FACULTY OF ENGINEERING AND SUSTAINABLE DEVELOPMENT

Analytical system for photovoltaic and concentrating solar power generation

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2013.11.16

Bachelor's Thesis in Energy Systems
15 credits

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Abstract

Energy is the material foundation of human survival and development. Throughout human industrialization process, the fossil energy has made tremendous contributions in the progress of human civilization, economic and social development. For a long time, the development of human energy use patterns makes fossil fuels rapidly depleted and the consequences of environmental deterioration by this pattern lead to the severe challenge for mankind. Many countries start paying more attention to develop the new energy. The solar electricity production system is one of the main new energy power generations. The thesis is a guide of principle for solar power generation system. It focuses on comparisons between photovoltaic and concentrating solar power generations and analysis of their market prospects. The merits and demerits of these two systems will also be pointed out in this thesis.

Introduction

The traditional fossil energy will produce pollutions in the process of consumption. In addition, the unevenly distribution of energy will lead the imbalance of energy supply. Therefore, the rate of renewable energy developing and exploiting needs to be accelerated, especially the solar energy. The hydrogen atoms of the sun will produce energy by nuclear fusion, so that sun supplies enormous amounts of energy ($3 * 10^{24}$ J/year) to earth [1].The energy used in human life is indirectly derived from solar energy, such as coal, oil, natural gas. The plants absorb oxygen to conduct photosynthesis. In this way, plants convert light energy into chemical energy which can be directly used. Coal, oil, natural gas and other fossil fuels are buried in the ground. That is evolved after a long geological formation.

Solar energy regards as a new renewable energy, and it has high potential for development. The application of solar energy consists of solar thermal energy and solar photovoltaic (PV). Compared with conventional energy, PV is easy to maintenance and reliable. Photovoltaic cells need large number silicon which with a huge reserve underground. The disadvantage is that sunlight is not steady from season to season and changes as the climate. PV can convert sunlight to electricity directly, which called Photoelectric Effect [2]. Off-grid PV system means which PV system does not connect with public grid. It is necessary to have a battery to store the energy otherwise it will cost much. The main raw materials of photovoltaic cells are crystalline silicon. The price of crystalline silicon is high and the photoelectric conversion efficiency is low, so that photovoltaic electricity tariffs are much higher than normal [3]. It also restricts the development of large-scale photovoltaic power generation. In Present and future period of time, the development still relies on the solar photovoltaic financial subsidies from national and local.

For solar thermal power generation, this thesis focuses on the concentrating solar power (CSP). CSP technologies exist in three different forms, parabolic trough, dish Stirlings and solar power tower.

The world's first testing power plant of solar power tower is designed by the Soviet Union in 1950. There is respectively built 5MW and 6MW of experiments solar tower power plant in Russia and Ukraine [4]. Heat carrier played a role in heat transfer. The initially steam turbine is used to generate electricity. Solar energy is affected by climate, so it is difficult to control steam parameters and heat loss is significant. Heat salt is used to melt as carrier, which has good heat transfer and the cost is relatively

low. The dish Stirlings is the world's earliest solar power system and it is also the most efficient solar thermal power generation system. Power generation efficiency is about 29.4%, but the dish Stirlings system's capacity is relatively small [5]. The concentrator of trough relies on focusing collector to concentrate light.

Method

Wikipedia is used as a library to get important information from it. Different key words are used to find a fundamental knowledge about the solar energy then search the related content from books and scientific articles on http://www.sciencedirect.com. Various articles which related to this thesis are selected from ScienceDirect. Combinations of the information from these articles have been done. Thesis is written with the guild of reference.

Principle of photovoltaic system

Solar photovoltaic system's design consists of solar cell array design, solar battery design, controller choice and grid-connected PV system design. Capacity and hardware design is the way to optimize the efficiency of solar systems. Optimization of capacity is reflected in the choice of inclination of solar cell array. One of the best situations is to choose the area which the radiation is largest throughout the year. The other one is to choose the best angle when the radiation difference is relatively small between summer and winter. And also the efficiency for PV system is higher in low-latitude due to the strong sunshine. The hardware design is optimized for hardware research. Get the weather date from weather station such as solar radiation, radiation intensity, temperature the number of continuous cloudy days. Solar photovoltaic power generation system is made up of solar cell panel, storage cell, controller, inverter and alternating current-distribution.

The functions of all major components are explained as follows [6]:

- Solar cell panel: solar cell panel is the hard core of solar power generation system. Its functions are covert to electric energy from radiating capacity of the sun, to send the radiating capacity to store and to push forward the radiating capacity to load.

- Solar controller: controller can control the charging and discharging of storage cell. The storage cell plays its roles of overcharge protection, over discharge protection and automatic control and management system based on demands. In the place with a large range of temperature, the controller should have temperature compensation.

- Storage cell: generally, it is a lead acid cell. Its function is to convert the direct current to the chemical energy.

- Inverter**:** it converts the direct current to the alternating current. The solar cell and storage cell are the direct current power. When the load is alternating load, the inverter should be needed.

