Keysight Technologies

Temperature Measurement Solution for Solar Cell and Module Testing

Application Note

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Introduction

In many countries, solar power is gaining popularity because the cost of solar cell modules and systems is rapidly decreasing; making it more competitively priced against electricity generated from fossil fuels. Some countries have reached grid parity, meaning solar, or another renewable power source, generates electricity at costs equal to, or less than, the conventional fossil fuel sources. In areas where the conventional electrical grid is hard to reach, solar energy has become a substantial alternative energy source. Solar energy is a clean, inexhaustible energy source and according to the International Energy Agency (IEA) publication, Technology Roadmap: Solar Photovoltaic Energy, Edition 2014, it could be a significant source of electricity by 2050.

Solar cell systems use a collection of solar cell panels to convert sunlight into electrical energy using the photoelectric effect. Each panel is made up of a few solar cell modules, which in turn consist of a matrix of solar cells that convert the solar irradiance into electricity. The failure of any solar cell may lead to a drop in power generation causing output yield losses. When a cell is shaded or not working, the cell consumes power from the adjacent series of solar cells instead of generating power. On solar farms, which may consist of up to a few thousand solar panels, electrical testing at each individual solar panel is time consuming and cumbersome. This application note looks at the use of data acquisition system together with thermal imaging as a method of testing solar cells and solar modules.

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Temperature Measurement in Solar Cell and Module Testing

In solar cell and module testing, you often need more than just the I-V curve of the cell or module under test. Typically, you will need to make temperature measurements and measurements of calibrated reference cells. Temperature has a direct effect on the output power of the cell or module, so you need to make temperature measurements during the test to fully understand all test conditions. Calibrated reference cells are often needed to gauge the effectiveness of the light source used to power the solar cell or module. Figure 1 shows an example setup for testing a solar module. This setup uses a switch measurement unit to avoid the need for costly, redundant measurement equipment. A switching configuration can also be used to allow multiple solar cells or modules to be tested in parallel.

Keysight offers three product families to address your switching needs for solar testing: the 34980A multifunction switch/measurement unit, the 34970A data acquisition switch unit, and the L44xxA family of switching modules.

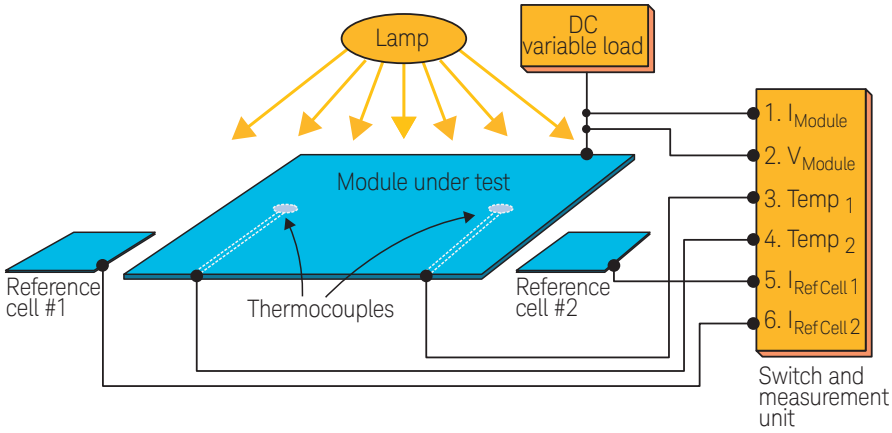

Figure 1. Solar module test setup example

Temperature Measurement for Large Solar Modules Testing

As the area of coverage for a single thermocouple sensor is limited, testing larger solar modules would require hundreds of thermocouple sensors to be mounted on the large solar module. A more efficient way of monitoring temperature on a large solar module would be to use a high resolution thermal imager. Figure 2 show hotspots detected on overheated solar module cells using the Keysight Technologies, Inc. U5850 Series True*IR* thermal imager.

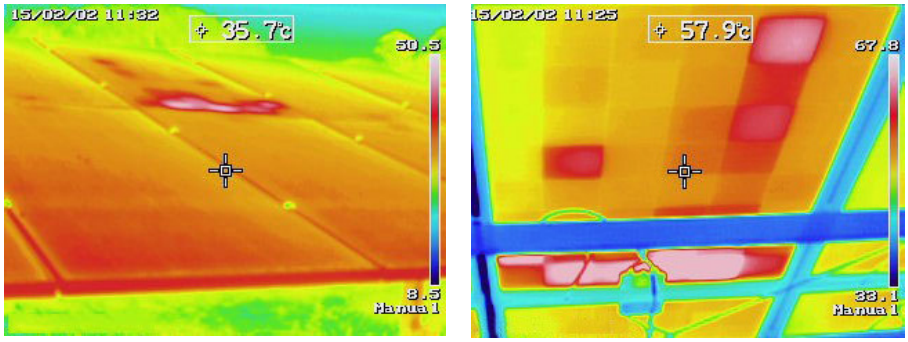

Figure 2. Thermography scan with thermal images using Keysight U5855A True*IR* thermal Imager shows multiple hotspots detected on a solar panel, indicated in pink/red

The Keysight U5855A thermal imager has 320x240 fine resolution that delivers a high-quality thermal image, which reveals finer details and enables users to quickly spot the problem. It works from –20 to 350°C, with thermal sensitivity as narrow as 0.07°C. This allows even a small variation of temperature to be detected and produces a clear image for problem analysis.

