IMPROVING ANALYSIS METHODS FOR IEC 61853 MATRIX MEASUREMENTS

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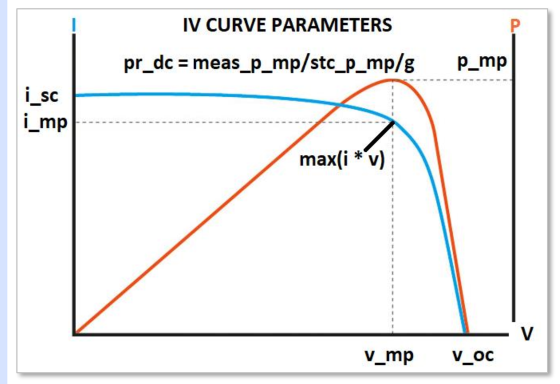
INTRODUCTION

- IEC 61853 "Matrix method" defines ~28 dc measurements at up to 7 irradiances (g=0.1 – 1.1 kW/m²) × 4 temperatures (t_mod=15, 25, 50, 75C)
- 4 independent coefficients are needed to uniquely fit a performance matrix :
  1) c_c : measured/nameplate performance at STC
  2) c_t : temperature coefficient (=1/X × dX/dt_mod [1/K]) X=p_mp, v_oc ...
  3) c_lg : low light drop (caused by v_oc drop or r_shunt loss increasing at low g)
  4) c_g : high light drop (caused by r_series as loss ~ I^2.r_series ~ g^2.r_series)
- Matrices of pr_dc, v_oc, v_mp etc. can be fitted easily with a mechanistic model "MLFM4" (with ~50% of the fit errors of SAPM or PVGIS as neither of them model r_series correctly, it needs a c_g term [PVSC-49])

DEFINITIONS



IV curve terms

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# GLOSSARY : nomenclature and definitions                    [unit]
# g = measured poa irradiance ~(0.1 - 1.1)                   [kW/m^2]
# t_mod = measured module temperature  ~(15,25,50,75)        [C]

g_stc = 1                                                    # [kW/m^2]
t_stc = 25                                                   # [C]
dt = t_mod - 25                                              # [C]
t_k = t_mod + 273.15                                         # [K]
t_stc_k = 298.15                                             # [K]

# normalise data for easier fitting and understanding)
# NAMING PREFIXES meas(ured) norm(alised) fit(ted), stc, lic, noct etc.
norm_i_sc = meas_i_sc / stc_i_sc / g                         # [%]
norm_v_oc = meas_v_oc / stc_v_oc                             # [%]
norm_pr_dc = meas_p_mp / stc_p_mp / g                        # [%]
norm_i_mp = meas_i_mp / stc_i_mp / g                         # [%]
norm_v_mp = meas_v_mp / stc_v_mp                             # [%]

# MLFM4+: 4 meaningful, normalised coefficients
#          1 const     2 temp coeff      3 low light       improvement   4 high light
norm_param  = c_c + c_t*(t_mod-25) + c_lg * log10(g)*(t_k/t_stc_k) + c_g*g
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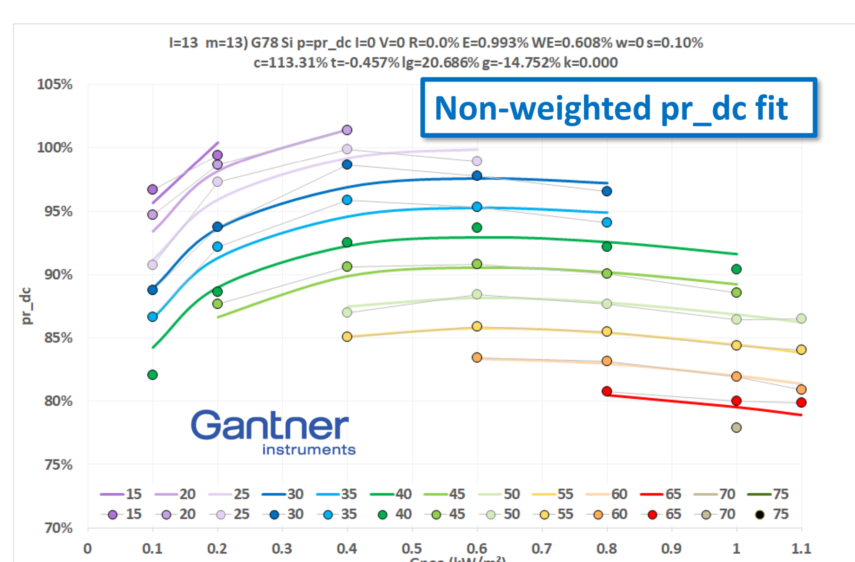
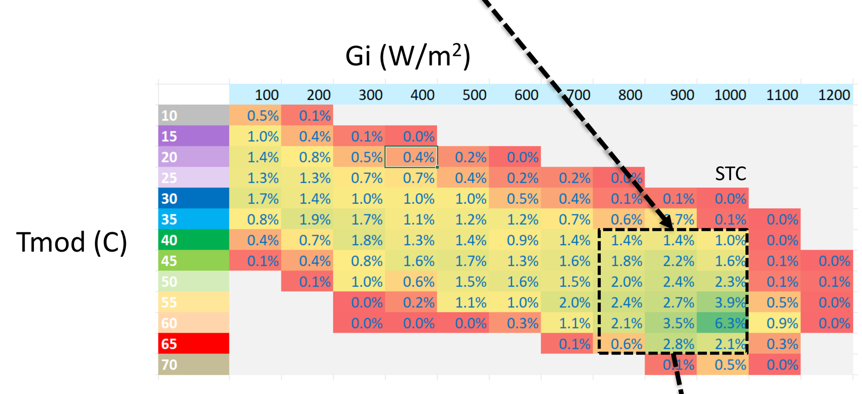
MLFM FITTING OUTDOOR MATRICES : pr_dc(G, t_mod)

