Economical Analysis of the Influence of Cleaning PV modules on Power Generating Cost of Photovoltaic Power Station

YANG Ruopu

(School of Electrical and Electronic Engineering,North China Electric Power University,Baoding 071003,China)

Key words: PV modules; ash fouling; equivalent generating hours; economic benefits

Abstract: Ash fouling on the surface of solar PV modules influences power generating efficiency. However, cleaning PV modules will increase power generating cost. Through comparative analysis of power generating cost between cleaned and uncleaned PV modules of same kind, it is concluded that the daily equivalent generating hours of cleaned PV modules raise by an average of 0.06. Furthermore, the economic benefits improve markedly. It is suggested that the photovoltaic power station of which PV modules are installed horizontally in Hefei and other subtropical humid monsoon climate zone shall be cleaned every two months in spring, autumn and winter.

1 Introduction

Ash fouling on the surface of solar PV modules seriously affects power generating efficiency and decreases power generating capacity[1-8]. The main reason is that ash blocking the light of PV modules[1-3]. Some scholars think that the absolute value of power generating efficiency of PV modules with clean surface is 4.13% higher than the uncleaned ones covered with ash for one year[2]. The more the ash, the greater the loss of generated output. Some scholar's researches show if the ash amount is 5.65g/m^2 , the power loss will be 15.2%[1]. Ju Fali and some other scholars regards the shadowing, temperature and corrosion effect as the reason for ash fouling affecting generating efficiency[2]. As the ash fouling time goes on, the daily power generating capacity has been declined continuously. What is more, it is also influenced by the solar radiation quantity. For the ash fouling modules, if the solar radiation gets stronger, the power generating capacity reduces less. On the contrary, if the solar radiation gets softer, the power generating capacity reduces more[1].

Therefore, cleaning the surface of PV modules is conducive to improving power generating efficiency. However, the cleaning work increases power generating cost, such as labor, water and some other expenses. What is more, achieving the most excellent economic benefits depends on when, how and how often clean the surface of PV modules. Some scholars put forward that 7-10 days shall be regarded as a period in dry and rainless inland area[1].

New energy industry develops rapidly in Hefei city of Anhui province. Try to build the "top city for PV application". Based on the JA solar photovoltaic power station of Golden Sun Project in Hefei city, compare the cleaned and uncleaned PV modules of same type in the article. Moreover, analyze the economic benefits and make a research on optimum cleaning period.

2 Overview of JA Solar Photovoltaic Power Station

JA solar photovoltaic power station is located within the JA solar factory in high-tech zone of Hefei city, Anhui province. There are two phases of JA solar photovoltaic power station, including phase I with 1.4016MWp capacity and phase II with 8.26875MWp capacity. Both of them are located in the same site.

Hefei has a subtropical monsoon and moderate climate and four distinctive seasons with appropriate rainfall. It rains less in spring, autumn and winter. It is hot and rains a lot in summer. Rain falls mainly during plum rain season from May to June. According to operating experience of photovoltaic power station these years, the maximum power generating hours achieves 1090h in Hefei. The maximum irradiance is near 1000W/m^2. Generally, the best time for power generating is from June to September. In order not to influence power generating capacity, clean the photovoltaic

© 2015. The authors - Published by Atlantis Press

modules in the mornings and evenings of spring and autumn.

The installed capacity of JA solar II photovoltaic power station is 8.26875MWp. There are total 33620 solar power modules. Most of these modules are installed horizontally (steel structure roof). Only a few of concrete roof are installed at an angle of 11 degrees. For those modules installed horizontally, there is still remaining dust on the surface of modules after the rain, which will impact the power generating efficiency of modules. Picture 1 and picture 2 as follows compare the ash fouling condition of modules installed horizontally in October 2014.

Picture 1 Ash fouling

Picture 2 After cleaning

3 Economical Analysis of Cleaned Photovoltaic Modules

3.1 Contrastive Analysis of Daily Equivalent Generating Hours Data of Photovoltaic Modules of Same Kind Before and After Cleaning

Both JA solar I and II are located in the same site. With the same sunlight, compare the samples of JA solar I and II. Clean the module sample of JA solar I, but not the JA solar II. Analyze the daily equivalent generating hours and the difference between JA solar I and II.

Daily equivalent generating hours of photovoltaic module=Daily generating capacity/installed capacity

The cleaning time of JA solar II is from Oct.10th to Oct. 18th 2014. It rained firstly on Oct. 31st after cleaning. Absolutely it influenced the cleanness of the module. So regard it as contrastive time period from Oct. 1st to Oct.30th.The contrastive index is daily equivalent generating hours.

