# Chint Power Systems North America Inc.

Inverter Field Testing
Engineering Report

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22 pages

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# Summary

Chint Power Systems (CPS) North America Inc. has contracted PV Evolution Labs (DNV GL PVEL) to deploy and monitor two (2) CPS SCA28KTL-DO/US-480 28 kW grid-tied transformerless string inverters with dual maximum-power-point trackers (MPPTs) at the PVUSA test and research facility in Davis, CA. The purpose of the deployment and monitoring of the SCA28KTL-DO/US-480 inverters is to evaluate their performances under real-world operating conditions. Deployment and monitoring of the inverters occurred over a Monitoring Period from March to June 2014. In this report, the conversion efficiencies and operating temperatures are evaluated over a Test Period from April 9th to May 9th, 2014, and the installation characteristics of the inverters are noted.

### *Conclusions*

Over the four (4) month Monitoring Period, the two (2) CPS SCA28KTL-DO/US-480 inverters operated reliably with no service interruptions.

During the month-long Test Period, the inverters achieved an average daily run-time of six-hundred and ninety-seven (697) hours and converted an average of five-thousand five-hundred and fifteen (5515) kilowatt-hours (kWh) of energy. The peak efficiencies of Inverter 1 and Inverter 2 under normal operating conditions at the PVUSA test and research facility were determined as 97.8 % at an output power of 9 kW.

The optional Shade Plate was installed on Inverter 1 during approximately half of the test period, and decreases in Inverter 1 case temperatures of 15.65 %, 6.26 %, and 4.20 % at the top, front, and back sides, respectively, of the inverter were measured.

The ease of installation of the SCA28KTL-DO/US-480 inverter was noted by the field installers. The improved Shade Plate is both easy to install/remove and effective for decreasing the operating temperatures of the SCA28KTL-DO/US-480 in the case of direct sunlight exposure. The design and construction of both the Shade Plate and AC/DC wiring compartment were improved by CPS after the conclusion of the analysis of the product by DNV GL PVEL

# Systems Details

The major photovoltaic (PV) array characteristics connected to the two (2) CPS SCA28KTL-DO/US-480 inverters are listed in Table 1 below. The PV arrays are in a fixed configuration and are composed of a variety of BP Solar modules of similar operating voltages. The irradiance, power, and weather measurement devices are listed in Table 2 below along with their associated measurement uncertainties.

| | Inverter 1 | Inverter 2 |
|---|---|---|
| **Inverter** | Chint Power Systems North America Inc. SCA28KTL-DO/US-480 | Chint Power Systems North America Inc. SCA28KTL-DO/US-480 |
| **Grid Connection** | 480 VAC, 3Φ | |
| **Module Types** | BP Solar BP2150S, BP4165T, BP175B, SX3175N | |
| **Total Number of Strings** | 14 | |
| **Number of Strings on Inverter MPPT 1** | 7 | |
| **Number of Strings on Inverter MPPT 2** | 7 | |
| **Modules per String** | 20 | |
| **Nameplate DC System Power** | 42 kW (approximate) | |
| **DC System Voltage** | 650 V (approximate) | |
| **System Location** | PVUSA (Davis, CA) | |
| **System Orientation** | 0° zenith, 350° azimuth | |
| **Testing Dates** | April 9$^{th}$ to May 9$^{th}$, 2014 | |

**Table 1** Major characteristics of the inverter systems and their PV arrays

| Parameter | Equipment | Uncertainty |
|---|---|---|
| AC power | Shark 100 | ± 1 % |
| DC power, current and voltage | Current shunts with Advantech ADAM 4117 | ± 2 % |
| Plane-of-array (POA) irradiance | Photovoltaic reference cell | ± 2 % |
| Module temperature | Type-T thermocouple | ± 1° C |
| Wind speed | Vaisala WXT520 | Greater of ± 0.3 m/s or ± 3 % |
| Wind direction | Vaisala WXT520 | ± 3° |
| Ambient temperature | Vaisala WXT520 | ± 0.3° C |
| Precipitation (rain, hail) | Vaisala WXT520 | ± 5 % |
| Relative humidity | Vaisala WXT520 | ± 3 % |
| Barometric pressure | Vaisala WXT520 | ± 0.5 hPa |

**Table 2** Inverter performance and weather monitoring equipment details and associated measurement uncertainties

# Systems Details


**Figure 2** Image of the installations of the two (2) CPS SCA28KTL-DO/US-480 – the inverter on the right-hand side of the image has a shade cover installed

Figure 1 above is an image of the two (2) CPS SCA28KTL-DO/US-480 installed at PVUSA. Inverter 1 is located on the right-hand side of the image with its shade cover installed. Inverter 2 is located on the left-hand side of the image without a shade cover. The locations of the installed thermocouples installed on the inverters to monitor case temperatures during the Test Period are shown in Figure 2 below.

