IEC 62093 – PV INVERTER RELIABILITY TEST STANDARD

11/14/13

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PURPOSE OF IEC 62093

- Identify a suite of accelerated tests to identify potential reliability weaknesses in PV inverters
- Develop recommendations for how tests are to be performed including sample size, environmental test conditions, duration, power and monitor, etc.
- Provide baseline for comparison of reliability performance between PV inverter manufacturers

Not intended to demonstrate useful life

TEST SUBCOMMITTEE PARTICIPANTS

- Greg Ball – IEC 62093 committee chair, Leader of WG6
- Paul Parker – SolarBridge, Accelerated Test subcommittee chair
- Peter Hacke – NREL
- Chris Deline - NREL
- Jon Kalfus – Independent Consultant
- Harry McLean – Enecsys
- Mike Fife – PV Powered
- Mike Silverman – Ops A La Carte
- Sig Gonzalez – Sandia

- Team first assembled Feb '12
- 2nd Edition completed Feb '13

CONTRIBUTIONS FROM OTHER STANDARDS

- IPC 9592: Requirements for Power Conversion Devices for the Computer and Telecommunications Industries
  - 3 categories of products related to functionality
  - 2 classes of products related to application, lifetime
  - Design for Reliability (DfR) best practices
  - Design Verification Testing
  - Accelerated Reliability Testing
  - Quality Processes
  - Manufacturing Best Practices

- IEC 61215
  - Thermal Cycle (TC): -40° C to 85° C
  - Humidity Freeze (HF): 85° C / 85% RH; -40° C
  - Damp Heat (DH): 85° C / 85% RH

HIGHLIGHTS OF 62093 ED 2

- Four categories of PV inverters
  - Category 1: Inverter and DC-DC converters < 700W AC
  - Category 2: Wall mounted assemblies, eg., string inverters and small 3-phase inverters
  - Category 3: Free-standing single bay assemblies up to 100 kW AC
  - Category 4: Free-standing multi-bay assemblies over 100 kW AC

- Two Levels of test requirements
  - Level 1: minimum set of requirements, currently applied to Categories 2-4
  - Level 2: more aggressive requirement, currently applied to Category 1

CRITICAL ASPECT OF IEC 62093

- Powering and real time monitoring critical
  - Many failure mechanisms require voltage / load to activate
  - Frequent functional monitoring (<= 1minute intervals)
    - Many failure modes are intermittent, e.g., fail at extremes, pass test at 25° C
    - Health monitoring, identify negative trends, e.g., efficiency degradation
  - AC and DC power cycling required

- Test beyond specification
  - Required to accelerate failure mechanisms
  - Level 1: + 10° C beyond spec
  - Level 2: + 20° C above spec

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FAILURE CATEGORIES

- Prioritizing failure modes
  - Class 1: Safety related
  - Class 2: Non safety related hardware failure. Unit under test fails to produce power under all test conditions
  - Class 3: Failure requiring an AC and / or DC power cycle to return to normal operation
  - Class 4: Soft failure, includes intermittent loss of power
  - Class 5: Error in data reporting accuracy

ENVIRONMENTAL TESTS

- Highly Accelerated Life Test (HALT)
  - Test beyond spec, step stress to failure
  - Purpose: identify design margin
  - Tests to be performed:
    - Cold Step Stress
    - Hot Step Stress
    - Rapid Thermal Cycling
    - Vibration Step Stress
    - Combined Environments
- Damp Heat (DH)
  - 85C / 85% RH
  - Purpose: identifies corrosion related mechanisms such as Electrochemical Migration (ECM), PCB Conductive Anodic Filament (CAF)

ENVIRONMENTAL TESTS

- Humidity Freeze (HF)
  - 85° C / 85% RH followed by -40C
  - Purpose: identifies weaknesses in environmental protection, moisture ingress paths
- High Temperature Operating Bias (HTOB)
  - 85° C RH
  - Purpose: identifies thermally activated mechanisms such as Electrolytic Capacitor electrolyte evaporation
- Thermal Cycle (TC)
  - -40° C to 85° C
  - Purpose: identifies mechanisms related to thermo mechanical cyclic fatigue such as solder joints and PCB vias