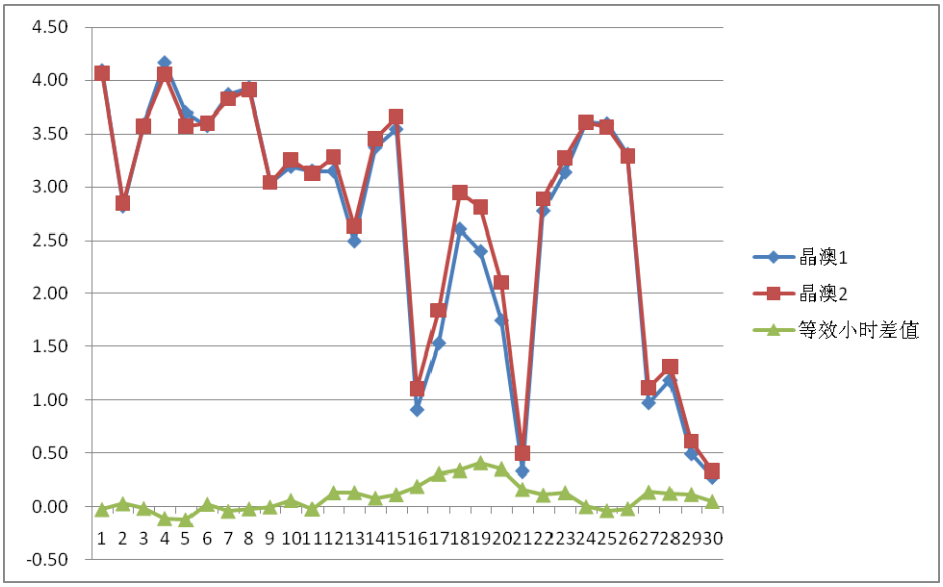
The difference of equivalent generating hours=daily equivalent generating hours of JA solar II--daily equivalent generating hours of JA solar I.

The data of daily equivalent generating hours of JA solar I and II is shown in Table I. The line chart of equivalent generating hours of JA solar I and II is shown in the picture III as well as the difference of equivalent generating hours of JA solar I and II.

Table 1 Comparison of Equivalent Generating Hours of Photovoltaic Module Before and After Cleaning

Date	JA solar II	JA solar I	Difference of equivalent generating hours	Date	JA solar II	JA solar I	Difference of equivalent generating hours
10.1	4.06	4.09	-0.02	10.16	1.10	0.91	0.19
10.2	2.84	2.81	0.03	10.17	1.84	1.53	0.31
10.3	3.57	3.59	-0.02	10.18	2.94	2.60	0.34
10.4	4.05	4.16	-0.11	10.19	2.81	2.40	0.41
10.5	3.57	3.69	-0.12	10.20	2.10	1.74	0.36
10.6	3.60	3.57	0.02	10.21	0.50	0.33	0.16
10.7	3.82	3.86	-0.04	10.22	2.88	2.77	0.11
10.8	3.91	3.93	-0.02	10.23	3.27	3.14	0.13
10.9	3.04	3.04	0.00	10.24	3.69	3.61	0.08
10.10	3.25	3.19	0.06	10.25	3.56	3.60	-0.04

10.11	3.13	3.15	-0.02	10.26	3.29	3.31	-0.02
10.12	3.28	3.15	0.13	10.27	1.11	0.97	0.14
10.13	2.73	2.49	0.23	10.28	1.32	1.19	0.13
10.14	3.45	3.37	0.08	10.29	0.61	0.49	0.12
10.15	3.66	3.54	0.11	10.30	0.33	0.28	0.05



Picture3 The comparison line chart of equivalent generating hours of JA solar I and II

Table 2 shows the mean difference of equivalent generating hours between JA solar I and II achieved from Table 1 and Picture 3.

Table 2 Mean difference of equivalent generating hours between JA solar I and II

Cleaning condition	Periods of time	Mean difference of equivalent generating hours	Changing situation
Before cleaning	Oct.1st-Oct.9th	-0.03	JA solar II is similar with JA solar I (JA solar II is slightly less than JA solar I.)
Cleaning a part	Oct. 10th-Oct.15th	0.09	JA solar II is slightly greater than JA solar I.
Cleaning a large part	Oct.16th-Oct.17th	0.25	JA solar II is obviously greater than JA solar I.
Complete cleaning	Oct.18th-Oct.22th	0.28	JA solar II is obviously greater than JA solar I.
Five days after complete cleaning	Oct.23th-Oct.30th	0.06	JA solar II is slightly greater than JA solar I.

From Table 2 we can see that the equivalent generating hours of JA solar I and the uncleaned JA solar II are approximately equal. Clean photovoltaic modules of JA solar II power station but not clean the JA solar I. The equivalent generating hours of cleaned JA solar II photovoltaic modules increase obviously. As time goes by after cleaning, the equivalent generating hours of JA solar I and II decrease gradually. Then ,the equivalent generating hours of JA solar I and II tend to be equal gradually. It is caused by the ash fouling on the surface of photovoltaic modules.

3.2 Economic Benefits Analysis of Cleaned Photovoltaic Modules of the Same Type

We mark the increased power generating capacity of JA solar II power station with cleaned photovoltaic modules as D, the increased equivalent generating hours as H, the installed capacity of JA solar II power station as G.

D=H* G The detailed results are shown in Table 3.