The basic thought of solar cell module design is to satisfy the demand of daily load in annual average. The individual solar cell cannot be used directly for power supply. Solar cell module is made up by several individual solar cells or several incised small cell piece weld. The solar cell module voltage production is based on certain amounts of series connection. When the terminal voltage of the solar cell module is equal to a suitable floating charge voltage of storage cell, the effect of charging is good [7].

If the amounts of solar cell module in series connection are fewer, the matrix cannot be charged because the series voltage is lower than the floating charge voltage of storage cell. If there are many amounts in series connection, the output voltage is higher than the floating charge voltage of storage cell and the current increment of storage cell cannot be shown obviously. The voltage of solar cell can be reduced by the increasing of temperature under the illumination. In order to adapt different temperature conditions, the solar cell module can be designed into different series connection groups [8].

In the actual design, the circuit is combined with parallel serial formation (series connection and parallel connection). Generally, the circuit in series connection can generate the power, but the simple series connection has its risk. If any cell is damaged and covered by the shadow, the whole solar cell will be out of function. The shadow issue needs to be considered in solar photovoltaic system. The photovoltaic cell power supply are depends on the sun illumination. In the process of generating electricity, it will become the shadow by the influence of buildings, trees and excrement of birds. In addition, with the increasing of working period of cell panel,

the aging and loss of photovoltaic cell are the factors that cannot be disregarded. These conditions cause the huge change of output characteristics of photovoltaic cell. So the efficiency of photovoltaic system is seriously decreased. In this regard, it is hard to become the arrangement mode of photovoltaic cell for simple series connection.

The energy storing device is the storage cell in solar photovoltaic generating system. In oxidation-reduction chemical reaction, the chemical energy can be converted to the electricity energy and the electrical energy can be converted to the chemical energy by storage cell. The energy can be saved in the storage cell as well. Currently, there are four storage cells in solar photovoltaic generating system: VRLA, ordinary plumbic acid storage cell, colloid storage cell and alkalinity nickel cadmium storage cell. It is vital to design a suitable accumulator capacity for continuous power supply of photovoltaic generating system. The power demand is different in each period of the year. When the generated capacity exceeds the quantity demanded, the redundant electric quantity should be saved in the storage cell. When the demand of generating energy is insufficient, it should be supplied by the saved power in the storage cell. The capacity of storage cell is decided by several factors: single working days of storage cell and daily discharge capacity of storage cell. The electric storage should have enough capacity to prevent the water loss of cell [9].

Photovoltaic cell depends on solar irradiance to generate the electricity. In the electricity generation, the photovoltaic cell is affected by buildings, trees and feces of birds become the shadow. With the increasing of years for using cell panel, the burn-in and damage of photovoltaic are assignable. These circumstances mentioned above give rise to the huge change of output characteristics of photovoltaic cell, so as to seriously reduce the efficiency for photovoltaic system. Hence, to research the output characteristic of photovoltaic cell panel in the function of shadow has an important significance of researching on the maximum power point search algorithm and improving the efficiency of photovoltaic system [10].

Principle of concentrating solar power

The tower solar power system includes heliostats, receivers, working fluid heaters, heat storage systems and steam turbine. The system will track the sun through controlling the collection device, and then it will focus reflected sunlight into the central heat absorber. The heat transfer medium will heat up, after that it will apply to

the evaporator to generate steam to drive a turbine to generate electricity. In order to ensure the continued energy supply, regenerative device can store up heat during peak periods.

Heliostat mirror is one kind of focusing reflector which mounted on a metal structure. It can automatically track the sun. The control system adjusts the position according to the sun move. The mirror is generally flat of the concave mirror with a slight curvature. As the winter sun angle is relatively large, so the mirror requires relatively high accuracy. Efficiency of heliostat depends on the sun tracking accuracy. Heliostat is one of the key technologies of solar thermal energy and it is also a major investment component of the power plant. The heat collecting system is composed of a heat collector and receiving tower. The collector is the equipment to convert light into heat. If the shape classification, tower divided into a planar shape, point, line and the cavity type. The cavity - type collector has characteristics that large collector surface and less heat loss. Currently, most of the world's solar thermal power towers are using this shape. Another part of a tower thermal power system is receiver tower. Receive tower erected in the mirror field stations. The design capacity of the plant is greater, the tower should be higher. Solar received is greatly influenced by the weather. When the sun is obscured, the heat storage system will use the saved heat to maintain normal operation. The solar tower power system has high-temperature and low-temperature heat storage devices. The choice of storage material is quite important, such as the water vapor which is relatively clean, and non-toxic.

The heat assembling/collection system is the core of trough solar power system. Solar energy is converted into heat energy then stored in the heat-transfer medium. Condenser generally composed by reflectors or lenses. According to optics principle, the light parallel to the axis of parabolic will gather in a line. Reflector made from glass, the outside is the protective layer and a black absorbing coating. Outside of collector tube is glass casing with vacuum. The casing is in favor of the energy storage to be vacuumed. Heat exchange system is formed by the preheater, steam generator, super heater. These devices provide heat for the turbine. The turbine is able to transfer heat to electricity. Auxiliary systems are usually constituted by the heater. When the storage is insufficient, it can replace the work of the solar collector field.

