Coefficient of Capacity Configure Optimization of PV Power Station based on Measured Irradiance Data

Xiang Chen [a], Jishu Pan [b]

CEEC Yunnan Electric Power Design Institute Co., Ltd., Kunming 650051, China;

[a]skiecx@126.com, [b]jspan2818@ceec.net.cn

Abstract

Some PV station adopting the design philosophy that the PV module's and inverter's capacity ratio higher than 1 in recent years, the definition of ratio is based on the designer's personal experience, lack of theory analysis. In this paper, based on the measured irradiance data in a certain place, analysis the ratio between the added generation of PV station and investments based on different efficiency and price of PV station by using value engineering method. At last, we give the optimized PV module's and inverter's capacity ratio in the certain palace for the similarly projects.

Keywords

PV power station; coefficient of capacity configure (CCC); measured irradiance data.

1. Introduction

The rapid development of PV power stations in China, the calculation of the coefficient of capacity configure(CCC) between the PV module capacity and the inverter is lack of quantitative analysis.

In recent years, the selection of the CCC of the PV power station is based on design experience. However, there are differences in location, power plant equipment selection, design level and investment of each PV power station. At the same time, as a evaluation of power station economical, there are few quantitative analysis of CCC.

For this, this paper will conduct in-depth analysis of this problem, and give a quantitative calculation method of reasonable CCC, which will provide a reference for future design of PV power station.

2. Analysis of measured radiation data in A region

This paper uses the measured radiation data in A region for a year, and selects the global irradiation and temperature data of the horizontal plane for the calculation and analysis[1].

The sampling time of the measured data is 1min, and there are 525600 groups in the whole year, and the complete rate of data is 96.32%[2]. After the completion of the missing data interpolation, the total horizontal surface radiation of A region was 6262.5MJ/m^2. According to the method of evaluation of solar energy resources (QX/T 89-2008) [3], the solar energy resources are very rich, and the resources have the development conditions for the PV power stations.

According to the above data[4], we can be obtained: the radiation (flux) distribution of month, day,. (among them: the time is true sun time, the same as following):

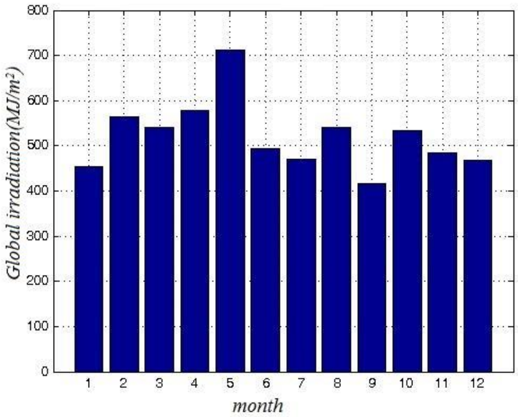

Fig. 1 Histogram of monthly global irradiation

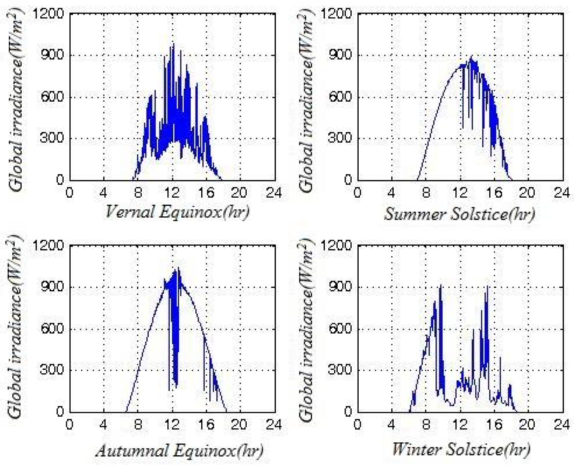

Fig. 2 Curve of characteristic day‘s global irradiance

According to figure 1~2, it can be found that the annual radiation distribution in A region has the following characteristics:

(1) Maximum of global irradiation in A region occurred in the spring and summer season in May; the monthly total amount of radiation is lower than the average monthly capacity of PV power stations throughout the year is little difference;

(2) The difference of maximum daily global irradiation in the A region is rather small. Among them, the difference between the 4 representative value s is mainly the difference between the total daily radiation and the instantaneous value of the radiation caused by the sunshine duration and the weather condition. At the same time, the ratio between the highest month and the lowest month is 1.63. According to the "*solar resource* assessment *method*", the stability level of solar resources is stable.

(3) From May to August, The global irradiation of the A region is more than 1000W/m^2. After analysis of raw data: The global irradiance exceeds 1100W/m^2 in June, which means that the inverter has higher input power in the DC side and abandoned energy in those times.

(4) From October to April, the air quality is good, the transparency is high, and the global irradiation value is relatively stable. The annual global irradiation of A region is characterized by "richer in spring& summer, poorer autumn & winter".

3. Calculation of CCC

3.1 Theoretical calculation method

In this paper ,a single PV array as the anylsis object. So, the CCC betweetn the PV module and the inverter is defined as follows:

$$\alpha = \frac{p_{md} L_{st} N_{st}}{P_{in}} \tag{1}$$

In the formula,where :

α :CCC; p_{md} :Single PV array capacity (W); L_{st} : Number of series of PV module; N_{st} : Parallel number of PV module string; P_{in} : Inverter capacity (W) of Single PV array.

The numerical interval of CCC is [0.8,1.5]. The minimum and maximum value of N_{st} can be calculated according to the formula 1, So:

$$N_{st\min} = INT\left(\frac{0.5P_{in}}{p_{md} L_{st}}\right) \tag{2}$$

$$N_{st\max} = INT\left(\frac{2P_{in}}{p_{md}L_{st}}\right) \tag{3}$$

3.1.1 Efficiency of PV array

In this paper, the efficiency of PV array refer between the PV module and the inverter AC side.

