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APEC Photovoltaic System Best Practice and Latest Development Comparative Study

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APEC Photovoltaic System Best Practices and Latest Development Comparative Study (PV-BPLD)

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The APEC region is the region where PV manufacturing, application and investment develops at the fastest pace.

	TOP 10 COUNTRIES IN 2014 FOR ANNUAL INSTALLED CAPACITY		TOP 10 COUNTRIES IN 2014 FOR CUMULATIVE INSTALLED CAPACITY	
1st	China	10,6 GW	Germany	38,2 GW
2nd	Japan	9,7 GW	China	28,1 GW
3rd	USA	6,2 GW	Japan	23,3 GW
4th	UK	2,3 GW	Italy	18,5 GW
5th	Germany	1,9 GW	USA	18,3 GW
6th	France	0,9 GW	France	5,7 GW
7th	Australia	0,9 GW	Spain	5,4 GW
8th	Korea	0,9 GW	UK	5,1 GW
9th	South Africa	0,8 GW	Australia	4,1 GW
10th	India	0,6 GW	Belgium	3,1 GW

NUMBERS HAVE BEEN ROUNDED

Source: IEA PVPS

Fig. 1-1 The statistical table of global PV installation in 2014

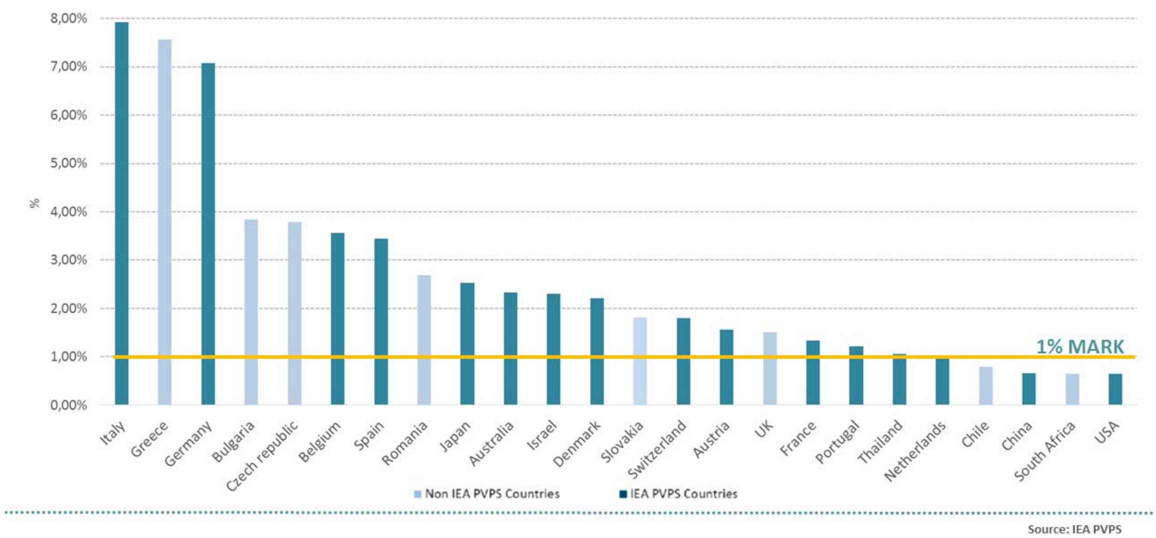

Fig. 1-2 The PV share of each economy in 2014

The APEC economies have been making constant innovations in the building of PV stations (including the installation site and method). The applications include the large-scale ground PV station projects, industry & commercial rooftop power stations, rooftop power station projects for residential use, PV agricultural greenhouse and off-grid PV system.

1.1 Large-scale ground PV station projects

Large-scale ground PV station projects can be developed in regions with ample solar energy and land resources. Its key pros and cons are as follows:

Tab. 1-1 Pros and cons of large-scale ground PV stations

Pros	Cons
Instead of supplying power directly to users, it transmits the power to high-voltage grid, which avoids potential damages to household appliances and grid facilities in cases of blackout.	Low local demand makes it hard to consume all the power from the large-scale development locally, which requires long-distance transmission to the outside.
The scale management helps to cut costs on equipment procurement.	Long-distance transmission drives up the investment in power transmission & transformation and leads to high transformation and line losses.
The concentrated supply of stable and quality power allows regular yet uninterrupted transmission; little impact on the grid due to the high quality of on-grid power and mild connection.	Complicated application process creates certain expenses.
It only needs to coordinate with one power dispatch due to the contract signed with the grid	It requires large area, yet the efficiency of space utilization is low.
Standardized management and in-time maintenance ensures the high efficiency of equipment and avoids losses by ruling out potential risks	
Large scale and professionalization helps accumulate talents, cultivate new technologies, revolutionize management and renovate equipment.	

Fig. 1-3 Figuretures of large ground PV stations

Aside from the flat land, the large ground PV stations could also be built on the slopes.

By spreading out PV panels and building PV stations on the barren land, it helps save energies and acquires income from on-grid power generation. Moreover, the PV panels protect the plants on the wasteland by shading the sunlight. Meanwhile, the project should also create jobs for local residents and promote the development of slopes into tourist site, which brings extra revenue for local tourism. As a clean and efficient project that helps improve the living standard of local people, it creates both social and economic benefits.

Fig. 1-4 Figure of PV stations on slopes

1.2 Industrial & commercial PV station project

Unlike the ground PV stations, the industrial & commercial station project in normally built on the rooftops that are in good conditions. It saves land resources and is close to users, thus making it convenient for user and avoiding line losses.

Compared with the PV stations set up on the pitched roof, those on the flat roofs are the most economically efficient, as: 1) it could be installed at the perfect angle, thus acquiring the largest power generation; 2) it adopts the standard PV modules and has the best performances; 3) it does not interfere with the building functions and; 4) its cost on PV power generation is low. Therefore, it is the best choice in terms of economic efficiency.

Among the pitched roofs, those facing the south enjoy better economic efficiency, as: 1) the installation at the perfect or almost perfect angle helps acquire largest or larger power generation; 2) the application of standard PV modules improves performances and cuts costs; 3) it has no conflicts with the building functions and; 4) its power generation cost is the lowest or lower.

The pros and cons of industrial & commercial rooftop stations are as follows:

Tab. 1-2 Pros and cons of the industrial & commercial rooftop PV station

Pros	Cons
Dependent stations can avoid large-scale blackout due to users' self-control, which is safer and more reliable.	Small scale and dispersed distribution.
It is more stable than large grid and can continue power supply in times of unexpected accidents, which has become an indispensable supplement to the concentrated power supply.	The dispersed distribution makes it hard for unified management and timely maintenance, leading to low efficiency and short life span of equipment.
It is subject to little power transmission & distribution (PTD) loss, needs no power distribution stations (low cost) and has low construction & installation cost.	The appearance of multiple power sources in the same region will create uncontrollable factors in the renovation and maintenance of electric system, thus adding potential risks.
It has excellent peak-load performance and is easy to operate as the number of systems involved is small, which makes the full automation possible.	Its power supply is irregular due to the nighttime and rainy days, which also affects the relay protection equipment. There still exist a lot of technical problems to be addressed.

Fig. 1-5 Industrial & commercial rooftop PV station projects

1.3 Rooftop PV projects for residential use

Residential rooftop projects have seen robust growth and dominated PV installation in developed APEC entities (such as America, Japan and Australia), where the power tariff for residential use is high and the social credit system is well-established.

Tab. 1-3 Pros and cons of residential rooftop PV stations

Pros	Cons
Considering the serious air pollutions at the current stage, PV power generation is environmentally friendly and the installation of residential PV stations will help residents make his/her own contribution to the environmental protection.	It is unlikely to be popularized in the near run due to its high initial investment and households' limited affordability.
The one-off investment in PV stations will support power supply for 25 years, during which no noise and pollution is created and no fuels consumed.	The equipment perfectness of household system cannot be guaranteed due to residents' lack of maintenance knowledge, which leads to low capacity efficiency and short life span of equipment.

Pros	Cons
When power rationing occurs during peak times in summer, the PV micro-grid system (off/on-grid coincidence system) will automatically trigger the off-grid electrical storage device, which should support the rigid power demand for lighting, refrigerator, electric fan and fish tank air pump.	PV system has potential safety risks due to lack of maintenance experience.
The large-scale pavement of PV module batteries on the rooftops will effectively lower the indoor temperature by 2~3℃ and indirectly reduce the power consumption of refrigerators.	The technical breakdown might not be resolved in time as residents have little basic technical knowledge and need help from professionals.

Fig. 1-6 Residential rooftop PV station project

1.4 PV hoop house project

PV hoop house is a new PV system project that combines with agricultural production: the roof generates solar power while the inside is for agricultural production. By building a hoop house PV project, it generates power with clean energy and is then connected to the grid. As the environmental protection and health gradually caught people's attention, the PV agriculture is bound to play a significant role in future's PV application market.

Tab. 1-4 Pros and cons of PV application to agriculture

Pros	Cons
The utilization of hoop house roof could help save land resources and make no changes to the land use.	High construction cost
It enhances the land's comprehensive ratio by realizing the efficient utilization of sunshine and land resources.	The conflict between light transmittance and power generation efficiency.
It addresses the power supply for lighting, ventilation and heating inside the greenhouse, which benefits both PV and agricultural products.	Low land use ratio due to sunlight angle and structure.
By setting up solar batteries with different light transmittance on the hoop houses, it meets the light demand of different crops (including high value added corps like organic agricultural products and rare seedlings).	
It creates new jobs and helps improve farmers' working environment and income.	

Fig. 1-7 PV agricultural greenhouse

In addition to the PV hoof houses, there is another PV application – PV fishery. The upper layer is for the PV power generation and the lower layer aquaculture. PV modules are set above the water or along the coast of fish ponds, which saves land and enhances the economic value of unit area land; moreover, it brings social & economic benefits and is environmentally friendly as it exerts no impact on the aquaculture.

Fig. 1-8 PV fishery

1.5 Off-grid PV system

Affected by the uneven distribution of energy and unbalanced economic development, nearly 20% of people around the world are still living without power supply. The off-grid PV system could generate and store PV power when the grid system is not available, which addresses the power needs in remote regions.

Tab. 1-5 Pros and cons of off-grid PV system

Pros	Cons
Effective solution to power supply in remote area; ;wide application to remote mountainous area, regions without electricity, communication base stations and road lamps.	High unit investment.
Its flexibility is convenient for nomadic nations with no fixed residences.	High cost of battery replacement; need of regular maintenance.
	Low operating efficiency.

Fig. 1-9 Off-grid PV system

1.6 Other construction types

1.6.1 PV+ transport

1) Combination with expressways

There are lots of segregated spaces and power demand (road lamp, tunnel fan, guideboard and emergency phone) along the expressways. As the establishment of an independent transmission network might not be economically efficient, the PV power generation turns out to be an effective answer.

Tab. 1-6 Pros and cons of the application of PV power to the expressways

Pros	Cons
Innovative development and compound use of expressway spaces and the supporting regions.	Impact on the generating efficiency
Preventative maintenance on the expressways should help reduce maintenance cost and avoid road accidents caused by road degradation.	Need of storage batteries.
The PV station can serve as a shield for expressways, thus avoiding drivers' dizziness caused by hard light exposure.	Scattered distribution of PV equipment makes it hard for maintenance.
The nearby charging on the expressways meets the electrical load demand of the remote area along the roadside, which saves the cost on the grid building and provides energy needs of long-distance transport.	

2) Roads installed with solar panels

The technology integrates the solar panels with the roads and provides electricity to urban public utilities, companies and households with the collected solar power. The roads are also integrated with light-emitting diode (LED), which could be used for lighting and heating (no need for salt to melt the snow). This technology has been tested in some American towns and is expected to put into actual use in 2016.

Fig. 1-10 PV expressway

3) Solar power high-speed railway(HSR) tunnel project

The railway operator (Infrabel) and developer (Enfinity) in Belgium jointly developed the 3.3MW solar power HSR tunnel project. The ~3.4km-long tunnel is located in Antwerp, which links the two important European cities of Paris and Amsterdam. It is a perfect example of the combination of solar power generation and modern railway transport. The coverage area of modules totals 50,000sqm, the size of 8 football pitches. The power generated by the PV modules is mainly used for the station signals, the railway infrastructure (lighting and heating) as well as the HSRs passing through the tunnel.

Fig. 1-11 PV railway tunnel

1.6.2 PV + sports facilities

Sports facilities like stadium usually take up a large area and requires high electric load, which makes the installation of PV station a possible choice.

Tab. 1-7 Pros and cons of the application of PV to sports facilities

Pros	Cons
Building Integrated Photovoltaics (BIPV) integrates the PV station with building, which builds a shelter from sunlight and rainwater.	Power consumption varies from time to time, especially when there is no game.
Rational use of the rooftops of public place.	
The installation of PV stations on the stadiums, a place frequently visited by the public, should help popularize the PV power.	
Green building.	

The 100KW on-grid PV project of China's National Stadium has a total installed capacity/area of 102.5KW and 1000sqm. In addition to the 1100 units of regular PV modules above the day-lighting bands on the roofs, the double glass PV modules were applied to the glass curtain wall on the south elevation for the first time in the OlymFigures history. The solar batteries on the upper side of the roof light and the south elevation of glass curtain wall protect the building from sunlight and rain and generate 212kWh power/day, supporting the lighting of a 20,000sqm underground garage (~500 parking stalls).

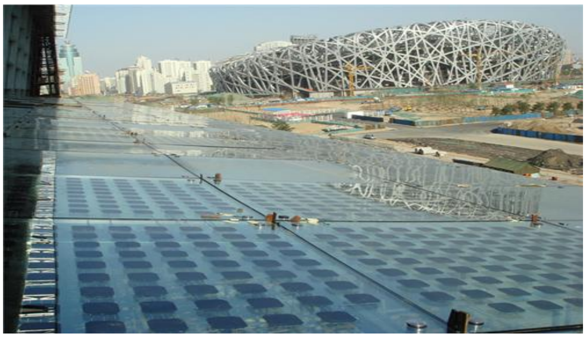

Fig. 1-12 National Stadium's PV station

The Longteng Stadium in Kaohsiung is the world's first stadium whose power is solely provided by solar energy. With 8844 units of PV modules installed on the roof, it shades 70% of lights and provides the power for lighting and air conditioners. The extra electricity could also be sold to power company when there is no sports game.

