Auburn University's Solar Photovoltaic Array Tilt Angle and Tracking Performance Experiment

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Outline

- Background
- Experimental Set-up
- System Modeling
- Data Collection
- Data Analysis
- Simultaneous Studies
- Summary

Textbook Background – Orientation

- A surface receives the max amount of energy when the direct component of solar radiation is exactly perpendicular to the surface
- Fixed vs. tracking arrays
- Optimal azimuth angle is due south
  - The effect of off-azimuth orientation is much less at lower tilt angles
  - Cloudy, diffusive Southern skies reduce orientation sensitivity

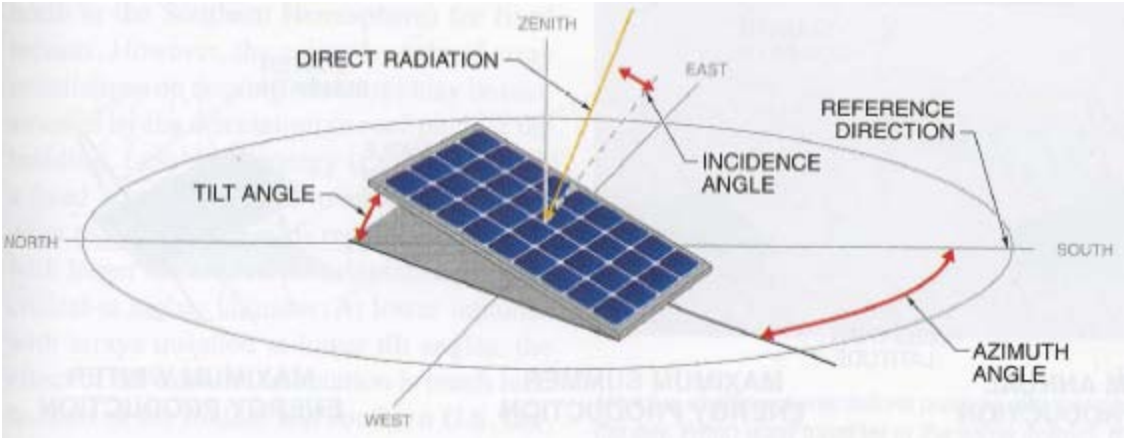


Image from "Photovoltaic Systems" by James Dunlop

Textbook Background - Optimum Array Tilt Angles

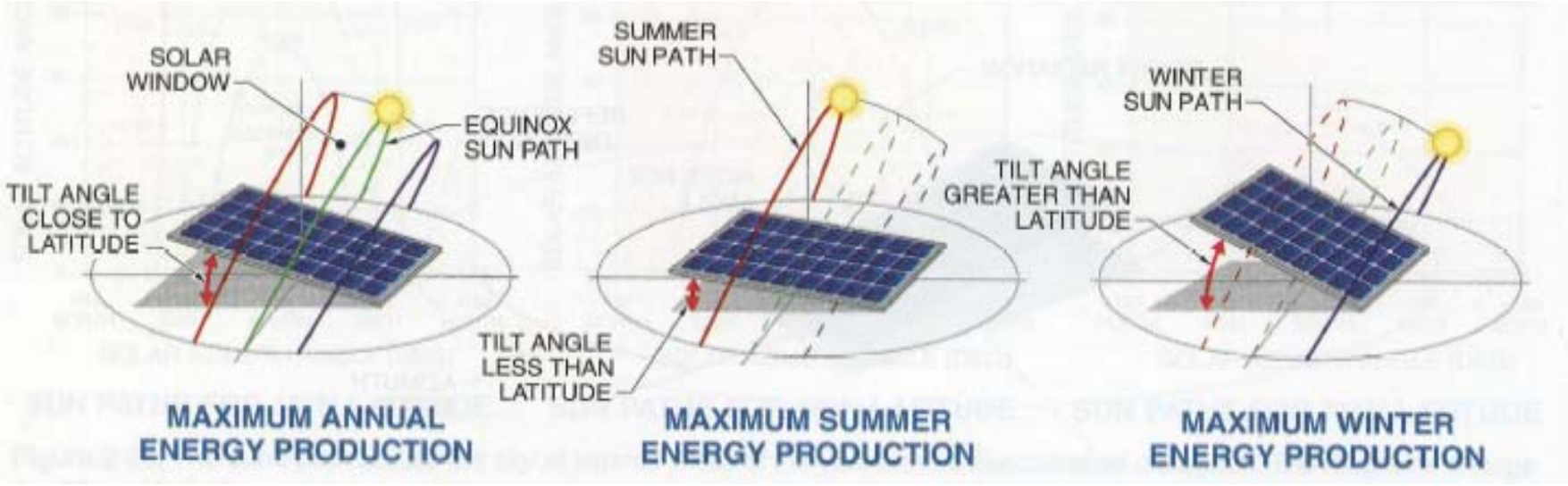
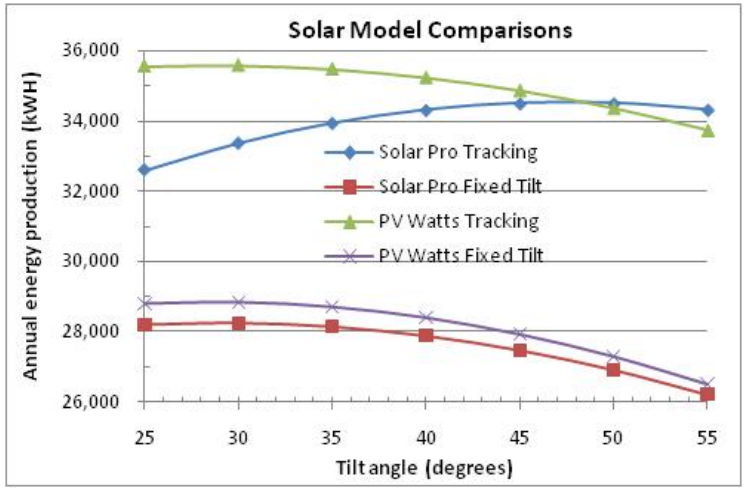


