SAND2010-6550P

PV Performance Modeling – An Overview

Presented to the Solar Instructor Training Network
September 27, 2010

Geoff Klise
Sandia National Laboratories
Earth Systems Department

Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

Purpose of the Presentation

- **Share with the Instructor Training Network recent research and activities surrounding PV performance modeling**

- **Help IREC and others understand where to find information and resources to meet ISPQ goals**
  - PV Performance modeling is discussed in:
    - NABCEP PV Tech Sales JTA
    - NABCEP PV Installer Task Analysis

Purpose of the Presentation

- **Gauge interest in this issue and discuss path forward**
  - Potential for developing curriculum
    - General overview of PV models
    - Best practices
    - Standardized approach?
    - Identify subject matter experts

Outline

- **Importance of PV Modeling**
- **Efforts to Describe and Analyze PV Models**
  - Papers, presentations and articles
  - PV Watts and beyond
- **PV Modeling Workshop at Sandia September 22 and 23, 2010**
  - Purpose of workshop
  - Results
- **What SNL can offer to the Solar Instructor Training Network**

Importance of PV Modeling

- **Allows for installers and systems designers to estimate energy produced and understand potential costs**
  - Can be fine-tuned for system type (c-Si, a-Si, CiGS, etc.) based on potential energy resource and incentives (federal, state, local)
- **Understand potential system losses**
  - Shading impacts performance and potential payback if tied to incentive-based system
  - Need to consider vegetation growth and zoning
  - Smart module layout

Importance of PV Modeling

- **System losses, cont.**
  - Wiring losses can be minimized with the right layout
- **Compare different technologies and system layouts**
  - Not all modules / inverters are alike, and perform differently as a function of latitude, climate and layout
- **Troubleshooting system performance**
  - Having a baseline can help understand when components fail
  - Performance degradation over time

Importance of PV Modeling

- **What are goals for installers?**
  - Minimize costs
  - Maximize system output
    - But at the same time, convey there is uncertainty in terms of measured vs. modeled
  - Maximize potential payback
    - Again, with an understanding that it is tied to system output

Efforts to Describe and Analyze PV Models

- **Recent activity**
  - Cameron et al. (2008) *Comparison of PV system performance-model predictions with measured PV system performance*, 33rd IEEE PVSC
  - Klise and Stein (2009) *Models used to assess the performance of PV Systems*, SAND report
  - Yates and Hibberd (2010) *Production modeling for grid-tied PV systems*, SolarPro April/May 2010
  - Stein et al. (2010) *Validation of PV performance models using satellite-based irradiance measurements: A case study*, ASES 2010
  - Stein et al. (2010) *A standardized approach to PV system performance model validation*, 35th IEEE PVSC
  - Klise et al. (2010) *Overview of the Sandia PV array performance model and module database* (in review), SAND report
  - Steve Ransome Consulting http://www.steveransome.com/index.html

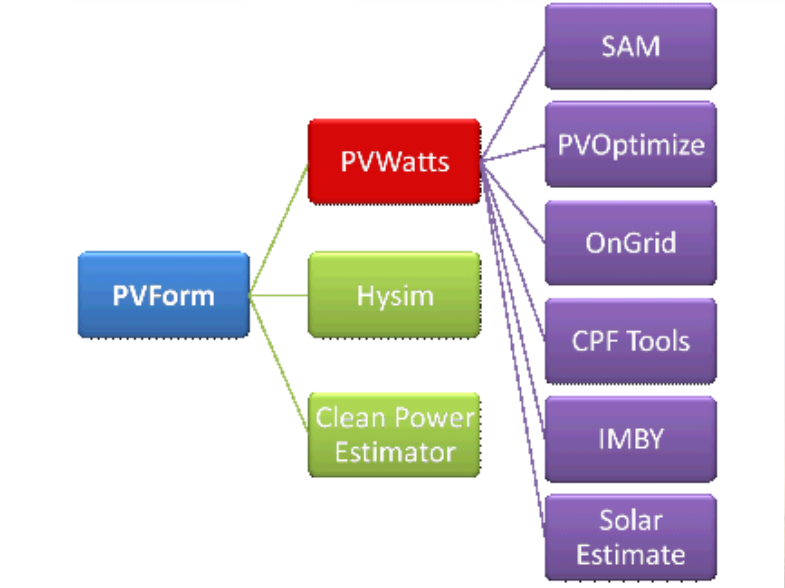
Efforts to Describe and Analyze PV Models