The dish solar concentrator system employs a point focusing collectors. The condenser and the tracking control system are the most important part in the dish solar system. The diameter of the parabolic mirror dish is generally 10-20m. The system

chosen is a point mirror reflector. Reflective surface adopts tempered glass plastic. The size of collection mirror of Disc-type power generation system depends on the power output of the maximum degree of sunlight, the efficiency of the Stirling engine and the efficiency of collection mirror. The ideal shape of the collection mirror is parabolic. The incident sunlight can be gathered in a small area. The tracking system is divided into two kinds. One is the photoelectric tracking, the other one is the apparent motion trajectory tracking mode. Light control transfers the solar radiation intensity signal on the different location of photoelectric sensor to digital signal. The processor receives the signal will judge them control the receiver angle. The light control system structure is relatively simple, but it does not automatically work when the sunshine is sufficient [11].

Solar thermal power can be thermodynamic analysis. Brayton cycle is a common one. Brayton cycle is a constant pressure heating cycle. The working fluid is compressed in the compressor then enters the combustion chamber (process1-2). Its absorbing fuel afterwards release heat (process2-3), this process is endothermic with constant pressure. After entering the gas turbine, heat transfer to work (process3-4). Finally the exhaust gas will be excluded to atmosphere for cooling. However, solar thermal power generation, the heat does not come from the combustion chamber, the receiver will absorb the sun's radiation heat [12].

Circulating heat absorption:

$q_1 = q_{23} = h_3 - h_2 = C_p(T_3 - T_2)$

Exotherm of circulation:

$q_2 = q_{41} = h_4 - h_1 = C_p(T_4 - T_1)$

C_p is Specific heat capacity, h is Enthalpy, q is heat and T is temperature.

Brayton cycle efficiency is $\eta_{t,B}$

$$\eta_{t,B} = 1 - \frac{q_2}{q_1} = 1 - \frac{C_P(T_4 - T_1)}{C_P(T_3 - T_2)} = 1 - \frac{(T_4 - T_1)}{(T_3 - T_2)}$$

The actual efficiency of Brayton cycle is different from the ideal situation. Compression and expansion process is irreversible. Fluid and wall friction is not negligible, because the working fluid flow rate is quickly on the machine. Friction loss is usually displayed by relative internal efficiency.

η_T=The work of real expansion/ the work for idea expansion=$\frac{W'_T}{W_T}$

η_T is relative internal efficiency[11].

General comparison of photovoltaic systems (PV) and concentrating solar power (CSP)

Solar thermal power generation is typically used to concentrate generate electricity (except dish-type). Its economy is also mainly reflected in large-scale centralized power generation. The PV can be used for both large-scale development as well as home-based distributed generation. Actually the photoelectric conversion of PV can be showed in a small module which has a independence function. The power is generated by cell modules superpose in a way like series and parallel and it is relatively simple to install and maintain. Photovoltaic technology can also use at low solar radiation areas. PV system can adapt to a land no matter how the shape looks like. However, solar thermal has a high demand for slope, flatness demanding of land [10].

But there are also some aspects that solar thermal system is better than PV system. The solar thermal system avoids costly silicon photoelectric conversion process that can reduce the cost of solar power generation. The water burned by solar energy can be stored in a huge container and the system is able to use molten salt technology to storage heat. During the day it changes the form of salt from solid to liquid and uses more than 400 degrees molten salt heat it up to steam for power generation at night. This method should not consider the problem of peaking regulation which cannot be solved by PV [11].

Location choice

Solar radiation composed by the direct and diffuse radiation. It is an important indicator for the reflection degree of a region rich in solar energy resources. Solar radiation can be effected by geographic latitude, sunshine hours, elevation height and atmospheric composition and other factors. Under normal circumstances, the total amount of radiation decreases with increasing latitude. But there are special circumstances, the cloud and high-latitude regions have relatively small amount of total solar radiation. As the altitude increases, atmospheric transparency increases. The main solar cell using the visible light region, that means weakened by energy becomes smaller, and thus increases the total radiant energy. Equivalent local solar

time is a measure of a value of the size of the available solar energy indicators. When the equivalent is higher, the value of the local solar energy available is greater. The distance that power from other electrical substations and city center closer is much better, that can reduce the amount of energy in the transport process consumption. The solar photovoltaic power plant requires a large area of cheap land, such as the Gobi desert, semi-fixed, saline, etc. Arable land, grassland and other land-use-value areas should not be developed.

PV power plant need to be built on flat, open area and not around tall buildings, trees, utility poles, etc. If a PV module with a partially shadow by an object, the shad cell will be different from the non-shaded cells. In the cell string, the shaded cell reduces the current which through the normal cell, it is often leading to normal cells produce higher voltage. So the shadow battery reverses bias operation. If a single solar cell is completely in the shadow effect, the output power is reduced by 30% [8]. The measures of shadow need to use a measurement tool which called Solar Pathfinder. Its dome can display all year round shelter sources. Solar site assessors will be able to determine the amount of occlusion. The resulting data can be used to estimate the amount of power array. Take Lexington, Kentucky City as an example, PV watts calculated 5KW array generated electrical energy show in Table 1 [9].