# Systems Details

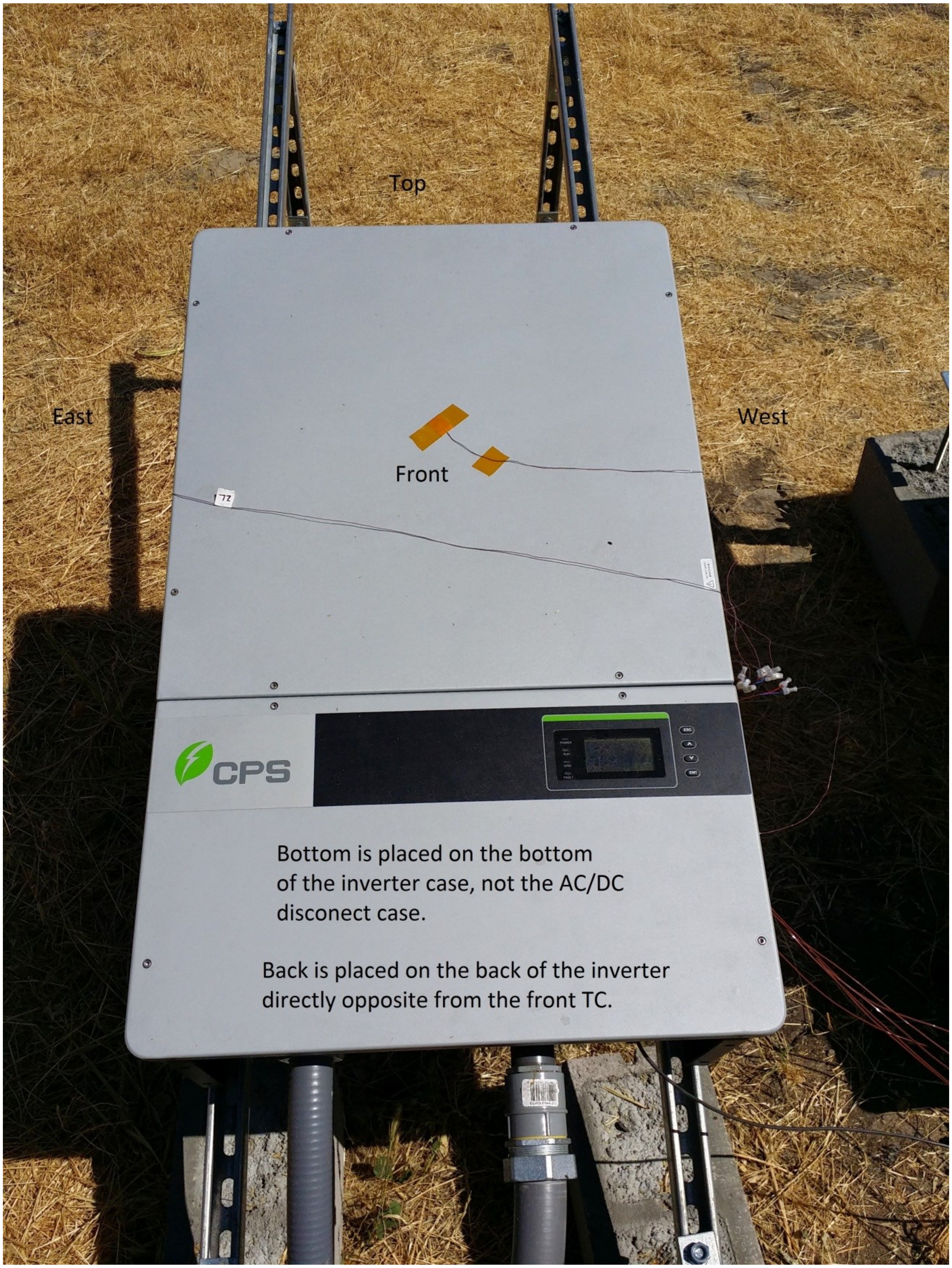


**Figure 2** Image indicating thermocouple placements

# Monitoring of Inverters

During the Monitoring Period, many operational parameters of each inverter were obtained from the inverters and recorded. The information extracted from each inverter is listed in Table 3 below. The average daily run-times of the inverters during the Test Period are listed in Table 4 below. The daily run-time values are a function of local insolation, the positions of the associated PV arrays with respect to objects in the test field that shade the arrays during early morning and late afternoon periods, and any inverter faults that occurred. No inverter faults occurred during the Test Period, which aided in achieving the excellent daily run-times.

| DC Parameters | AC Parameters | Other Parameters |
|---|---|---|
| DC Voltage MPPT 1 (V) | Phase AB Voltage (V) | Energy - Per Day (kWh) |
| DC Current MPPT 1 (A) | Phase AB Current (V) | Energy - Running Total (kWh) |
| DC Voltage MPPT 2 (V) | Phase AC Voltage (V) | Run Time - By Day (minutes) |
| DC Current MPPT 2 (A) | Phase AC Current (V) | Efficiency (%) |
| DC Power (kW) | Phase BC Voltage (V) | Inverter Temperature (°C) |
| | Phase BC Current (V) | Ambient Temperature (°C) |
| | Real AC Power (kW) | Isolation Resistance (kΩ) |
| | Apparent AC Power (kVA) | |
| | Power Factor | |
| | Frequency (Hz) | |

**Table 3** Operating parameters directly monitored by inverters are recorded over the monitoring period

| Inverter 1 Run-time (minutes) | Inverter 2 Run-time (minutes) |
|---|---|
| 685 | 708 |

**Table 4** Average daily run-time of the inverters over the Test Period

# Performance Evaluations

### *Inverter Production*

The energy converted by the inverters over the Test Period are listed in Table 5 below. The energy converted by the inverters is a function of local insolation on each PV array over the Test Period and the DC capacity of each PV array.

| Inverter 1 Energy Conversion (kWh) | Inverter 2 Energy Conversion (kWh) |
|---|---|
| 5554 | 5476 |

**Table 5** Energy converted by the inverters over the Test Period

The AC power output of each inverter versus irradiance incident on the plane-of-array (POA) is shown in the plot of Figure 3. Inverter clipping is evident in the plot at 28 kW. Figures 4 – 7 below are weekly plots of AC output power and irradiance for both inverters over the Test Period