4) Simulation of PV array output

According to the theory of Liu & Jordan[5], with the measured annual radiation data:

(1) The simulation output of PV array is carried out by 1min horizontal surface global irradiation.

(2) The solar elevation angle and azimuth can be caculated base on the Spherical astronomical theory.

(3) According to the principle of solar radiation, the diffuse radiation can be calculated by Erbs[2] method base on the global radiation.

(4) The solar radiation on the PV module‘s tilting surface can be conducted by The Klein method [5].

(6) The temperature of the surface of the PV module is correction by the ambient temperature. Combined with the parameters of PV module, the power generation power of 1 minutes per year is calculated under different values, and the value of the step is 1.

3.1.2 Overloading of inverters

When the input power exceeds a certain ratio of the rated capacity of the inverter, the PV array will abandon energy. Therefore, this paper defines the percentage of the inverter to allow short time more than rated capacity: β (%). According to the operating principle of the inverter [6], the generation is calculated according to the following formula.

$$P_{sys}^{'} = \begin{cases} P_{sys}\eta_{sys}, P_{sys}\eta_{sys} < (1+\beta)P_{in} \\ (1+\beta)P_{in}, P_{sys}\eta_{sys} \geq (1+\beta)P_{in} \end{cases} \tag{4}$$

3.1.3 Economic analysis

(1) The plant investments is calculated according to the price of the equipments in the PV array.

(2) The yield of the PV array of different N_{st} can be calculated.

$$E_{gain} = \sum_{i=1}^{365}\sum_{j-1}^{1440}\frac{P_{sys}^{'ij}}{60000}p_{elc} \tag{5}$$

In the formula,where :

E_{gain}:Income (yuan); p_{elc}:Electric charge of PV power station (yuan /kWh)

(3) Combined with the value engineering method, the maximum net present value(NVP) can be obtained according to the results of the above steps, and the CCC is determined by the final formula 1.

3.2 Calculation of CCC in A region

The PV array model in the A region as follows:

PV array latitude: 23°; 60 PV module type, capacity of 275W, on the number of strings is 22, the series parallel is160~220; the efficiency of power plant is taken 80% and 85%; the electricity charge is 0.60 yuan /kWh; industry discount rate is 8%; power plant integrated unit price to take 6.5 yuan /W, the price of PV module is 3 yuan /W; PV power plant life period is 25 years. After calculation according to the 2.1 section method, The following conclusions are drawn:

1) When the efficiency of power stations(η_{sys}) is 80% ; the β are 0%, 5% and 10%, the maximum NPV corresponds to 172, 181 and 189, and the CCC is 1.041, 1.095 and 1.143 respectively.

2) When the efficiency of power stations(η_{sys}) is 85% ; the β are 0%, 5% and 10%, the maximum NPV corresponds to 162, 170 and 178, and the CCC is 0.980, 1.028 and 1.077 respectively.

3) The efficiency of the PV power station directly affects selcetion of CCC. With the increasing of efficiency, the CCC will be reduced. At the same time, the power station can reduce the initial investment of the PV module, and also improve the revenue of the power station.

4) It is suggested that the power station should use the local radiation data and choose the inverter with short time overload. For A region, the selection of inverter should require 10% short time overload capability. The technical requirements for short time overload of the inverter should be based on the statistics of hourly power generation calculated in the preceding text.

5) The selection of PV optimal CCC include: the radiation data of plant location, the efficiency of the plant, the overload capacity of the inverter, the unit price of the power plant, the unit price of PV module and the industry discount rate.

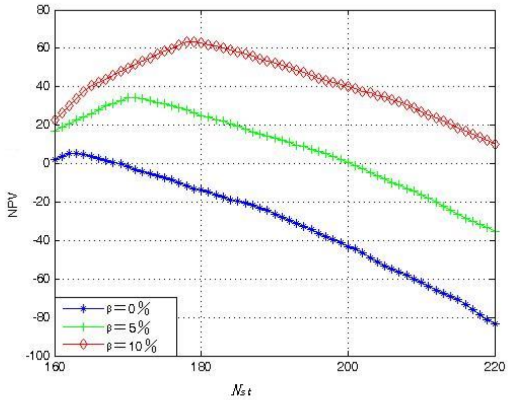

Fig. 3 Curve of PV station's NPV (η_{sys}=80%)

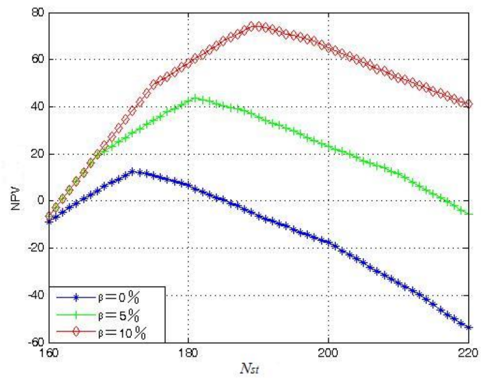

Fig. 4 Curve of PV station's NPV (η_{sys}=85%)

4. Conclusions and Suggestions

In this paper, we first analysis of measured radiation resource data in A region, geeting the hourly output of PV power station, setting up PV power station and calculating the different financial NPVs, selecting the maximum NPV, and determining. The calculation method of CCC of PV power station has certain reference value.

Through the analysis of this paper, we can see that selection of PV Plant's CCC should be based on the local measured radiation data, and the parameters of PV plants. At present, the PV power station can not meet the requirements of the optimize design.

Therefore, the CCC of the PV power station should be analyzed and calculated in the early stage design with combination with the above factors to enhance the earnings of the PV power station.

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