Table 3 The increased generating capacity of JA solar II power station with cleaned photovoltaic modules

Date	H	D	Date	H	D
10.10	0.06	509.2	10.21	0.16	1363.6
10.11	-0.02	-171.5	10.22	0.11	920.4
10.12	0.13	1103.2	10.23	0.13	1111.7
10.13	0.23	1941.2	10.24	0.08	679.5
10.14	0.08	684.8	10.25	-0.04	-293.5
10.15	0.11	948.9	10.26	-0.02	-143.9
10.16	0.19	1598.1	10.27	0.14	1147.2
10.17	0.31	2545.6	10.28	0.13	1057.3
10.18	0.34	2816.3	10.29	0.12	969.3
10.19	0.41	3377.7	10.30	0.05	419.2
10.20	0.36	2935.7	/	/	/
Total		**25520kWh**			

After cleaning the photovoltaic modules, the increased generating capacity achieved 25520kWh before the rain on Oct.31st. If the electric charge is 0.68RMB/kWh,the increased earnings of cleaned modules will be 25520*0.68=17353.6RMB

Calculation of charges for cleaning the modules:

(1) Labour charges(So far, photovoltaic modules are cleaned by man in China. It is the most costly way. If it is automated, the cost will be reduced.

(2)Water charges: Approximately 2100t water is used. Water charges for operating service in Hefei city is 2.65RMB/ton.So the total water charges is 2100*2.65=5565RMB.

(3)Earnings from cleaning the photovoltaic modules is 17353.6-13427.6-5565=-1639RMB.

4 Comparison of daily equivalent generating hours of photovoltaic power station in the same area

Compare the daily equivalent generating hours between JA solar II power station with cleaned photovoltaic modules and other photovoltaic power stations of same kind. The power generating data on Nov.2nd are shown in Table 4.

Table 4 Comparison of daily equivalent generating hours between JA solar II power station cleaned 15 days ago and other photovoltaic power stations of the same kind

Power Station	Installed capacity(MWp)	Daily generating capacity(kWh)	Daily equivalent generating hours
JA solar II	8.26875	26560	3.21
Meizhi photovoltaic power station	4.7715	12320	2.58
Hitachi photovoltaic power station	8.6959	26399	3.04
Dongfeng mechanical and photovoltaic power stations	1.6575	5010	3.02

From Table 4,we can see that the daily equivalent generating hour of JA solar II photovoltaic power station with cleaned photovoltaic modules is 3.21.For other photovoltaic power stations in Hefei, Hitachi photovoltaic power station is the highest 3.04. The difference of daily equivalent generating hour is 0.16. Furthermore, JA solar II photovoltaic power station is obviously higher than Meizhi photovoltaic power station, Dongfeng mechanical and photovoltaic power station. The importance of cleaning photovoltaic modules will be inferred naturally.

5 Conclusion and Suggestion

(1)Through contrastive analysis between JA solar II photovoltaic power station with cleaned photovoltaic modules and JA solar I photovoltaic power station with uncleaned photovoltaic modules, the equivalent generating hours of JA solar II photovoltaic power station is higher than JA solar I. Moreover, the generating capacity also increases. Although the cost is increased, it is generally profitable. The economic benefit is obvious. All these reflects the necessity of cleaning photovoltaic modules of photovoltaic power station in Hefei city.

(2)The daily generating capacity of photovoltaic modules with ash fouling, is also influenced by the change of solar radiation quantity[1]. For the photovoltaic modules with ash fouling, if the solar radiation level is high, the attenuation of generating capacity will be weak and vice versa. The solar radiation level in summer is high. So the attenuation of generating capacity is weak. There is much rain in summer in Hefei city. Therefore, we suggest that the photovoltaic power station of which the PV modules are installed horizontally in Hefei of subtropical humid monsoon climate shall be cleaned every two months in spring, autumn and winter. As the case may be, PV modules can not be cleaned in summer. Certainly, the cleaning frequency of PV modules shall be determined by pollution status of different time and service time of PV modules.

References

[1]Chen Dongbin, Li Daxin. Analysis of the impact test generation power station on the PV module surface dust and pole shadow [J]. Solar Energy，2011(9)：39-41.

[2]Feng Zhicheng.Study on the Influence FactorsofPhotovoltaic Performance [D]. Inner Mongolia University of Technology，2013.

[3]Ju Fali. Study on The Effect of Photovoltaic Power Generation Project By Dust[D].Chongqing University , 2010.

[4]Wang Feng,Zhang Yongqiang. Xi'an City fouling of distributed PV power plant output power of impact analysis [J]. Solar Energy，2013(13):38-41.

[5]Wu Qiong,Ren Hongbo. Economic assessment of residential photovoltaic system based on dynamic load characteristics [J]. Renewable Energy Resources，2014，32(2):133-137.

[6]Wang Fenggao.Thinking of new solar PV modules based cleaning system. Silicon Valley. 2012.24.

[7]Zhang Li,Zhong Yun. Experimental study of photovoltaic module considering shadow effects [J]. Solar Energy，2009(10)：27-28.

[8]Zhang Xueli, Liu Qihui,Ma, Huimeng. Analysis of Influencing Factors of Output Power of Photovoltaic Power Plant [J] .Power System and Clean Energy，(05):75-81.