Solar Thermal Lab Instrumentation

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Kellogg Honors College Capstone Project

ABSTRACT

Collecting weather data, especially on-site data, is important for implementing engineering energy harvesting applications. Local weather stations are also providing with weather data; however, those data usually apply for a broader area such as a city. The on-site weather information can be helpful to achieve more accurate results in performing engineering energy harvesting applications on campus. In addition, the weather data can be used for educational purposes such as ME 407 Solar Thermal Engineering. The primary goal of the project is to install the Pyrheliometer by Hukseflux next to the solar panels on the roof of Building 17 at Cal Poly Pomona. The Pyrheliometer measures direct solar radiation from the Sun. A mounting bracket is designed and fabricated to hold the Pyrheliometer in place. The cable from the Pyrheliometer is extended to connect to the Omega Data Logger in room 17-2238 Environmental Test & Analysis Laboratory, which is connected to computer software, called DaqLab, to record and export data to Microsoft Excel in order to plot the distribution of direct solar radiation versus local time. The secondary goal of the project is to install the Weather Station by Davis Instruments next to the solar panels as well. The weather station records weather information such as temperature, humidity, wind speed, wind direction, and rainfall. A wireless display panel is placed in room 17-2238 next to the Omega data logger. With these two instruments installed, real-time and easy-to-access weather and direct solar radiation data can be obtained locally and accurately.

OBJECTIVES

- Design and fabricate a mounting bracket to install the Pyrheliometer on the roof of building 17
- Log Data onto Omega Data Logger in room 17-2238 Environmental Test & Analysis Laboratory
- Design and fabricate a pole to install the Weather Station

BACKGROUND

- Solar Radiation
  - Solar angles for a tilted solar panel

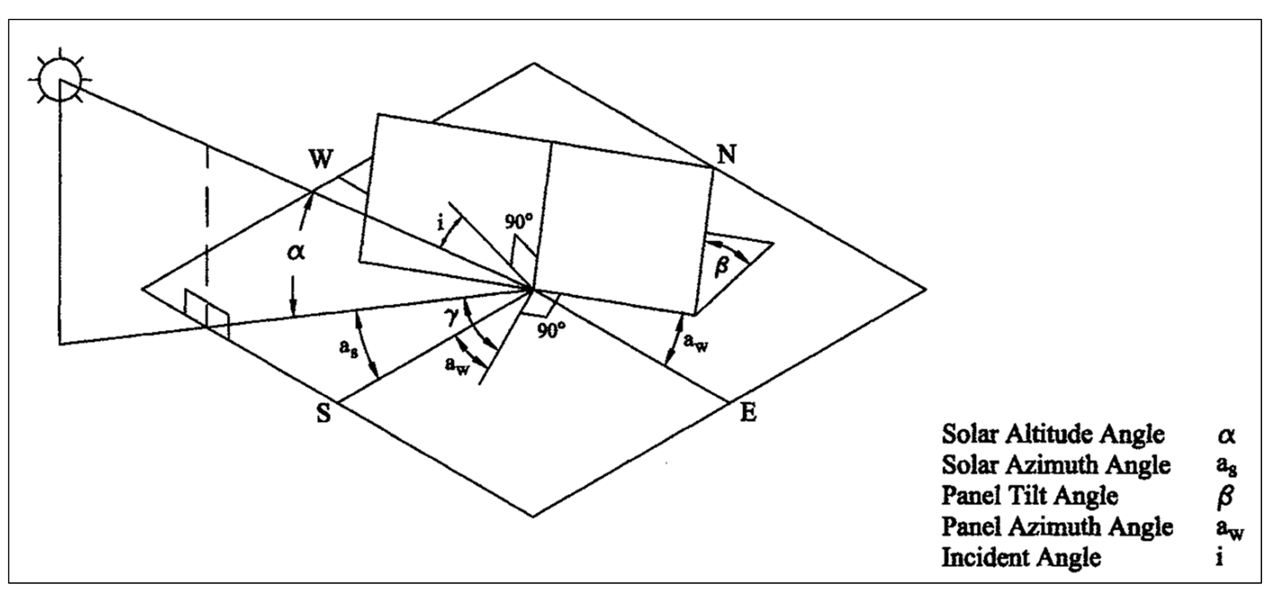

Figure 1. Definitions of solar angles for a tilted surface. *Courtesy of Goswami, Principles of Solar Engineering, 2nd ed.*

  - Key Equations

$$\delta_s = 23.45^0 \sin[360(284+n)365^0]$$

$$\sin\alpha = \sin L \sin\delta_s + \cos L \cos\delta_s \cos h_s$$

$$\sin a_s = \cos\delta_s \sin h_s / \cos\alpha$$

$$h_s = \frac{\text{minutes from local solar noon}}{4\ \text{min/degree}}$$

Where, n is the day number during the a year with January 1 being n = 1;
δ_s is solar declination angle; α is solar altitude angle; L is local latitude angle
α_s is solar azimuth angle; h_s is solar hour angle

  - Using the four equations above with given latitude angle and measured azimuth angle, the optimum solar altitude angle and local time to take data are calculated depending on each day.

