Experimental Study of PV Panel Cleaning in Solar PV Farm in Rainy Season of Thailand

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ABSTRACT

This paper presents the experimental study of photovoltaic (PV) cleaning in the solar PV farm of rainy season in Nakhon Ratchasima province, Thailand. The aim of study is to find the economical cleaning frequency of PV panels. Normal operation and maintenance of solar PV farm, the cleaning of soiling PV panel is not proceeded during rainy season. The experimental study is applied to solar PV farm with string inverter installation. The similar five string inverters are setting for experimental cleaning frequency. The different timing of PV cleaning is studied in the energy generation of each set. The results of study show that energy output of PV cleaning of twice a month is reasonable energy yield with the energy price of 8.00 Baht adder, 6.50 Baht adder and 4.00 Baht feed in tariff (FiT) prices.

1. INTRODUCTION

In renewable industry section, the solar PV farm is one of interested investment. Revenue of investment is energy producing in daytime. If the solar radiation is reduced impacting to solar cell, the power generation is also reduced. Thus, the surface of PV panel should be cleaned. In rainy season of Thailand, the rain can clean the surface of PV panel from dust. However, the surface of PV panel is still covered by some stain film. This stain film might make the power producing from PV panel decreasing. Cleaning of PV panel cost needs to consider that cover by energy increasing.

Soiling on PV panel, the power generation is decreased [1]. Many researches have been reviewed to understand how the soiling PV panel makes the lower power output. Moreover, the partial hard shading of PV cell may occur hot spot. Although, the bypass diode can solve hot spot [1], in practical PV panel is not install the bypass diode for all cell of PV panel. Normally in practical PV panel only three diodes are installed. Thus, the hot spot-on PV panel cannot be avoided when hard shading is occurred. Also, in [2], the voltage and current characteristics are impacted by dust accumulation on surface of PV panel. Many methods have been implemented to clean the surface of PV panel. All methods need to consider with economic. Several countries as in [3] and [4] have own solving method to clean the soiled PV panel. Also, the economic study is depending location that make the PV panel soiling. In [5], the best PV panel cleaning is applied by water. In Thailand, the most of solar PV farms are installed in rural areas. Especially in Nakhon Ratchasima province, the dust from road, rice filed, cassava filed and industry section can make soiling on surface of PV panel. Economical cleaning of PV panel should be considered with locally cleaning cost.

Thus, in this paper, the experimental study is considered for finding the optimal scheduling of PV panel cleaning. The real 3MW solar PV farm with each 17kW string inverter is studied. The five inverters with its connected PV panels are serving for experiment of five timings criteria. Different time duration of each experiment cleaning is considered. The cleaning cost comprises man power, water and washing material costings. Aim of this paper should be gain to solar PV operator and investor. The finally gaining to the world that we can produce the power from solar efficiently.

2. PERFORMANCE RATIO AND SOILING LOSS

Performance ratio (PR) shows the performance of solar PV grid-connected systems as in [6].

$$\mathrm{PR} = \frac{Y_F}{Y_R} \tag{1}$$

where Y_F is the final yield that evaluation of actual energy PV production to theoretical PV power at standard test condition (STC) and Y_R is the reference yield that defined as ratio of solar radiation to the reference radiation. This PR always include in the commercial PV system designing program as PVsyst [7].

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Soiling loss is the loss in power resulting from snow, dirt, dust and other particles that cover the surface of the PV panel [1]. Dust accumulation on surface of PV panel makes solar radiation impacting to cell of PV panel reducing. Then, the output power of PV panel is also reduced. Thus, if the PV panel surface is cleaned, the output power of PV system should be increased making higher PR. Normally in commercial programming, the soiling loss is setting as 3 percentage of PV power installation.

In rainy season of Thailand, the surface of PV panel is cleaned by natural rain falling. Although, general dust from environment can be removed, the surface of PV panel is still covering with some stain by visual. Removing of stain and dust on PV surface in rainy season will economically cleaning or not is so challenging to the PV farm operator. Then, this experimental study is explored.

