Photovoltaic Communication and Cooperation Platform

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APEC Photovoltaic Communication and Cooperation Platform (PVCCP)

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Introduction

As one of the most significant clean power sources in the APEC region, solar PV power stations have produced an accumulative PV installed capacity of 177GW globally. At the meantime, grid parity of PV power generation has been realized in more and more APEC economies without large-scale government subsidy with constant technological innovation and rapidly decreasing cost. In order to lead social capital to flow into this area, objective and accurate evaluation of PV power station risks and profits is required.

Based on analysis and risk assessment of each link related in PV power station investment and construction including resource assessment, key devices selection, engineering construction, power station financing as well as operation and management, this report aims to establish an economic calculation model of PV power station with detailed presentation of its investment and construction process, coming up with a PV power station evaluation model that can be referred to by all APEC economies. Moreover, a communication and cooperation platform is expected to be established so as to provide services for future construction, investment and financing of PV power stations.

1 PV Power Station Risk Analysis

During more than 25 years effective working life of PV power stations, risks may occur in technology, policy, environment and financing, etc.

1.1 Technological Risks

As regards the whole process of power station construction including stock assessment of sunlight, design, equipment selection, construction, operation and maintenance and post evaluation, etc, technological risks may cover the following aspects:

Tab. 1-1Technological Risks

Technolo-gical Risks	Stock Assessment Risks	Stock assessment of PV power stations requires historical irradiation data of many years coming from either local measured data or satellite meteorological data, which however, mainly bring potential risks regarding its source, accuracy and representativeness;
	Power Station Design Risks	Unequal design technological capability of PV power stations may result in less generated capacity than expected and safety risks due to unreasonable design;
	KeyEquipment Quality Risks	Uneven PV equipment quality of various manufactures may lead to early breakdown or scrap because of poor quality, or lack of after-sales services due to manufacture close-down;
	Power Station Construction Risks	Different technological capabilities of PV power station construction side may contribute to low efficiency, safety risks and higher operation and maintenance cost, etc of the power station due to unreasonable construction;
	PowerStation Operation and Maintenance Risks	Long-term exposure of PV power station equipment may cause decreased power generation efficiency and generated capacity and even fire disasters due to module contamination and wire aging, etc.

1.1.1 Sunlight Resource Assessment Risk

Profit calculating is regularly carried out in advance as a determinant of PV power station investment and construction based on the solar energy data of prospective power station site, which mainly comes from three means, including satellite data, calculated data according to climatology and measured data.

As for PV power station analysis of solar energy resources including general radiation quantity and variation trend, meteorological station with long-term solar radiation observational data near the power station site, if possible, should be selected as reference. In addition, at least 1 year uninterrupted site observational data should be utilized for solar energy resource analysis. Solar radiation site observation station is required to be established near the prospective site of large-scale PV power station with at least one year site observational data recorded before construction of the power station. Reliable sunlight resource data so substantial to cast influence on dip angle calculation in designing of the power station.

Nevertheless, during practical construction process, certain errors exist between meteorological station data and practical sunlight resource of PV power station site due to time limit for most PV power stations to collect sunlight resource data by establishing sunlight measuring station one year in advance and moreover, infrastructure construction level varies among APEC economies with China has only 3 meteorological stations for one province in average which are able to provide related radiation data for PV power station design.

During feasibility research and resources assessment of PV poser station project, a lot of APEC economies usually adopt NASA satellite meteorological data, which is calculated by data reversion of satellite observational data with resolution ratio of 3km~110km. Comparison and analysis shows that deviation of different levels of the NASA data exists in different APEC areas. For example, the NASA data is more than 10% higher than measured data in Middle and Eastern China with more rainy days, which will result in over optimistic profit calculation based on NASA data exclusively.

In addition, incomplete data collection exists in some large-scale ground PV power stations despite of the meteorograph installed inside. A well-equipped meteorograph consists of at least four solar radiation meters, measuring general radiation value, scattered radiation value, dip angle radiation value and direct light data respectively, among which the dip angle radiation value can better reflect the generated capacity and operation status of the power station. Since the high-accuracy tracking device used for direct radiation requires high cost, some power stations calculate direct radiation value by subtracting scattered value from general value to save related budget, which need to be get rid of.

1.1.2 Power Station Design Risks

General demand for PV power station design includes the following:

a) The power generation system of large and medium-scale ground PV power stations mainly adopt multi-level confluence, disperse contravariant and concentrated grid connection; disperse contravariant requires boosting on the spot, after which the collecting power lines loop number and voltage classes should be determined after technological and economic comparison.

b) PV module strings accessed by the same inverter should keep identical voltage, matrix orientation and installed dip angle.

c) Design voltage of PV power generation system DC side should be higher than the maximum open circuit voltage of PV module string under the local extreme temperature during daytime; while the highest permit voltage of adopted devices and materials should be no less than the designed voltage.

d) The capacity configuration of the inverter in PV power generation system should be in match with the installed capacity of the PV matrix, and maximum permit DC input power should be no less than the actual maximum DC output power of corresponding PV matrix.

e) The maximum power working voltage variation range of PV module string should be controlled inside the maximum power tracking voltage of the inverter.

f) The installed capacity of independent PV power generation systems should be determined in accordance with electric energy required by the load and local sunlight conditions.

g) PV matrix design is required to provide a convenient way for PV module surface cleaning; moreover, cleaning system or cleaning equipment is of necessity if the power stations are located in areas with poor atmospheric environment with module surface too seriously contaminated to be cleaned by itself.

PV power station design requires further improvement for many APEC developing economies. The following shows the design flaws of an existing PV power station:

1) Middle path open circuit should be adopted in long and narrow site;

2) A total of 39 matrix with 36 1MW matrix and 3 1.5 MW matrix for a 40MW project;

3) Dip angels of south and north side are different with 33° and 29° respectively;

4) Comprehensive management district is located in excessively remote area;

5) Ambiguous drawing description: failure to indicate the turning radius, distance between the path to the modules, and distance between each house.

6) Matrix layout: the inverter room can be set in the middle of the matrix for optimal wiring design.

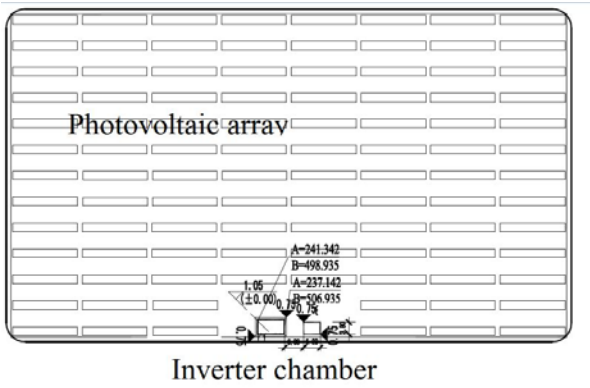

Fig.1-1PV matrix design

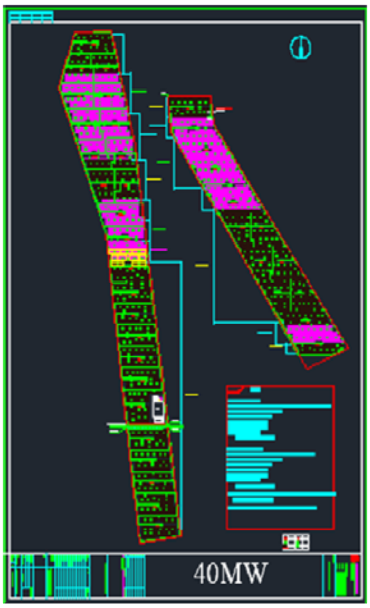

Fig.1-2PV matrix design

Errors resulted by design is hard to change or correct in later construction, operation and maintenance. In order to deal with risks triggered by design, we can adopt advanced design assistant software, enhance capability and accumulate experiences for design personnel and also organize excellent experts for design review. Problems can be solved in the preliminary stage by establishing review mechanism so as to lay a solid foundation for the following operation and maintenance.

1.1.3 Key Equipment Quality Risk

The equipment quality varies greatly in the PV market with some substandard products, resulting in the early break-down and scrap of key equipment and even leading to serious loss for power station owners. As a result, quality problems can be controlled by key equipment selection, supervision, receiving inspection and completion evaluation.

Possible quality risks for PV modules are:

Tab. 1-2 Module Quality Risk

Quality Problem	Representation	Possible Results
Cell quality problem	Cell subfissure, chromatic aberration, varied power	Decreased module power
Module welding problem	PV module dry joint, cell sealing-off	Invalid local connection of modules, lowered generation efficiency, hot spot and even fire disaster
EVA quality problem	EVA leafing and yellow-stain	Decreased module power
rear panel problem	Rear panel bump and yellow-stain	Affected module barrier property and shorter working life
Front cover glass quality problem	Front cover glass cracking	Module break-down

Besides, PV industry requires rapid technological innovation. Presently, poly-crystalline silicon plays a major role in the market with the highest cost performance and stable property. Nevertheless, PV power stations that are mainly built with crystalline modules will be threatened on the profit and economical efficiency presume more economic, efficient and mature modules or other solar utilization technologies appear and even with industrial mass production.

a) High efficiency cell technological breakthrough, such as PERC, IBC and HIT, etc. Since the technology of high efficiency cell has passed laboratory verification on its conversion efficiency, its mass production and well-controlled cost may bring upgrading risks for the existing crystalline technology.

b) Development of other thin film modules including GIGS, cdte, and gaas, etc. Improved conversion efficiency and lowered production cost of these modules may further reduce market share of crystalline modules.

c) Development of other solar utilization technologies such as solar thermal power generation technology may also bring impacts to the PV industry.

1.1.4 Power Station Construction Risk

Factors including varied construction side technology and capability, lack of personnel training and inappropriate on-site construction management may lead to risks of lower generated capacity than expected and more safety loopholes for the power station and even result in dangers for human life and property security. In the construction site of some large-scale ground PV power station, some problems may appear due to time limit or other reasons, including nonconforming bracket construction, lightening protection, wiring and equipment installation, etc. Possible results include:

Tab. 1-3 Power Station Construction Risk

Construction Risks	Presentation	Possible Results
Nonconforming bracket construction	Substandard bracket piling length and pile foundation size, poor bracket quality, etc.	Invalid bracket and inclined PV matrix and even collapse
Nonconforming lightening protection	Unreliable grounding for lightening, or connecting resistance exceeding the code requirements.	Risk of lighting stroke
Nonconforming wiring	Unreliable wiring and wiring disorder	Unreliable wiring may lead to high temperature due to increased local resistance, which may even result in fire disaster;

Construction Risks	Presentation	Possible Results
		wiring disorder may do harm to operation and maintenance.
Nonconforming equipment installation	Uneven module installation, violent construction such as stamping on modules during construction.	Reduced working life of key equipment

Power station construction risks can be prevented and managed by establishing construction code, personnel training, on-site supervision, and post-evaluation of power station, etc.

1.1.5 Power Station Operation and Maintenance Risk

PV power station converts light to electric energy by PV modules, therefore, the power generation process involves movement, friction and mechanical energy conversion apart from slight vibration, which provide an easier way of operation and maintenance than other power generation equipment of thermal power generation and wind power generation, etc.

However, lack of emphasis on operation and maintenance of PV power station may leads to a lot of problems. For example, excessively high weeds in the PV matrix may block modules, which will result in hot spots; long-term lack of cleaning of PV modules may cast impact on the light radiation the cell and reduce power generation efficiency due to accumulated dust; damages of some devices such as combiner box fusing, failure to change the fuse timely may result in break-down of the whole string and further reduce the power generation efficiency.

1.2 Policy Risks

PV policy risks frequently seen in the APEC region include two aspects: subsidy policy risk and grid connection and electricity limiting risk, each being directly related to the investment return of the PV power station project.

a) Subsidy Policy Risk

Take China as an example, at present, subsidies renewable energy including wind power, PV and biomass power all come from renewable energy development foundation, which is made by 1.5 cent renewable energy additional charges per Kwh for the power consumed apart from residential and agriculture production electricity consumption. in 2014, the general electricity consumption that requires renewable energy additional charges approximates 4.5 trillion Kwh, charging a total of RMB 67.5 billion yuan.

However, the gap for renewable energy electricity price additional funds still exists due to rapid development of renewable energy in China. By the end of 2014, there has been a subsidy gap of about RMB 20 billion yuan for the renewable energy development foundation, casting great influence on power station income because of delayed subsidy for power station owners and dramatic increase of financial costs for power stations.

b) Grid Connection and Electricity Limiting Risk

In some APEC economies especially those concentrating on large-scale ground power station for newly increased PV installed capacity, it is hard to consume all of the generated power locally due to limited local load, thus requiring long-distance transmission via the grid. However, electricity limiting risks may appear due to limited grid transmission capacity attributed to excessively fast increase of ground power station installed capacity.

In the meantime, low voltage side grid connection that mainly realized in a distributed way may result in a more complicated grid. In addition, this kind of connection is always self sufficient, which may lead to conflicted interest with the power grid company without appropriate policy coordination and further bring grid connection risks.

The above-mentioned risks can be prevented if the owner actively investigates grid connection status of the invested project to make optimal choices of areas with better transmission conditions or develop some self-sufficient distributed power generation projects.

1.3 Environment Risks

The environment of PV power station covers natural environment and cultural environment.

a) Natural Environment Risk

As is known to all, PV power stations are exposed in the open air without any protection so that natural environment factors have a great impact on their quality. For example, shaky power station foundation in dessert areas due to water shortage and wind erosion, bracket deformation in cold frozen areas due to frozen earth or high altitude and cold weather, as well as factors including winter, rainy season and mid-summer weather which will also do harm to construction quality of PV power stations.

Natural environment risks and disasters mainly refer to fire disaster, thunder and lightning, explosion, storm, flood, animal biting damage, snow pressure and hail, etc.

Fig.1-3 Heavy snow

Fig.1-4 Snow disaster

Fig.1-5 Dust contamination

Fig.1-6 Geological disaster

Fig.1-7 Fire disaster

b) Cultural Environment Risks

PV power stations may also be impacted by cultural environment.

Cultural environment mainly includes obstruction for power station construction by interested local people and physical loss and damage to power station property due to human factor, etc.

1.4 Financing Risks

Since PV industry is a capital-intensive investment industry of stable investment return and affluent cash flow, it is important for PV power station investors to have broad financing channels and low financing cost. The development of some medium and small-sized PV power station are impeded due to failure to get appropriate capital out of different reasons.

