THERMAL PERFORMANCE OF PV COMBINERS

JIM PEPLINSKI
INNOVATIVE SOLAR INC.
224 Airport Pkwy Suite 190 - San Jose, CA 95110

TEST REPORT

Thermal Performance of PV Combiners

Overview

Data in the following report demonstrates that ambient temperature rise in proximity to fuses in PV combiners can be virtually cut in half with proper design. Increasing panel current and the increased heat loss of most 1500vdc fuses, has made old combiner box design practices inadequate.

It's no surprise that fuses are a thermal device and respond to the environment that they operate in. What not everyone thinks about is that virtually every aspect of design and implementation contribute to their proper function. It is critical that the designer understands the relative impact of every design choice that is made.

The following tests demonstrate the performance of an ISI combiner and compare it against one of the other popular products on the market. Tests were performed at room temperature with values of current at both Isc and (Isc X 1.25).

Table 1.1

Measuring Point	Designation	Temperature rise over external ambient [°C]						
		Isc (10A) X 13 dual strings = 260A (20A x 13 = 260A)				Isc X 1.25 X 12 dual strings = 304A (25.35A x 12 = 304.2A)		
		Other designs	ISI	Delta		Other designs	ISI	Delta
1	Body of fuse #1, (left)	88.2	66.3	21.9		145.3	106.5	38.8
2	Body of fuse #2, (2nd from left)	91.0	67.4	23.6		150.7	107.9	42.8
3	Bus Bar	35.1	30.0	5.1		50.4	43.8	6.6
4	Internal ambient, top (2" from left side & top)	20.6	14.8	5.8		29.7	21.4	8.3
5	Internal ambient, bottom	8.3	7.6	0.7		11.6	10.8	0.8
Calculated	Ambient @ hottest fuse location	19.3	10.0	9.3		27.9	14.3	13.6

In both the 260A and 304A tests, the ambient temperature at the level of the hottest fuse was reduced by nearly half (9.3°C and 13.6°C respectively). This is the result of a more efficient switch, moving the fuses to a lower level in the box, and increasing internal convection air flow.

The temperature of the fuses was ultimately reduced by 20-40°C. This is the result of better air flow and reduced mutual heating from adjacent fuses. Other tests have shown that the temperature rise of fuses at the top of a column can exceed that of the bottom by 35%.

With 35°C outside ambient temperature and 10A string current through the ISI combiner box, ambient temperature in proximity to the fuses would be 45°C. The appropriate fuse derating would be x.91, based on Mersen recommendations. With fuse temperature indicating the additional effect of mutual heat in the competing product, the appropriate fuse derating may be as great as (x.80).

Advantages of ISI Combiner boxes over in-line fuse solutions

1. ISI Combiners comply with the disconnect requirements of NEC2017. An in-line fuse solution that serves the function of a combiner greater than 30A do not comply with sections 690.15 & 690.15(A), which require that a load break disconnect be present within 10ft of PV fuses.
2. AFCI capability will soon be available in 1500v combiners. Multiple jurisdictions in both the US and Canada are now beginning to enforce code requiring that AFCI be implemented on 1500v systems. If more than 4 or 5 strings are combined prior to reaching an enclosure, AFCI cannot be effectively implemented because the signal becomes too small.
3. A failed or underperforming input circuit can be proven quickly in one location with a combiner. With in-line fuse solutions, measurements have to be taken along the entire length of the trunk.
4. In combiners, measurement points are accessible for activities such as trouble shooting and measuring open circuit voltages during commissioning.
5. Automated monitoring and diagnostics may be added to combiners.