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ENVIRONMENTAL TESTS

- Salt Mist
  - Follow test procedure in IEC 60068-2-52
  - Unpowered, pre and post functional test, visual
  - Purpose: Identifies corrosion typical of coastal areas
- UV
  - Follow test procedure in IEC 60904-3
  - Unpowered, pre and post functional test, visual
  - Purpose: Identifies vulnerabilities to UV degradation such as cables, connectors, labels, etc.

SAMPLE SIZE

	Environmental Stress Test Requirements by Product Category and Level Sample Size Requirements							
	Category 1		Category 2		Category 3		Category 4	
Test	Level 1	Level 2	Level 1	Level 2	Level 1	Level 2	Level 1	Level 2
HALT	NA	4	2	NA	1	NA	1	NA
DH	NA	8	2	NA	1	NA	1	NA
HF	NA	8	2	NA	1	NA	1	NA
HTOB	NA	8	2	NA	1	NA	1	NA
PTC	NA	8	2	NA	1	NA	1	NA
SF	NA	1	0	NA	0	NA	0	NA
UV	NA	1	0	NA	0	NA	0	NA

HALT - Highly Accelerated Stress Test
DH - Damp Heat
HF - Humidity Freeze
HTOB - High Temperature Operating Bias
PTC - Powered Thermal Cycle

QUESTIONS / CONCERNS / AREAS FOR IMPROVEMENT

- Design Verification Testing section not yet started
- Need additional participants, especially from larger power inverter companies and customers
- Tests not well correlated to field use conditions
- Concerns with testing beyond spec, inducing failures not representative of use conditions
- No good source of field failure data for reference
- Enforcement – guideline or standard?

QUESTIONS / CONCERNS / AREAS FOR IMPROVEMENT

- Manufacturer concerns
  - Cost of performing tests, large capital investment
  - Time to perform test – delayed time to market
  - Cost and availability of test samples, especially for large systems
- Fault Coverage:
  - Insufficient sample size to expose all failures
  - Limited breadth of stress conditions
  - Software / Firmware
- Ramifications of failure – Delay all shipments until all tests pass?
- Who performs test (in house vs 3rd party lab)
  - Sufficient expertise and test equipment at 3rd party labs?
  - Accountability when performed by manufacturer?

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US DOE "PREDICTS" PROJECT

- PREDICTS: Physics of Reliability (PoR): Evaluating Design Insights for Component Technologies
- 3 year project to create reliability qualification test standard for Microinverters and DC-DC Microconverters
  - Focus on intrinsic failure mechanisms
  - Extensive use of PoR modeling
  - Use existing field data to identify at risk mechanisms
  - Predict lifetime
- Sandia awarded project
  - Jack Flicker – PI
  - TUV, Bosch, ViaSol, University of Utah, Arizona State University
  - Support from Enphase, SolarBridge, SolarEdge, Tigo, and others
  - ANSI standard
    - TUV-R 71830: Microinverters and Microconverters - Design Qualification and Type Approval,

PREDICTS PROJECT CHALLENGES

- Young industry, 5 years of field experience for 25+ year intended life
- Many wearout mechanisms have not yet appeared
- Field failure statistics hard to come by, data very sensitive to manufacturers
- Many field failures are extrinsic, difficult to model
- Some intrinsic models have been in development for decades without consensus (solder joint)
- Models are dependent on MI/MC design, difficult to make generic, especially for potted products

IEC 62093 NEXT STEPS

- WG 6 initial feedback completed
- Soliciting feedback from other industry participants
- Expand committee to include more manufactures, users
- Schedule:
  - CD – Dec ‘13
  - CDV – May ‘14
  - Implementation – Q1 ‘15