Image from "Photovoltaic Systems" by James Dunlop

- Energy production at certain times of the year can be optimized by adjusting the array tilt angle
- Longer summer days favor a lower tilt angle
- Winter favors a higher tilt angle
- Compromise is the latitude degree

Background

- Solar tracking mechanisms were developed to maximize the energy yield of solar cells
- Recently, solar cells have become so inexpensive that it may not be economically sensible to use expensive multi-axis trackers
  - Single axis tracking system alternative
  - Software models predict the optimum angle to point the single axis tracker
    - Compensate for the change of path by the sun throughout the year
    - Predict which angle will result in maximum energy output for the entire year



- Modeling programs do not agree when used to predict the optimal angle and for this region

Experimental Set-up

- Auburn University designed and built a test structure to verify the accuracy of solar modeling programs
  - Test bed uses a 2-D Wattsun AZ-125 tracker with Sharp NT-175U1 panels
  - The tracker is used solely in the single axis, N-S azimuthally tracking mode
- Consists of six test panels
  - Five panels are rotated in a single axis at the tilt angles of 20º, 25º, 32º (latitude), 40º, and 50º
  - Another panel is a control panel that is fixed facing south at latitude tilt (32.4º)

AZ-125 TRACKER

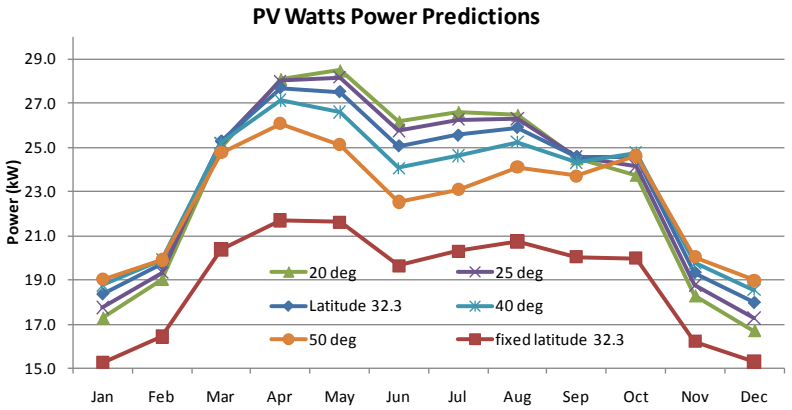
# 5, *1447 20 deg	# 4, *0760 25 deg
# 6, *1989 50 deg	# 1, *0837 40 deg
# 3, *2295 32.4 deg	

