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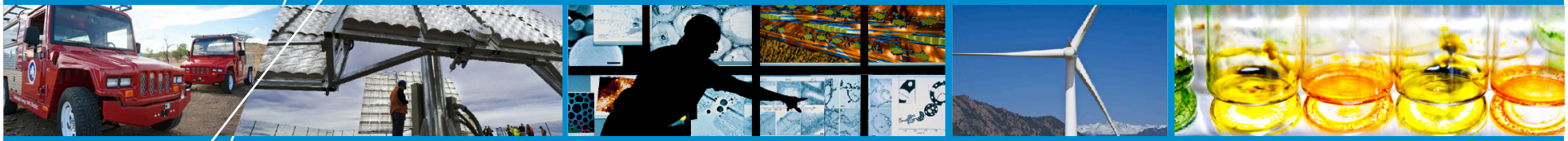
Deriving the Solar Resource Using PV Data



NREL PV Reliability Workshop

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Goal

- **Can we use PV system performance data to determine the solar resource (direct and diffuse) which can then be used to model the performance of other PV systems?**
  - Provides source of data based on ground measurements with small incremental cost
  - Millions of micro-inverters have been deployed that are collecting performance data

Approach

- **Determine the plane-of-array (POA) irradiance from the PV system performance data.**
- **Determine the direct and diffuse horizontal irradiance from the POA irradiance.**

POA to Direct and Diffuse

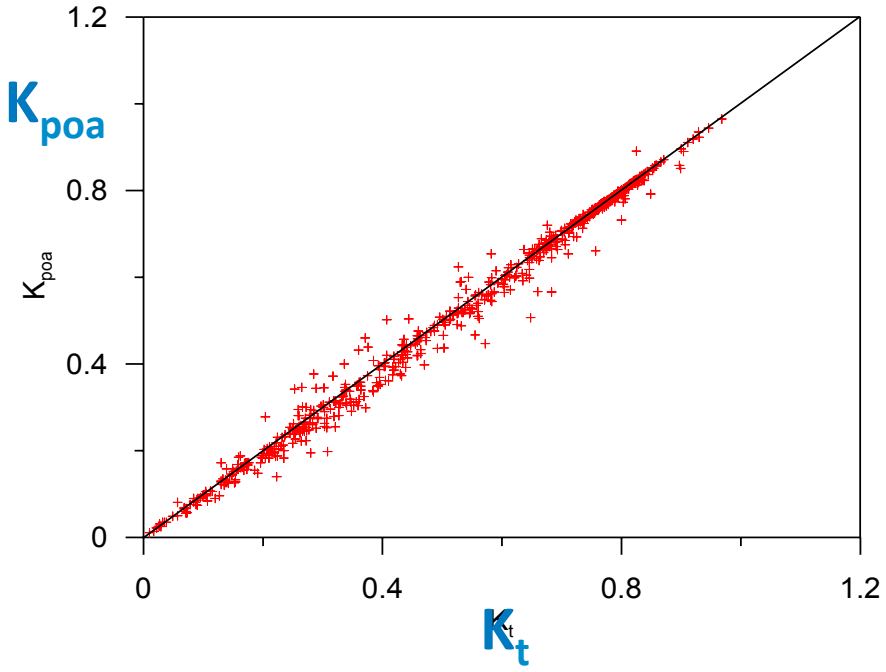
- **Problem is similar to using global horizontal irradiance (GHI) to estimate direct normal irradiance (DNI), for which we have solutions.**
  - Perez et al. (1992) modifications to NREL's DISC model
  - Key model parameter – GHI transmittance, K_t

