Economic Optimisation of PV Panel Orientation for Commercial Installations

A PGDipSci in Energy Science Dissertation by Xiaodong Shu, University of Otago

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Introduction

With the rapidly falling cost of photovoltaic (PV) modules there has been an increasing interest in installing PV solar panels on buildings to generate electricity and offset the cost of buying electricity from the grid. A student research project was carried out to evaluate the economics of rooftop PV for commercial organizations.

The conventional approach to installing PV panels has been to orient them towards the north and tilted at an angle that maximizes year-round generation of electricity. However, this orientation is not necessarily the most economic orientation for commercial institutions. This is because solar radiation intensity and therefore electricity generation peaks during the middle of the day, whereas commercial electricity prices unlike residential prices vary during the day and are often higher during the morning and evening. Figure 1 shows a comparison of the daily variation of a solar panel and commercial electricity prices.

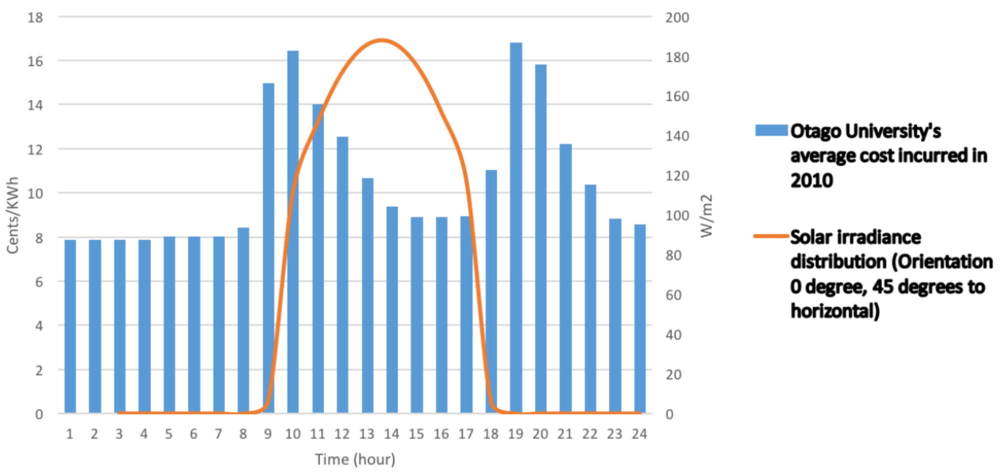

Figure 1: Average daily variation of commercial prices (we have used the Otago University's electricity costs including time of use and congestion charges) and solar irradiance in Dunedin on a panel oriented North and tilted 45 degrees to the horizontal (the optimum for Dunedin).

The aim of this project was to determine the optimum orientation and angle of a PV panel given varying commercial electricity charges.

Method

The project consisted of developing a detailed model of the amount of solar radiance on a PV panel oriented in and direction. The model was developed along the lines of Ref. [1]. Due to the seasonal nature of solar irradiance and electricity charges the economic evaluation was carried out over a full year. 2010 was chosen as the year for evaluation due to the availability of data. Solar irradiance data for 2010 was collected from the University of Otago Physics weather station for the model [2]. Electricity generation data from the PV installation on the St David lecture theater at the University of Otago was used to calibrate the model. The economic evaluation was carried out using the University of Otago's 2010 electricity charges. The evaluation was carried out for a full year based on hour-level data for both irradiance and charges. The economics of a number of other pricing scenarios were also evaluated. Note that in the analysis we assumed that all electricity was consumed on site.

Results

The predicted energy from the model and the measured energy from one of the St David PV panels over a week-long period are shown in Figure 2. The good agreement demonstrates the validity of the model.

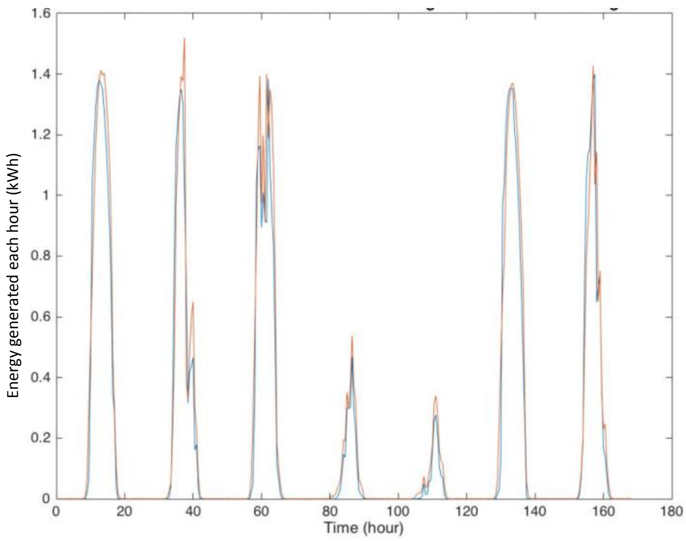

Figure 2: A comparison between the energy generated each hour from one of the St David PV panels and the model prediction.