Fig. 1-13 Kaohsiung PV stadium

1.6.3 Technological Risks

Combining photo voltaic packages and carport's roofs can save cost than adding packages on the roofs. As such, this method can not just realize all functions of traditional carports but also produce profits for owners by generating electricity when beautifying the environment.

Fig. 1-14 Photovoltaic carports and charge piles

Electric Vehicle Autonomous Renewable Charger has been launched in the USA.

EnvisionSolar has developed the first “Electric Vehicle Autonomous Renewable Charger”. The size of EVARC is perfectly fit for the size of a parking space. With solar of 2.5KW or 3.3KW, this independent system is equipped with storage of 21.6KW. ENVARC is composed of one quick charger or two normal chargers that are capable of charging one typical EV when its owner is at dinner or in a meeting. Furthermore, they can charge 25% more for a small-sized EV which is suitable for urban district driving.

Fig. 1-15 Electric Vehicle Autonomous Renewable Charge

1.6.4 Photovoltaic electric car

The influence on car industry brought by the development of new energy technology has formed two concepts: one is develop and produce car of new energy to be marketized; the other is to supply photovoltaic electricity for the production of traditional cars. Both of two concepts are intended to reduce energy cost and emissions and to conserve environment.

Thin-film electricity generating technology, being flexible, light, dystophotic, and shapable, is fit for car of new energy. A 6m2 flexible thin-film solar battery of gallium arsenid, when integrated in a car and under average 4 hours of sunshine per day, is capable of driving a car of one ton to cover a 80 to 100 mile journey.

Fig. 1-16 Photovoltaic electric car

1.6.5 Floating photovoltaic power station

The development of floating photovoltaic power station can not only loosen the land's bound and expand the application of photovoltaic electricity generation, but also increase generating capacity and protect water resources. However, it may take a while to develop this technology in various fields and in a large scale since the reliability of packages in humid condition and the bearing capacity and longevity of the floating platform needs to be verified.

Japan applies the most floating photovoltaic power station in the world. In accordance with the statistics by the end of 2014, Japan has 2.824MW connected grid and will have 15 MW connected grid in 2015. In the early 2016, there will be another 15 MW connected grid.

In June 2013 in Saitama, Japan, a 1.18 MW project named "Okegawa Water Solar Energy", invested by Japan Western Holding Group, was established and put into operation in an impotable water reservoir of 30,000 m2 in Okegawa. This project's raft-shaped base, covering 13,000 m2 (43% of the reservoir), is fixed by anchors. On the base there laid 4,536 solar panels of 260 W with 12-degree angularity and centralize inverters.

Fig. 1-17Floating photowvoltaic power station in Ogekawa, Japan

India National Hydroelectric Power Station plans to build the world's biggest floating photovoltaic power station with the installed capacity of 50MW in southern Kerala, India. It is announced that the floating solar photovoltaic power station for experiment in Culcutta has been completed in January. This project, consisting of 10 glass fiber photovoltaic packages of 1 KW, is capable of generating electricity at least 1,400 kilowatt-hour annually—4 kilowatt-hour per day. Topsun is set to develop a floating photovoltaic electricity generating system of 100 MW Korea. An experiment project of 100 MW has been launched in 2013 and its scale will be expanded to 100 MW from 2014 to 2015.

The floating photovoltaic electricity generating system, with installed capacity of 5KW, in Bi'an Park in Singapore has succeed in connecting the grid and generating electricity. This system, invested by a private cooperation fund from Phoenix Solar Energy Co. Ltd, is about to test its adjustability in fresh waters. In addition, it will also strictly monitor its influence on water quality, plants, and animals, quantify estimated benefits such as the improvement of photovoltaic 's efficiency through hydro cooling, reduced evaporation quantity due to the cover of water, and the prevention of algae's breeding by keeping water from sunshine.

Early in 2007, SPG has built up a floating solar energy column matrix of 400 KW in California. With 4 years' improvement, this company again launched a commercialized floating solar energy column matrix which was installed in an irrigation pool in Sonoma County. The system is connected through cables laid at the bottom of the pool and electricity supply network. This project, with the installed capacity of 12.5MW, was connected with grid in 2006.

In 2015, Australia's first floating photovoltaic power station has been launched. This project , with the installed capacity of 4MW, is located at a sewage plant in Jamestown of southern Australia. Covering three sewage processing pools, this power station supplies electricity for sewage processing facility, as well as enterprises in this town.

1.6.6 Solar energy plane

Solar energy is driven by solar radiation. Its engine is composed of solar battery pile, direct current motor, decelerator, propeller, and controlling equipment. Due to low density of energy from solar radiation, this kind of plane should possess big surface for acquiring sunshine so as to lay solar battery for the sake of enough energy. As a result, the surface of the plane's airfoils is big.

"Sunshine Power" plane, able to fly during the night, has 200 m² photovoltaic panel. The plane has 11,628 solar batteries, with 10,748 on airfoils, 880 on horizontal balancer. Theoretically its average speed is 70 kilometers per hour. Its fuselage is made from super-light carbon fiber composite materials with airfoils as long as 63.4 meters, the size of which can almost be as large as a Boeing 747-700. But its overall weight, the pilot's included, doesn't exceed 1,600 kilograms—a weight is equivalent to a normal family car whose framework can be lift by two adults.

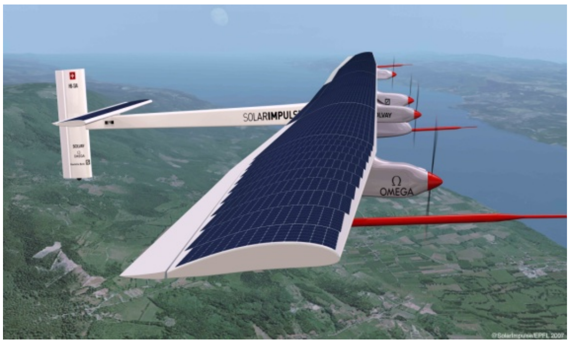

Fig. 1-18 Solar energy plane

1.6.7 BIPV

BIPV is suitable for most constructions such as flat roof, pitched roof, curtain wall, and ceiling.

Besides electricity generation, to meet the demand of BIPV, photovoltaic curtain wall needs external maintenance, transparency, mechanics, esthetics, and safety, so it has high-cost packages; it should be designed, and installed simultaneously with construction since the photovoltaic project's progress needs to keep pace with the construction's progress; photovoltaic array needs to deviate from the best installation inclination and its power capacity is relatively low; its electricity generation cost is high; and it enhance social value for the construction to bring the effect of environment-friendly concept.

Photovoltaic ceiling requires transparent packages, so the efficiency of the packages is low; except electricity generation and being transparent, the ceiling's packages should meet the demand of mechanics, esthetics, and structure link, so it has high-cost packages; its electricity generation cost is high; and it enhance social value for the construction to bring the effect of environment-friendly concept.

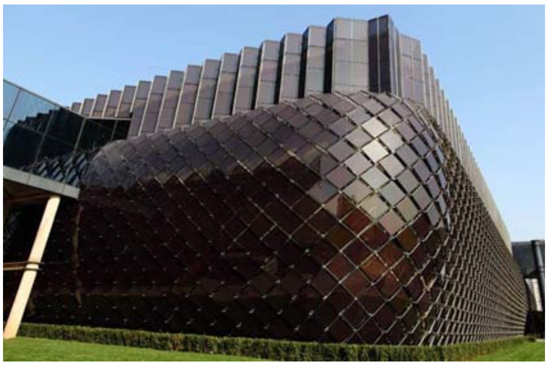

Fig. 1-19 BIPV Photovoltaic project

1.6.8 Photovoltaic water pump

Photovoltaic water pump, as the most attractive water supplying way in areas abundant with sunshine and especially outlying areas short of and even lack of electricity, automatically operates from dawn to dusk via inexhaustible sunshine everywhere. This water pump, in least need of manual maintenance, is an ideal green energy system of economic efficiency, reliability, and environmental protection benefits.

Solar energy water pump works through solar pumping inverter that drives pump by taking advantage of electricity generated by photovoltaic array. The whole system is composed of photovoltaic array, solar pumping inverter, and water pump.

Fig. 1-20 Photovoltaic water pump

Tab. 1-8 Advantages and disadvantages of photovoltaic water pump

Pros	Cons
Photovoltaic power supply rarely takes advantage of moving parts, so it is reliable.	Its energy is disperse.
Safe and noiseless, it is never a pollution nuisance, generating no polluting matter, liquid, or gas and is perfectly environmental friendly.	It is of great intermittence.
easy to install and maintain, it is of low operation cost and of no man guard. And it attracts attention due to its high dependability.	Its efficiency is largely decided by geography.
With high inclusiveness, its electricity generating system can co-work with other power supplies; also its photovoltaic system capacity can be easily extended meeting different demands.	Its up-front cost is high.

1.6.9 Inter-complementation of photovoltaic and hydroelectric stations

This combination is intended to make up one power supply. As both hydroelectric and photovoltaic electricity generation are of disperse distribution, intermittent supply, and weather affection, high power supply demand is satisfied by enlarging the capacity of photovoltaic system or using other kinds of power supplies to supply power in mixed ways. Therefore, by adjusting hydro turbine’s power to offset photovoltaic fluctuations from electricity generation, photovoltaic and hydroelectric stations can obtain stable motive power.

In terms of the equipment's use, hydroelectric station includes corresponding transformer room and transformer equipments, as well as complete power transmission grid, solar energy photovoltaic system's power transformation and transmission can, therefore, share existing equipments to greatly enhance the usage ratio, decrease system cost, and shorten construction period of photovoltaic system.

2 Latest Development of PV Technology

2.1 Module

2.1.1 Double-glazed module

The composite bed of double-glazed PV module comprises two pieces of glass and solar cells, which are connected by wires in parallel. In the past, the module was made of heavy PV glasses which are difficult for carriage. It has never been put into mass production due to the power loss as a result of the leakage of light between battery cells.

Since 2013, PV power stations have been put into operation for some time in China, the quality problems with power stations have boomed both home and abroad, such as PID decay. These problems have drawn people’s attention to the quality of power stations. Since organic materials are short in life and climate-vulnerable, people pay great attention to EVA film and backboard. The use of inferior EVA film by some domestic power stations leads to the problem of snail-like lines in 70% of the modules and 60% of decay after only one-year operation.

The double-glazed module is the best solution to high quality PV power stations with the following strengths.

1）Power generation higher than the life cycle and higher by 21% than ordinary modules.

2）The warranty for ordinary modules is 25 years while 30 years for double-glazed ones.

3）The decay rate of traditional modules is about 0.7% while that of double-glazed modules is 0.5%.

4）With zero water leakage of glass, we don’t need to consider what if water and vapor enters the module and lead to water dissolution of EVA film. The backboard of traditional crystalline silicon solar modules has a certain level of water leakage and the entering water and vapor will help inferior EVA resin dissolute into ethylic acid, resulting in electro chemistry corrosion within the modules and a higher possibility of PID decay and snail-like lines. This is especially applicable to PV stations alongside the beach, waterside, and high-temperature areas.

5）Glass is inorganic silicon with a good tolerance of climate and corrosion-resistant. This makes it more applicable to PV power stations in places with more frequent acid rain and salt fog.

6）The wear-resistance of glass has also resolved the sand wind problem for modules in the wide. The double-glazed ones have a better performance in places with huge sand winds.

7）The module is not in need of aluminum frames unless when there is a huge exposure in the glass surface. The lack of aluminum frames leads to the failure of setting up PID power stations and reduction in PID decay.

8）The insulation capacity of glass is better, which can meet the demands of higher systematic voltages for double-glazed modules to save the systematic cost of the entire power station.

9）The fire protection level of the module has upgraded from level C to level A, so that it can better be adapted to places in need of fire protection like residential area and chemical plants.

Fig. 2-1 Double-glazed PV modules

2.1.2 CIGS

In Sept. 2014, Manz created the new world record of 21.7% in terms of CIGS film solar power efficiency with the partnership of ZSW. It should be noted that Manz adopted the GISS key delivery production line. With a certain scale of capacity, over 94% of CIGS modules they produce are of good quality and the efficiency is up by over 15.3%, a very reliable investment.

With the outstanding performance in low sunlight, CIGS solar battery modules can be integrated into buildings and their curtains (i.e.: vertical installation) with a clean, modern and elegant look. CIGS film solar batteries has a strong absorption capacity of light from a broad range of spectrum and wave length, and over 10% more gross power generation compared with crystalline silicon solar batteries. Also, they can achieve outstanding power generation, which is the best application that can be applied to ground and roof power stations.

CIGS film solar batteries have a high conversion rate, stable performance, low manufacturing cost, strong anti-radiation capacity, good power generation in low light, light in weight, flexible, adjustable in color and can be integrated into PV buildings. In terms of BIPV or BAPV, CIGS has a good advantage in per-unit power generation. In vertical angles which are not beneficial for PV module generation, the low light effect of CIGS modules is more obvious.

Fig. 2-2 Application of CIGS Modules

2.1.3 Smart modules

By using smart chip technology, smart modules will upgrade the power output of modules, eliminate the heat spots and potential risks caused by sheltering, and improve the reliability of modules. The integration of MPPT function of modules into PV module batteries can make breakthroughs in traditional PV design, even the battery upgrading. Its strengths include:

1) Upgrade battery substring and solve the power mismatch problem within battery cells and modules;

2) In practical application, improve the shelter space between battery cells, achieve

the most tight battery cell distance, maintain the same or more power generation, so as to improve land use rate;

3) Improve the convenience of PV power station operation while smart power generation frees the manual maintenance cost and even for large-scale PV projects, it can reduce the operation cost as well;

4) Problem with long and short cluster modules and modules of different directions, so as to secure the power generation;

5) It can achieve MPPT and direct current upgrading in each battery; this design has reduced the shadow, dust, snow, and power loss due to other mismatch factors to the minimum.

2.2 Holder

PV power station holders can mainly be applied to five aspects: best angle fixed type (most widely applied), flat uniaxial tracking mode, tilted uniaxial tracking mode, biaxial tracking mode, and adjustable fixed mode.

The fundamental difference between different operation methods lies in their power generation capacity, as well as in the initial investment and operation maintenance cost.