# Performance Evaluations

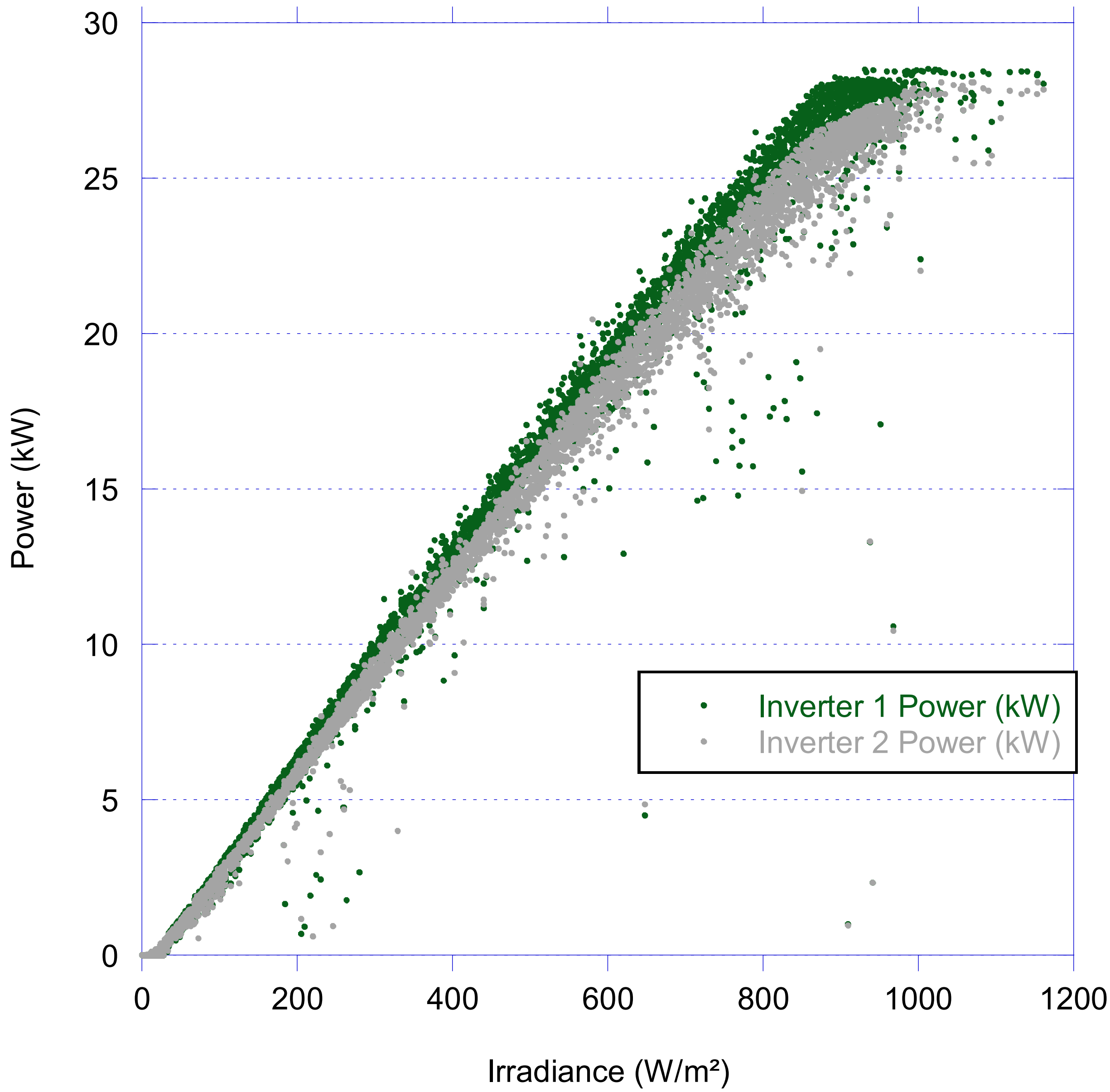


**Figure 3** Plot of AC output power versus irradiance for both inverters over the Test Period

# Performance Evaluations

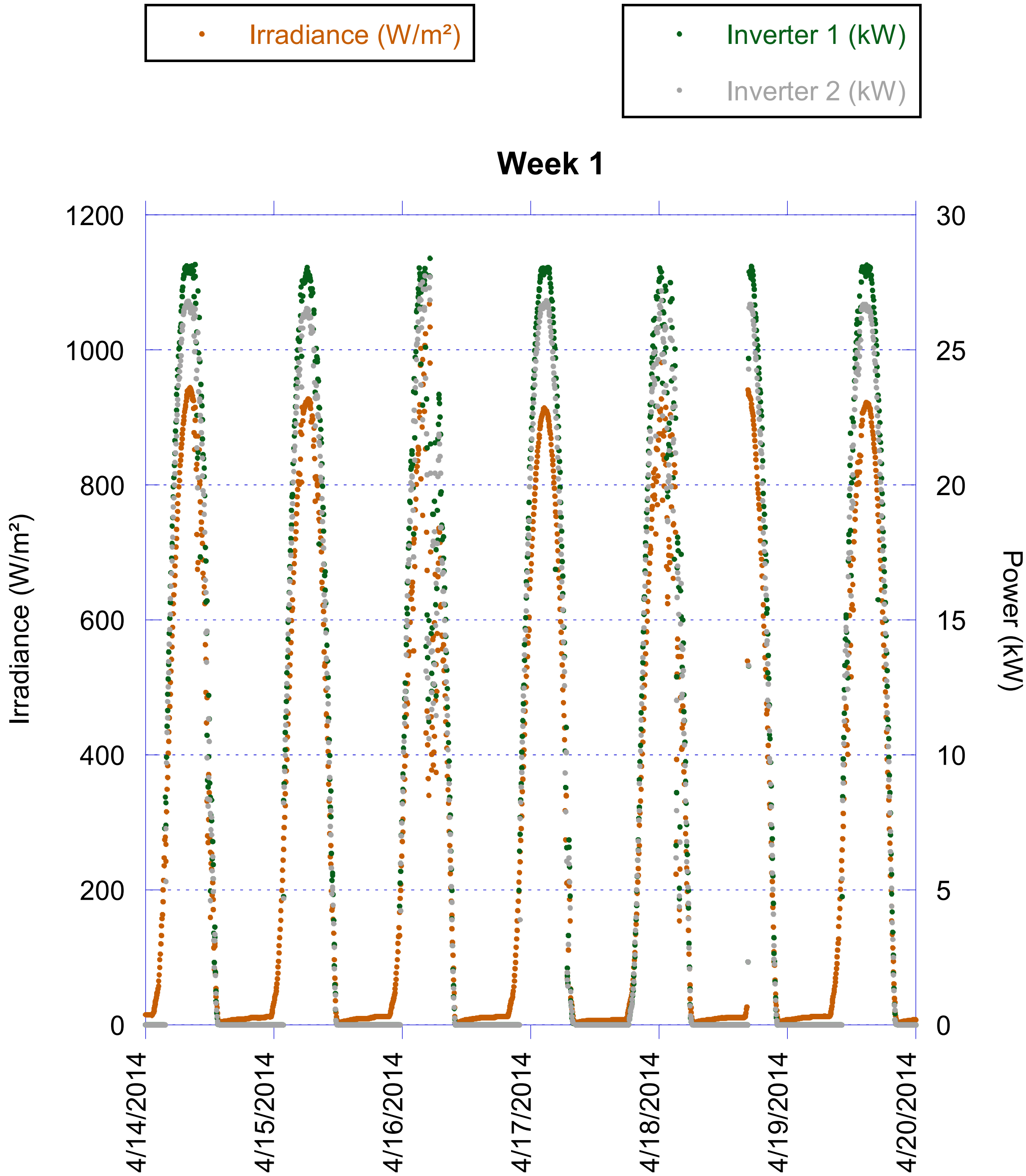


**Figure 4** Plot of AC output power and irradiance for both inverters over Week 1 of the Test Period

# Performance Evaluations

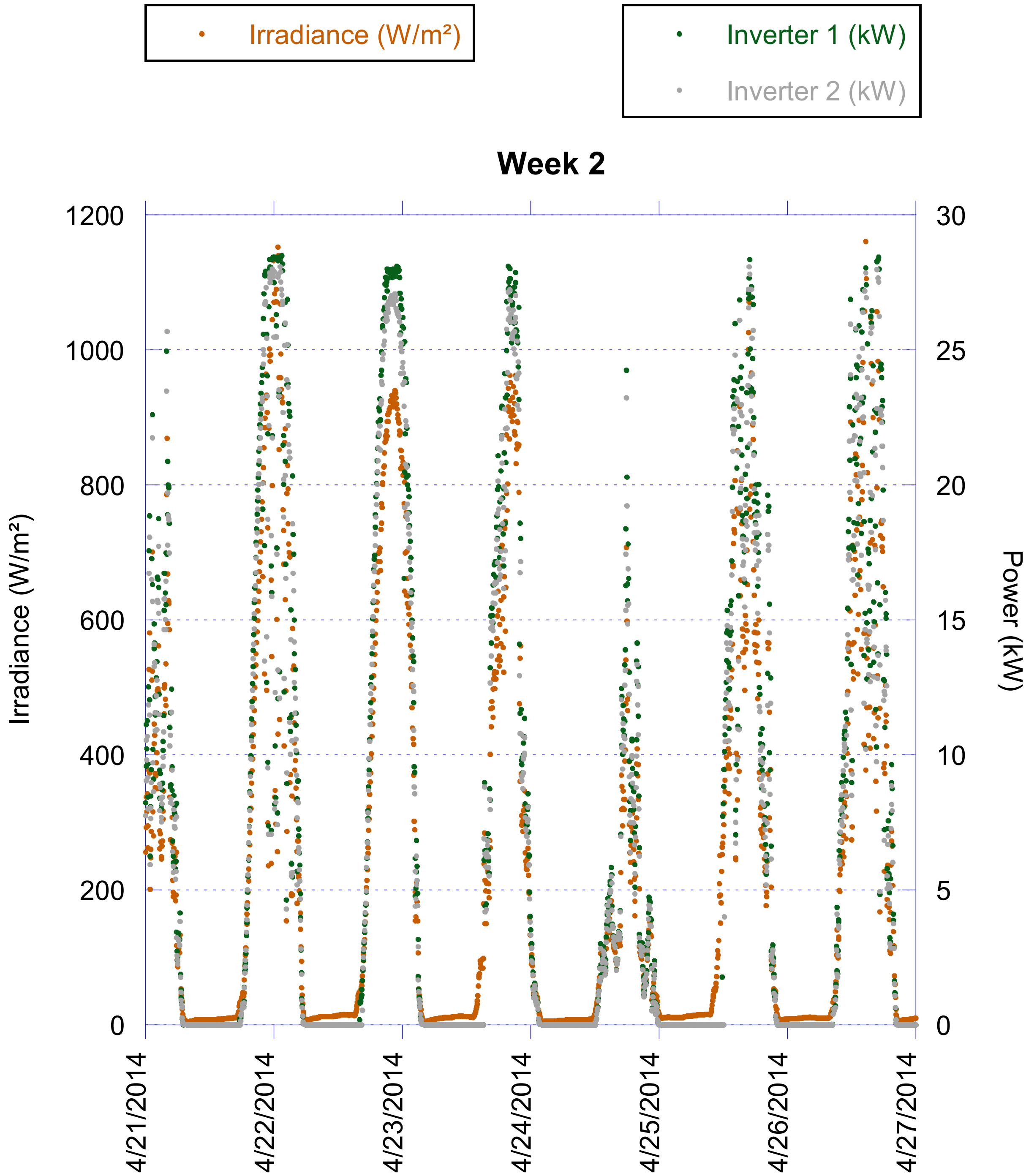


**Figure 5** Plot of AC output power and irradiance for both inverters over Week 2 of the Test Period

# Performance Evaluations

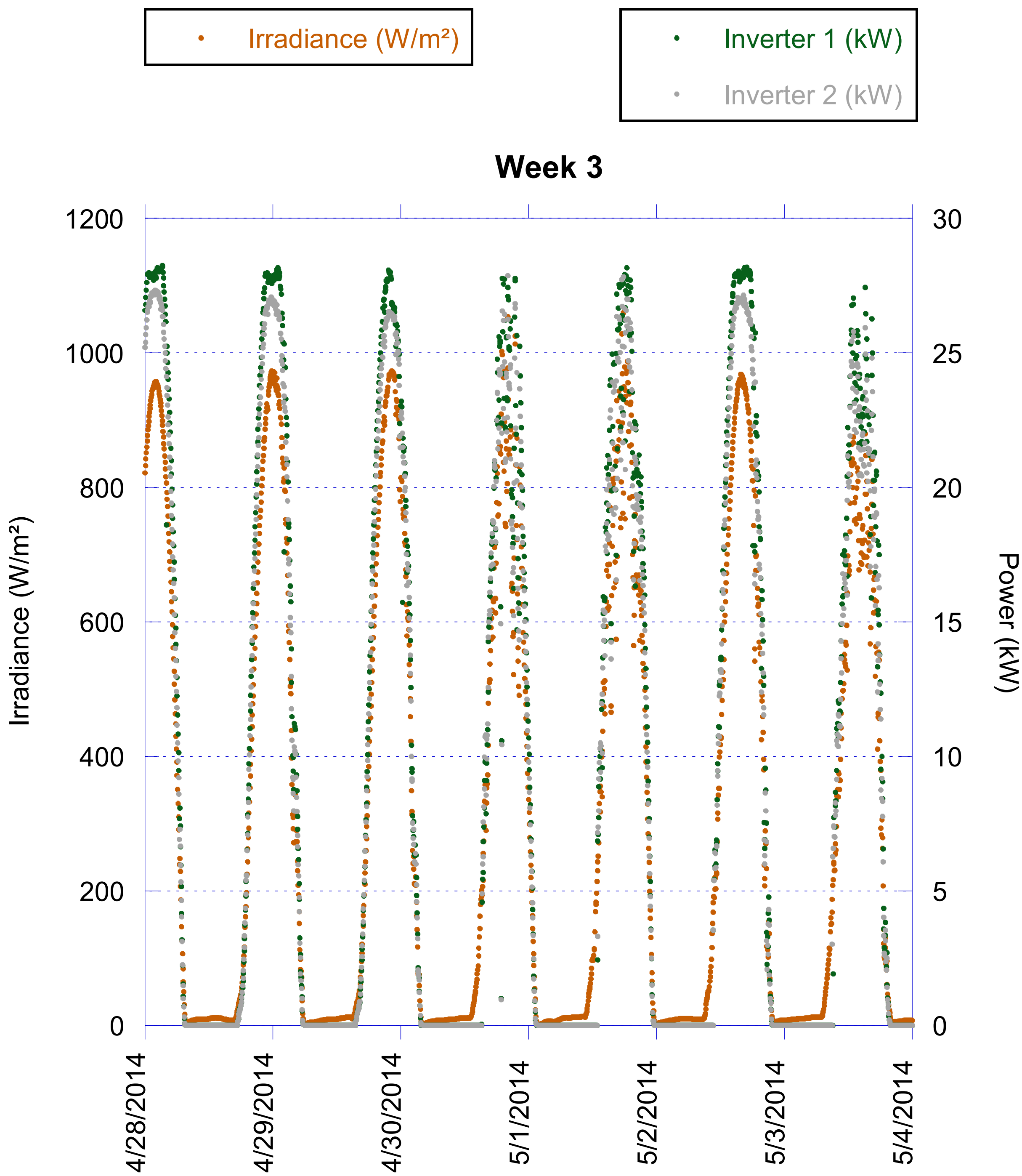