The annual savings due to self-generated electricity at different orientation and tilt angles is shown in figure 3. The key results from this figure are

- savings can vary by a factor of 2 depending on orientation
- the optimum angle for 2010 was 20 degrees to the east of North providing slightly more overlap with the morning peak in charges and 45 degrees to the horizontal
- the savings are relativity insensitive to angle and orientation within +/-20 degrees about the optimum

Summary and discussion

A model that can predict the power output of a solar PV panel for an arbitrary orientation has been developed for Dunedin. This can be extended to other parts of the country by using appropriate solar irradiance data. The model was used to evaluate the savings potential of different orientations given varying electricity prices that are common for commercial organizations. The results show that the orientation that maximizes electricity generation is not necessarily the optimum from an economic savings perspective. A range of other pricing scenarios were also considered (see [3] for details).

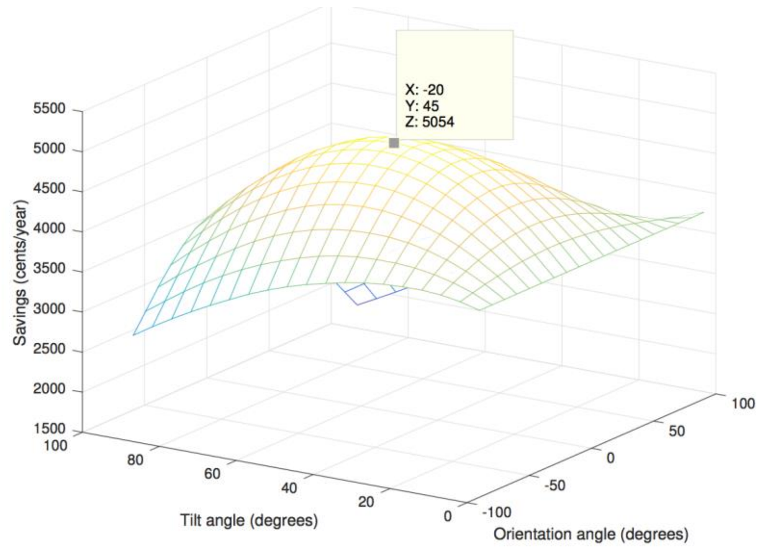

Figure 3: Annual savings for a commercial PV installation (80, 1600mm by 992 mm panels) based on University electricity charges

The results from this study have important implications for the PV installations at commercial sites. Our model enables a commercial site to evaluate the savings from different orientations depending on the precise electricity charges at their site.

From an environmental perspective, one could object to optimizing on economic savings rather than renewable electricity generation. However, the variation in electricity prices is a reflection of constraints on the electricity grid - higher prices signaling that supply at a particular location is not able to keep up with demand. PV solar generation during these times is therefore beneficial to the grid as a whole. A particular case of this will occur if PV solar becomes widespread in a particular region. In this case, with all panels oriented to optimize energy generation, there will be excess energy during the middle of the day making balancing the grid even more difficult and resulting in price rises. This situation can be mitigated if time-of-use pricing reflects the true costs of supply and the choice of orientation of panels is driven by economic savings rather than energy generation.

These results also have policy implications. Current building regulations specify that panels should be oriented to maximize energy generation, however as explained above this is not necessarily the optimal orientation from an economic perspective. These regulations may therefore reduce the economic viability of a PV installation making it more difficult to reach renewable energy and GHG targets.

References

[1] David Santos-Martin and Scott Lemon. *SoL - A PV generation model for grid integration analysis in distribution networks*. Solar Energy, 120:549-564, 2015.

[2] http://www.physics.otago.ac.nz/eman/weather_station

[3] Xiaodong Shu, *Economic Optimisation of PV Panel Orientation for Commercial Installations* (PGDipSci dissertation, Physics Department Otago, 2016)