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Results of Parameter Estimation Exercise

2nd PV System Modeling Workshop

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Motivation

- Workshop participants invited to estimate parameters from data for 2 modules
- Intended to illustrate degree of variation in parameters and in model results
- Motivated by anecdotes about the uncertainty in performance modeling that is ascribed to modeling coefficients
  - “Everone has a different PAN file for the same module, which PAN file should we trust?”
- Invited responses specifically from PVsyst and CEC model users
- 7 responses (4 PVsyst, 3 CEC)

Questions of interest

- How do parameters compare?

- Compare predicted IV curves with data
- Compare predicted IV curves for the same model
- Compare predicted IV curves among models

- Compare predicted energy production

Module B – Known parameter recovery

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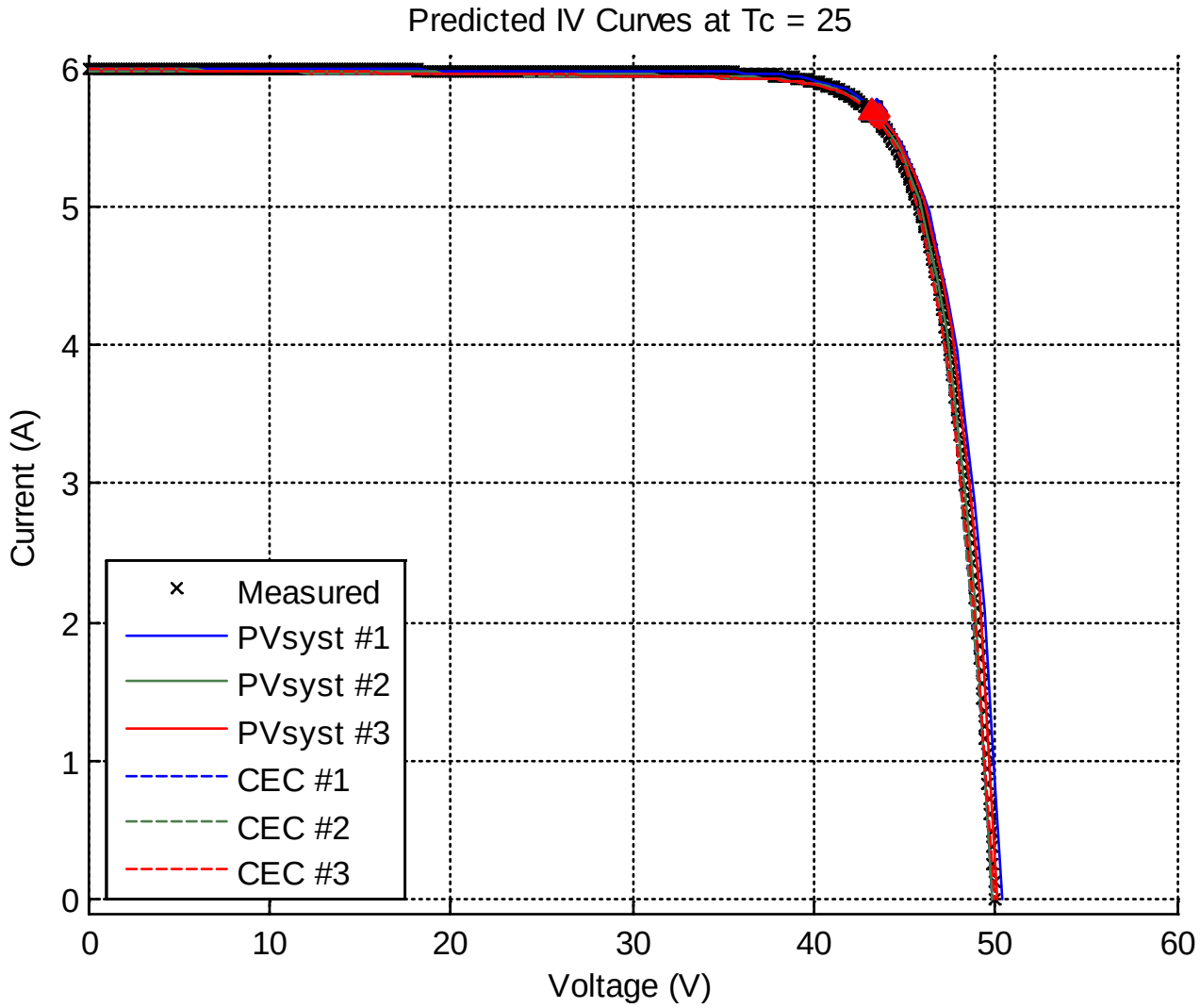
- I made this one up, to represent a module with high fill factor (0.82)
- IV curves were calculated precisely using assumed values
- Parameters for IV curve at STC:

