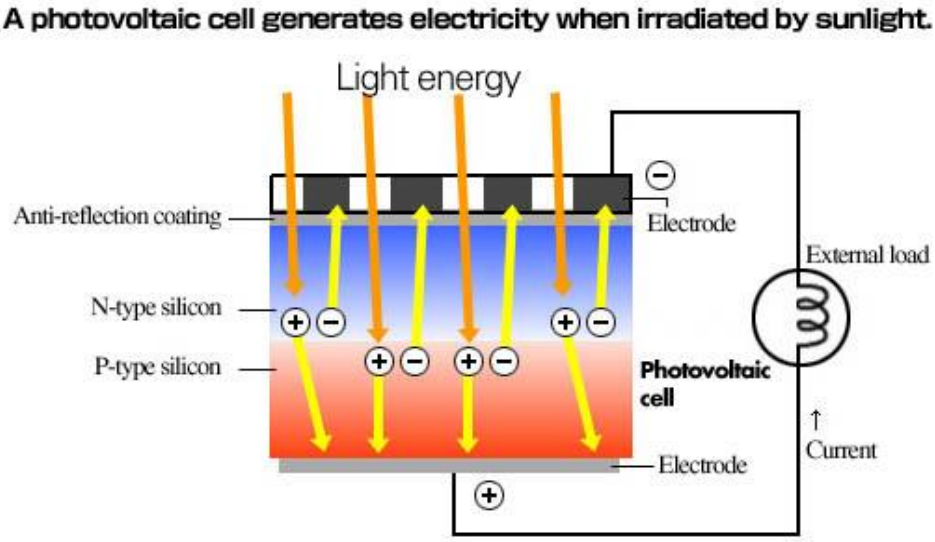

Figure 4. PV cell. (F. Kineavy 2014.05.01)

4 COMPOSITION OF SOLAR PHOTOVOLTAIC SYSTEM

After learning the principles of solar photovoltaic power generation, scientists have designed a solar photovoltaic component, and according to their respective functions, these established to generate electricity.

4.1 INTRODUCTION OF SOLAR PHOTOVOLTAIC SYSTEM

Solar photovoltaic system can use the solar cell module to produce the electrical energy by solar power directly. Solar cell is a device which can achieve the transform of P-V by the electronic characteristic of semiconductor materials, in the majority of the off-grid areas, the device can be easily implemented as a user-powered lighting of life. It can be also with the regional power grid to achieve complementarity in some developed countries.(Bhubaneswari Parida, S. Iniyan and Ranko Goic 2011.04.)

4.2 SETTING CONDITIONS

The factors for designing solar photovoltaic system are as follows:

1. Need to consider the use of solar photovoltaic systems places and solar radiation conditions;

2. Need to consider how much load power should be carried by the solar photovoltaic system;

3. For the output voltage of the system, the use of a DC or AC power should be considered;

4. The number of hours per day the systems need to work;

5. If there is no sunlight in rainy weather, how many days should the system supply continuously;

6. It should be considered whether the case of the load is purely resistive, capacitive or inductive, starting current size. (Gray Davis, Governor 2001.06)

4.3 COMPOSITION OF SOLAR PHOTOVOLTAIC SYSTEM

PV[2] system is composed of square solar cells, a battery, a charge controller, an inverter, an AC Power Distribution Cabinet, an automatic solar tracking system, an automatic dust removal system, solar modules and other equipment.

4.3.1 SOLAR CELL

Solar cell is made of two types of semiconductors which are called P-type and N-type silicon. Because of adding atoms, the P-type silicon loses one electron. The N-type silicon is made by adding atoms so that it gets one more electron.

A solar cell is made by a P-type silicon layer and the N-type silicon layer. There are too many electrons in N-type layer, and in P-type layer, there are too many electron-holes. Near the junction of those two layers, the electron moves into the electron-hole from N-type layer, this creates a depletion zone so that the electrons fill the holes. (Copyright © 2016 American Chemical Society 2015.04.02.)

[2] PV = photovoltaic

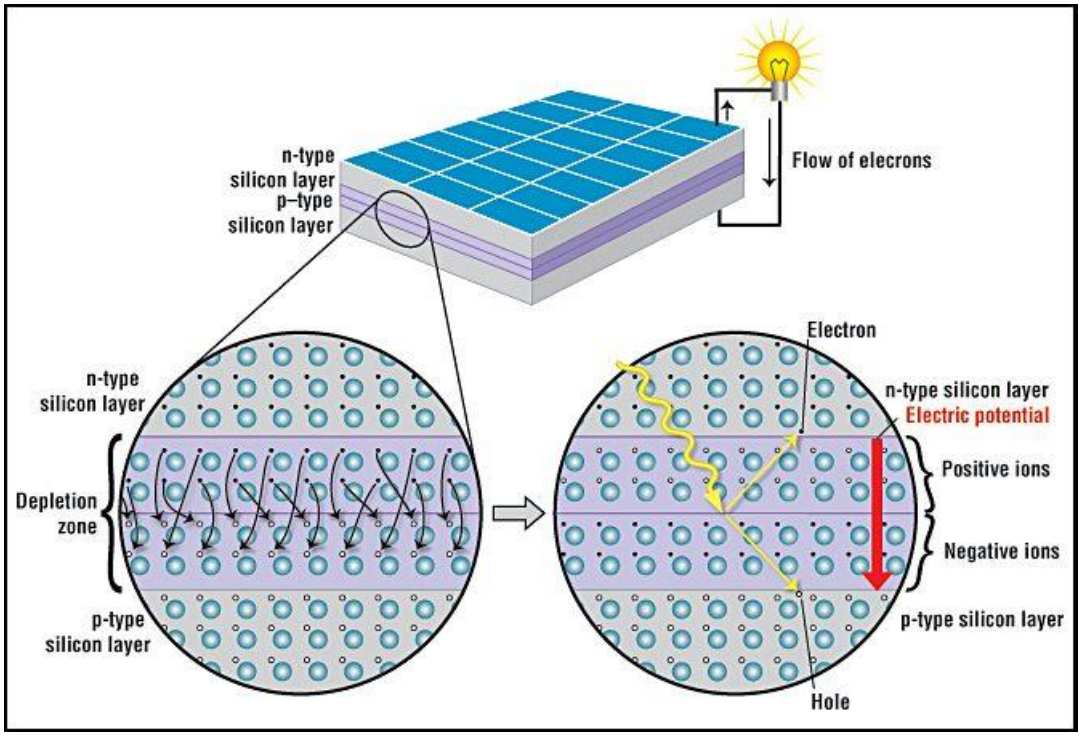

Figure 5. N and P type layers. (Copyright © 2016 American Chemical Society 2015.04.02.)

Solar cell is a device which can catch the sun light and transform it to electrical energy directly. The size of a solar cell is about a size of a palm of an adult. The shape is an octagon, and the color is blue-black. Solar cells are built with the solar batteries together very often. The large units are solar modules. The case of many solar cells are built together which are called a solar panel. (Chris Woodford on 2016.04.28.)