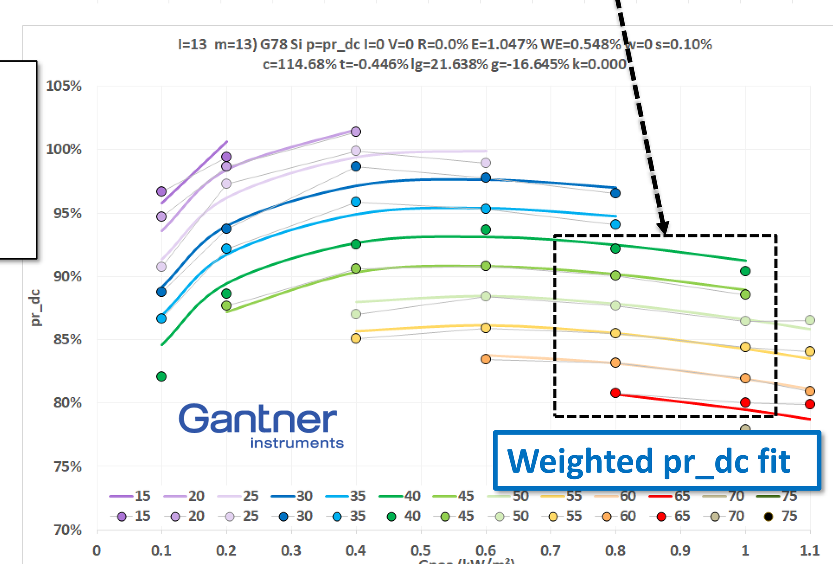
Fit data non-weighted or "weighted by occurrence"

[Gantner #78 c-Si] normalised efficiency pr_dc



Occurrence of external data at Tempe, AZ, 1m each h for 1 yr
Most frequent region (g ~0.8-1.0kW/m², t_mod ~40-65C)
Can ignore least frequent and any 'outliers' (<0.1%)





Dots = Measured
Smooth lines = Fits

c_t = -0.46%/K (gamma)
rmse ~0.99%
wrmse ~0.61%

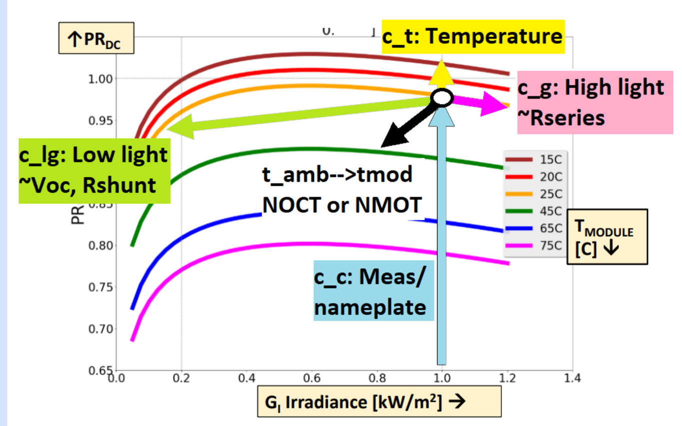
c_t = -0.45%/K (gamma)
rmse ~1.05%
wrmse ~ 0.55%