Parameter	Exact Value	PVSyst #1	PVSyst #2	PV Syst #3	CEC #1	CEC #2	CEC #3
		Mermoud	Sauer	Joshi	Boyd	Dobos	MacAlpine
IL (A)	6	6.00	6.00	5.99	5.992	5.992	6.002
Rsh (Ω)	2000	2065	700	700	675	675	594
Rs (Ω)	0.02	0.03	0.037	0.02	0.175	0.175	0.183
Io (nA)	1	0.82	0.111	0.186	0.0034	0.0034	0.0053
n	1.2	1.13	1.09	1.12	0.957	0.957	0.974

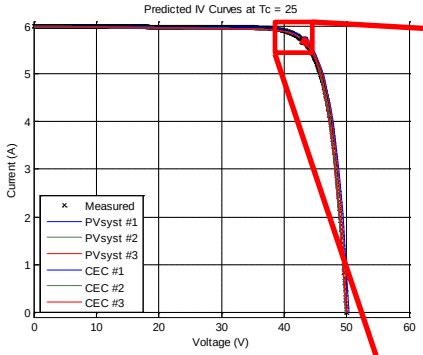
Module B: Modeled performance off STC

Parameter	Exact	PVsyst #1	PVsyst #2	PVsyst #3	CEC #1	CEC #2	CEC #3
γ_{MP} %/C	-0.37	-0.38	-0.33	-0.34	-	-	-
Rsh0 (Ω)	24000	23000	3270	3985	-	-	-
Rshexp	5.5	5.5	4.8	5.5	-	-	-
μGamma	0	0.0003	-0.0001	-0.0002	-	-	-
Adjust	0	-	-	-	0%	0.34%	3.9%

