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Durability Testing for Module-attached Micro inverters

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Durability Strategy Considerations

- **Attached inverter subsystem durability should aim at that of the PV-Module host subsystem (15-25 year life)**
- **Inverter/Module Thermal and Mechanical closely coupled**
- **Durability testing of inverter must include all elements of the system. System test is unwieldy**
- **Subsystems could be tested alone – implies standardized test conditions that simulate the interaction of the PV module/Inverter subsystems**
- **Combined mix of Mechanical and Electrical/Electronic failure mechanisms for both subsystems is complex**

PV-attached inverter failure mechanisms

- **Module/Inverter Interconnect System failures**
  - Corrosion
  - Moisture ingress
  - Mounting mechanical failure

- **Inverter Electromechanical/Mechanical failures**
  - PCB/Solder system mech. Integrity- Mechanical fatigue
  - Enclosure integrity – moisture ingress
  - Enclosure/Cabling – UV integrity

- **Inverter Electronic Device failure Mechanisms**
  - Passive components (Caps,Xfmers etc): Dielect/Ins bkdwn
  - Power devices(FETS etc): Various
  - Control (uP,IC,Memory): HCI, TDDB etc

PV Module Failure mechanisms

Field Failure	Failure mechanism	Accelerated test
Interconnect Breakage	Thermal expansion & Contract	Thermal Cycling
De-lamination of Cell Metallization	Moisture penetration	Humidity Freeze
Corrosion of Cell Metallization	Moisture penetration	Damp Heat

Wohlgemuth, John, "Long Term Photo-Voltaic module reliability", NCPV and SPRM, 2003

- **PV Module failure modes and associated Accelerated lifecycle elements for comparison**
- **IEC 61215 is a module qualification test**
- **Variations/extensions of IEC-61215 have also been used by PV Module vendors to verify durability of PV modules**

Attached inverter failure mechanisms

System Element	Failure mechanism	Accelerated test
Enclosure/Interconnect	Mechanical deformation, Moisture ingress, Corrosion, Dielectric breakdown	TC/HF/Damp heat UV precondition
PCB/Solder system	TCE mismatch, electromigration	HF/TC
Passive components	Dielectric, Insulation breakdown	HF/TC/Elevated Heat
Active devices	Many	TC/Damp Heat (Elevated temp)
Integrated circuit devices	HCI, TDDB etc	TC/HF/Damp heat

- **Attached inverter failure mechanisms are addressed by HF,TC and Damp Heat (Extended High temp operation)**
- **It is feasible to apply HF,TC and Damp heat as accelerated lifecycle tests for durability. Duration/mix?**

Attached inverter Durability Test Elements

- **Durability testing –** Inverter subsystem failure mechanisms can be addressed with the same three elements applicable to the modules subsystem i.e. TC,HF, Damp heat
- **HF,TC, Damp Heat parameters/mix –** Need optimization for inverters
- **Lightning related issues–** i.e. lightning effects can be addressed by a derivative of standard inverter acceptance surge.
- **Independent Inverter Performance testing -** can be addressed with a standardized thermal profile

Research needed

- **Thermal/thermoelectric effects** of the inverter attachment to the PV module backsheet
- **Standardized thermal profiles** against which we can execute performance tests on the individual inverters

Standard updates ?

- **IEC-61215- standard update to take account of the Inverter attachment to the PV backsheet**
  - Module UUT orientations etc
- **Standardized test profiles/methodology to allow independent testing of Inverter and Module subsystems?**

Conclusion

- **Majority of the failure mechanisms in PV attached inverter subsystems can be addressed with a variation of the mix of elements in IEC 61215 as accelerated lifecycle tests**
- **Optimization of HF,TC, Damp Heat parameters required for inverter: Excite all failure modes**
- **Require some optimization to Module qualification/durability testing to account for presence of Module/Inverter interconnect**