Development of a Rating System for a Comparative Accelerated Test Standard

Sarah Kurtz, representing discussions with Task Group #6 and seeking your input!

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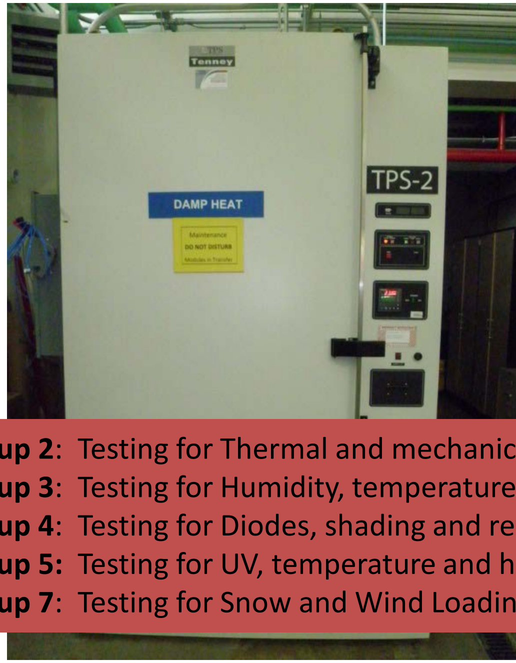
NREL is a national laboratory of the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, operated by the Alliance for Sustainable Energy, LLC.

Objective: Develop a Useful Rating System

- Identify field failures that could be reduced by improved accelerated testing
- Analyze how to group types of accelerated tests to best correlate with field performance
- Propose how to structure a useful Rating System
- Propose how to communicate the results of the Rating System

Need for Rating System

Task Groups develop accelerated tests to predict experience in the field



Task Group 2: Testing for Thermal and mechanical fatigue
Task Group 3: Testing for Humidity, temperature, and voltage
Task Group 4: Testing for Diodes, shading and reverse bias
Task Group 5: Testing for UV, temperature and humidity
Task Group 7: Testing for Snow and Wind Loading

How do we communicate the results?

Rating System

Types of Accelerated Tests – This work focuses on Comparative tests, even though we would prefer Lifetime testing

	Qualification	Comparative	Lifetime
Purpose	Minimum design requirement	Comparison of products	Substantiation of warranty
Quantification	Pass/fail	Relative	Absolute
Mechanisms studied	Infant mortality	Wear out	Wear out
Climate or application	No differentiation	Differentiated	Differentiated

What failures are seen in the field?

Observation	Sample size
Laminate internal electrical circuit 36% of failures (~2% of modules failed after 8 yr); glass 33%; j-box and cables 12%; cells 10%; encapsulant, backsheet 8%	21 manufacturers; ~60% of fleet of > 1.5 GW
16% of systems required replacement of some or all modules because of a variety of failures, with many showing breaks in the electrical circuitry	483 systems
3% developed hot spot after < 7 years; 47% had non-working diodes	1232-module system
External wiring, shattered, failed	~70,000 modules
Early degradation linked to optical transmission losses (through glass and encapsulant) and light-induced degradation; Later degradation from increased series resistance is more dramatic	204 modules from 20 manufacturers
Encapsulant discoloration 66%; delamination 60%; corrosion 26%; glass breakage 23%; j-box 20%; broken cells 15%*	~2000 reports
200 thermal cycles corresponded to ~10 y in the field	?

A.L. Rosenthal, M.G. Thomas, and S.J. Durand "A Ten Year Review of Performance of Photovoltaic Systems". Proc. 23rd IEEE PVSC, pp. 1289-1291.
D. Degraaff, R. Lacerda, and Campeau "Degradation Mechanisms in Si Module Technologies Observed in the Field", PV Module Reliability Workshop, 2011
K. Kato "PVRessQ!: a research activity on reliability of PV systems from a user's viewpoint in Japan". Proc. SPIE, San Diego
K. Kato ""PVRessQ!" PV Module Failures Observed in the Field", PV Module Reliability Workshop, Golden, CO2012
A. Skoczek, et al "The Results of Performance Measurements of Field-aged Crystalline Silicon Photovoltaic Modules", Prog. in PV, 17, 2009, pp. 227-240.
D.C. Jordan, J.H. Wohlgemuth, and S.R. Kurtz "Technology and Climate Trends in PV Module Degradation". Proc. 27th Eu PVSEC, Frankfurt, Germany
J.H. Wohlgemuth, et al. "Using Accelerated Tests and Field Data to Predict Module Reliability and Lifetime". Proc. 23rd Eu PVSEC, Valencia, Spain, 4EP1.2.
J.H. Wohlgemuth, D.W. Cunningham, A.M. Nguyen, and J. Miller "Long Term Reliability of PV Modules". Proc. 20th Eu PVSEC, Barcelona, Spain, pp. 1942.