**Figure 6** Plot of AC output power and irradiance for both inverters over Week 3 of the Test Period

# Performance Evaluations

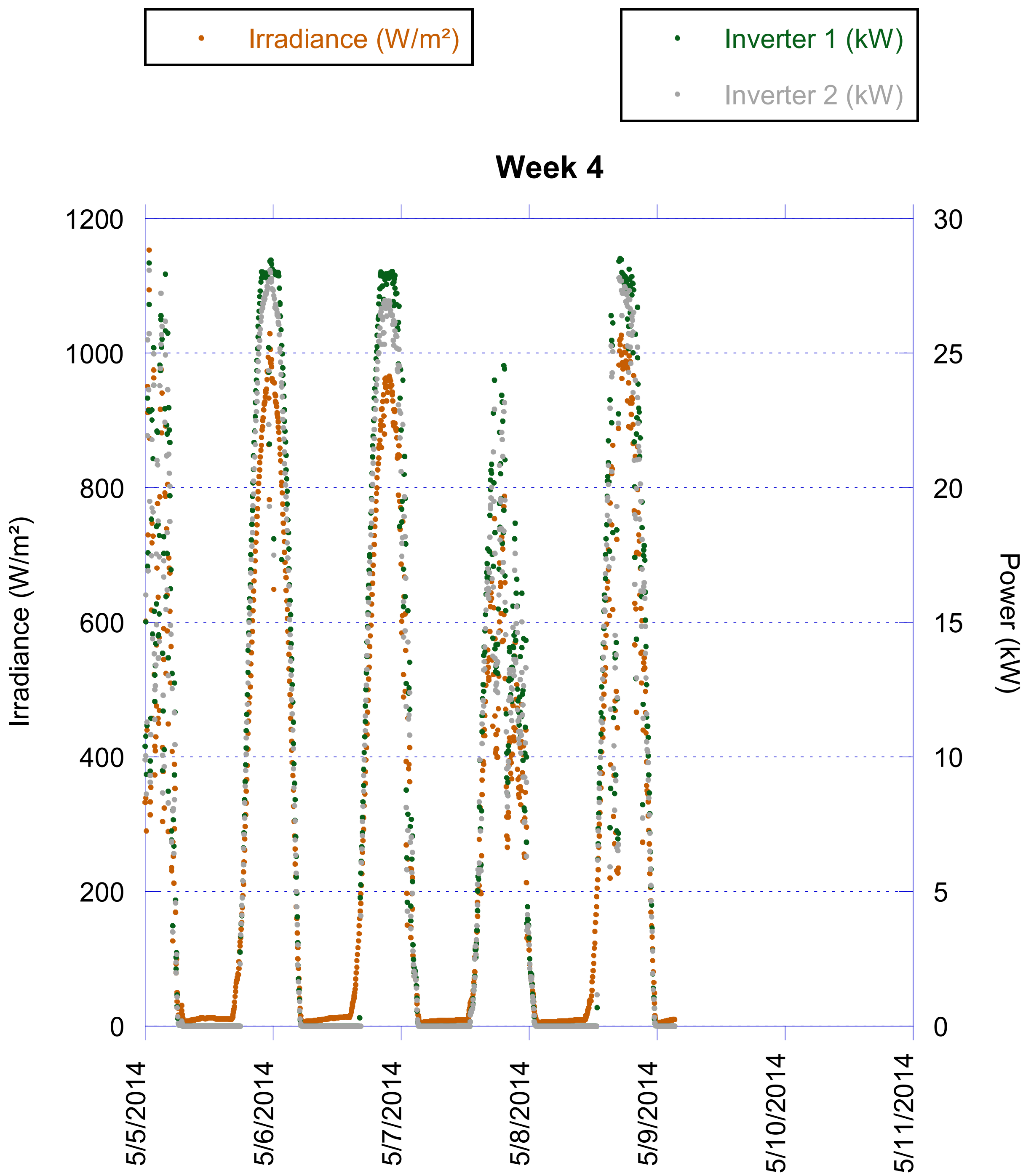


**Figure 7** Plot of AC output power and irradiance for both inverters over Week 4 of the Test Period

# Performance Evaluations

### *Inverter Efficiency*

In order to evaluate the conversion efficiencies of the inverters over the Test Period, both DC input powers of the two (2) MPPT inputs of each inverter as well as the AC output powers of each inverter were measured and recorded at five-minute intervals. Measured data for which either the total DC input power (the sum of the