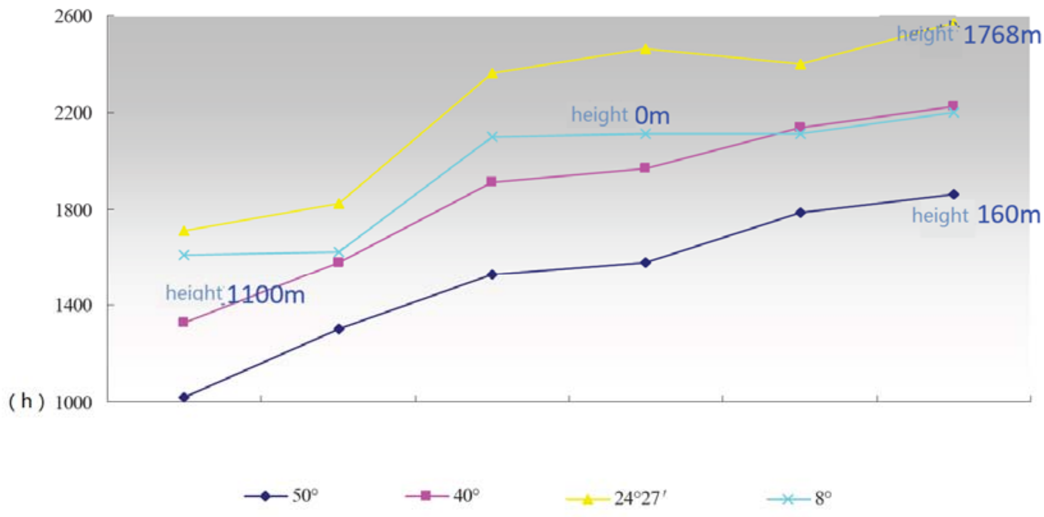

Fig. 2-3 Peak Daylight hours in different latitudes and altitudes

According to the Figure above, compared with the best angle fixed installation, power generation of horizontal uniaxial tracking is up by 17 to 30%, that of leaning 5° uniaxial tracking up by 21 to 35%, and that of biaxial tracking up by 35 to 43%. The power generation promotion rate is different in different operation modes of different latitudes. But the principle is listed as follows:

2.2.1 Best angle fixed mode

In low latitude areas, due to small best angles, power generation is less promoted (unchanged at 8°); in high latitude areas, due to large best angles, power generation is obviously promoted (up by about 25% at 50°).

2.2.2 Flat uniaxial tracking mode

This operation mode tracks the changes of the sun's incident angle in a day and power generation is more promoted in low latitude areas than high latitude ones. Generally speaking, this mode is suitable for areas with the latitude lower than 30° and can promote power generation by 20% to 30% compared with fixed ones. In high latitude areas, power generation can also be promoted by about 20% compared with fixed ones.

2.2.3 Tilted uniaxial tracking mode

It obviously combines the strengths of fixed and flat uniaxial modes. Like fixed ones which are not suitable for low latitude areas, this mode does not excel flat uniaxial mode in low latitude areas. Therefore, it suits high latitude areas better.

In this mode, supporting structures alongside the two sides must bear different stress, including the stand and axis of rotation. Since high latitude areas have a bigger best angle, if the "best tilt angle uniaxial mode" is adopted, then the stress of the two sides will be different. Therefore, a smaller angle will be selected in projects.

2.2.4 Biaxial tracking mode

After tracking the changes of the sun's incident angle in a day and a year, we find that power generation will be promoted the most by this mode.

2.2.5 Adjustable fixed mode

According to this mode, the angle of the stand is changed from time to time according to the changes of the sun's incident angle in a year, so as to promote power generation. It is popular in recent years.

The actual data of different operation modes is listed as follows:

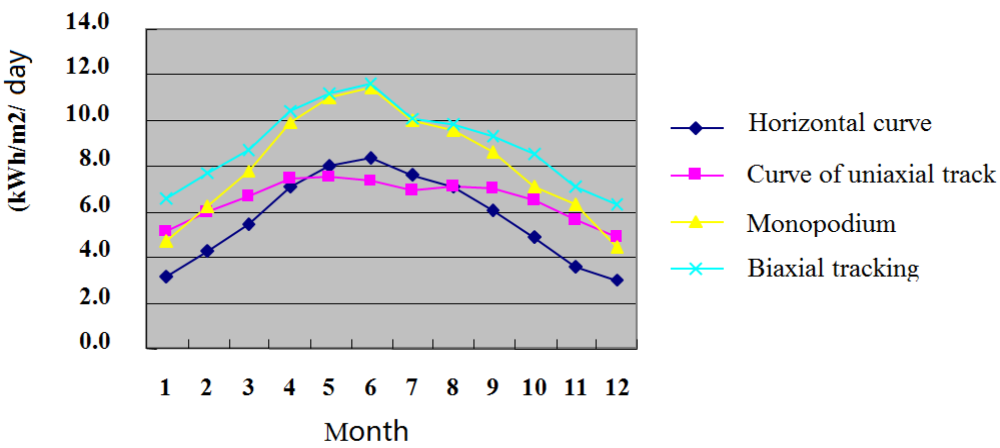

Fig. 2-4 Monthly power generation difference between different operation modes in a year

Based on the above chart, the fixed mode promotes the power generation in spring, autumn and winter at the cost of summer; the curve of uniaxial tracking is completely in parallel with that of horizontal curve; biaxial tracking promotes the power generation in spring, autumn and winter.

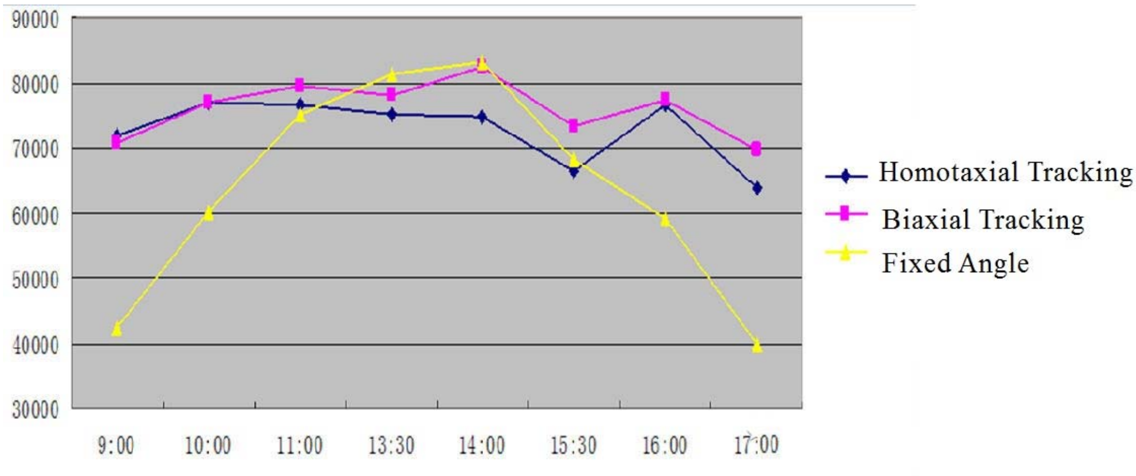

Fig. 2-5 Hourly power generation difference between different operation modes in a day (Wuwei, mid May)

Based on the above chart:

Tracking mode including uniaxial and biaxial ones promotes the power generation in the morning and evening;

Since this is the data in spring, biaxial and fixed modes share about the same amount of power generation in the noon, higher than the uniaxial mode.

The following chart shows the power generation of a place in Qinghai.

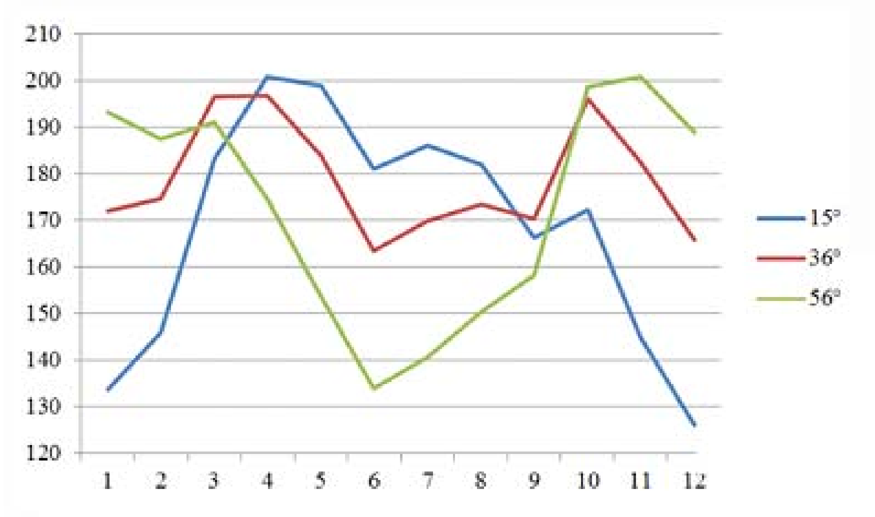

Fig. 2-6 Monthly power generation with three different angles

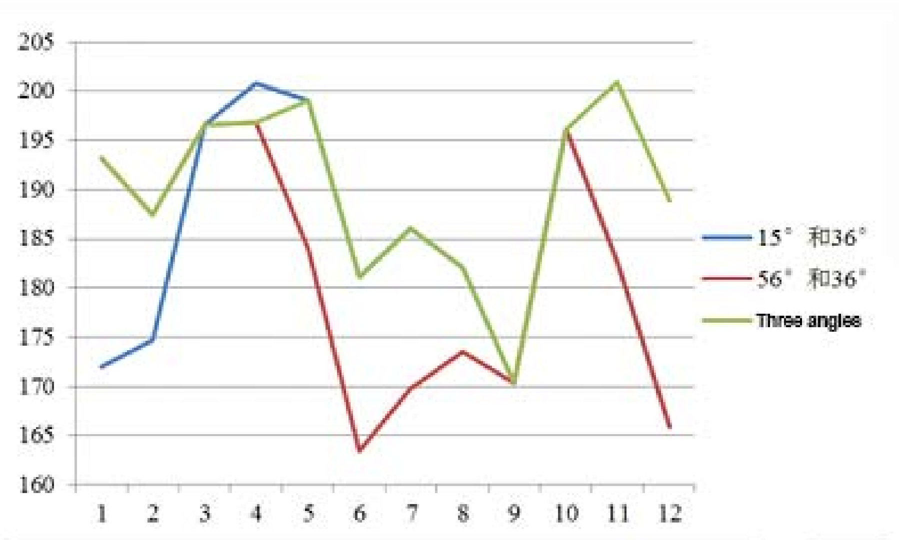

Fig. 2-7 Monthly power generation with different adjustment plans

Relative to optimum tilt angle:

Three angles (3 adjustments each year), power generation up by 6.2%, increase fore-and-aft clearance, bigger floor space;

15°and 36°(1 adjustment each year), power generation up by 2.9%, same fore-and-aft clearance, same floor space;

55°and 36° (1 adjustment each year), power generation up by 1.6%, bigger fore-and-aft clearance, bigger floor space;

Therefore, fixed best angle should be adopted.

Compare the following four adjustable fixed stands.

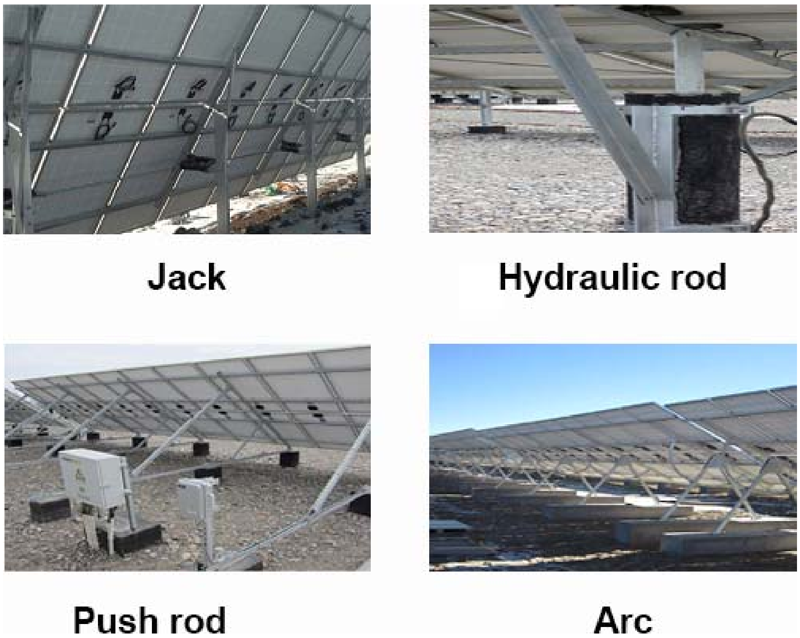

Fig. 2-8 Comparison of 4 adjustable fixed stands

According to operation and maintenance staff at power stations, tilt angle regulating is very tiring, which affects their work efficiency and initiative and may easily lead to the generating capacity lower than expectation. Jack is the key to this problem. And according to constructors there, jack can also make it easier to fix.

2.3 Inverter

There are two main types of inverters available in the market: central inverter and string inverter.

Central Inverter: device power between 50KW to 630KW, power devices using a large current IGBT, system topology using DC-AC power electronic devices for full-bridge inversion, the power frequency isolation transformer mode, protection class general IP20, large volume, indoor vertical installation.

String inverters: device power less than 30KW, power switching tube using a small current MOSFET, topology using DC-DC boost circuit and DC-AC full-bridge inversion, protection class generally IP65, small volume, outdoor wall-mounted installation.

Large-scale plant for central inverters are generally designed for large-scale power generating system such as large plants with well distributed sunlight, desert power plants, ground-based plants, with large system power, generally above megawatt. It has the following advantages:

1) small number of inverters, easy to manage;

2) small number of inverter components, high reliability;

3) less harmonic content, few DC component and high power quality;

4) high integration, high power density, and low cost;

5) multiple protection functions and high power safety;

6) power factor adjustment function and low voltage ride-through capabilities, good adjustment ability of the grid.

The main drawbacks are:

1) High breakdown rate of DC combiner box, affecting the entire system.

2) Voltage range of central inverter MPPT is small, and component configuration is not flexible. Time for power generation is short on rainy days and in foggy areas.

3) It is difficult to install and deploy in the inverter room, and requires specialized room an equipment.

4) The inverter itself and the room ventilation consume power, and system maintenance is relatively complex.

5) In centralized grid inverter system, the component matrix arrives inverter after two times of confluence. Inverter maximum power tracking (MPPT) cannot monitor the operation of each component, thus impossible to make each component operate in the optimum point. When there is a component failure or obscured by shadows, it will affect the power generation efficiency of the whole system.

