

Detecting and Classifying Issues in the DC Field

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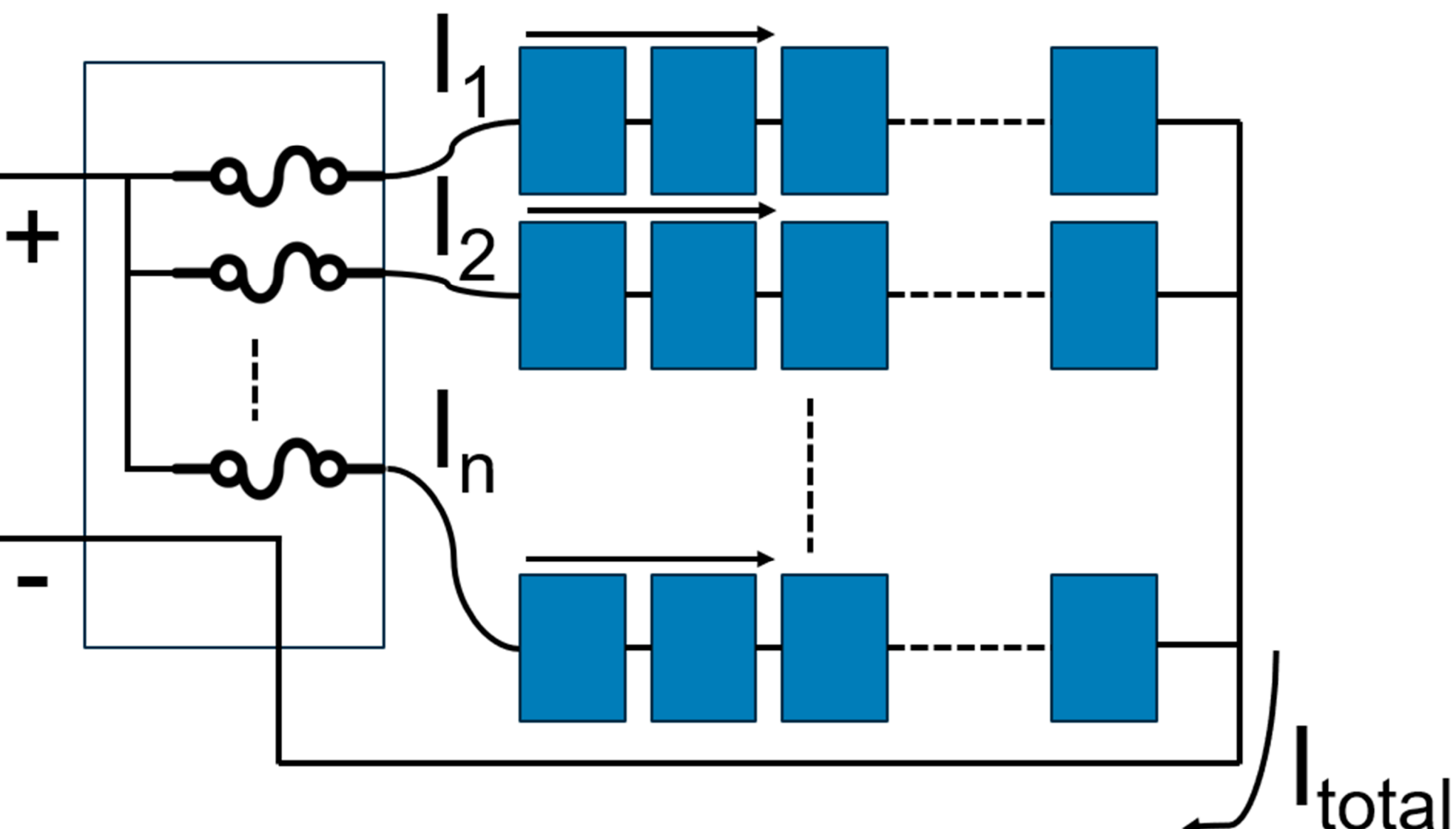


Introduction

In a large photovoltaic solar plant, the number of module-strings can be in the 100's of thousands. To monitor each string would be cost prohibitive due to the required number of sensors needed. While it can be hard to diagnose an exact type of fault, we can detect when a combiner box is under performing to a large degree if we monitor the DC current from the combiner box and we have the string count for the combiner boxes. Using these values, an expected current per string can be calculated and used as a metric for evaluating the health of each combiner box at the site.

Theory

The total DC current leaving the combiner box is a summation of all string DC currents connected to the combiner. Knowing the number of strings connected to the combiner box and having an accurate measurement of the DC current, a current per string estimation can be calculated to use as a combiner health comparison test.

