The Investigation of Sea Salt Soiling on PV Panel

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ABSTRACT
Renewable energy promises a better future for humankind and more flexible to be installed in a remote area such as a fisher village. The installation of PV panels by the seashore is prone to sea salt soiling. The unfortunate downside of solar energy is that it is highly affected by environmental changes. Therefore, the effect of sea salt deposition in time can reduce the installed PV panel's electrical performance. This paper presents the effect of sea salt soiling on PV panel performances during the rainy season and floated PV panel above a water body of an estuary to investigate the effect of sea salt soiling. The soiling PV panel simulation with sea salt resulting in a 2.09 W difference of the produced power from normal and sea salt soiling settings. A floating experiment is conducted for 29 days, and the electrical properties were measured on the last day. Even though the sea salt soiling can reduce PV panel performance, the benefit of PV panel application is significant, such as by installing a PV panel on a fisher boat, it can supply the electricity when the fisher goes fishing far to the sea.

Keywords: *Brackish water, estuary, partial shading, renewable energy, sea salt soiling*

1. INTRODUCTION

The application of renewable energy to substitute conventional energy has been the increasing subject to be investigated and applied due to the depletion of conventional fossil fuel [1]-[3]. Indonesia has a high potential for harvesting energy from the sun due to its location in the equator where solar energy promises unlimited energy to harvest in powering places and cities as the substitute for depleting conventional fossil fuel [5]-[10]. Solar energy has a high potential in a remote area where the government utility cannot reach it, such as the fishing village in Sungsang, South Sumatra. Sungsang estuary is located in a sunny area, which has a promising solar energy utilization. The problem with solar panel performance is highly affected by climate and environment changing [11]. The slight change of weather can significantly affect the resulting output and efficiency [12].

The sea salt containment in brackish water is affected due to the climate, during the dry season the sea water is higher than fresh water, while during monsoon and tidal, the fresh water is higher. As the amount sea water is higher, the containment of sea salt is higher. The environmental properties that affect the PV performance are temperature, soiling, and the amount of irradiance received by PV panel surface [13]-[19]. One of the efforts to reduce the overheated due to tropical temperature, a cooling system is designed and applied. The cooling system can be natural by installing heatsink and PCM and active method by letting the water flows on the surface of PV panel [20].

One of the natural methods that researchers currently develop is by floating the PV panels above a water body [21]-[26]. This method can enhance natural cooling and reduce the surface temperature of the PV panel and prevent the possibility of overheated. The overheated can lead to a cell's failure, and without proper care, this failure can extend to the whole panel. Our previous research is by floating the panel on Sunsang estuary, as presented in [21].

The soiling of dust or seasalt deposition reduce the output due to partial shading. The partial shading increases the heat at the shading cell, the overheat leads to cell and panel failure. This paper presents the climate effect on sea salt deposition on PV panel and to investigate how this condition affects the output and efficiency of solar panel. This paper is the continuation of our previous study where the data was taken during dry season [19], and floating data taken during rainy season [21].

2. ESTUARY AND BRACKISH WATER

The estuary is the sea's tidal inlet, a semi-enclosed coastal body of water connected to the sea and freshwater or river. The brackish water in an estuary has an extreme spatial variability in salinity; the sea salt is higher during the dry season and lowers during the rainy season or tidal. The estuary's dynamic environment makes it a productive habitat for fish communities, such as shrimps and crabs. The estuary is also home for birds to lay their eggs annually and contribute to the many habitat survivals.

Figure 1 Skyline view in Sungsang Estuary.

Sungsang estuary shown in Figure 1 is located between the Musi River and Bangka Strait, supporting natural food goods and services. This estuary functions as the fisherman village since this estuary is the nursery, spawning, and feeding ground. These various functions make it an area of high diversity. The community of Sungsang estuaries is growing every year; therefore, fishermen's enrichment creates more opportunities for fishers by increasing fishing capacity induced by the fishing pressure on fish stocks, which is subsequently caused by over-exploitation depletion of available fish stocks.