Weighted rmse (wrmse) is ~50% the rmse for good outdoor data as it tends to fit well behaved, bright, hot conditions and not cool, dull, infrequent and/or outliers

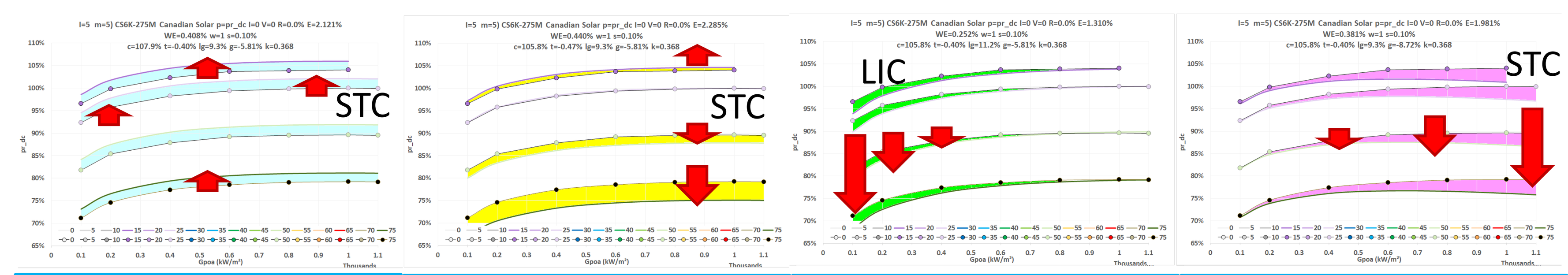
MLFM fits both weighted and unweighted well

MLFM COEFFICIENTS ARE INDEPENDENT FOR UNIQUE MATRIX FITS

- Alter each of the mlfm4+ coefficients (c_c, c_t, c_lg, c_g) separately
- Show sensitivity : shape and magnitude of apparent performance change (red arrows)
- Changes are independent meaning there's a unique best fit



4 independent terms are needed to model matrix behaviour



1) c_c vs. 10% rise
Constant change
Fits: "meas/nameplate"

2) c_t vs. 20% rise
Change ∝ (t_mod-25C)
Fits: gamma, beta etc.

3) c_lg vs. 20% rise
Changes most at low g
Fits: v_oc, r_shunt drop

4) c_g vs. 50% rise
Changes most at high g
Fits: r_series loss

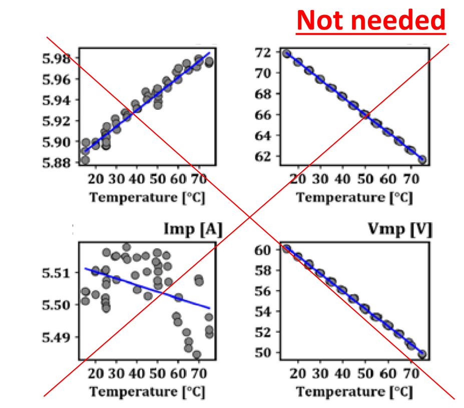
A BETTER METHOD TO FIND TEMPERATURE COEFFICIENTS

Temperature coefficients can be more simply and accurately derived using c_t from mlfm matrix fits without needing extra measurements and trend fits as used in IEC 61853

IEC 61853 TREND values and residual from MLFM fits

IEC trend temp. coeffs.	Parameters	A) MLFM4
0.03%	norm_i_sc	0.00%
-0.24%	norm_v_oc *	-0.01%
0.00%	norm_i_mp	0.00%
-0.29%	norm_v_mp	-0.01%
-0.08%	norm_ff	-0.01%
-0.30%	pr_dc	-0.01%
1/K	Residual error	(1) < +/- 0.01%