Table1. 5KW array generated electrical energy in Lexington, Kentucky City [9].

moth	Solar radiation/ $(\mathrm{kw \cdot h/m^2/days})$	AC energy/$(\mathrm{kw \cdot h})$	Energy value/dollars
1	3.23	397	24.22
2	3.85	420	25.62
3	4.38	516	31.48
4	5.28	578	35.26
5	5.48	603	36.78
6	5.84	599	36.54
7	5.51	586	35.75
8	5.40	575	35.08

9	4.94	521	31.78
10	4.61	513	31.29
11	3.36	376	22.94
12	2.58	307	18.73
year	4.54	5991	365.45

The following changes in the case with shadow. Its Solar Pathfinder test case which in the shadow of the actual generating capacity.

Table2. 5KW array generated electrical energy with shadow [9].

Moth	Solar radiation/ $(kw \cdot h/m^2/days)$	AC /$(kw \cdot h)$ Without shadow	With shadow
1	3.23	397	326
2	3.85	420	378
3	4.38	516	464
4	5.28	578	549
5	5.48	603	603
6	5.84	599	599
7	5.51	586	586
8	5.40	575	575
9	4.94	521	521
10	4.61	513	487
11	3.36	376	338
12	2.58	307	276
year	4.54	5991	5632

In view of this, in order to meet the energy requirements, the array needs to be increased. To achieve optimal performance, from 9:00 to 15:00, the window portion of solar radiation should occupy 75% -80% solar radiations throughout the day [9].

Table 1 and Table 2 can be shown in figure, and it will be easily to compare the AC energy in different month.

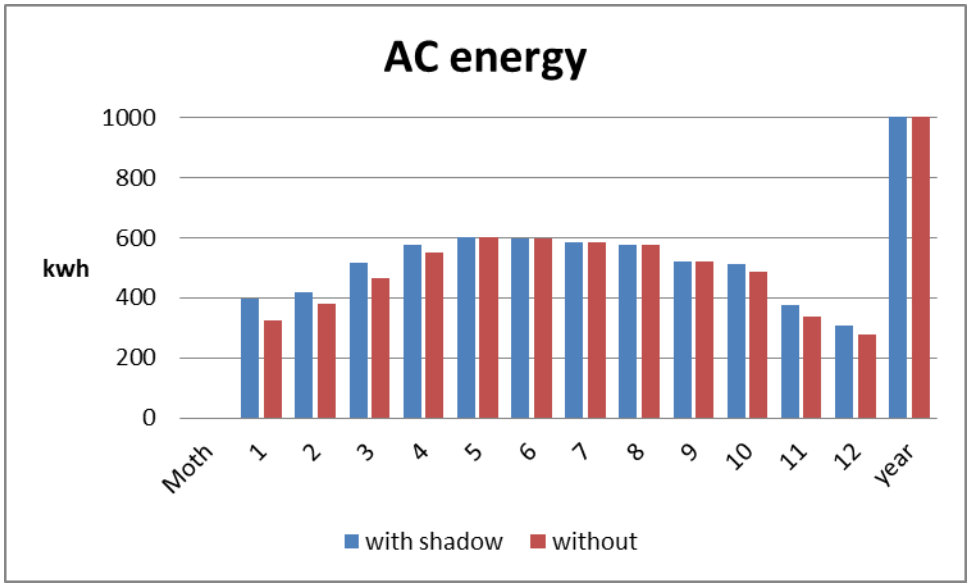

Figure 1. The data compares of those two kinds of situation.

As can be seen from the figure, the amount of electricity production is the same in month 5, 6,7,8,9. In those few months while the sun's radiant energy is relatively strong, the shadow shielding rate is smaller. Therefore, it should be avoided tall buildings, trees, poles and other shelters in around the plant. If there is bird activity, it should set devices to driven birds out. Need to keep the ground clean and avoid being blown debris on the ground solar panels.

The CSP can only use Direct Normal Isolation (DNI) from the sun. DNI is the most criterion factor in location choice. CSP need very flat ground. The trough power plant requires ground slope that cannot be more than 1 degree and CSP plant requires is less stringent. Ground slope which greater than 3 degree is not suitable for CSP. Theoretically, the power generation potential of an area can be predicted. DNI (per day) values need to be simplified to deal with [11].

Table3. The date simplified table.

Value $(\mathrm{kw}\cdot\mathrm{h})/m^2$per day	<5	5-6	6-7	7-8	8-9	>9
Simplified value	0	5.5	6.5	7.5	8.5	9

The slope also needs to be simplified. If the slope of the ground is less than 3 is considered to be one hundred percent can be used for CSP, if it more than 3 degree, it will regarded as completely unavailable. The efficiency of the power plant should be considered as a condition. It all depends on the type of the plant. For example, trough solar power plant's efficiency is about 15%. The followings are two formulas for predicting regional power generation potential.