MPPT input powers) is less than 0.5 kW or calculated efficiency is greater than 100 % are neglected from this analysis. Figure 8 below is a plot of measured conversion efficiency versus output power of Inverter 1 over the Test Period.

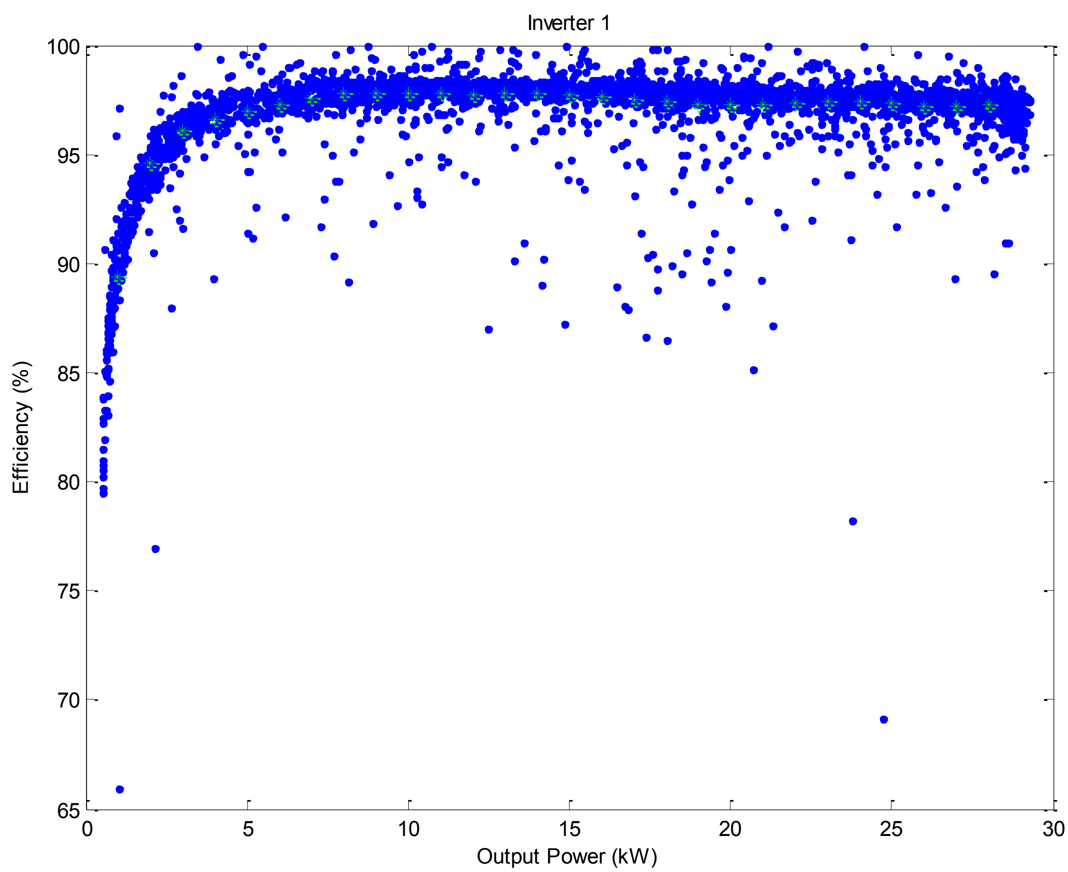


**Figure 8** Inverter 1 conversion efficiency versus output power (blue dots) and the resulting tenth-order polynomial fit (green asterisks) evaluated over the output power range at 1 kW intervals

# Performance Evaluations

Figure 9 below is a plot of measured conversion efficiency versus output power of Inverter 2 over the Test Period.

