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Optimization of Orientation of Photovoltaic Cells to Match Electricity Demand

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The aim of my project was to optimize the orientation, that is to find the best slope and azimuth of Photovoltaic (PV, solar) cells to match electricity demand. The slope is the angle at which the collectors are mounted relative to the horizontal whereas the azimuth is the direction towards which the PV collectors are faced.

Solar radiation that reaches the earth's surface can be split into two categories: direct solar radiation that passes through the atmosphere directly to the earth's surface and diffuse solar radiation which is scattered or reflected to the surface. While not all solar radiation is converted to the electricity we can introduce the useful solar radiation E(t) by the following formula:

$$E(t) = \text{efficiency} \ [\ I_{direct}(t) \ + I_{diffuse}(t)]$$

Here efficiency parameter varies depending on the type of solar cells. Direct radiation ($I_{direct}(t)$) and diffuse radiation ($I_{diffuse}(t)$) are some functions of azimuth and slope depending on time period t. Furthermore, to achieve the aim of this project I used the unmet load u(t), which is electrical load that the power system is unable to serve. It occurs when the electrical demand L(t) exceeds the supply of photovoltaic cells E(t).

$$u(t) = L(t) - E(t)$$

In addition, to be able to find the optimum azimuth and slope I minimized the sum of the set of 8760 values representing the hourly unmet load for a single year with respect to the slope and azimuth.

$$U(t) = \sum_{1}^{8760} u(t) \qquad u(t) > 0$$

I analysed 3 different problems that possibly can arise with dealing with solar energy optimization. For example the mathematical model has shown that the optimal position for the Photovoltaic collectors in Adelaide, by looking at the electricity demand over the year, is when slope is 31 degrees from the horizontal surface and when azimuth is 17 degrees to the North- East. Whereas if we want to lower the peak demand, we get dramatically different orientation of 70 degrees to the North-West. Therefore, from this project it was possible to conclude that the best orientation for PV collectors depends on the question to be investigated.

In conclusion, the summer vacation scholarship was great way to get to know a number of mathematicians and to find out more about carriers in mathematics. It gave me an insight into research and importance of solar energy. I am very thankful for the opportunity that I had to attend Big Day In and to visit Sydney for the first time in my life.

Zivana received an ICE-EM Vacation Scholarship in December 2005.
See www.ice-em.org.au/students.html#scholarships05