6) There is no redundant capacity in centralized grid inverter system. If accidental shutdown occurs, the entire system will stop power generation.

String inverters are for small and medium roof photovoltaic systems, small ground station.

Main advantages of string inverters are:

1) The string inverter adopts modular design, each photovoltaic string corresponding to an inverter. The DC side has a maximum power tracking, and the AC side is parallel connected to the grid. Its advantage is that it is not affected by the difference between

modules and shadow blocking effects, while reducing the dispatch between the optimum operating point of photovoltaic battery modules and inverters, maximizing generating capacity.

2) String inverters MPPT have a wide voltage range, and component configuration is more flexible. Time for power generation is long on rainy days and in foggy areas.

3) String grid-tie inverter is small and light, very convenient to handle and install. It neither require professional tools and equipment, nor a special distribution room. In a variety of applications it can simplify construction, reduce the area, the DC line connection does not require a DC combiner box and DC power distribution cabinet. It also has advantages like self-low power consumption, small fault influence, easy replacement and maintenance advantages.

The main drawbacks are:

1) There are many electronic components. Power devices and signal circuits are on the same board. Design and manufacture are difficult, and less reliable.

2) small gap between electric power device, not suitable for high altitudes. Outdoor installation. Wind and sun exposure can easily lead to the aging of shell and radiators.

3) Without isolation transformer design, less electrically secure, not suitable for thin-film modules negative ground systems, and the DC component is large, big impact on the grid.

4) when inverters are in parallel, the total harmonic is high. THDI single inverter can control more than 2 percent. but if more than 40 inverters are connected in parallel, the total harmonics will be incremented and more difficult to suppress.

5) The more the inverters are, the higher the total failure rate will be, and the more difficult system monitoring is.

6) No DC and AC breaker, no DC fuse. When the system fails, it is not easy to disconnect.

7) A single inverter can achieve zero voltage ride-through function. But when multiple inverters are connected in parallel, it is difficult to achieve zero voltage ride-through function, reactive power regulation and active power regulation.

2.4 Micro-inverter

Micro-inverters are those that incorporate mini-inverter in each solar cell module, and maximize the overall output power by optimizing the output power of each module. Even if part of the battery plate is affected by shadows and dust cover, etc., the inverter power optimizer can still track the best local MPP (maximum power point), and restore more than 57% loss of generating capacity.

Advantages of micro-inverter comprises:

1) To increase the generating capacity of each inverter module and track the maximum power. Tracking of maximum power point of each module can greatly improve the power output of photovoltaic systems, by 25%.

2) Adjusting the voltage and current of each row of photovoltaic panels until all balance can avoid mismatch of the system.

3) In addition, each module includes a monitoring function which reduces maintenance costs of the system, and the operation is more stable and reliable.

4) Flexible configuration. The size of photovoltaic cell can be decided in accordance with user’s financial resources in the domestic market.

5) No high-voltage, more secure, easy to install, faster, low installation costs, less dependence on the installation service providers, able to DIY.

3 Cost analysis of photovoltaic power plants

3.1 Static total investment of photovoltaic power plants

PV power plant investments include equipment purchase costs, installation costs, and other expenses (basic reserve fund, liquidity, interest during construction, etc.). In order to more clearly illustrate proportion of breaks, a common sample of photovoltaic power plants in China will be chosen for analysis.

The photovoltaic plant generates 7.34MW of electricity, roof distributed projects, convenient transportation, favorable construction conditions. The proportion of the various costs of the plant is shown below:

Tab. 3-1Proportion of various costs of the plant

Costs of Photovoltaic Power Generating projects (Unit: Ten Thousand RMB)								
Serial Number	Name of the project or costs	Unit Cost	Equipment Purchasing Cost	Installation Cost	Other Cost	Total Cost	Total Units	%
	Total Investment	6.94	5092.92	350.00	392.00	5834.92	7.95	100.00%
	Other Assets	0.00	0.00	0.00	30.00	30.00	0.04	0.51%
1	Project Cost	6.94	5092.92	350.00		5442.92	7.42	93.28%
1.1	Photovoltaic Generating System	6.94	5092.92	350.00		5449.86	7.43	93.40%
1.1.1	Battery Module and Installation	4.50	3302.33	150.00		3456.83	4.71	59.24%
1.1.2	Combiner Box	0.10	73.39			73.49	0.10	1.26%
1.1.3	Inverter and Installation	0.60	440.31	20.00		460.91	0.63	7.90%
1.1.4	Module Stand and Fastener	0.75	550.39	80.00		631.14	0.86	10.82%

Costs of Photovoltaic Power Generating projects (Unit: Ten Thousand RMB)								
Serial Number	Name of the project or costs	Unit Cost	Equipment Purchasing Cost	Installation Cost	Other Cost	Total Cost	Total Units	%
1.1.5	Roof Reinforcement Cost	0.00	0.00			0.00	0.00	0.00%
1.1.6	AC Control Cabinet	0.05	36.69			36.74	0.05	0.63%
1.1.7	DC Control Cabinet	0.05	36.69			36.74	0.05	0.63%
1.1.8	Distribution Room	0.08	58.71			58.79	0.08	1.01%
1.1.9	Ready-made Branch Cable	0.00	0.00			0.00	0.00	0.00%
1.1.10	Cable and Connecter	0.65	477.00	100.00		577.65	0.79	9.90%
1.1.11	Checking and Monitoring Center	0.16	117.42			117.58	0.16	2.02%
1.2	Transportation Cost		0.00			0.00	0.00	0.00%
1.3	Attached Production Project		0.00			0.00	0.00	0.00%
2	Other Cost	0.00	0.00	0.00	292.00	292.00	0.40	5.00%
2.1	Prior-period Cost				7.00	7.00	0.01	0.12%
2.2	Survey and Design Cost				100.00	100.00	0.14	1.71%
2.3	Project Consulting and Reviewing Cost				30.00	30.00	0.04	0.51%

Costs of Photovoltaic Power Generating projects (Unit: Ten Thousand RMB)								
Serial Number	Name of the project or costs	Unit Cost	Equipment Purchasing Cost	Installation Cost	Other Cost	Total Cost	Total Units	%
2.4	Construction Supervision Cost				30.00	30.00	0.04	0.51%
2.5	Measure Cost				40.00	40.00	0.05	0.69%
2.6	Inspection and Acceptance Cost				15.00	15.00	0.02	0.26%
2.7	Grid-connected Commissioning Cost				30.00	30.00	0.04	0.51%
2.8	Insurance Cost				5.00	5.00	0.01	0.09%
2.9	Production Personnel Training and Early Entrance Fee				10.00	10.00	0.01	0.17%
2.10	Joint Commissioning Cost				5.00	5.00	0.01	0.09%
2.11	Other Cost				20.00	20.00	0.03	0.34%
3	Reserve Cost	0.00	0.00	0.00	100.00	100.00	0.14	1.71%
3.1	Basic Reserve				100.00	100.00	0.14	1.71%
3.2	Mark-up Reserve					0.00	0.00	0.00%
4	Initial Working Capital				0.00	0.00	0.00	0.00%

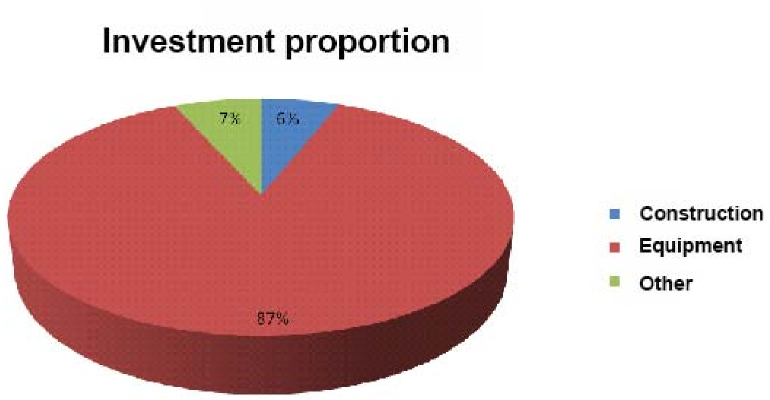

Fig. 3-1 PV Power Plants Total Investment Ratio

From the above chart we can see that about 87.3% of static equipment investment accounts for project investment. Construction costs accounts for about 6%, other expenses accounts for 6.7%.

3.2 PV Power Plants Investment Economic Evaluation Index- CLOE

CLOE is an important economic index evaluating generating system, defined as follows:

CLOE= Life-cycle cost/ Life-cycle generating capacity (RMB/kWh)

Life-cycle costs, including initial investment and operation maintenance costs, taxes, the discount rate and tax rates; factors affecting life-cycle generating capacity, including local solar energy resources, configuration of photovoltaic systems (PV - Inverter capacity ratio), the operation mode of the system (fixed installation or the sun facing track) and photovoltaic systems PR (Performance Ratio, PR). PR influence factors include: Component degradation, dust loss, mismatch loss, blocking losses, temperature losses, inverters efficiency, abandoned light rate, fault loss, AC / DC line losses and so on.

3.3 LCOE improvement methods

Technological innovation measures at the application side that most effectively reduce the cost of photovoltaic electricity are:

PV - Inverter capacity ratio: input-output ratio of 1: 2, net earnings at least up by 10% ;

To adopt the solar tracker with high reliability, low cost: input-output ratio of 1: 3, net earnings at least up by 20%;

Distributed maximum power point tracking (MPPT): earnings up by 3-5% without increasing investments;

Intelligent management and operation & maintenance: less operation and maintenance costs and downtime losses, earnings up by 3-5% without increasing investment;

Performance Ratio of some PV power plants in APEC region is currently low, only about 75%. At least 5% increase is still possible.

Adopting multiple methods described above at the same time can possibly increase 40% more net earnings than conventional PV power plants.

3.3.1 PV - Inverter capacity ratio overweight

Conventional capacity ratio of PV system and inverter is designed at 1:1. Generating capacity of PV power plants rate DC power according to PV modules. In recent years, European and American power grid enterprises have required PV power plants to declare and put on records according to grid-tied AC power and also made requirements on a rated AC power operation. In order to ensure that photovoltaic power plants run at full power within a certain period, PV modules on DC side must be increased. Expanding proportions range from 20% to 40% in the light of local conditions and electrical efficiency of the system. After expansion, a significant increase in profits was found in PV power plants. of the different loading conditions ranging depending on local resources and system electrical efficiency from 20% to 40%.The expansion spread quickly in Europe and America and was written in the soon published international standards: IEC / TS 62738 "Design guidelines of PV Power Plants."

Example: Location: China Qinghai Golmud Rated power of the inverter: 500kW Date: September 13, 2014

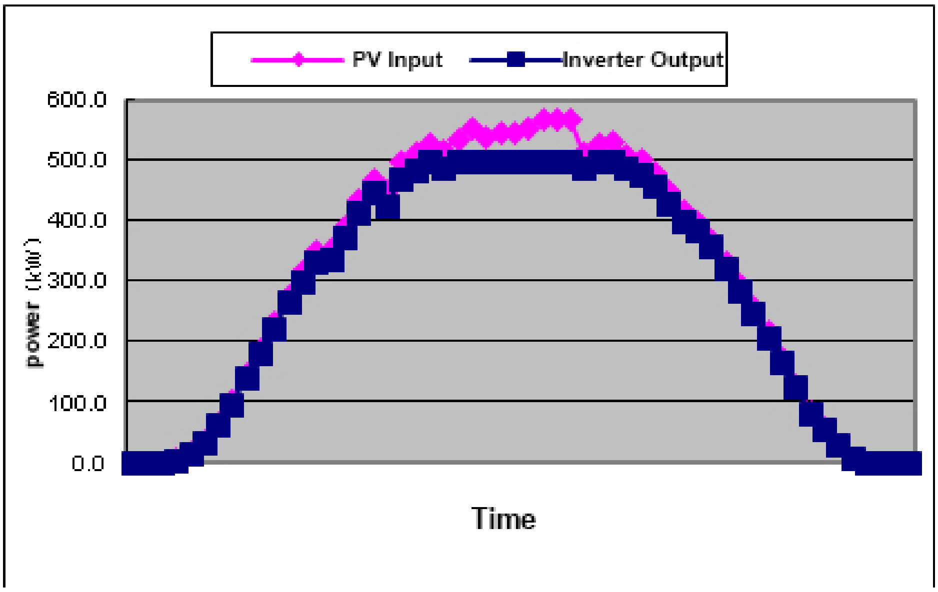

Fig. 3-2 Input Power Comparison of Different PV-inverter Capacity Ratio

Before expansion, the inverter's maximum output is 447kW. After expansion by 20%, the maximum output is 500kW and PV limit rate is 1.24%.

500kW matrix is expanded by 20%.100kW PV array, brackets, combiner box, cable are increased, increased investment is about 400,000 RMB, an increase of 18.52% electricity (PV limit rate 1.24%). Local PV electricity on-grid price is 0.9 RMB / kWh, and annual increased revenue is 128,000 RMB. The new payback period is only 3.52 years, IRR of new investment is up to 28.8%. Equivalent annual number of hours of photovoltaic power plants increases from 1800 hours to 2100 hours, obvious benefits.

Expansion ratio of PV matrix is not the higher the better. According to IEC / TS 62738 requirements, in order to protect the inverter, the operating power should be limited when the inverter reaches rated power(power excess is not allowed by grid companies). Therefore, the high proportion of installed PV expansion will lead to an increase in the proportion of limited power. Design of photovoltaic inverter capacity ratio should be optimized , for example:

Location: Golmud Station power: 10MW Operation period: 20 years

The initial use of the equivalent number of hours: 1800 Linear decline within 20 years : 20%

Tab. 3-2 Relations between PV / inverter capacity ratio and life-cycle leveled cost of electricity (LCOE)

PV: Inverter	Life-cycle Total Investment （ten thousand RMB）	PV Limit Rate(%)	20 years' Total Generating Capacity (MWh)	Life-cycle LCOE(RMB/kwh)
1.00	13600.00	0.00	324000.00	0.462
1.10	14280.00	0.00	356400.00	0.441
1.20	14960.00	1.24	383978.88	0.429
1.25	15300.00	2.85	393457.50	0.428
1.30	15640.00	4.83	400856.04	0.429
1.40	16320.00	8.74	413955.36	0.434

Best PV - Inverter capacity ratio is 1.25.