Besides, the financing issue of PV power station is also related to PV power station quality risks, defective PV power station rating system, settlement and refunding risks, non-transparent assets pricing, limited credit increasing measures, immature second-hand equipment market, low standardization level and some other factors.

1.5 Risk Responses and PV Power Station Insurance

Insurance is one of the effective means to deal with various PV power station risks. Nowadays, common PV power station insurances in the APEC region include property/machinery damage insurance, business interruption insurance, PV power station public liability insurance, and PV modules long-term quality insurance, etc, which can be applied to different stages of the PV power station:

Tab. 1-4 Risk Responses and PV Power Station Insurance

Power Station Construction Stage	Power Station Operation Stage	Specific Risk Guarantee
Direct loss insurances during the construction stage: 1. Construction/installation all risks insurance 2. Designer errors and omissions insurance Indirect loss insurances during the construction stage: 1. Expected profit loss insurance/ engineering delay insurance Contract risk insurances: 1. Engineering Letter of Indemnity 2. Engineering performance bond insurance	Direct loss insurances during the operation stage: 1. Property all risks insurance 2. Machine breakdown insurance Indirect loss insurances during the operation stage: 1. Business interruption insurance	Guarantee for insufficient solar irradiation 1. Aims to protect financial loss of the investors 2. At most 5-year guarantee Guarantee for PV power station reliability and performance 1. Based on the overall technological evaluation of the PV power station 2. Guarantee for one-year minimum generated capacity PV module long-term quality guarantee insurance

2 PV Power Station Evaluation System

PV power station development has witnessed more and more application modes including large-scale ground power station, distributed PV roof projects, PV agricultural greenhouse, fishing and PV hybrid, PV curtain wall and PV pump, etc. Some APEC economies have already organized representatives from different PV industry chains to jointly carry out researches on PV power station evaluation system.

2.1 PV Power Station Evaluation Modules

PV power station evaluation system is divided into 4 modules in this report:

a) Subject Evaluation: management level and construction subject, general situation of power station and electricity consumers, etc

b) Technology Evaluation: equipment, design, construction, operation and maintenance, etc.

c) Investment environment evaluation: industry policy, market demand, supporting and consumption, etc.

d) Financial Evaluation: net cash flow, inner rate of return and credit increasing, etc.

2.2 Trusolar PV Power Station Evaluation System

Trusolar™ is an industry-established, accessible, standard credit screen for commercial and industrial (C&I) photovoltaic (PV) project selection, underwriting and approval. The trusolar™ credit screen provides a comprehensive assessment of risks – including project, system, construction, performance and financing– from development to long-term operation.

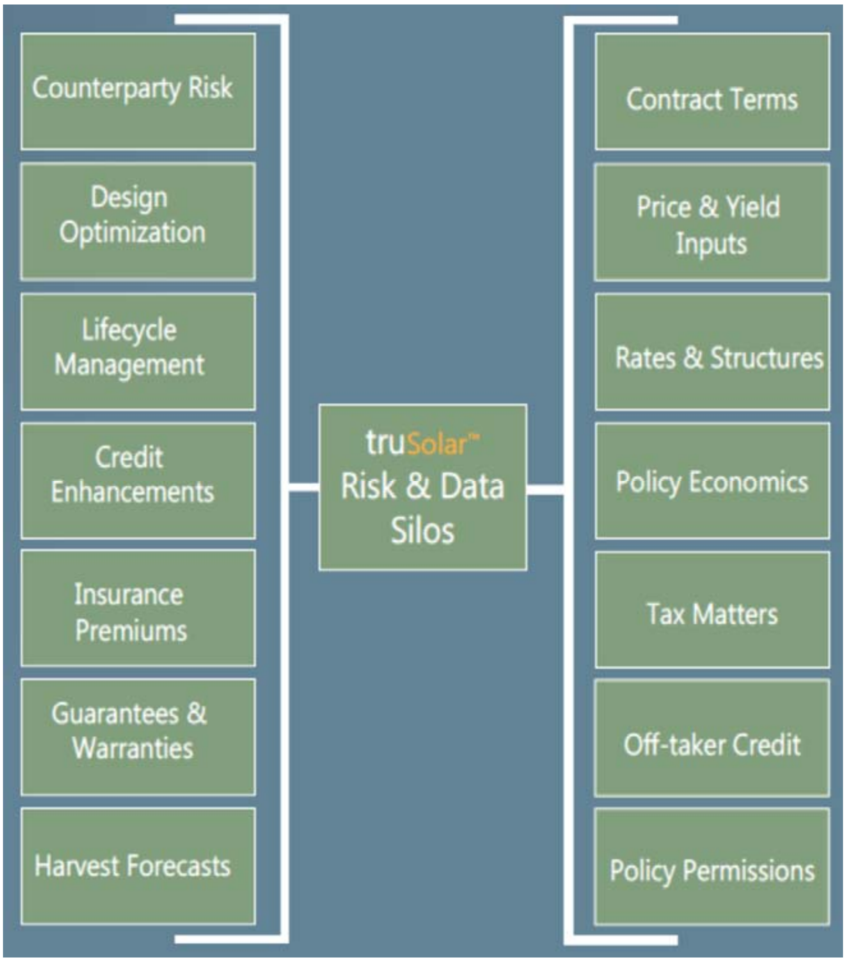

Fig.2-1 Trusolar system

Trusolar system classifies the 14 aspects of PV power stations, including Counterparty Risk\Design Optimization\Life-cycle Management\Credit Enhancements\Insurance Premiums\Guarantees&Warranties\Harvest Forecasts\Contract Terms\Price &Yield Inputs\Rates&Structures\Policy Economics\Tax Matters\Off-taker Credit\Policy Permissions.

The trusolar Working Group has developed a comprehensive Risk Screen Criteria and Methodology (RSCM) that evaluates approximately 850 unique risk elements for commercial and industrial solar projects in the United States. The trusolar RSCM is organized into a hierarchy that is used to unbundle and analyze project risk elements before scores and their associated weighting are applied. The RSCM's unique ability to precisely articulate exactly which aspects of a solar project are most at risk allows users to pinpoint areas for improvement and implement the necessary changes to maximize the likelihood of securing project financing.

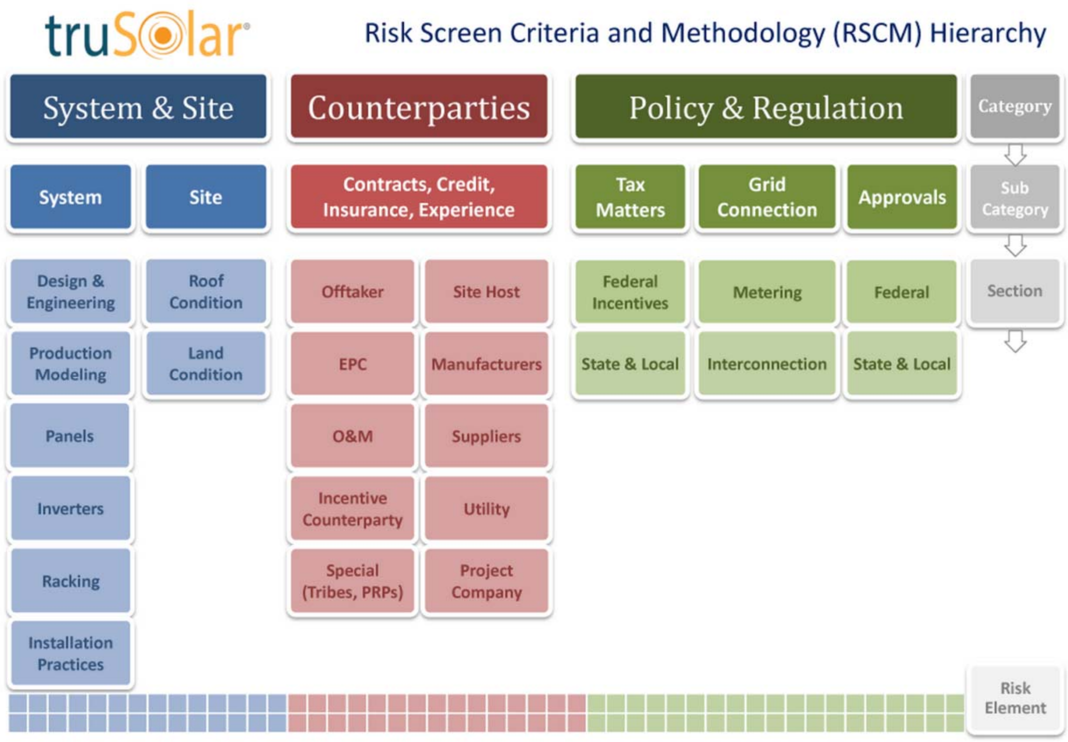

Fig.2-2Trusolar Risk Screen Criteria and Methodology(RSCM) Hierachy

3 PV Power Station Subject Evaluation

PV power station subject evaluation covers evaluation of power station management and construction subjects, the power station itself and electricity consumption subjects.

3.1 PV Power Station Management Level and Construction Subject

Evaluation of PV power station management and construction subjects mainly focuses on their professional background, knowledge structure, operation and management ability (including qualification, experiences, capability and performance, etc), including the following aspects:

a) General situation of the enterprise: registered capital, enterprise type, employees number, total assets and administrators, etc.

b) Industry qualification: whether the enterprise has obtained the access qualification and its level.

c) Industry experiences: including number of years in the industry and installed power station capacity scale, etc.

d) Market share: market share occupied the enterprise in manufacturing side or power station side.

e) Credit record: credit status and record of the enterprise in banks and other financial institutions.

f) Profitability evaluation: advantages of the its technology, stability of purchasing sales channel as well as income and gross profit of. the power station, etc

3.2 General Situation of PV Power Station

Core examination goes to conditions and foundations for project proposal with retrospective analysis on various important conditions including site selection, solar energy evaluation, generated capacity forecast and grid connection access. In addition, analysis of the influence of accuracy level and deviation of preliminary forecast on later period of the project by reviewing forecast and analysis of each important proposal conditions with comparison of practical situation after production.

Detailed contents are: PV power station name, reasonability of site selection (ground flatness, land price, construction difficulty, access condition, clear property right, building structure (brick and concrete, frame), roof status (concrete, color steel tile), roof life should be taken into consideration if roof is selected for distributed PV), power station generated capacity (power station capacity, system efficiency, solar energy testing (uninterrupted measured solar irradiation data for one year at project site or site-representative place by on-site photometry and satellite photometry and related solar energy evaluation result according to one year), climate condition (frequency of typhoon, snow pressure, hail, flood, earthquake, mud flow, thunder stroke and haze, etc), affiliation, feasibility research report and PV power station permit application, travel permit, project approval record and related official documents.

3.3 Electricity Consumption Subject Evaluation

For distributed projects, electricity consumption subject evaluation mainly means to analyze the subject’s contract compliance via evaluating its credit level and financial status, making sure whether contract breach due to electricity fee default and delayed electricity fee settlement will happen.

4 PV Power Station Technical Evaluation

Technical evaluation of PV power station covers the following aspects:

4.1 PV Power Station Site Selection

Local geological environment and surrounding conditions should be researched during the site section period of PV power station construction. Take large-scale ground power station as an example, PV power station should not be constructed on seismically active zones, river bed, valleys frequented by mud flow and other areas with bad natural conditions. In addition, the status of blocking should be taken into consideration so as to guarantee no blocking appears in the PV power station construction site from 9 O'clock am to 5 O'clock pm of local time. Moreover, grid connection point and conditions for local consumption should also be included to evaluate local solar energy and calculate economic efficiency of the project.

Take roof power station as an example, load capacity of the roof should be evaluated during the preliminary work of its construction to ensure utilization and safety of existing buildings will not be impacted. Besides, long-range planning of surrounding buildings should also be considered to prevent too many planned projects which will block or affect normal operation of the PV power station.

4.2 PV Power Station Feasibility Research

The feasibility research period requires clear presentation of equipment selection, site condition, engineering task and scale, general scheme design of the system, preliminary and secondary electric project, communication project, building project, engineering fire safety, construction organization, engineering management, engineering transportation, energy conservation and emission reduction, financial evaluation and social effect analysis, etc to provide comparatively reasonable guiding advises.

4.3 Code Compliance of Preliminary Work

Each stage of preliminary work should be evaluates regarding the compliance of related management regulations of each economy on PV power station construction. For example, at least the following documents should be examined according to realted management methods and regulations of China:

—National or local Bureau of Land Management: construction project site selection permission notes, project site approval opinion

—National or local Development and Reform Commission: project approval material

—Grid company: gird access approval opinion

—Environment protection department: environment evaluation report approval opinion

—Project feasibility research report

—Financing commitment document of project loan allowance by financial institutions

—Construction load evaluation report by building design side should be examined if the PV power station is to be installed on the roof

—Other approval documents should be evaluated according to related regulations for specific PV power generation projects such as concession biding project, Golden-sun demonstration project and building integrated photovoltaic project.

4.4 Equipment Selection

PV equipment evaluation aims to carry out analysis of various risks regarding technology, quality and performance, production manufacturing and operation existed for equipment including modules, combiner box and inverter, etc appointed in the planned grid connection PV power station contract.

PV equipment evaluation mainly covers modules of equipment manufacturer evaluation, key components and parts evaluation, production examination capability evaluation and past operation evaluation as is showed in the following.

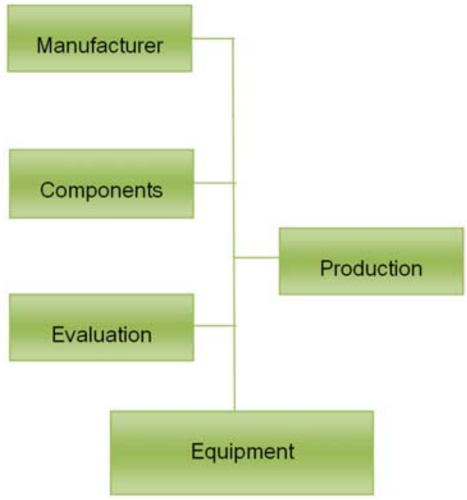

Fig.4-1 PV Equipment Evaluation Modules

a) Equipment Manufacturer Evaluation

Equipment manufacturer evaluation refers to analysis regarding general situation, technological level and market share of the enterprise, evaluating potential risks generally.

b) Key Components and Parts Evaluation

Key components and parts evaluation gives a general evaluation of possible risks by analyzing the general situation, product performance and products application of key components and parts enterprises.

c) Production Examination Capability Evaluation

Production examination capability evaluation covers the generally evaluation of potential dangers via analysis of producing equipment, examination equipment, technique control, technology level of operating personnel and other aspects.

d) Past Operation Evaluation

Past operation evaluation analyzes past operation status of appointed equipment in the purchasing contract to come up with general evaluation of potential risks.

e) Key Points of Equipment Selection

PV modules key equipment selection requires comprehensive consideration of local resource conditions, surrounding geographical environment, project site constraints and owner demand, etc for matching and differentiated selection of key equipment, focusing mainly on differentiated selection of modules, inverter, bracket, wire cable and other key equipment.

