CPV Reliability

Reliability in an Expanding Technology

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Reliability Importance

- Minimizing risk of failure during deployment
- Assuring investors
- Assuring reliability of totally new products, design improvements and manufactured products
    - Failure of one company's product can have impact on all companies.
- Evolving business model
    - Drives need for international collaboration and international reliability standards

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Early Technology Deployment Without Qualification Standard

60 kW stand-alone system near San Diego in 1981--before the first PV standards were available---removed completely after 6 months due to encapsulant failure and power loss.

Early Technology Deployment Without Qualification Standard

6 MW low concentration PV system installed in 1984 to sell electricity in the Pacific Gas and Electric Company grid--later dismantled due to encapsulant failure and power loss.

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Early Technology Deployment Without Qualification Standard

- 440 kW high concentration PV system installed in Tenerife, Spain in 1998 suffered early losses due to mirror failures and PV solar cell shorting in high humidity salt air
- Only the trackers work today
- IEC CPV standards working group visited the project in 2004

Early Technology Deployment Without Qualification Standard

Early 1970s wind turbine

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Early Technology Deployment Without Qualfication Standard

1970's wind turbine failure due to lack of safety standards

Challenges

- Identification of failure modes
  - Convene specialists from balanced group of manufacturers, customers and testing labs
- Identification of appropriate reliability tests
  - Convene specialists from balanced group of manufacturers, customers and testing labs
- Test time and cost
  - Balance achieved through negotiation between manufacturers, customers and testing labs

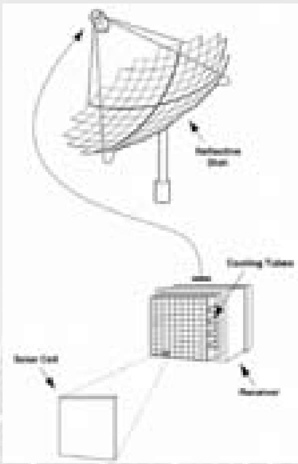
Best Approaches

- Work closely with existing standards organizations (IEC, IEEE, ASTM, UL, Solar ABCs,…)
  - Set up working groups with membership balanced among manufacturers, customers and test labs
  - Meet, discuss and revise
  - Meet, discuss and revise
  - etc.
- Define your terms
  - IEC Working Group 1
    - AA and ALT not in IEC dictionary

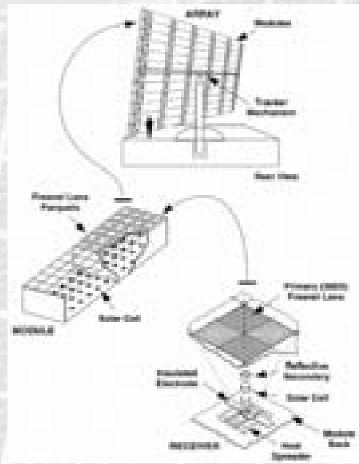
IEC Qualification Standard

- In general, standards specify minimum requirements for such issues as performance, safety and qualification.
- Qualification standard, subject of this presentation, targets reliability of long-term operation in the field.
- Qualification minimizes risk of deployment failure for manufacturer, customer and investor.
- Tests in the standard can be adapted by manufacturer for quality assurance of product coming off assembly line or by customer to inspect products received.
- This is an international CPV standard developed under the aegis of the International Electrotechnical Commission (IEC based in Switzerland) and its Working Group 7 (17 members from 9 countries) within Technical Committee 82 (PV).