3. PV PANEL ELECTRICAL PROPERTIES

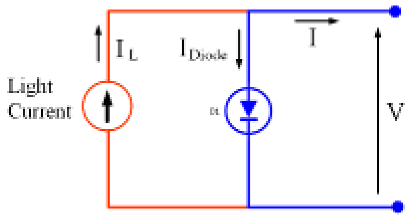
The electrical properties of PV panels are shown in Figure 2, where the PV panel is modeled as the ideal diode illustrated by Figure 3(a). The irradiance received by the panel generates electrical current (I) and voltage (V) are given as

$$I = I_o \left[\exp\left(\frac{qV}{nkT}\right) - 1\right] - I_L, \tag{1}$$

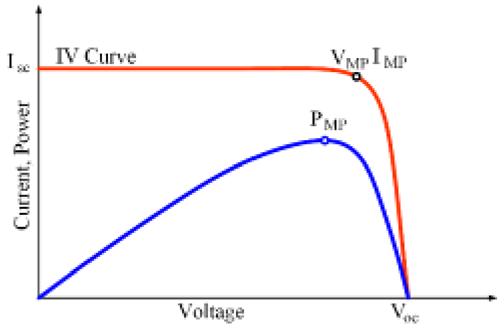
and

$$V = \frac{qV}{nkT} \ln\left(\frac{I_L - I}{I_o}\right), \tag{2}$$

where I_o is dark saturation current in A, $\frac{qV}{nkT}$ is the thermal component, q is charge in coulomb, n is ideality factor, T is the temperature in Kelvin, V is voltage, I_L is the light generated current, and k is the Boltzmann ($1.38064852 \times 10^{-23}$ m^2 kg s^{-2} K^{-1}) constant.



(a) Ideal diode



(a) IV Curve

Figure 2 PV cell modelling as an ideal diode and IV curves.

The total power produced by the PV panel is given in IV curve shown in Figure 2(b), which is also the function of short-circuit current (I_{sc}) and open-circuit voltage (V_{oc}). I_{sc} and V_{oc} are the current and voltage produced without the application of load on a PV system. V_{oc} is given by

$$V_{oc} = \frac{nkT}{q} \ln\left(\frac{I_L}{I_o} + 1\right), \tag{3}$$

while $I_{sc} \approx I_L$.

The IV curve in Figure 2(b) is giving the maximum power that can be harvested from a PV panel within efficiency as

$$\eta = \frac{P_{out}}{P_{in}} x100\%, = \frac{I_{mp} \cdot V_{mp}}{P_{in}} x\ 100\%, = \frac{I_{sc} V_{oc} FF}{P_{in}} x\ 100\%, \tag{4}$$

and

$$E = \frac{\text{Solar Irradiance}}{m^2}, \tag{5}$$

where I_{mp} and V_{mp} are the maximum current and volage, E is the solar energy, and is the fill factor, which is defined as the maximum power produced by a solar panel relative to the PV panel area.

4. EXPERIMENTAL SETTING

The objective of this study is to investigate the effect of climate change in sea salt soiling. The data is taken by spraying sea saltwater on the PV surface and observe the effect. The same experiment had been conducted in [19], which was conducted in the dry season, in August. The sea salt deposition on the PV panel is shown in Figure 3, which is visible compare to the normal setting. The effects of produced voltage, current, power, and efficiency due to sea salt soiling are investigated and compared to the normal setting without sea salt soiling. Figure 4 shows the measurement setting to record the data of short-circuit current, open-circuit voltage, produced power, and efficiency of the system.