PID tolerance features of modules should be considered when used in high temperature and humidity environment; anti-ammonia gas experiment in alkaline environment should be carried out for module testing when used around animal husbandry; and differentiated selection are required for high-mechanical strength modules applied in BIPV.

Heat dissipation modules should be added for inverter application in the plateau, and small-scale inverter is recommended for environment surrounded by a lot of blocking items.

Bracket selection varies with soil texture, loading conditions, corrosion degree and other factors. For example, zinc coating of the bracket should be strengthened in gobidessert to improve its corrosion resistance; mechanical loading density should be enhanced in places with drought, heavy rain or snow to ensure safety of the entire system; and aluminum alloy post is recommended in places of weak roof loading contributed to its light weight and high intensity.

Cable selection is made according to different equipment and territories. For example, since the short circuit current of thin film modules is less than that of crystalline modules, thin film modules cable can be thinner compared to that of crystalline modules; cold-resistant cables are recommended in environment with temperature less than 15℃ below zero; armored cable should be used if direct burial method is adopted.

4.5 PV Power Station Design and Construction

PV power station design and construction evaluation includes:

a) Comparison of commencement and completion time of construction project and all major individual and unit projects with construction organization design progress plan to evaluate project plan management, construction period control and measure implementation and analyze major reasons and influences of related changes.

b) Evaluation of project quality guarantee system, safeguard measures and project quality completion status as well as existing problems and corresponding result.

c) Evaluating major quantities completed by the project so as to analyze reasons and estimate the rationality for large divergences appeared according to the designed quantity.

d) Engineering construction capital source, in place, use control status and corresponding influences.

e) Construction drawing design situation including optimal design during implementation process of the project, major design changes and reasons as well as corresponding influences on construction period and cost.

f) Related evaluation on adoption of new construction technology, new materials, new techniques and research achievements.

g) Construction observation (supervision) evaluation including compliance of qualification and level of construction observation (supervision) organization, formulation of detailed observation outline, implementation plan and guarantee measures, evaluation of concrete execution status and practical effect of observation to come up with improvement advises for similar projects.

h) Evaluation of legal compliance and validity, completeness and effectiveness of project management system, including contract management, quality management, cost management, resources management, progress management, documents and information management and to indicate existing problems and major experiences and lessons.

4.5.1 PV Power Station Key Design Points

Key design points of PV power station include:

a) General View

Presenting detailed geographical location, surrounding environment, general layout of matrix, basic position of transformer substation and peripheral roads planning of project site so as to ensure reasonability and optimality of the project

b) Electric

The voltage grade of PV power station access to grid connection should be in accordance with practical situation of PV power station capacity and power grid and be decided after technical and economic comparison in the access system design. In addition, electric energy provided to local alternating load as well as quality of electric energy to the power grid by the PV power station should satisfy electric energy quality requirements of public power grid. PV power station should be equipped with corresponding relaying protection function. Large and medium scale PV power station is required to have data communication function with power dispatching department and the communication system of both sides of grid connection should cater to the safe and economic operation demand of power grid on electrical power telecommunication. Moreover, detailed single phase and three-phase short circuit current calculation result table should be made accordingly.

c) Civil Engineering and Structure

PV power generation system structure layout should be in line with the general layout requirements, site geological condition, equipment type, power supply inlet direction, external traffic as well as conditions which are favorable to site construction, equipment installation and maintenance and project management. According to economic comparison, extension space should be planned for building design. As for BIPV, PV modules type, installation location, installation method and color should be selected according to building function, appearance and surrounding environmental conditions to be an organic part of the building. Moreover, the building design should provide bearing conditions and spaces or PV module installation, application and maintenance.

While adding PV power generation system to existing buildings, reliability evaluation should be carried out according to related regulations. In addition, anti-earthquake evaluation is required in accordance with related regulations as for its design intensity, earthquake fortification type, durable years and structural type for buildings in areas with earthquake fortification intensity of 6 to 9 degree. Buildings required for seismic hardening by anti-earthquake evaluation should be constructed according to regulated design. Moreover, measures to prevent animal destruction such as snake and mouse should be taken in electric rooms.

As for buildings with PV power generation system, its planning and design should be in line with geography, climate conditions, building function and surrounding environment of the planned site and thus deciding its architectural composition, orientation, separation distance, group combination and space environment. Besides, the planning should cater to technical requirements of PV power generation system designing and installation.

The building design should provide favorable conditions for installation, utilization and maintenance of PV power generation system and safety protection measures should be taken in the parts installed with PV modules. Electric shock warning labels should be used in positions with PV power generation system accessible for people. Moreover, the installation position of PV modules should be planned reasonably so that the building and it surrounding environmental landscape and green planting will not block sunlight projected to the PV modules.

The location of all constituent parts of PV power generation system inside the building should satisfy requirements on waterproofing, drainage, heat preservation and thermal insulation of that location as well as system maintenance, overhauling and update. While establishing building envelop structure directly with PV modules, the PV modules should not only be combined to the building organically and surrounding environment harmoniously, but also cater to requirements of their locations on structural safety and building enclosure function.

PV modules should not be installed across the building deformation joint. BIPV modules should be constructed and installed with aeration cooling measures. It is recommended to design artificial snow melting and clearing exit passageways while PV modules are to be installed on roof of building located in snowy districts. As for those to be installed on waterproof layer of roof, it is required to add waterproof layer at the bottom of the bracket base if there is not protective layer for the waterproof layer. Water string is required to be buried in advance on the spot crossed by lead of the PV modules with waterproof sealing measures, and it should be buried before construction of roof waterproof layer.

4.5.2 PV Power Station Construction Key Points

Key points of PV power station construction include:

Site construction of PV power station requires standard construction in line with related technological code with construction observation as well as supervision on construction quality, consistency and timeliness. Moreover, construction process and order should be under strict control regarding each link of construction including field engineering, orderly entry of equipment, infrastructure construction and equipment installation, etc so as to guarantee consistency of construction quality with preliminary designing plan.

a) Conditions required before construction

- Related approval process of construction unit before commencement of construction.
- Completed examination of construction unit qualification, specific operating personnel qualification, construction machinery, construction materials and measuring instruments, etc.
- Joint hearing of construction drawing.
- Arrangement of temporary building facilities according to general construction arrangement plan by the construction unit.
- Required conditions for engineering positioning survey.

b) Construction Requirements

- Construction prohibited for outdoor working during days of heavy wind higher than grade 5.
- Construction prohibited in atrocious weather of rain, heavy snow, heavy fog and sand storm, etc.
- Construction prohibited without satisfactory illumination for night working.

c) Construction Advises

- Equipment and material type should be in compliance with design requirements with unverified and unqualified equipment and materials strictly prohibited during construction.
- Out of box audit of equipment to ensure a full line of specification including certificated of inspection, specification, test record, accessory and replacement parts.
- Transportation and storage of equipment and materials should be in line with the code requirements and specific demand should be satisfied to cater to specific regulation of products requirements.
- Intermediate inspection and acceptance record should be provided before commencement of concealed work.
- A complete range of construction record and construction trial sheet.

d) Preparation for Construction

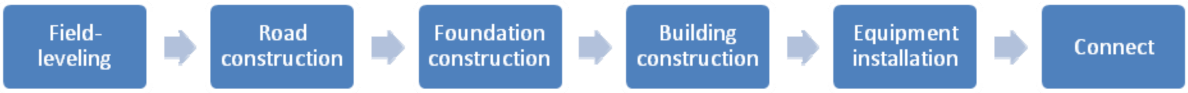

Fig.4-2 Preparation for Construction

e) Principle and Basis for Construction Site Arrangement

- Transportation should be arranged reasonably according to practical situation of construction to ensure an unimpeded transportation corridor; construction conditions are required to be optimized with less rehandling of construction materials for convenient utilization and better economic effect.
- To divide construction regions in line with construction flow under conditions of reasonable arrangement and comprehensive consideration, so that interference between different domains and occupation can be reduced for more convenient management.
- To improve all construction technological and economic indicators so as enhance land utilization efficiency and reduce construction land under premise of safe construction and fire protection.

f) Construction Region Divisin

Lack of temporary construction land on construction site requires more on the general construction layout, which according to practical situation of site, can divide construction site into regions of living, office, concrete mixing, material processing and storage, steel template processing and storage as well as warehouse, etc.

4.6 PV Power Station Acceptance Inspection

PV power station acceptance inspection provides an opportunity to check operation status of equipment, via which spot inspection of key equipment can show their performance and consistency. Examination of the system construction status, system safety and overall performance enables a comprehensive judgment of the project quality.

Evaluation of PV power station acceptance inspection covers:

1） Evaluation of process and result of final acceptance of the project.

2）Evaluation of basic situation and conclusion of each stage acceptance of single event, unit and subproject of the construction, as well as the existing problems, treatment suggestion and execution status of the construction unit to the treatment suggestion.

3） Project quality assessment by project quality supervision unit.

4） Final acceptance of the project requires examination on PV modules power, PV string current, string consistency, PV matrix nominal power, inverter efficiency, system electric efficiency, electric energy quality, PV matrix insulation resistance, protector and equipotential body connection, etc.

Tab. 4-1 Project Examination Result Summary Sheet

No.	Test Items	Analysis and Specification	Testing Result	Qualification Evaluation Standards	Remarks
1	IR scan	Hot spot modules		Analyzing hot spot reason according to testing results	
2	Average dirt retention of PV string	Average value of all tested string dirt retention		May be no more than 5% according to power station set point	
3	Temperature increase and loss of PV string	Average value of all tested string temperature increase and loss		Evaluating thermal dissipation conditions according to the testing result	
4	Average power decrease of PV modules	Module type 1		Based on contract agreement or specifications of MIIT: (9.5 joints)mono-crystalline module within 1 year ≤3.0%; poly-crystalline module ≤2.5%; thin film module ≤5.0%	
		Module type 2			
		Module type 3			
5	EL scan	Subfissure modules		Analyze subfissure reasons in accordance with test results	
6	Module bypass diode testing	Diode malfunction		Analyzing malfunction and its portion in line with test results	
7	Average	Module - string		3rd phase mismatch loss	

No.	Test Items	Analysis and Specification	Testing Result	Qualification Evaluation Standards	Remarks
	mismatch loss of integrated inverter series and parallel connection	String –combiner box		≤5%	
		Combiner box - inverter			
	Average mismatch loss of string inverter series and parallel connection	Module - string		2nd phase mismatch loss ≤3%	
		String – inverter			
8	Direct current line loss of integrated inverter PV system	String formation close, medium and far away average		2nd phase direct current line loss ≤3%	
		Combiner box close, medium and far away average			
	Direct current line loss of string inverter PV system	String close, medium and far away average		≤1.5%	
9	PV matrix blocking loss	Measuring matrix dip angle and distance		Based on design principle of GB/T50797-2012	
10	Average line loss of integrated inverter alternative current	Inverter – transformer		2nd phase alternative line loss ≤ 3%	
		close, medium and far away average			
		Transformer – grid connection point			
		close, medium and far away average			
	Average line loss of string	Inverter – alternative		2nd phase alternative line loss ≤ 3%	

No.	Test Items	Analysis and Specification	Testing Result	Qualification Evaluation Standards	Remarks
	inverter alternative current	current combiner box			
		close, medium and far away average			
		Alternative combiner box – transformer			
		close, medium and far away average			
		Transformer – grid connection point		AC line loss ≤ 1.5%	
		close, medium and far away average			
11	Inverter weighting efficiency	Weighting efficiency of regions with specific climate		≥ 96%	
12	Inverter MPPT tracking accuracy			≥ 98%	Optional
13	Transformer weighting efficiency	Weighting efficiency of regions with specific climate		≥ 98%	
14	PV matrix insulation resistance test	Positive pole to the ground (≥120V)		≥ 1MΩ	
		Negative pole to the ground (≥120V)		≥ 1MΩ	
		Positive and negative pole short circuit to the ground (≥120V)		≥ 1MΩ	
15	Ground	Maximum		≤ 100mΩ	

No.	Test Items	Analysis and Specification	Testing Result	Qualification Evaluation Standards	Remarks
	connection consistency test	resistance value between matrix			
		Maximum resistance value between matrix and combiner box			
		Maximum resistance value between matrix and control room ground connection side			
		Ground connection resistance at combiner ground connection point		＜ 4 Ω	
16	Electric power quality at grid connection point	Average voltage deviation		≤ 20kv：± 7% ≥ 35kv：± 10%	
		Average frequency deviation		± 0.5 Hz	
		General harmonic current distortion		General harmonic current distortion should be less than 5% of inverter rated output current	
		Three-phase unbalance		Negative sequence voltage unbalance at public connection point should be no more than 2% and 4% in short term	
		Direct current component		≤ 0.5 %	
17	Active/reactive power control ability			In compliance with GB/T19964-2012 requirements	Optional
18	Islanding protection	Input voltage grade		In compliance with GB/T29319-2012 requirements	Optional

No.	Test Items	Analysis and Specification	Testing Result	Qualification Evaluation Standards	Remarks
19	Low voltage ride through	Input voltage grade		In compliance with GB/T19964-2012 requirements	Optional
20	Voltage/ frequency adaptability testing			In compliance with GB/T19964-2012 requirements	Optional
21	Power station performance ratio	Evaluation period		Analyze reasons of high or low figure according to practical data	
22	Power station standard performance ratio	Evaluation period		Analyze reasons of high or low figure according to practical data	
23	Sample inverter 1 performance ratio	Evaluation period		Analyze reasons of high or low figure according to practical data	
24	Sample inverter 2 performance ratio	Evaluation period		Analyze reasons of high or low figure according to practical data	
25	Sample inverter 3 performance ratio	Evaluation period		Analyze reasons of high or low figure according to practical data	

5）Analysis and comparison of approved investment on stages including PV project pre-feasibility research, feasibility research (preliminary design) and final settlement, stating reasons for overspend or surplus and evaluating investment controlling status.

6）Auditing opinions to the project by auditing department.

7）Major conclusion opinions regarding the final acceptance of the project.

4.7 PV Power Station Operation and Maintenance

Operation and maintenance of PV power station requires comprehensive judgment regarding operation manual, operation and maintenance tools, operation and maintenance personnel as well as monitoring system, etc of each assignment.