Figure 6. Solar cells panel. (Chris Woodford on 2016.04.28.)

4.3.2 SOLAR BATTERY

For some problems, such as unstable grid energy, over-charging or discharging and irregular full recharging, is for the solar battery important to meet those demands. And for nowadays, lead-acid batteries are the main batteries which are used in solar photovoltaic system.

Lead-acid batteries: these solar batteries are mainly used in the car, but it is a good choice for solar photovoltaic system. It is a starting battery; it can produce a short burst of high power to start the engine of the system. There are also some deep-cycle batteries. Lead-acid batteries are used very widely, but all of lead-acid batteries are used for starting or prociding deep cycle power. There is an obviously difference, that is how much power it deliveres and how long it needs to deliver. (Kathie Zipp 2015.08.21)

4.3.3 BATTERY PACK

The main function of a solar battery pack is to store solar energy by the square under the light and be ready to supply the electricity energy to the load at anytime.

Here are the basic requirements for solar power batteries:

1. Low self-discharge rate;
2. Long service life;
3. Deep discharge capacity should be strong;
4. High charging efficiency;
5. Low-maintenance rate or maintenance is free;
6. Wild range of operating temperature;
7. Low price.

For currently, the most battery packs used with solar photovoltaic system together are lead-acid batteries and nickel-cadmium batteries. Generally, it is used in stationary or industrial sealed lead-acid batteries, more than 200Ah lead-acid batteries are used more, and the rated voltage of each battery is 2VDC[3]. Generally, it is used small sealed maintenance-free lead-acid battery if the need is less than 200Ah lead-acid battery, and the rated voltage is 12VDC for each battery. (Zachary Shahan 2015.03.01.)

[3] V = voltage DC = direct current

Figure 7. Battery packs. (Copyright © 2016 Neutron Battery 2016.04.06.)

4.3.4 CHARGE CONTROLLER

The charge controller can prevent battery over-charge and over-discharge automatically. Due to the cycle times of charge, discharge and the depth of discharging is the main factor to determine the usage of battery life. Therefore, a charge controller is an essential equipment. (© 1986-2016 Solar Direct 2016.04.07.)

Figure 8. Charge controller. (© GEESYS Technologies 2016.04.07.)

The charge controller can be used to supply power for DC device which is with solar panels. The charge controller can supply a regulated DC output and store the excess energy in a bat-

tery, and it can also prevent over or under charging by monitoring the battery voltage. (© 1986-2016 Solar Direct 2016.04.07.)

4.3.5 INVERTER

The device can transform direct current into alternating current. Since solar cells and batteries are DC power supplyer so that an inverter is necessary when it is an AC[4] load. According to operating mode, the inverter can be divided into stand-alone inverters and grid inverters. As a stand-alone inverter, it is used in an independently operated solar power generation system for supplying a separate load. Grid inverters are used in network operation solar power generation systems. The inverter can be divided into square wave inverter and sine wave inverter according to the type of output waveform. The circuit of square wave inverter is simple, cost of production is low, but the harmonic component is large. It is generally used for the system which is a few hundred watts or less and low requirements on the harmonic. However, the cost of sine wave inverter is high, but it can be applied to a variety of loads. The inverter can be connected with a charging output controller to drive AC loads.

Here are some protection functions of an inverter:

1. Overload protection;
2. Short circuit protection;
3. Reversal protection;
4. Undervoltage protection;
5. Overvoltage protection;
6. Overheating protection. （© 2016 Rudge Energy 2016.04.08.）

[4] AC = alternating current

Figure 9. Inverter. （© 2016 Rudge Energy 2016.04.08.）

4.3.6 SOLAR AC AND DC POWER DISTRIBUTION CABINET

Solar AC and DC Power Distribution Cabinet includes AC control cabinet and photovoltaic DC control cabinet. it is mainly used in those huge photovoltaic power plants. It can prevent lightning and over-current, and detect the PV single array string current, voltage, lightning protection state and short circuit state. The professionally design and the carefully choice of components can guarantee a long and stable period of the use of solar AC and DC power distribution cabinet. AC control cabinet is a device which can implement the inverter's output, detect, display and the device protection and so on. The output interface of the inverter AC distribution cabinet can provide it, the output AC circuit breaker can be configured with network (or for AC load use) directly, and the maintenance state of the PV system can not influence the security of the PV system and grid (or the load), but also protect the maintenance workers.

The main function of solar AC and DC power distribution cabinet is the switching for the back-up inverter in the power plant system, to ensure the power supply system is normal, as well as the measurement of the energy line. (©Guangzhou Pingou Electrical Co. Ltd. 2016.04.09.)

Figure 10. AC Power Distribution Cabinet. (©Guangzhou Pingou Electrical Co. Ltd. 2016.04.09.)

And here is the principle of the schematic distribution cabinet,

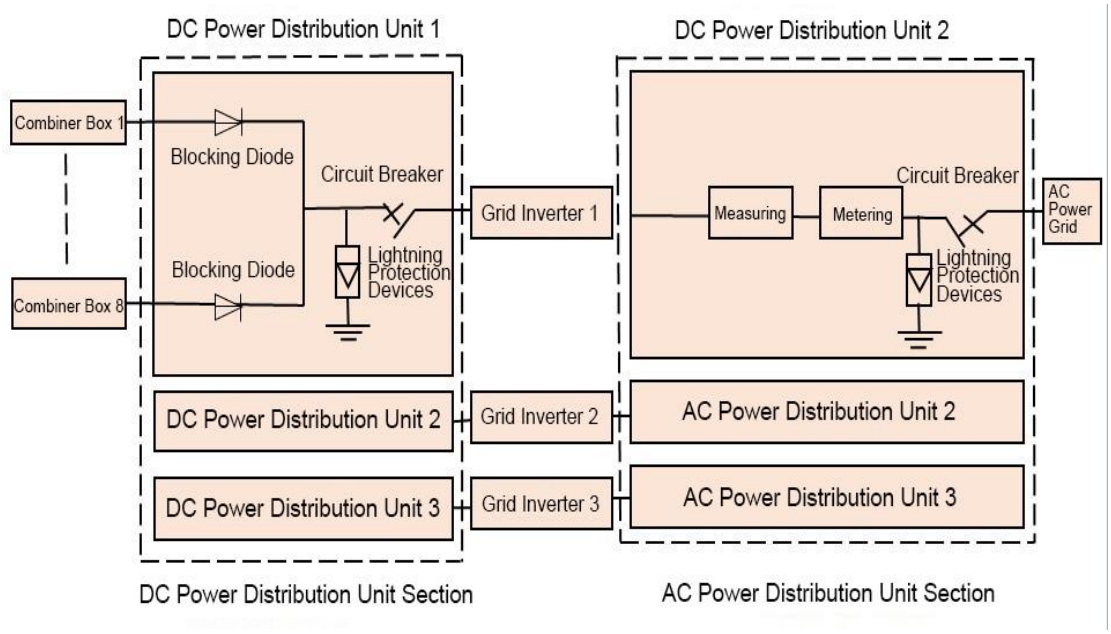

Figure 11. Schematic Distribution Cabinet. (©Guangzhou Pingou Electrical Co. Ltd 2016.04.09.)