3. EXPERIMENTAL METHODOLOGY

The aim of study is to find the economical cleaning of PV panel surface. Water and cleaning shampoo are material in this experimental cleaning. Human cost is used the local PV farm site at Nakhon Ratchasima province of Thailand. For archiving to the aim, the experimental PV panel and inverter set are prepared into five sets. The procedures of study are as following:

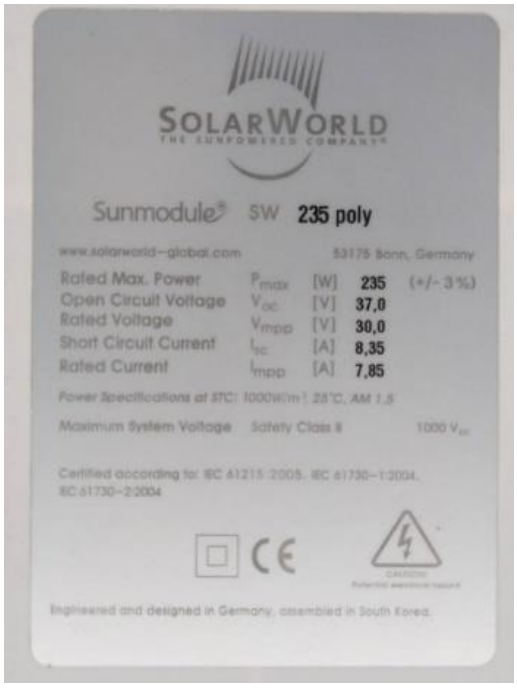
- Select the 5 sets of PV panel and inverter in the closing area.
- Clean the first 4 sets of PV panel and inverter for different time duration while the other last one no any cleaning during rainy season. Set 1 of PV panel and inverter will clean in every 15 days. Set 2 will clean for every 30 days. Set 3 will clean for 45 days. And the set 4 will no clean for any day. All 4 sets are cleaned at the study starting. The set 5 will not any clean at all during study excluding normally PV farm maintenance.
- Record the energy producing of those 5 sets during rainy season.
- Conclude the experimental study.

Fig. 1: PV Farm Location Picture from Google Map.

The location of experimental study is Muang district, Nakhon Ratchasima province of Thailand. The cassava field is surrounding the PV farm site. The picture of PV farm from google map is shown in Fig. 1.

The mainly experimental equipment in PV farm system is 17kW SMA grid-connected string inverter and 235Wp polycrystalline PV panel. These important equipment data are shown as following figures.

(a) PV panel surface and installation array



(b) Back sheet data of PV panel

Fig. 2: PV Panel for Experimental Study.

Both PV panel and inverter are world class brand. The inverter has own energy data storage program called Sunny Explorer. From Fig. 2 and 3, the solar PV farm was designed and installation on year 2011. For each string inverter was designed as following single line diagram.

(a) SMA inverter, Sunny Tripower 17000TL model.

(b) Inverter data

Fig. 3: Grid-connected String Inverter in Studied Site.

In Fig.4, the total DC power input to inverter is 21,620Wp. The 60 inverters are served for 1MW PV power plant. Although, the input power is higher than maximum DC input range as in Fig.3 (b), the system is still operated with properly condition. If it on the high solar radiation day, the maximum AC output power might be limited by inverter power limiting.

During the PV panel cleaning, at the sunset is proceeded for avoiding to energy producing. The cleaning procedure is as following figure.

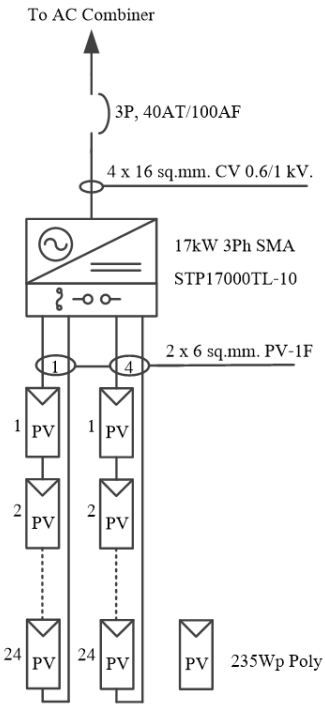


Fig. 4: Single Line Diagram of Installed PV System.

Fig. 5: PV Panel Cleaning on Sunset.

Energy selling price in this study is depended on government policy. For this PV power plant, the energy price per kWh is 8.00 Baht adder from generally energy buying price around 4.00 Baht. Thus, the totally energy selling price is around 12.00 Baht. Then, the other one government policy price is 6.50 Baht adder per kWh. The last energy price after the contract for energy selling with

government is end on 25 years contracting, the energy investor will can sell energy to the grid around 4.00 Baht per kWh. These energy prices are used to consider in economical cleaning. The cleaning cost needs to cover when considering with energy selling price.

The cleaning cost depends on labor, water and cleaning shampoo costs. Labor cost depends on the location of PV farm site. In Nakhon Ratchasima 2018 year, the totally cleaning cost is 0.84.00 Baht per square meter of PV panel area. The area of a PV panel is 1.67 square meter.