STATIONARY

2, *1992 32.4 deg

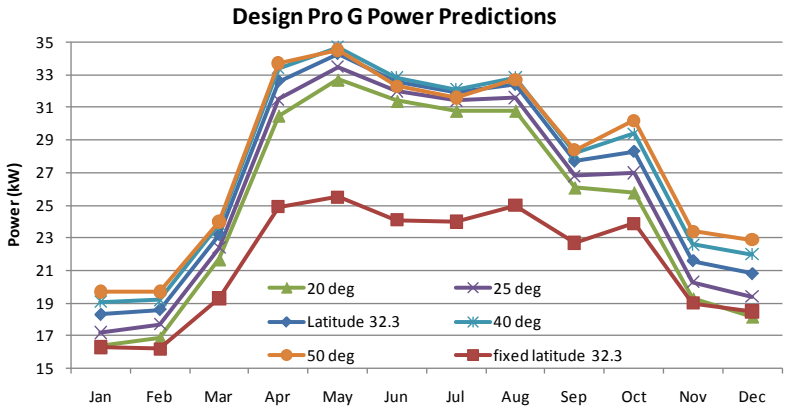
System Modeling – PV Watts

- Developed by DoE's National Renewable Energy Laboratory
- More simplistic program
  - Uses basic information such as location, tilt, rating to determine performance
  - Use of the default derate factor of 0.77
    - May be under predicting the performance
- Optimal angle prediction
  - 20º - April through August
  - 50º - October through February
  - For the overall year predicts an optimal angle of 32.3º or latitude
    - It is well known that the industry standard is to tilt fixed solar arrays at latitude for peak output
- PV SYST agrees more closely with PV Watts
  - Used by major companies around the world



System Modeling – PV Design Pro G

- Developed by Maui Solar Software
- Requires detailed information
  - Daily load, specific module and inverter parameters, wiring specification, system costs, the specific location's shadowing effects, etc.
- PV Design Pro G predicts higher power performance for every panel over PV Watts
- For the overall year, predicts the optimal angle to be 50^{o}



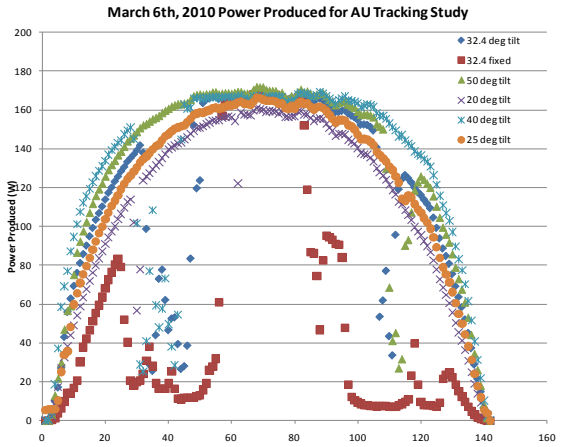
Data Collection

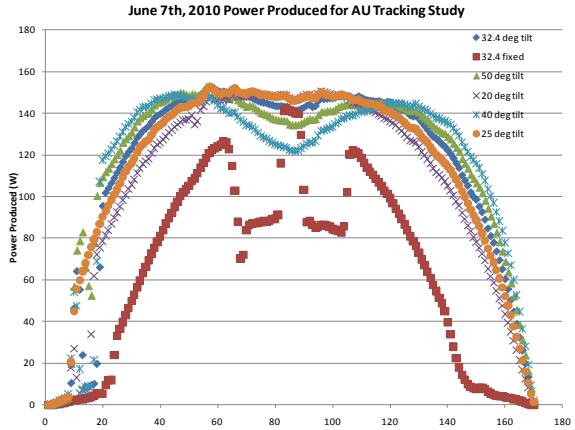
- SMA's WebBox and SensorBox collect array environment data onto SMA's SunnyPortal
  - Insolation (tilted at latitude)
  - Module temperature
  - Ambient air temperature
  - Wind speed

- Each panel has its own Enphase inverter
  - Each with an Independent Maximum Power Point Tracker circuit
    - Allows us to gather each individual panel's performance information for comparison
  - Provides primary power, voltage, and performance information
- Data will be recorded for at least one year
- Excellent teaching and demonstration tool