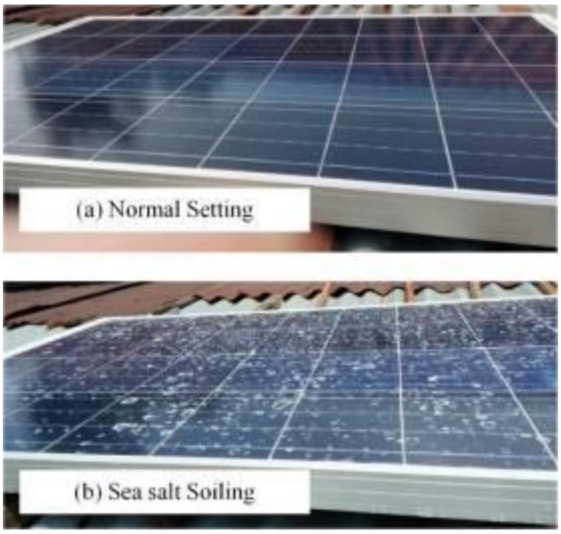


Figure 3 Experimental setting of sea salt deposition on the PV panel.

Figure 4 Measurement setting.

This research is extended by floating the PV panel for one day over brackish water and recording Voc, Isc, P, and η. The PV panel was floated from March 30 to April 28, 2019, before the data was taken. The floating PV panel over the brackish water is shown in Figure 5.

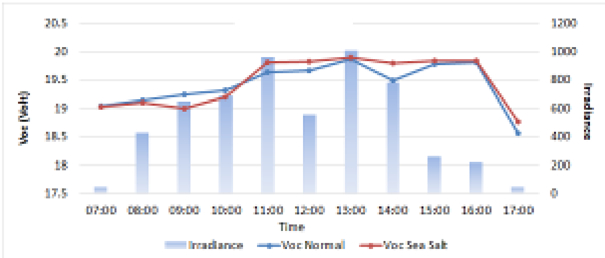
Figure 5. Floating PV panel over brackish water.

5. RESULT AND DISCUSSION

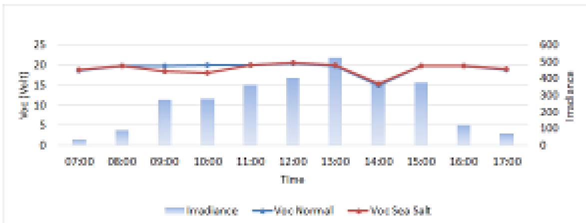
The results presented in this paper are divided into: (1) the result from soiling a PV panel for two weeks, and the data was taken for 4 days consecutively. (2) Floating a PV panel for 29 days and take the data for one day. The data of Voc, Isc, P, and η are taken, and the climate effect is noted.

5.1. Sea Salt Soiling Effect

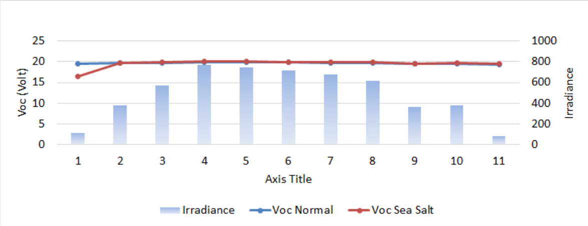
The sea salt soiling effect to a PV panel is investigated in this subsection. The effect of sea salt soiling on open-circuit voltage (Voc) is shown in Figure 6. Figure 6 shows that the effect of sea salt soiling on open-circuit voltage is not very significant. However, the clean PV panel gives more open-circuit voltage rather than the soiling one.