4.3.7 THE LIGHTNING PROTECTION SYSTEM

As a new power generation system in the field of energy generation, solar photovoltaic power generation system has been widely used. Because of the particularity of solar photovoltaic

power generation system, such as the installed location and environment of the solar photovoltaic system, the components of the system will be caused damage by the lightning.

Therefore, the protection for the systems according to the actual situation of the systems can make sure the system run safer and more efficient.

The solar photovoltaic power generation equipment external lightning protection system is to prevent the thunder cause damage to solar cells directly. External lightning protection system consists of three parts: the air terminal, ground deflectors and ground network. Solar power system must have a relatively external lightning protection measures to ensure that the exposed outdoors solar panels are not directly damaged by lightning.

4.4 CLASSIFICATION OF SOLAR PHOTOVOLTAIC SYSTEM

Solar photovoltaic power generation system can be divided into independent photovoltaic systems, grid-connected photovoltaic power generation systems and distributed PV systems:

1. Independent photovoltaic power generation systems, are also known as off-grid PV systems. It mainly consists of solar modules, controller, battery. If it needs to supply an AC load, it also need to configure AC inverter. An independent PV power plant include the power supply system of the village in remote areas, household solar power systems, communications signal power, cathodic protection, solar lights and other PV systems. （Ivalls 2016.04.09.）

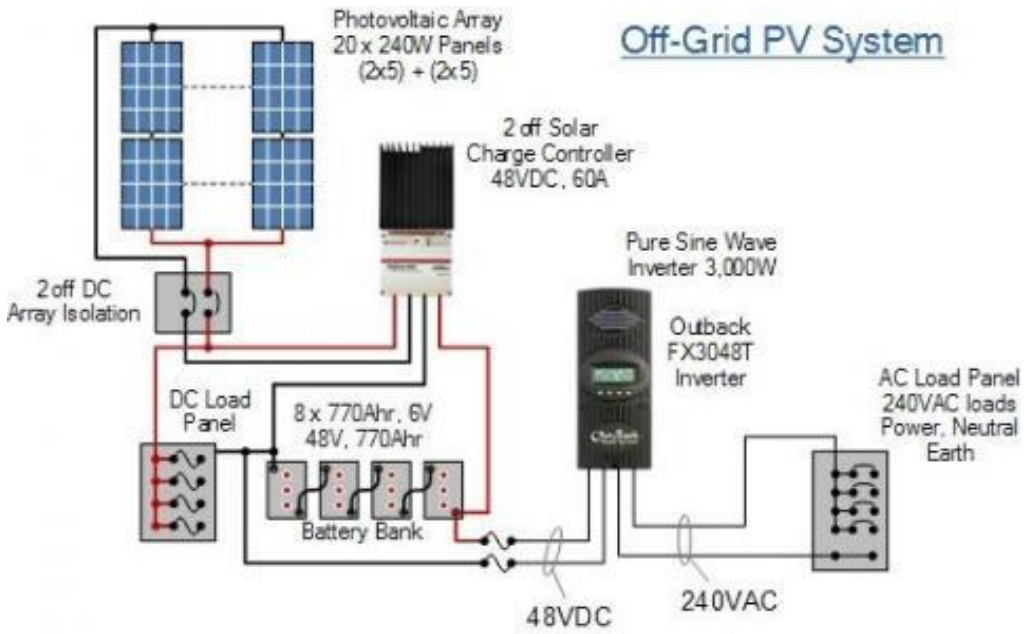

Figure 12. Off-Grid PV system. （Ivalls 2016.04.09.）

According to the characteristics of the load, independent photovoltaic systems can be divided into DC system, AC system and AC-DC hybrid systems and other types. The main difference is whether the system is with an inverter. In general, the composition consists of solar cell matrix, controller, battery, DC / AC inverter and some other off-grid solar photovoltaic systems. （Ivalls 2016.04.09.）

2. A Grid-connected PV system is that is directly connected to the public grid after the DC current is generated by solar modules and then through grid an inverter transforms if into alternating current mains in line with the electricity grid requirements.

It can be divided two types of grid-connected PV systems according to whether they have a battery. The grid-connnected PV system with battery is schedulable so that it can be incorporated into or out of the grid as required. It also can be as a backup power when the grid has some problems. However, the grid-connected PV system without battery can not be a backup power and unschedulable. （Anil Kumar 2016.04.11.）

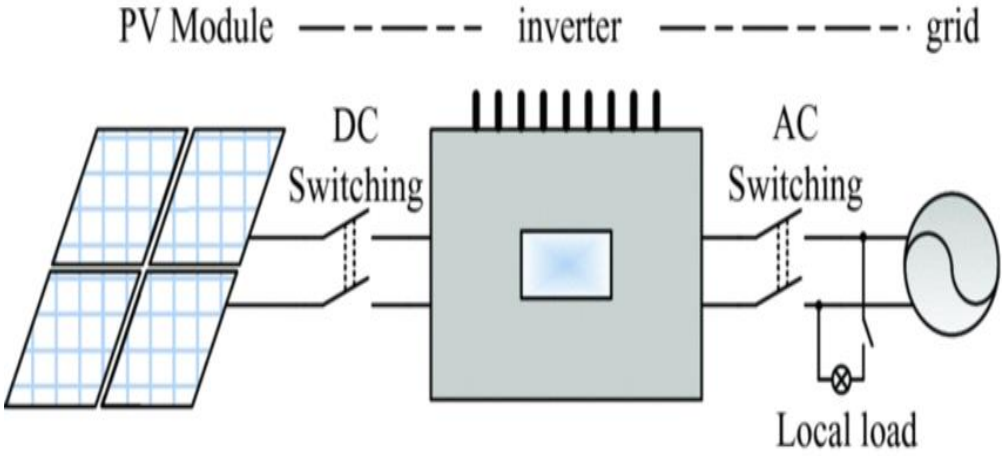

Figure 13. Grid-connected photovoltaic power generation systems. （Anil Kumar 2016.04.11.）

3. Distributed photovoltaic systems are often built near the position of the users or near the PV plants to achieve some special needs of users.

