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Photovoltaic System Energy Performance Evaluation

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Objectives

- Develop/modify simulation model to estimate more accurate hourly PV system power generation and energy prediction (within 3%) over selected period, typically annual (or TMY), by using:
  - More detailed PV module characteristics (per IEC 61853, part 1).
  - PV system specific components specifications
  - Specific inverter efficiency curve

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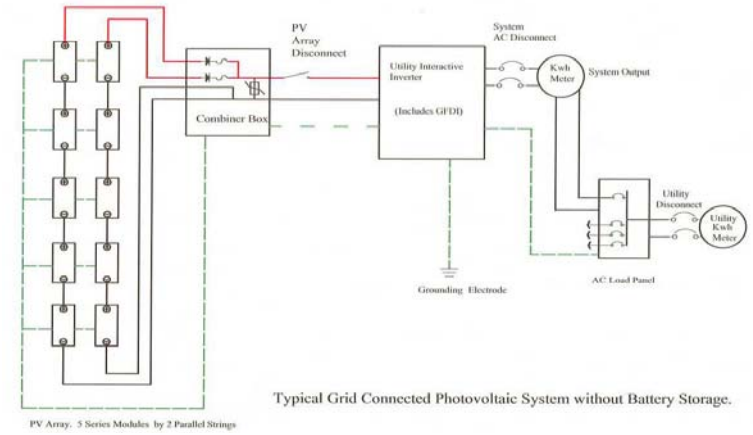
Typical System



Typical Grid Connected Photovoltaic System without Battery Storage.

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Scope

- Hourly/daily performance evaluation can be compared with actual performance data using actual hourly inputs to check the system is functioning well and that there are no failed modules or components.
- Annual performance evaluation for TMY can be used as PV system energy rating and for comparison of different PV systems.
- Monthly system performance evaluation can be used to determine month-to-month variations to determine the auxiliary power or battery storage needed.

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Approach

- Model uses detailed PV module maximum power matrix at seven irradiance levels and four module temperatures
- Model is applicable to all PV cell technologies, including X-Si, TFS, CdTe, CIS, GaAs, others.
- Model calculates DC and AC wiring and component power losses more accurately by using their specifications rather than "ball park" value of the power losses.
- Model uses specific inverter efficiency curve instead of generic inverter efficiency curve.

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Approach (Cont'd)

- Year-to-year variations in solar irradiance accounted by:

  Corrected Predicted Annual Performance (kWh) = Predicted Annual Performance with TMY data x (Actual Annual Irradiance / TMY Annual Irradiance)

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Input Parameters for Simulation Module

- **Typical Meteorological Year (TMY) data —** including solar irradiance, ambient temperature, wind speed, wind direction (ambient temperature, wind speed and wind direction are needed to calculate PV module temperature), etc.
- **PV module characteristics —** i.e., module power matrix at seven irradiance levels and four module temperatures (per IEC Std. 61853, Part 1, provided by module manufacturer or generated in a test lab)

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IEC 61853-1:
PHOTOVOLTAIC (PV) MODULE PERFORMANCE TESTING AND ENERGY RATING – Part 1: Irradiance and temperature performance measurements and power rating

P_{max}, I_{sc}, V_{oc}, and V_{max} versus Irradiance and Temperature

Irradiance (W/m^2)	Spectrum	Module Temperature			
		15°C	25°C	50°C	75°C
1100	AM1.5	NA			
1000	AM1.5				
800	AM1.5				
600	AM1.5				
400	AM1.5				NA
200	AM1.5				NA
100	AM1.5			NA	NA

Indoor & Outdoor Test Methods

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Input Parameters for Simulation Model

- **PV array layout** — including array tilt angle, number of modules in series and parallel
- DC wiring and component specifications
- AC wiring and component specifications
- Specific inverter efficiency curve

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Improved Simulation Model Input Data and Output

Site-Specific TMY Hourly Data
(solar irradiance, ambient temperature, wind speed and direction, etc.)

Inverter Efficiency Curve

DC Power Output

AC Power Output

Simulation Model

- / ~

$\sum_{n=1}^{n=mx24}$

AC Energy Output for Selected Period of m Days

Module Power Output Matrix
(at 7 irradiance levels and 4 module temperatures, per IEC 1853, Part 1)

PV Array Description
(array tilt, number of modules in series and parallel, component specs including wiring, switches, circuit breakers, disconnects, etc.)

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