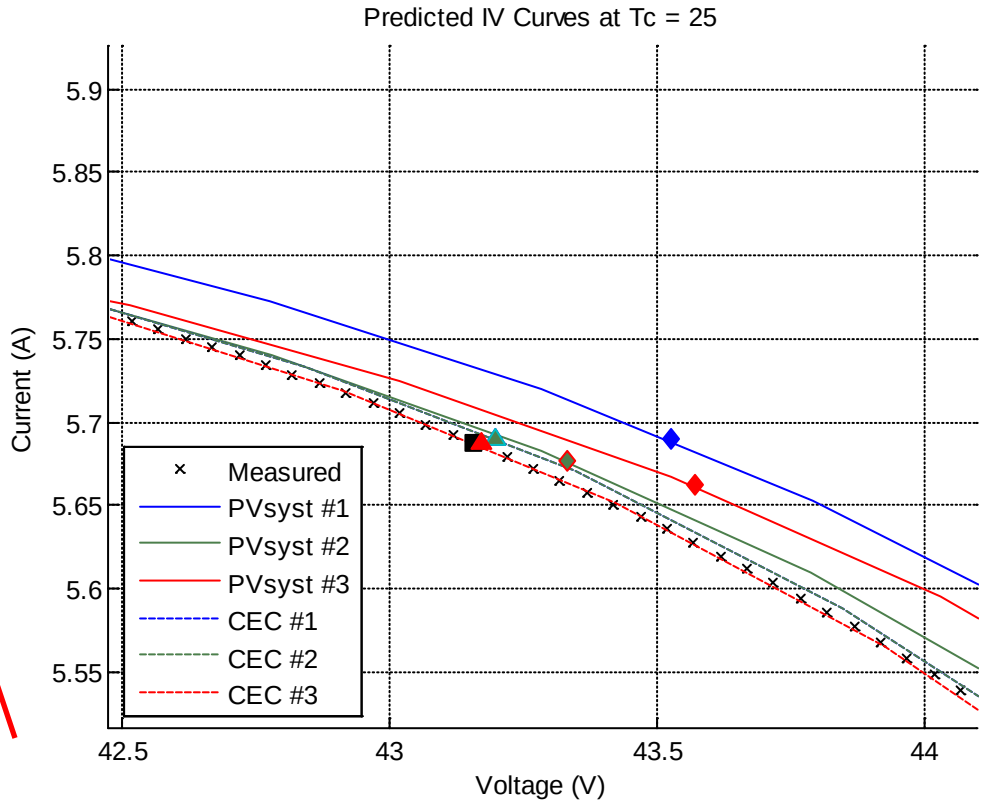
B: Comparison between parameter sets



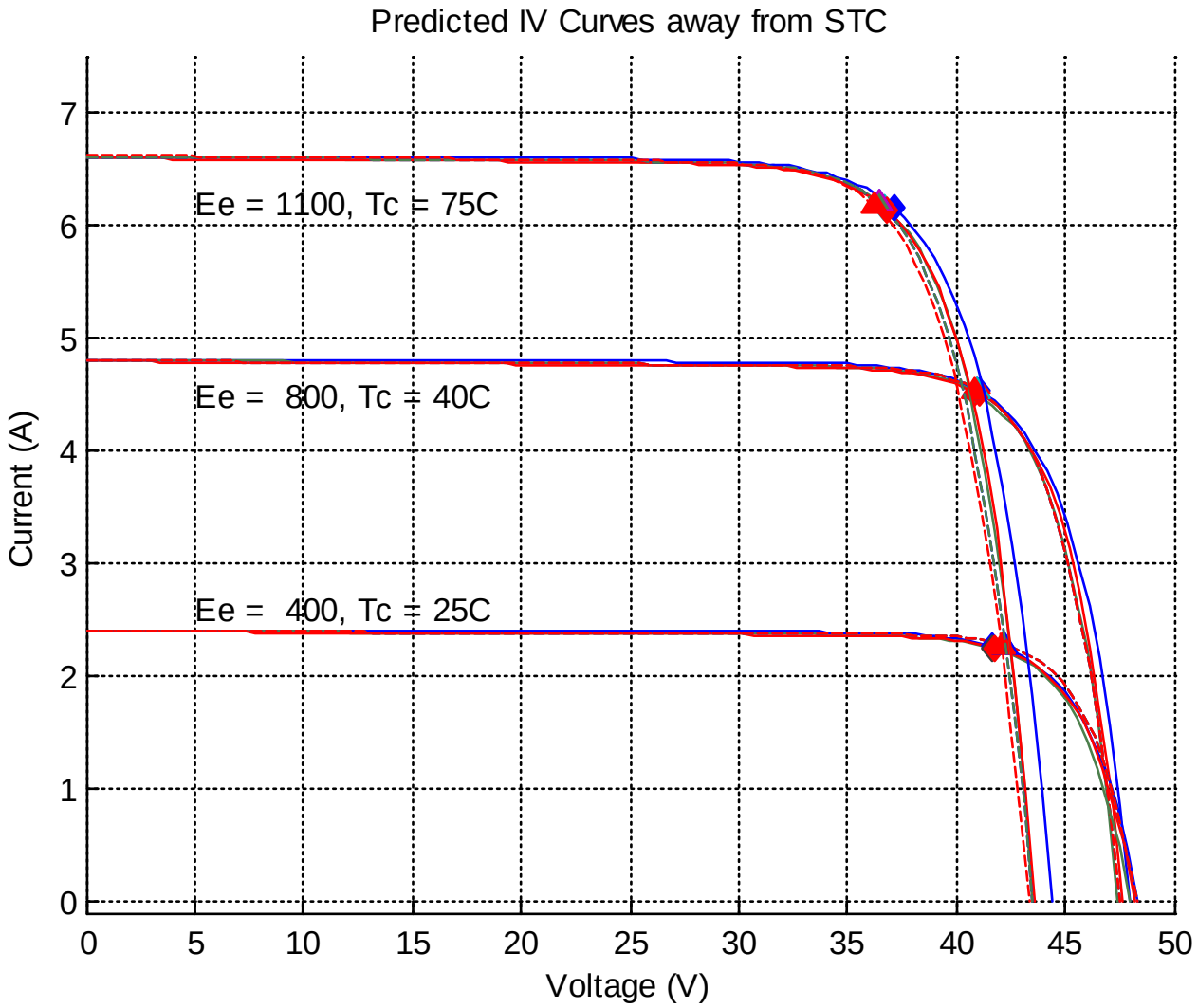
B: Comparison of predicted Pmp



- Differences between Pvsyst and Measured are likely from my emulation of Pvsyst