The basic components of distributed PV systems include photovoltaic modules, photovoltaic array bracket, DC combiner box, DC power distribution cabinet, grid-connected inverter, AC power distribution cabinets and other equipments. There are also power system monitoring and controlling devices and environmental monitoring devices. When the system is under the radiation of sun light, the solar cell module array of photovoltaic systems will transform the solar power to electrical energy, and then send the energy into DC power distribution cabinet by DC combiner box, then reverse into AC power by the inverter and supply the load of the system,

the excess or shortage of electricity through the grid connection to be adjusted. （Anil Kumar 2016.04.11.）

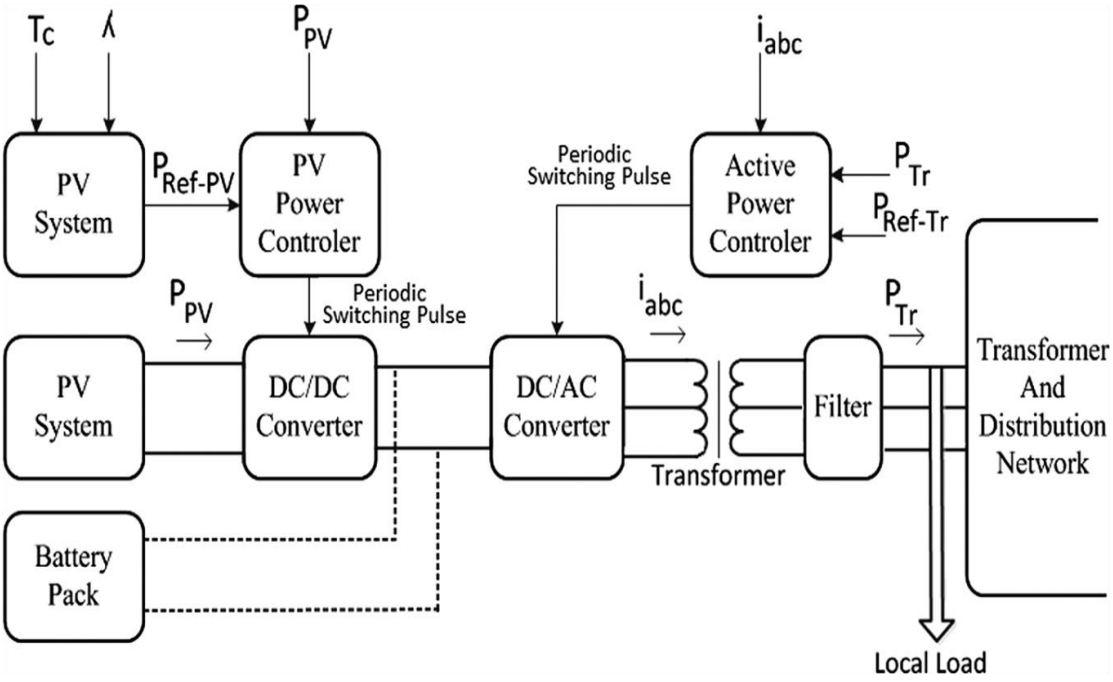

Figure 14. Distributed photovoltaic systems. （J. Sol 2013.01.25.）

According to the function and the operation requirements, the configurations of the components and the ways of the connection that are between equipments and the other power sources and electrical loads, the solar PV system can be divided into two main systems, grid-connected or utility-interactive systems and stand-alone systems.

The most important component in grid-connected PV system is the inverter, or power conditioning unit (PCU). The DC power produced by the PV array can be transformed into AC power by the PCU, the voltage and power quality are in the light of the requirements of the utility grid, and can stop supplying power to the grid automatically when the grid is not energized. （© 2007-2014 University of Central Florida 2016.04.10.）

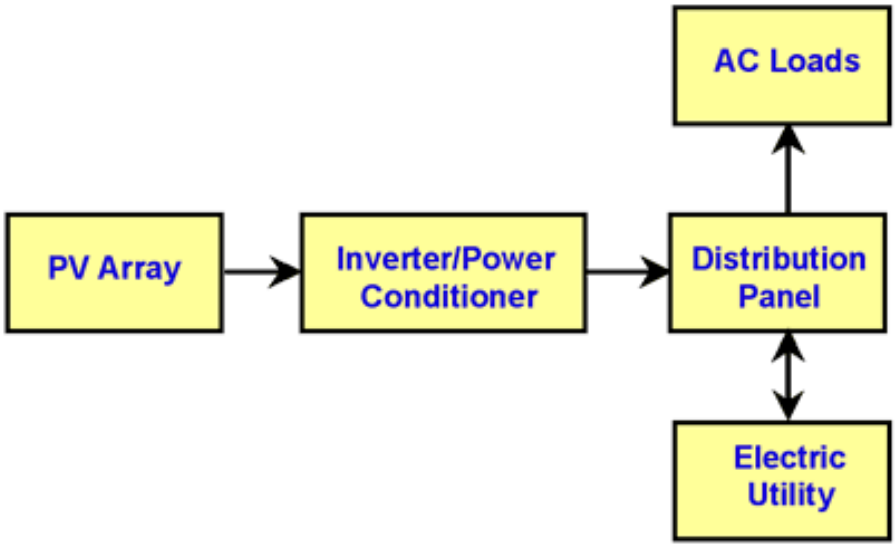

Figure 15. Diagram of grid-connected photovoltaic system. （© 2007-2014 University of Central Florida 2016.04.10.）

Grid-connected photovoltaic power generation systems can be divided into two types of centralized large-scale photovoltaic networked systems and distributed network of small photovoltaic systems. In the large-scale photovoltaic power plant, the power can be delivered to the electricity grid directly. The investment of this system will be quite huge and have a long period to built it.

Stand-alone PV systems are designed to supply DC or AC power electrical loads generally. （© 2007-2014 University of Central Florida 2016.4.10.）