Power Production March vs. June

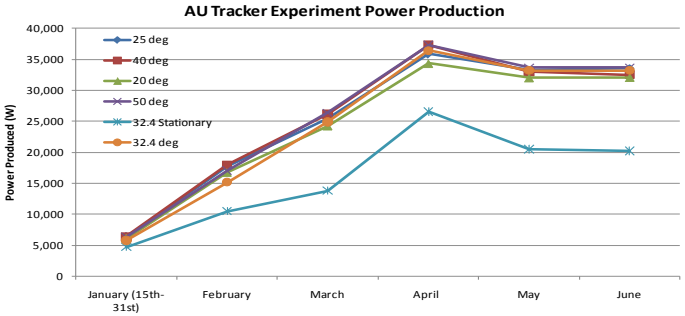
- Power produced on a typical full sun day in March and June for all the modules
- Shadowing effects seen mid-morning and mid-afternoon
  - Not consistent between panels
- At Dawn and dusk the 40º tilted array produces the most power
  - Followed by: 50º, 32.4º (latitude), 25º, 20º, and finally the fixed array
- For the summer months (higher sun angle) the lower tilted arrays become the top power performers for the hours of 10 am to 2 pm





Overall Power Production Jan - Jun

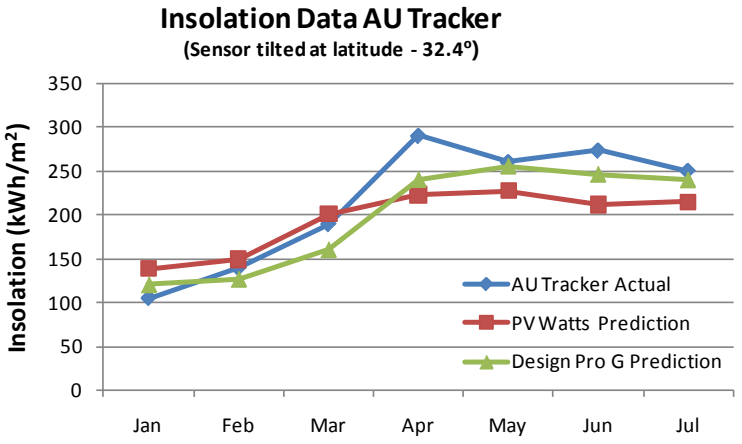
	Module 1 (0760)	Module 2 (0837)	Module 3 (1447)	Module 4 (1989)	Module 5 (1992)	Module 6 (2295)
	25 deg	40 deg	20 deg	50 deg	32.4 Stationary	32.4 deg
January (15th-31st)	6,358	6,400	6,083	6,326	4,697	5,763
February	17,689	17,982	16,728	17,048	10,484	15,156
March	25,459	26,152	24,235	26,367	13,789	24,908
April	35,872	37,342	34,341	37,288	26,557	36,402
May	33,292	32,971	32,020	33,662	20,475	33,195
June	33,537	32,495	32,095	33,675	20,206	33,202
Yearly Total	152,208	153,341	145,501	154,366	96,207	148,626



- The 50º tilted panel has produced the most overall
- The 40º tilted panel falls close behind
- Data seems to verify the PV Design Pro G modeling
  - Suggests that for this Southeastern region of the US, a higher tilted panel will produce more power throughout the year
  - A more in-depth analysis is being performed
- Shadowing has not been fully taken into account
  - but it mostly affects the 40º and 50º tilted panels

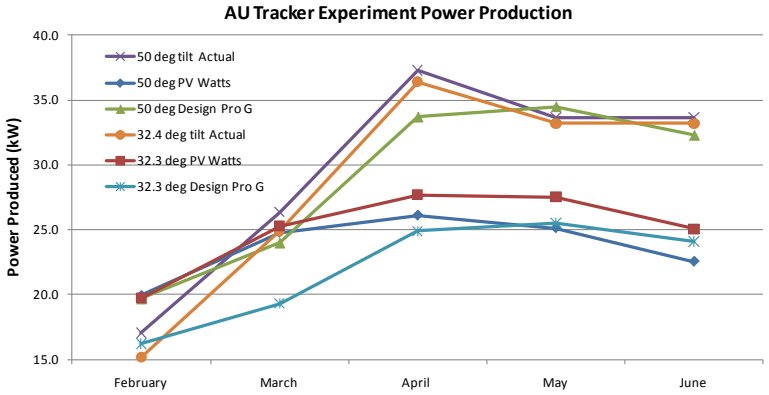
Insolation Data

- April was the peak power month
  - Both modeling programs predict May
    - Based on 30 year insolation data
  - Insolation was greater in April this year
- Insolation determines power performance
- Actual insolation measured on the tracker and the insolation used to predict the power performance for the two modeling programs shown
  - Results are similar



