SOLAR CELL ARRAYS: DEGRADATION DUE TO DIRT

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ABSTRACT

Comparison of a washed and an unwashed solar cell array has been made over a six year period from 1983 through 1988. The performance of the washed solar cell array has remained constant over the six year period while that of the unwashed solar cell array has deteriorated at a rate of about 1.4% per year.

1. INTRODUCTION

When a solar cell array is installed, one often worries about how often the array should be washed and what would be the effects on the performance if the array was not washed. This can be particularly important if the array is mounted in an inaccessible or remote location. There have been studies that looked at the build up of dirt on the arrays over a one or two year period. Since solar cell arrays are designed to stay in the field for up to thirty years we decided to take a longer look at the problem of dirt build up. At present, this experiment has been running for nearly six years.

The advantages of a longer study are that a more precise estimate of the rate of degradation can be obtained and the effect of a dirty surface on the accumulation of additional dirt can be observed. Over a long time period, fluctuations in the rate of dirt build up which occur from year to year should average out. For short-term studies an unusually dusty or rainy year could distort the observed degradation rate. Only by measuring the performance of washed and unwashed arrays over long time periods can a reliable estimate of the degradation of performance be obtained.

This article is organized in the following manner. In the next section, our experimental arrangement is described and an estimate of the accuracy of the data is given. Our results are analyzed and summarized in section 3. A discussion of the experimental results follows in the last section.

2. DESCRIPTION OF EXPERIMENT

In the summer of 1983 several Solarex solar cell arrays were mounted on the roof of the physics building at the University of Oregon in Eugene along with an Eppley Precision Spectral Pyranometer (PSP). The arrays and the PSP were mounted at a 45° angle which is approximately the latitude of the site (44.05° N latitude).

Eugene is located in the verdant Willamette valley. From late October thru May it rains on a fairly regular basis. During the summer it rains only occasionally. In August and September the skies are filled with particulates and smoke from field and slash burning. The physics building is located across the street from the physical plant which burns sawdust to produce steam and electricity. While the plant has received awards for its pollution control efforts, it occasionally dumps soot which falls on the arrays.

The Solarex HE60 arrays were loaned to the University of Oregon Solar Monitoring Laboratory by the Bonneville Power Administration. Each array consists of seventy-two hexagonal silicon solar cells connected in series. A 0.200Ω resistor was connected across the output of each array and the short-circuit current is measured across this resistor. The short-circuit current of each array is about 1 amp on a clear day. One array was washed weekly and the other array left unwashed. The short-circuit current of the arrays and the incident solar energy observed by the pyranometer have been measured for over five and a half years.

The data acquisition system was built by the University of Oregon electronics shop and has an accuracy of about 0.2%[1,2]. The front end of the data acquisition is a voltage to frequency converter which integrates the signal and sends pulses to the data logger in proportion to the measured voltage. By having an integrated signal, effects from time constant difference between solar cells and the pyranometer are avoided. Every 5 minutes the number of counts is stored in memory and every hour the five minute data are written onto cassette tape. The cassette tape was then read into a computer and the data analyzed. The absolute accuracy of the pyranometer reading is about 3%[2], while the accuracy of the measurement of the short-circuit current is 0.2%, the accuracy of the data acquisition system.

3. ANALYSIS

A standard method for monitoring the calibration of pyranometers is to look at clear day solar noon values. By tracking the clear day solar noon values over the years any change in the calibration of the pyranometer can be observed. A similar method should work for checking the performance of the solar cell arrays. In this article the average short-circuit current of the solar cell array from 11 to 12 o'clock on clear days is used to monitor the performance of solar cell arrays. When these values are divided by the corresponding incident solar energy, they can be used to observe any change in performance of the arrays.

The ratio of short-circuit current to incident solar radiation for the washed and unwashed solar cell arrays is shown in Fig. 1 for clear days. Data points for the washed array are along the top of the figure and show a consistent pattern year after year. No degradation of performance over the years