3.3.2 Solar tracker

The contribution of solar trackers to improving electricity generation

The aim of using solar tracker is to reduce cosine losses (ie oblique loss), and allow PV matrix to directly face the sun as much as possible,that is to make normal of matrix surface in parallel with the sun rays. Solar tracker can greatly improve the generating capacity of photovoltaic power generation system. The following is 30-year average data comparison between radiation on different tracking surface and horizontal radiation by the meteorological station in Phoenix, America (1961-1990):

Meteorological station: US Phenix WBAN No.: 23183 Station

Latitude: 33.43 °N, Longitude: 112.02 °W, Elevation: 339 meters, Air Pressure: 974 mbar

Data: 1961-1990 30-year average

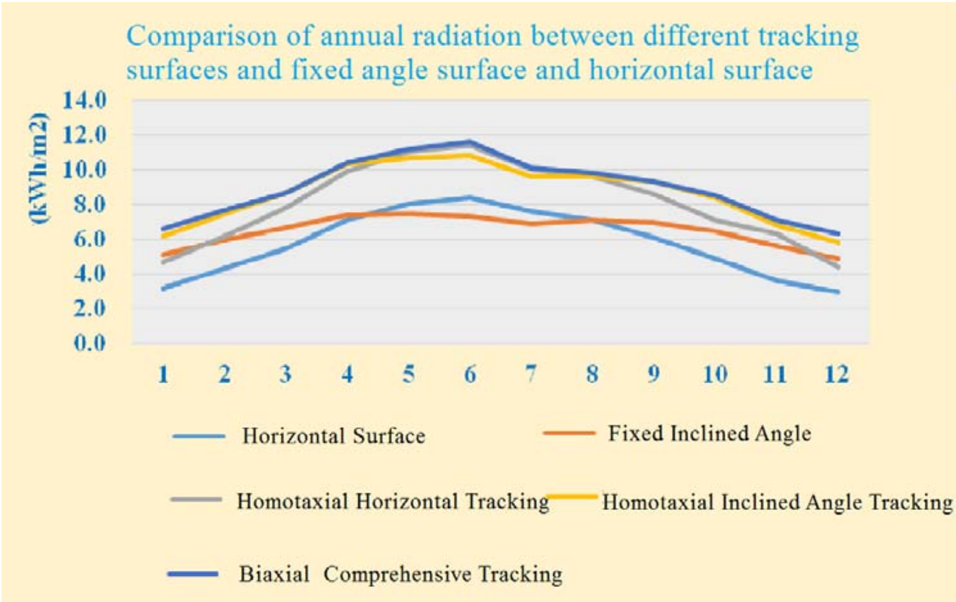

Fig. 3-3 Comparison of annual radiation between different tracking surfaces and fixed angle surface and horizontal surface

Tab. 3-3 Different tracking ways and horizontal solar daily radiation comparison (kWh / m2)

Month	1	2	3	4	5	6	7	8	9	10	11	12	Annual Average
Horizontal Surface	3.2	4.3	5.5	7.1	8.0	8.4	7.6	7.1	6.1	4.9	3.6	3.0	5.7
Fixed Angle	5.1	6.0	6.7	7.4	7.5	7.3	6.9	7.1	7.0	6.5	5.6	4.9	6.5
Flat Homotaxial Tracking	4.7	6.2	7.8	9.9	11.0	11.4	10.0	9.6	8.6	7.1	6.3	4.4	8.0
Oblique Homotaxial Tracking	6.2	7.5	8.7	10.3	10.7	10.8	9.6	9.6	9.3	8.4	6.8	5.8	8.6
Biaxial Tracking	6.6	7.7	8.7	10.4	11.2	11.6	10.1	9.8	9.3	8.5	7.1	6.3	8.9

Comparison of the radiation results between different types of solar trackers and horizontal and inclined surfaces fixed matrix as follows:

Tab. 3-4 Radiation Increase Effects of Different Types of Solar Trackers

Installation Mode	Annual Average Daily Radiation (kWh.m2)	Radiation Increase Compared with Horizontal Surface(%)	Radiation Increase Compared with Fixed Angle(%)
Horizontal Surface	5.7	0.00	-12.31
Fixed Inclined Angle	6.5	14.04	0.00
Homotaxial Horizontal Tracking	8.0	40.35	23.08
Homotaxial Inclined Angle Tracking	8.6	50.88	32.31
Biaxial Comprehensive Tracking	8.9	56.14	36.92

As can be seen, the use of solar trackers can increase the generating capacity by 23.1% -36.9% compared to conventional fixed angle matrix, with an average increase of 31%. The increase is related to the proportion of local direct light. The larger the direct component, the more significant the tracking effect is.

1) Examples of solar trackers

a) Horizontal coordinate system

Horizontal coordinates can be divided into fixed installations (any direction), the azimuth tracking, tilt angle regulating and biaxial tracking systems, as Figuretures shown below:

Fig. 3-4 Fixed PV matrix on flat ground and fixed PV matrix on the slopes

Fig. 3-5 Fixed square angle, to track the sun azimuth from the east and west

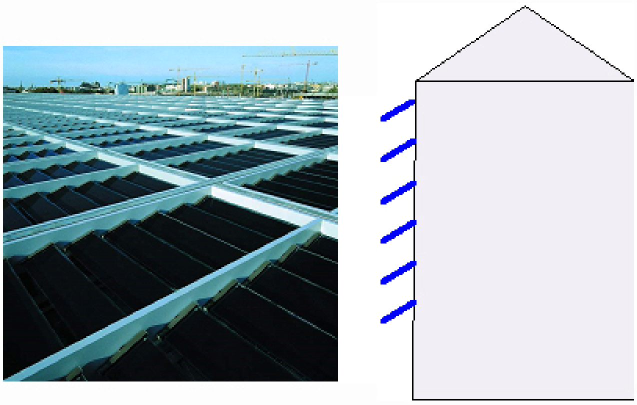

Fig. 3-6 Matrix facing south, adjusting the angle

Fig. 3-7 Horizontal coordinate biaxial tracking (condenser, panel)

b) Equatorial coordinate system

Equatorial coordinates can be divided into flat homotaxial tracking, inclined nomotaxial tracking and biaxial tracking systems (difference between fixed installation and the horizontal coordinate).

Fig. 3-8 Flat homotaxial hour angle tracking matrix (E-W rotation)

Fig. 3-9 Inclined homotaxial hour angle tracking matrix (W-E rotation)

Fig. 3-10 Biaxial tracking matrix (simultaneously tracking hour angle and declination angle)

In short, PV solar trackers of both horizontal coordinate system and equatorial coordinate system have already been applied in the world. Apart from the fixed installation, there are six kinds of tracking mode. The solar tracker of horizontal coordinates have simple balance weight but complex structure; while that of equatorial coordinate system is quite opposite, so the developers are free to choose according to their needs.

2) Backtracking technology and its theories

As can be seen from the diagram below, if the photovoltaic tracking matrix is designed to face the sun at 8:00 am, the matrix start at 8:00 following the sun from the east to the west till the evening at the designed position. However, from the sunrise to the time when matrix face the sun in the morning, and from the designed position in the afternoon to the sunset, matrix in the east-west direction, if no measures are taken, will block each other, shown as below:

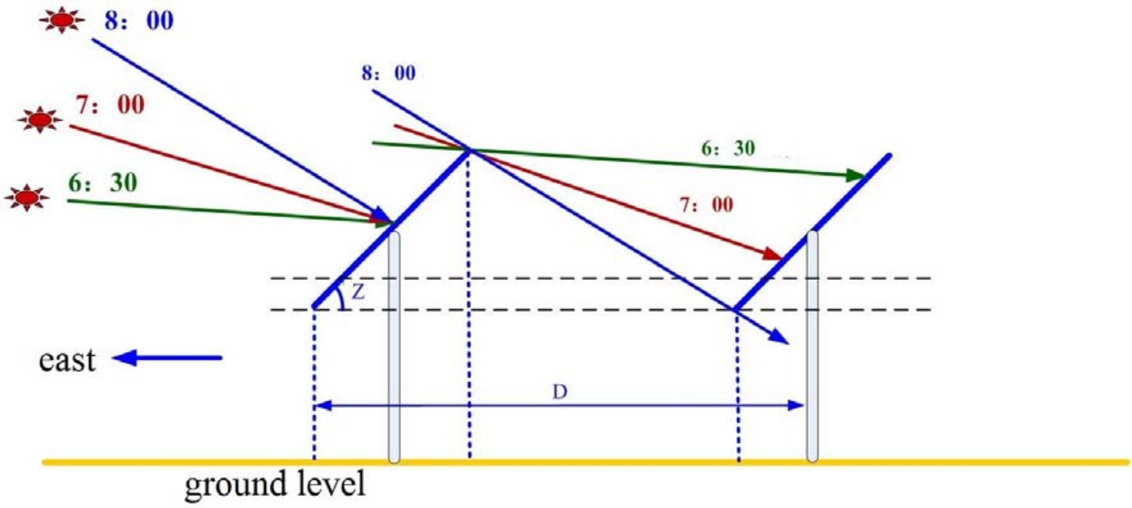

Fig. 3-11 Mutual block of tracking matrix in the morning

For tracking matrix, in order to avoid mutual block of the tracking matrix from sunrise to the time when the matrix facing the sun, backtracking technology needs to be adopted. IEC / TS 62727-2012 (solar tracker) technical standards for the solar tracker have "backtracking" requirements.

The so-called "backtracking" technology is that when the sun rises, the PV matrix is adjusted to a horizontal position. As the sun rises, the PV matrix rotates eastward (rather than follows the sun from east to west) , gradually facing the sun while avoiding blocking each other until it is fully aligned with the sun. Then PV matrix starts following the sun from the east to the west. After reaching the designed position in the afternoon, PV matrix starts to rotate in the opposite direction from west to east, always avoiding mutual blocking until reaching flat position. "Backtracking" technology enables PV matrix with solar trackers to avoid blocking, which can increase generating capacity by 3%-5% from morning to night. Fixed matrix, due to the lack of regulating capacity, will be more or less.

Design of the angle that avoids blocking during "backtracking" period of the equatorial coordinate system:

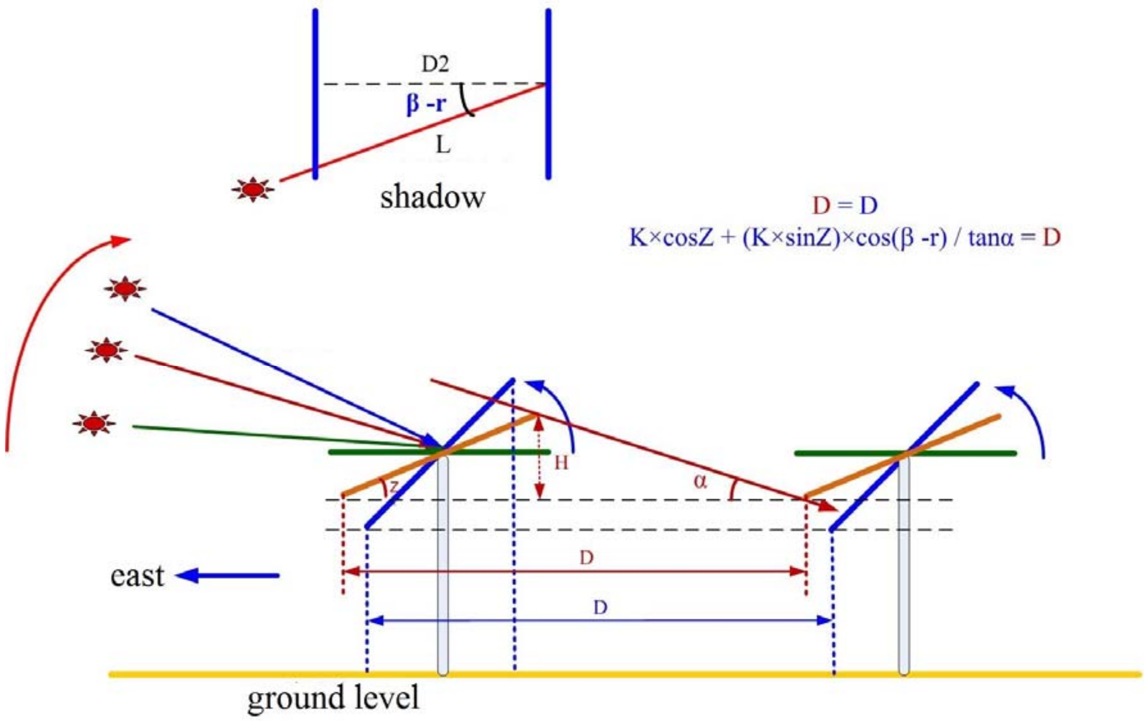

Fig. 3-12 Design of the inclination angle that avoids blocking during "backtracking" period of the equatorial coordinate system

As can be seen from the diagram, spacing D on the east-west axis as designed spacing is known. The inclination angle that avoid blocking at any time can be obtained through the following equation:

$K \times \cos Z + (K \times \sin Z) \times \cos\beta / \tan\alpha = D$ D is known，to obtain Z.

D: Axis spacing of PV matrix

K: Width of PV matrix

Z: Inclination of PV matrix

β: Azimuth of the sun

r: Spindle direction of the matrix, south, r = 0

α: Elevation angle of the sun

Solar elevation angle formula: $\sin\alpha = \sin\varphi \sin\delta + \cos\varphi \cos\delta \cos\omega$

Solar azimuth formula: $\sin\beta = \cos\delta \sin\omega / \cos\alpha$

Local latitude φ, after the declination angle (date) δ is determined, you can calculate solar elevation angle and azimuth every five minutes after sunrise,and then obtain the inclination angle that avoid blocking from the above formula.