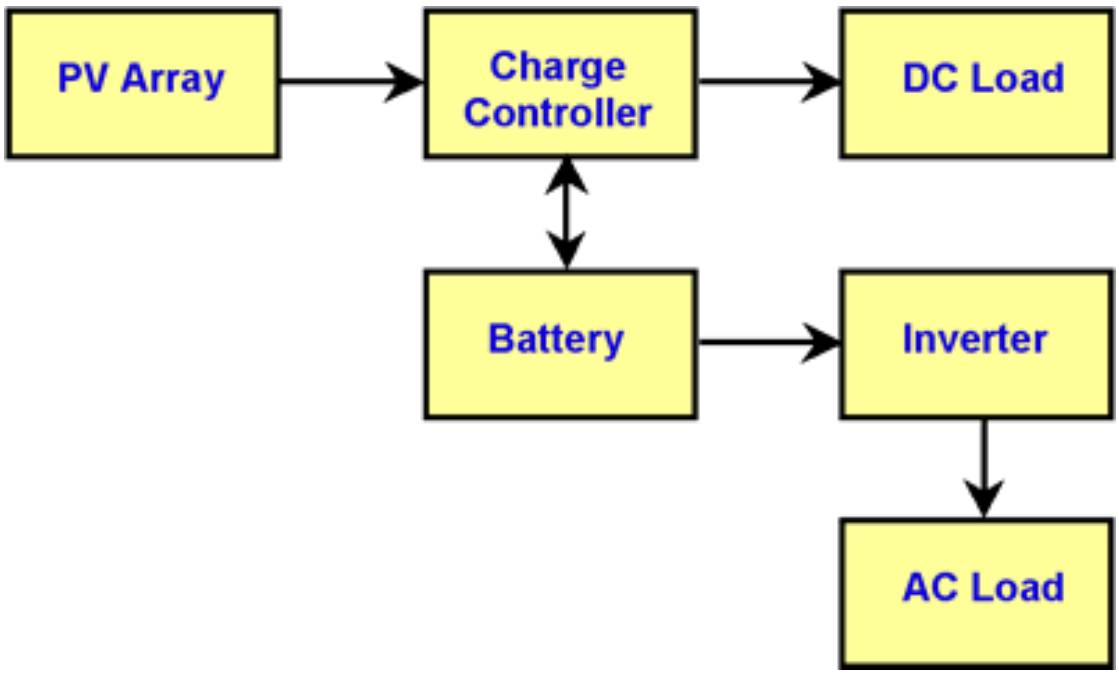

Figure 16. Stand-alone PV system. （© 2007-2014 University of Central Florida 2016.04.10.）

4.5 ADVANTAGES AND DISADVANTAGES OF THE SYSTEM

Every coin has two sides, for solar photovoltaic system, there are also advantages and disadvantages. But in one word, solar photovoltaic system is quite good for humans' development.

Advantages:

1. Solar energy is inexhaustible, solar radiation receiving by the surface of the earth is able to meet the global energy demand as 10,000 times. As long as the installation of solar photovoltaic systems are done in the 4% of desert in the world, the generated electricity meets global needs. Solar energy is safe, reliable, does not suffer from the energy crisis or the impact of the fuel market instability;

2. Solar energy exists everywhere. It could supply the electricity power near the place where the energy is produced, there is no long-distance transportation, and the loss of long-distance transmission lines are avoided;

3. Solar energy is without fuel, and has low running costs;

4. No moving parts, not easy to break, easy maintenance, particularly suitable for unattended use;

5. Solar photovoltaic system does not produce any waste, no pollution, no noise pollution, no adverse effects on the environment. It is an ideal clean energy;

6. Solar photovoltaic system construction period is short, convenient and flexible, and can be increased or decreased depending on the load, any additions or reductions of the solar capacity of the square, avoid wastage.

Disadvantages:

1. Being intermittent and random, electricity production and climatic conditions can not or rarely generate terrestrial applications at night or rainy days;

2. The conversion rate is low, and the system must be run under standard conditions, the received solar radiation intensity is 1000W / m^2 on the ground. It needs to occupy a large area;

3. Prices are still more expensive. They are higher than conventional power generation from 3 to 15 times and high initial investment. （Dino Green 2012.12.19.）

5 THE APPLICATIONS OF SOLAR PHOTOVOLTAIC SYSTEM

With the development of society and the solar photovoltaic technology, solar photovoltaic power generation involves many aspects. People can see the applications everywhere in the life. Such as solar photovoltaic power plant, household solar photovoltaic power generation system, solar lights, solar cars and some other applications.

5.1 SOLAR PHOTOVOLTAIC POWER PLANT

Solar photovoltaic power plants are made by the solar cells square which can transform the solar radiation energy to electrical energy. According to the operation mode, solar photovoltaic power plant can be divided into independent solar power stations and grid-connected solar photovoltaic power plant.

Independent solar power station does not couple with the public grid. It mainly uses in those places where are no electricity and some special places. Such as remote and isolated rural and pastoral areas, islands, plateaus and desert for those farmers and fishermen, to ensure that they can watch TV, lighting, listening to the radio and other basic living electricity. It also can be used for communications relay station, coastal and inland buoy, cathodic protection of pipelines, meteorological station, road class and road border posts and other special premises. Independent system consists of solar cell matrix, the system controller, battery, DC / AC inverter and other components.

Grid-connected solar photovoltaic power plant does not connect with the public power grid. It is very important for large-scale commercial stage and the electric power industry components. It is the main trend of the world's solar photovoltaic technology development. Grid system consists of solar cell matrix, the system controller, and network inverter and other components. (Zhao Yu 2012.03.13.)

5.2 HOUSEHOLD SOLAR PHOTOVOLTAIC SYSTEM

Household solar power system consists of solar batteries, solar controller, battery components. It will need to configure inverter if the output power is 220V AC or 110V.

The conditions of the household solar photovoltaic power generation system as follows:

1. Where do people want to use the household solar photovoltaic system and what is the solar radiation situation of the place?

2. How much is the power of the load?

3. How much is the output power?

4. How long should the system work per day? How long should the system supply power when the weather is not good? (Zhao Yu 2012.03.13.)

6 MAINTENANCE OF SOLAR PHOTOVOLTAIC SYSTEM

Maintenance is also an important part of the PV system. Since any components of the system are broken, the system can not work well, and the system is quite huge, so the workers should do the maintenance regularly to ensure the system can work as designed. If there is no maintenance for the system, when there are some problems, it will cost too much to repair it and maybe take too much time to do it. Doing regular maintenance can prevent it.

6.1 ESTABLISH A GOOD TECHNICAL DOCUMENT MANAGEMENT SYSTEM

1. Establish a system for power plant equipment design and construction drawings and technical documents files.

2. Establish a system for information management systems of the plants.

3. Establish a system for power plant operation of archives.

4. Establish Operation Analysis System.

Each station should establish a full and complete technical documentation file and the person who is responsible for the establishment of power plant technology file management for providing strong technical support of the underlying data. (Zhao Yu 2012.03.13.)

6.2 THE MAINTENANCE OF THE COMPONENTS

In the sand larger areas, periodically wiping system components to ensure the system can work properly. Wipe the surface of the components with sofe cloth, do not use those hard and rough cloth. And check inspect the various components and wiring regularly, take preventive measures. Make the notes after checking the system detailly. Do the replace or repair for those components according to the actual situation. (Zhao Yu 2012.03.13.)

6.3 TRAIN THE MAINTENANCE WORKERS

Training is mainly aimed at two aspects of personnel, one of that is the professional and technical personnel training for those major and difficult issues and operation maintenance management. And organization those people to do the professional training and research some special topics, ehance their profeesional abilities.

Secondly, training those system operators is important, and almost all of those people are the local stuff. But usually, the local stuff will not have too much professional knowledge of solar photovoltaic, so they have to be trained with the basic knowledge. (Zhao Yu 2012.03.13.)

7 THE MARKETING OF SOLAR PHOTOVOLTAIC

Under the pressure of rigorous energy crisis and the environment (greenhouse effect), the advances in technology and the gradually improving regulations and policies, the solar PV had been developing rapidly since 1990s. Especially after the Germany promulgated the law about the PV price, the production of the PV system had been in short supply, caused by the serious shortage of silicon material.

