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IMPROVED NOMINAL OPERATING CELL TEMPERATURE (NOCT) TEST PROCEDURE

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Objective

- Understand causes of data scatter in currently used NOCT evaluation procedures
- Develop procedure modifications as required to reduce scatter and NOCT test costs

Nominal Operating Cell Temperature

- Significance
  - A direct measure of module thermal design
  - Representative temperature for average environmental conditions in the United States
- Applications
  - Prediction of array energy production
  - Lifetime assessment
- Definition
  - Open circuit
  - Open-back rack mount
  - Nominal thermal environment (NTE)
    - Effective insolation = 80 mW/cm^2
    - Ambient temperature = 20°C
    - Average wind speed = 1 m/s
- Principle
  - Temperature difference is largely a function of insolation

$$(Tc - Ta) = m \cdot S$$

Current NOCT Test Procedure

- Adjustable tilt angle
- Detailed instrumentation
- High sampling rate
  (two to four measurements/minute)

Current NOCT Evaluation Procedures

- Conventional evaluation
  - Run tests for one or two days with suitable weather
  - Select data points that satisfy wind-level screening criteria
  - Determine average value using all valid data points
  - Apply correction factors for wind and air temperature
- Alternative evaluation
  - Run daily tests over extended period (months)
  - Select data from days with suitable 10-minute (calm-air) periods
  - Determine one NOCT for each day (10-minute period)
  - Determine NOCT as average for selected test days

Discussion

- Both evaluation procedures contain significant scatter
- Scatter attributed to two factors
  - Secondary test environments are not controlled
    - Sky radiation
    - Ground reflection
    - Ground emission
    - Tilt angle
  - Steady-state analysis ignores transient thermal effects

Proposed NOCT Refinements

- Define NOCT for particular secondary NTE conditions
  - Atmospheric radiation: clear sky
  - Ground reflection: 10% of insolation level
  - Ground emission: from 30°C ground temperature, effective emittance of 0.8
  - Effective wind direction: 135° from north
  - Module tilt angle: 30° from the horizon
- Measure module temperature relative to calibrated reference plate
  - Painted aluminum plate (front-black, back-white), Bostic paint
  - Plate temperature calibrated under refined NTE is 48.3°C
  - Level of ΔT, (T cell-T plate) is approximately constant
  - NOCT = 48.3°C + ΔT

Proposed Test Setup and Conditions

- Test set-up
  - Module and reference plates subjected to the same test environments
  - Two reference plates; refinished surface coating at staggered 6-month intervals
- Test conditions
  - Minimal constraints on wind
  - Minimal constraints on air temperature
  - Minimal constraints on secondary test environment conditions
  - Insolation level higher than 60 mW/cm^2
  - 3 to 4 hours test duration around solar noon
  - 30° tilt

Proposed Test and Evaluation Procedure

- Data collection
  - Module and test plate temperatures
  - Relative temperature accuracy: 0.5°C
  - Measurement frequency approximately one per minute
  - Approximate insolation level
- Data processing
  - Average cell-plate ΔT over selected time interval
    - Interval to have initial and final temperatures within 0.2°C (for all thermocouples)
    - Interval length to be longer than 40 minutes
  - NOCT = 48.3°C + average ΔT

Conclusions

- Proposed procedure offers improved
  - Simplicity
    - Does not require long-term testing
    - Does not require sophisticated wind and irradiance instrumentation
    - No data screening judgment or tedious corrections
    - Broader test window
  - Accuracy
    - Excellent repeatability (accuracy depends on temperature error)
    - Some discoloration of reference plate over one-year field exposure, but no measurable change in calibration temperature
- Requires additional demonstrations