4. EXPERIMENTAL RESULTS

The experimental study is proceeded in rainy season on July until September. The 5 sets of 17kW string inverter connecting with 92 panel of 235Wp PV panels are experimented. Each set is experimental cleaning as detail in Section 3. The typical accumulated energy of each month in rainy season is shown in Fig. 6. Also, the aggregated energy of three months of all five experimenatal sets are shown in Fig. 7.

In Fig. 6, the accumulated energy on July is shown while the other following two months are not shown here but accumulated energy are the same manner.

In Fig. 6, PV set 1-4 are cleaned at the month beginning of July while set 5 is no any cleaning. Set 5 will depend on PV site cleaning that four month ago. The accumulated energy yield from set 1 is highest. If we consider the revenue after cleaning cost reduction of 0.84Baht per square meter, the net revenue is shown in Table 1.

In Table 1, if we consider in term of the different of net revenue between no any cleaning and different frequency cleaning, the following Table 2 is shown.

In Table 2, if we clean the PV panel for every 15 days as Set 1, the PV plant investor will more revenue as 4,615.59Baht per one set or predict as 276,935Baht per 1MW. For the other cleaning period, the revenue is as Table 2 and all predicting the different of net revenue as in Table 3.

Table 1: Net Revenue in Baht For Three Months After Removal Cleaning Cost For Different Energy Price per kWh

Experimental set no.	8.00 Baht adder price	6.50 Baht adder price	4.00 Baht based price
1	89,231.42	77,984.76	29,249.21
2	87,895.97	76,862.61	29,051.36
3	87,799.36	76,793.53	29,101.59
4	85,728.33	74,996.84	28,493.68
5	84,618.83	74,041.47	28,206.28

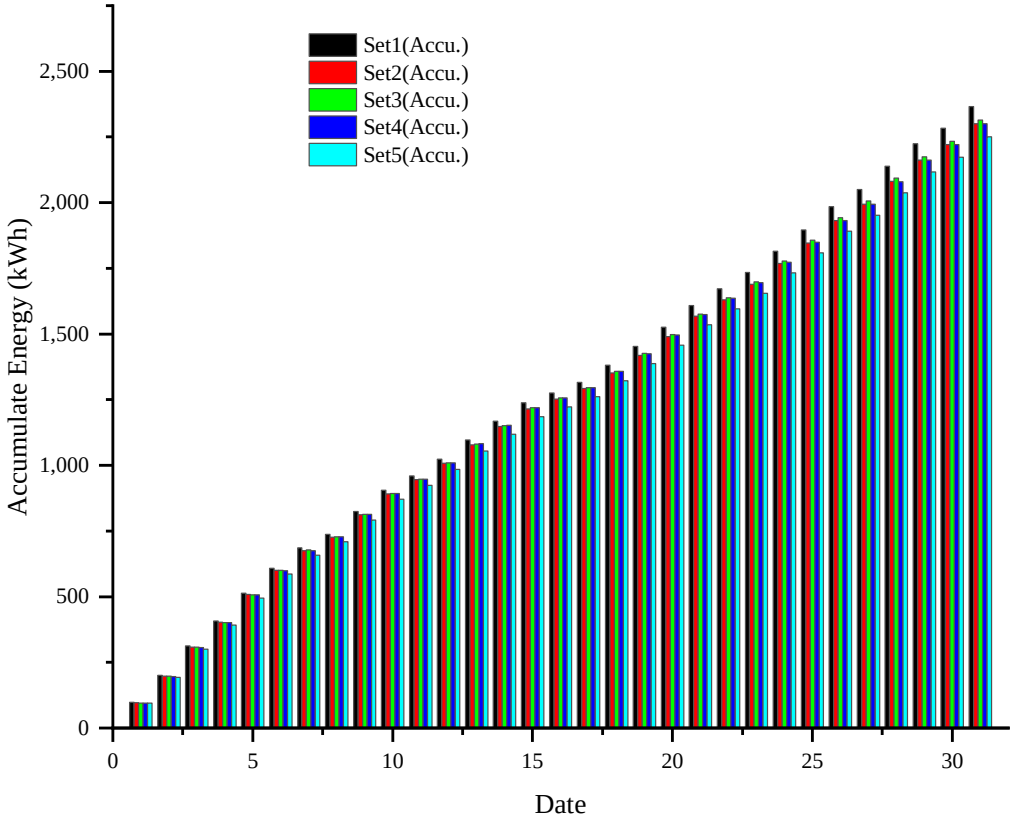


Fig. 6: Accumulated Energy on July.