1) Operation and maintenance materials are:

- PV power station safety manual,
- PV system on and off operation specifications,
- Monitoring system operation specifications,
- PV modules and bracket operation and maintenance standard operation procedure,
- PV combiner box operation and maintenance standard operation procedure,
- Direct current distribution box operation and maintenance standard operation procedure,
- Inverter operation and maintenance standard operation procedure,
- Alternative current distribution box operation and maintenance standard operation procedure,
- Transformer operation and maintenance standard operation procedure,
- Breaker operation and maintenance standard operation procedure,
- Disconnector operation and maintenance standard operation procedure,
- Generatrix operation and maintenance standard operation procedure,
- Lightening arrester operation and maintenance standard operation procedure,
- Electric reactor operation and maintenance standard operation procedure,
- PV power station safety protection instrument operation and maintenance standard operation procedure.

2) Regular Examination and Maintenance of PV Modules

Regular examination on the following aspects should be carried out for timely repairing:

- Module frame deformation,
- Severe glass scratch and damage,
- Cell damage, subfissure and hot spot, etc.,
- PV module surface bubble, EVA leafing, water vapor and obvious discolaration,
- Rear panel scratch, glue failure, bump and bubble;
- Junction box plastic deformation, warping, cracking, aging and burning down,

- Unreliable conductor jointing and wire damage,
- Wire conduit damage,
- Uneven nameplate and ambiguous typeface,
- Lack of electric shock warning labels on PV modules,
- Substandard connection of frame and supporting structure for PV modules with metal frame ground connection and their contact resistance higher than 4Ω,
- Other flaws.

3) Regular Examination and Maintenance of PV Matrix Bracket

Regular examination on the following aspects should be carried out for timely repairing:

- PV matrix deformation, malposition and looseness,
- Force support component, jointing element and connecting bolt damage, looseness, welding line break,
- The erosion resistant coating of mental materials should be complete without pealing-off or corrosion,
- The prefabricated base PV matrix should be steady and in order without being moved,
- Satisfactory connection of equipotential connecting line of matrix holder without looseness and erosion,
- Reliable PV matrix ground connection with each ground connecting electric resistance no more than 4Ω,
- Other flaws to be examined and repaired.

4) Regular Examination and Maintenance of Combiner box

Combiner box structure as well as equipment cabinet workmanship, main circuit connection as well as secondary line and electric component installation should be in line with the following requirements and related problems should be timely repaired:

- Related components and parts for rack installation should satisfy their respective technical requirements;
- Strong box with smooth and flat surface without pealing-off, erosion and cracking;
- Solid box installation, steady and smooth elements jointing, connecting bolts

without damage and looseness as well as reliable welding line;

- Satisfactory box encapsulation with protection level conformism to design requirements;
- Erosion and dust stratification inside the box should be prevented;
- Flat pannel with clear characters and symbols;
- Clear and complete nameplates, warning labels and signs;
- Normal status of all components and parts without damage;
- Flexible and reliable on-off operation;
- Reliable connectors without traces of charring, fusing and damage;
- Generatrix and ground connection line in good condition;
- Fuse type inside the combiner box should be valid and conforming to the design requirements;
- Surge protective devices inside the combiner box should be valid and conforming to the design requirements;
- Combiner box made of non-insulation materials case should be connected to the ground with ground connection resistance no more than 4Ω;
- Other flaws to be examined and repaired.

5) Regular Examination and Maintenance of Inverter

Inverter structure as well as equipment cabinet workmanship, main circuit connection as well as secondary line and electric component installation should be in line with the following requirements and related problems should be timely repaired:

- Related components and parts for rack installation should satisfy their respective technical requirements;
- Strong box with smooth and flat surface without pealing-off, erosion and cracking;
- Solid box installation, steady and smooth elements jointing, connecting bolts without damage and looseness as well as reliable welding line;
- Satisfactory box encapsulation with protection level conforming to design requirements;
- Erosion and dust stratification inside the box should be prevented;
- Flat pannel with clear characters and symbols;

- Clear and complete nameplates, warning labels and signs;
- Normal status of all components and parts without damage;
- Flexible and reliable on-off operation;
- Reliable connectors without traces of charring, fusing and damage;
- Generatrix and ground connection line in good condition;
- Fuse type inside the combiner box should be valid and conforming to the design requirements;
- Surge protective devices inside the combiner box should be valid and conforming to the design requirements;
- Inverter should be reliably connected to the ground with ground connection resistance no more than 4Ω;
- Other flaws to be examined and repaired.

6) Regular Examination and Maintenance of Transformer

Problems of major loop boosting transformer of PV power station should be repaired in time:

- Related components and parts for rack installation should satisfy their respective technical requirements;
- Strong box with smooth and flat surface without pealing-off, erosion and cracking;
- Excessive dust should be prevented on surface of transformer and each connector of the insulator;
- Reliable connectors without traces of charring, fusing and damage;
- Status of each genetraix and ground connection lines of transformer should be examined;
- Working voice of transformer should be with the required range;
- Clear and complete nameplates, warning labels and signs;
- Transformer should be connected to the ground with the ground connection resistance no more than 4Ω;
- Other flaws to be examined and repaired.

7) Power Station Data Collection

The operation status of each key equipment of the power station requires real-time monitoring to ensure comprehensiveness, consistency and accuracy of essential data.

As for unattended power station, uninterrupted monitoring all day long should be guaranteed by power station operation and maintenance company so that failure warning can be received with timely repairing.

4.8 Power Station Real-time Monitoring System

The real-time monitoring system of PV power station should satisfy the function of data collection and ensure comprehensiveness, steadiness, security and accuracy of collected data.

Data comprehensiveness requires full-scale monitoring of environment for the PV power station, including wind direction and speed, environment temperature and humidity, rear panel temperature, gross irradiation energy of the dip angle, and if possible, gross irradiation monitoring of direct irradiation, scattered irradiation and irradiation on horizontal surface. In addition, as for some distributed PV power station, related equipment for aerosol condensation test and cloud cover test should be installed in case of influences of various climate conditions on the power generating efficiency of PV power station. Moreover, apart from a full range of environment monitoring devices, real-time monitoring should also be carried out on the electric meter and inverter and if possible, even on the combiner box, high and low voltage distribution cabinet as well as operating status of modules.

Data steadiness mainly refers to stable and consistent data transmission during parallel transmission of various PV power station data, with timely data replacement for data loss on rare occasions via identification of the system itself as well as on-site inspection for continuous data loss by staff after timely warning. For large-scale ground power station in remote areas especially, overall optimal design is required to ensure effective and stable data transmission. Local monitoring is essential with long-distance transmission realized by other means. Considering data is the major means for PV power station development, stable data plays as a basic requirement for analysis of power station security and performance.

As for data security, since PV power generation belongs to the electric industry, the security and stableness of which is closely related to the safety of people's livelihood, thus requiring encryption of electric power data. Besides, as the only proof for settlement of PV power station electric charge income, PV power station generated power measurement data is under high demand for security to prevent impact on direct income of PV power generation.

Data accuracy requires teamwork of on-site personnel due to various environment of PV power stations such as remote gobidessert or crowding downtown area. Considering different operation and maintenance methods for equipment of PV power stations in different environment, the most direct measure for data accuracy is equipment maintenance and routing inspection.

5 PV Power Station Investment Evaluation

PV power station investment evaluation covers the following aspects:

5.1 Industry Policy

From the aspect of PV power station investment environment, establishment of a PV power station is decided by compliance of industry policy on the one hand and market demand on the other. As a result, it is required to judge whether the invested PV power station is in line with policy requirements of the related economy it locates, the implementation of related subsidy policy as well execution of grid connection rules and regulation.

Currently, the grid connection electricity price of PV power station has subsidy in some APEC economies. Take China as an example, there are two ways of subsidy for PV power station, one is benchmark electricity price for unified grid connection in three kind of areas, with the part of desulfuration benchmark electricity price purchased and paid by local grid and other part receiving subsidy from renewable energy foundation; the other is distributed electricity price subsidy, by which RMB 0.42 yuan/kwh subsidy is provided by renewable energy foundation based on user side electricity price.

5.2 Market Demand

Market demand evaluation focuses on analysis of market demand compliance of generated power, quality and type of the PV power station as well as its competitive capability. Generally, electricity consumption demand, social purchasing power, electricity supply and power generating status of similar power stations are to be investigated so as to provide forecast evaluation on future supply and consumption of PV power station, thus deciding the necessity to construct a PV power station. In addition, relations between PV power generation and hybrid electric power as well as replacement electric power should be taken into consideration. In conclusion, electricity consumption analysis of the electric power of PV power stations should be carried out based on principles of nearby access and local consumption regarding long distance transportation, discarding PV power and electricity supply limit as well as line loss and other losses.

5.3 Electricity Access Situation

PV power station grid connection access should be mainly evaluated regarding supporting grid plans (local grid plan) and construction status, coordination with grid enterprises for better supporting electricity delivery project (output path, access point distance and capacity status), grid condition in the plant (input voltage grade, transformer quality and capacity), electricity consumption weighting average electricity price and unified electricity grid connection. For example, with advanced technologies such as smart grid, output of PV power generation can be improved by enhancing the capability of grid acceptance of PV power generation.

6 PV power station Financial Evaluation

Financial evaluation of PV power station should be in line with the fiscal and taxation system of related economies the PV power station locates, calculating direct financial benefit and cost of PV power station to measure evaluation indicators via compiling and analysis of certain financial statement in order to investigate the profitability, liquidity and foreign exchange equilibrium, thus judging the financial feasibility of the PV power station.

6.1 Net Present Value

Net present value is the sum of present value calculated by discounting the net cash flow of each year within the PV power station working life to the preliminary stage of construction (i.e. the benchmark year) according to industry base earning ratio or set discount rate. Positive net present value means higher ROI than base earnings ratio or set discount ratio, while negative net present value means lower ROI than base earnings ratio or set discount ratio. Practical calculation is generally carried out by adding 1% to 2% RPN to comprehensive weighting average capital cost of the PV power station or bank loan interest rate as the base earning ratio.

Cash inflow includes electric charge income (PV grid connection electric price constitutes desulfuration coal-fired power generation electricity price and government subsidy price), fixed assets recycling balance, subsidy and working capital recycling, etc.

Cash outflow covers fixed assets investment, working capital, operation cost (total cost – depreciation amortization – interest, rent, insurance cost, guarantee fee (if included), taxes (sales tax and income tax), etc.

Specific conditions of APEC economies should be taken into consideration for calculation, including but not limited to the following boundary conditions: annual effective utilization power generation hours, annual system attenuation rate, power transmission or consumption percentage, working capital proportion, loan proportion, loan interest rate, loan years, grid connection electricity price (FIT, distributed power consumption electricity price and government subsidy), electric charge gain of distributed electricity price, preliminary government investment and subsidy, subsidy year, operation and maintenance personnel quantity, operation and maintenance equipment, cost for regular change of electric equipment, residual value, depreciation life, insurance cost, added-value tax, income tax, sales tax and additional tax, inflation rate and discount rate, etc.

6.2 IRR Evaluation

Internal rate of return refers to the discount rate when the total present value of capital inflow is equal to that of capital outflow and nee present value is zero. As interest rate return expected by an investment, the higher IRR is, the better. Generally, a project is feasible when IRR is higher than base earning ratio.

Sum of the discounted value of each year cash flow of a invested project is its net present value, while its IRR is the discount rate when net present value stays at zero.

6.3 PV Power Station Financial Evaluation Model

Sensitivity analysis of PV power station to all indicators covers power generating hours, IRR, investment recovery year, loan proportion and loan interest rate, etc.

1) Economic Calculation

Distributed PV power station project earnings can be calculated by statistic analysis of different light conditions, installed capacity, electricity price, self-sufficient ratio, equipment cost, financing limit, financing interest rate and financing maturity, etc.

Basic analysis principle of financial cash flow is stated as follows:

Tab. 6-1 Basic analysis principle of financial cash flow

Cash flow = sales income – (operation cost + loan amount + loan interest rate + added value tax + sales tax and additional tax + income tax)

Added value tax = sales income/(1 + added value tax rate) × added value tax rate

Sales tax and additional tax = added value tax × sales tax and additional tax rate

Income tax = (sales income – operation cost – loan interest – added value tax – sales tax and additional tax – depreciation) × income tax rate

Sales income = grid connection

electricity price (including added value tax)

× power supply volume

Constant payment mortgage = loan amount + loan interest

Note: sales tax and additional tax includes urban construction and maintenance and education, etc; constant payment mortgage return each installment of the loan based on fixed interest rate and equal amount installment payment.

2) Risk Calculation

Risk calculation includes three aspects as power station risk factors, contract risk factors and user risk factors. Data of each indicators related should be collected for evaluation and grading after responsible investigation, thus coming up with the total grade of risk calculation.

a) Power Station Risk Factors

Power station risk factors calculation covers five parts: light resources, site selection, performance (once completed), equipment, operation and maintenance.

- Light resources indicator includes four sub-indexes: data source, annual equivalent sunshine hours, local air contamination index, surrounding possible air or dust pollution source.
- Indicator site selection covers roof surface, live load, roof type, roof orientation, superior transformer capacity, annual enterprise electricity consumption volume, enterprise TOU electricity price, local TOU electricity price, enterprise load power, power limit situation and construction condition, etc.
- Performance (tested once completed), power station efficiency, annual power generating hours, power station inspection report.
- Equipment referred includes modules, inverter, combiner box, online power station testing system and other equipment.
- Operation and maintenance covers operation and maintenance personnel, monitoring system, operation and maintenance system, operation and maintenance effect evaluation, operation and maintenance statement.

b) Contract Risk Factors

Contract risk factors consist of energy management contracting agreement, roof renting agreement, power purchasing and selling agreement, general contract, design contract, supervision contract and insurance contract.

- Two sub-indicators under energy management contracting agreement are signature of agreement and settlement electricity price. The higher settlement electricity price, the higher the grade.
- Roof rent agreement has two sub-indicators as signature of agreement and renting term, the longer the term, the higher the grade.
- Electricity purchasing and selling agreement has one sub-indicator as signature of agreement.
- The general contract has three sub-indicators as EPC enterprise qualification, industry experiences as well as EPC power generation promise.
- The design contact has one sub-indicator as power design qualification, the better the qualification, the higher the grade.
- The monitoring contract has one sub-indicator as engineering monitoring qualification, the better the qualification, the higher the grade.
- The insurance contract consists of five sub-indicators as construction installation and engineering all-risk insurance, property insurance, public liability insurance, 25-year quality insurance and business interruption insurance.

c) User Risk Factors

User risk factors indicator covers basic enterprise information, basic information of actual enterprise controller, enterprise competitiveness capability, profitability evaluation and growth assessment.