7.1 TYPES OF SOLAR PANEL

As the most important part of solar PV system, solar cell matrix is in a big role for transforming light into electricity. According to the raw materials, it can be divided into three types, single crystal silicon solar cells, polycrystalline silicon solar cells, and amorphous silicon solar cells. In the solar PV systems of China, single crystal and polycrystalline maximum battery are the main types currently. From the above analysis, the development of crystalline silicon is closely related to photovoltaic industry and manufacturing industries. The development of photovoltaic industry will directly promote the development of crystalline silicon production industry. (Yang Mingjing 2016.04.20.)

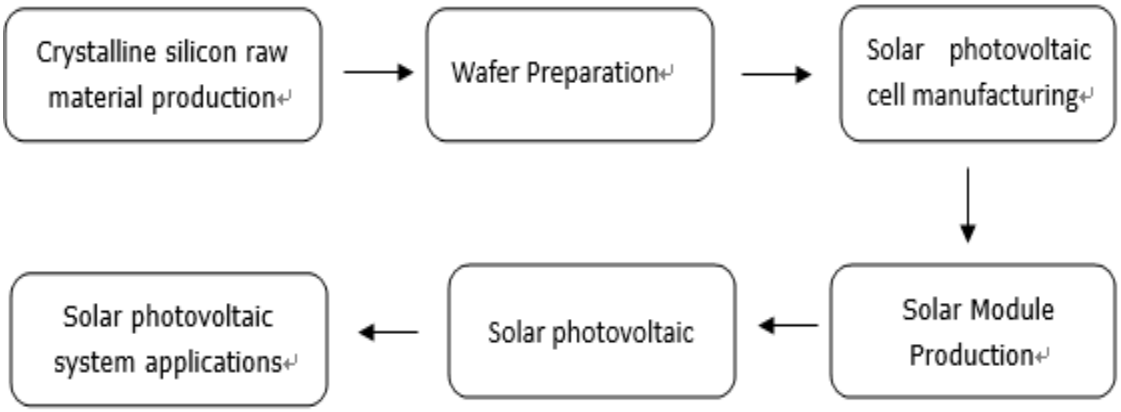

Figure 17. PV industry chain. (Yang mingjing 2016.04.20.)

7.1.1 MONOCRYSTALLINE SILICON (SINGLE SILICON)

The efficience of the solar panel depends on the content of silicon. The more silicon included, the efficience will be higer. So the single silicon solar panel is the most popular panel. The same amount sunlights irradiate on the single silicon solar panels, the panel will absorb much more energy than other types of panel, the more electricity will be produced. But with so many advantages, the disadvantage is the price. The single silicon solar panels are very expensive. (© 2014 NRG Residential Solar Solutions LLC. 2016.04.25.)

Figure 18. Single silicon soalr panel. (© 2014 NRG Residential Solar Solutions LLC. 2016.04.25.)

7.1.2 POLYSRYSTALLINE SILICON (MULTI-SILICON)

Polycrystalline solar panel is made of polycrystalline silicon solar cells, and array of PV modules of different power are arranged in different ways to meet the electricity demand of different appliances.

Crystalline silicon solar cell film and thin film solar cells are the main market mainstream, both of which have advantages and disadvantages. For the crystalline silicon solar cell film, the produce cost is lower, but the consumption is very high. The photoelectric conversion efficiency is too high. For the thin film solar cells, most of them are used outdoor power generation. The cost of the equipment is high, but the efficiency of power generation is higher. (© 2014 NRG Residential Solar Solutions LLC. 2016.04.25.)

Figure 19. Multi-silicon solar panel. (© 2014 NRG Residential Solar Solutions LLC. 2016.04.25.)

7.1.3 AMORPHOUS SILICON SOLAR PANEL

Amorphous silicon solar cells are the new thin-film solar cells, appeared in 1976. The production method is quite different with monocrystalline and polycrystalline silicon solar cell. The process is greatly simplified. The consumption of silicon is decreased too much, and the consumption of electricity is lower. Its main advantage is in low light conditions where it can also generate electricity. The main problem is the presence of amorphous silicon solar cell conversion efficiency is low. The international advanced level is about 10%, and it is not stable enough. With time, the conversion efficiency is attenuated. (© 2014 NRG Residential Solar Solutions LLC. 2016.04.25.)

Figure 20. Amorphous silicon solar cells. (© 2014 NRG Residential Solar Solutions LLC. 2016.04.25.)

In Figure 21 and 22, there are new type of amorphous silicon solar cells, the flexible solar cells, a thin film solar cell. They are technologically advanced, with high performance, low cost, and wide range of uses. It can be applied to solar backpacks, solar convertible, solar flashlights, solar car, solar sailing and even solar-powered aircraft. An important application area is flexible solar BIPV (Building Integrated Photovoltaic). It can be integrated in the window or roof, wall or inside the wall. (© 2014 NRG Residential Solar Solutions LLC. 2016.04.25.)

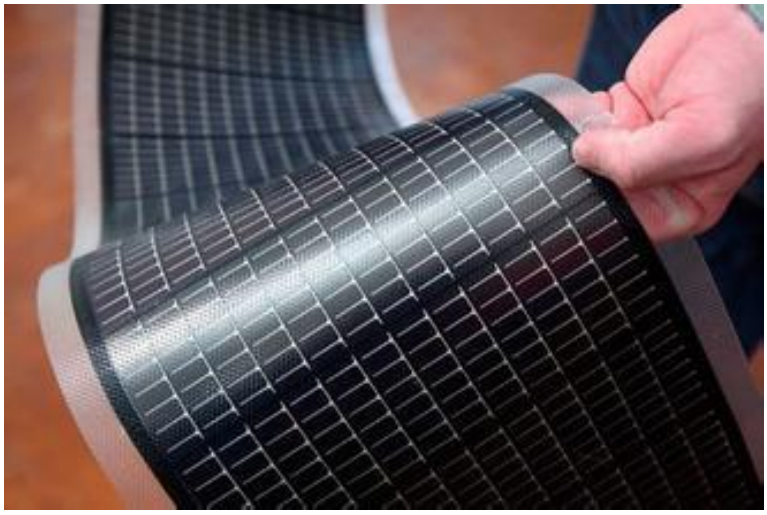

Figure 21. The flexible solar cells. (© 2014 NRG Residential Solar Solutions LLC. 2016.04.25.)

7.2 THE COST AND THE MARKET SHARE IN THE WORLD

The rate in the world of solar PV production in 2011 is presented in Figure 23.