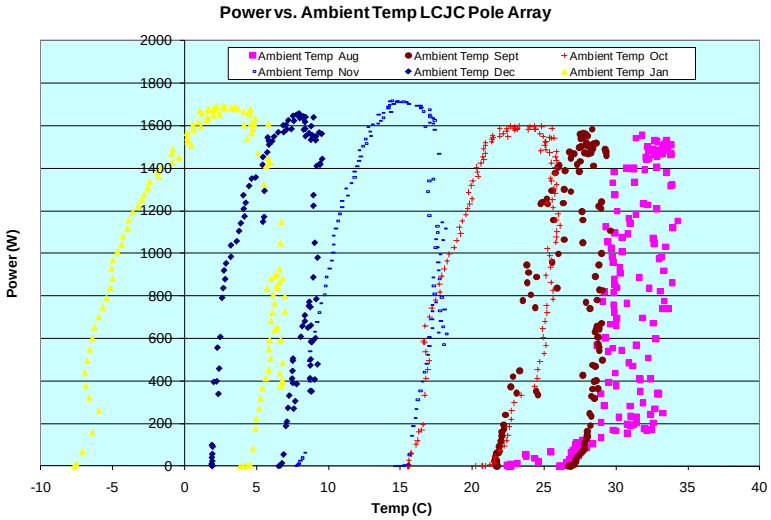
Actual Power vs. Predictions

- Compares the actual power performance of the AU tracker to the modeled performance
  - Only the 32.4º (latitude) and 50º panel data shown since they were the two panels that were modeled as the peak performers
- The PV Design Pro G performance prediction of the 50º tilted panel is quite close to the actual performance of that panel
  - The latitude tilted panel prediction is quite a bit off from the actual
    - This is under inspection
- Both predictions by PV Watts are lower than the actual performance
  - Possibly due to using too high (0.77) a derate factor



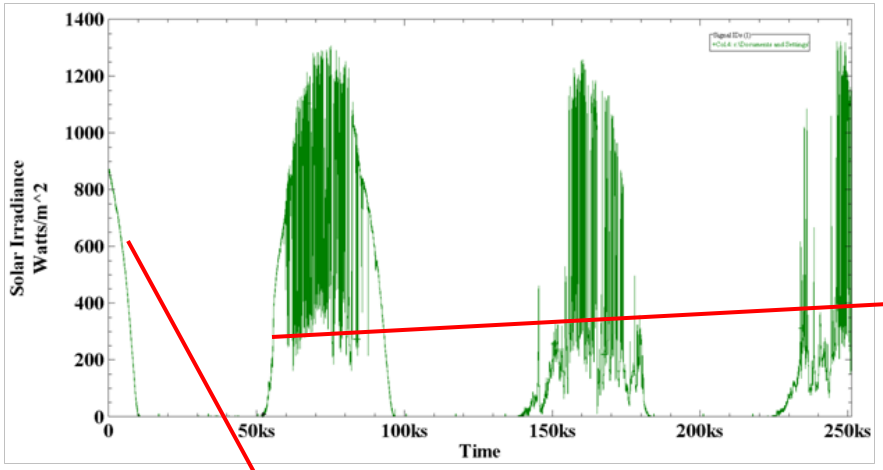
Additional Areas of Study

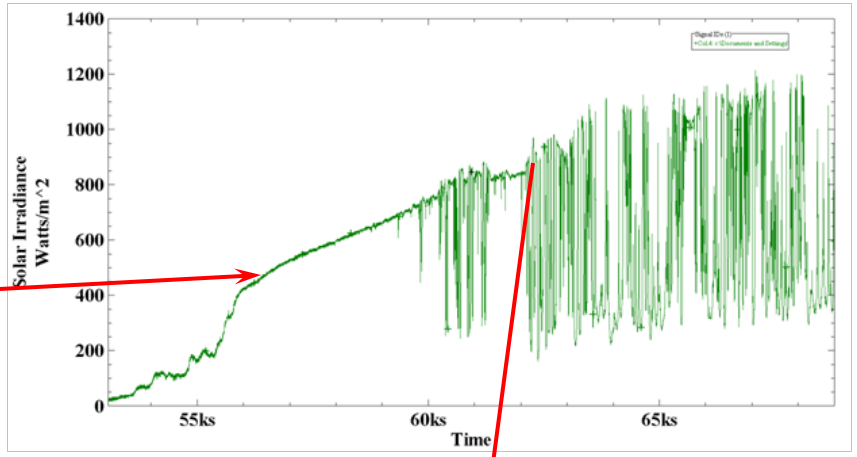
- Auburn is looking at the negative-temperature coefficient effect on PV
- Insolation is better in the southwest by ~20%
  - However, the negative temperature effects on the PV modules eliminates some of the advantage that the southwest has vs. the southeast part of the U.S.
- Figure takes a full sun day from different months that show a large temperature differential
  - Power produced in colder temperatures is greater than in hotter temperatures
- Analysis is still underway

