Update on the activities of PVQAT Group
4: Diodes, Shading and Reverse Bias

Vivek Gade — Jabil, representing the Americas
Paul Robusto — Miasole, representing the Americas
Yasunori Uchida — JET, representing Japan
Hubert Volz — Multi-Contact Essen, representing Europe
Jos Van Loo — Diotec Europe
Xian Dong — Zhongshan University, representing China
Chandler Zhang — Hohai University, representing China
US Task Group 4 Update

IEC Technical Specification on ESD

• A technical specification/Guideline: IEC 62916 was approved in early 2014
• IEC 62916 was sent out Jan 21, 2015 for final review and will become a draft technical specification

Model for Predicting Vulnerability of Diodes to Thermal Runaway

• Vivek Gade and Narendra Shiradkar have developed a theoretical framework for assessing the vulnerability of bypass diodes for thermal runaway based on the diode datasheet parameters.
• Currently options of incorporating this into NWIP on thermal runaway proposed by Japanese group are being explored.

Thermal Runaway Testing at SunEdison

• Kent Whitfield and Shuying Yang at SunEdison tested various diodes for thermal runaway at ambient temperatures of 50 C and 90 C and forward current equal to 1.25 x Isc
• It was concluded from the experiments that the condition of ambient temperature= 90 C and short circuit current equal to 1.25 x Isc in the thermal runaway test draft maybe too harsh and a somewhat lower ambient temperature maybe better.
Estimating Field Stressors Affecting Bypass Diodes

- Models are being developed at Jabil to estimate the field stressors (TJ and ΔTJ) during service life of bypass diodes as a function of shading configuration and TMY data of various locations.

- Outdoor experiments are being performed on a rooftop array in Florida to monitor the diode junction temperature for model verification.

Thermal Resistance Measurement of Bypass Diodes / Junction Boxes

- Thermal resistance (Junction→Ambient) has been measured using 1-Dimensional heat conduction model for 9 different types of bypass diode / junction box samples at various ambient temperatures and forward currents.

- It is shown that the thermal resistance (Junction→Ambient) at standard conditions (say Tambient = 25 C, If = 10 A), can be used to quantify heat dissipation properties of various junction box designs (Poster #32 at PVMRW 2015)

Extended Bypass Diode Test According to Qualification Plus

- Extended bypass diode test as described in the Qualification Plus Standard (Ambient temperature = 75 C, I = Isc, Duration = 96 hours) is being carried out at Jabil on 9 different types of bypass diodes / junction boxes.

- This test is expected to generate useful representative data for describing the effect of Extended Bypass Diode Test on various sample types.

Thermal Cycling With Current Through the Diodes

- It was proposed that during thermal cycling test, current should be cycled through the diodes for last 50 thermal cycles

- Experiments have been initiated at Jabil to understand the effect of such thermal /current cycling on diodes.
Japanese Task Group 4 Update

- **NWIP on Thermal Runaway**

  - Diodes can undergo thermal runaway during forward bias to reverse bias transition when the shading is suddenly removed.
  - NWIP draft for "Thermal runaway test for bypass diodes" was submitted by team from Japan to TC82/WG2 and it has been accepted.
  - Preparation of special measuring equipment for establishing Vf-TJ relation to calculate Tj has been undertaken by the team from Japan
  - It has been shown that the VF-TJ method is more elaborate and accurate method of junction temperature measurement.
  - The difference between the junction temperatures measured using VF-TJ method and Tlead method could be close to 10 C. (Poster # 46 at PVMRW 2015)
Hubert Volz has proposed a method for characterizing the forward I-V properties of the bypass diodes in a junction box in design phase. This method can be used for determining the current rating of the new junction box designs. The method involves holding the junction box at various temperatures in oven and passing known amount of current through the diode for a short duration to measure the forward voltage. Data is then extrapolated to get the I-V characteristics of diodes at other temperatures. They have also proposed a thermal model for junction box based on various thermal resistances.
Chinese Task Group 4 Update

• The Chinese regional Task Group 4 was started in July 2014, with 22 participant organizations, including diode manufacturers, junction-box manufacturers, module manufacturers, system installers, universities, and testing and auditing organizations.

• The Chinese Group has initiated efforts to:
  • Define a diode test to be used to confirm that a diode is good, since sometimes the diodes increase in resistance without failing completely in the open or shorted configuration.
  • Define a high temperature durability test for diodes.
  • Support international efforts already underway on ESD and thermal runaway associated with the transition between the forward and reverse bias conditions.

• It has been decided to arrange quarterly conference calls between the Chinese group and the US group in order to coordinate the efforts.
Goals of Task Group 4

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<td>2. NWIP on Thermal Runaway was approved</td>
<td>2. Revise thermal runaway test specification</td>
<td>2. Complete the test standard for high temperature, reverse bias endurance testing of cells</td>
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<td>3. Experiments to support TG2 initiative of diode thermal cycling testing in leg #1</td>
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<td>4. Submit NWIP on high temperature, reverse bias endurance testing of cells</td>
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