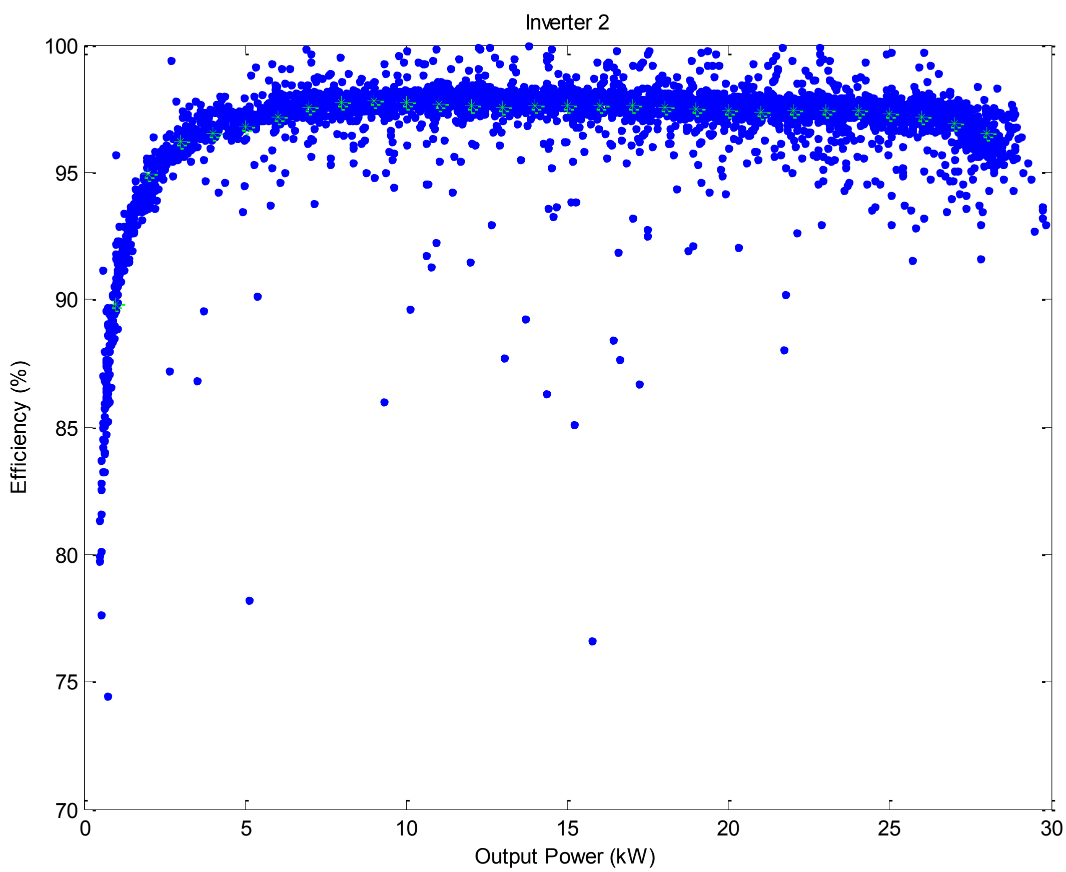


**Figure 9** Inverter 2 conversion efficiency versus output power (blue dots) and the resulting tenth-order polynomial fit (green asterisks) evaluated over the output power range at 1 kW intervals

# Performance Evaluations

Table 5 below contains the conversion efficiencies of both Inverter 1 and Inverter 2 calculated using the tenth-order polynomial fits of the measured data of each inverter that are evaluated throughout the SCA28KTL-DO/US-480 output range at intervals of 1 kW.

| Output Power (kW) | Inverter #1 Efficiency (%) | Inverter #2 Efficiency (%) |
|---|---|---|
| 1 | 89.4 | 89.8 |
| 2 | 94.6 | 94.9 |
| 3 | 96.1 | 96.2 |
| 4 | 96.6 | 96.5 |
| 5 | 97.0 | 96.8 |
| 6 | 97.3 | 97.2 |
| 7 | 97.6 | 97.5 |
| 8 | 97.8 | 97.7 |
| 9 | 97.8 | 97.8 |
| 10 | 97.8 | 97.7 |
| 11 | 97.8 | 97.6 |
| 12 | 97.8 | 97.6 |
| 13 | 97.8 | 97.6 |
| 14 | 97.8 | 97.6 |
| 15 | 97.7 | 97.6 |
| 16 | 97.7 | 97.6 |
| 17 | 97.5 | 97.6 |
| 18 | 97.4 | 97.5 |
| 19 | 97.3 | 97.5 |
| 20 | 97.3 | 97.4 |
| 21 | 97.3 | 97.4 |
| 22 | 97.4 | 97.4 |
| 23 | 97.4 | 97.4 |
| 24 | 97.4 | 97.4 |
| 25 | 97.3 | 97.3 |
| 26 | 97.2 | 97.1 |
| 27 | 97.2 | 96.9 |
| 28 | 97.3 | 96.5 |

**Table 5** Calculated efficiencies of Inverter 1 and Inverter 2 using tenth-order polynomial fits of measured performance data

# Performance Evaluations

Table 6 below contains the coefficients of the tenth-order polynomial fits applied to the performance data of Inverter 1 and Inverter 2.

| Polynomial Coefficient | Inverter #1 | Inverter #2 |
|---|---|---|
| c0 | 7.458E+01 | 7.422E+01 |
| c1 | 2.308E+01 | 2.452E+01 |
| c2 | -1.056E+01 | -1.146E+01 |
| c3 | 2.712E+00 | 2.940E+00 |
| c4 | -4.246E-01 | -4.534E-01 |
| c5 | 4.245E-02 | 4.429E-02 |
| c6 | -2.761E-03 | -2.805E-03 |
| c7 | 1.162E-04 | 1.148E-04 |
| c8 | -3.050E-06 | -2.929E-06 |
| c9 | 4.531E-08 | 4.238E-08 |
| c10 | -2.908E-10 | -2.654E-10 |

**Table 6** Coefficients of the tenth-order polynomial fits of the performance data of Inverter 1 and Inverter 2

# Performance Evaluations

### *Inverter Operating Temperatures*

In addition to evaluating the conversion efficiencies of the inverters over a wide range of loadings, the external case temperatures of Inverter 1 and Inverter 2 were monitored over same the Test Period under the associated operating conditions. Figure 10 below are the temperatures measured at various locations on the inverter's case as well as ambient temperature throughout the Test Period. Please see Figure 2 above for an image indicating the locations of the thermocouples on the inverters under test. The thermocouples labeled "Bottom" are located at the bottoms of the inverters' case, not the bottoms of the disconnect switches. The thermocouples labeled "Front" are centrally located on the inverters' front case (not considering the added dimension of the disconnect switch). The thermocouples labeled "Back" are located at the back of the inverters opposite the "Front" thermocouples. Only temperature data during output powers of the inverters of at least 10 kW are considered in the temperature analyses.

