High Current ESD Test of Advanced Triple Junction Solar Array Coupon

Kenneth H. Wright, Jr. (University of Alabama - Huntsville)
Todd A. Schneider and Jason A. Vaughn (NASA/Marshall Space Flight Center)
Bao Hoang and Frankie Wong (Space Systems Loral, LLC)

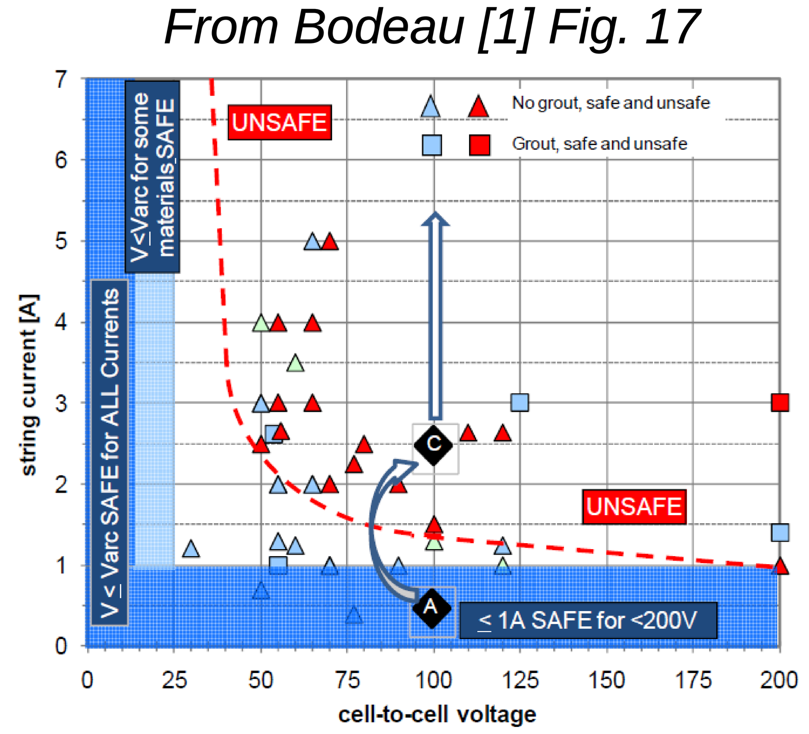
Abstract

Testing was conducted on an Advanced Triple Junction (ATJ) coupon that was part of a risk reduction effort in the development of a high-powered solar array design by Space Systems Loral, LLC (SSL). The ATJ coupon was a small, 4-cell, two-string configuration of flight-type design that has served as the basic test coupon design used in previous SSL environmental aging campaigns. The objective of the present test was to evaluate the performance of the coupon after being subjected to induced electrostatic discharge (ESD) testing at two string voltages (100 V, 150 V) and four string currents (1.65 A, 2.0 A, 2.475 A, and 3.3 A). An ESD test circuit, unique to SSL solar array design, was built that simulates the effect of missing cells and strings in a full solar panel with special primary arc flashover circuitry. A total of 73 primary arcs were obtained that included 7 temporary sustained arcs (TSA) events. The durations of the TSAs ranged from 50 micro-seconds to 2.75 milli-seconds. All TSAs occurred at a string voltage of 150 V. Post-ESD functional testing showed that no degradation occurred due to the TSA events. These test results point to a robust design for application to a high-current, high-power mission.

Introduction

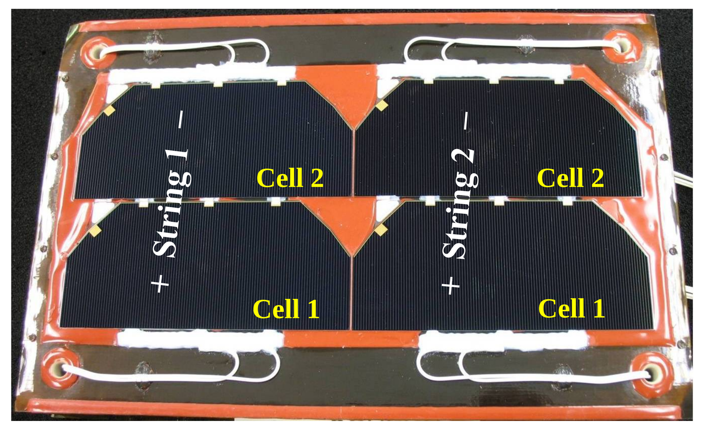
- Increasing demands on satellite power systems may drive photovoltaic array (PVA) string voltages and string currents to exceed 100 V and 1 A respectively.
- Bodeau [1] surveyed a large amount of ground test data and compared it with a large amount of vacuum arc data to derive a safe operating region: string currents < 1 A for string voltages < 200 V. (See figure below)
- Coupon-level tests were performed at the Marshall Space Flight Center (MSFC) to investigate PVA design robustness for voltages > 100 V and currents > 1 A.
- The protocol for ESD testing is based on the recent standard ISO-11221.