- Pyrheliometer
  - Model: Hukseflux DR01
  - Measure Direct Solar Radiation
  - Measurement Range: 0 – 2000 W/m^2
  - Full Field of View Angle: 5^0
  - Sensitivity: 10.46 µV/(W/m^2)
  - Response Time: 18 sec

Figure 2. Pyrheliometer by Hukseflux. *Courtesy of Hukseflux.*

- Data Logger
  - Model: Omega OM-DAQPRO-5300
  - Eight-channel Data Logger
  - Synched with DaqPro Software
  - Range 0 – 50 mV
    - Resolution: 3 µV
    - Accuracy: ±0.5% FS

Figure 3. Data Logger by Omega. *Courtesy of Omega.*

- Weather Station
  - Model: Davis Instruments Wireless Vantage Pro2
  - Solar-powered Integrated Sensor Suite: Rain Collector, Temperature and Humidity Sensors, and Anemometer
  - Wireless Console range up to 1000 ft
  - Fast updates every 2.5 seconds

Figure 4. Weather Station. *Courtesy of Davis Instruments.*

DESIGN AND FABRICATION

- Mounting Bracket and Pyrheliometer

(a) (b) (c)
Figure 5. Mounting Bracket. (a) Solidworks Modeling. (b) Fabricated Bracket. (c) Full Assembly with Pyrheliometer

- Weather Station

(a) (b) (c)
Figure 6. (a) Weather Station. (b) Weather Station with Solar Panels. (c) Weather Station Console and Omega Data Logger

RESULTS

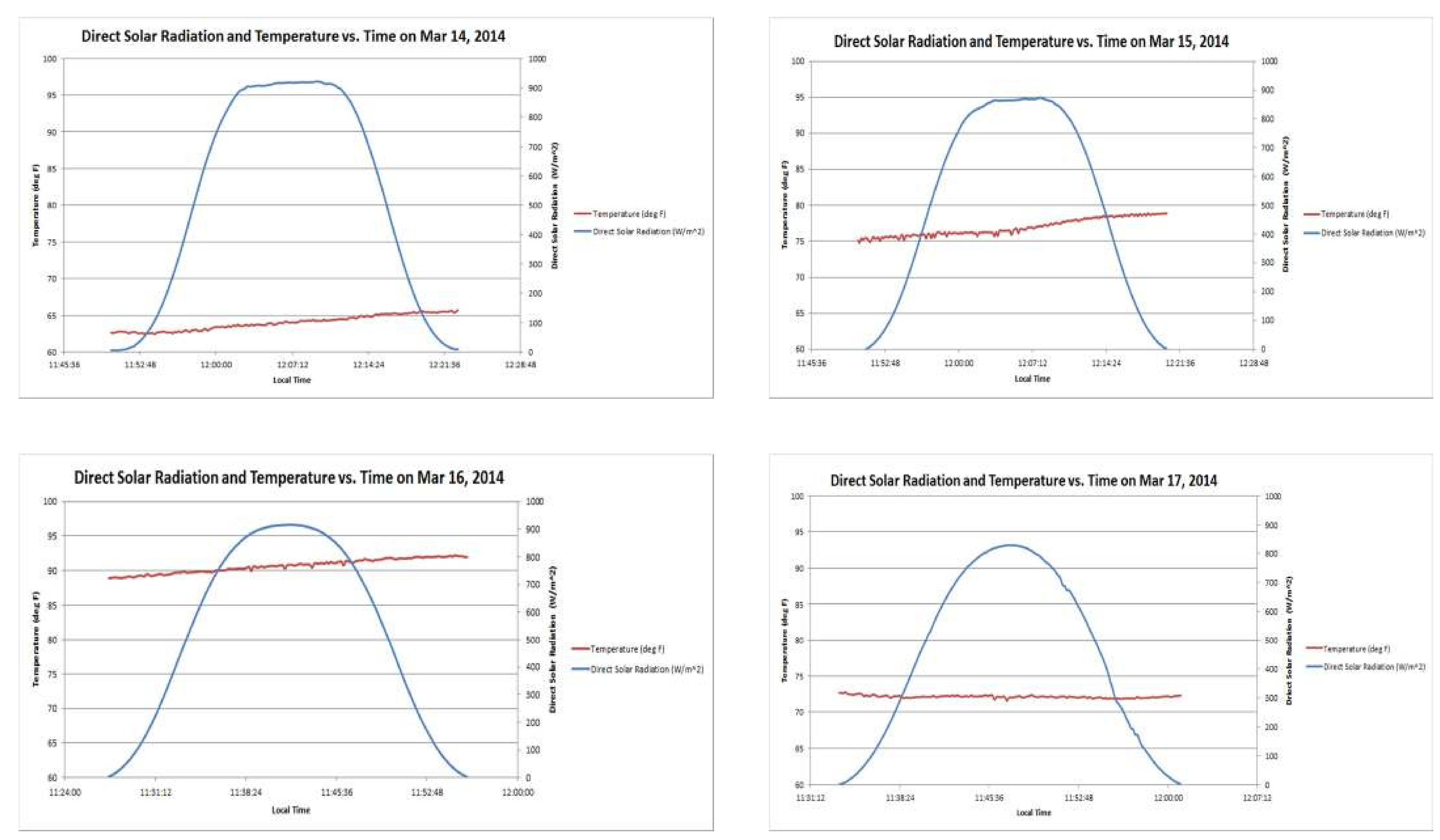

Figure 7. Direct Solar Radiation vs. Time and Temperature vs. Time plots

DISCUSSION/FUTURE WORK

The direct solar radiation and outside temperature measured by the Pyrheliometer are in the expected ranges, which proved that the Pyrheliometer is working properly. However, the solar altitude angle needs to be adjusted weekly or bi-weekly in order to measure the maximum possible direct solar radiation. In the future, it is necessary to develop a solar tracker for more accurate results and convenience. In addition, instruments setup procedures for ME 407L Solar Thermal Engineering Laboratory should be written for educational purposes.

ACKNOWLEDGEMENTS

Special thanks to Dr. Kevin Anderson, ME Professor and Faculty Advisor, to David LeFay, ME Lab Technician, for their valuable guidance and support; and to Kevin Martin for his contribution as a dedicated teammate to the project.

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