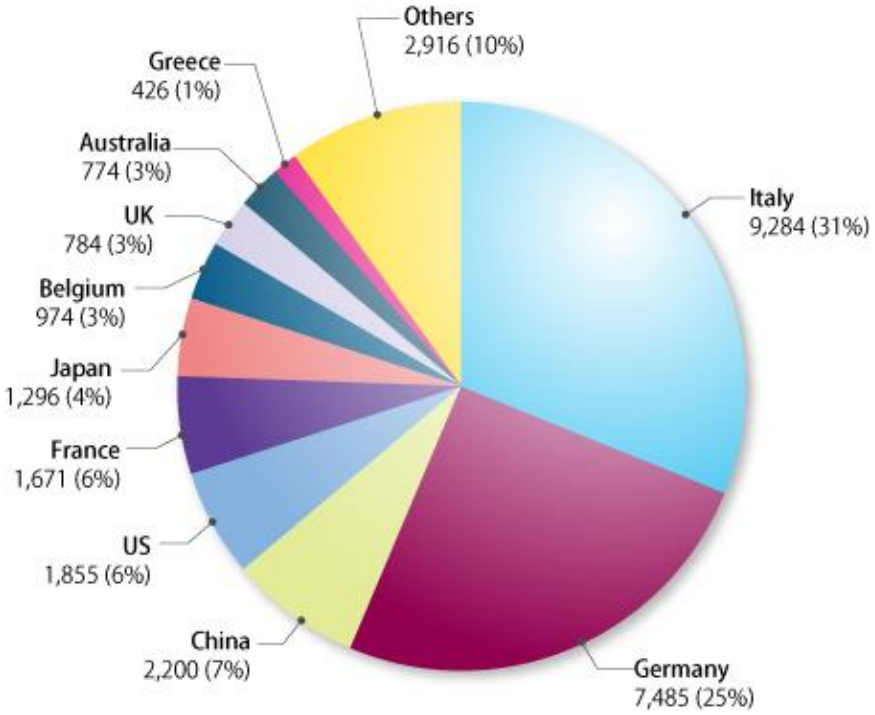

Figure 22. The rate in the world of solar PV production in 2011. (Copyright New Energy Foundation on 2012.05.)

With the exploitation and utilization of materials, such as silicon, which is the main material of solar cells, there is less and less silicon in the world day by day, and it has caused the price of the silicon increase too much. In other aspects, with the rapid development of technology, the quality of the solar PV productions is getting better and better, but meanwhile, the cost of the raw productions has increased. (Copyright New Energy Foundation on 2012.05.)

As seen in Figure 23 and 24, China, Japan and the USA are the main solar power generation country, and one year later, the demands of solar power are increased almost in every coutry. Because the solar power is clean and unexhausted, the governments support to develop this power to relace the fuel resources.

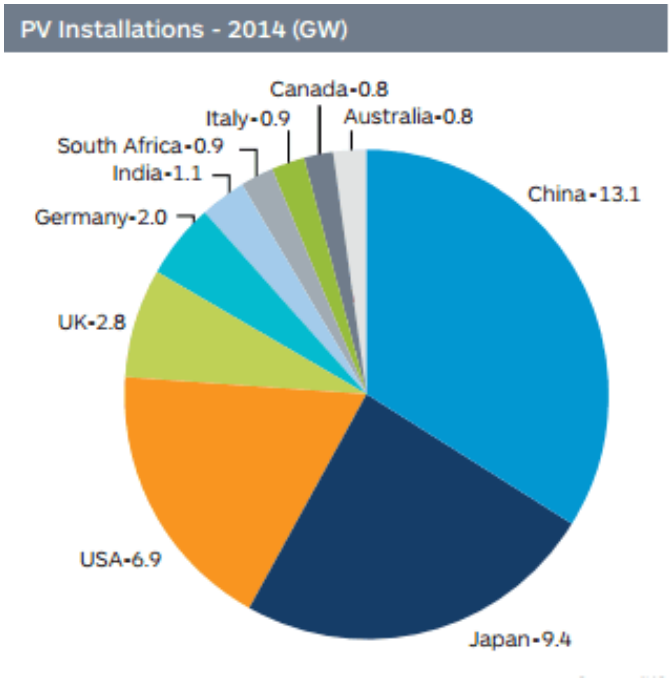

Figure 23. PV installations in 2014. (Copyright New Energy Foundation on 2012.05.)

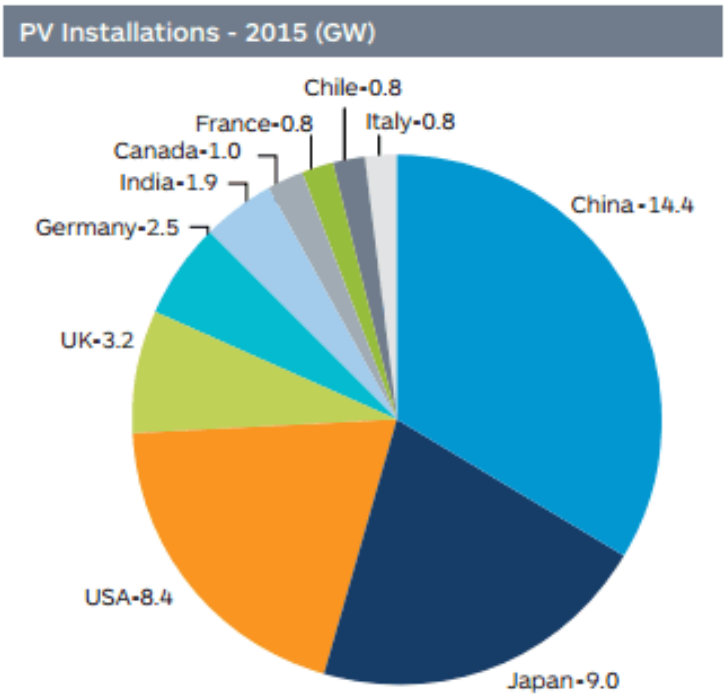

Figure 24. PV installations in 2015. (Copyright New Energy Foundation on 2012.05.)

7.3 SWOT OF SOLAR PV MARKET

Swot is an important way to do the analysis of marketing. It includes strengths, weaknesses, opportunities and threats.

Table 1. SWOT of solar photovoltaic.

Strength:	Weakness:
1. Clean, efficient and renewable energy 2. No conventional energy consumption, save energy 3. Environmental protection: none environmental pollution. 4. Easy to install, no cabling 5. One-time investment of a lifetime	1. Conversion rate is low 2. Need large area 3. Affected by the weather (sun light) 4. High cost 5. Intense competition
Opportunity:	Threats:
1. Scientific and technological progress 2. Market expectation is broad 3. More and more public use 4. Support of national policy	1. Grid initiative 2. Frequent fluctuations in product prices, the demand for subsidized financing policy and a greater impact

7.4 THE GREENHOUSE INFLUENCE

The solar PV system can transform the solar energy into electrical energy directly, which is like the plant photosynthesis converting light energy into chemical energy, but here is one different thing which is that the relatively low conversion rate of solar PV system. It will be absorbed the power by the object on the Earth, and then it comes out in the form of infrared radiation. (Ash Sharma 2016.05.01.)

8 CONCLUSION

The reason why countries in the world pay attention to photovoltaic power generation are mainly the technological development of the predictability, cost-competitive applications, and control of environmental issues. In the past 30 years of development of solar photovoltaic, the photovoltaic industry has accumulated a wealth of experience. It is already a mature industry. Many scientists believe that perhaps one day some new energy technologies may arise, and solar power is the most promising technology. Therefore, the development of photovoltaic technology is not an expedient measure, not a whim, but a low-carbon development, the inevitable choice. All the countries 'photovoltaic industry should work together to strengthen re-

search and development, accelerate technological progress, eliminate trade barriers, and expand PV application market.

