2020 GLOBAL SOLAR AERIAL THERMOGRAPHY REPORT

SUMMARY OF RESULTS FROM PRECEDING YEAR

Overview

Aerial thermography is increasingly required within the solar photovoltaic (PV) industry to monitor the condition of PV assets.

In the solar PV industry, aerial thermography is used to reduce investment risk, increase asset performance, generate investor reports, audit responsible parties, and standardize and digitize analytics and asset management across portfolios. It is also utilized during the commissioning phase to generate a quantitative baseline and ensure transparency during the handoff process.

The purpose of this annual report is to aggregate findings to provide a benchmark for PV system status to improve and strengthen the PV industry. This report draws from the Raptor Maps data repository of sites inspected in 2019 and includes an overview of aerial thermography findings and the relative impact on PV systems.

Data Collection

This report includes data collected for PV systems between January 1, 2019 through December 31, 2019 via manned aircraft and small unmanned aerial systems (sUAS). All systems were equipped with a radiometric thermal camera and over 95% of inspections also captured visible-spectrum (color) images.

Parties collecting data included asset owners, asset managers, operations and maintenance (O&M) providers, engineering firms, and drone service providers. End users were provided original thermograms and supporting color images to verify the results.

Thermal image resolution for the sUAS systems ranged from a ground sample distance of 15 centimeters per pixel for rapid, high-level inspection (module, string outages) to 3 centimeters per pixel (sub-cell detail in accordance with IEC TS 62446-3:2017 specifications). On average, 233 images thermal and color images were captured per megawatt (MW).

Findings

This report draws upon the verified PV systems inspected in 2019, encompassing 31,295,692 modules across 826 PV systems, with a total nominal capacity of 7,882,069 kW_{DC}. Sites ranged from 10 kW to 350,000 kW across 25 countries and 6 continents. 700,494 modules contained findings (2.2% of total analyzed), with an affected power of 126,845 kW_{DC} (1.6% of analyzed).

The cumulative affected power from identified anomalies by Raptor Maps in 2019 could offset 145,000 metric tons of carbon dioxide emissions annually and results in a Net Present Value (NPV) worth $200 million of potential revenue loss.

Production affected by category

Finding	**Production Affected (kW_{DC})**	**Production Affected in Category ÷ Total Production Affected**
String	37,452	29.5%
Inverter	34,266	27.0%
Combiner	18,758	14.7%
Tracker	10,562	8.3%
Cell Multi	5,901	4.6%
Cell	4,280	3.3%
Shadowing	3,025	2.4%
Diode	2,856	2.3%
Row	2,565	2.0%
Offline Module	2,093	1.6%
Vegetation	2,066	1.5%
Missing	860	0.67%
Cracking	710	0.56%
Soiling	308	0.24%
Internal Short Circuit	294	0.22%
Diode Multi	255	0.19%
Reverse Polarity	176	0.14%
Hot Spot	163	0.13%
Hot Spot Multi	136	0.11%
Delamination	107	0.08%
Junction Box	12	0.01%
Total	126,845	100%

Table 1: Relative effect of finding on production.

Production affected continued

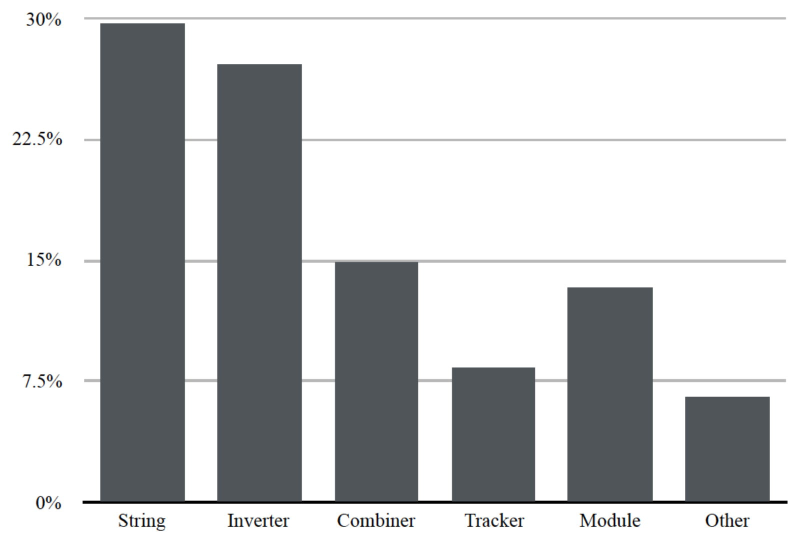

Figure 1: Relative effect of findings on production of functional units.