Annual generation capacity = Effective area × DNI × Power plant generation efficiency × Condenser of the total area ratio.

Power generation potential = Local effective area × the ratio of plant capacity and Area [11]

Through this way, it could predict the CSP'S potential for China, Spain and USA. Following are the data after calculation:

Table4. The energy production estimated in available area [11].

	GW	TW h/ year	The power which DNI larger than 7k (GW)
China	16,000	42,000	1,400
USA	15,000	40,000	1,300
Spain	720	1,900	0,7

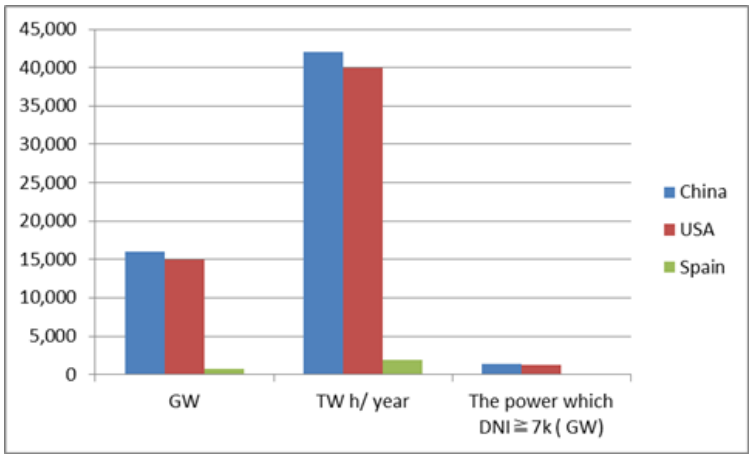

Figure 2. The development compares for three countries.

This can be seen that China and the United States can take advantage of a large amount of geographical resources, which the future CSP development has played a decisive role.

Use the land as the standard of comparison, the calculation result is: Twelve 5MW-500MW CSP power plants of California project assessment calculations, the average output power of the land is 39.47MW/km^2 .Five units of photovoltaic power plants in California, the average power output of the land is 32.53MW/km^2. This means that in solar thermal power stations, the average utilization rate of land is relatively high [11].

However, PV and CSP cannot be compared directly to the question of the potential of land resources. As mentioned before, each of the geographical conditions has different requirements.

Business competition

PV and CSP, both are important ways to solve the future's energy problem. The characteristics of each option can complement each other and reach common development. However, in a commercial point of view, both using the same natural resource - sun. Therefore, there is commercial competition between the two.

From the commercial point of view, the global PV industries have showed explosive growth in recent years. From 2002 to 2008, the world production of photovoltaic cells doubles every two years. Photovoltaic cells average annual growth rate is 48%. While the credit crunch leads to a negative impact on the PV industry financing in 2009, but PV installed capacity is still growing by 44% [9]. CSP investment costs need to be controlled to achieve greater development. American Sunlab institutions estimated the cost of CSP power production. The cost of electricity is 10.0-12.6 cents / (kWh) in 2004, it will reduce to 3.5-6.2cents / (kW h) in 2020. So those shows the PV and CSP also have good market prospects [11].

Solar photovoltaic power generation system consists of photovoltaic cells, controllers, inverters and batteries and other components. Therefore, the cost of photovoltaic power generation system consists of the following components:

The initial investment: PV array, controller and inverter, battery, support systems and power distribution systems (including installation and commissioning, cable and other expenses), other costs (transportation costs and other miscellaneous expenses, etc.);

Running costs: maintenance cleaning fees, management fees, labor wages.

The cost of solar photovoltaic systems consists of the initial investment and running costs. The solar PV system operation is relatively simple, relatively low operating costs. The one of the major costs is photovoltaic cells; its price is more expensive [14]. The photovoltaic cell assembly plant, the output power value is usually given in standard test conditions. The practical application of the photovoltaic cell power output is changing, those related to radiation on the surface of PV cell arrays. Solar radiation is changing with the use of location, season, time of day and weather conditions and other factors. As the cost of diversity, reduce the cost of photovoltaic cells should be regarded as a key target [10]. In Fig 3, there is a cell price comparison between US and EU.