- Basic enterprise information includes enterprise life cycle judgment, social reputation and information transparency;
- Basic information of actual enterprise controller covers industry experiences of actual controller, his bank credit record, qualification, and marriage status.
- Enterprise competitiveness capability includes sales channel, purchasing channel and production technology.
- Profitability means gross profit rate and business income taxing.

- Growth assessment includes turnover tax amount increasing rate, which can be calculated by (added value tax, business tax and other tax of current period tax return - added value tax, business tax and other tax of previous period tax return) / added value tax, business tax and other tax of previous period tax return.

Economic calculation result (IRR refers to return rate of economic calculation) and risk factors grading (P) can provide a comprehensive judgment of PV power station evaluation level. Confirmation of these two variants can provide the rating result.

Tab. 6-2 Rating results

P\IRR	<9%	9%	10%	11%	12%	13%	14%	>15%
>95%	CC	CCC	B	BB	BBB	A	AA	AAA
>90%	CC	CC	B	BB	BBB	A	AA	AA
>80%	CC	CC	B	BB	BBB	A	A	A
>70%	C	C	B	BB	BBB	BBB	BBB	BBB
>60%	C	C	B	BB	BB	BB	BB	BB
<=60%	C	C	B	B	B	B	B	B

7 Photovoltaic evaluation toolkit

Photovoltaic evaluation toolkit consists of 14 dedicated software tools for photovoltaic evaluation, including: evaluation tool for the scale of power plant, computing tool for optimum tilt angle of power plant, computing tool for fore-and-aft clearance, selection tool for support structure, selection tool for component layout, evaluation tool for component connection, analysis tool for mismatch of component connection, comparison tool for location of electrical equipment, conversion tool for radiation, evaluation tool for shade, computing tool for storage capacity, evaluation tool for operation and maintenance, economic evaluation tool for malfunction, economic evaluation tool for the project, etc.

Tab. 7-1 Photovoltaic evaluation toolkit

Toolkit	Reference
evaluation tool for the scale of power plant	IEC 61725
computing tool for optimum tilt angle of power plant	PVSYST
computing tool for fore-and-aft clearance	PVSYST
selection tool for support structure	PKPM
selection tool for component layout	Calculate
evaluation tool for component connection	EPC
analysis tool for mismatch of component connection	Calculate
comparison tool for location of electrical equipment	Calculate
conversion tool for radiation	IEC,Pvsyst,Fraunhofer
evaluation tool for shade	Pvsyst
computing tool for storage capacity	Expertise
evaluation tool for operation and maintenance	Power companies
economic evaluation tool for malfunction	Expertise
economic evaluation tool for the project	Prediction

7.1 Major features of evaluation toolkit for power plant

Evaluation tool for the scale of power plant: in accordance with the standards of IEC61725, comprehensive consideration for the practical conditions of power grid, solar resource and surroundings in the region where power plant is built shall be taken so as to determine the optimum design proportion for photovoltaic capacity.

Computing tool for optimum tilt angle of power plant: referring to pvsyst software and comprehensive analysis on the east-to-west angle of the power plant, consideration for maximum capacity, stable output, reduction of shade, scale and covering area of the power plant shall be taken to determine the optimum angle design for maximum capacity.

Computing tool for fore-and-aft clearance: referring to the optimum tilt angle calculated by pvsyst software, comprehensive consideration on three-dimensional design based on spot investigation, surroundings and designed scale of the power plant shall be taken to determine the optimum fore-and-aft clearance.

Computing tool for line loss: based on preliminary selection and structure design of the power plant, consideration for cable type, wire diameter, economical efficiency shall be taken to calculate the line loss.

Selection tool for support structure: referring to PKPM software and based on the structure design and type selection of the power plant, consideration for the analysis on different loads through software and spot investigation on environment shall be taken to select the economical support structure.

Selection tool for component layout: consideration for the compound mode of component and inverter determined by the arrangement mode shall be taken to determine the component layout, with cable length considered in the meantime.

Evaluation tool for component connection: the evaluation includes the economical differences among different connection modes based on analysis and calculation, the component layout and the difference brought by line loss.

Analysis tool for mismatch of component connection: consideration for the power loss brought by difference between series and parallel currents through theoretical calculation shall be taken.

Comparison tool for location of electrical equipment: this tool is aimed to reduce the cable length and power loss through locating the inverter and switching room based on theoretical calculation.

Conversion tool for radiation: referring to IEC, pvsyst and fraunhofer, this tool considers the radiation difference caused by radiation conversion at different longitudes, latitudes, altitudes and horizontal levels.

Evaluation tool for shade: based on the pvsyst software and spot investigation, more accurate shade area within and among arrays and its influence on the whole system will be evaluated.

Computing tool for storage capacity: based on the calculation model for storage analysis, this tool considers the current photovoltaic power generating capacity, local power consumption and load of auxiliary power supply to determine the most efficient proportion of storage capacity.

Evaluation tool for operation and maintenance: considering the empirical data from power enterprises as well as the critical path analysis for data from power management system, the power loss caused by dust or hot spot will be determined based on simulation analysis.

Economic evaluation tool for malfunction: the power loss caused by malfunction will be determined through empirical analysis of the project.

Economic evaluation tool for the project: the relationship with finance will be determined through the predictive analysis on generating capacity.

7.2 Calculation model for optimum tilt angle

The optimum tilt angle for the photovoltaic power plant is determined by such parameters as the actual position, topographic map, meteorological data and aerosol concentration based on local environment. It has a direct influence on the revenue of the photovoltaic power plant, especially for fixed ones. We will optimize the design of this diameter through the simulation of professional software and the correction of empirical data.

In calculating the optimum tilt angle, the scattering and ground reflection are presumed to be isotropic; referring to the computing method of Klein, the formula for total radiation on the slope is as follows:

$$Q_S=D_S+S_S+R_S;$$

$$D_S=D_H\times R_b;$$

$$S_S=S_H\left(\frac{1+\cos\beta}{2}\right);$$

$$R_S=Q_H\left(\frac{1-\cos\beta}{2}\right)\bullet\rho;$$

$$R_b=\frac{\cos(\varphi-\beta)\cdot\cos\delta\cdot\sin\omega+\frac{\pi}{180}\omega\cdot\sin(\varphi-\beta)\sin\delta}{\cos\varphi\cdot\cos\delta\cdot\sin\omega+\frac{\pi}{180}\omega\cdot\sin\varphi\cdot\sin\delta};$$

$$\omega=\min\left[\cos^{-1}(-\tan\varphi\cdot\tan\delta)\cos^{-1}(-\tan(\varphi-\beta)\cdot\tan\delta)\right]$$

Of which QS, DS, SS and RS are total radiation, direct corrosion, scattered radiation and reflected radiation on the slope respectively; QH, DH and SH are total radiation, scattered radiation and reflected radiation on the horizon respectively; Rb is the monthly mean ratio between daily direct radiations on the slope and horizon; ϕ is latitude, β is the included angle between the slope and horizon (tilt angle), δ is the solar inclination on the representative day of each month, ω is the sunset angle on the representative day of each month, all of which are calculated in angle and the representative days of all months can be seen in Tab. 7-2; ρ is the monthly mean surface reflectivity and the reflectivity of typical underlying surfaces can be seen in Tab. 7-3.

Tab. 7-2 calculated in angle and the representative days

Month	Representative Day	N (serial number of the day) (common/leap year)	δ (°) (common/leap year)
January	17th	17	-21.1
February	16th	47	-13.0
March	16th	75/76	-2.5/-2.1
April	15th	105/106	9.1/9.5
May	15th	135/136	18.4/18.7
June	11st	162/163	22.9/23.0
July	17th	198/199	21.5/21.3

August	16th	228/229	14.3/14.0
September	15th	258/259	3.7/3.3
October	15th	288/289	-7.8/-8.2
November	15th	318/319	-17.8/-18.0
December	10th	344/345	-22.7/-22.8

Notes: the selection of representative day of each month refers to Solar Photovoltaic Power Generation Technology written by Yang Jinhuan, etc. (Electronic Industry Press, 2009, P27); the declination angles of representative days of all months are quoted from the Ground Meteorological Observation Norms from China Meteorological Administration (China Meteorological Press, 2003, P140).

Tab. 7-3 the reflectivity of typical underlying surfaces

Bare land	Desert	Grassland	Forest	Snow land (tight and clean)	Snow land (wet and dirty)	Sea (solar altitude>25°)	Sea (solar altitude <25°)
10-25	25-46	15-25	10-20	75-95	25-75	<10	10-70

Note: quoted from *Atmospheric Sciences Dictionary*

7.3 Calculation Model For Optimum Clearance

At present, the distributed photovoltaic system is mainly applied on the roofs of industrial, commercial and civic buildings. As the arrangement of photovoltaic array is an important part in the design of distributed system, the optimization of the fore-and-aft clearance generally takes the principle of keeping the arrays unshaded fore and aft at 9 a.m. and 3 p.m. in winter for reference, with comprehensive consideration for the solar altitude, solar azimuth and installation angle at local latitude as well as the gradient, inclined direction and azimuth of the roof. However, current research literatures on the fore-and-aft clearance mainly talks about the horizontal roof facing due south; although some of them involve slope angle or azimuth analysis, the analysis is not comprehensive, therefore having some limitations. Considering that the actual roof may have slope angle and azimuth at the same time, have an east-to-west slope or have main and subsidiary slopes at the same time, in-depth analysis on the array clearance of these complicated situations shall be conducted.

The fore-and-aft clearance of the photovoltaic power plant shall meet the requirement of no shade among photovoltaic arrays during certain periods, therefore the clearance shall be designed in a rational way to avoid unnecessary system loss caused by fore-and-aft shade.

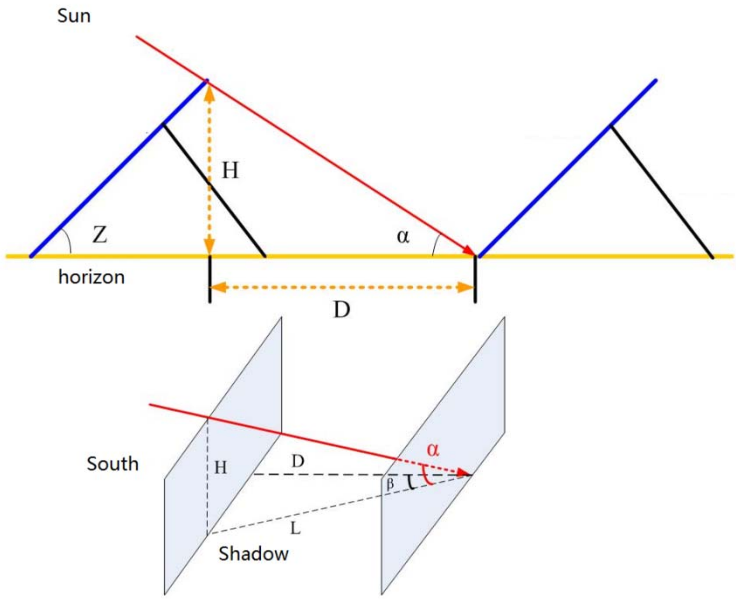

Fig.7-1 Calculation Model For Optimum Clearance

Solar Altitude Formula：sinα=sinϕsinδ+cosϕcosδcosω

Formula for calculating solar azimuth: sinβ=cosδsinω/cosα

D=cosβ×H/tan[arcsin (sinϕsinδ+cosϕcosδcosω)]

ϕ: local latitude; ω: hour angle (45° at 9 a.m.); δ: solar declination (-23.5° at Winter Solstice).

For the calculation model for horizontal array clearance, relevant parameters are marked in the following figure (referring to relevant literatures to find more details). Here we consider the Triangular Pyramid BCDA and Triangle AFE as the basic model for calculating the clearance on the horizon, which is very useful and lays foundation for the calculation of clearance on the complicated situations of the roof. In this model, Plane BCD is the horizontal plane and Point A is the zenith of the component: if the components are installed longitudinally, the zenith will be on the long frame; if installed horizontally, the zenith is on the short frame (here take longitudinal installation as example); Point B is the orthographic projection of Point A on the horizon and the solar ray goes through Point A and intersects with the horizon at Point D; BD is the orthographic projection of AD on the horizon and CD is the orthographic projection of BD to the due south; the solar altitude ∠α=∠BDA , solar azimuth ∠β=∠BDC and the absolute fore-and-aft clearance is d, then d can be expressed as:

d=|AB|·cot ·cosβ (1)

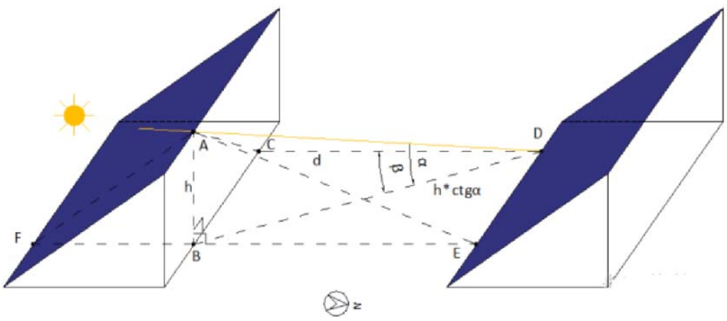

Fig.7-2 Classical model for the calculation of clearance between horizontal arrays

Based on this model, the following paragraphs will analysis these two typical roofs in detail: first is north-to-south slope and the second is east-to-west slope; then expand to the formula for general solution covering slope azimuth variables.

7.4 Design model for set of string

To minimize the power loss of photovoltaic power plant, connection conditions of all sets of string in the photovoltaic array shall be kept in accordance; then key equipment shall be selected according to local situations. What type of connection in each array can optimize the photovoltaic plant shall be calculated to reach a conclusion.

The sets of string in the photovoltaic power generation system shall be connected as follows:

Nmax=Vdcmax/Voc；

Nmin=Vdcmin/Vmp；

$$\frac{V_{mppt\,\min}}{V_{mp}\times[1+(t_1-25)\times\beta]}\le N\le\frac{V_{\mathrm{mpptmax}}}{V_{mp}\times[1+(t_2-25)\times\beta]}$$

N——number of strings of photovoltaic modules

Vmpptmin——minimum voltage of inverter’s MPPT

Vmpptmax——maximum voltage of inverter’s MPPT

Vmp——Peak voltage of photovoltaic modules

t1——lowest working temperature for photovoltaic modules

t2——highest working temperature for photovoltaic modules β——voltage temperature coefficient of photovoltaic modules

By calculation, photovoltaic modules in every string can be reduced to 18 to 22, meeting the requirement of 20 recommended by the design institute.