- Variation among Pvsyst points are from parameter variation



B: Comparison between parameter sets

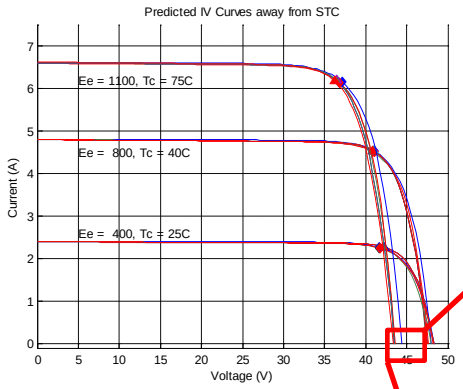


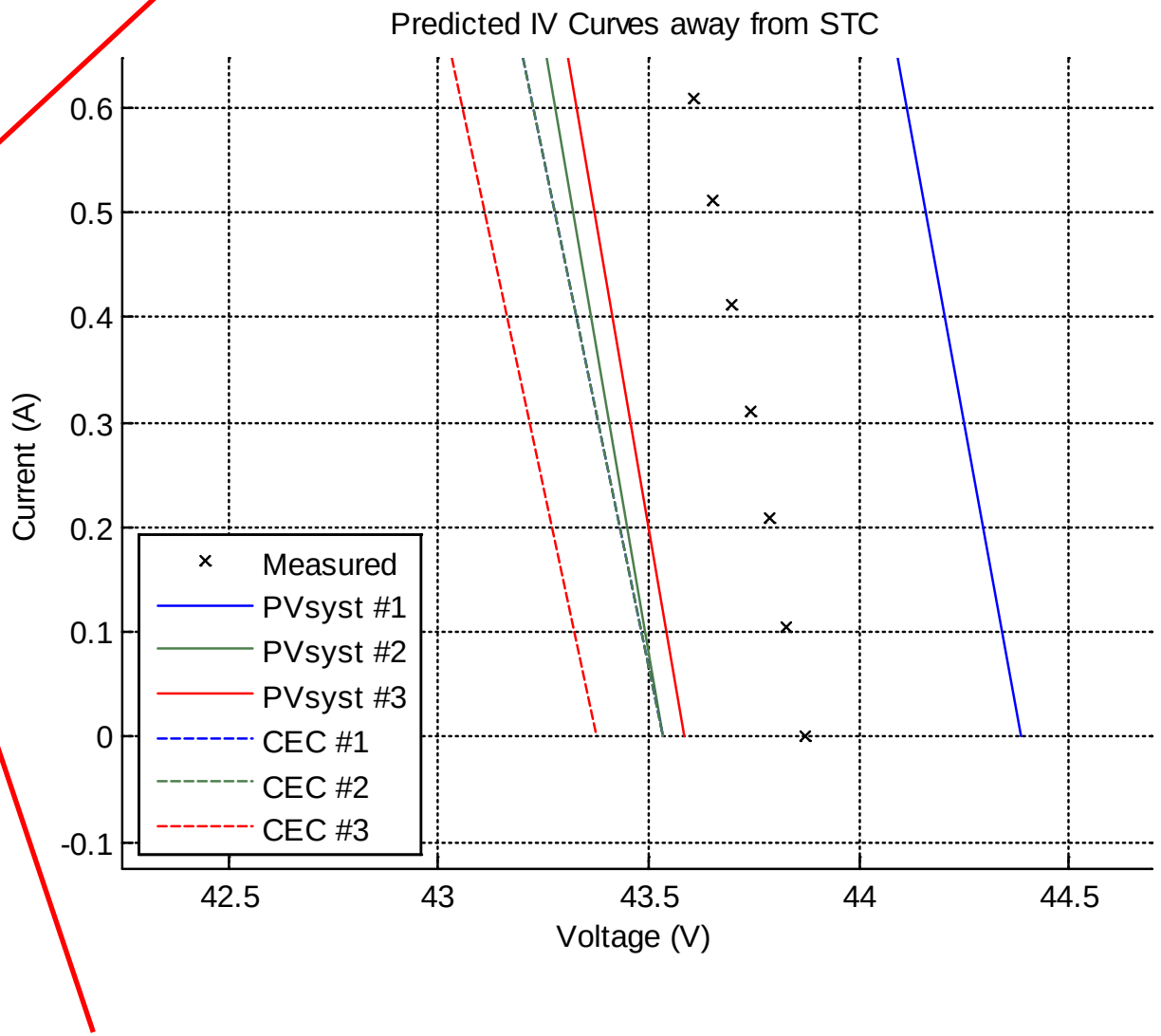
Ee = 400:
Pmp = 93.5W + error
Pvsyst ~1W
CEC ~ 3W