Figure 1 displays the percent of power affected from functional units within a PV system. Functional units include: inverters, combiners, trackers, strings and modules. Module includes: cell, cell multi, cracking, delamination, diode, diode multi, hot spot, hot spot multi, internal short circuit junction box and offline module. Other includes: reverse polarity, row, shadowing, soiling, and vegetation.

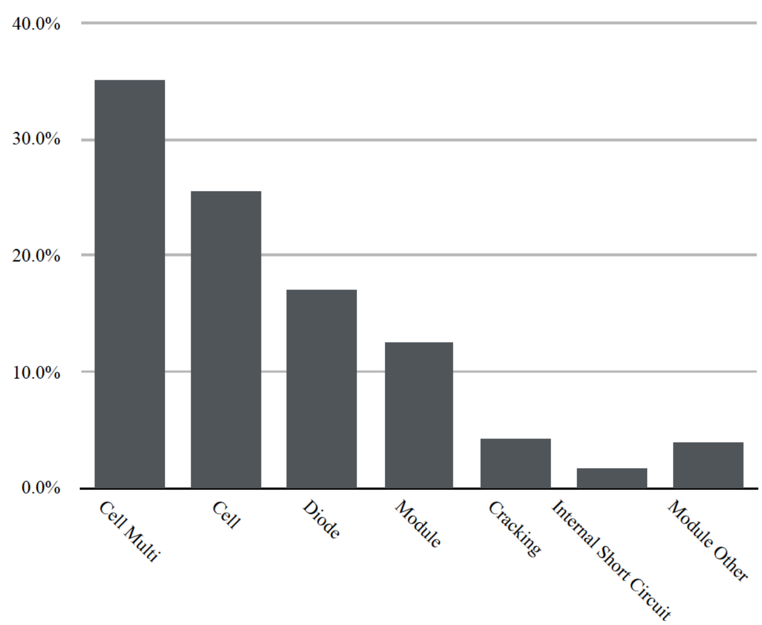

Figure 2: Relative effect of findings on production of module-level findings.

Figure 2 displays the breakdown of power affected for module-level findings from Figure 1.

Number of modules affected by category

Finding	**Number of Modules Affected**	**Modules Affected in Category ÷ Total Modules Affected**
Inverter	144,251	20.6%
Tracker	139,021	19.8%
String	134,043	19.1%
Combiner	88,803	12.7%
Cell	41,204	5.9%
Cell Multi	39,748	5.7%
Shadowing	30,969	4.4%
Diode	28,155	4.0%
Vegetation	20,833	3.1%
Row	9,656	1.4%
Offline Module	8,528	1.2%
Missing	3,733	0.54%
Cracking	2,713	0.39%
Soiling	2,339	0.33%
Hot Spot	1,839	0.26%
Hot Spot Multi	1,393	0.21%
Diode Multi	1,291	0.18%
Internal Short Circuit	923	0.13%
Reverse Polarity	560	0.08%
Delamination	435	0.06%
Junction Box	57	0.01%
Total	700,494	100%

