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Purpose: Quantify uncertainty in parameters for the Sandia Array Performance Model (SAPM) and investigate the effect of parameter uncertainty on model results.

Background

The fundamental equations for the Sandia Array Performance Model:

$$I_{SC} = I_{SC0} f_1(AM_a) E_e (1 + \alpha_{SC} (T_C - T_0))$$
$$I_{MP} = I_{MP0} (C_0 E_e + C_1 E_e^2) (1 + \alpha_{MP} (T_C - T_0))$$
$$V_{OC} = V_{OC0} + N_s \delta(T_C) \ln(E_e) + \beta_{OC} (T_C - T_0)$$
$$V_{MP} = V_{MP0} + C_2 N_s \delta(T_C) \ln(E_e) + C_3 N_s (\delta(T_C) \ln(E_e))^2 + \beta_{MP} (T_C - T_0)$$
$$\delta(T_C) = nkT_C/q$$

Values for parameters are estimated by regression from results of three sequential tests:

1. Thermal test – irradiance constant near 1000 W/m², low winds, module cooled by covering, then exposed and voltage and current measured as module temperature rises. Estimate $\beta_{OC}, \beta_{MP}, \alpha_{SC}, \alpha_{MP}$.
2. Clear sky test – stable module temperature, constant near 1000 W/m², low winds, air mass < 2. Estimate $I_{SC0}, I_{MP0}, V_{OC0}, V_{MP0}, f_1(AM)$.
3. Cloudy sky test – range of irradiance and air mass conditions. Estimate n, C_0, C_1, C_2, C_3 .

Sources of Uncertainty

We quantify and propagate parameter estimation error resulting from the regressions. Other sources of uncertainty that affect parameter values (and model results) include:

- Environmental variability (irradiance and temperature)
- Variability among modules of same manufacture
- Model uncertainty

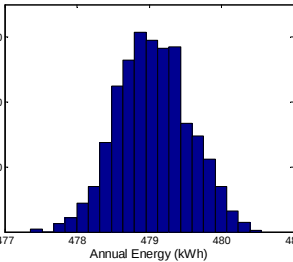
Examining effects of parameter uncertainty can reveal the presence of model uncertainty. Parameters estimated by regression cannot reflect uncertainty from module variability unless multiple modules are tested or test results are simulated.

Correlations

Parameters are estimated from each test's results using multivariate multiple regression techniques. Parameter estimation error is randomly sampled to obtain a sample of parameter values. High correlations between simultaneously observed temperature, voltage and current cause correlations in the sampled parameter values.

Results

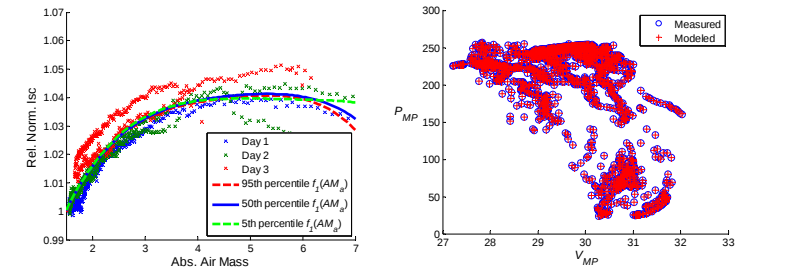
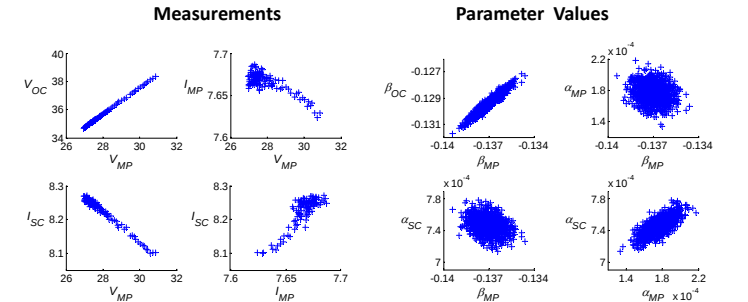
We propagate the parameter sample using Monte Carlo methods and TMY2 data for Albuquerque, NM to quantify uncertainty in annual energy. Sensitivity analysis identifies which parameters significantly contribute to uncertainty in annual energy.



Step	Variable	R ² ^a	SRRC ^b
1	β_{MP}	0.42	0.64
2	α_3	0.77	-0.57
3	α_{MP}	0.86	0.17
4	I_{MP0}	0.88	0.13

a: Cumulative R2 with entry of each variable into model
b: Standardized rank regression coefficient in final model

Model results are compared to measured quantities to detect model uncertainty.



References

[1] D.King et al. (2004). Photovoltaic Array Performance Model. Albuquerque, NM, Sandia National Laboratories.

Conclusions

- Parameter uncertainty from estimation error results in insignificant uncertainty in model output (annual energy)
- Model uncertainty is present; however, model uncertainty is not significant for flat-plate cSI modules.