To easily detect the location of anomalies, especially for a matrix of solar cells on a large solar module, the fusion camera mode in Keysight U5855A adds the *IR* image on top of the visible image. The captured images can be imported to the True***IR*** Analysis and Reporting software tool, where it is easy to analyze and edit thermal images and quickly generate reports using pre-made templates (see Figure 3). The thermal images and visual images can be displayed side-by-side for further analysis.

Once the location of anomalies is identified, thermocouples could be placed at the affected location for more accurate temperature measurement to determine the cause of the anomalies.

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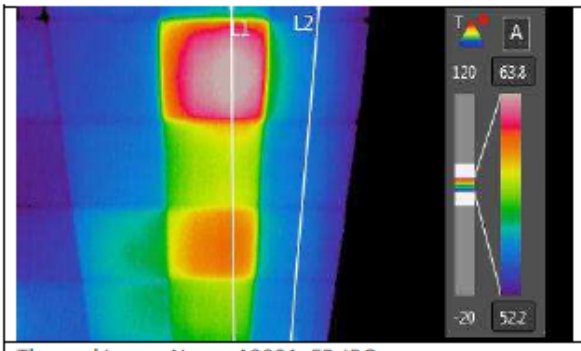
TrueIR Series

Penang Solar Farm, Feb 2nd, 2015

Thermal Imager, U5855A



Thermal Image Name:A0091_FR.JPG | Visual Image Name:A0091_VB.JPG

Measurements

Spot:
Data not available

Line:

Name	Min	Max	Average	Start Coordinates	End Coordinates	Max Coordinates	Min Coordinates
L1	55.6	64.2	60.46	(176,1)	(178,239)	(177,42)	(176,1)
L2	53.8	55.0	54.60	(248,1)	(225,239)	(226,237)	(248,8)

Box:
Data not available

Parameter:

Emissivity	0.85
Reflected Temp	26.2
Ambient Temp	25.0
Distance	1 m
Humidity	50 %

Remarks:

Bottom view of the suspected faulty module. Line profiles below indicate significant higher temperature on the suspected faulty cells comparing to adjacent cells.

Line Profile:

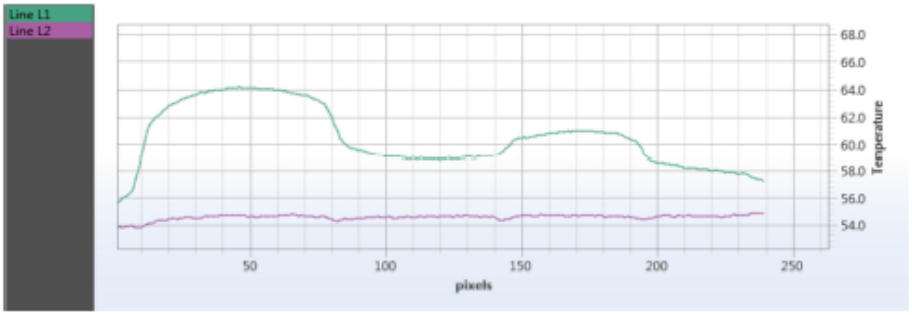


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Figure 3. Analysis report generated from the True*IR* Analysis and Reporting Tool using the pre-made templates

Keysight's Temperature Measurement Solutions for Solar Cell and Module Testing

Keysight's U5850 Series True*IR* Thermal Images

Detect potential problems faster with the higher resolution and affordability of our TrueIR Series of thermal imagers. Only from Keysight Technologies, can you get four times more in-camera fine resolution of 320 x 240 pixels from its detector resolution of 160 x 120 pixels. With the built-in image logging capability, easily track performance of the system you monitor at a specific interval. Plus you can analyze temperature changes over time with trending a graph. Coupled with the powerful manual focus feature, users can focus on an object as close as 10 cm away - our solution provides clearer, sharper and reveals even finer details.

- Identify abnormalities faster with four times more in-camera fine resolution
- Monitor temperature changes through image logging and temperature trending capabilities
- Compact, lightweight, ergonomic
- High temperature range (up to 1200°C)
- Easy-to-use customizable color palette
- Single-handedly change settings with the configurable quick access buttons

Figure 4. 34980A multifunction switch and measurement unit front and back views

34980A multifunction switch/measurement unit

The Keysight 34980A is an eight-slot mainframe that includes an optional built-in 6½ digit DMM. You can choose from 21 optional plug-in modules that offer a broad range of functionality that includes various switch matrices, MUXs, and general-purpose configured switching modules – in one compact, high-performance modular platform.