Table 2: Relative percentage of modules affected by finding

Description of Findings Categories

Anomaly	Description
Cell	Hot spot occurring with square geometry in single cell
Cell multi	Hot spots occurring with square geometry in multiple cells.
Combiner	Fault in contiguous strings matching the inverter layout.
Cracking	Module anomaly caused by cracking on module surface
Delamination	Module anomaly due to compromised adhesion between glass, encapsulant, active layers, and/or back layers. More common with thin film modules.
Diode	Activated bypass diode, typically 1/3 of module.
Diode multi	Multiple activated bypass diodes, typically affecting ⅔ of module.
Hot spot	Anomalous spot on a cell.
Hot spot multi	Multiple hot spots on a thin film module.
Internal short circuit	Multiple cell anomalies as a result of a short circuit.
Inverter	Fault in contiguous strings matching the inverter layout.
Junction box	Hot spot at the junction box location on the module.
Missing	Module is present on as-built but missing from PV system.
Offline Module	Entire module is heated.
Shadowing	Sunlight obstructed by vegetation, man-made structures, or adjacent rows.
Soiling	Dirt, dust, or other debris on surface of module.
Tracker	Tilt tracker position affecting power production.
Vegetation	Panels blocked by vegetation.

Functional units are verified using the as-built drawing of the PV system. Suspected potential-induced degradation (PID) is detected from a pattern-based analysis of the above findings; PID itself is not used as a finding category.

Categorization is refined based upon the presence of color images. Raptor Maps software cross-checked all thermal images with their color image counterpart (provided in over 95% of inspections) to properly classify the source of the anomaly.

Modules

Modules from 79 manufacturers are included in this report. Of the total number of modules inspected, 26% were First Solar modules, 27% were Jinko Solar modules, and 37% were JA Solar modules. The most common module technology was polycrystalline.

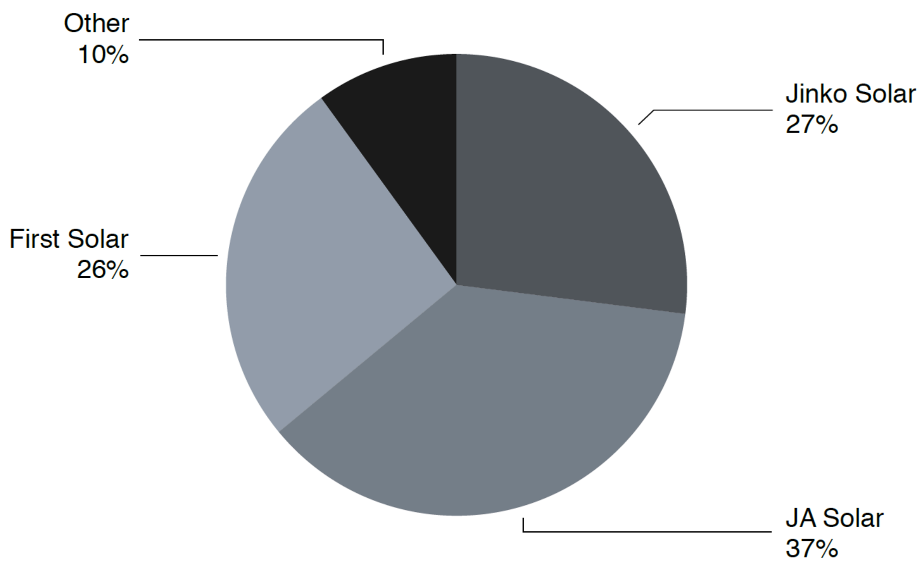

Figure 3: Analyzed module composition.

Publication

Charts and graphs extracted from this press release for use by the media must be accompanied by a statement identifying Raptor Maps, Inc. as the publisher and the study from which it originated as the source. Findings are based on empirical data and not necessarily on statistical significance.

Source

Raptor Maps 2020 Global Solar Aerial Thermography Report.

Contact

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Disclaimer

This report is a work product of Raptor Maps, Inc. Raptor Maps is the leading software provider of aerial thermal analytics, with a data repository spanning over 15 GW of PV systems across 6 continents. This analysis is drawn from the Raptor Maps data repository. The authors have used their best efforts to ensure that the data is reliable, but the accuracy or completeness of the data and resulting analysis are not guaranteed. Raptor Maps disclaims all warranties, implied or express, including without limitation all implied warranties of merchantability, non-infringement and fitness for a particular purpose.