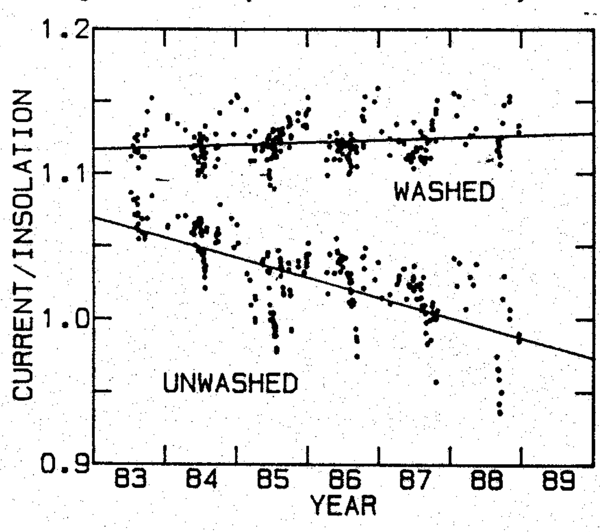

Fig. 1. Plot of the clear day short-circuit current of the solar cell array (in milliamps) from 11 to 12 o'clock divided by the incident solar radiation (in watts/m^2). Data for the washed array are above the data for the unwashed array. The lines through the data represent the linear least squares fits.

was observed for the washed array. The unwashed array shows a steady decrease in performance over the six year time period. The ratio of the short-circuit current to the insolation for the unwashed array has decreased at a rate of 1.4% per year. This rate of decrease appears steady and does not show any sign of leveling out or accelerating.

The ratio of short-circuit current to the solar intensity appears to vary in a seasonal manner. This seasonal variation can be more clearly seen by plotting the ratio as a function of time of year as is done in Fig. 2 for the washed array. There is a small but repeatable variation in the output of the array as compared to the incident solar energy. The curve through the data is a fit to the average of the data points. The variation is on the order of 2% over the year and seems to repeat year after year. A minimum appears between June and July and a maximum appears around December. The cause of this variation may be spectral in nature, but more information is needed before any conclusions can be drawn.

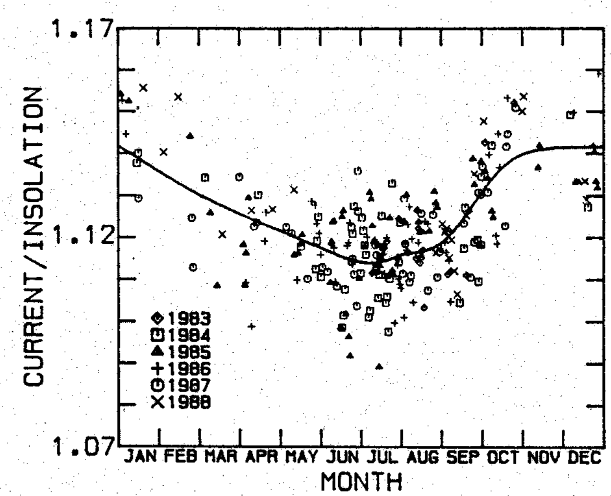

Fig. 2. Plot of the clear day short-circuit current of the washed solar cell array (in milliamps) from 11 to 12 o'clock divided by the incident solar radiation (in watts/m^2). Each year's data is plotted with a different symbol. The line through the data is a fit to the average of the data points.

Since the two array are identical and since there is a spectral mismatch between the response of solar cells and the response of pyranometers, a comparison of the short-circuit current of the unwashed array to that of the washed array should provide a better way to study the effects of dirt build up. This is done in Fig. 3 which shows that the short-circuit current of unwashed array is decreasing by about 1.4% per year. This figure also shows that there is a large seasonal variation in the ratio of the output of the arrays. Each summer there is a 4 or 5% decline in performance of the unwashed array which is slowly reversed from winter through spring. In Eugene the summer is the driest and dustiest time of the year. It is not unreasonable to suspect that much of the decline in the ratio is due to the build up of dust on the array. From October through May it rains fairly consistently and the ratio of the outputs from the arrays increases. However, the rains, snow, and ice never seem to remove all the dirt that has accumulated on the array and the decrease in performance appears to be steady year after year.

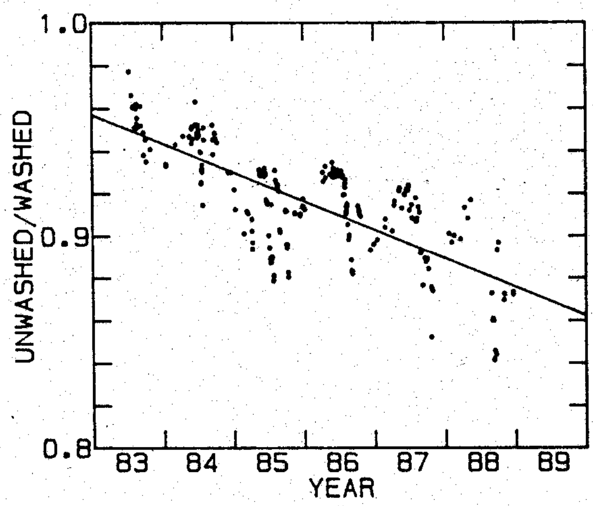

Fig. 3. Plot of the ratio of the short-circuit current of the unwashed solar cell array to the short-circuit current of the washed array. The solid line represent the linear least squares fit to the data.