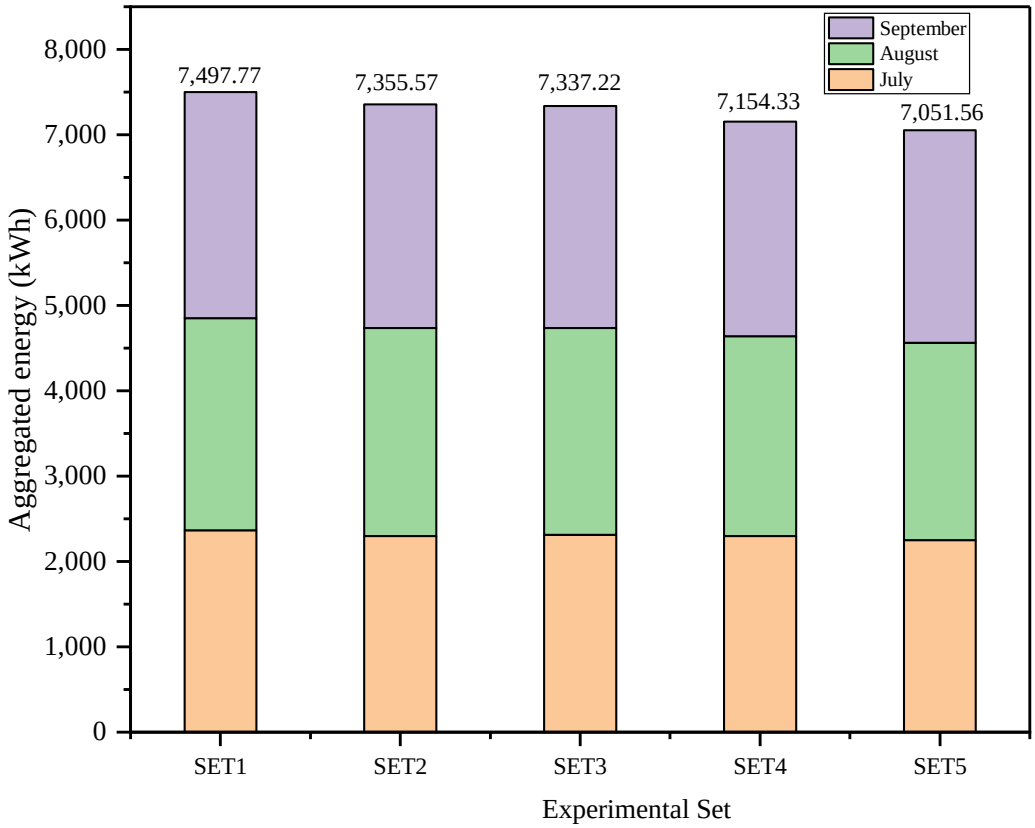


Fig. 7: Aggregated Energy of Three Month of Five Experimental PV Sets.

Table 2. The Different of Net Revenue in Baht of Different Frequency Cleaning

Experimental set no.	8.00 Baht adder price	6.50 Baht adder price	4.00 Baht based price
1	4,612.59	3,943.29	1,042.93
2	3,277.14	2,821.14	845.08
3	3,180.53	2,752.06	895.31
4	1,109.50	955.37	287.40
5	0.00	0.00	0.00

Table 3: The Predicting of Different of Net Revenue in Baht For 1MW Solar PV Farm

Experimental set no.	8.00 Baht adder price	6.50 Baht adder price	4.00 Baht based price
1	276,755.40	236,597.40	62,575.80
2	196,628.40	169,268.40	50,704.80
3	190,831.80	165,123.60	53,718.60
4	66,570.00	57,322.20	17,244.00
5	0.00	0.00	0.00

In Table 3, the different of net revenue are predicted from Table 2 multiple to 60 units of PV panel and inverter that is for 1MW system. This predicting shows that if we clean the PV panel during rainy season for 15 days frequency, we will gain the revenue 276,755.40 Baht per 1MW solar PV farm.

5. CONCLUSION

Normal of practical PV cleaning in the solar PV farm of Thailand is not preceded in rainy season since believing that the rain can clean the PV panel surface. Then, this paper is presented to experiment the PV panel surface cleaning during three months in rainy season. The often cleaning can increase the energy yield. If we chose to clean for twice a month, the predicting of the different of net revenue is increased by 276,755.40 Baht per 1MW PV system. Also, the often cleaning makes the labor revenue increasing. Although at lowest energy price, the predicting of the different of net revenue is still valuable at 62,575.80 Baht per 1MW PV system.

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