Table 1.2

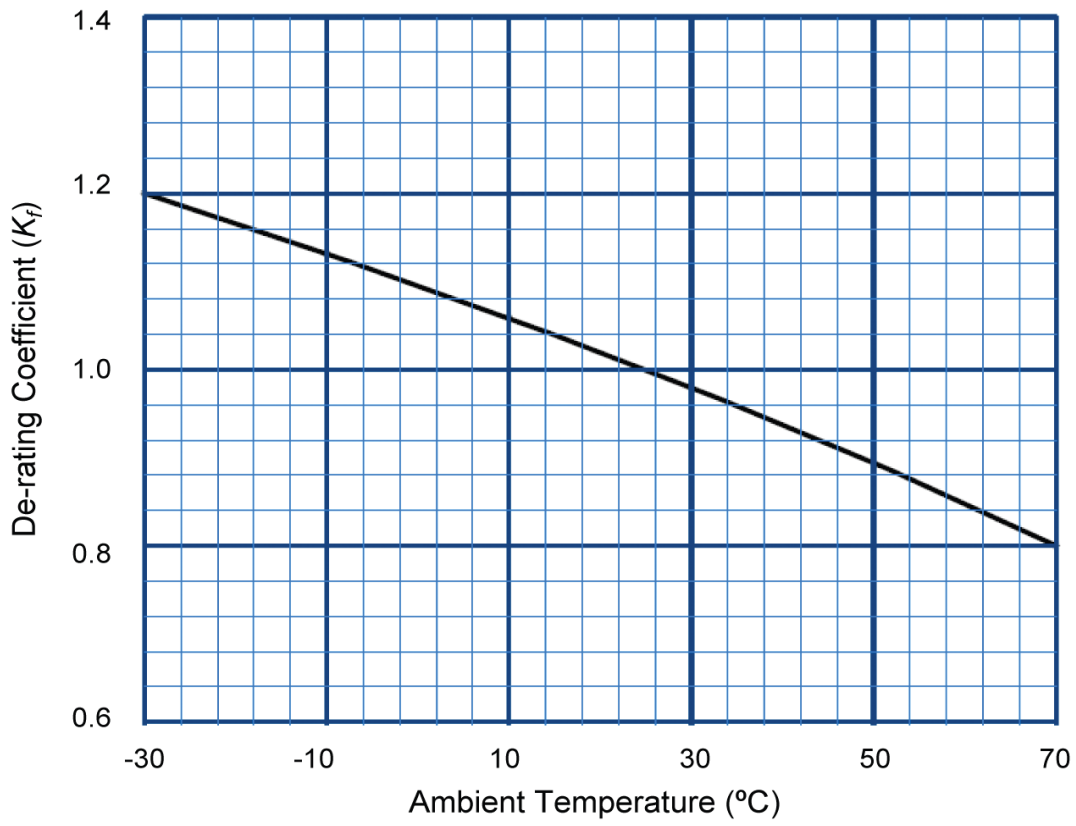
Test description:	**Thermal tests on ISI and competing combiner configurations.**		
Document name:	**Test report, thermal management techniques on PV combiners .doc**		
Author:	**Jim Peplinski**	**Date:**	**1/30/19 – 2/12/19**
Responsible tester:	**Jim Peplinski**	**Location:**	**San Jose**
Test context:		**Test index:**	
Test specification:			
Project title:	**Thermal performance of PV combiners, ISI versus other designs.**		
Project director:	**Jim Peplinski**		
Model Number:	**1500v PV combiners**	**Serial number:**	**N/A**
Version number:	**N/A**	**Option code:**	**N/A**
Firmware version(s):	**N/A**		
Remarks:			

Table 1.3

Test equipment	
E1.	**Digital Multi-meter: Fluke 115 s/n: 30871292WS**
E2.	**Current shunt 500A:50ma**
E3.	**Thermal Camera:**
E4.	

Table 1.4

Relevant Documents	
D1.	SIZING FUSES FOR PHOTOVOLTAIC SYSTEMS PER THE NATIONAL ELECTRICAL CODE®



Mersen De-Rating Chart for Abnormal Ambient Temperatures

Test setup:

- Thirteen 6 foot lengths of 10 awg wire was cut and installed inside the Generic combiner between the fused inputs and the negative terminal block.

- A current source was connected to the output terminals and adjusted to either 256A or 304A.

- Six 30 awg Thermocouples were installed in select locations.

Summary of Measuring Points

Table 2.1

Measuring Point	Designation
1	Body of fuse #1, (top)
2	Body of fuse #2, (2nd from top)
3	Comb Bus, (center)
4	Internal ambient, top (2" from left side & top)
5	Internal ambient, bottom (2" from left side and bottom)
6	External ambient

Table 2.2

1/1	Test procedure and results		
Tester:	Jim Peplinski	Date:	2/13/19
Voltage:	n/a	Temperature:	23°C nominal
Current:	260A & 304A		
Measurement data:			
Remarks:			

Procedure:

1) Turn on current source.
2) Ramp current to desired value.
3) Record temperature of all thermocouples on a half hour increment until stable.
4) Take thermal immages at stable temperature.
5) Measure voltage drop across disconnect switch.
6) Proceed to next test.

Results

Table 2.3

Ultimate measured temperatures at stable operation:

Measuring Point	Designation	Measured value [°C]						
		Isc (10A) X 13 dual strings = 260A				Isc X 1.25 X 12 dual strings = 304A (25.35A x 12 = 304.2A)		
		Other designs	ISI	Delta		Other designs	ISI	Delta
1	Body of fuse #1, (left)	111.4	89.3	22.1		168.4	129.4	39.0
2	Body of fuse #2, (2nd from left)	114.2	90.4	23.8		173.8	130.8	43.0
3	Bus Bar	58.3	53.0	5.3		73.5	66.7	6.8
4	Internal ambient, top (2" from left side & top)	43.8	37.8	6.0		52.8	44.3	8.5
5	Internal ambient, bottom	31.5	30.6	0.9		34.7	33.7	1.0
6	External ambient	23.2	23.0	0.2		23.1	22.9	0.2

Table 2.4

Calculation of temperature rise:

Measuring Point	Designation	Temperature rise over external ambient [°C]						
		Isc (10A) X 13 dual strings = 260A				Isc X 1.25 X 12 dual strings = 304A (25.35A x 12 = 304.2A)		
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1	Body of fuse #1, (left)	88.2	66.3	21.9		145.3	106.5	38.8
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5	Internal ambient, bottom	8.3	7.6	0.7		11.6	10.8	0.8
Calculated	Ambient @ top fuse location	19.3	10.0	9.3		27.9	14.3	13.6