Besides, experts also suggest that the design of 22 modules in a string may apply to this region considering local solar energy resources: on one hand, it can reduce the quantity of combiner boxes; on the other hand, when the resource is moderate, the 2 extra modules in every string may help the inverter work around the maximum power, contributing to increase the generating capacity.

a) Evaluation model for load capacity of the system

Calculation of load on bracket and the load effect shall comply with the following stipulations:

1)Without seismic action effect combination, design value of the load effect combination shall be determined according to the following formula:

Of which:

S ——design value of the load effect combination;

γ_G ——partial factor for permanent load;

S_{GK}——standard value for permanent load effect;

S_{wK}——standard value for wind load effect;

S_{sK}——standard value for snow load effect;

S_{tK}——standard value effect of temperature action;

γ_w、γ_s、γ_t——partial factors for wind load, snow load and temperature action, defined as 1.4;

Ψ_w、Ψ_s、Ψ_t——combination value coefficient for wind load, snow load and temperature action.

2) Without seismic action effect combination, each partial factor for load in displacement calculation shall be defined as 1.0; in calculation of bearing capacity, combination value coefficient for load shall be defined as follows:

Tab. 7-4 Combination value coefficient for load without seismic action effect combination

Load combination	Ψw	Ψs	Ψt
permanent load, wind load and temperature action	1.0	—	0.6
permanent load, snow load and temperature action	—	1.0	0.6
permanent load, temperature action and wind load	0.6	—	1.0
permanent load, temperature action and snow load	—	0.6	1.0

Note: "—" means that this load or action is not considered in the combination.

3)With seismic action effect combination, design value of the load effect combination shall be determined according to the following formula:

Of which:

S ——design value of the combination of load effect and seismic action effect;

γ_{Eh}——partial factor for horizontal seismic action;

S_{EhK}——standard value effect of horizontal seismic action;

Ψ_w——combination value coefficient for wind load, defined as 0.6;

Ψ_t——combination value coefficient for temperature action, defined as 0.2.

4)With seismic action effect combination, each partial factor for load in displacement calculation shall be defined as 1.0; in calculation of bearing capacity, combination value coefficient for load shall be defined as follows.

Tab. 7-5Combination value coefficient for load with seismic action effect combination

Load combination	γ_G	γ_{Eh}	γ_w	γ_t
Permanent load and horizontal seismic action	1.2	1.3	—	—
Permanent load, horizontal seismic action, wind load and temperature action	1.2	1.3	1.4	1.4

Notes: 1. γG: when the permanent load effect is conductive to bearing capacity of the structure, it shall be defined as 1.0;2. "—" means that this load or action is not considered in the combination.

5) In the design of bracket, the maintenance load for construction shall be checked and comply with the following stipulations:

- Maintenance load for construction shall be defined as 1kN or defined at the most adverse position on the bracket according to the practical load;
- In checking the bearing capacity of support members, the load combination shall include permanent load and maintenance load of construction with the partial factor of the former defined as 1.2 and that of the latter as 1.4.
- In checking the displacement of support members, the load combination shall include permanent load and maintenance load of construction with the partial factors of both defined as 1.0.

6)The structure of steel bracket shall comply with the following stipulations:

- Thickness of the plate used on the secondary beam shall be no less than 1.5mm while that of the plate used on main beam and column shall be no less than 2.5mm or can be 2mm with reliable support.
- The slenderness ratio of tension members and compression members shall comply with the following stipulations:

Tab. 7-6Limited value for slenderness ratio of tension members and compression members

Component types		Allowed slenderness ratio
Compression members	Major bearing members	180
	Other components, brackets, etc.	220
Tension members	Major components	350
	Column bracket	300
	Other brackets	400

Note: for the structure supporting dead load, it is acceptable to calculate the slenderness ratio of tension members on the vertical direction only. The above figures are recommended values; if the required value is lower than the recommended one, relevant calculation result shall be provided.

8 APEC PV Project Exchange Cooperation Platform

8.1 Enetf

As a third party resources integration platform serving for PV power stations and financial institutions, the enetf has four core function modules as follows:

a) Project Development Platform

To develop high quality PV power station project resources of good economic efficiency and marketization investment in scale based on traditional PV industry channels and cooperation partners as well as O2O model internet channel;

b) Valuation and Rating Platform

To carry out whole process monitoring on PV production, construction, operation and maintenance via IT management system and data base in accordance with the specific methodology developed by the team, and providid evaluation and rating report to financial institutions;

c) Assets Management Platform

To provide smart operation and maintenance management system based on smart monitoring and cloud calculation so as to provide third party assets management services for financial institutions in investing distributed power station;

d) Power Station Trading Platform

To provide standard PV investment in accordance with rating results facing institutional investors at preliminary stage, and to constantly stimulate online finance innovation and expand project goal and invested products.

A PV project exchange and cooperation platform can be established with IT technology based on the above mentioned foundations, consisting of four modules as project declaration, power station rating, engineering management and monitoring system.

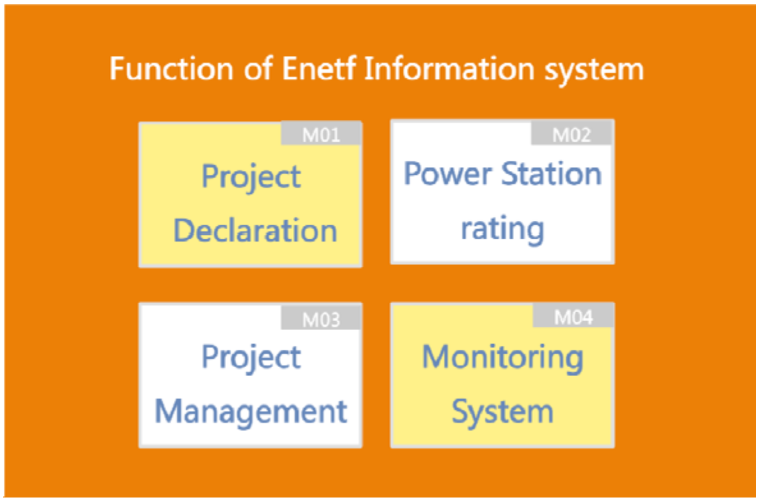

Fig.8-1PV Exchange and Cooperation Platform

A series of functions can be realized including online project information recording, online investor verification, project examination, project presentation, investor presentation and project promotion. In addition, off-line cooperation partner expansion, investment trading can be realized via this platform.

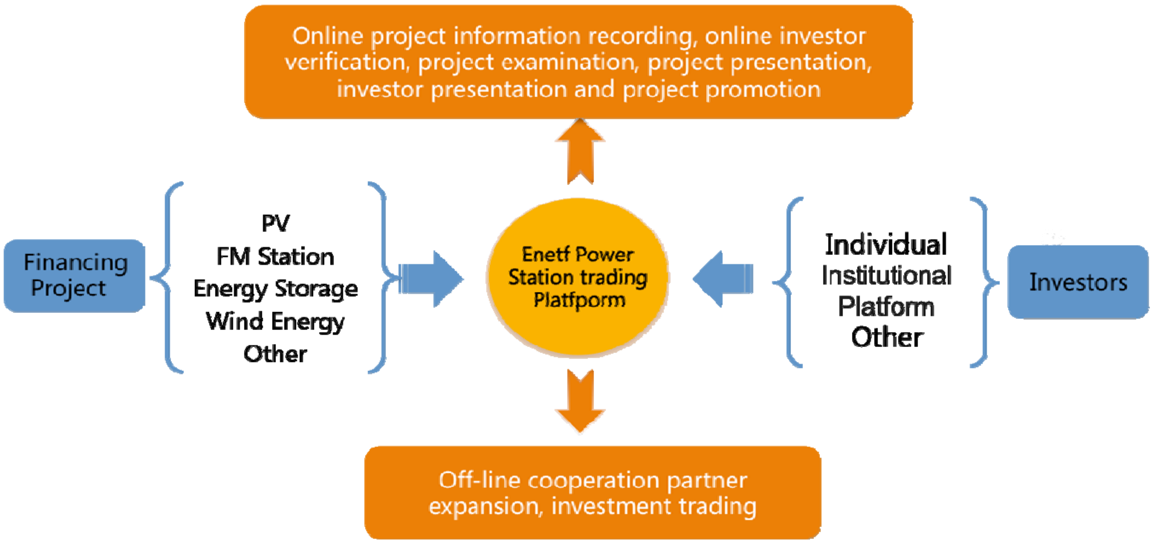

Fig.8-2 Functions of Exchange and Cooperation Platform

Once the essential evaluation module extracted in line with the above-mentioned analysis, automatic rating and rating report can be realized after project information input.

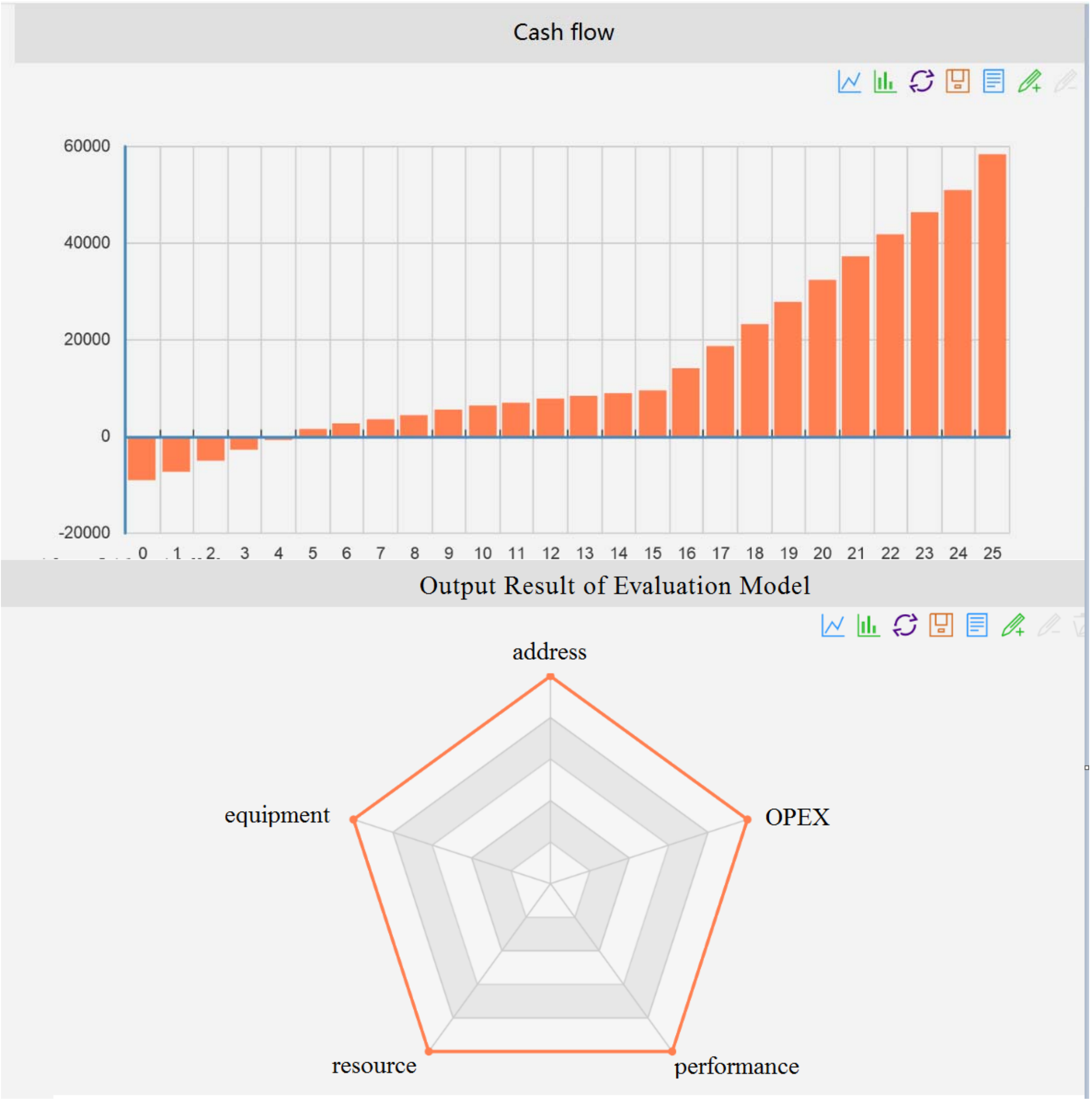

Fig.8-3 Output Result of Evaluation Model

After completion of the project, remote monitoring of the whole project process can be realized via online monitoring system logged in by computers or mobile phones, thus providing a convenient way for PV power station assets management.

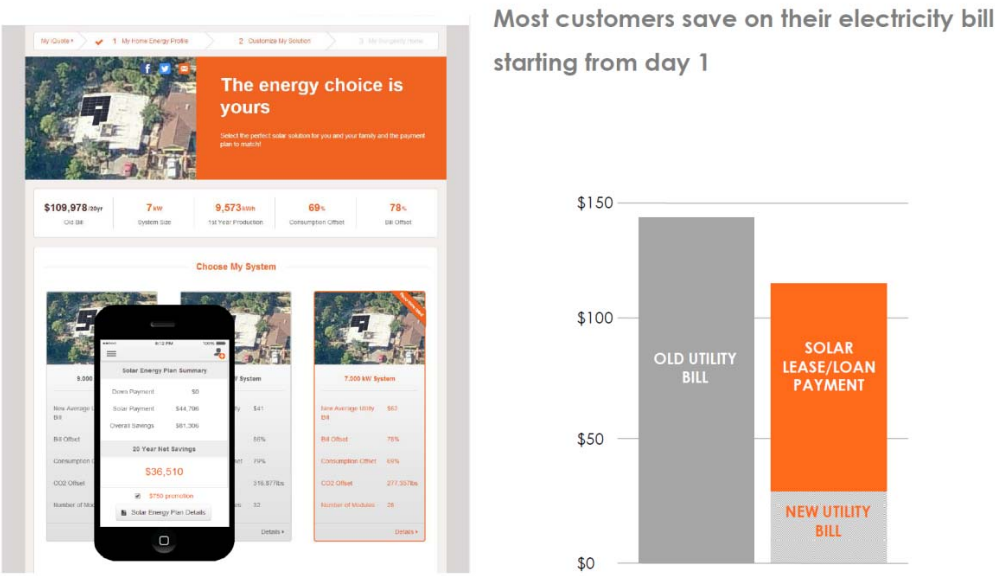

Fig.8-4 Online Monitoring System

8.2 Retscreen

Retscreen, ananalyzing software, is the most frequently used software by all APEC economies in calculating dip angle and generated power of PV power generation system. As a specific decision supporting tool funded and invested by the Canadian government with the core of standardized energy analysis model, it can be utilized across the world to evaluate various energy efficiency, energy production of renewable energy technology, energy-conserving benefit, working life cost, green gas emission and financial risks.