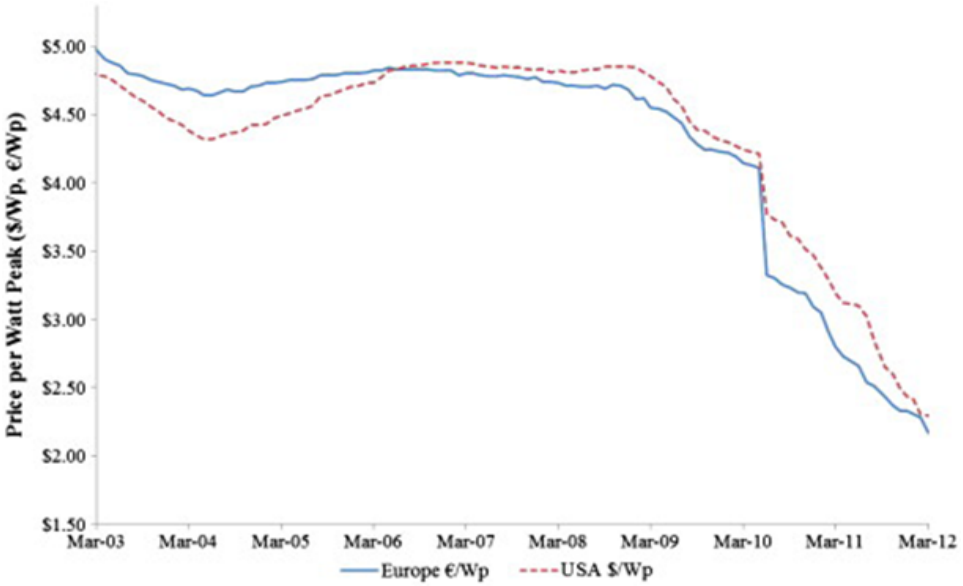

Figure 3. Presents an average retail prices in Europe and the US [13].

The price in Fig 3 includes a variety of solar cells which comprises a different type of technology, different manufacturers and different States of the cell. Such as China, the average price of a solar cell is much lower in other countries. In 2000, the emergence of thin-film photovoltaic technology is driven the development of PV market. Higher production capacity so that it effectively achieve a lower cost. Thin-film modules with an average cost of $ 2.75 / WP in 2005 reduced to $ 1.35 / WP in 2010. In recent

years, with the join of China and Taiwan decreasing the cost of photovoltaic cells, this also led to price adjustments in Europe and the United States [13].

According to the International Energy Agency IEA latest release of the renewable energy market trends and forecasts that by 2017 the PV industry will show strong growth. Installed capacity will reach 230GW in 2017. As the International Energy Agency is expected, with installed capacity rising, photovoltaic annual generating capacity will reach 35TWh. In all photovoltaic solar technologies, photovoltaic expected growth will be fastest [13].

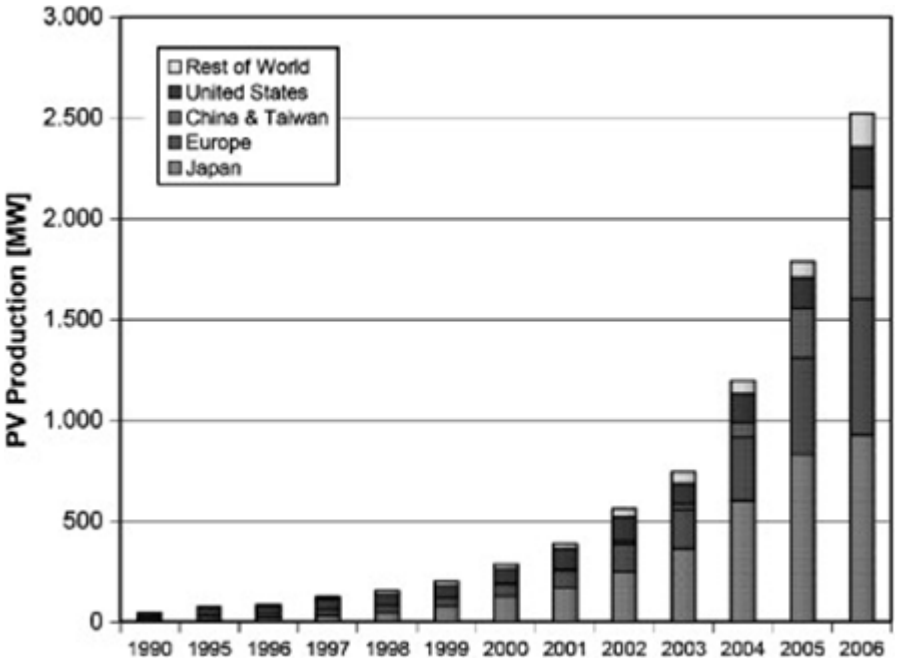

Figure 4. Cumulative installed capacity of PV systems [14].

It can be seen from the figure, from 1990 to 2006 years, although the installed capacity in China is not increase too much, but the fastest growth, which benefited from the government's strong support for the photovoltaic industry.

The International Energy Agency IEA claims that the main driving force of growth will come from the Chinese market. In 2017, PV installed capacity in China is expected to reach 32GW. The United States which may be 21GW of installed capacity ranks second, followed by Germany, Japan, installed capacity of 20GW, Italy was 11GW. However, IEA indicates that in view of the rise and fall of many countries in the past period, the intensity of policy support will be able to achieve the expected level of installed capacity is the crux. Therefore, it is a very complex issue to determine the actual annual photovoltaic power generation [14].

Currently trough and tower power generation is expensive than electricity produced by Fossil fuel. On the one hand it needs government policy support, but on the other hand it needs to reduce to achieve market competitiveness. Sargent & Lundy Company's (S & L) studies show that 100MW trough solar power plant after 12 hours heat storage, the direct cost structure as shown below.

