Thrust Area 4: Solar (Thermal)

Concentrating Solar Power Program

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Description: The objective of this effort is to produce a detailed map of Florida that shows the monthly solar direct beam and global resource available for the past eleven years. This solar resource map will give potential users or designers of solar systems, the solar input values for their location latitude and longitude and they will receive a table of solar energy monthly averages for that specific site as derived from the past eleven years of data. The concept employed to determine these solar values is to use NOAA satellite photos and utilize the brightness of the cloud cover as a clearness factor predictor of the solar resource that gets through to the ground below.

Budget: $50,000
University: UCF/FSEC

Progress Summary

The objective of this effort is to produce a detailed map of Florida that shows the monthly solar direct beam and global resource available for the past eleven years. This solar resource map will give potential users or designers of solar systems, the solar input values for their location latitude and longitude and they will receive a table of solar energy monthly averages for that specific site as derived from the past eleven years of data. The concept employed to determine these solar values is to use NOAA satellite photos and utilize the brightness of the cloud cover as a clearness factor predictor of the solar resource that gets through to the ground below.

The process used to determine the solar direct bean and global resource was to first complete a literature search. From the literature and experience, equations were derived and programmed that predict theoretical optimum clear sky daily insolation (Hc). The clearness value (x) of each pixel in satellite photos was used to mediate the clear sky insolation values to produce ground level predicted values (H) for that pixel area (5 miles x 5 miles). The hypothesis was tested by using NOAA weather satellite data from summer and fall of 2010 retrieved, and real irradiance values were measured at FSEC. Correlations (r sq) of predicted vs. real values were found to be above 0.90 at the 95% confidence level. This work validated the concept to provide a “go” for the purchase of archive data.

Daytime satellite photos of the past eleven years were purchased from NOAA archives. The archive photos provide a 200 by 100 pixel area that includes Florida. In each photo, a pixel covers a 5 mile x 5 mile square and there are 10,272 pixels over the Florida area in each photo. Using printed NOAA navigational charts, latitude-longitude values were assigned to each pixel. The 20,075 photos were reviewed and if any anomalies (blank areas or bands across the photo) were found, the photo was corrected. Programs were written to correct photos, determine darkest tones, calculate normalized brightness value and, finally, the output the theoretical clear sky direct beam solar energy available for each day of the year for each Florida location (value Hc in the general equation above).

Using the NOAA historical data sets now developed and actual ground measured data taken at FSEC, new correlations were developed that calculate the ground measured direct beam and direct diffuse solar daily insolation. Using these correlations, solar direct beam and direct diffuse radiation values were calculated for each day of the eleven year data base for each of the 10,272 Florida locations (each pixel). Each daily value for each location was averaged across the 11 years of data to produce an average value representative of each day of the year. Daily values for each month were then averaged to produce direct beam and direct diffuse monthly averages for each of the Florida locations. These monthly data were also averaged to produce an annual average data set. Monthly averages and annual average data were formulated into a master table and loaded into an excel spread sheet. An excel program was written that when given a Florida latitude and longitude as input, it retrieves the specific table of the expected monthly direct beam and direct diffuse averages for that Florida location in both W/sq m. and Btu/sq ft. formats.

The excel algorithms were incorporated into a web page format and a Google based map was provided to allow a user to select a physical geographical location in Florida and by clicking on that location, the latitude and longitude of the location is determined and the appropriate table representing that location of monthly averages and annual averages is provided the user. This web page is provided as a link titled “Solar Resource Calculator” on the “Customer” page of the Florida Solar Energy Center web site. The direct link is http://livewire.fsec.ucf.edu/src/

Thus, derived from historical weather satellite data, direct beam and direct global solar resource data are now available for any latitude-longitude location in Florida., These data are especially critical for evaluation of concentrating collectors which use only direct beam sunlight.

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A literature search was completed and the equations to predict theoretical optimum clear sky daily insolation (Hc) were programmed. The clearness value (x) of each pixel in satellite photos was used to mediate the clear sky insolation values to produce ground level predicted values (H) for that pixel area (5 miles x 5 miles) by the general equation:

$$H = Hc\,(a + b\mathrm{EXP}(-x/c))$$

Where a , b, and c are correlation coefficients. The hypothesis was tested by using NOAA weather satellite data from summer and fall of 2010 retrieved over the internet, and real irradiance values measured at FSEC. Correlations (r sq) of predicted vs. real values were found to be above 0.90 at the 95% confidence level. This work validated the concept to provide a “go” for the purchase of archive data.

Daytime satellite photos of the past eleven years were purchased from NOAA archives. The archive photos provide a 200 by 100 pixel area that includes Florida. These photos were cropped to generate a photo approximately 100 by 100 pixels that includes Florida. In each photo, a pixel covers a 5 mile x 5 mile square and there are 10,272 pixels over the Florida area in each photo. Using printed NOAA navigational charts, latitude-longitude values were assigned to each pixel. The 20,075 photos were reviewed and if any anomalies (blank areas or bands across the photo) were found, the photo was corrected. Because the gray scale map varied among photos, a program was written to correct all photos to represent a standard gray scale map and all photos' pixels were adjusted to this gray scale base with this program. A program was written that searched the pixel files to determine the darkest tone recorded for each location and these were determined. A program was written that calculated the normalized brightness value (value x in the equation above) for each pixel of each photo and these were loaded into master "clearness" files. A program was written that calculated and output the theoretical clear sky direct beam solar energy available for each day of the year for each Florida location (value Hc in the equation above).

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Thus, derived from the last eleven years of historical weather satellite data, direct beam and direct global solar resource data are now available for any latitude-longitude location in Florida., These data are especially critical for evaluation of concentrating collectors which use only direct beam sunlight. With these data and given a potential site for a solar installation in Florida, calculations can be made to make viable comparisons of the various solar configurations, concentrating collectors vs. photovoltaic for example, and the data is now available to calculate a particular solar installation sizing to meet a given load.