The Ravina Project

Summer 2007 Data Run 04

Comparing Array Angles

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Comparing Array Angles

Introduction

In this paper we present the data from our Summer 2007 data run. We collected data to compare two angles, 28 degrees from horizontal which is the industry standard angle for this latitude (43 degrees north) and flat (zero degrees from horizontal). The zero degree angle was chosen because our calculations indicated it would generate more power over the course of a summer.

We present the data in this paper and a short commentary on the statistical relevance between the data sets by Prof. Fraser Bleasdale from Trent University.

Method

Each day during the data run from May 7th to August 5th inclusive we collected power generation data. On alternate days we either had the array set at 28 degrees or zero degrees. The 25th of June was left out of the data. By leaving it out we changed the periodicity of alternating days by 180 degrees. This was done to eliminate any effects of a possible 48 hour weather cycle.

Data

The 28 degree elevation data is listed below.

Angle 28 Degree Data

Date	kWh Gen
8-May-2007	8.0
10-May-2007	7.0
12-May-2007	6.5
14-May-2007	5.4
16-May-2007	1.1
18-May-2007	8.9
20-May-2007	6.8
22-May-2007	7.3
24-May-2007	7.3
26-May-2007	5.8
28-May-2007	8.0
30-May-2007	8.0
1-Jun-2007	3.8
3-Jun-2007	3.2
5-Jun-2007	2.9
7-Jun-2007	7.1

9-Jun-2007	8.9
11-Jun-2007	8.4
13-Jun-2007	8.0
15-Jun-2007	8.4
17-Jun-2007	7.5
19-Jun-2007	3.8
21-Jun-2007	8.1
23-Jun-2007	8.3
26-Jun-2007	7.7
28-Jun-2007	8.1
30-Jun-2007	6.9
2-Jul-2007	7.8
4-Jul-2007	1.0
6-Jul-2007	7.1
8-Jul-2007	2.7
10-Jul-2007	7.1
12-Jul-2007	7.5
14-Jul-2007	1.7
16-Jul-2007	7.1
18-Jul-2007	7.0
20-Jul-2007	7.8
22-Jul-2007	8.0
24-Jul-2007	5.0
26-Jul-2007	7.0
28-Jul-2007	5.8
30-Jul-2007	7.8
1-Aug-2007	7.2
3-Aug-2007	6.6
5-Aug-2007	7.5

Some Statistics for the 28 Degree Data Run

average	6.5	kWh
median	7.1	kWh
stdev	2.1	kWh

Total Gen	292.9	kWh

Angle Zero Degree Data

Date	kWh Gen
7-May-2007	8.5
9-May-2007	4.4
11-May-2007	8.1
13-May-2007	8.8
15-May-2007	6.1
17-May-2007	7.7

19-May-2007	8.8
21-May-2007	9.1
23-May-2007	8.2
25-May-2007	6.1
27-May-2007	2.6
29-May-2007	9.0
31-May-2007	4.1
2-Jun-2007	7.5
4-Jun-2007	4.7
6-Jun-2007	6.7
8-Jun-2007	6.8
10-Jun-2007	9.1
12-Jun-2007	8.2
14-Jun-2007	9.4
16-Jun-2007	6.5
18-Jun-2007	7.7
20-Jun-2007	8.6
22-Jun-2007	9.3
24-Jun-2007	8.5
27-Jun-2007	6.6
29-Jun-2007	9.3
1-Jul-2007	6.5
3-Jul-2007	8.0
5-Jul-2007	5.8
7-Jul-2007	6.6
9-Jul-2007	6.4
11-Jul-2007	6.4
13-Jul-2007	6.5
15-Jul-2007	6.5
17-Jul-2007	6.0
19-Jul-2007	5.1
21-Jul-2007	7.9
23-Jul-2007	5.6
25-Jul-2007	7.4
27-Jul-2007	2.7
29-Jul-2007	8.2
31-Jul-2007	7.2
2-Aug-2007	6.7
4-Aug-2007	8.3

Some Statistics for the Zero Degree Data Run

average	7.1	kWh
median	7.2	kWh
stdev	1.7	kWh

Total Gen	318.2	kWh

Analysis

Here is an excerpt from Prof Bleasdale's commentary on the statistical significance of the data.

"*I used the rank order for each day (calculated first for 0 degree angle then separately for 28 degree angle) as a covariate with KWHrs produced each day as the dependent variable in an Analysis of Covariance to compare the difference between the two angles. The results of the Analysis of covariance indicated that the difference in KWhrs produced was significantly better for the 0 degree angle than for the 28 degree angle. The second attachment shows that the significance level was .001 which means the probability that the difference between the two angles being just an experimental fluke created by random sampling error is less that 1 in a 1000, which is good enough for most scientists to bet their careers that they have an effect that is real.* "

We expect that others will take the data published above and subject it to statistical analysis. If you do such an analysis please let us know. We would like to know your results.