Design of the angle that avoids blocking during "backtracking" period of the horizontal coordinate tracking system:

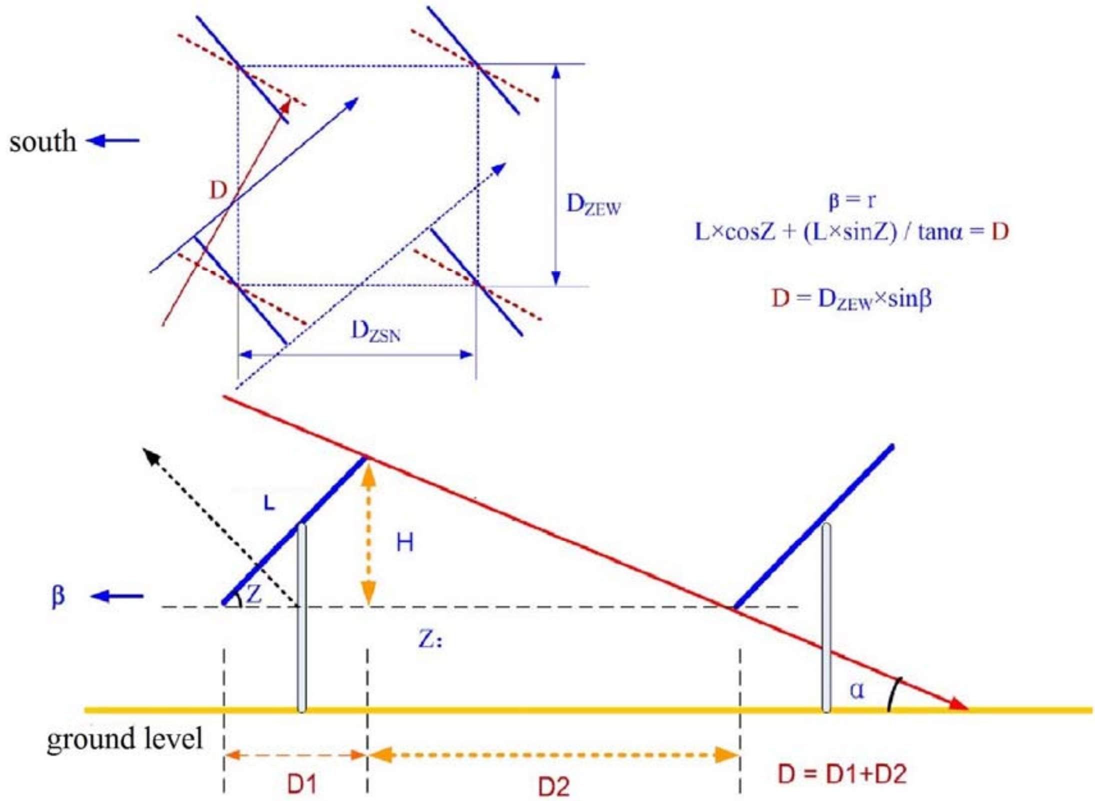

Fig. 3-13 Design of the angle that avoids blocking during "backtracking" period of the horizontal coordinate tracking system

As the diagram shows, the spacing DZEW on the east-west axis as designed spacing is known, with which can spacing D at any time be obtained. For horizontal coordinate tracking system, there is alway a matrix azimuth equal to solar azimuth, ie β = r. The inclination angle that avoid blocking at any time can be obtained through the following equation:

D = DZEW × sinβ

L×cosZ + (L×sinZ) / tanα = D   D is obtained from DZEW，then Z is able to be obtained.

D: spacing in the east-west direction

L: width of the PV matrix (known)

Z: PV matrix inclination

β: solar azimuth

r: matrix azimuth

α: solar elevation angle

Through the above formula, the inclination angle that avoid blocking every 5 minutes after sunrise can be calculated.

To reduce LCOE of PV system, apart from reducing the cost of photovoltaic components and systems, other LCOE factors should be noted, such as the operation & maintenance costs of PV system. And what is more importantly is to improve the life-cycle generating capacity.

4 Financing Model of PV Power Plants

4.1 Financing Model of PV Power Plants

Financing costs of PV power plants in most APEC region is too high, which is contrary to the inherent features of low-benefits and stability of PV power plants, one of the main factors for its high “soft costs”. Therefore, innovative financing models are needed for large-scale application of PV systems in APEC region.

Current main financing models are: third-party finance leasing mode, PPA, crowd funding mode, debt financing, equity financing, asset securitization, real estate trusts, Yield Co. and so on.

4.1.1 Leasing

Leasing, according to the rental mode,can be divided into direct lease and leaseback which are respectively designed for newly purchased equipment and existing equipment. In accordance with accounting standards, leasing can be divided into finance leasing and operation leasing. Finance Leasing as finance on balance sheet, it is the inner asset depreciation; operation leasing as finance off balance sheet, for current expenses, can reduce asset-liability ratio.

For roof projects, builders can lease the roof to developers who can install solar systems on the roof, and sell the generated electricity to builders and utility companies. Developers can not only get government subsidies, but also benefit from the power generation. At the same time builders can also benefit from roof lease and enjoy the same or cheaper price of electricity.

4.1.2 Yieldco

YieldCo, the abbreviation of Yield Corporation, belong to yield-oriented financing instruments. Yieldco, established by the pre-established renewable energy developer, is a publicly traded company. Developers will entrust Yieldco to manage the investment portfolio of assets generated by energy. Conversely, Yieldco raise fund and manage assets generated by energy, and provide shareholders with a stable and long-term cash flow. In most cases, the original developer is one of the main shareholders of Yieldco. Yieldco is prevalent in North America and spreads to Europe, and has become a common form of project financing.

YieldCo, initiated and set up by the parent company, is a publicly listed entity that holds a certain project assets and operates independently. Different from conventionally listed companies, YieldCo company does not emphasize profitability and the rate of expansion, most of whose benefits generated by its holdings is paid to shareholders in the form of regular payment of dividends. Although investors get equity, cash flow is stable and expectable, thus making it as reliable as creditor’s rights.

4.1.3 REITs

Real estate investment trusts (REITs), widely used in the real estate market, brings together funds through the issuance of yields certificate, then entrust specialized investment institution for its investment and management, and allocate overall benefits pro rata to investors. Rental income and interest income are the main income source of REITs.

PV REITs refers to PV estate trusts. Its characteristics are as follows:

1). Low cost. The current project must be wholly foreign-owned (BVI) investment;

2) PV REITs package and sell to overseas investment institutions. BVI remit obtained proceeds to domestic subsidiaries for further investment; to continue to invest; the original domestic subsidiaries, still as a project manager, charge management fees every year;

3) The original investors, as financing side, schedule interest payments; PV REITs are open funds, and can be freely traded;

4) Portfolios must be large enough high,and amortize high issuance costs.

Because the US federal investment tax credit (ITC, reduction amount is 30% of system installation costs),an important pillar of American PV market, and the California Solar Initiative (CSI, the nation's largest electricity users sharing subsidy bill) will be expired by the end of 2016, during the transition period of the next few years,REITs, as a matured and booming pattern in real market, is expected to be more widely explored and applied in the US PV market, and gradually become one of the mainstream modes in the “post- subsidy ear “after 2016.

4.1.4 ABS

ABS is a specific asset management plan and is within the scope of business asset securitization. Security companies act as plan administrators to issue asset-backed beneficiary certificates with specific asset management plan as SPV and purchase underlying assets that will generate stable cash flow from original rights and interests holders by appointment, and then distribute the earnings of underlying assets to beneficiary certificates holders. Unlike Reits, ABS belongs to the direct financing of enterprises and provides them with approaches for capital market financing. Reimbursement of special project derives from the underlying assets and their stable cash flow. The issuance and transaction objects are institutional investors in the capital markets.

4.1.5 PPA

For Power Purchase Agreements, different size of photovoltaic power stations has different business models: the large-scale grid system PPA and the small and medium-sized electrical power generating system PPA of third party.

1) The large-scale grid system PPA

The large-scale grid system PPA is mainly funded by three parts: the project developers, the mortgage lenders, and the tax equity investors. Project developers such as NRG, Borrego Solar develop the project and search for investors, while provide a portion of the capitals; the mortgage lenders loan to the project and gain earnings in the form of interests, for example JPMorgan and Banco Santande; the tax equity investors invest in the form of tax equity, and gain profits in the form of Investment Tax Credit, US Bank、Wells Fargo are typical tax equity investors. Through this pattern, developers can sell the electric energy generated from photovoltaic power generation project to large power grid companies in the form of PPA, thus gaining profit from it. In addition, tax equity investors as a source of financing is mainly applicable to the United States, according to the statutory regulation, 30% of the tax will be deducted if the company invest in a photovoltaic power generation project which is an opportunity for those investment banks that need to pay lots of tax, however, this way of investment based on tax system has not been widely applied in the APEC region.

2) The small and medium-sized electrical power generating system PPA of third party

The small and medium-sized electrical power generating system PPA of third party is similar to the third party leasing model in basic structure, differences lie in that proprietors purchase electric energy generated by photovoltaic system through PPA, rather than lease electrical power generating equipments. In the third party PPA model, the third party investors (PPA suppliers) purchase solar photovoltaic power generation system, and provide various services including equipment installation, operation and maintenance, meanwhile enjoy relevant tax credits and rebates and incentives; the proprietors agree to have photovoltaic system equipped on their roofs, and purchase all the electric energy generated by this system at a fixed price within prescribed period of time. It is regulated in the PPA that price of the electricity generated by photovoltaic system should be adjusted according to the price of local grid system in the first year, and make sure that the expected electricity price of local grid system in the following years be higher than the electricity price of photovoltaic system regulated in PPA. If the power purchase agreement is due, the proprietors can choose to extend the contract period, purchase the PV system or to remove the system. This model of third party power purchase agreement can reduce the upfront costs the proprietors need to pay for photovoltaic system, and release the proprietors from the responsibility of system maintenance; therefore, it is widely welcomed in relevant field of business.

4.1.6 Crowd funding

Crowd funding, also known as public financing or mass financing, means to raise project fund from the public in the form of group purchase plus pre-order. Modern ways of crowd funding refer to publish fundraising projects on the internet and call for funds from the public. Compared with traditional ways of funding, crowd funding tends to be more open and the commercial value of projects is not seen as the only criterion that decides the possibility of gaining investment. A project, once favored by the netizens, can obtain the first startup fund by crowd funding.

The improved model of PV crowd funding is a newly developing innovation model, photovoltaic enterprises obtain money by crowd funding from the public rather than loans from the banks or institutional investors in order to provide solar power generation facilities to the consumers. For potential investors, the costs of solar energy, operation life of the panels and rate of return are much more transparency. Besides the lower risk, this kind of project usually has a stable rate of return between 4% and 12%, similar to investment in mutual fund. According to the regulations, photovoltaic enterprises will raise money for the installation of solar roofs by crowd funding, and cooperate with solar energy service provider. Once obtain enough fund, they can start to install solar panels on the roofs. The proprietors can rent the solar system and sign a 20-years fixed low electricity price contract in general with the service provider.

4.2 Case Analysis

4.2.1 SolarCity

SolarCity leases the rooftop photovoltaic power generation system to the users (typical property owner) and charges rental fees or electricity fees following the electricity selling agreement, under which mode users in California pay a 15% lower price for each unit of electricity than the average cost of electricity purchased from the state grid. Photovoltaic power generation has the price advantage to compete with traditional energy sources.

The basic logic of SolarCity business model is that SolarCity is the core in its relations with the consumers, the government and investment fund, it firstly transfer photovoltaic power generation subsidies provided by the federal and local governments into the attractive preferential price it can offer to the consumers, and monetize the future profits gained from the power purchase contract by investing in funds; Monetization of recycling funds into the reinvestment will achieve a benign condition of continuous replication, rolling development and large-scale development. Early investment of SolarCity is their own funds, and is then gradually enlarged and replaced by social investment; though early returns is negative, it will gradually turn positive.

As a system integrator, SolarCity mainly has two sections of business: one is to sell photovoltaic power generation system, with continuous lower costs of photovoltaic components, it is easier for system integrators to gain a higher gross profit rate; the other is the leasing and PPA of photovoltaic system. Photovoltaic leasing business is mainly for residents' projects, SolarCity constructs and maintains rooftop photovoltaic system for residential users, and guarantee the output of electricity. Net metering meters are adopted, so residents only need to pay the net amount of electricity. After the adoption of SolarCity to install photovoltaic system, electricity charge has been cut sharply from which residents could save to pay for photovoltaic system leasing fees monthly to SolarCity. PPA model is mainly for commercial users. In general, SolarCity signs the third party agreement with commercial users and electric power companies; it is responsible for the construction and maintenance of photovoltaic system, sells electricity to the electric power companies, and charges them per month according to the electricity power generated.

Furthermore, for leasing business, SolarCity has developed a household energy monitoring system named PowerGuide so that clients can check the net electric quantity and greenhouse gas emissions in real time.

4.2.2 Solar Mosaic

Solar Mosaic was established in October, 2010, and has been testing crowd funding platforms similar to Kickstarter in the following two years. It has been kept on record in supervisory department and can share profits of negotiable securities with the public. During the vote of confidence concerning crowd funding bills held in 2012, this company passed smoothly.

As for the business framework of Solar Mosaic, one end of the crowd funding platform is to cooperate with solar developers or service providers like SolarCity and Sungevity, to provide financing to them, but at the other end of the platform, its sources of funding are predominantly non-professional investors. Once gain funds, they can start to install solar panels on the roofs. The proprietors can rent the solar system and sign a fixed low electricity price contract with the service provider - usually for about 20 years.

Solar Mosaic in the testing phase of its website once raised about $1 million from 400 people, and has built 12 rooftop photovoltaic projects in California, New Jersey, and Arizona. In June 2012 VC fund led by Spring Ventures provided $2.5 million for Solar Mosaic.

Since January 14, 2013, Solar Mosaic officially opened their website to residents in California and New York, as well as other qualified investors to let them make money by investing in solar power projects, setting a 4.5%annual rate of return, and promised that investors can withdraw the principal in 9 years. The minimum investment of an individual is $25. The whole process of financing is like loans: investors pay in advance to fund the solar power generation projects, the proprietors pay for the electricity fees according to the agreement, resulting in profits, then Solar Mosaic returns money back to the original investors following the agreed rate of return.

From a financial point of view, the operation pattern of Solar Mosaic is like a virtual bank of renewable energy sources: to raise funds for a period of 10 years or so for project construction and then return the income from investment to the investors by income of electricity charge. In the process, Solar Mosaic provides an interest of 5.5% for the capitals to these developers and charges them 1% of the service fees, then returns money back to investors at an interest rate of 4.5%. The company promises that investors can withdraw the principal within 9 years.

4.2.3 Renewable Energy Trust Capital

Located in San Francisco, Renewable Energy Trust Capital, Inc (RET) has been a typical example to try REITs financing and promote it to get the approval of IRS. Since its foundation in 2011, RET has received support from the California Clean Energy Fund. The company aims to contribute to innovative financial platforms for clean energy, and to coordinate with the advanced finance industry, policies and technology support of America to accelerate the development of clean energies. RET provides liquidities for existing and future electricity generating assets and market, its object of financing is low-cost capitals in America.