All models are wrong

(and some are more useful than others)

PV Watts and Beyond

- **PV Watts is very visible**
  - It is a good ‘screening’ tool for a first approximation as it uses TMY data for estimating solar resource
  - There are other software tools that give a system designer more flexibility



PV Watts and Beyond

- **Commonly used "stand-alone" models**
  - PVSyst
  - Solar Advisor Model (SAM)
    - PVWatts
    - CEC 5-Parameter model
    - Sandia Array Performance Model
  - PVDesign Pro
    - Sandia Array Performance Model
  - PVSol
    - New to U.S. Market. Used in over 70% of PV installs in Germany (2009)

PV Watts and Beyond

- **Commonly used ‘web’ and ‘spreadsheet’ models**
  - PV Watts
  - In My Backyard
  - Clean Power Estimator (California)
  - Energy Matters
    - Solar Estimate (SolarPro)
    - Energy Periscope
    - Clean Power Finance (CPF) Tools
  - OnGrid
  - PVOptimize (California)

PVWatts and Beyond

- **All models have their strengths and weaknesses**
- **Some work better with certain technologies than others**
- **Financial capabilities for the US market vary between models**

- **In Germany, it is said that modelers can be fined for over or under predicting power**
  - European PV performance models tend to be more conservative (according to their developers)

SNL Modeling Workshop

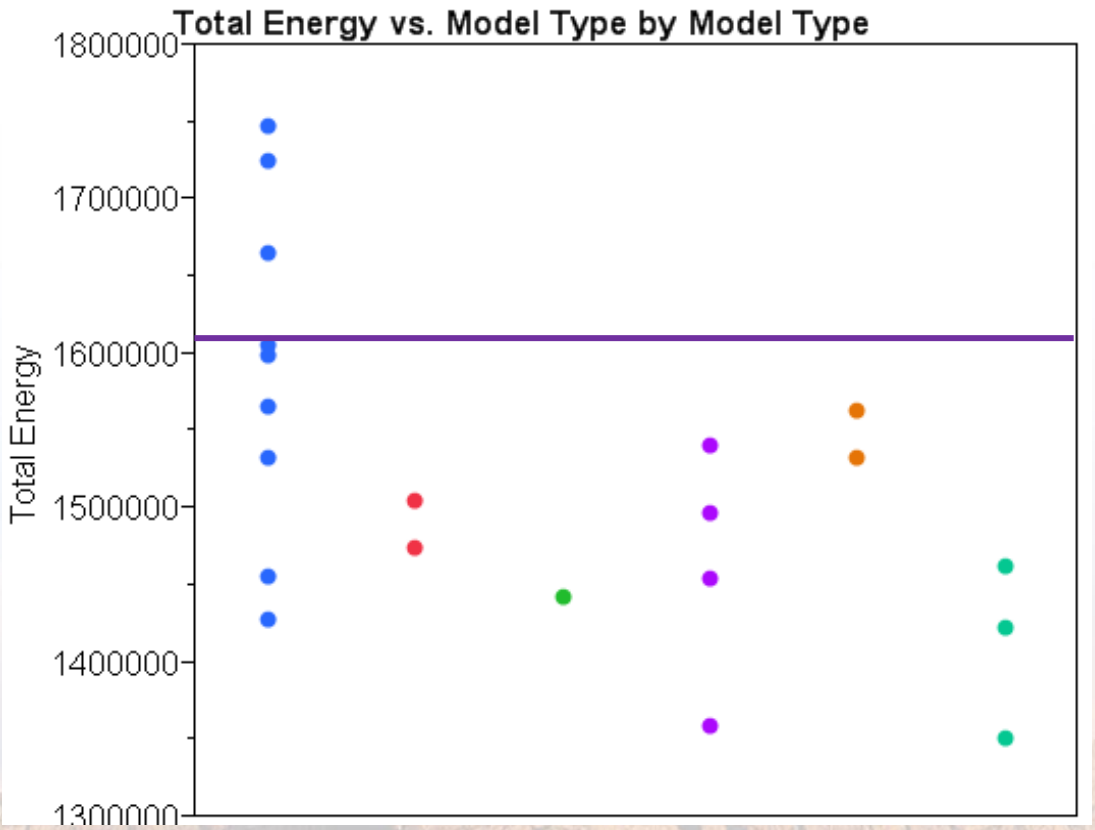
- **Purpose was to get model developers, module manufacturer's and system integrators together to discuss PV performance models**
  - Blind modeling exercise
    - Each participant was given data to model three systems
    - Results showed variation of model results based on assumptions by modelers
  - Uncertainty in input parameters
  - Standardization of inputs from manufacturer's
  - 3rd party verification
  - Model improvements