China's solar energy resources are very rich; the theoretical ton of coal reserves are about 1.7 trillion annually. China's photovoltaic power industry started in the 1970s. In the mid-90s entered a steady development period. After 30 years of effort, we have ushered in a new stage of rapid development.

Since solar photovoltaic power generation has unique advantages, more and more people pay attention to the universal application of solar power. Light is around the world, creating a powerful natural conditions for the use of solar energy, and it has got rapid development in recent years. Solar photovoltaic is small proportion of the energy, but with the development of society and technology, its share will increase year by year. Experts predict that by mid-21st century, solar photovoltaic power generation will become the mainstay of the world's energy supply. A brilliant solar era is coming.

REFERENCE

Siyu Wang on 2012.04.22. Solar PV. Available from: http://wenku.baidu.com/link?url=kk2bFjNLsQqJPJxKay3P8kL9QIVJX6fgxXbHczMDhVmOnWoZdpzzMgpR6s-nAPWzwm5ZbDmF-J6yCvDlriANZZuLq6s33arGsLUyY27YHwS

Cho Hyun Seok on 2015.03. Research of design, simulation and demonstration of solar reactor with ceria coated ceramic foam device for two-step thermochemical water-splitting cycle. Available from: http://dspace.lib.niigata-u.ac.jp/dspace/bitstream/10191/32205/2/h26ftk424.pdf

Devarajan Srinivasan on 2015.10.20. The impact of weather and related environmental variables on Solar-PV Performance. Available from: http://poundra.com/the-impact-of-weather-and-related-environmental-variables-on-solar-pv-performance/

Ned Haluzan on 2012.11.05. Explaining the working principle of photovoltaic cells. Available from: http://solarword.blogspot.fi/2012/11/explaining-working-principle-of.html

F. Kineavy on 2014.05.01. Solar Photovoltaic Panels. Available from: https://fkineavy.wordpress.com/solar-photovoltaic-panels/

Bhubaneswari Parida, S. Iniyan and Ranko Goic on 2011.04. A review of solar photovoltaic technologies. Available from: http://www.sciencedirect.com/science/article/pii/S1364032110004016

Gray Davis, Governor on 2001.06. GUIDE TO PHOTOVOLTAIC (PV) SYSTEM DESIGN AND INSTALLATION. Available from: http://www.energy.ca.gov/reports/2001-09-04_500-01-020.PDF

Copyright © 2016 American Chemical Society on 2015.04.02. How a Solar Cell Works? Available from: http://www.acs.org/content/acs/en/education/resources/highschool/chemmatters/past-issues/archive-2013-2014/how-a-solar-cell-works.html?cq_ck=1396892718960

Chris Woodford on 2016.04.28. Solar cells. Available from: http://www.explainthatstuff.com/solarcells.html

Kathie Zipp on 2015.08.21. Solar battery technologies. Available from: http://www.solarpowerworldonline.com/2015/08/what-is-the-best-type-of-battery-for-solar-storage/

Penn State on 2015.08.26. Solar Cell Research Funded by US Department of Energy. Available from: http://www.ecnmag.com/news/2015/08/solar-cell-research-funded-us-department-energy

Zachary Shahan on 2015.03.01. Tesla's Home Battery Offering in Context — Pricing Much Lower Than Expected
Available from: http://cleantechnica.com/2015/05/01/tesla-home-battery-price-competition/

Copyright © 2016 Neutron Battery on 2016.04.06. Solar Battery. Available from: http://www.neutronbattery.com/solar-battery/

© 1986-2016 Solar Direct on 2016.04.07. PV Controllers. Available from: http://www.solardirect.com/pv/pvlist/control/control.html

© GEESYS Technologies on 2016.04.07. Solar Charge Controllers. Available from: http://www.geesysindia.com/solar_charge_controller.php

© 2016 Rudge Energy 2016.04.08. Inverters. Available from: http://www.rudgeenergy.co.uk/solar-pv/inverters

©Guangzhou Pingou Electrical Co. Ltd on 2016.04.09. Solar AC and DC Power Distribution Cabinet. Available from: http://www.waterheaterchina.com/product_show.asp?id=94

Ivalls on 2016.04.09. Complete Off-Grid PV System. Available from: http://www.skharchitects.com/content/complete-grid-pv-system

© 2007-2014 University of Central Florida on 2016.04.10. Types of PV systems. Available from: http://www.fsec.ucf.edu/en/consumer/solar_electricity/basics/types_of_pv.htm

Anil Kumar on 2016.04.11. Study of Solar Photovoltaic Panel. Available from: http://www.slideshare.net/AnilDhanda1/solar-photo-voltaic-panel

J. Sol on 2013.01.25. Distributed Generation, Using Battery/Photovoltaic. Available from: http://solarenergyengineering.asmedigitalcollection.asme.org/article.aspx?articleid=1674787

Dino Green on 2012.12.19. Advantages and disadvantages of Solar Photovoltaic – Quick Pros and Cons of Solar PV. Available from:

http://www.renewableenergyworld.com/ugc/blogs/2012/12/advantages-and-disadvantages-of-solar-photovoltaic-quick-pros-and-cons-of-solar-pv.html

Siyu Wang on 2012.04.22. Solar PV. Available from: http://wenku.baidu.com/link?url=kk2bFjNLsQqJPJxKay3P8kL9QIVJX6fgxXbHczMDhVmOnWoZdpzzMgpR6s-nAPWzwm5ZbDmF-J6yCvDlriANZZuLq6s33arGsLUyY27YHwS

Zhao Yu on 2012.03.13. Interim Measures for the management and maintenance of photovoltaic power generation. Available from: http://wenku.baidu.com/link?url=v0qpU-1PMMBYcu6q9_hd8M9jR2zAIs3VtDLQIj0J8ZVOcyMPRdqn5pqsnkRaSCxvxDSWHmb04wDy7hzdlNSJuJTB37M95eLoSeSWYzuYY4y

Yang mingjing on 2016.04.20. China has become the world's largest PV market. Available from: http://www.qianzhan.com/analyst/detail/220/140608-bbeb1d2e.html

© 2014 NRG Residential Solar Solutions LLC on 2016.04.25. Types of Solar Panels. Available from: https://pureenergies.com/us/how-solar-works/types-of-solar-panels/

Copyright New Energy Foundation on 2012.05. China Is Number One in the World at Solar Power Production. Available from: https://www.asiabiomass.jp/english/topics/1207_06.html

Ash Sharma on 2016.05.01. Top Solar Power Industry Trends for 2015. https://www.ihs.com/pdf/Top-Solar-Power-Industry-Trends-for-2015_213963110915583632.pdf