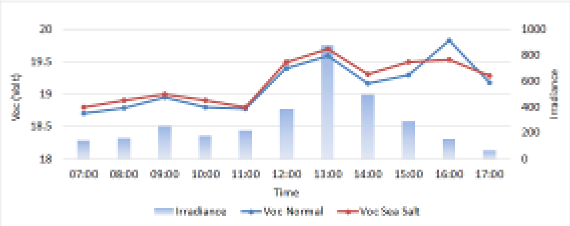
(a) Voc taken on Dec 26



(b) Voc taken on Dec 27



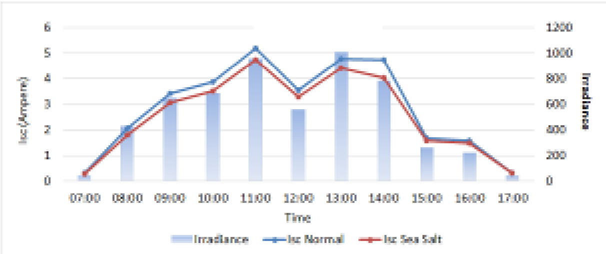
(c) Voc taken on Dec 28



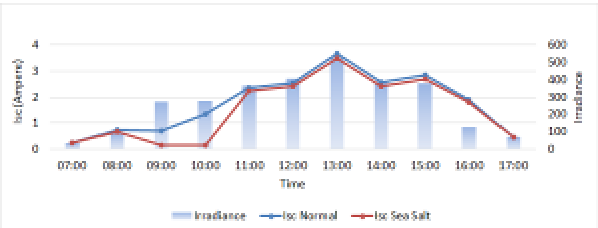
d) Voc taken on Dec 29

Figure 6 Open-circuit voltages differences between normal setting and sea salt soiling setting.

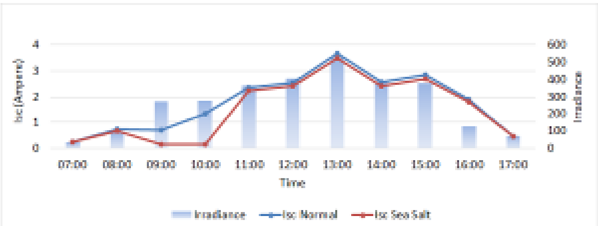
Short-circuit current (Isc) is highly affected by the amount of irradiance received by the panel, as shown in Figure 7, and as the sea salt soiling blocked the irradiance, the generated current is also reduced. Voc and Isc are the electrical properties measured when the load is not applied to the system. The data was taken instantaneously which a high chance of failure due to short-circuited measurement.



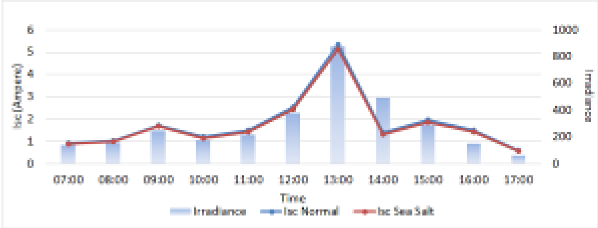
(a) Isc taken on Dec 26



(b) Isc taken on Dec 27

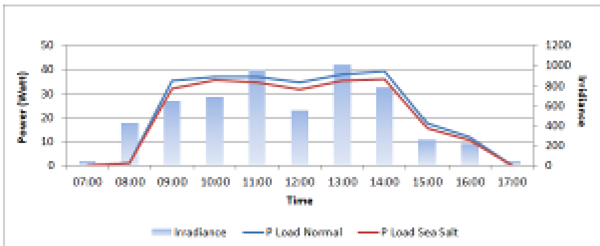


(c) Isc taken on Dec 28

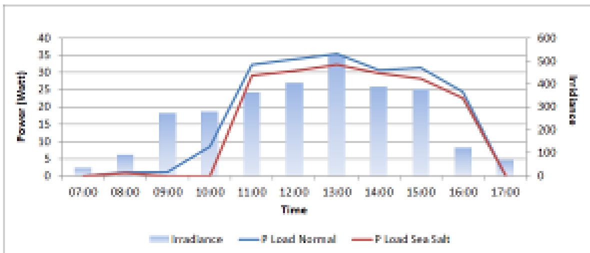


d) Isc taken on Dec 29

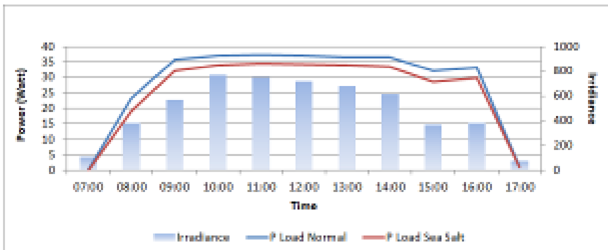
Figure 7 Open-circuit voltages differences between normal setting and sea salt soiling setting.



