World Scientific Research Journal (WSRJ) ISSN: 2472-3703
www.wsr-j.org

Calculation of String numbers base on PV module's mechanism model

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: At present, the calculation of PV power station's string numbers lack correction way for the lowest temperature, the string numbers contains a certain margin. In this study, Firstly, we analyzed the PV module's IV curve, Secondly, simulate the PV module's voltage curve at different temperature and radiation, Finally, we get the string numbers based on the mechanism model.
Keywords: PV power station, String number.

1. INTRODUCTION

At present, the calculation of the PV module's string number in PV power stations refer to the formula [1] in the clause 6.4.2 of the Design specification for PV power station (GB50797-2012). Due to the lack of the extreme temperature (high temperature and low temperature) correction method of the PV module, the local environment extreme temperature is mostly adopt. At present, some China's PV power stations have made some breakthroughs for this problem, and most of them use empirical formula to correct extreme temperature.

This paper tries to use different method to verify the string number, to exploring the reasonable value of the string number by using the PV module's mechanism model.

2. THE TRADITIONAL METHOD OF CALCULATING

The parameters of a proposed PV power station are as follows:

The module uses polysilicon 270 modules (1000V module), of which: V_{oc} =38.39V, V_{pm} =30.68, voltage temperature coefficient: -0.33%/ C; historical extreme lowest temperature: -11.4℃.

The inverter uses 500kW centralized inverter, which: $V_{dc\max}$ =1000V, $V_{mppt\min}$ =460V, $V_{mppt\max}$ =850V.

2.1 Calculation results base on Specification

Without considering the temperature correction and the difference of the parameters under different working conditions. According to the formula in the GB50797-2012 clause 6.4.2:

$$\begin{cases} N \le \dfrac{V_{dc\max}}{V_{oc} \times \left[1+(t-25)\times K_v\right]} \\ \dfrac{V_{mppt\min}}{V_{pm} \times \left[1+(t^{'}-25)\times K_v^{'}\right]} \le N \le \dfrac{V_{mppt\max}}{V_{pm} \times \left[1+(t-25)\times K_v^{'}\right]} \end{cases} \quad (1)$$

In the formula, where:

K_v: Open circuit voltage temperature coefficient of the PV module; $K_v^{'}$:Working voltage temperature coefficient of the PV module; N : Serial number; t : Extreme lowest temperature (centigrade) of PV module's working condition; $t^{'}$:Extreme highest temperature (centigrade) of PV module's working condition; $V_{dc\max}$:Maximum DC input voltage (V) of inverter; $V_{mppt\min}$:Minimum voltage of the inverter MPPT voltage (V); $V_{mppt\max}$:Maximum voltage of the inverter MPPT voltage (V); V_{oc} :Open circuit voltage of the PV module (V); V_{pm} :Working voltage of the PV module (V);Integrated with formula 1~2, In order to reduce the investment, String number of PV module is 22.

2.2 Empirical formula for temperature correction

When PV modules work, the PV module's temperature is different from ambient. The extreme temperature of the traditional calculation method is mostly referring to the ambient temperature, which is different from the specification requirements. In some power stations, the working temperature of the PV module is corrected by the following methods [2]:

2.2.1 Method I

$$t = t_{am} + (\frac{T_{NOCT} - 20}{K_c}) \bullet G \quad (2)$$

In the formula, where:

t_{am} : Ambient temperature (centigrade); T_{NOCT} : Standard operating temperature(Usual value: 45 degrees centigrade); K_c : Test data calculated based experience value (Usual value:0.7~0.8); G : Global irradiation (kW/m^2).

2.2.2 Method II

$$t = t_{am} + (T_{NOCT} - T_{am,NOCT}) \bullet (\frac{G}{G_{NOCT}}) \bullet (1 - \frac{\eta}{\tau\alpha}) \quad (3)$$

In the formula, where:

$T_{am,NOCT}$: Temperature of environment under PV module's NOCT (Usual value: 20); G_{NOCT}: Global irradiance under NOCT (Usual value: 0.8kW/m^2) ; $\frac{\eta}{\tau\alpha}$: Default constant (Usual value: 0.083/0.90).

2.2.2 Method III

$$t = t_{am} + (\frac{G}{G_{NOCT}}) \bullet (T_{NOCT} - 20) \tag{4}$$

According to the above method, the correction temperature of the module is obtained as follows:

Table 1. Corrected temperature by using empirical formula

Method	Corrected temperature	V_{oc} of PV module	Mark
I	-5.15	1013.03	G=0.2, Kc=0.8
II	-5.73	1014.78	G=0.2
III	-5.15	1013.03	G=0.2

After temperature correction, the string number of PV modules is unchanged. At the same time, the empirical formula does not take into account the characteristics of the module. There is still a certain margin.

In the project, the system simulation is carried out to complete the selection of equipment according to the actual climate characteristics.

3. TEMPERATURE CORRECTION BASED ON PV MODULE 'S MECHANISM MODEL

3.1 PV module 's mechanism model

According to the mechanism model of PV module, the VI curve formula of PV module is as follows:

$$V_{pm} = \frac{AkT}{q} \ln\left[\frac{1+\left(I_{ph}/I_0\right)}{1+qV_{pm}/AkT}\right] \approx V_{oc} - \frac{AkT}{q}\ln(1+\frac{qV_m}{AkT}) \tag{5}$$

In the formula, where:

A : Module structure factor; k : Boltzmann constant; T : Absolute temperature; q :Electronic electricity; I_{ph} : Photogenerated current; I_0 : Index factor.