From Bodeau [1] Fig. 17



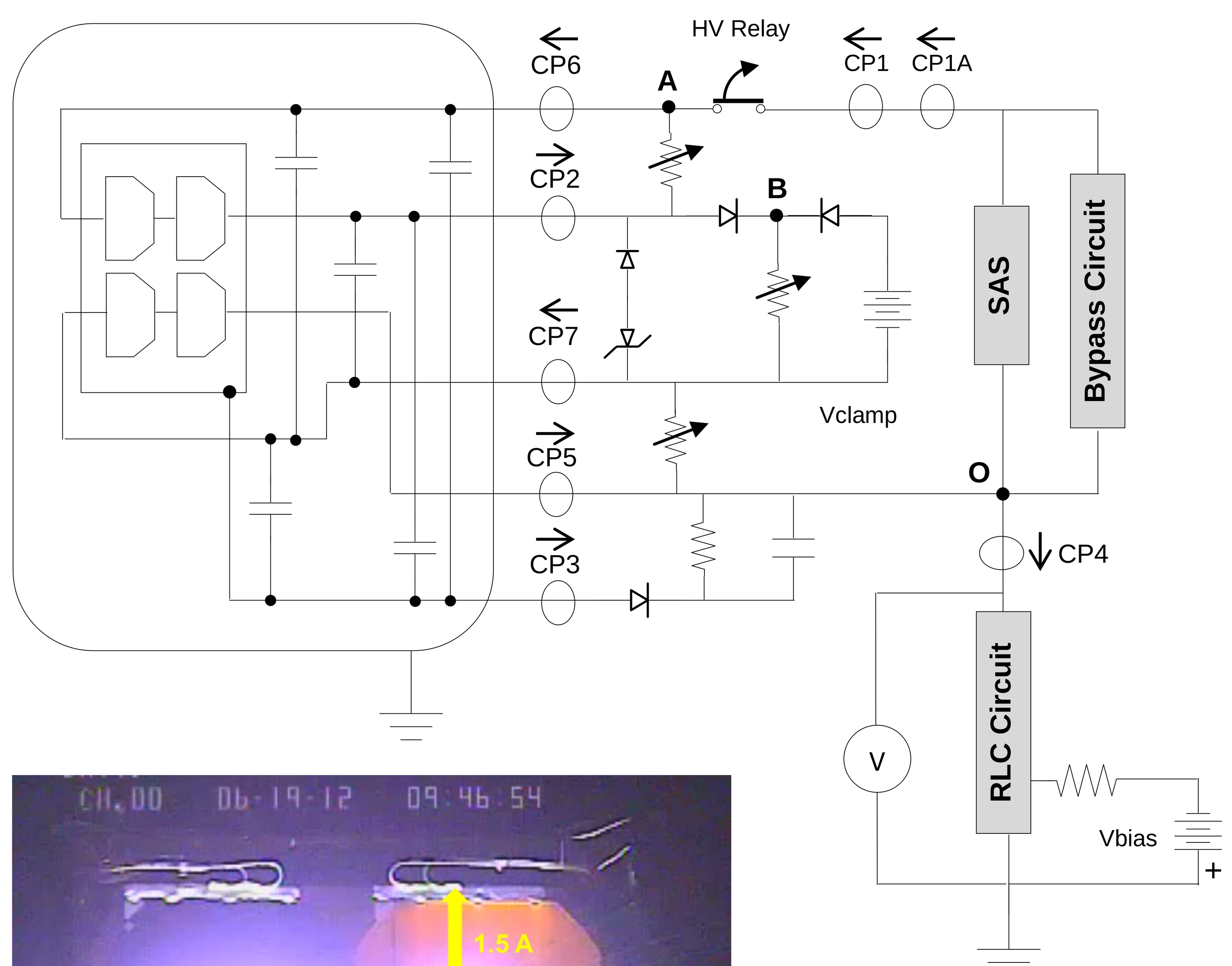
Test Plan

- ESD testing at two string voltages (100 V, 150 V) and four string currents (1.65 A, 2.0 A, 2.475 A, 3.3 A)
- Test article is small ATJ coupon: two strings with two cells per string (see picture below).
- RTV coating on busbars, on interconnects, and between cells
- Minimum 70 arcs distributed among the various voltages and currents.



Test Setup

- Test performed in MSFC vacuum chamber (Wright et al. [2] [3])
- Special ESD test circuit developed by SSL (Hoang et al. [4])
- RLC network provides primary arc waveform (~ 190 µs long with 28 A peak)
- Solar Array Simulator (SAS) provides power
- Inverted gradient potential condition
- Various current probes (CP) and voltage probes (V) to diagnose circuit. HV relay opens 3 ms after arc initiation.



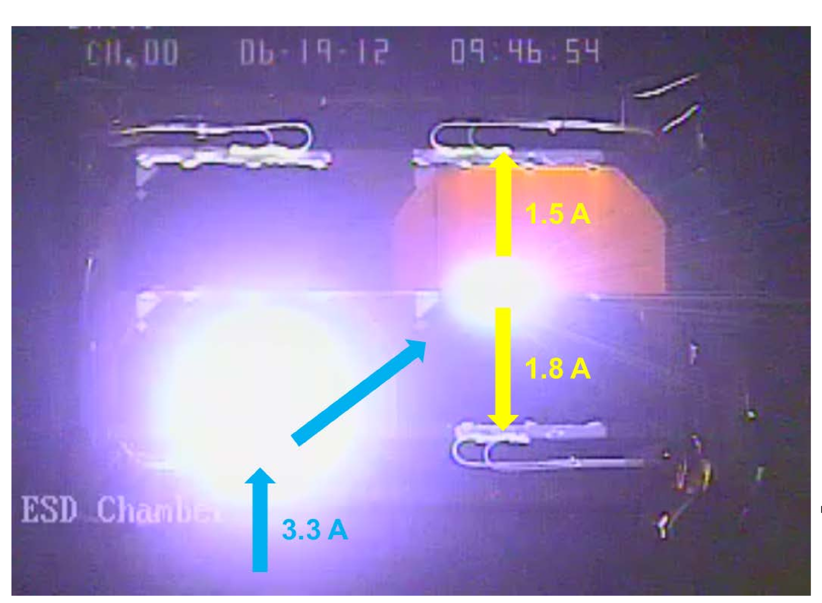


Image of arc event (see adjacent data)