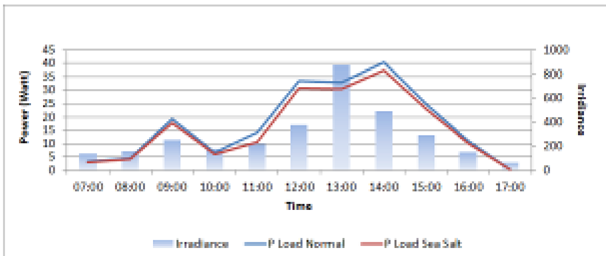
(a) P_{load} taken on Dec 26



(b) P_{load} taken on Dec 27



(c) P_{load} taken on Dec 28



d) P_{load} taken on Dec 29

Figure 8 The comparison of the produced Power between normal setting and sea salt soiling setting.

The final comparison of PV panels with and without sea salt soiling is shown in Figure 8, which gives the power produced when the load is applied to the PV system. The normal setting PV panel produces more power than the PV panel with sea salt deposition on the surface, and the difference averagely is 2.09 W. This difference can get bigger as the sea salt deposition is distributed more on the surface of the PV panel.

The efficiency differences of these two settings are given in Table 1. However, at the last day of data measurement, there is an abnormality in 02.00 PM measurement where the efficiency is more than 100%. This could be a result of a mistake during measurement

Table 1. Efficiency comparison between normal setting and sea salt soiling PV panels.

Time	26-Dec		27-Dec		28-Dec		29-Dec	
	η normal	η sea salt	η normal	η sea salt	η normal	η sea salt	η normal	η sea salt
07:00 AM	3%	2%	1%	1%	4%	0%	19%	17%
08:00 AM	3%	3%	8%	7%	65%	59%	23%	22%
09:00 AM	54%	55%	8%	1%	60%	58%	60%	55%
10:00 AM	50%	53%	32%	1%	49%	47%	29%	28%
11:00 AM	36%	37%	69%	65%	42%	41%	50%	39%
12:00 PM	50%	49%	65%	61%	44%	43%	68%	65%
01:00 PM	40%	40%	49%	47%	46%	44%	31%	30%
02:00 PM	42%	45%	80%	80%	56%	54%	150%	146%
03:00 PM	53%	50%	56%	53%	73%	68%	65%	63%
04:00 PM	38%	36%	65%	62%	68%	64%	38%	37%
05:00 PM	2%	2%	3%	3%	8%	7%	3%	3%

5.2. Floating PV Panel Above Brackish Water

In order to further investigate the sea salt soiling on the PV panel, a PV panel is floated above brackish water for 29 days, and the electrical properties were measured on the last day. Figure 9 shows the Voc and Isc measured on a floating PV panel. The produced current measured when no load is applied for shows that this property is highly affected by irradiance changing. As the day sun shines brighter than in the early hours, the measured Isc is higher and lower as the irradiance drops. The graph profile of Isc follows the profile of irradiance of the day. The highest measured Isc is at 12.50, as the peak of irradiance on April 28.

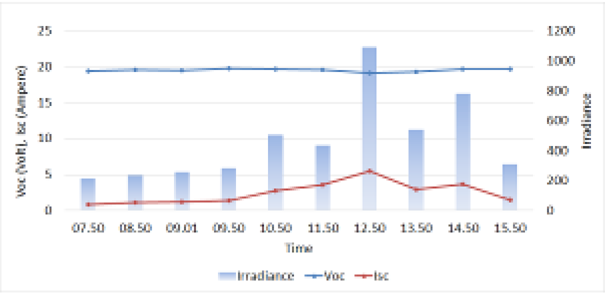


Figure 9 Voc and Isc measured at floating PV panel.