Combined with the module parameters, the IV curve of the PV module is obtained as follows:

$$V_{pm} = \frac{\mathrm{Ak}T}{\mathrm{q}} \ln\left[\frac{1+\left(9.246\ 5/1.039\ 4\cdot 10^{-10}\right)}{1+\mathrm{q}V_{pm}/\mathrm{Ak}T}\right] \tag{6}$$

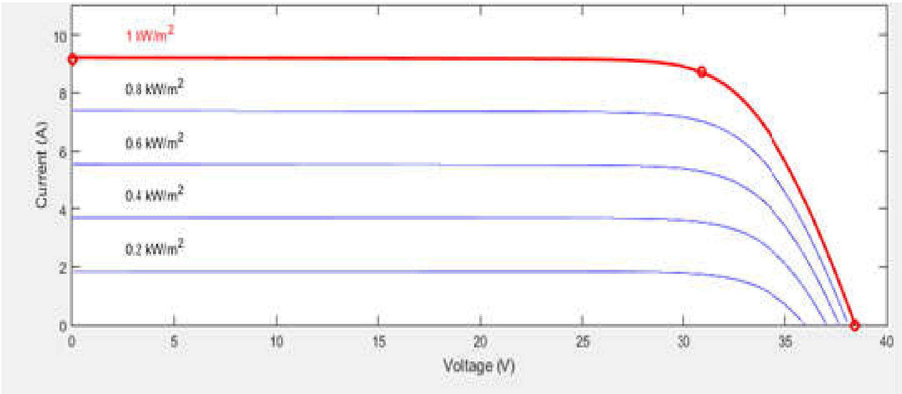

Fig. 1 IV curve of the selected module

3.2 Simulation of module voltage variation under different environment parameters

In order to get the conditions of different radiation and different temperature conditions of the PV module, this paper assumes that the ambient temperature and radiation change curves of the sunrise period are as follows:

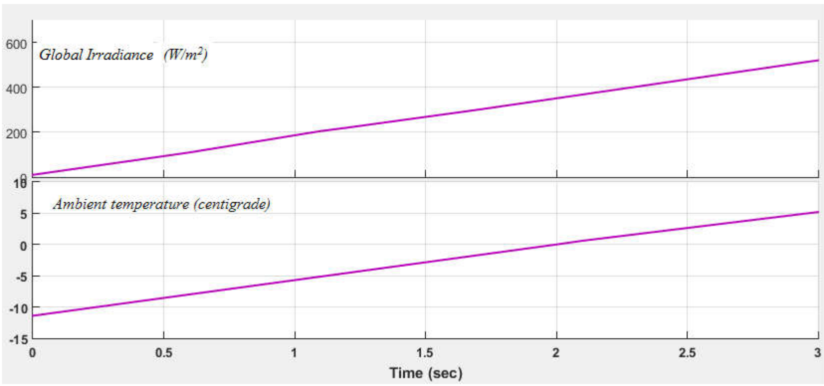

Fig. 2 Simulation of ambient temperature and radiation changes in the sunrise

According to the above steps, the simulation results are as follows: when the number of PV modules is series 24, the results are as follows:

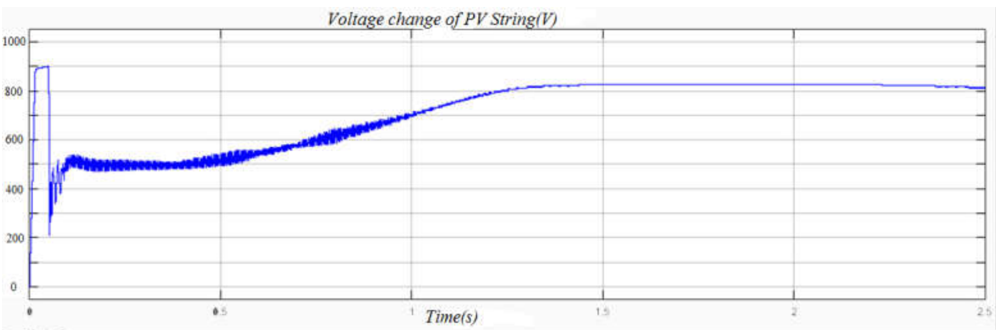

Fig. 3 Dynamic response curve of PV string's voltage

As can be seen from Figure 3, the lowest temperature in the local historical environment is -11.4 C, and when the string number is 24, the voltage of the MPPT reach 832V, which is slightly lower than the value of the inverter. It's safe and reliable.

It can be concluded that: compared with the traditional calculation method, the unit MW cost difference when the string number is 24 is as follows:

Table 2. Unit MW project cost ($).

Item	$N=\mathbf{22}$	$N=\mathbf{24}$	Mark
Cabel(1*4mm^2)	4307.69	3846.15	Actual project cost
Cabel(1*70mm^2)	43938.46	36615.38	Actual project cost
DC Box	10338.46	8615.38	Actual project cost
Cable trench & Others	18461.54	15384.62	Actual project cost
Total	77046.15	64461.54	

According to the above table, when the string number is 24, the cable and related expenses of the unit MW are saved $12584.62, Reduce investment by 16.33%.

4. CONCLUSION AND SUGGESTIONS

In this paper, base on the IV curve of PV module, we simulated the voltage change curve of string number under different environmental temperature and radiation value. Compared with traditional calculation method, the project cost decreased 16.33%. This method has certain positive significance to reduce the cost of the project.

REFERENCES

[1] China Electricity Council. Code for design of PV power station : GB50797-2012[S]. Beijing : China Planning Press, 2012:10.

[2] Ali Keyhani. smart grid renewable energy system design [M]. Beijing: Beijing: Machinery Industry Press, 2012.207~208.

[3] Yang Jinhuan, Yu bushes, Ge Liang. Solar PV power application technology (Third Edition) [M]. Peking: Electronic Industry Press, 2017.64~67.