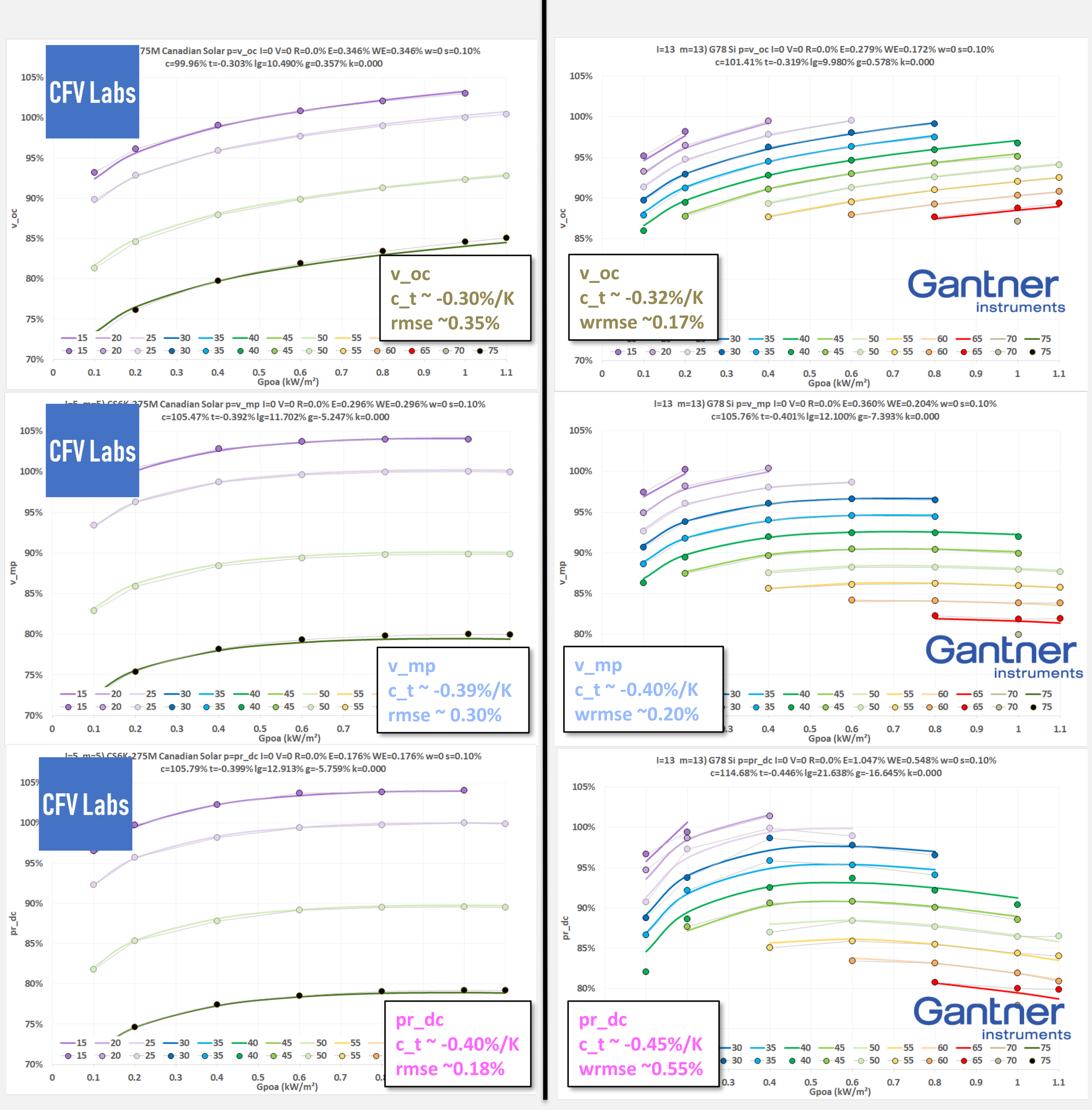
IEC 61853 values and linear trend fits
Not needed



MLFM FITTING v_oc, v_mp, pr_dc : INDOOR vs. OUTDOOR

Indoor: CFV IEC61853
Module #5 Canadian Solar : rmse

Outdoor: Gantner Tempe AZ, 1year
Module #78 Solar World : wrmse



Fitting good indoor vs good outdoor data :

- Weight outdoor data by occurrence
- Outdoor weighted v_mp and v_oc fits can be as good as indoor!
- Higher pr_dc variability outdoors (soiling, aoi, beam fraction and spectrum affect i_sc)
- MLFM fits matrices well

SUMMARY

- MLFM is better than SAPM or PVGIS fitting matrices for all parameters with only 50% of their rmse (they don't model r_series) [see PVSC49]
- MLFM has optimised fits to indoor measurements and fits good outdoor measurements well
- Weighting outdoor measurements by occurrence mean infrequent extreme or transient data don't affect the fits
- The MLFM matrix fit c_t parameter is an accurate temperature coefficient (without needing extra measurements at 1000W/m²)

References : www.steveransome.com email : steve@steveransome.com
[PVSC 49] http://www.steveransome.com/pubs/2206_PVSC49_philadelphia_4_presented.pdf
PVPMC/PVLIB : https://pvpmc.sandia.gov/ https://github.com/pvlib/pvlib-python

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