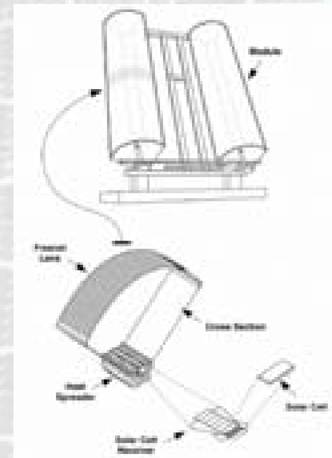
Wide Range of CPV Configurations



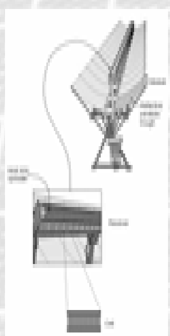
Point-Focus Dish



Point-Focus Fresnel Lens



Linear-Focus Fresnel Lens



Linear-Focus
Trough

Heliostat

Terms for CPV

<table>
<tr><td colspan="2">Primary optics</td><td rowspan="7">CPV Module – prefabricated and the focus point is not field adjustable, like most Fresnel lens systems.

CPV Assembly – needs some field installation and the focus point is field adjustable, like most reflective systems.</td></tr>
<tr><td>Secondary optics</td><td rowspan="4">CPV Receiver</td></tr>
<tr><td>CPV Cells</td></tr>
<tr><td>Electrical energy transfer means</td></tr>
<tr><td>Thermal energy transfer means</td></tr>
<tr><td colspan="2">Interconnection</td></tr>
<tr><td colspan="2">Mounting</td></tr>
</table>

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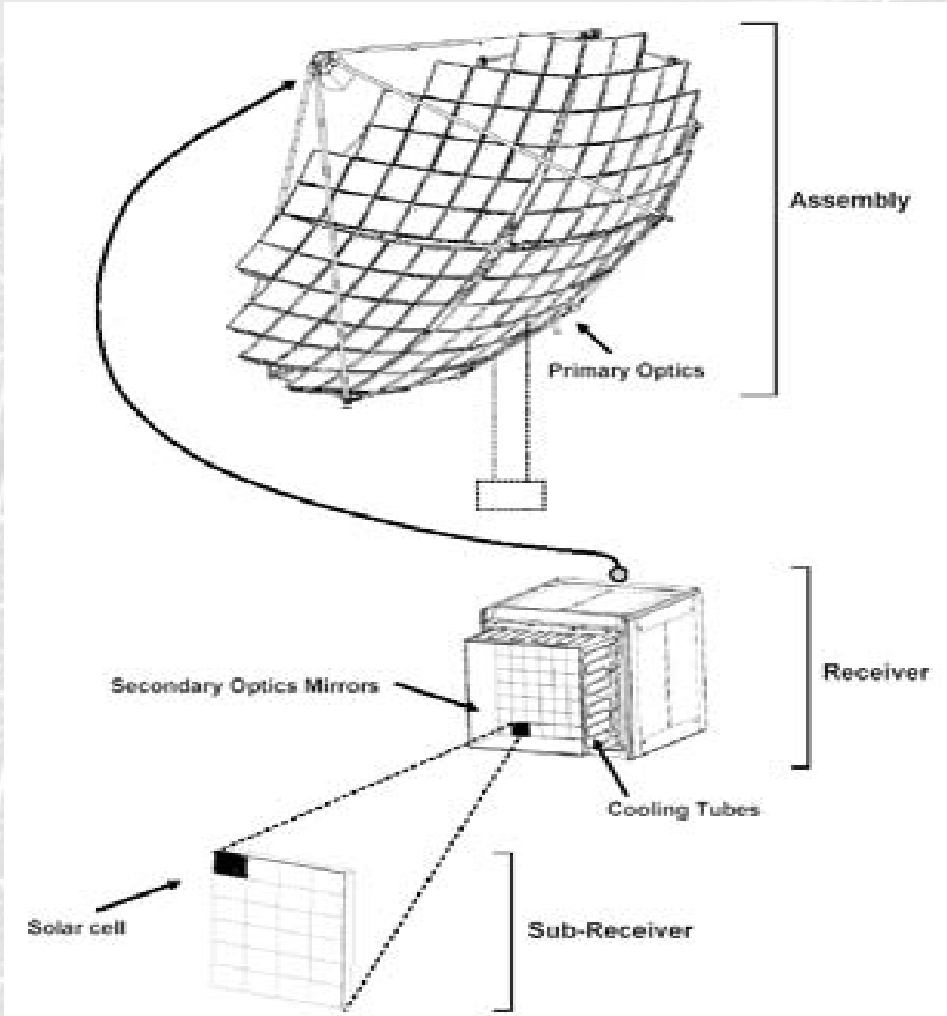
Why Specify Representative Samples?
A Whole Module is too Large.