Test Results

As-Run ESD Arc Data

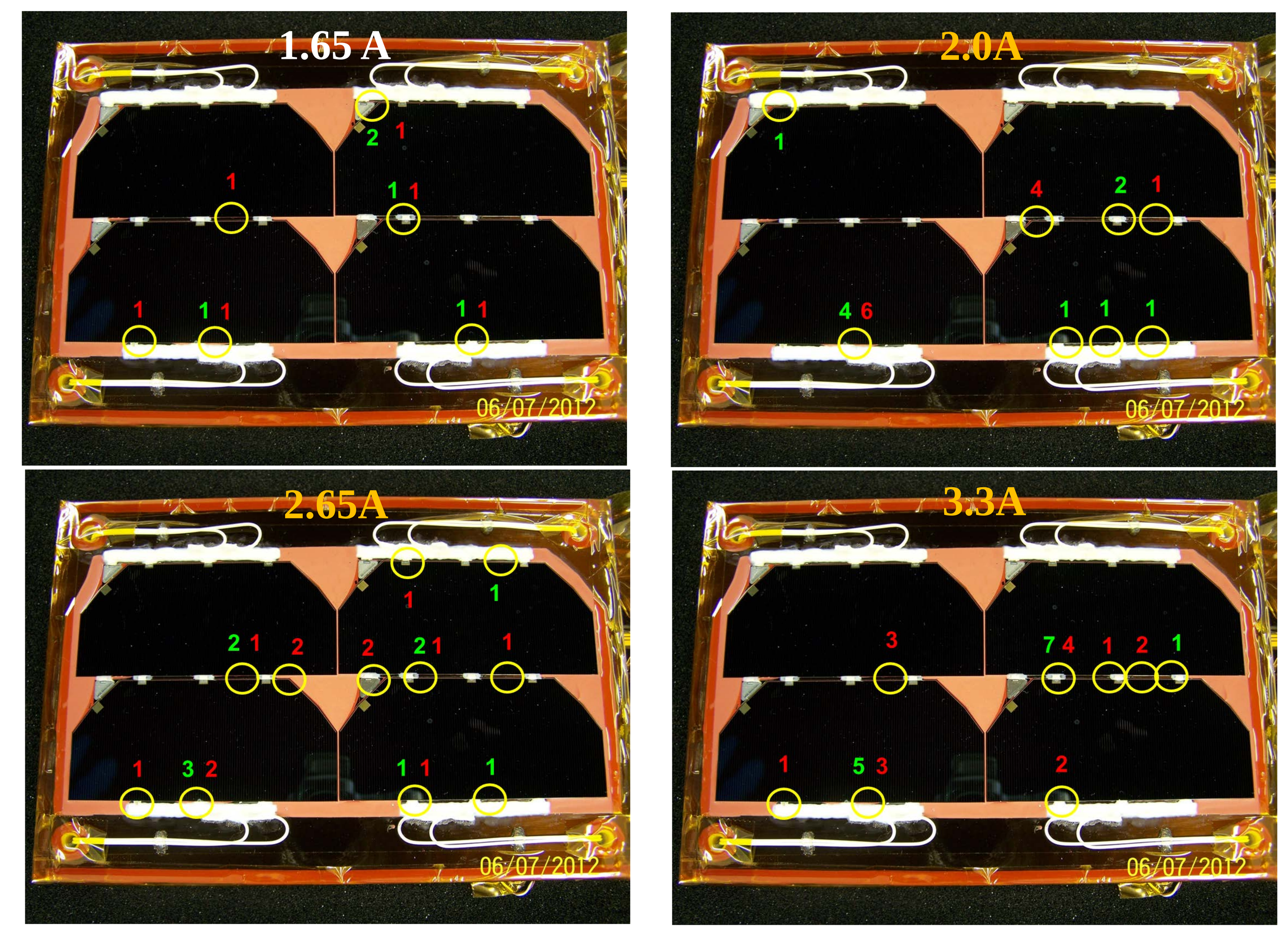
(TSA = Temporary Sustained Arc)

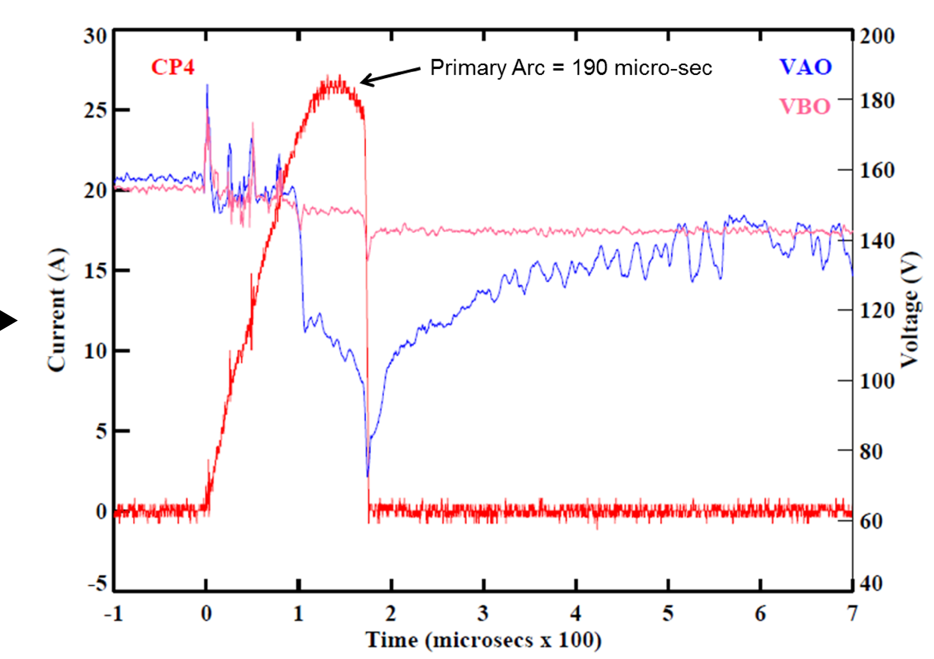
String Potential (V)	String Current (A)	Number of ESD Arcs Acquired	Number of TSAs
100	1.65	5	0
150	1.65	5	0
100	2.0	10	0
150	2.0	10	1
100	2.475	10	0
150	2.275	10	2
100	3.3	12	0
150	3.3	11	4
Arc Summary Total		73	7