The produced power when a 20-Watt lamp is applied is shown in Figure 10. Since the generated current is highly affected by irradiance variation, the produced power is also varied during the day. Table 2 shows the floating solar panel's complete electrical properties giving how the properties are varied as the irradiance is changing.

Sea salt soiling affects the electrical properties of the PV panel, and in time reduces the performance of a PV panel. However, the electricity produced by a PV panel is needed by the remote are where the government utility cannot reach. The sea salt-affected areas commonly are fisherman villages. The floating PV panel can be installed on the roof of a boat to supply the electricity when the fisherman goes fishing far to the sea.

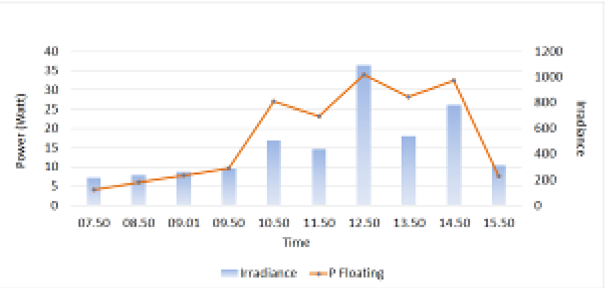


Figure 10 The produced power of floating PV panel.

Sea salt soiling affects the electrical properties of the PV panel, and in time reduces the performance of a PV panel. However, the electricity produced by a PV panel is needed by the remote are where the government utility cannot reach. The sea salt-affected areas commonly are fisherman villages. The floating PV panel can be installed on the roof of a boat to supply the electricity when the fisherman goes fishing far to the sea.

Table 2. Floating PV Panel Data.

Time	Voc	Isc	P Wo Load	V	I	P Load	Irradiance
07.50	19.4	0.87	16.88	4.45	0.95	4.23	214
08.50	19.6	1.09	21.36	5.56	1.09	6.06	234.9
09.01	19.5	1.20	23.40	6.44	1.20	7.73	259.2
09.50	19.8	1.39	27.52	7.38	1.31	9.67	283.4
10.50	19.7	2.74	53.98	13.70	1.97	26.99	503.1
11.50	19.6	3.60	70.56	12.50	1.86	23.25	436.5
12.50	19.2	5.52	105.98	15.70	2.16	33.91	1093
13.50	19.3	2.92	56.36	14.01	2.01	28.16	540.4
14.50	19.7	3.73	73.48	15.02	2.16	32.44	782.1
15.50	19.7	1.50	29.55	6.29	1.20	7.55	312

6. CONCLUSION

This paper presents the effect of sea salt soiling on PV panel performances during the rainy season, and the panel is floated above a water body of an estuary to investigate the effect of sea salt soiling. The soiling PV panel simulation with sea salt resulting in a 2.09 W difference of the produced power from normal and sea salt soiling settings. This difference can get bigger as the sea salt deposition is distributed more on the PV panel's surface. A further experiment of the sea salt soiling on the PV panel, a PV panel is floated above brackish water for 29 days, and the electrical properties were measured on the last day. Sea salt soiling affects the electrical properties of the PV panel, and in time reduces the performance of a PV panel. However, the electricity produced by a PV panel is needed by the remote are where the government utility cannot reach. The sea salt-affected areas commonly are fisherman villages. The floating PV panel can be installed on the roof of a boat to supply the electricity when the fisherman goes fishing far to the sea.

AUTHORS' CONTRIBUTIONS

All the authors share contributions in this manuscript. T. Dewi, and A. Taqwa designed and directed the project; R. D. Kusumanto and C. R. Sitompul performed and supervised the experiments; T. Dewi, and Rusdianasari conducted data analysis and wrote the article.

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