Ee = 1100:
Pmp = 226W + error
Pvsyst ~ 3W
CEC~ –2W

Differences are greatest at predicted Voc, for conditions away from STC

B: Comparison of predicted Voc





B: Observations

- No method recovered parameter values exactly
  - Suspect dI/dV approximation is responsible for Rsh errors
  - Voc errors likely result from issues with Io estimation
  - Trading Io, n, Rs in neighborhood of Pmp
- Pmp errors are generally small but biased
- Errors increase with voltage
  - No surprise, as high voltage is where single diode equation balances terms with greatly different magnitudes
- Difficult (for me) to verify Pvsyst results
- How important is accurate prediction of Voc?

Module A

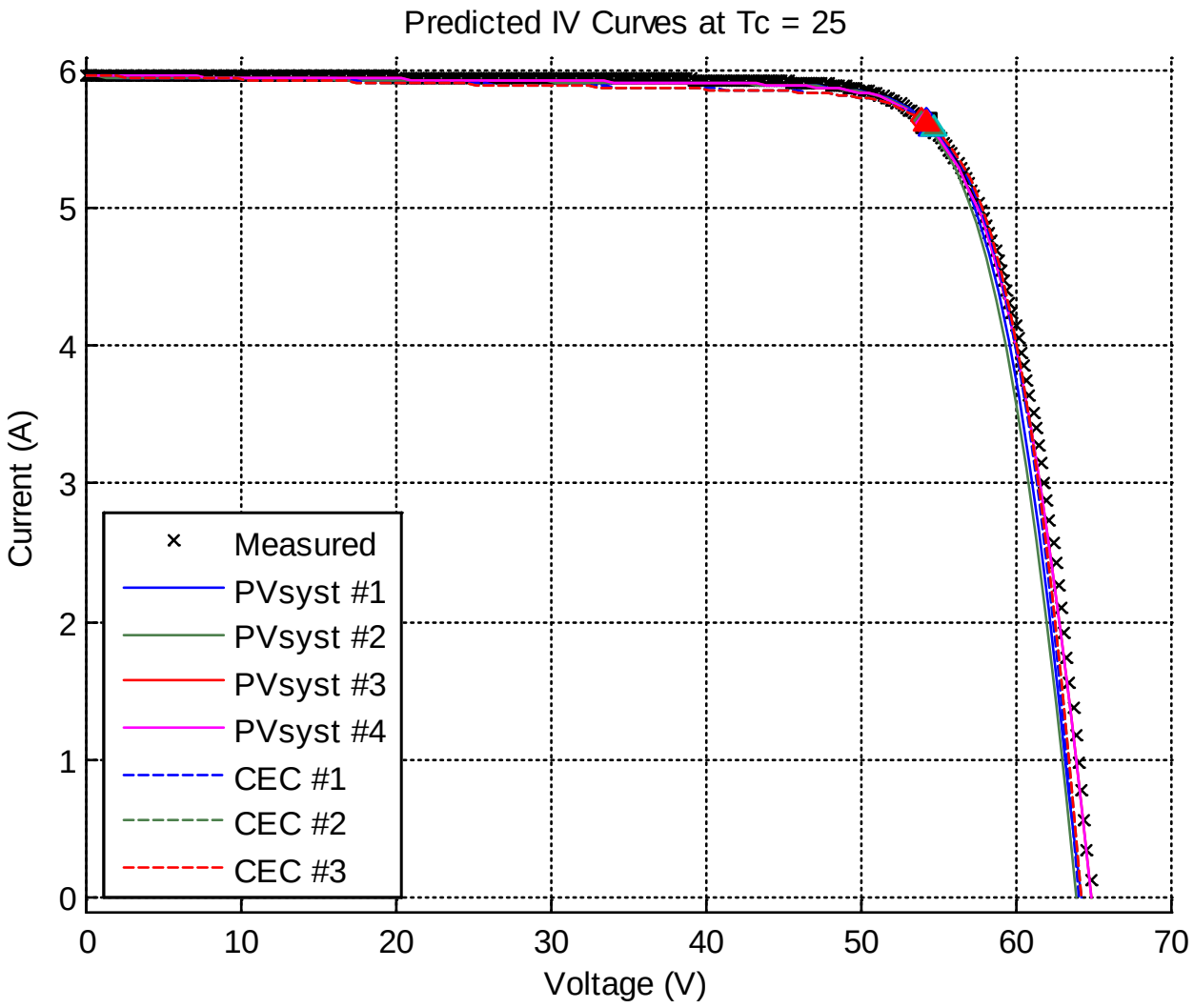
- SunPower 305 WHT, characterized at CFV Laboratories (and outdoors at Sandia)
- Values for IV curve at STC:

Parameter	PVsyst #1	PVsyst #2	PVsyst #3	Pvsyst #4	CEC #1	CEC #2	CEC #3
	Mermoud	Sauer	Joshi	Klise	Boyd	Dobos	MacAlpine
IL (A)	5.96	5.96	5.97	5.96	5.964	5.965	5.97
Rsh (Ω)	960	800	700	500	438	419	688
Rs (Ω)	0.43	0.48	0.52	0.42	0.31	0.34	0.53
Io (nA)	0.017	0.006	0.046	0.006	0.03	0.017	0.035
n	0.98	0.94	1.03	0.94	1.00	0.981	1.02

A: Modeled performance off STC

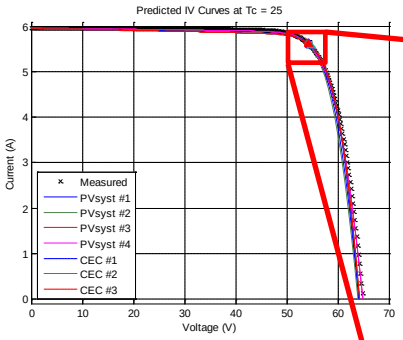
Parameter	PVsyst #1	PVsyst #2	PVsyst #3	Pvsyst #4	CEC #1	CEC #2	CEC #3
γ_{MP} %/C	-0.38	-0.36	-0.38	-0.31	-	-	-
Rsh0	4800	11833	7075	0	-	-	-
Rshexp	5.5	9.1	5.5	5.5	-	-	-
µGamma	-0.0006	-0.0004	-0.0003	0	-	-	-
Adjust	-	-	-	-	0%	-4.34%	1.94%