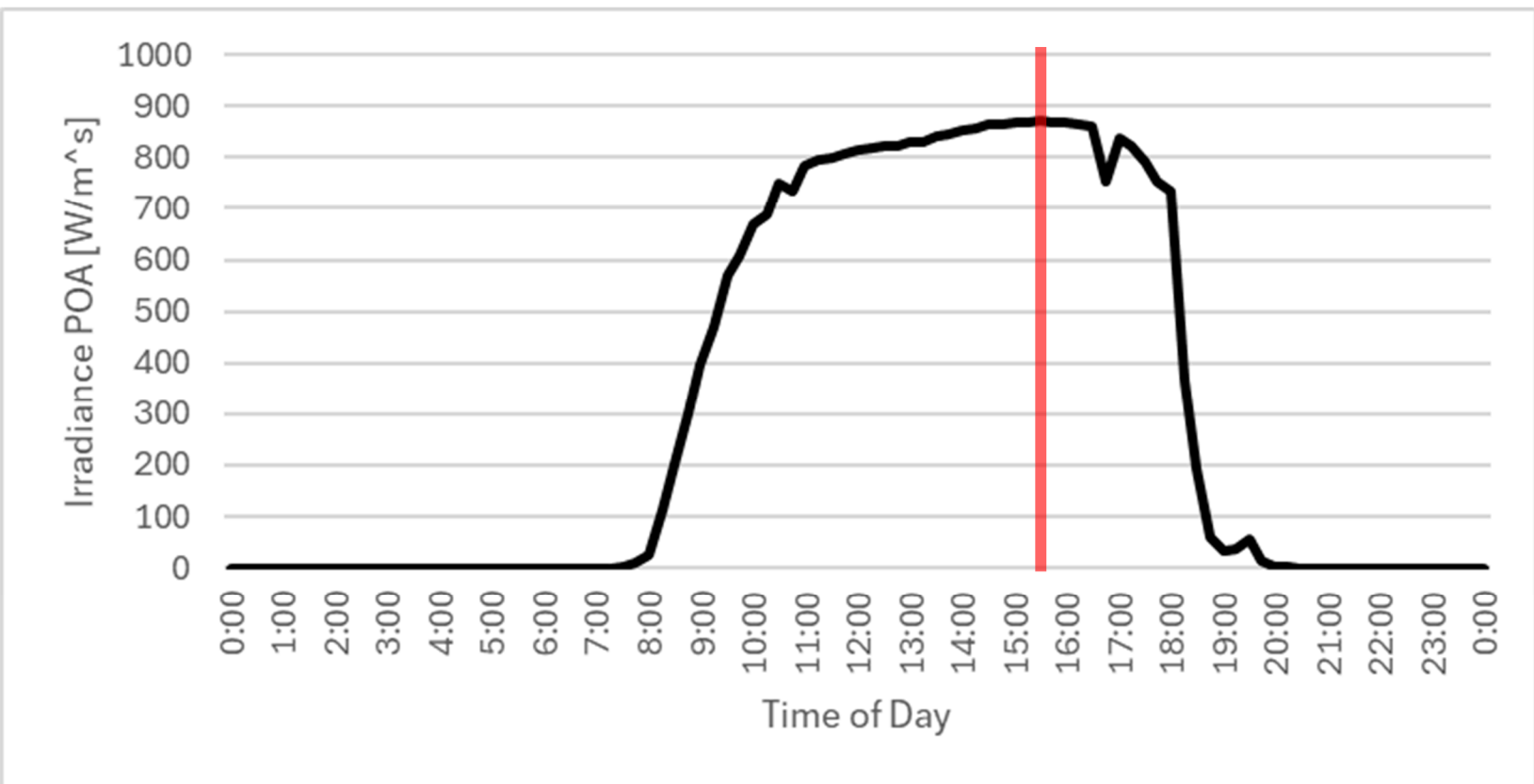


Simple model of combiner box and PV Module strings

Dividing the combiner box's DC current by the estimated current per string will give the estimated number of strings for that combiner box. This can be compared to the known string count for the combiner to indicate if there are string outages.

Method

- For this evaluation, ensure all PV modules are the same technology.
- Choose a clear-sky day and find a time with stable irradiance to use as a point for comparison of each combiner box. Ensure no other factors are affecting the site, such as curtailment.
- Note the DC current value for each combiner at the selected time.
- Using the combiners boxes with the highest string count, find the current per string. Filter out zeros, negatives, and outliers beyond one standard deviation from the mean. Calculate the average DC current for the filtered values. Divided the average current by the string count. This will be the current per string value to use for comparison of all combiner boxes.
- List each combiner box's DC current and its known string count.
- Divide each DC current by the current per string to estimate string count.
- Subtract the estimated count from the known string count to find the number of strings out.
- Note that slight variations will introduce some error.



Irradiance is stable at 15:30. No curtailment.