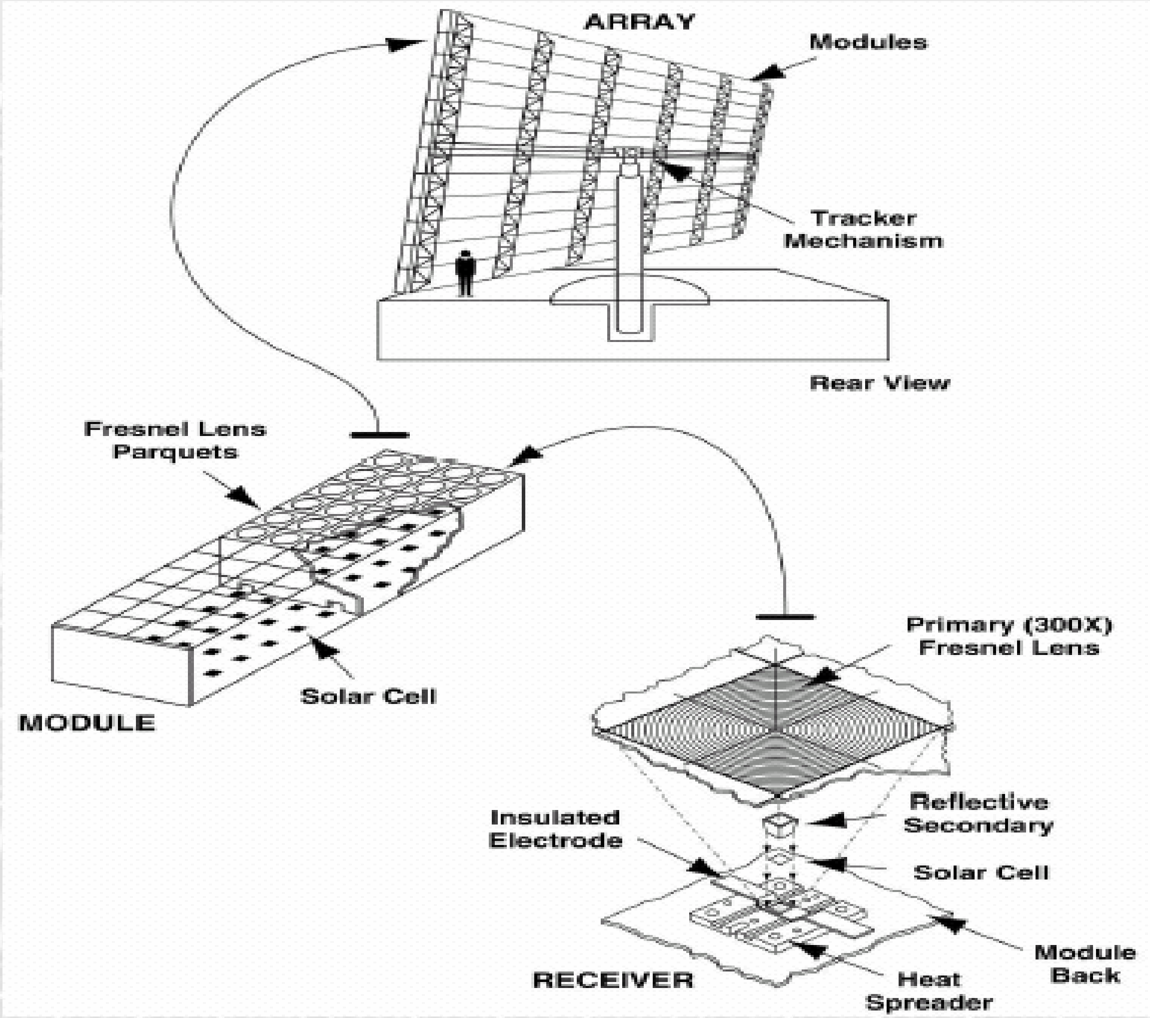
Amonix, USA

Why Specify Representative Samples?
A Whole Assembly is too Expensive.

