Uncertainty Analysis for Photovoltaic Degradation Rates

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Introduction

1. Financially:
   - Cash flow
   - Uncertainty directly related to risk

2. Technically:
   - Lifetime prediction
   - Product improvement

Need to determine degradation rates ($R_d$) accurately

Long-term PV Performance

1.4 kW multi-Si system

Seasonality can lead to systematic deviations

Temperature-corrected metrics are preferred over non-corrected metrics.

Ishikawa Diagram

Sources of variations & strategies for degradation rate uncertainty

- Uncertainty due to instrumentation
- Uncertainty due to irradiance source
- Uncertainty due to degradation rate

Irradiance Source Strategies

Precision (relative accuracy) more important than absolute accuracy

Using irradiance from nearby system may be adequate

Total Uncertainty Simulation

Instrumentation Uncertainties

Drift has significantly more impact at the end of the monitoring period than in the middle

Intentionally Drifting Pyranometer

Condensation film on dome

CM10 pyranometer (high humidity) drifted about 1%/year

Uncertainty for “Clean” Data Set

With a “clean” data set $R_d$ can be determined to within 0.2%/year after 4 years of field data

Seasonality & Metrics

Seasonality

- DR1000: DC power (uncorrected)
- DR1000q: DC power (corrected)
- POA: Plane-of-array power
- PDC: Plane-of-array power (corrected)

Temperature-corrected metrics: excellent agreement down to 5 years.

Drift Occurrence

Monte Carlo Simulation

1. Set mean degradation rate ($R_d$) for each realization
2. Set drift rate (0.5%/year, 1%/year, triangle distribution)
3. Set drift mean (0.5%/year, 1%/year)
4. Set drift standard deviation (0.5%/year, 1%/year, triangle distribution)
5. Set drift duration (0.5%/year, 1%/year)
6. Set drift start date (0.5%/year, 1%/year)
7. Set drift end date (0.5%/year, 1%/year)

If drift occurs during middle of field exposure → negligible effect
If drift occurs at end of field exposure → may have large effect

Conclusion

- Seasonality caused by temperature, angle-of-incidence, spectral effects can lead to systematic errors and higher uncertainties
- Temperature-corrected metrics are preferred over non-corrected metrics.
- Changes (drift) of instrumentation during field exposure is more critical than absolute accuracy
- Drift has significantly more impact at the end of the monitoring period than in the middle
- Nearby irradiance sensors may be used to determine degradation rate

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