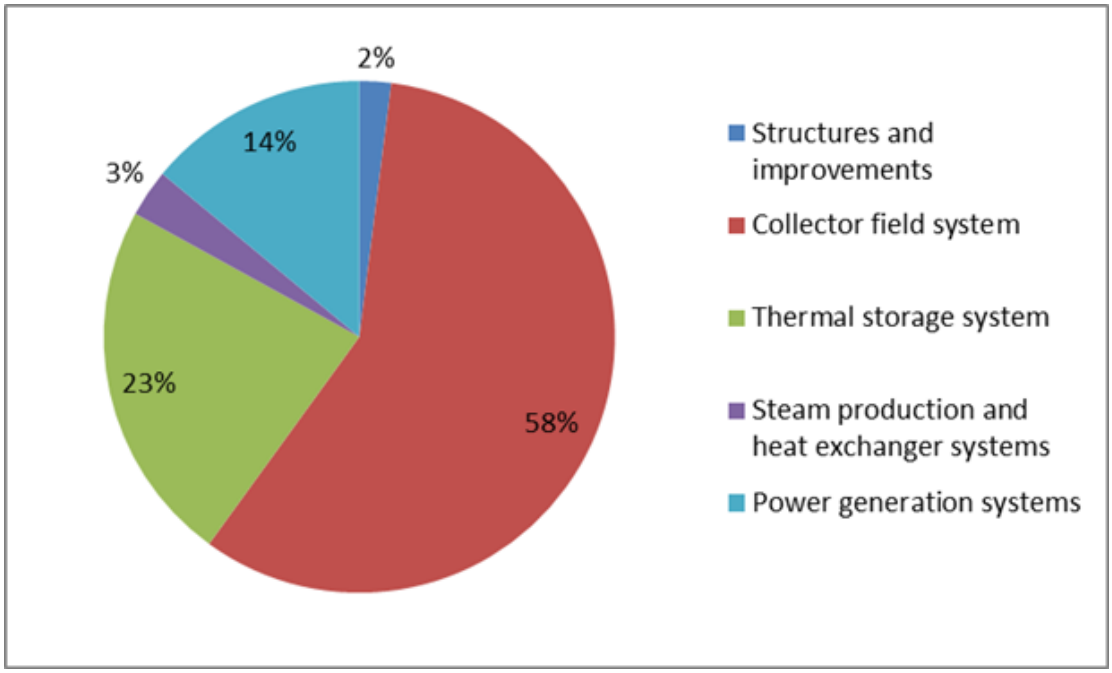

Figure 5. The share of the cost for each part [11]

The collector field generating system possesses a large proportion of the total cost. By changing in technology, the collector field can decrease costs. The cost of the collector field composed of the following aspects:

1. Collector support structure: Support structure is made from metal framework. Maximum wind speed at the wind loads determines its strength. To optimize the design wind speed tests can provide data for optimized design and mass reduce.

2. Mirror of collector field: In the long run, mirrors alternative technologies are essential. But now thick glass is still the first choice of large-scale trough power plants. Large-scale production and competition is conducive to the development of technology.

3. The cost of power generation system items includes turbine, generator, water supply and condensing system.

The production of electricity and installed capacity are two factors which reflect production capacity and market occupancy. Fig 6,7and 8 is related to power production and installed capacity.

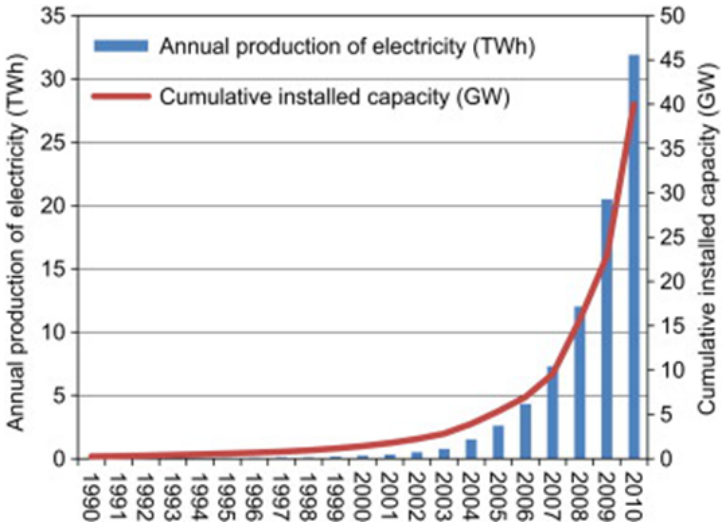

Figure 6. PV global cumulative installed capacity (GW) and annual electricity production (TW h) from 1990 to 2010 [14]