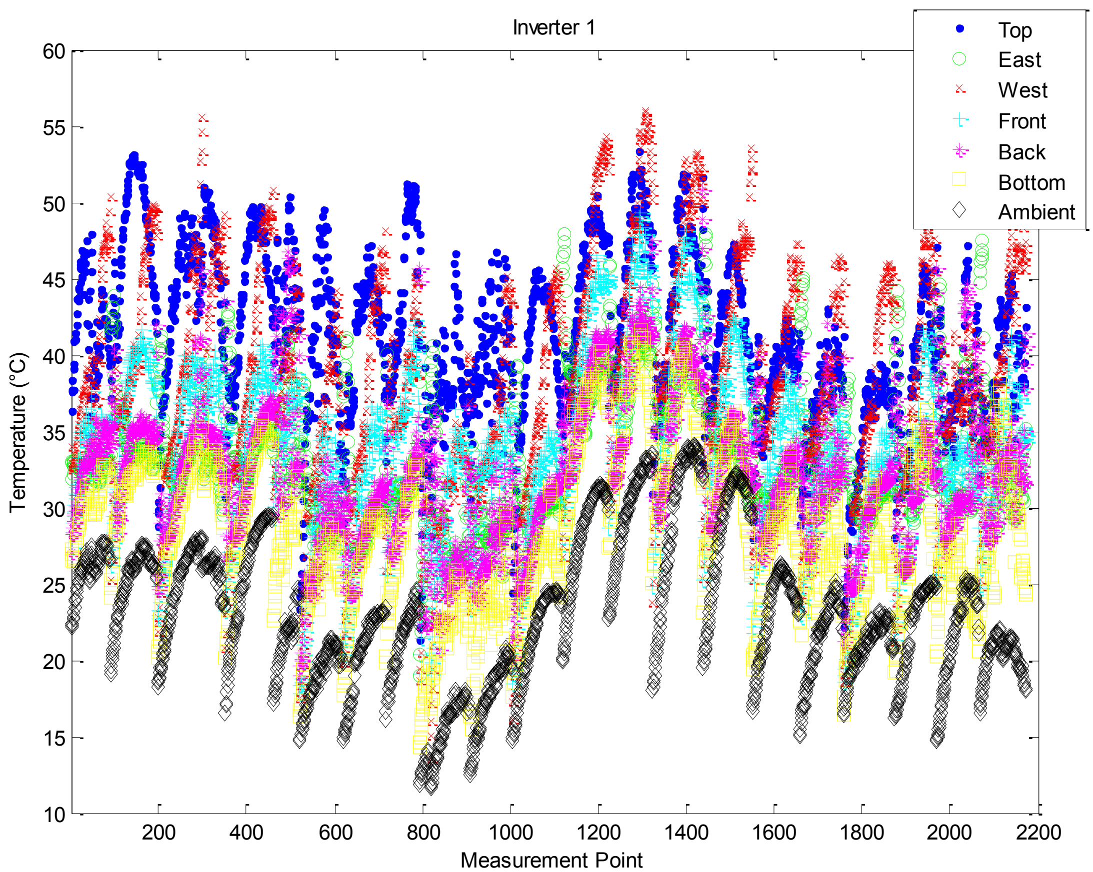


**Figure 10** Inverter 1 temperatures at various locations on its case and ambient temperature throughout the Test Period

# Performance Evaluations

Figure 11 below are the temperatures measured at various locations on the inverter's case as well as ambient temperature throughout the Test Period.

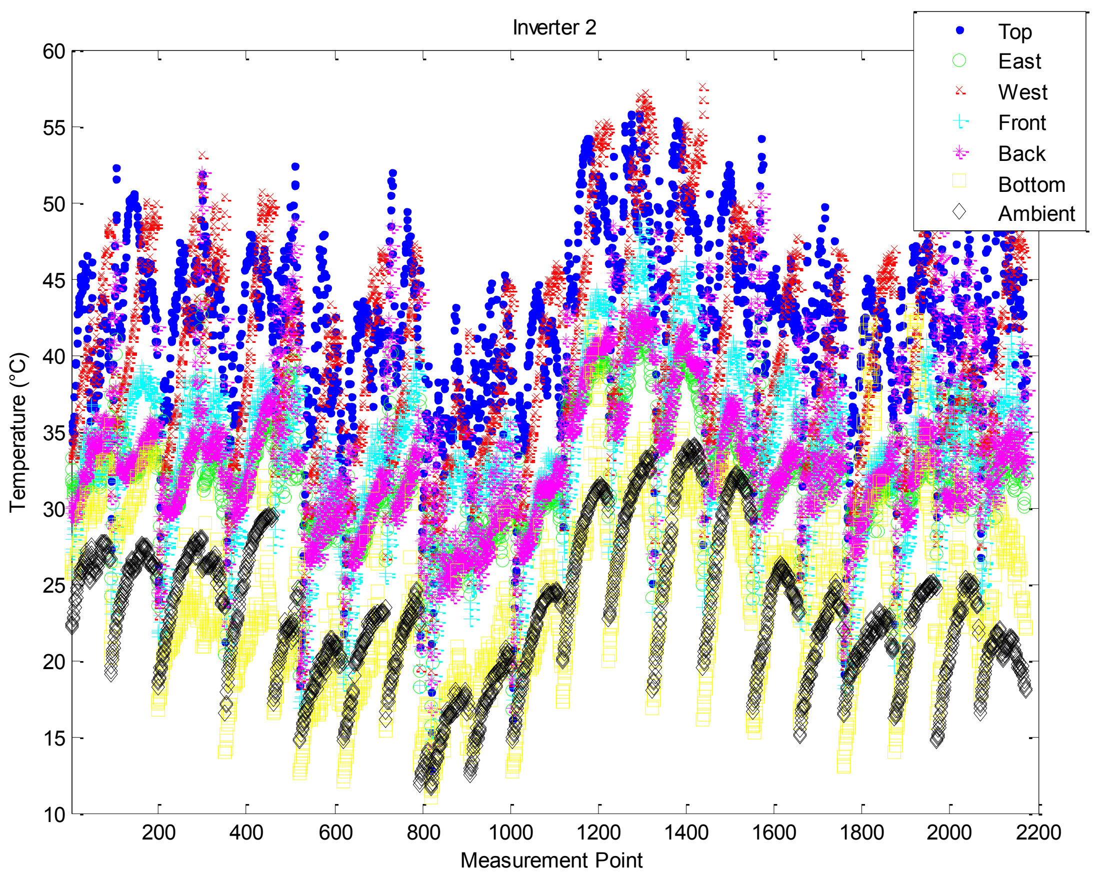


**Figure 11** Inverter 2 temperatures at various locations on its case and ambient temperature throughout the Test Period

# Performance Evaluations

In order to evaluate the performance of a shade plate that may be installed on the SCA28KTL-DO/US-480 inverter, the case temperatures of Inverter 1 were recorded without the shade plate in place for the first half of the Test Period and then with the shade plate in place for the second half of the Test Period. The case temperature values of both inverters were normalized by the corresponding measured ambient temperatures, and the two (2) periods (without and with Inverter 1 shade plate) were isolated, averaged, and analyzed. Table 7 below compares the normalized case temperatures of Inverter 1 during the period with Shade Plate installation to the period without Shade Plate installation.

| | Inverter 1 | | | | | |
|---|---|---|---|---|---|---|
| **Measurement Location** | **Top** | **East** | **West** | **Front** | **Back** | **Bottom** |
| **Without Shade Plate [$T_{Case}/T_{Ambient}$]** | 1.98 | 1.53 | 1.71 | 1.54 | 1.47 | 1.26 |
| **Shade Plate on Inverter 1 [$T_{Case}/T_{Ambient}$]** | 1.67 | 1.47 | 1.66 | 1.45 | 1.41 | 1.23 |
| **Percent Difference [Shade Plate - without Shade Plate] (%)** | -15.65 | -3.36 | -3.01 | -6.26 | -4.20 | -2.34 |

**Table 7** Normalized (to measured ambient temperatures) case temperatures at the various locations on Inverter 1 and the percent differences between the period during which the Shade Plate was installed and the period during which the Shade Plate was not installed

Table 8 below compares the normalized case temperatures of Inverter 2 during the period with Inverter 1 Shade Plate installation to the period without Inverter 1 Shade Plate installation. Since there was never a Shade Plate installed on Inverter 2, these data are simply provided for reference to estimate the affects of variables unassociated to inverter shading on any changes in case temperature during the test period.

| | Inverter 2 | | | | | |
|---|---|---|---|---|---|---|
| **Measurement Location** | **Top** | **East** | **West** | **Front** | **Back** | **Bottom** |
| **Without Shade Plate [$T_{Case}/T_{Ambient}$]** | 1.89 | 1.44 | 1.77 | 1.48 | 1.49 | 1.01 |
| **Shade Plate on Inverter 1 [$T_{Case}/T_{Ambient}$]** | 1.84 | 1.41 | 1.70 | 1.46 | 1.49 | 1.09 |
| **Percent Difference [Shade Plate - without Shade Plate] (%)** | -2.88 | -1.97 | -3.51 | -1.78 | -0.54 | 8.37 |

**Table 8** Normalized (to measured ambient temperatures) case temperatures at the various locations on Inverter 2 and the percent differences between the period during which the Shade Plate was installed on Inverter 1 and the period during which the Shade Plate was not installed on Inverter 1

# Installation Notes

The following are substantive installations that were recorded by the field installers during the installations of Inverter 1 and Inverter 2 at PVUSA:

1. Installation of inverters
    a. The installation process was straightforward.
    b. Attaching the mounting bracket to the structure that supports the inverter was straightforward.
    c. Hanging the inverter on the mounting bracket requires two people but is straightforward.
2. Installation of shade plate
    a. The installation process is straightforward and can be accomplished by a single person.