$$K_t = GHI \div (I_0 \cdot \cos(\theta_z))$$

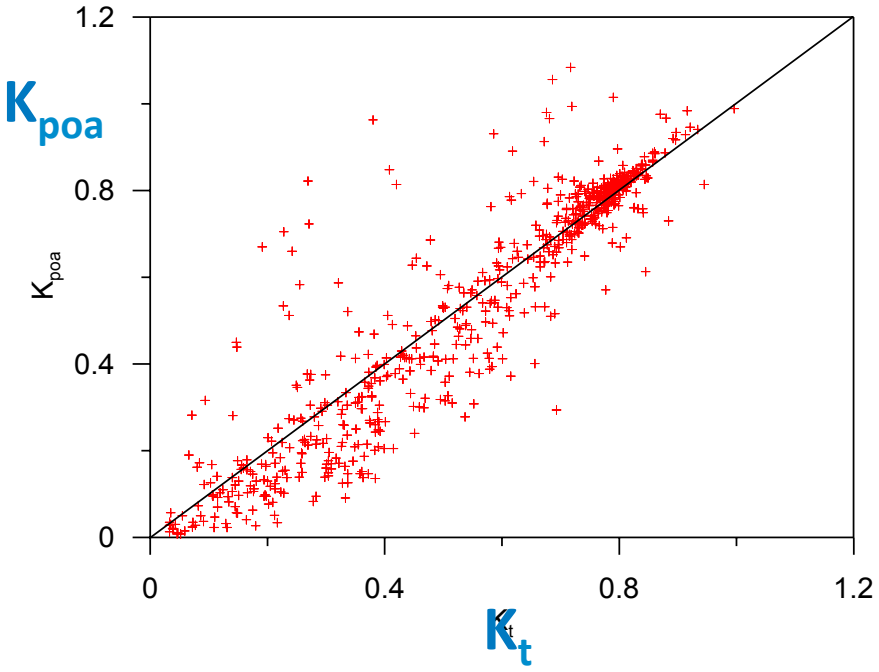
- **Substitute model parameter – POA transmittance, K_{poa}**
  - $$K_{POA} = POA \div (I_0 \cdot \cos(\theta))$$

K_t and K_{poa} Relationship Depends on Tilt

- **More similar for small tilt angles**



10 Degree Tilt



40 Degree Tilt

Method for POA to Direct and Diffuse

1. Substitute POA for GHI for input to Perez modified DISC model: model calculates K_{poa}, an DNI and diffuse horizontal irradiance (DHI).
2. Calculate error term as difference between measured POA and POA modeled using the DNI an DHI and the Perez et al. (1990) tilt irradiance model.
3. Add error term to POA input values, repeat steps an 2 t minimize error.

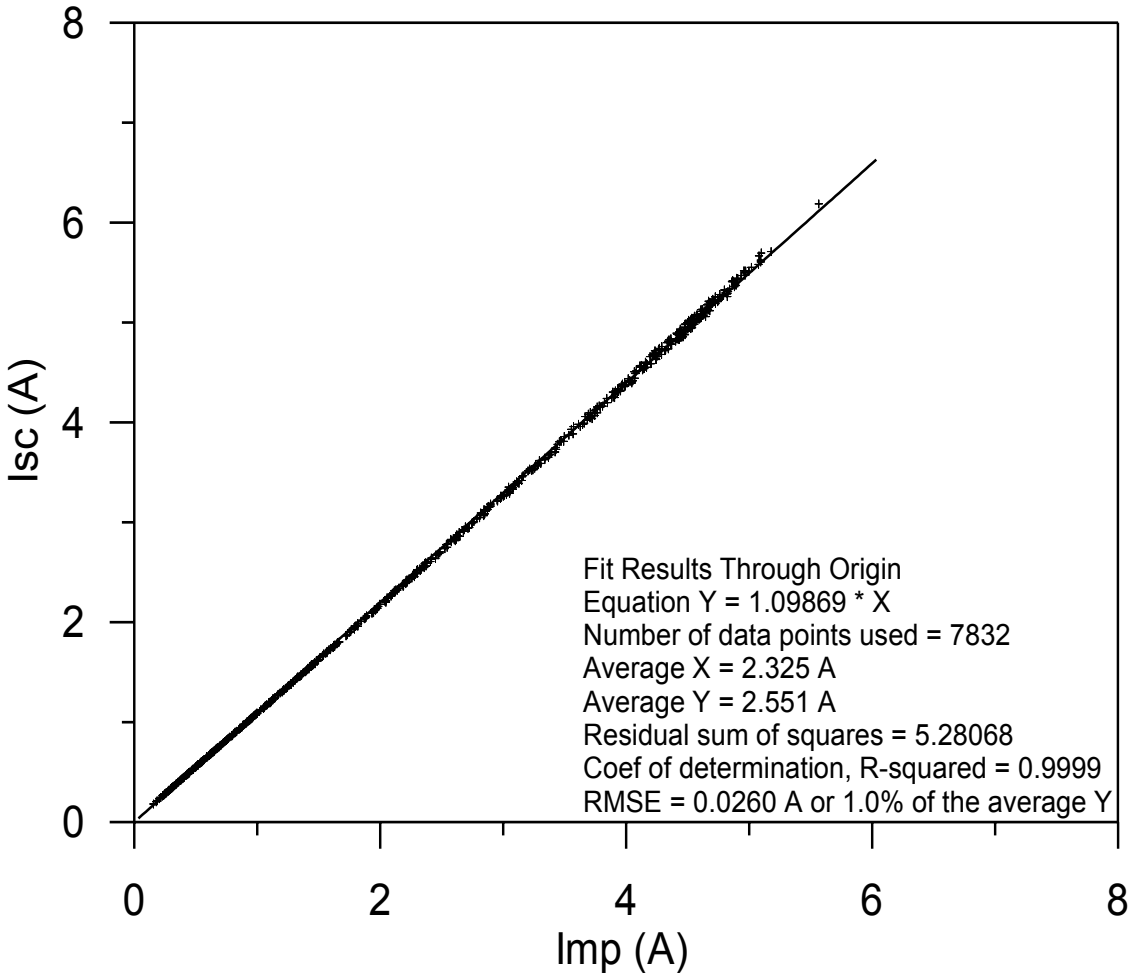
- Compared to using GHI, use of POA increases errors for modeled DNI and DHI, but when subsequently used to model POA, errors in modeled POA for same tilt are reduced.