Fig.8-5Retscreen analyzing software

Retscreen energy project model can be developed in excel working documents, which is made up of a series of worksheets. There are 6 worksheets for PV project, including energy model, solar energy resources and systematic load calculation, cost analysis, green gas (emission reduction) analysis, financial outline as well as sensitivity and risk analysis.

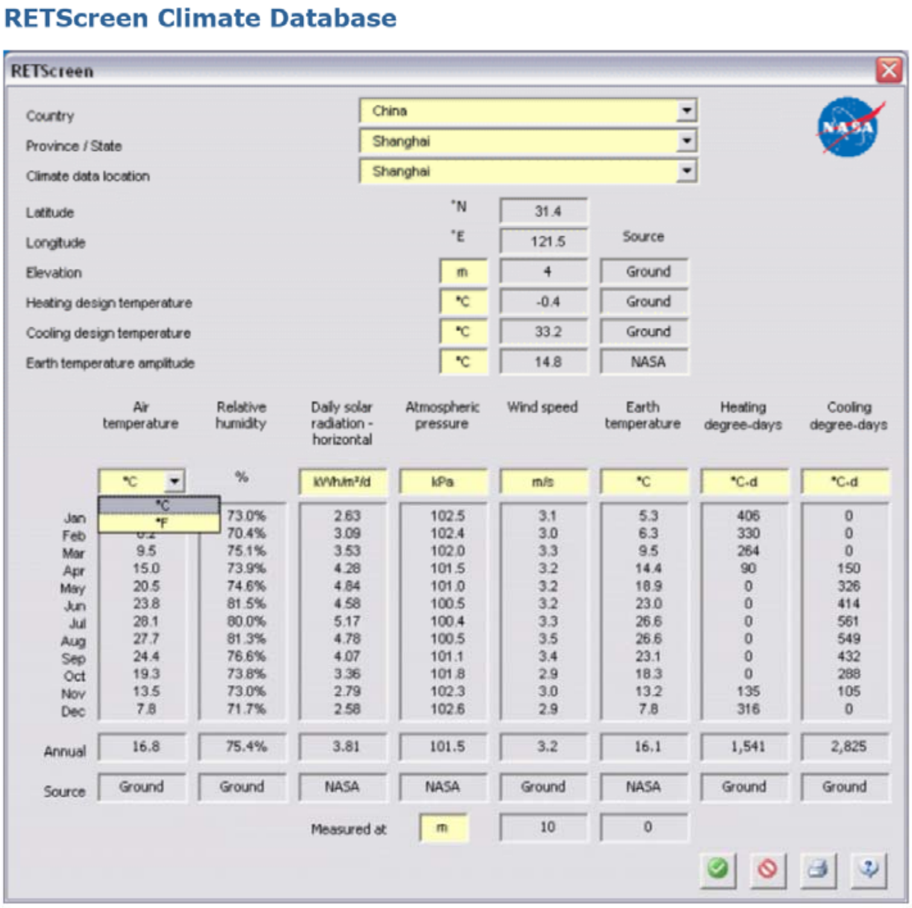

Fig.8-6Retscreen energy project model

Energy model and solar energy and system load calculating worksheet is used to calculate annual energy output of PV power station according to local site condition and system performance.

Solar energy and system load calculating worksheet is connected to energy model worksheet for calculation of energy load and energy saved by PV system.

Cost analysis refers to preliminary input or investment as well as annual or regular cost, which can be acquired in accordance with product data base to get knowledge of demanded price and other information.

Green gas analysis is optional, which requires specific data input into financial outline worksheet to calculate green gas emission reduction profit and cost.

Financial outline, which is used for assessment of all energy engineering project, generally consists of six parts for the worksheet: annual energy balance, financial parameter, project cost and balance, financial feasibility, annual cash flow and accumulated cash flow chart. Among them, annual energy balance and project cost and balance provide related energy model, cost analysis and green gas emission reduction analysis worksheet outline for every research projects. Financial feasibility provides financial indicators for all analyzed energy engineering projects, with the basis of input data in financial parameter by users. The annual cash flow can visualize flow trend of pre-tax, post-tax and accumulated cash flow.

Sensitivity and risk analysis worksheet mainly focuses on sensitive changes of major project financial indicators due to changes of major economic and technological indicators currently. These two provides relationship between key parameter and major project financial indicators and presents which parameters bring the greatest impact on financial indicators. Sensitivity analysis (including Monte Cario Stimulation) faces ordinary users while risk analysis mainly points to users knowing statistics. In addition, these two analysis are both optional without influence on the analysis and result of other worksheet.

The tools also include products, climate and cost data base, online manual, website, engineering manual, project example research and training classes, etc. The global climate data base used by the software comes from NASA.

8.3 PVSYST

As a PV system design assistant software, PVSYST aims to guide PV system design and carry out analog computation on PV system energy output.

a) The main functions are:

1) To set up PV system types: grid connection, independent, PV pump, etc.

2) To set up PV modules pattern parameters: fixed method, PV matrix dip angle, line spacing, azimuth angle, etc.

3)To carry out influence assessment of building block on PV system and calculate blocking period and blocking portion

4) To simulate energy output and system power generation efficiency of PV system

of different types

5) To investigate environment parameters of PV system

b) The design functions are:

1) Preliminary Design

Reading and analyzing selected engineering project, geographical location and corresponding sun operating parameters of grid connection PV system.

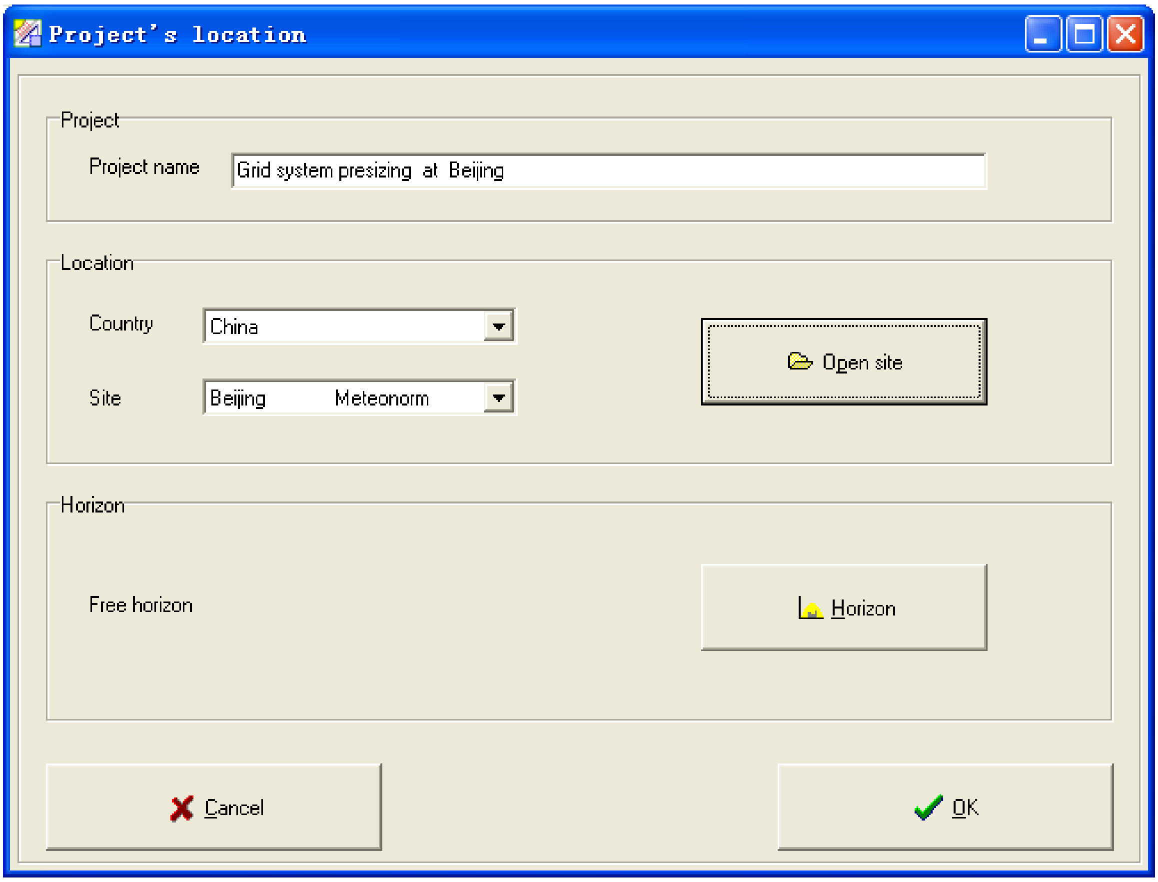

Fig.8-7 Project location

Setting up basic parameters of PV system by enter modules surface, installed capacity, annual energy output as well as internal formula shift. The azimuth angle is generally 0 degree, i.e., facing south in the Northern Hemisphere and north in the Southern Hemisphere.

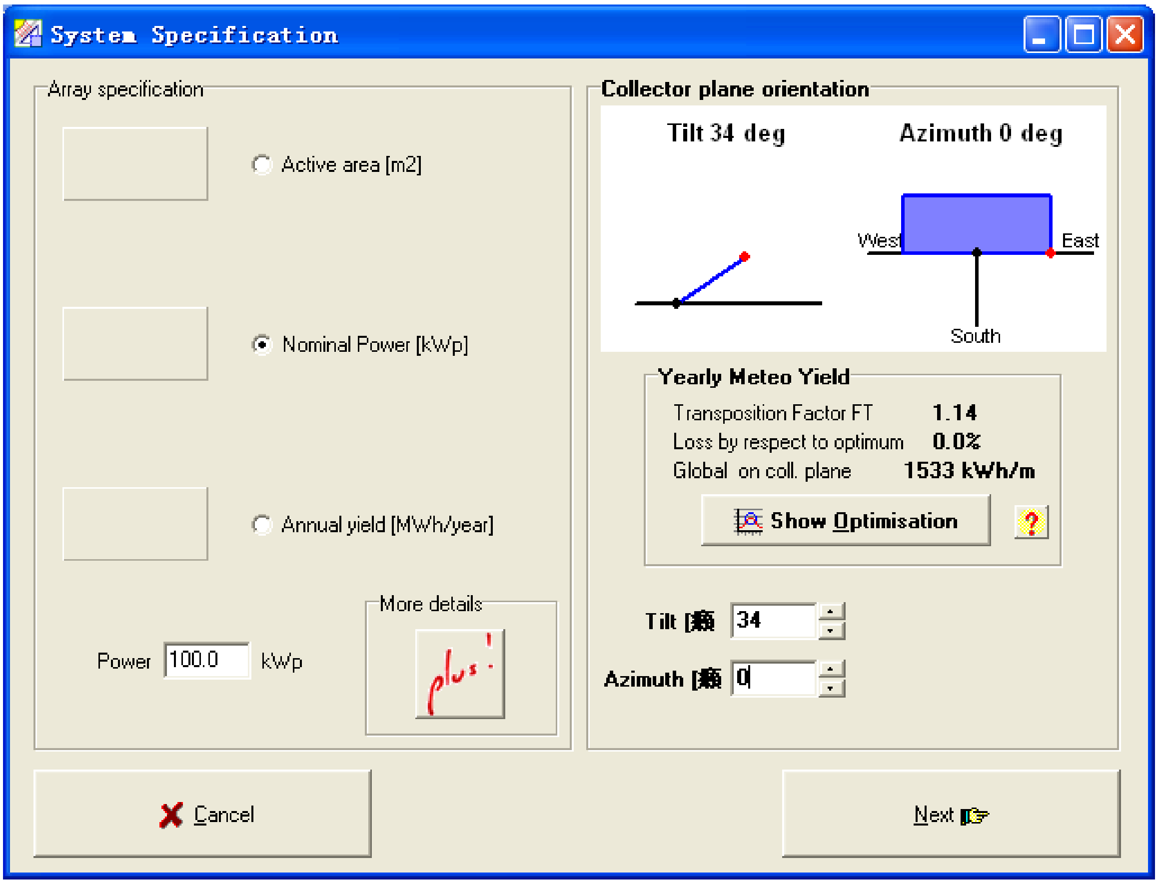

Fig.8-8 System specification

Line spacing design should select to enter ground PV power station pattern design so as to come up with reasonable design value for blocking loss