Conclusions

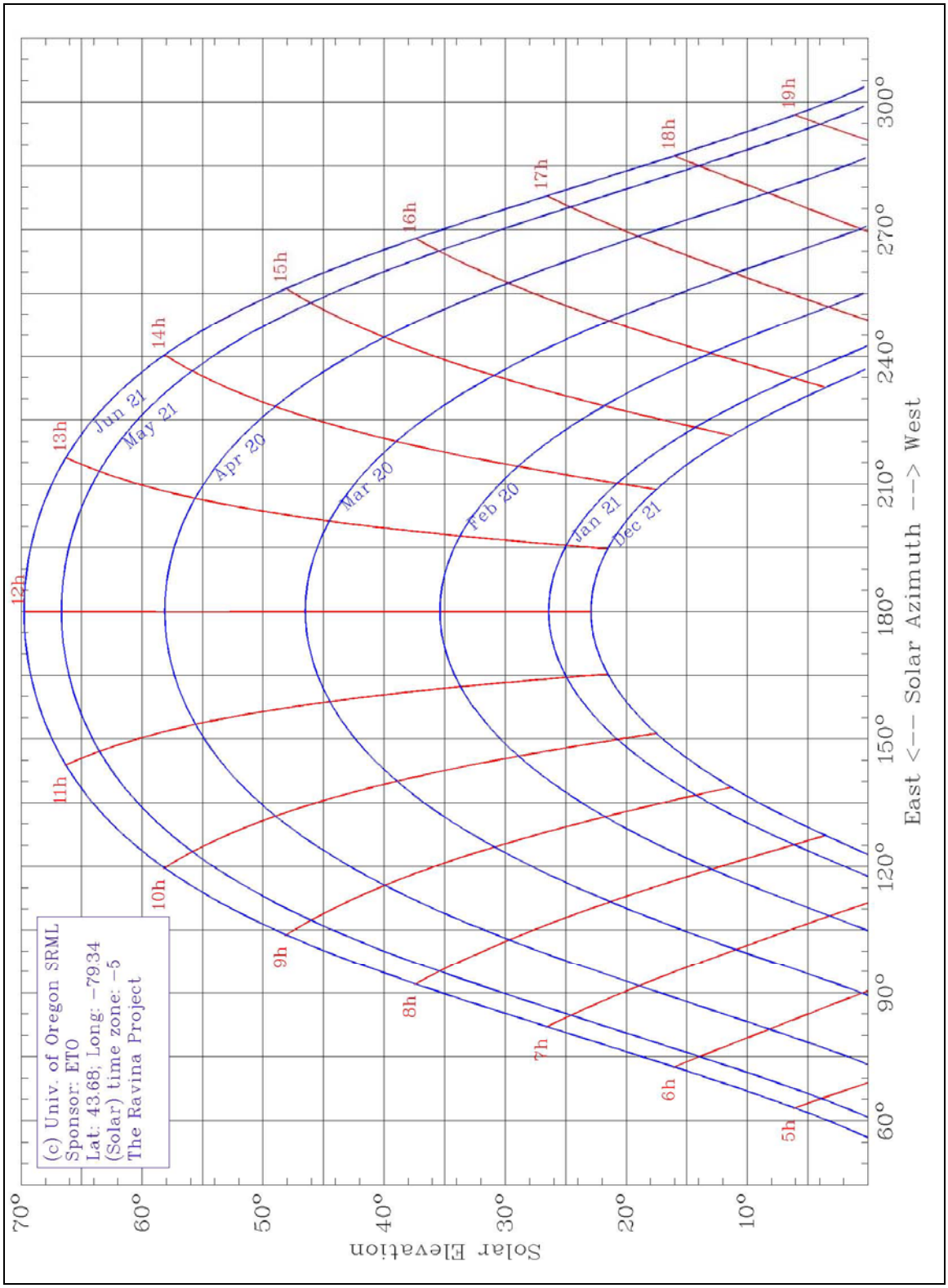
We will repeat the experiment over the next four summers to see if the trend holds up.

Our calculations indicate that at this latitude, the sun spends a significant amount of the day, both in the morning and in the evening, behind a tilted array's East-West axis. This geometry, caused by the sun's azimuth, tends to increase the acuteness of the sun's rays upon the collecting surface during the morning and evenings, which during the summer time here, can be quite lengthy. We know that more acute sun angles generate less power. Laying the array flat eliminates any effects that azimuth might have upon power production.

A good location for sun here will have access to summer sun angles over an azimuth range of 240 degrees. That is, the summer sun may vary by +/-120 degrees from south (180 degrees azimuth) and not encounter any objects that shade the array surface.

During the three summer months here the sun rises around azimuth 60 degrees and sets around azimuth 300. If a solar array is installed facing an azimuth of 180 degrees, that is, pointing south, the half power point of the collector occurs at about 9:45 AM sun time on May 21st. At that time the offset angle of the sun on the horizontal or azimuth axis is 60 degrees because the sun is at azimuth 120 degrees. The altitude of the sun is about 54 degrees which when added to the 28 degree tilt gives a sun offset of 8 degrees on the collector's vertical axis. The collector is producing near full power on its vertical axis yet only half power on the horizontal axis. As a result the whole collector is working at half power. At 9:50 AM the sun has been above the horizon for at least 5 hours. So for those 5 hours the collector has been averaging much less than half power. This sun geometry and the times given are typical of the three summer months here in Toronto.

When the collector is flat it reaches half power at about 7:30 AM (with the sun greater than 30 degrees above the horizon) more than 2 hours before the tilted array. The same process occurs in reverse during the last five hours of the day.


Solar Elevation
East <-- Solar Azimuth --> West
70°
60°
50°
40°
30°
20°
10°
60°
90°
120°
150°
180°
210°
240°
270°
300°
5h
6h
7h
8h
9h
10h
11h
12h
13h
14h
15h
16h
17h
18h
19h
Jun 21
May 21
Apr 20
Mar 20
Feb 20
Jan 21
Dec 21
(c) Univ. of Oregon SRML
Sponsor: ETO
Lat: 43.68; Long: -79.34
(Solar) time zone: -5
The Ravina Project

"If we knew what we were doing, it would not be called research."
- A. Einstein

Project Directors

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Friends of The Ravina Project

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NABCEP Certified Solar PV Installer™
Designer of the Dynamic Array structure

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Trent University