Application

This process is tested at a site with known DC health issues. Both before and after maintenance work. Each test conducted on a clear-sky day. A table was setup with all combiner box information needed: DC current at selected time and the string count. 817 combiner boxes are located at this site.

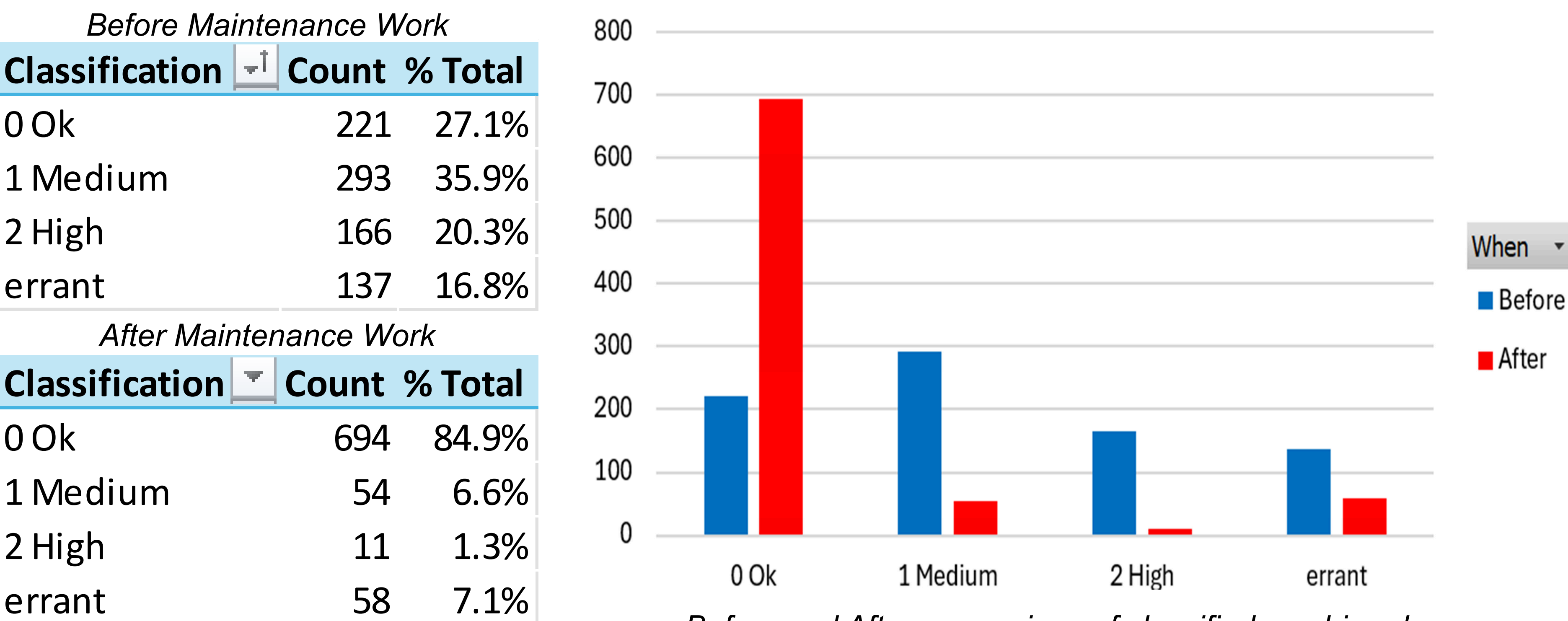
Combiner	Current	String Ct	Est Ct
INV1 CMB01	205	28	27
INV1 CMB02	207	28	27
INV1 CMB03	190	28	25
INV1 CMB04	176	24	23
INV1 CMB05	207	28	27
INV1 CMB06	211	28	28

First few rows of table containing the combiner box data. Includes the estimated string count (Est Ct).

After the information is gathered it is filtered for the highest string counts, then outliers and erroneous values are removed (zeros, negative, etc.). The average current is taken and estimated current per string calculated.

$$\text{Current per String} = \frac{\text{Average Current}}{\text{String Count}} = \frac{212.54 \text{ A}}{28 \text{ count}} = 7.591 \text{ A}$$

This value is then used to calculate the estimated string count for each combiner box. The difference between the actual string count and the estimate is an indication of DC losses to the combiner box.



Before and After comparison of classified combiner boxes
Classification based on number of outages: ['0 OK': <4; '1 Medium': 4-8; '2 High': >8; 'errant': outliers]

Result

Technicians inspected, troubleshot, and fixed issues in the DC field over a period of two months. Using the complete list generated for underperforming combiners, they were able to prioritize the highest impacted first. While it is impossible to maintain a perfectly performing site, this method adds a tool for maintenance teams to keep them on top of issues and address high impacting issues within the DC field.