SNL Modeling Workshop

- **Overview of blind modeling results**
  - High degrees of variability between results from three systems
  - Reflects the large degree of uncertainty in inputs
    - Participants were purposely given limited information on the systems to see what assumptions are used
  - Different models will over AND underpredict power for different module technologies

SNL Modeling Workshop

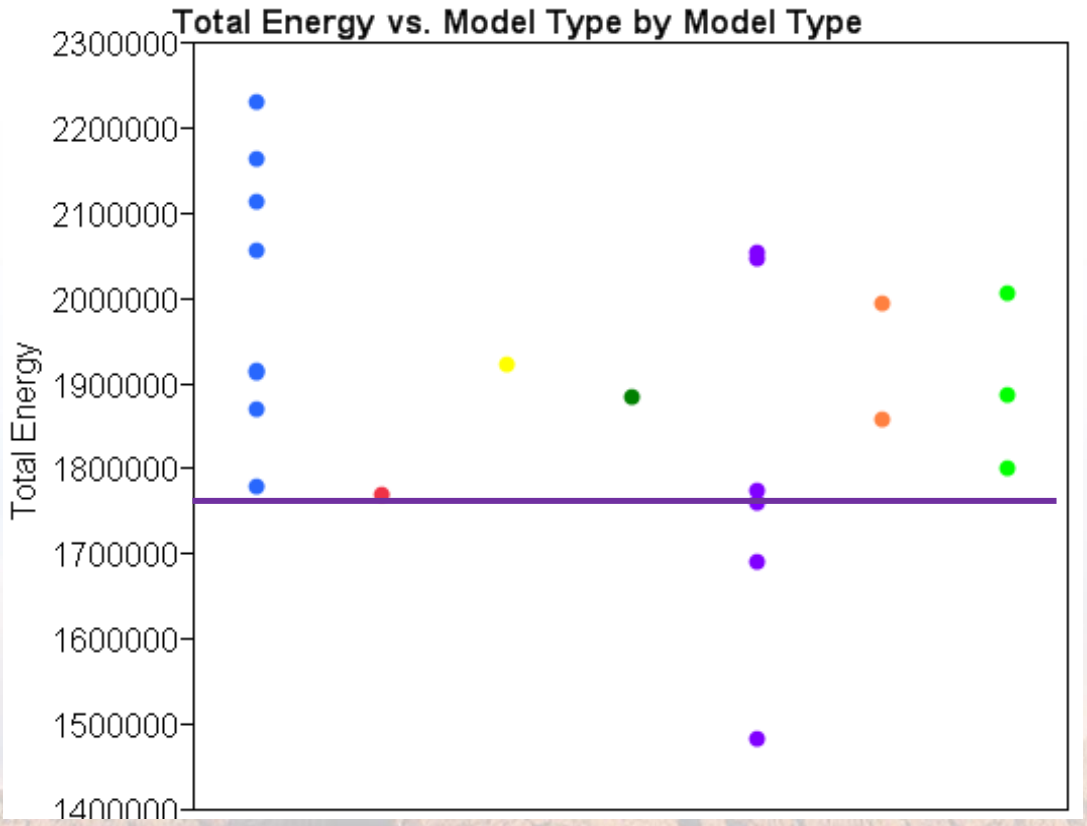
- **System 1**



Sandia National Laboratories

SNL Modeling Workshop

- **System 2**



SNL Modeling Workshop

- **Needs expressed by modeling community**
  - Develop set of ‘tests’ to allow industry to use, standardized test procedure, not model driven
  - Have manufacturer's provide data for non-STC operating conditions
  - Better understanding of module degradation
  - Which parameters should be modeled using a statistically significant sample size?

Overall, these needs and others will hopefully drive improvement by module manufacturer’s, PV model developers and installers / integrators

SNL Modeling Workshop

- **Why this is important for training instructors**
  - Training materials should address model limitations and inherent variability and uncertainty in parameters used in PV performance models
  - Instructors need to know the state-of-the art in terms of model development and appropriateness
  - System payback is a large driver in system design
  - This could give instructors a voice in this process

Thank You

Contact information:

Geoff Klise
gklise@sandia.gov
505 284-2500

Sandia National Laboratories