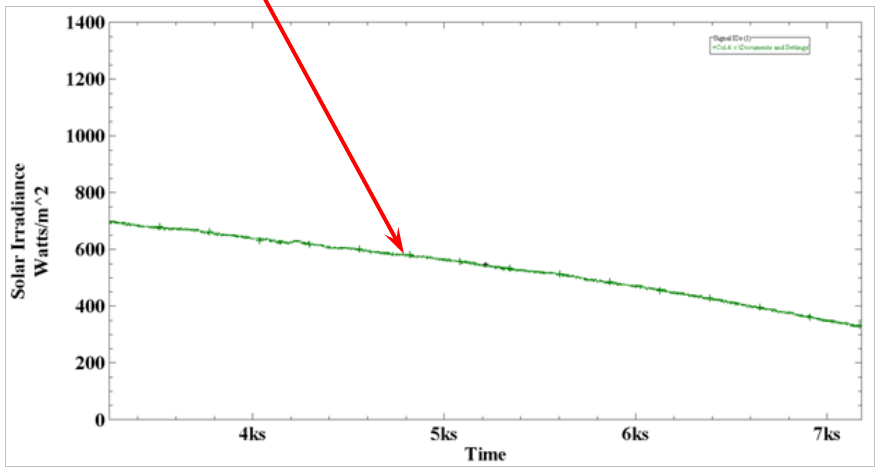


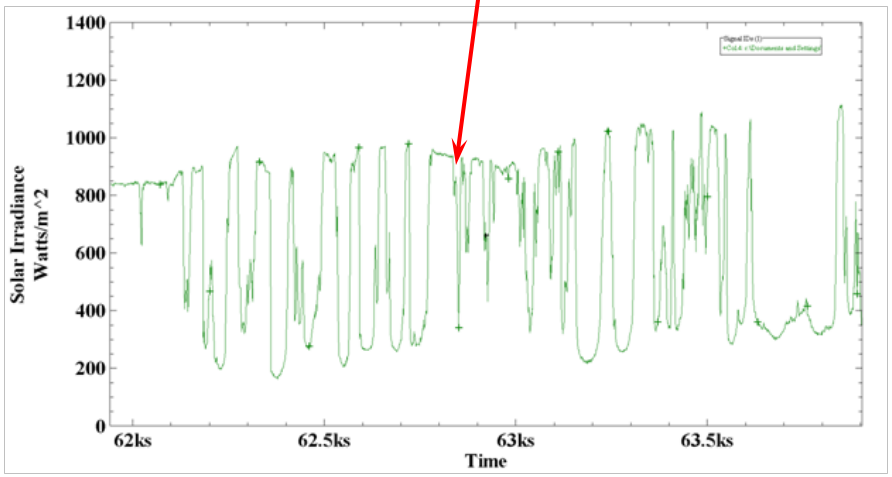
Intermittency Data Collection

(Simultaneous study at Auburn using tracker system)









Summary

- Comparison of performance data to the results obtained from PV modeling programs was obtained
  - Performance has closely resembled the modeling done by PV Design Pro G software
    - For the first 6 months
  - A more in-depth analysis is being performed
- Initial findings suggest a higher tilted panel (50º) will produce more power throughout the year compared to modeling from PV Watts that suggests a 32º tilt.
- When considering the negative temperature coefficient, the effect of reduced total solar radiation in the Southeast U.S. may in part be offset by the lower temperatures reducing somewhat the apparent advantage of the Southwest locations

SRI's Solar Objectives

- The Space Research Institute is interested in helping to explain how alternative energy, especially solar, can be economical for Alabama and the Southeast U.S. in general
- We want to overcome the mindset that solar energy is not practical for the Southeast U.S.
- We hope to serve as a model of how and why PV should be used for commercial, government, and individual energy use
- We hope to provide an excelled teaching and demonstration tool for all sectors and allow wide access to agencies, businesses, and individuals to inspire them to incorporate solar energy
- Please visit the Auburn University's Space Research Institute website at **sri.auburn.edu** where we go into more detail on all our solar projects and installations

QUESTIONS …

ACKNOWLEDGEMENTS

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