Rating System – First address wear out that is slipping past the qualification tests

1. In response to:

- Broken interconnections, solder bonds, diodes

Add:

- Additional thermal cycling or mechanical stress, plus bypass diode/shading testing

2. In response to:

- Encapsulant discoloration and/or delamination

Add:

- Additional UV stress

Rating System – Additional testing

	New Tests Will Require Additional Stress					Targeted Meaning of Rating	
Failure types, loosely grouped	Thermal cycling & diode testing	UV	High Temperature	High humidity	Proposed labels	★	★★★★★
Infant mortality	-	-	-	-	**Qualification test**	-	-
Interconnects, discoloration, delamination	✔	✔	-	-	Hot-cold	Better than qualification test	30 y in location/appl. w worst thermal cycling
Heat-induced failures	✔	✔	✔	-	Hot-dry	Better than qualification test	30 y in location/appl. w worst heat-induced degradation
Humidity-induced failures	-	✔	✔	✔	Hot-humid	Better than qualification test	30 y for location/appl. w worst heat-induced degradation

The two primary extremes that have not yet been addressed are:
Heat
Humidity
So add additional stress for these, indicated by ✔
Note: Wind is also a priority in some locations

Principles for creating tests/rating system

- Must be predictive
    - (correlate with field experience)
- Must be relevant
    - (predict 10-40 y, not 1 y or 300 y)
- Must be communicated in useful ways
    - (both simple and detailed for different audiences)
- We'll do our best and communicate uncertainty
    - (when we don't know, we'll communicate that we guessed)
- Must be designed so we learn from the results
    - (application of the standard will help improve standard)
- Must be cost and time effective
    - (manufacturers must bring the product to market)
- Must define who is responsible/accountable
    - (customers need confidence in information)

Rating System Proposal – Communicate four ways:

1. Nameplate:

Pmax 205 W

Durability rating:

Hot-cold ★★★

Hot-dry ★ ★

Hot-humid not rated

Snow/wind 2400 Pa

Salt spray etc.

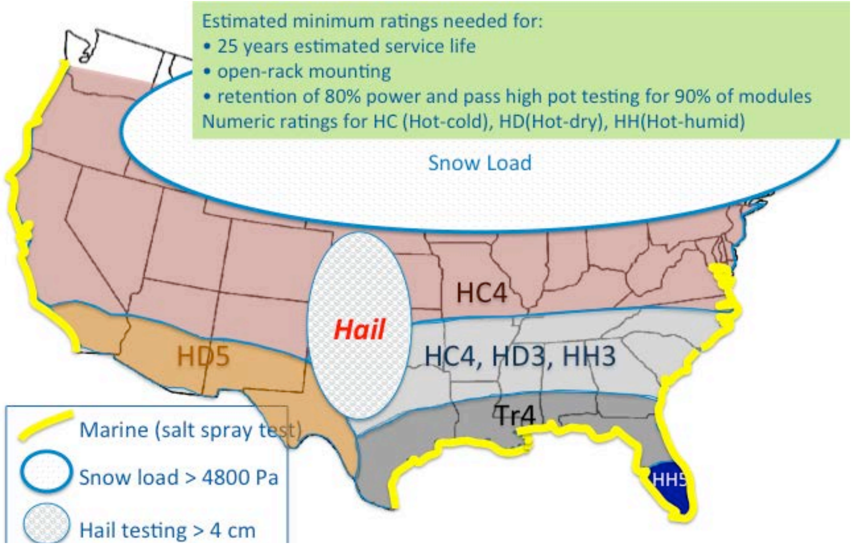
Standards

A high level summary on the nameplate will allow researchers to correlate tested rating with field experience 20 y from now.

2. Report:

Test results
By Test Lab X

A detailed report can be used by engineers to more closely compare specific products



3. Interpretive maps:

Publications/Guides

4. Climate charts that link climates with stresses (see next slide):

Climate charts – similar to the interpretative maps: define relationship between climate zones and stress testing needed in these.

Chart can define:

- 25 years estimated service life
- retention of 80% power and safe operation of 90% of modules

Use environment	"Hot-dry"	"Hot-humid"	"Hot-cold"	Snow load
Cfa/open rack	★	★	★★★★	2400 Pa
Geneva/open rack	★★	★	★★★★★	5600 Pa
Tropical/rooftop	B	A	C	n.a.
Choose your favorite use environment	?	?	?	

Communicate meaning of tests for all climate zones, locations, and applications

Other challenges

Different module constructions will have different acceleration factors. Good science tells us that the test must vary with module construction, but manufacturers will complain if they have to bake longer or shake harder.

The stresses are applied in different combinations and different sequences. We need to simplify a complex problem! Can we simplify and still be meaningful?

Conclusions

- A Rating System is necessary for the success of the QA Task Force
- Building consensus on:
  - Principles: tests must be meaningful/useful
  - Assessing today’s most common wear out mechanisms and those expected in hotter and wetter climates defines our current opportunity to strengthen the standards
  - Must find simple way of summarizing *test results* to standardize communication of a complicated picture
  - *Meaning of test results* should be communicated in maps and publications