# Appendix

The AC/DC wiring compartment and the Shade Plate of the SCA28KTL-DO/US-480 inverter were improved by Chint Power Systems based on feedback from DNV GL PVEL. The modifications were recommended by DNV GL PVEL to achieve greater installation efficiency and ease. Figure A1 below is an image of the SCA28KTL-DO/US-480 inverter with the improved Shade Plate installed.

**Figure A1** Image of SCA28KTL-DO/US-480 inverter with installed Shade Plate

# Appendix

The original and improved AC/DC wiring compartments are shown, respectively, in Figure A2 and Figure A3 below. The improved wiring compartment utilizes touch-safe fuse holders, more robust wiring terminals, eliminates the terminal/fuse PC board, and affords more space for the AC and DC conductors.

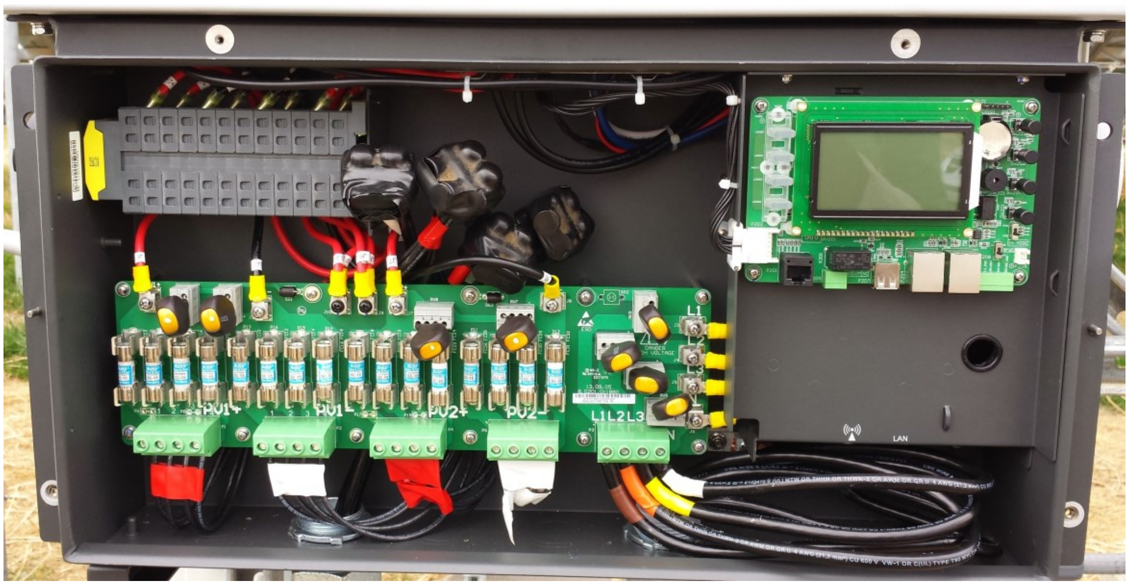


**Figure A2** Image original AC/DC wiring compartment

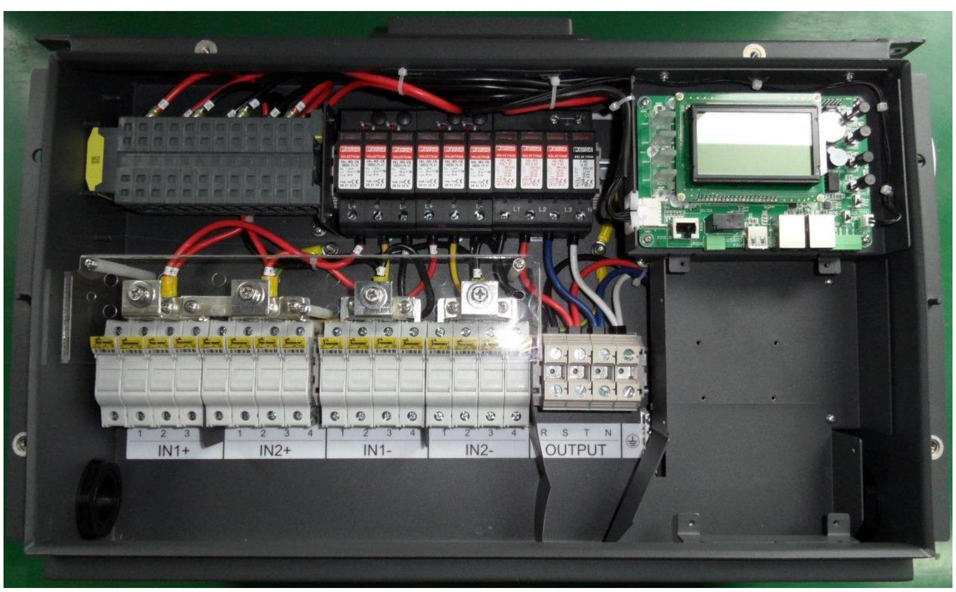


**Figure A3** Image improved AC/DC wiring compartment

# About Us

For companies developing PV products and projects, PV Evolution Labs (DNV GL PVEL) is the premier solar panel performance and reliability testing lab. We provide secure, expert testing and validation services so you can be confident that you're making intelligent decisions based on the most reliable data.

DNV GL PVEL is founded on the principle that understanding solar panel aging behavior through testing is a fundamental aspect of safety, cost reduction, and reliability – all of which are imperative to the growth, health, and evolution of the solar industry. DNV GL PVEL is committed to increasing photovoltaic product quality while reducing product time to market.

Our dedicated environmental, mechanical, and electrical testing systems are designed specifically for the flat plate PV module form factor. Utilizing dedicated characterization systems ensures optimal data quality and repeatability. DNV GL PVEL's calibrated equipment base is closely maintained to ensure optimal availability and reliability. Our specialized services are available for product and process qualification, raw material and supplier evaluation, ongoing reliability testing (ORT), risk assessment, lot acceptance, energy yield evaluation, and more.

The DNV GL PVEL team possesses unparalleled expertise in test and measurement techniques for semiconductor devices and PV modules. Our highly qualified technical staff is dedicated to serving the needs of the solar industry with a commitment to excellence in test quality and customer service. DNV GL PVEL aims to collaborate with our clients throughout the development cycle. By working with you from start to finish, we ensure the highest quality product with a faster time to market.

*Our mission at DNV GL PVEL is to facilitate the dramatic growth of the North American solar industry.*