Targets of RET mainly include: to establish a standardized investment structure of the photovoltaic industry, to simplify the process of project financing, to lower capital entry costs, and to reduce the cost of generating electricity by clean energies in American.

At present, RET has submit its application to the Internal Revenue Service (IRS) to list photovoltaic projects as "real estate" in order to meet the requirements of REITs. Since this year the IRS has approved other atypical assets to be listed as real estate (including energy projects), the market shows optimistic attitude towards the approval of RET photovoltaic projects. Once the photovoltaic projects are listed as real estate that can be financed by REITs, the scope of the REITs photovoltaic fund investors managed by RET will expand rapidly, and everyone (from individual to institutional investors) can have their own share in this rapid developing photovoltaic market by taking advantage of this simple platform of liquidity.

4.2.4 Hannon Armstrong

Hannon Armstrong Sustainable Infrastructure Capital (hereinafter referred to as HA) has a history of more than 30 years, it mainly provides debt or equity financing to sustainable projects. Since 2000， HA has arranged or provided more than $4 billion in financing for the transaction of more than 450 sustainable infrastructures. The company is now managing total assets of $1.8 billion. The initial public offering was on April 17, 2013, $12.5 for each share, and later went public in NYSE. At the same time, the company was approved by the IRS and transferred to real estate trust (REIT), which means the company will distribute most earnings to shareholders regularly, and is free from tax as a company.

Before being listed, the financing sources are mainly insurance companies and commercial banks, with major companies in the field of infrastructure as its customers, and it has also completed many projects for the government of U.S. projects for financing are as follows:

1) Energy efficiency project: Executed by energy service provider, this type of project is aimed at reducing energy consumption or costs of buildings or facilities through the design and installation of lifting scheme.

2) Clean energy projects: Projects that use light energy, wind energy, geothermal energy, bio-energy and natural gas.

3) Other sustainable infrastructure projects: Water conservancy projects or communication projects that will contribute to reduce energy consumption, and pose a

positive impact on the environment.

HA invests in clean energy projects in the forms of stock equity or debt, if through equity financing, HA will hold the project when it is completed and obtain a stable revenue stream; if through debt financing, HA will obtain interest income, in the meanwhile, as a financial intermediary, HA will also get commissions in cooperation with institutional investors.

Three types of financing:

1) Structural financing: More than $3.9 billion of structural finance transactions have been carried out from tender, negotiate to transact, including: Federal Service Contracts, Energy Savings Performance Contracts (ESPC), Utility Energy Savings Contracts (UESC), and Federal Leasing, etc.

2) Investment banking: Debt financing and assets financing include project financing, post - venture funding corporate finance, mergers and acquisitions, tax consulting. A registered trading securities broker will operate under Hannon Armstrong Securities.

3) Commercial banking: To carry out venture investment with their owned capitals.

- Income distribution:

The target of HA is that dividend reach to 7% of its IPO price, and all the interests be distributed. The 3rd quarter of 2013 witnessed a core profit of $2.3 million, with $0.14 dividend per share, and an annualized return of 4.5%, calculated at the closing price of $12.39. The earnings increased by 133% compared with $0.06 of the last quarter. Earnings of 4th quarter increased to $0.22 per share, which has reached the target already.

- Securities:

In November 2013, Subsidiary HASI SYB I LLC and HAT SYB I LLC issued $100 million bonds, with a coupon rate of 2.79%, and will be due in November 2019. These bonds were guaranteed by the cash flow of more than 100 wind, light, and energy conservation projects held by HA, the service provider.

HA has issued $3 billion of ABS (Asset Backed Securities), and all have no external rating. HA describes these bonds as investment grade bonds, the interest rates of which are usually lower.

4.2.5 Terra Form Power

Terra Form Power is a YieldCo enterprise holding and operating the corresponding solar equipment founded by SunEdison, and plans to be dedicated in the field of solar power. Its target rate of return is 85% of the available cash as dividends distributed to the investors.

In the morning of July 18, 2014, Terra Form Power began trading on the NASDAQ, coded TERP, with an initial public offering of 20 million shares, each share for $25, and a turnover of $500 million. The starting quarterly dividend was $0.2257 per share, the forward annual yield rate was 4.5%, and Terra Form Power plans to increase the dividends. The shares price jumped to $33.40 in two hours after the opening quotation.

Terra Form Power owns 808 megawatts of solar power. It also contains some large projects, such as the 266-mw Mount Signal project in southern California and the 101-mw Amanecer CAP project in Chile. Besides projects in the UK and Canada, most of its portfolios are in the United States, up to 557 megawatts.

Later, SunEdison will allocate more profitable assets to Terra Form Power, including 135-million distributed projects in the United States and Canada. In addition to its initial 808-megawatt projects, SunEdison also plans to transfer projects that will generate about $175 million a year to yieldco during the first year after the completion of its initial projects.

5 Typical Cases

5.1 Large-scale ground power station:

Case analysis of the ground photovoltaic project in Jiangsu province of China:

5.1.1 Basic information:

Tab. 5-1 Basic information

System installed capacity	27.035MW	Type of power station	Ground power station
Type of holder	Screw pile, and deposit concrete	Installation method of the system	Fixed angled installation
Voltage of combined branches	35kV、110kV	Angle of installation	30°
Floor space of the system	2000 mu	Scope of the power supply	3km
Grid-connected operation time	From 2014-4	Accumulative generated electricity power of the first year	31396-thousand kWh

The photovoltaic power station is divided into two sub stations; one has a total installed capacity of 9.878 MWs, and covers an area of about 300 mu. It uses 245 watts components, with an installation angle of 30°, every 20 components in a string, every 16 strings enter a combiner box and access to a 1 megawatt inverter before they are changed to alternating current. After the voltage increases to 10 KV, the electricity will be sent through the iron tower overhead primary loop to the side 10-kv of the 35-kv substation.

The other station has an installed capacity of 17.156MWs, and covers an area of 1.7 thousand mu. This project uses components of 250 watts, every 20 components in a string, every 16 strings enter a combiner box and access to a 500-kilowatt inverter before they are changed to alternating current. After the voltage increases to 10 KV, the electricity will be sent through the iron tower overhead secondary loop to the side 10-kv of the 110-kv substation.

5.1.2 On-site photos

Fig. 5-1 Appearance of the 9MW power station

Fig. 5-2 Appearance of the 16MW power station

Fig. 5-3 The inverter used in this project

Fig. 5-4 Combiner box used in this project

Fig. 5-5 Holder and foundation used in the 9MW project

Fig. 5-6 Holder and foundation used in the 16MW project

Fig. 5-7 Monitoring system

5.1.3 Assessment results of the project

Tab. 5-2 Assessment results of the project

A. The inspection of the documents

1. The power station is complete in approval documents; 2. The electricity price of the power station is RMB 1.25/kWh, and will be subsidized for 20 years; 3. The total investment of this power station is 231.1092million RMB, 8.55RMB for each watt. 4. This is an overall invested project, no other financing is arranged. 5. The electricity income has realized 0.68RMB/kWh, the subsidy of 0.57RMB/kWh has not been settled; 6. The electricity fees are calculated every month.	
B. Construction quality of the project and system operation	
1. The power station is complete in process documents; 2. Altogether 12 types of the on-site items in the photovoltaic power station that are 67 sub-items in total have been checked, which prove that the power station is in good condition.	
C. Investment for project construction	
Total investment (ten thousand RMB)	23110.92
Include: key facilities (ten thousand RMB)	18529.72
Construction costs (ten thousand RMB)	3770.47
Expenses for land leasing and reimbursement (ten thousand RMB)	502.73
Other expenses (ten thousand RMB)	308
D. Economic profits of the project	
1. Based on historical data, the generation capacity of the project is measured to be 31.396 million kilowatt hours, and equivalent generated power of alternating current side for effective use is 1256 hours each year.	

2. IRR=12.68%, the static payback period is 5.59 years.
3. The price of this power station after being discounted according to the income capitalization approach (discount rate of 8%): 310.0483 million RMB.

5.2 Distributed PV Projects in Commercial Area

Take a commercial real estate project in Beijing for example:

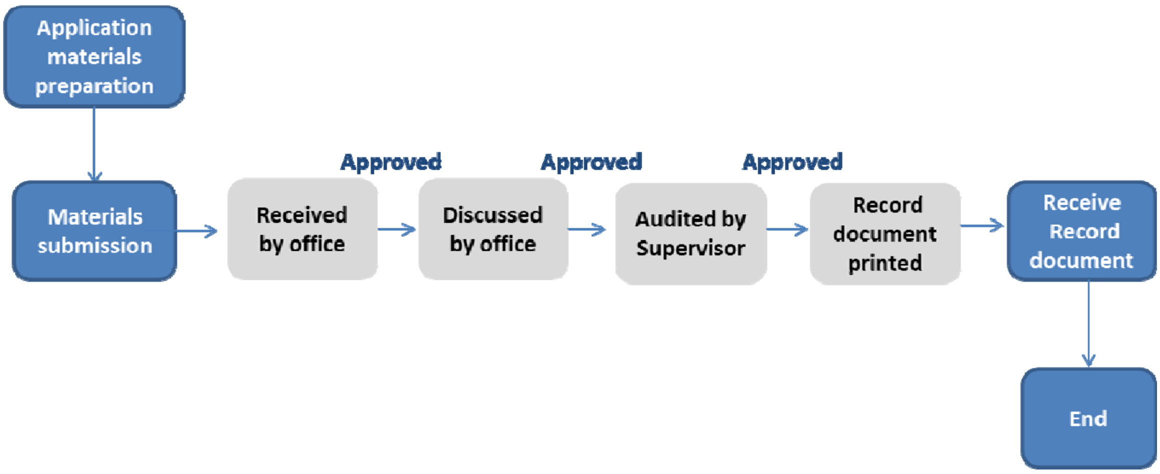

Fig. 5-8 Declaration process of the project

Light Resource in Beijing:

- The light resource in Beijing is relatively abundant with an annual solar radiation in a horizontal plane totaling 1480.1 kWh/m2. According to the richness degrees of solar energy resource set by Assessment method for solar energy resources（QX/T 89-2008）, Beijing lies in an area full of solar energy resources.
- The PV array paved on a Steel tile roof, with a tilt angle of 5°, has an annual total radiation of 1556 kWh/m2.
- The PV array installed in a tilt angle of 33°, the best tilt angle, has an annual total radiation of 1777 kWh/m2.
- According to the actual electricity generation in the first year of the project in Beijing, it can be calculated that the generation duration reached 1150 hours.

The electricity price of business and industry in Beijing is consulted and listed in the following tables:

Tab. 5-3 The electricity price of business and industry in Beijing (RMB/kwh)

Types	Voltage level	Electricity price/kwh				Basic electricity price	
		Critica-peak	Peak	Mid-peak	Off-peak	Maximum demand RMB/kw·month	Transformer capacity RMB/KVA ·month
General business	<1 KV	1.5295	1.4002	0.8745	0.3748		
	1-10 KV	1.5065	1.3782	0.8595	0.3658		
	20 KV	1.4995	1.3712	0.8525	0.3588		
	35 KV	1.4915	1.3632	0.8445	0.3508		
	110 KV	1.4765	1.3482	0.8295	0.3358		
	>220 KV	1.4615	1.3332	0.8145	0.3208		
Large-scale industry	1-10 KV	1.0941	1.0044	0.6950	0.3946	48	32
	20 KV	1.091	0.9904	0.6850	0.3886	48	32
	35 KV	1.0631	0.9764	0.6750	0.3826	48	32
	110 KV	1.0361	0.9514	0.6550	0.3676	48	32
	>220 KV	1.0131	0.9284	0.6350	0.3496	48	32
Agriculture	<10 KV		0.9472	0.6435	0.3558		
	1-10 KV		0.922	0.6285	0.3398		
	20 KV		0.9242	0.6215	0.3338		
	>35 KV		0.9162	0.6135	0.3268		

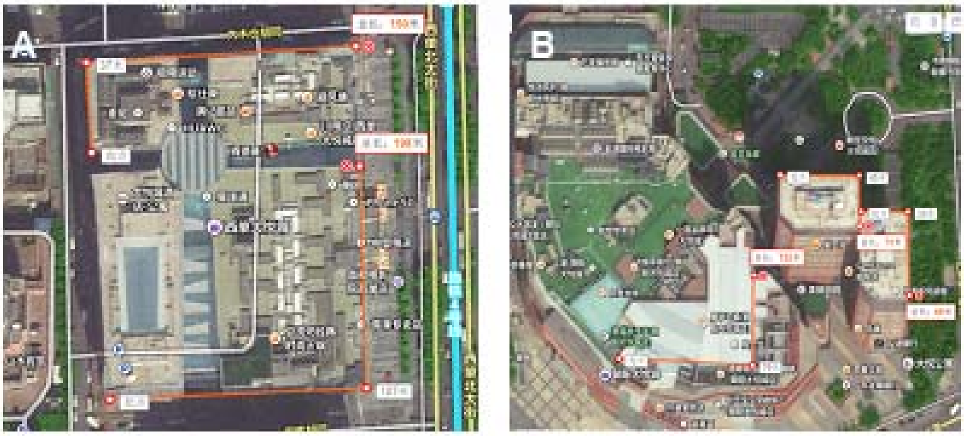

Fig. 5-9 Top views of the building roofs in the project location

Roof A's area is estimated to be:

A、107*90=9063

B、37*100=3700

The total area is 12,763 m2.

But the Figure shows that many obstructions lie on the roof and PV power station can be installed in the top right and bottom left parts for they are relatively flat. It is preliminary estimated that the installed PV power station can cover 1/3 of the roof, nearly 4000 m2, producing 500kW of electricity.

Roof B's available area is estimated to be (calculate the relatively plain parts):

A、76*46=3496m2

B、45*26=1170m2

C、26*43=1118 m2

The total area is 5,784m2.

The relatively plain roof is estimated to install about 500kW of electricity.

- All the 16 transformers can load 29,392kW of electricity while the 500kW PV installation only counts for 1/60, which can be totally assimilated.
- The total electricity consumption in 2014 is about 46 million kWh, of which the 500kW PV installation generates 1.3% electricity.

