DNV Renewables Services

Global impact for a safe and sustainable future

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History: More than 145 years of managing risk

- DNV (Det Norske Veritas) was established in 1864 in Norway
- DNV is a leading international provider of services for managing risk
- DNV is a foundation and reinvests all profits in services, research and development
- Shipping → Maritime Wind → Renewable Energy → BEW Engineering
OVERVIEW

• Our perspective
  • Begin with client goal: energy production
  • Identify root causes of failures to meet goal in historical record
  • Review evidence that root causes have been addressed in new projects

• Categories of root causes
  • Capacity
  • Weather
  • Reliability

• Potential benefit of utility-scale test projects
  • Wide access to results
CLIENT GOALS : QUESTIONS

• How much energy will this system produce? (income)
  • First year?
  • Over time?

• How much will O&M cost? (expense)

• What are the risks for this project? (expense)
  • Performance
  • Reliability
  • Safety
  • Schedule

• Is the project proceeding according to plan? (income)
  • Plans are complete and correct?
  • Built according to plans?
  • Begin producing energy on schedule?
ROOT CAUSES: PERFORMANCE

- Energy production
  - Efficiency (Power Rating?)
    - At test conditions vs. real world variety of conditions
      - Irradiance Level
      - Temperature (ambient→module)
      - Spectrum
      - Exposure history
      - Sample-to-sample variation
  - In general, requires a combination of field data to identify and lab data to model
ROOT CAUSES: WEATHER

- More irradiance = more generation
- Interaction of weather with equipment yields energy
- BUT
  - Instrument accuracy?
  - Diffuse measurement?
  - Spectrum?
  - Length of history?

<table>
<thead>
<tr>
<th>Year</th>
<th>Annual Average Irradiation (kWh/m²/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1970</td>
<td>3</td>
</tr>
<tr>
<td>1980</td>
<td>4</td>
</tr>
<tr>
<td>1990</td>
<td>5</td>
</tr>
<tr>
<td>2000</td>
<td>6</td>
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</tbody>
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Source
- CIMIS Camino
- Meteonorm (Site)
- NSRDB Sacramento
- NSRDB Sacramento Metro
- Prospector (Site)
ROOT CAUSES: MATERIALS RELIABILITY

- Stability
  - Photovoltaic Material
- Stability and Robustness
  - Encapsulation
    - Breach
    - Change in reflection / transmission / absorption properties
- Stability and Robustness
  - Structure
    - For some technologies, custom structure is essential
  - Electrical Infrastructure
    - Connector failure rates
    - Grounding Corrosion
      - Copper/Aluminum
EVIDENCE: QUALIFICATION TESTING

- Is not “reliability testing” because it represents “minimum exposure”
  - IEC 61215 Mono/Poly Silicon
  - IEC 61646 Thin-film
- Bankability
  - Extended cycle test results
  - Fielded equipment failure rates
- Temperature cycling
- Damp-heat
- Hot-spot
- Reverse current
- Mechanical tests
EVIDENCE: LABORATORY PERFORMANCE

- **Parameters**
  - STC
  - Varying Temperature
  - Varying Irradiance
  - Varying Diffuse Fraction
  - Before and After Exposures
    - Light/Dark
    - Hot/Cold
    - Electrical Polarity

- **Statistics**
  - Typical qualification and safety tests only determine performance approximately, and on at most a few samples
  - What is production stability for millions of samples?
EVIDENCE: SAFETY TESTING

- NRTL Listing is norm for US demand-side generation (UL1703)
- For generation-only facilities, IEC standards may be more appropriate
- Lessons learned from NEC should not be forgotten
- Records of acceptance of installed systems by (more than one) local AHJ
EVIDENCE: FIELD PERFORMANCE

• System Measurements
  • AC Power/Voltage
    • 60Hz
  • DC Voltage/Current /Power
  • Rapid sampling (1 sec)
  • Short Aggregation (1-5min)
• Special Tests
  • String Current “Sign-Of-Life”
  • IV Curves
  • Periodic Flash IV Testing

• Environmental
  • Irradiance
    • GHI – broadband
    • DHI – BB or Silicon Detector
    • POA – BB and SD and Reference Cell
  • Spectrum
  • Temperature
    • Free Air (“Ambient”)
    • Module
  • Wind
    • Free Air
EVIDENCE: FIELD PERFORMANCE

- **First year of performance**
  - Basic measure of project viability
  - New technologies may have complicated modeling requirements: confirm models
  - Availability

- **Degradation**
  - Small effect builds over time
  - Difficult to confirm in less than 5 years

- **Ground-measured weather data**
  - High quality meteorological data is necessary for evaluation
  - Value of recorded data will be high
    - Future projects located near the test sites
    - Calibration of resource models

- **Soiling**
  - Site-dependent
  - Technology impact
EVIDENCE: INSTALLATION/O&M

- Familiar technologies
  - Cheaper installation
  - Cheaper maintenance
  - Well-understood spares management
  - Shorter downtime
- Mitigation
  - Similarity to existing tech
  - Training
  - Clear documentation
- Evidence
  - Installed systems
  - Testimonials by construction teams

Graph:
- Current (A) vs. Voltage (V)
- Lines: I, Ibypassed, Iblocked

- Current (A): 
  - 8
  - 3
  - -2

- Voltage (V):
  - -10
  - 10
  - 30
  - 50
EVIDENCE: MUTATION OF PROCESSES

- Common response when problems arise
  - “We don’t build it that way anymore.”
- Common pitch when selling newest model
  - “We have built lots of these”

- Problem
  - How to confirm that changes introduced to address problems have not reduced the advantages of the old product?

- Possible solution
  - Document mfr processes of fielded products
  - Hold documentation in escrow
  - Later compare processes of new product under NDA
CONCLUSION

• New technology that fits existing physical profiles (e.g. framed flat plate) mostly needs performance, stability and reliability evidence (installation years)

• New tech that alters physical profile (e.g. concentrators, flexible substrate) also needs demo of constructability and O&M

• Field installations have limited environmental profile
  • Multiple locations needed to address Desert, Agricultural, Humidity, Sub-Freezing profiles