A: Comparison between parameter sets

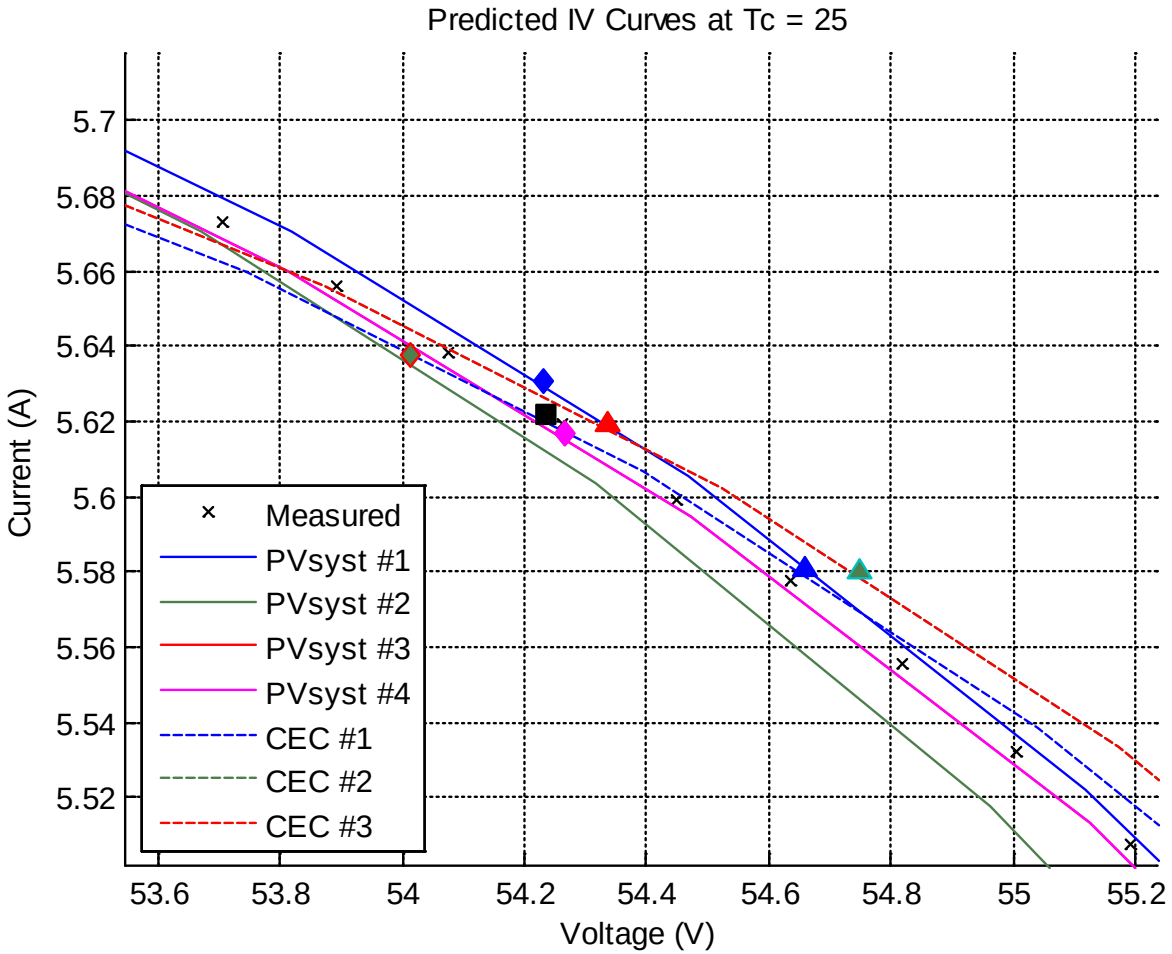


Differences at Voc likely due to my emulation of PVsyst

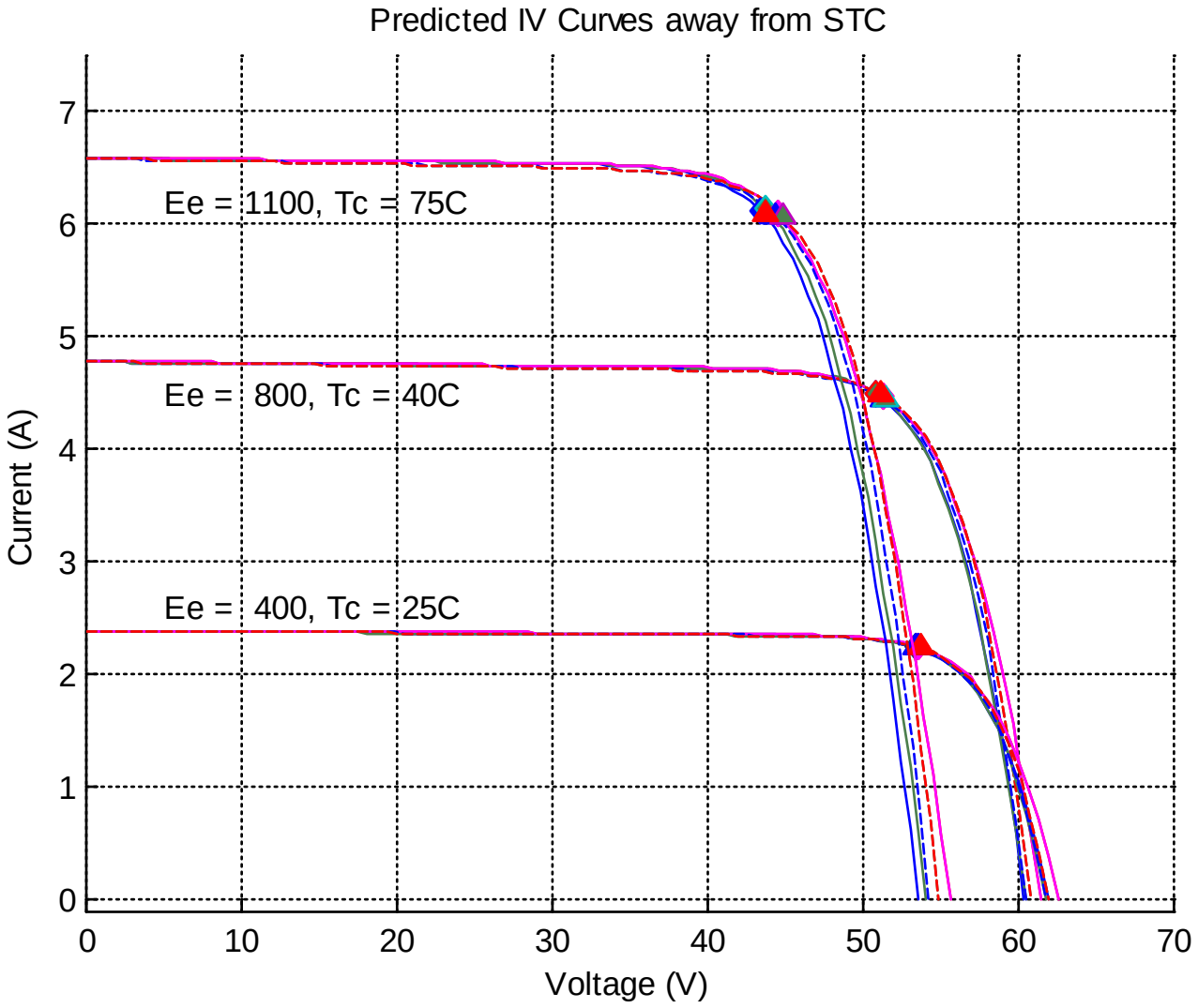
A: Comparison between parameter sets



- Pmp agrees with data
- But, Imp, Vmp may be 1% different



A: Comparison between parameter sets



Differences are greatest at predicted Voc, for conditions away from STC

At low irradiance, Pmp within 1 W (120 +/-0.4W)

At high irradiance, Pmp differs by 6W (265 to 271W)

Summary of Findings

- Many parameters sets give similar model results for the same data set
- Are the parameters different?
  - Yes, judged solely on parameter values
- Are the parameters different enough to matter?
  - That depends on what model output and precision is desired
  - IV curves are generally within a few percent of provided data
- Is one method / model better than another?
  - I couldn't reach any conclusion from this brief exercise
  - Energy modeling involves much more than the IV curve model
  - I'm not an expert user of either Pvsyst or SAM

So, what do we do? Some suggestions to hopefully provoke discussion

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- If we can't tell "good" parameters from "bad" by looking at parameters, how can we tell "good" methods from "bad"?
  - I think we can, if:
    - We agree on a set of test cases with known solutions
    - Methods are more transparent so that independent verification is possible
    - I'm not saying that method *implementation* should be open source
- How do we judge "good" and "bad"?
  - Criteria for prediction accuracy? Energy, Pmp or also Voc?
  - Will depend on purpose of modeling
- Can we judge good and bad by comparing predicted IV curves to data?
  - Certainly but we need the data