By plotting the ratio of the output of the unwashed array to the washed array as a function of time of year, as was done in Fig. 2, one can see if there is a seasonal pattern in the decrease in performance of the unwashed array. In order to make each years data comparable, the data were adjusted by the average decrease in performance of the unwashed array. The adjusted ratio of the output of the unwashed to the washed array as a function of time of year is shown in Fig. 4. The performance of the unwashed array drops off dramatically during the late summer. It is only after the rainy season that the ratio of the two solar cell arrays reach a maximum. Therefore the performance of the unwashed solar cell array varies in a seasonal manner which corresponds to the dry and wet seasons in Eugene.

Another interesting feature in the performance of the unwashed array is the occasional large departures from the average trend. Occasionally the performance of the unwashed array will decrease by about 4 or 5% from the average for about a month. We expect that these periods are when large amounts of dirt accumulate on the array. Most of the episodes occur during the summer when there is little rain. Therefore in addition to the gradual build up of dirt there are periods when a lot of dirt can accumulate on the array which will be washed away later by the rain.

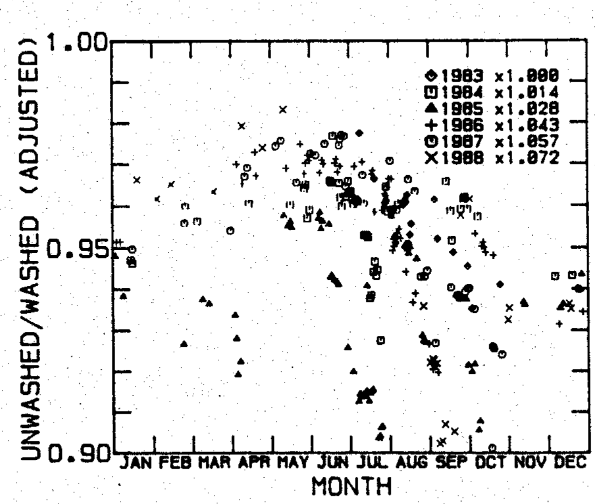

Fig. 4. Plot of the ratio of the short-circuit current of the unwashed solar cell array to the short-circuit current of the washed array adjusted for the average degradation rate. Values for each year are multiplied by the average degradation for that year.

4. DISCUSSION

Two identical solar cell arrays have been monitored for a six year period. One array was washed weekly and the other has not been washed since it was installed. The washed array is performing the same as it was when it was installed. Dirt has built up on the unwashed array and is degrading its performance. The short-circuit current of the unwashed array has decreased at a rate of 1.4% per year over the almost six years of this study.

The performance of the arrays has been analyzed by comparing the short-circuit current of the arrays on clear days in the hour before solar noon with the corresponding solar radiation. In general the ratio of the short-circuit current to the solar radiation should be the same year after year because the atmospheric patterns tend to repeat. In other words the spectral distribution of solar radiation should be about the same from one June to another and any change in the performance of the solar cell array should be mainly attributed to deterioration of the solar cells or build up of dirt on the array. The precision of this method is demonstrated in Fig. 2 which compares the clear day data for the washed solar cell array on an annual basis. A small seasonal variation on the order of 2% is found.

To measure the effect of the accumulation of dirt on the solar cell array, the output of the unwashed array has been compared to that of the washed array. With this method spectral affects due to the difference in spectral response of the solar cells and the pyranometer are avoided and one is left with just the build up of dirt on the array. Any general degradation of the solar cells themselves should be about the same.

A final check of washing the unwashed array and comparing its performance with the original values would hopefully confirm the hypothesis that the deterioration is due to the build up of dirt on the glass cover. However, such an experiment would end the test. We plan to continue the present study as long as the deterioration is linear. It is of interest to see how long this linear deterioration lasts.

Long term testing of the degradation of solar cell arrays is needed. A large seasonal variation in degradation due to the accumulation of dirt on the array is demonstrated in Fig. 4. This means that at least two years are needed to obtain an accurate estimate of the degradation. Fluctuations in degradation do exist from year to year and an accurate estimate of the loss of performance requires a study of many years.

5. ACKNOWLEDGEMENT

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6. REFERENCES

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