POA from PV Performance Data

- Use operating current to determine POA irradiance (similar to using a reference cell)
- Correct for PV angle-of-incidence (AOI) effects for optimal application of the Perez models.

Relationship between I_{mp} and I_{sc}

- **Essentially linear for crystalline silicon**



Validation Data and Method

- PV modules at NREL with micro-inverters. Step 1: Measure PV module current and voltage for one PV module. Step 2: Determine POA and direct and diffuse radiation. Step 3: Use direct and diffuse radiation to model POA for other orientations.
- Direct, global, and diffuse horizontal irradiance measured at nearby Solar Radiation Research Laboratory (SRRL).

Preliminary Results - Using Measured POA

- **Measured with Kipp and Zonen pyranometers**
- **Evaluates POA to direct and diffuse method, and their use for modeling POA**

Parameter	MBE (%)	RMSE (%)	RMSE (W/m^2)
DNI	-1.4	24	108
DHI	2.5	35	56
10° Tilt POA	0.3	3	16
25° Tilt POA	0.7	2	10
40° Tilt POA*	-0.1	1	3
40° SW Tilt POA	-0.2	3	15
2-X Tracking POA	-0.2	15	95

*used for modeling DNI and DHI

Preliminary Results - Using Measured POA (cont)

- RMSE for DNI when using POA for input was about 20 W/m^2 greater than if GHI was used for input to the Perez modified DISC model.
- RMSE for fixed tilt POA irradiances generally within accepted RMSE for Perez tilt irradiance model when using measured DNI and DHI inputs (15 W/m^2)
- RMSE of 95 W/m^2 for the 2-X tracking POA irradiance is mostly attributed to the larger DNI RMSE.

Preliminary Results - Using Measured PV Data

Parameter	MBE (%)	RMSE (%)	RMSE (W/m^2)
DNI	-4.1	25	115
DHI	4.4	35	55
10° Tilt POA	-0.9	5	22
25° Tilt POA	-0.4	4	19
40° Tilt POA	-1.3	4	21
40° SW Tilt POA	-1.2	6	25
2-X Trking POA	-1.8	16	103
10° Tilt DC Pm	-0.5	4	
25° Tilt DC Pm*	-0.5	3	
40° Tilt DC Pm	-0.5	3	
40° SW Tilt DC Pm	-0.1	5	
2-X Trking DC Pm	1.0	16	

*used for modeling, POA, DNI, and DHI

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Questions?

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