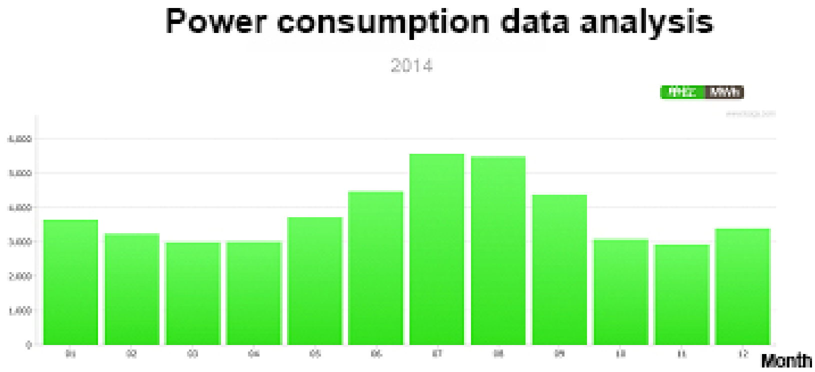

Fig. 5-10 Power consumption data by month

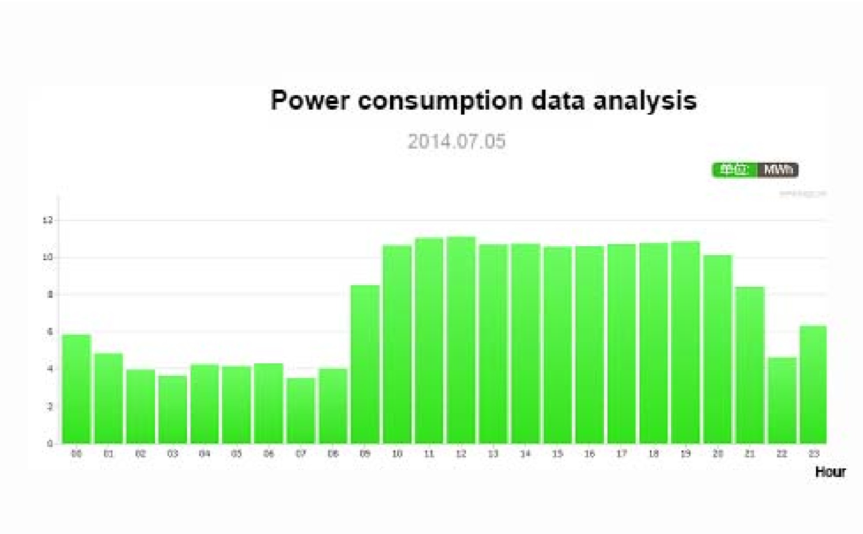

Fig. 5-11 Power consumption data by hour

Tab. 5-4 Basic information of the program

<table>
<tr><td colspan="8">Basic Information of the Program</td></tr>
<tr><td>Project Name</td><td>Project Owner</td><td>Electric Capacity(kW)</td><td>Project Location</td><td>Total Investment(million RMB)</td><td>Annual generation duration</td><td>On-grid energy (10,000 kWh)</td><td>On-grid price</td></tr>
<tr><td>Beijing 500kW PV Power Generation Project</td><td>Beijing XX Real Estate Company</td><td>500</td><td>Beijing</td><td>3.75</td><td>1150</td><td>57.50</td><td>1.000</td></tr>
<tr><td colspan="8">Result of Calculation</td></tr>
<tr><td>IRR</td><td colspan="2">Cumulative Net Cash Flow (million RMB)</td><td>Stable Investment Payback Period(year)</td><td colspan="2">Dynamic Investment Payback Period(year)</td><td colspan="2">Value of Power Station(million RMB)</td></tr>
<tr><td>42.117%</td><td colspan="2">9.01182</td><td>1.238</td><td colspan="2">2.546</td><td colspan="2">7.14477</td></tr>
<tr><td>Notes</td><td colspan="7">1) The generation duration in the first year is 1150 hours. According to the yearly degeneration rate of 0.8% of the electricity capacity, the average duration in 25 years is 1016 hours.
2) On-grid Price: 1.72 RMB in the first 5 years (with an average step-by-step price of 1 RMB /kWh+0.42 RMB /kWh+0.3 RMB /kWh); 1.42 RMB in the following 15 years (with an average step-by-step price of 1 RMB /kWh+0.42 RMB /kWh) the subsidy is provided for 15 years or longer.
3) Finance 70% of the money with an interest rate of 5.4% and invest 7.5 RMB per watt.
4) 88% of the overall investment is used to purchase the equipment.
5) Take into consideration that the enterprise's income tax is exempted in the first three years and half rate reduction in the next three years.
6) The operation and maintenance rate is 0.3% in first two years; 0.5% from 3rd to 5th year; 0.7% from 6th 10th year; 0.8% since the 11th year. Take into consideration that the inverter needs to change in the 11th year and the inflation maybe happen.
7) The equipment will be depreciated in the 15th year and the salvage value is 5% of the original value.</td></tr>
</table>

5.3 Roof PV Project in Industry Area

Differences between the distributed PV installation in commercial area and industrial area lie in:

1) Lower price;

2) Different conditions of the roof. Most of the industrial roofs are paved by Steel tile and are extensive, however, the burden of the roof should also be considered. Generally speaking, the commercial roofs are made by concrete with a lot of obstructions and covers, which need more refined design.

3) The electricity loads between them are different. Based on the different industrial products, the factory will have different loading curves, some fluctuating greatly and some slightly. The design of PV power station should keep in line with the traits of products' loading curve. In commercial area, the load of power station is relatively stable, especially when the daytime PV power generation fits the peak period of electricity consumption and the power produced fits the loading curve.

Tab. 5-5 Basic information the program

<table>
<tr><td colspan="8">Basic Information of the Program</td></tr>
<tr><td>Project Name</td><td>Project Owner</td><td>Electric Capacity(kW)</td><td>Project Location</td><td>Total Investment(million RMB)</td><td>Annual generation duration</td><td>On-grid energy (10,000 kWh)</td><td>On-grid price</td></tr>
<tr><td>500kW PV Power Generation Project</td><td></td><td>500</td><td></td><td>3.75</td><td>1150</td><td>57.50</td><td>0.800</td></tr>
<tr><td colspan="8">Result of Calculation</td></tr>
<tr><td>IRR</td><td colspan="2">Cumulative Net Cash Flow (million RMB)</td><td colspan="2">Stable Investment Payback Period(year)</td><td colspan="2">Dynamic Investment Payback Period(year)</td><td>Value of Power Station(million RMB)</td></tr>
<tr><td>25.497%</td><td colspan="2">6.350</td><td colspan="2">2.463</td><td colspan="2">4.211</td><td>5.74563</td></tr>
</table>

Notes	1) The generation duration in the first year is 1150 hours. According to the yearly degeneration rate of 0.8% of the electricity capacity, the average duration in 25 years is 1016 hours. 2) On-grid Price: 1.52 RMB in the first 5 years (with an average step-by-step price of 0.8 RMB /kWh+0.42 RMB /kWh+0.3 RMB /kWh); 1.22 RMB in the following 15 years (with an average step-by-step price of 0.8 RMB /kWh+0.42 RMB /kWh) the subsidy is provided for 15 years or longer. 3) Finance 70% of the money with an interest rate of 9% and invest 7.5 RMB per watt. 4) 88% of the overall investment is used to purchase the equipment. 5) Take into consideration that the enterprise's income tax is exempted in the first three years and half rate reduction in the next three years. 6) The operation and maintenance rate is 0.3% in first two years; 0.5% from 3^{rd} to 5^{th} year; 0.7% from 6^{th} 10^{th} year; 0.8% since the 11^{th} year. Take into consideration that the inverter needs to change in the 11^{th} year and the inflation maybe happen. 7) The equipment will be depreciated in the 15^{th} year and the salvage value is 5% of the original value.

Sensibility analysis about this project: defining the annual actual electricity generation from less than 30% to more than 30% of the estimation, the changes of present values, investment return rate (IRR), payback period and LCOE are listed in the following table:

Tab. 5-6 Sensibility analysis by actual electricity generation

Actual Electricity Generation	Sliding Scales	Accumulative Present Value of Power Station Assets	IRR	Stable Investment Payback Period	Dynamic Investment Payback Period	Net Present Value	LCOE
805	-30%	413.47	9.10%	11.77	20.86	14.75	1.04
862.5	-25.00%	444.42	11.52%	7.21	16.02	45.71	0.97
920	-20.00%	475.29	14.07%	5.36	11.94	76.58	0.91
977.5	-15.00%	506.16	16.76%	3.99	7.62	107.44	0.86
1035	-10.00%	536.96	19.57%	3.37	5.85	138.25	0.81
1092.5	-5.00%	567.76	22.49%	2.87	4.79	169.05	0.77
1150	0.00%	598.27	25.50%	2.46	4.21	199.56	0.73
1207.5	5.00%	628.68	28.58%	2.12	3.74	229.97	0.69
1265	10.00%	659.08	31.73%	1.85	3.36	260.37	0.66
1322.5	15.00%	689.49	34.93%	1.63	3.04	290.78	0.63
1380	20.00%	719.89	38.17%	1.44	2.80	321.18	0.61
1437.5	25.00%	750.29	41.44%	1.28	2.59	351.58	0.58
1495	30.00%	780.70	44.74%	1.13	2.41	381.99	0.56

Sensibility analysis about this project: defining the annual actual credit interest rate from less than 30% to more than 30% of the estimation, the changes of present values, investment return rate (IRR), payback period and LCOE are listed in the following table:

Tab. 5-7 Sensibility analysis by actual interest rate

Actual Interest Rate	Sliding Scales	Accumulative Present Value of Power Station Assets	IRR	Stable Investment Payback Period	Dynamic Investment Payback Period	Net Present Value	LCOE
6.30%	-30%	594.10	30.95%	1.89	3.42	236.97	0.73
6.75%	-25.00%	594.79	29.99%	1.97	3.54	230.74	0.73
7.20%	-20.00%	595.49	29.05%	2.06	3.66	224.50	0.73
7.65%	-15.00%	596.19	28.14%	2.15	3.79	218.27	0.73
8.10%	-10.00%	596.88	27.24%	2.25	3.92	212.03	0.73
8.55%	-5.00%	597.58	26.36%	2.36	4.06	205.80	0.73
9.00%	0.00%	598.27	25.50%	2.46	4.21	199.56	0.73
9.45%	5.00%	598.97	24.66%	2.58	4.37	193.33	0.73
9.90%	10.00%	599.67	23.84%	2.69	4.53	187.09	0.73
10.35%	15.00%	600.36	23.04%	2.81	4.70	180.86	0.73
10.80%	20.00%	601.06	22.27%	2.94	4.88	174.62	0.73
11.25%	25.00%	601.75	21.51%	3.07	5.10	168.39	0.73
11.70%	30.00%	602.41	20.78%	3.21	5.42	162.11	0.73
13.95%	55%	605.66	17.40%	3.98	7.70	130.71	0.73
18.00%	100%	611.50	12.54%	7.72	15.03	74.18	0.73
20.70%	130%	615.14	10.01%	11.58	18.64	36.24	0.73

5.4 Household System

Compared with the distributed PV projects in business and industrial areas, household system projects are rarely applied in China at present. The main reason is because the electricity consumed in households is relatively of low price, small projects and long payback period.

The clients of household electricity consumption are ordinary residents. According to the analysis by CREIA, if one invests PV power station (with electricity generation of 80kW and generation duration of 1,200 hours) of a residential building at an expense of 9 RMB per watt, generating and consuming by the residents themselves with a power price of 0.6 RMB, then he has to get credit of 500,000 RMB (70% of the total investment) with an interest rate as personal credit or general commercial loan and a loan period of 15 years. After all these, he must recover the cost in 17 years with an internal return rate of 6.11%, so the project is basically of low financial feasibility. Due to the low electricity price in households in China, the roof-distributed PV power station for residents is of low return rate when taking the operation cost and other factors into account.

6 Conclusion

6.1 Establishment of Electricity Price Mechanism

Electricity price, as a key factor of power market reform, is the core of this market-based reform of electricity. Therefore, to establish an electricity price mechanism beneficial to PV connection and assimilation will promote the sustainable development of PV industry. Meanwhile, it will foster the construction of PV assets transaction system and the market of PV electricity and power stations in APEC region.

6.2 Establishment of Policy Risk-proof System

This is to prevent the transregional and transnational asset transaction risks of PV electricity and power station in the APEC region. The risks are from national macro-control policies (such as structure readjustment in economics and energy conservation and emission reduction), bargain price, trade quantity of electricity and electricity grid security. Therefore, the policy risk-proof system is in need to realize the risk control of asset transaction of PV electricity and power station. As a result, it will improve the asset transaction system in APEC region and ensure the PV electricity and asset market operating in a successful, orderly and healthy way.

6.3 Establishment of PV Power Station Evaluation System

Due to the great differences in administrative structure, policies, electric market, solar resource and construction and operating cost of PV power station, the economies in APEC region should gradually explore an evaluation system of PV power station which can be applied in different nations and regions and is in accordance with their own developments.

Such evaluation system will become a guiding system and high-speed channel for the PV development in this region. It will provide a general and cautious evaluation on project risks and a reasonable estimation for its future cash flow and return rate, which is reliable data for the transnational, trans-regional and cross-industry investors.

6.4 Establishment of Risk Management System of Whole Life Cycle

The construction of whole-life-cycle risk management system of PV power station is to prevent and control some main risks in four periods of a PV station: investment and planning, feasible research, design and construction and operation and maintenance. The potential risks in every period will be found through a comprehensive analysis and recognition for all the risks lurked in the four periods, which will further lay a foundation for the risk quantization. Such system will fully and meticulously assist the PV projects and make the risk management more scientific and accurate, benefiting the risk management in APEC region. Its establishment can ensure the safe operation of PV power station and help the investors judge the quality of station so as to lower down the risks.

6.5 Financial Innovation

Nowadays, the high financing costs of PV power station in most APEC regions run counter to the inborn natures of low return and high stability of PV stations. Therefore, to explore a new financing mode of PV power station and reduce the soft costs of it is of great social and realistic meaning for the development of PV power stations in the APEC region.

6.6 Enhancing the Personnel Training

More workers and higher qualities of them are new trend in PV industry, which is in line with the constant development of PV products and assets transaction. Hence it is very important to train the PV workers systematically, especially in the fields of design, construction, operation and maintenance and financing. Providing more systematical training to the workers is of vital importance to ensure safe and high efficient PV power stations and lower the investment and financing risks in them. The R&D research, applied cases, innovative financing mode and business mode by the APEC economies can provide precious training reference and materials in the future.

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