Table 2.5

Voltage drop and power dissipation switches @304A:

	Voltage Drop	Current	Power Dissipation
3-pole ABB switch with aluminum jumpers	109 mv	304 A	33.1 W
2-pole Socomec switch	57 mv	304 A	17.3 W
Difference in heat loss of the disconnect switch			15.8 W

Table 2.6

Benefit of new 2-pole disconnect switch:

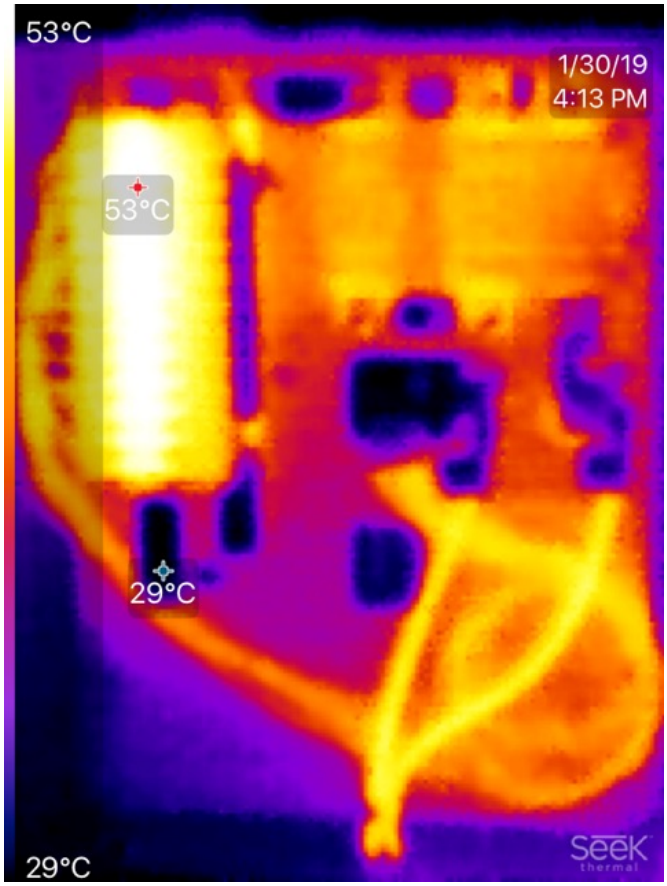
ISI combiner total	393 mv	304 A	119.5 W
Improvement in heat loss and total enclosure temperature rise as a result of the newest disconnect switch			13%

Summary of results

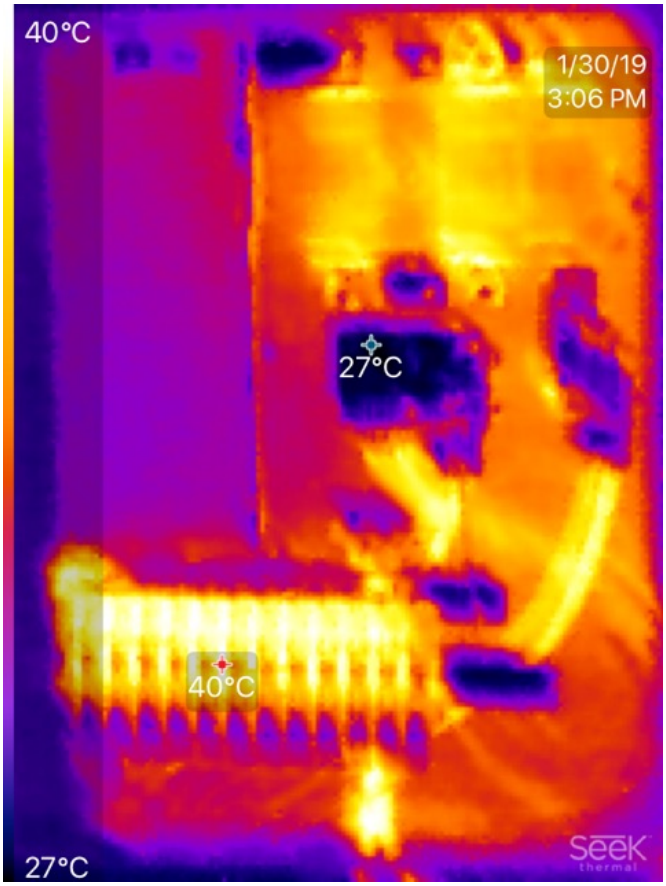
- Total heat loss was reduced by over 10% by the ISI combiner.
- Max air temperature rise in the combiner box was reduced by 28% by the ISI combiner.
- Air temperature rise in proximity to the fuses was reduced by 48-49% by the ISI combiner.
- The fuse bus bar temperature rise was reduced by 13-15% by the ISI combiner.
- The temperature rise of the fuses was reduced by 25-28% by the ISI combiner.

Effects of changing fuse location and orientation

Typical fuse location



Fuses located low in horizontal row



Review			
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Approval			
Name:		**Date:**	