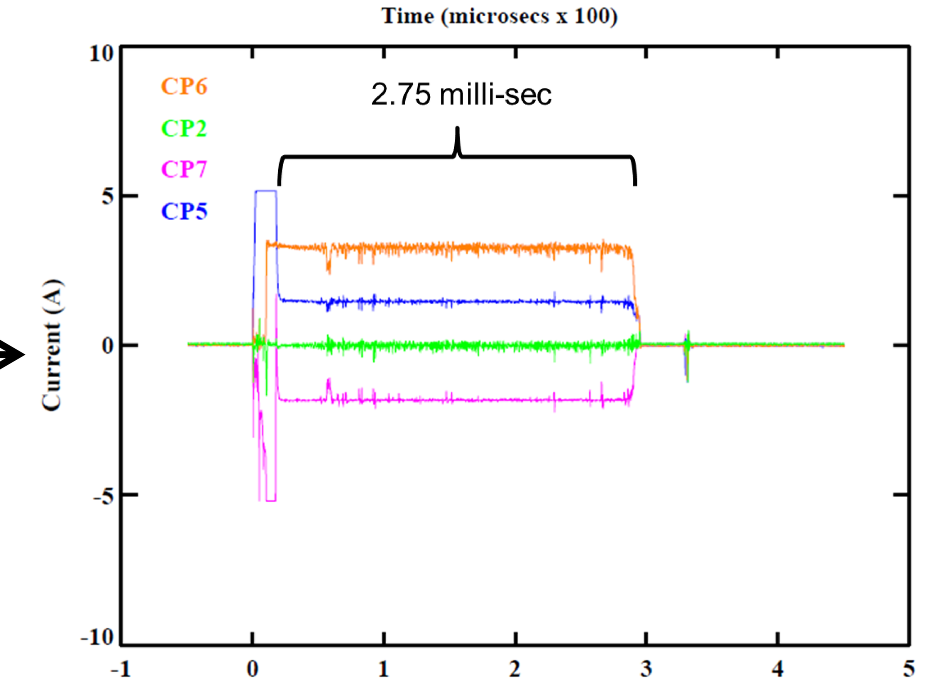
TSA Occurrence Condition and Duration

String Potential (V)	String Current (A)	Duration (µs)
150	2	250
150	2.475	160
150	2.475	230
150	3.3	50
150	3.3	190
150	3.3	-
150	3.3	2750

Arc site location map. Each number by the circle indicates the number of events at that site. Green number is arc count at 100 V and red number is arc count at 150 V.