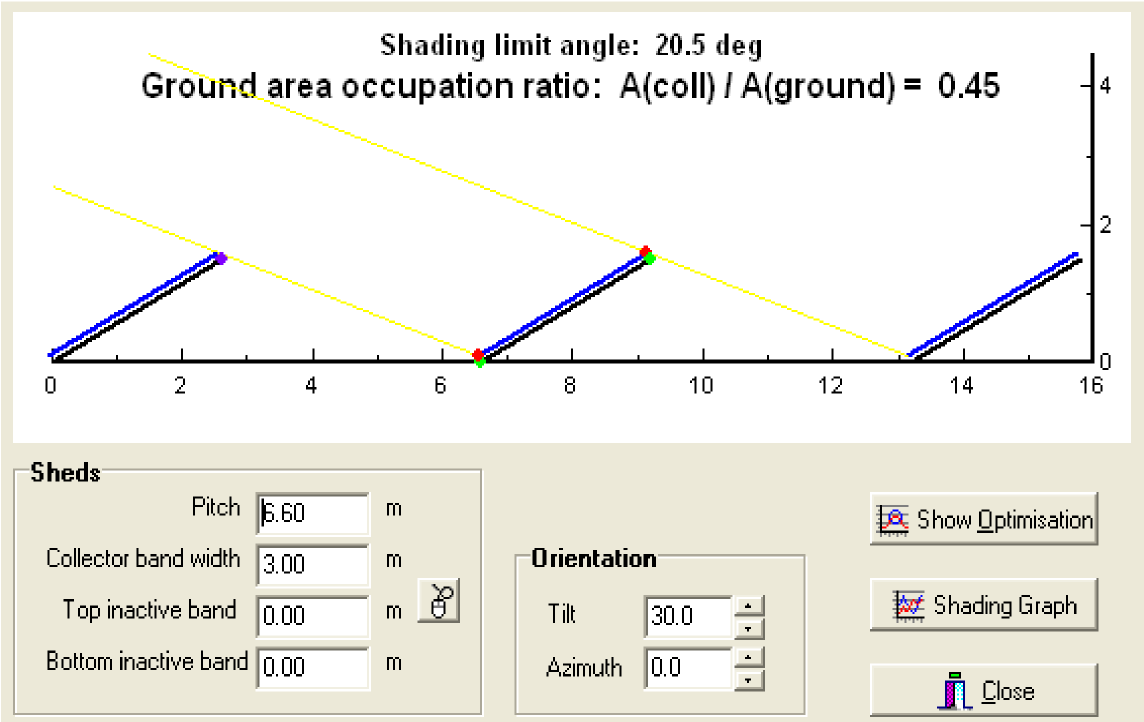

Fig.8-9Preliminary Design

2) Engineering Design

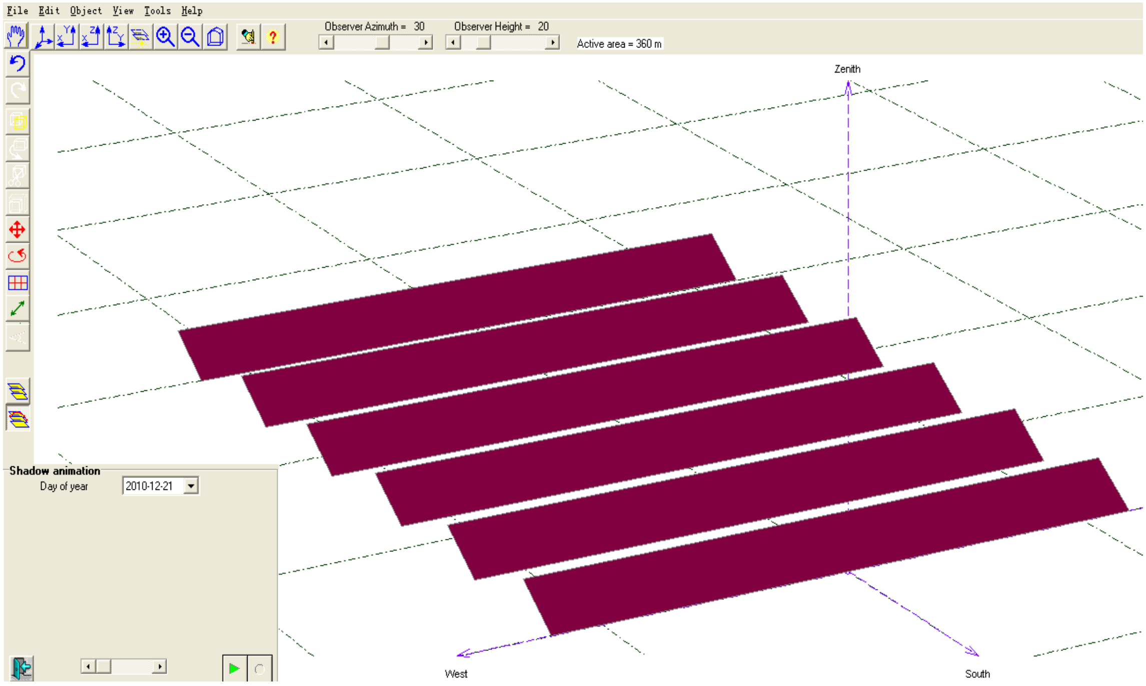

Fig.8-10 Stimulating the sun moving trend lengineering design interface

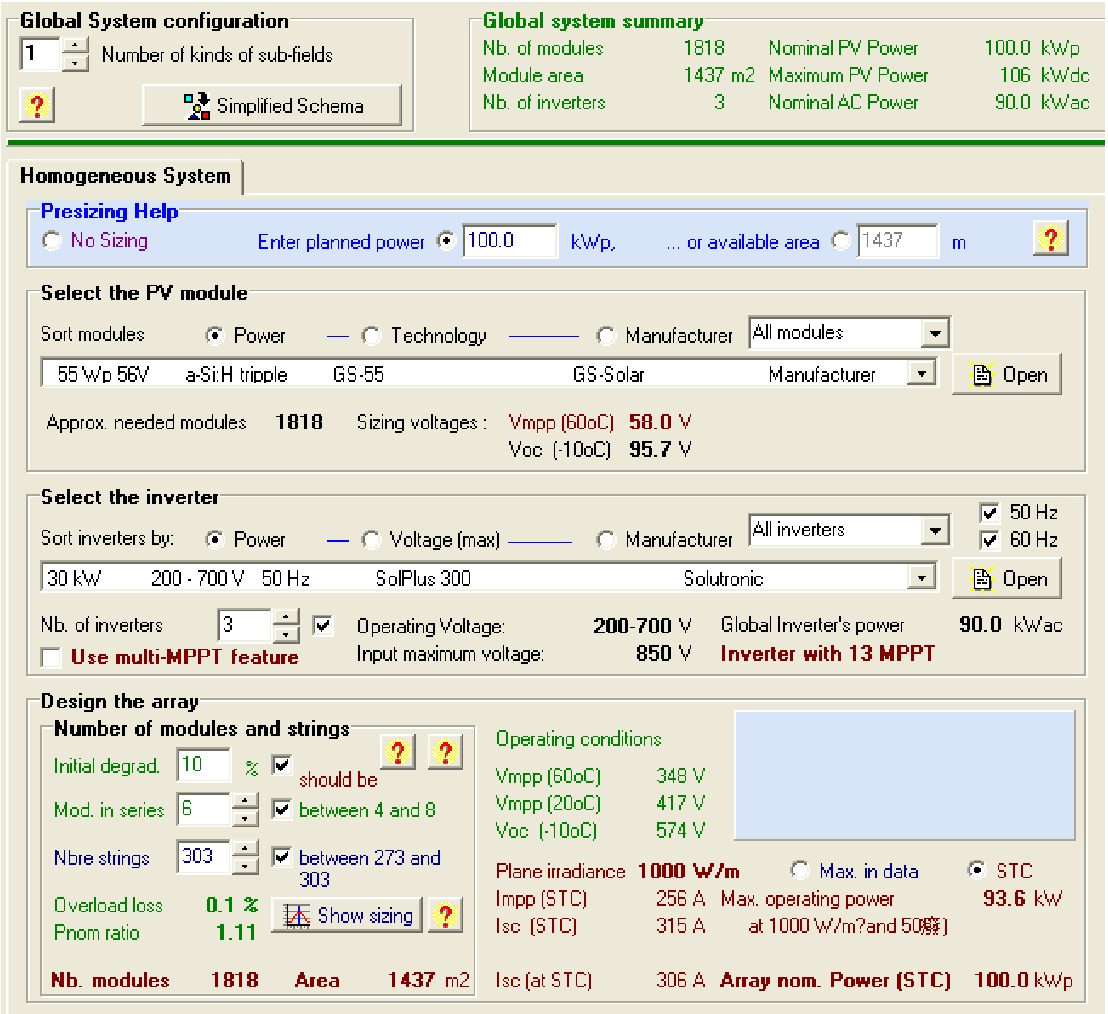

Fig.8-11 Impact of various parameters of PV system design

3) Tools

Major design systems include grid connection PV system, independent PV system, pump PV system and direct current grid connection PV system.

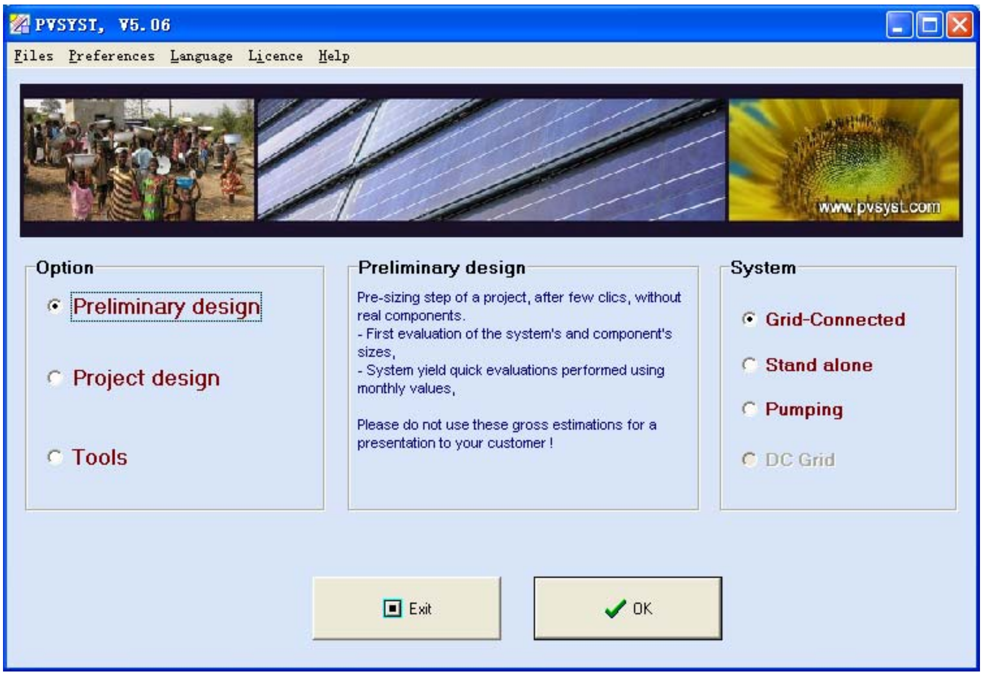

Fig.8-12 Tools

c) PV system parameter setting is as follows:

Module type setting influences relationship of module surface and installed capacity;

Ventilation type influences relationship of installed capacity and energy output;

Installation type influences installation cost.

Fig.8-13 PV system parameter setting

d) Preliminary Design Result

The preliminary design result comes with parameters of monthly ground irradiation, inclined surface irradiation and energy output. The generated energy of preliminary project can be compared by adjusting different parameters.

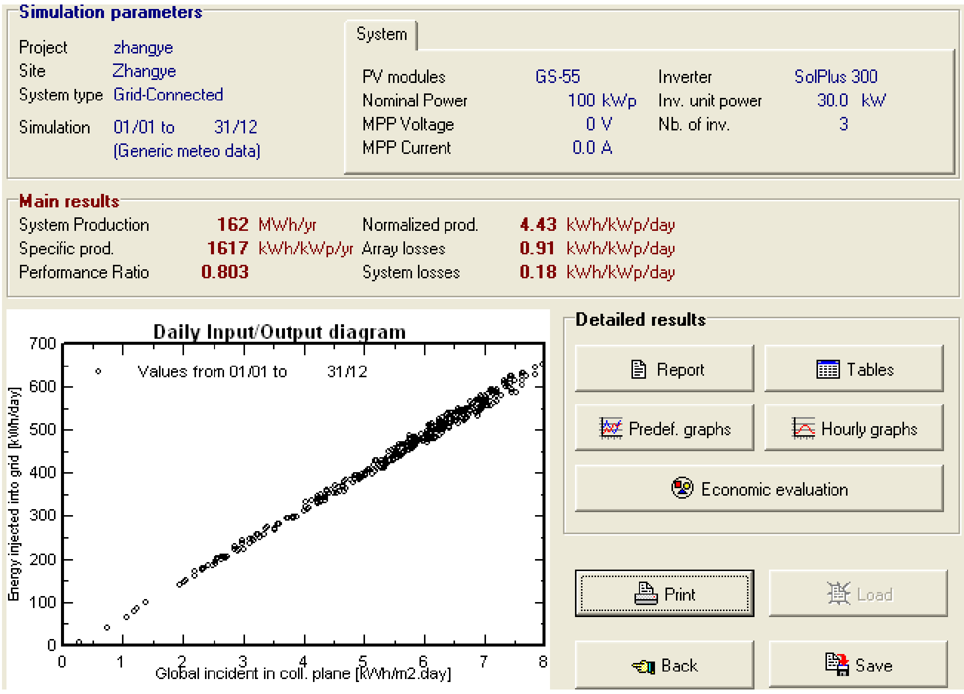

Fig.8-14 Preliminary Design Result

e) Design Result Simulated

Generated energy result analysis, utilization efficiency analysis according to different climates and regions, attenuation analysis.

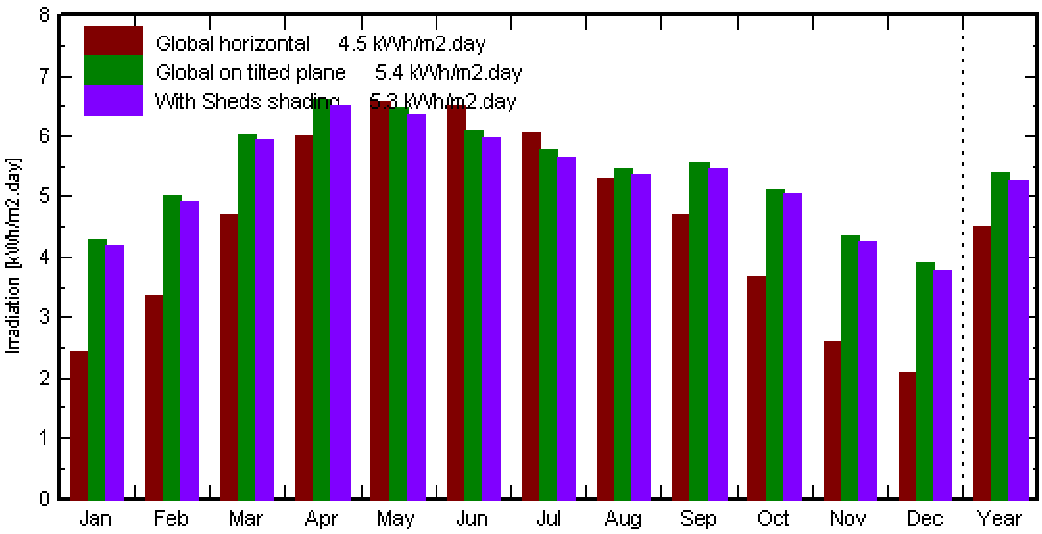

Fig.8-15Design Result Simulated

With increasing PV application scale, more and more APEC economies start to put emphasis on risk analysis and management of PV power stations by establishing professional PV evaluation system with specific software and constructing PV exchange and cooperation platform, not supporting rapid development of PV bu also integrating PV to emerging energy storage, charging piles, demand response and other solutions under the background of energy Internet, thus forming a brand new three-dimensional distributed energy solution.

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