Solar Systems, Australia



Terms for CPV Assemblies



Terms for CPV Modules

Tests Targeting the Failure Modes

- Thermal cycling (e.g. 2500 cycles from 85^{o}C to -40^{o}C)
- Damp heat (e.g. 85% humidity at 85^{o}C for 1000 hours)
- Humidity and freeze (e.g. 20 cycles of 85% humidity at 85^{o}C for 20 hours then to -40^{o}C and back in 4 hours)
- Hail impact
- Water spray
- Heat protective diode (module heated and current applied)
- Robust connectors
- Mechanical loads (e.g. wind, snow, ice and engineering analysis)
- Off-axis damage (focal point moves off of solar cell)
- Ultraviolet exposure
- Outdoor exposure (full-size module or assembly tested and witnessed)
- Hot-spot (not needed if each cell has protective bypass diode)

Before and After Measurements to Identify Degradation

- Visual inspection
- Electrical performance measurement
  - Side-by-side I-V using a reference sample
  - Solar simulator
  - Dark I-V
- Ground path continuity
- Electrical insulation under dry operation
- Electrical insulation under wet operation

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Side-by-Side I-V Measurement

Method based on assumption that changes of reference module’s electrical performance are negligible during whole qualification test period.

Test condition variables (e.g., irradiance [DNI] level, spectrum, ambient temperature, wind speed) are self-correcting, and complex translation procedures are eliminated.

This method evaluates relative power before and after stressing a representative module.

Absolute power measurement will be covered by “Power and Energy Rating” standard. (subject of IEC TC82 WG7 meeting in San Francisco on May 19 and 20, 2008)

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Advancements Needed

- Lab/field correlation?
  - Convene balanced group--as before--and designate/delegate lab/field correlations
- Quantify degradation rates?
  - Major degradations usually lead to design changes
- ALT protocol?
  - Extend qualification tests (Extend test limits: more cycles, higher test voltages, lower insulation resistance pass/fail, etc.)

Conclusion

- Qualification standards provide assurance to both customers and manufacturers that products are likely to operate reliably for years.
- Qualification standards specify minimum requirements for passing rigorous test procedures meant to identify weaknesses and failures that could occur during deployment.
- The first IEC qualification standard draft for concentrator PV was approved by international vote in September 2006. The final standard was approved by international vote and made available for purchase through www.iec.ch in December 2007.
- Safety, Performance and Tracker standards under development next for CPV systems (WG7 meeting in May 2008)

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Acknowledgements

- 16 members from 9 countries collaborating jointly for the development of international CPV standards
- International Electrotechnical Commission
  - www.iec.ch
- Technical Committee 82 (Photovoltaics)
- Working Group 7 (Concentrator Photovoltaics).

Country	Organization	IEC TC82 WG7 Key Contact
US	NREL	Robert McConnell (Convener)
Norway	REC Group	Helge Aamodt
Spain	IES-UPM	Ignacio Anton-Hernandez
Japan	Daido Steel Co.	Kenji Araki
UK	Whitfield Solar	Roger Bentley
Germany	Fraunhofer ISE	Andreas Bett
Spain	Isofoton	Vicente Diaz-Luque
US	Underwriters Laboratories	Liang Ji
Australia	Solar Systems	John Lasich
Canada	Day4 Energy	Rubin Leonid
Spain	Inspira	Ignacio Luque-Heredia
Germany	ZSW	Hans-Dieter Mohring
Spain	IES-UPM	Gabriel Sala-Pano
US	PTL ASU	William Shisler
Japan	Sanyo	Ebara Toshiyuki
Korea	TS Corporation	Se-Wang Yoon

Guascor Foton: 10 MW Installation in Spain

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