34980A features that make it a good fit for solar cell test systems:

- Up to 560 2-wire multiplexer channels or 4096 matrix cross-points in one mainframe
- Switch current carrying capabilities up to 8 A
- Built-in Ethernet, USB 2.0, and GPIB connectivity, standard connectors and software drivers for most common programming environments
- Lower cost than a comparably configured PXI-based switching solution
- Optional built-in 6½ digit DMM lets you make measurements at greater than 3000 readings/second
- Switch relay counters help predict end of switch life
- Temperature measurement capabilities with thermocouples, RTDs, or thermistors

Keysight's Temperature Measurement Solution for Solar Cell and Module Testing *continued*

Figure 5. 34972A data acquisition switch unit

34970A or 34972A data acquisition switch units

The Keysight 34970A and 34972A are three-slot mainframes with a built-in 6½ digit digital multimeter. Each slot can hold one multi-channel plug-in module and each channel can be configured independently to measure one of 11 different functions without the added cost or complexities of signal-conditioning accessories. Choose from eight optional plug-in modules to create a compact data logger, full-featured data acquisition system or low-cost switching unit. On-module screw-terminal connections eliminate the need for terminal blocks, and a unique relay maintenance feature counts every closure on every switch for easy, predictable relay maintenance. The 34970A comes standard with GPIB and RS-232 interfaces, whiile the 34972A comes standard with easy to use USB and LXI interfaces to reduce your set-up time. Our most popular module, 34901A, features a built-in thermocouple reference and 20 two-wire channels.

The 34970A/34972A are low-cost instruments that are great for low-density switching requirements and any portable data acquisition requirements. The Keysight BenchVue DAQ app is available for no cost for use with the 34970A and 34972A. For advanced Data Logging and control, use the BV0006A BenchVue Data Acquisition Pro App.

Figure 6. Three modules from the L4400 Series switching instruments

L4400 Series LXI switch instruments

The Keysight L4400 Series switch instruments offer high-performance switching in standalone LXI instruments. With their small 1U half-rack size and Ethernet connectivity, these LXI instruments can be placed wherever your application needs them. Since these switching instruments are standalone, there is no need for an expensive card cage.

Features of the L4400 Series switching instruments that make them a good fit for solar device testing:

- L4421A 40-channel armature multiplexer
  40 channels of armature multiplexer switching up to 300 V, 1 A. A built-in thermocouple reference junction is available for easy temperature measurements with an external digital multimeter.
- L4433A dual/quad 4x8 reed matrix
  High-speed matrix with 64 2-wire or 128 1-wire cross-points with high-speed reed relays
- L4437A 32-channel Form A/Form C general-purpose switch
  General-purpose switch with 28 1A Form C relays and 4 high-power relays for switching up to 5A

Figure 7. Keysight DMMs

Keysight digital multimeters

Keysight offers a family of DMMs that vary in accuracy, measurement speed, and price to fit your solar device test requirements.

	34401A	34410A	34411A	3458A
Resolution	6½ digits	6½ digits dual display	6½ digits dual display	8½ digits
Basic DC accuracy	35 ppm	30 ppm	30 ppm	8 ppm
Max readings/s	1,000	10,000	50,000	100,000

Conclusion

Using a tool such as the U5850 Series True*IR* thermal imager with data acquisition systems provides improved temperature measurement coverage and reduced test setup time for larger solar modules. *IR* thermography has been used for more than a decade to assess the performance of the solar cell panels. Malfunctions and material defects can be detected easily without disruption of the solar cell module using infrared analysis.

Looking Ahead

Explosive growth in the solar power generation industry has intensified the need for solar inverter test and measurement solutions. As solar energy gains momentum towards a wider adoption, Keysight continues to drive innovation with technologies that help ensure optimal performances of your solar cells and solar arrays. Specifically in the areas of design and test, Keysight offers solutions that can help you efficiently develop, verify and maximize the performance of today's high-powered PV inverters. Deliver energy-efficient solar power today with the N8900APV Series PV / solar array simulator and SAS control software. Visit www.keysight.com/find/n8900apv to learn more, and explore various PV simulator solutions that can help you characterize solar cells under different temperature conditions.

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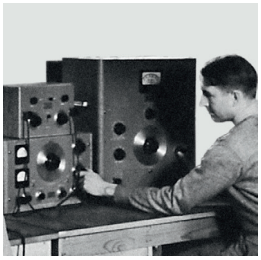

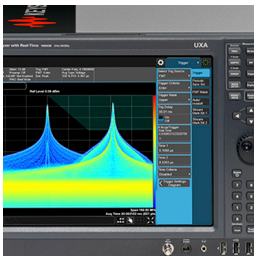

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