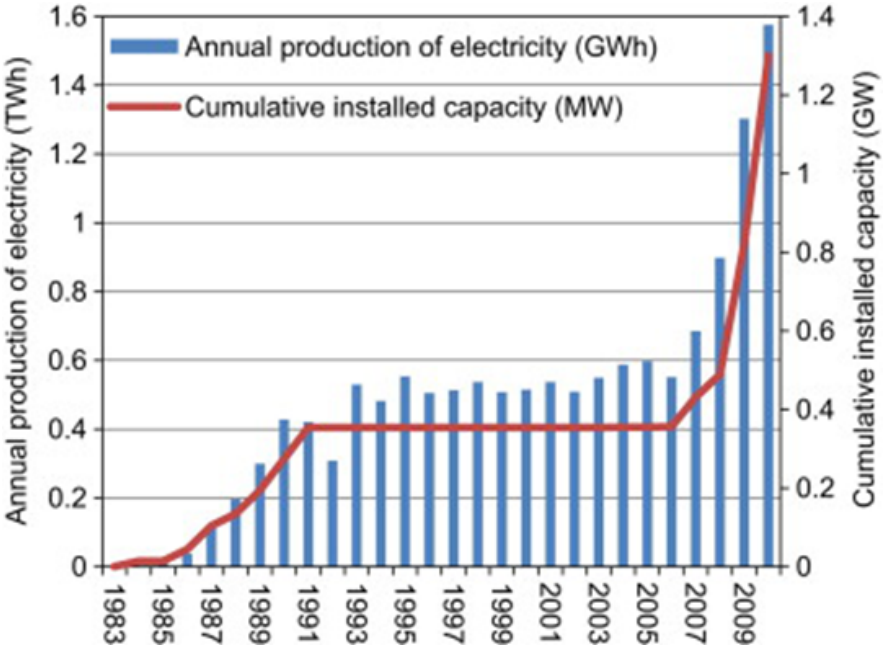

Figure 7. CSP global cumulative installed capacity (GW) and annual electricity production (TW h) from 1983 to 2010 [14]

In a very long time since CSP technology immaturity lead to the closure of a number of companies, such as LUZ Company but after that the study of CSP keeps going. As can be seen from the figure 6 and 7, the number of installed and generating capacity, PV is much larger than the CSP.

There is a comparison about cumulative installed capacity between PV and CSP system.

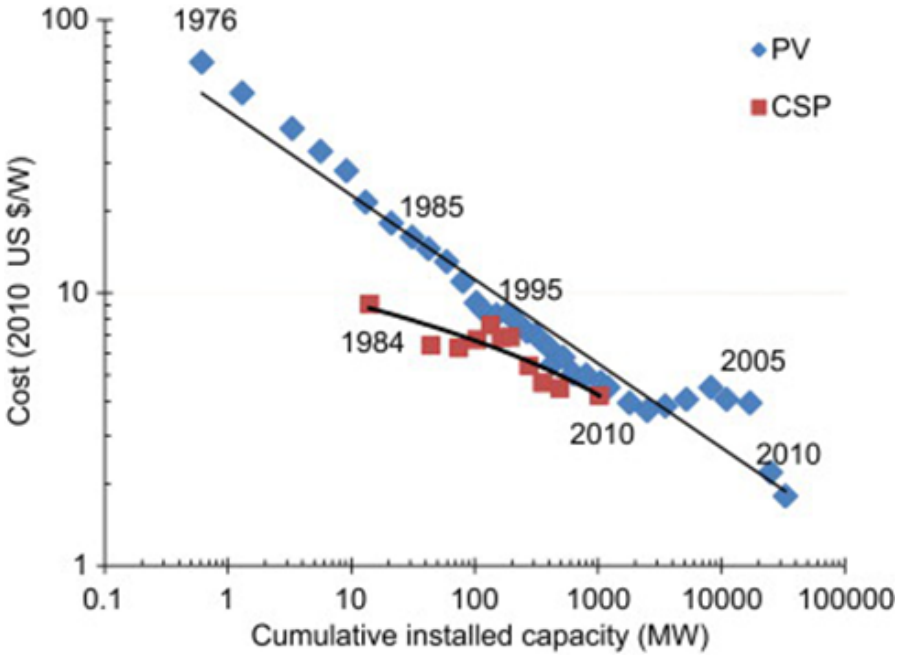

Figure 8. PV modules between 1976 and 2010, CSP systems between 1984 and 2010 [14]

A comparison can be drawn, photovoltaic cost lower than CSP. This does not mean that the PV system is cheaper than CSP system, but from the foregoing data, the prospects for the development of photovoltaic may be better.

Conclusion

The solar energy system is a new renewable energy. Its system is installed flexibly and conveniently. It is suitable for individual distributed installation and utilization, so it has broad market application prospects. In this dissertation, the research object is a solar energy system and the key issues of system is analyzed and researched. The main research work is as follows:

1. The application of Solar photovoltaic is wider than CSP, which can be used for large scale power generation and small household electricity as well. In china, PV has been extensively used for Solar Home Systems in rural area. Through this, this solves the lack of regional grid.

2. For the average output power of the land, CPS is more than PV system. On the other hand, CPS has higher demand about the land, so the land utilization of CSP is less.

3. PV installed capacity is larger and its price is cheaper.

Specific situations should be considered in accordance with the actual status, this thesis is theoretical analysis.

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