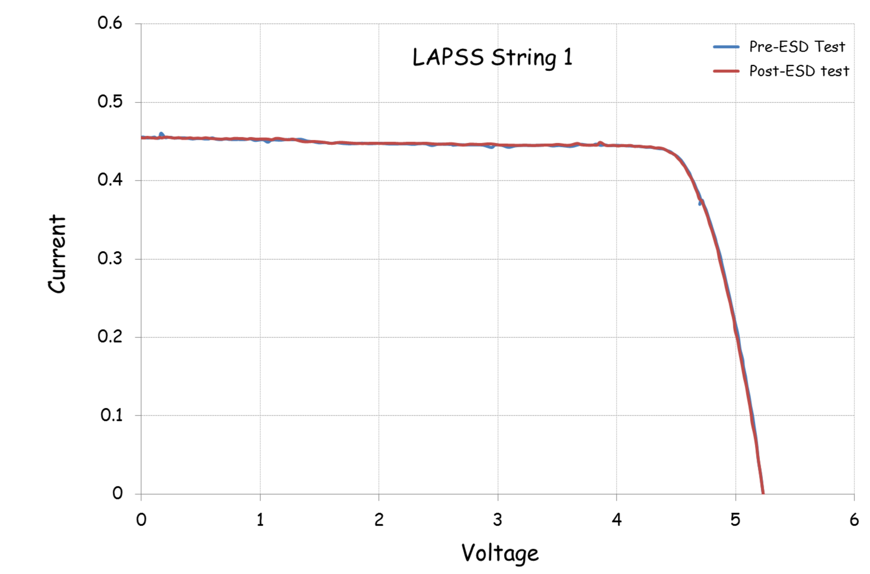


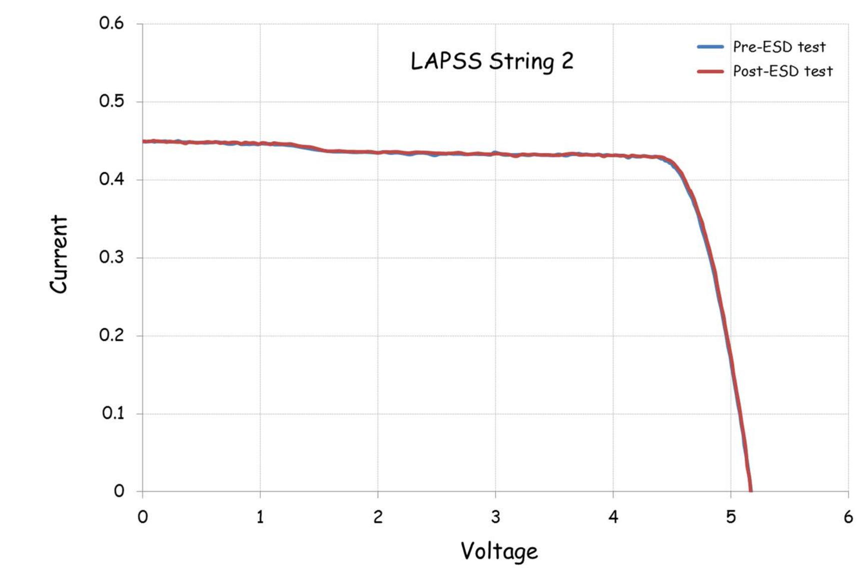




Functional Test Results

LAPSS = Large Area Pulsed Solar Simulator





Summary

- ESD test parameters were chosen to anticipate future SSL array bus voltages and currents and extend the test parameters used in the previous study of Hoang et al. [4].
- Two string voltages (100 V, 150 V) were tested.
- All TSA events occurred at 150 V over three different string currents (2 A, 2.475 A, and 3.3 A) with the number of TSA events increasing with increasing current level.
- The duration of the TSA events in this test exhibit no discernible pattern.
- It is important to note that the longest TSA event was terminated via a pre-determined test circuit operation.
- All functional test data obtained post-ESD testing indicated no degradation in cell performance.
- The ESD test string voltages and currents are in the high-risk operating zone as defined by Bodeau [1].
- The present SSL design indicates robustness against some region of high power operation.
- If string power in the 150 V, 3A region is envisioned, further design and test work is needed, especially when the reality of environmental aging is considered [2] [3].

References

1) M. Bodeau, IEEE-Trans. Plasma Science, Vol. 40, No. 2, pp 192-200, Feb. 2012.
2) K. H. Wright, Jr. et al., IEEE-Trans. Plasma Sci., Vol. 40, No. 2, pp 334-343, Feb. 2012.
3) K. H. Wright, Jr. et al., 12th Spacecraft Charging and Technology Conference, Kitakyushu, Japan, 14-18 May, 2012.
4) B. Hoang, et al., 35th IEEE Photovoltaic Specialists Conference (PVSC), Honolulu, Hawaii, 20-25 June 2010.

13th SCTC Poster # 186