Integrating a Solar Concentrator Photovoltaic Array with a Grid-connected Commercial Building

Andrew Tubesing, Kevin Wedeward

Department of Electrical Engineering, New Mexico Institute of Mining and Technology, Socorro NM USA

Introduction

This study evaluates the integration of a solar concentrator photovoltaic array (CPV) system with a commercial building's energy load and its electric grid connection. Solar resource conversion, load characterization, power quality, and grid integration are the primary aspects addressed by the study.

Local solar radiation and renewable energy source (RES) conversion data were used to determine a profile for annual energy production of the CPV, which uses a non-traditional method of solar energy conversion. The load was characterized by creating an annual profile for the building's power demand using a combination of historical monthly billing data and a week of detailed real-time power consumption data (real, reactive, and apparent).

A custom power balance analysis was performed, both in time segments and total project lifetime figures. This quantifies, at one-minute resolution, the energy produced by the RES, consumed by the building, and metered to and from the grid.

The study concludes that the CPV system will make a valuable contribution to the energy supply, it can pay for itself in energy savings over a number of years, and it provides a substantial environmental benefit by reducing pollutant emissions. Financial considerations are dependent upon a number of variables, including the panel quantity, buy/sell prices of grid energy, project lifetime, financing options, and renewable energy credit programs.

Background

The study was performed for a commercial building in Playas, New Mexico, a small town treated as a microgrid with a single utility electrical connection. The study utilized Solar radiation data from nearby Las Cruces and Deming NM, and weather data from Hachita NM.

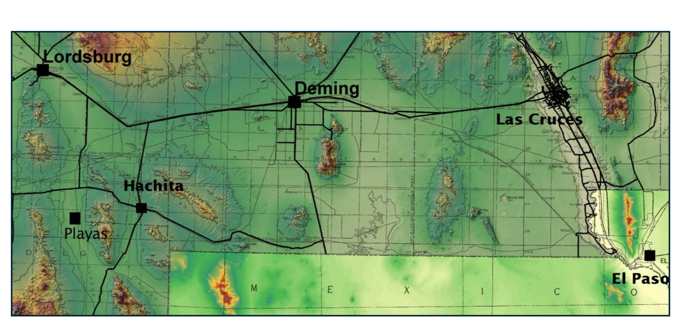

Figure 1

Concentrator Photovoltaic Array (CPV)

The Concentrator Photovoltaic Array (CPV), made by Emcore (Figure 2), uses an array of Fresnel lenses to focus a large area of sunlight onto small PV cells, increasing efficiency and reducing total PV surface area. It is rated for 25 kW, measures 18 x 8 m, and weighs 8620 kg. A precision tracking system keeps the panel normal to the direct solar rays with accuracy error of less than 1°.

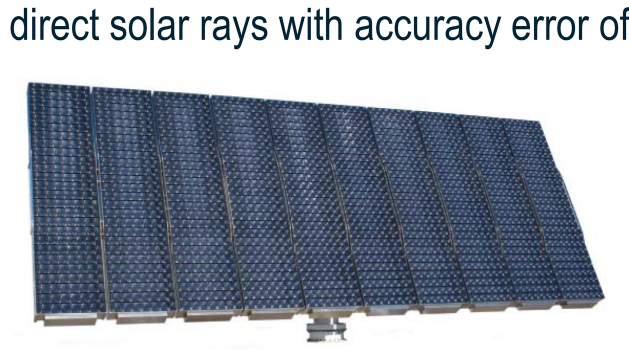

Figure 2

Characterizing the CPV Source

Power output data for a single day test of the CPV (Figure 3) was combined with actual solar data collected for that day (Figure 4) to characterize its power output as a function of solar radiation.

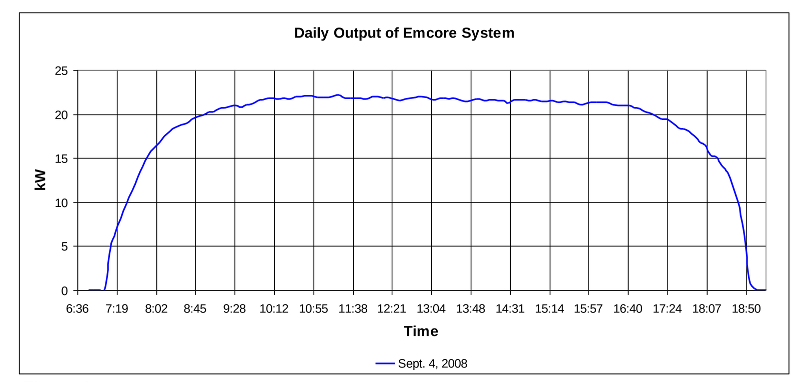

Figure 3

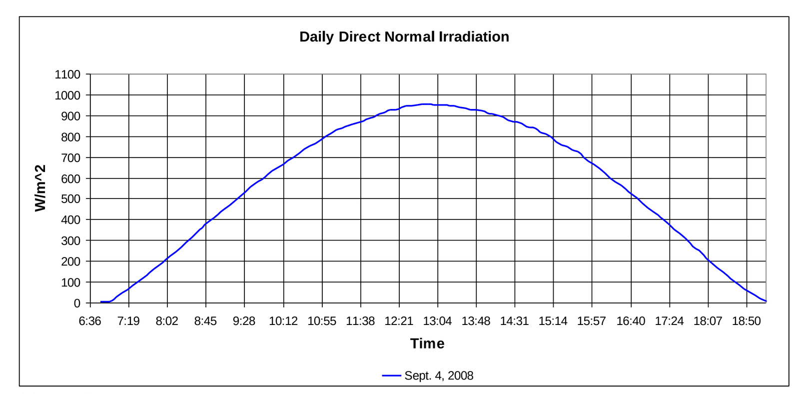

Figure 4

A polynomial was fit to the solar and production data (Figure 5) and tested on the original day's data to validate its use for projecting CPV output for given solar exposure (Figure 6).

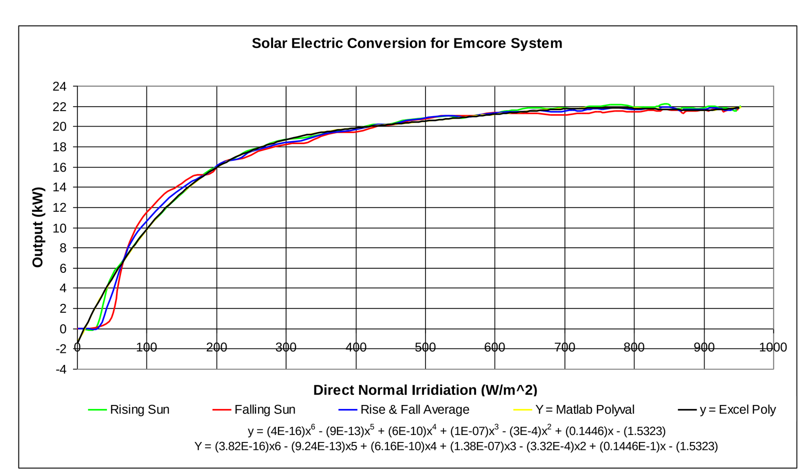

Figure 5

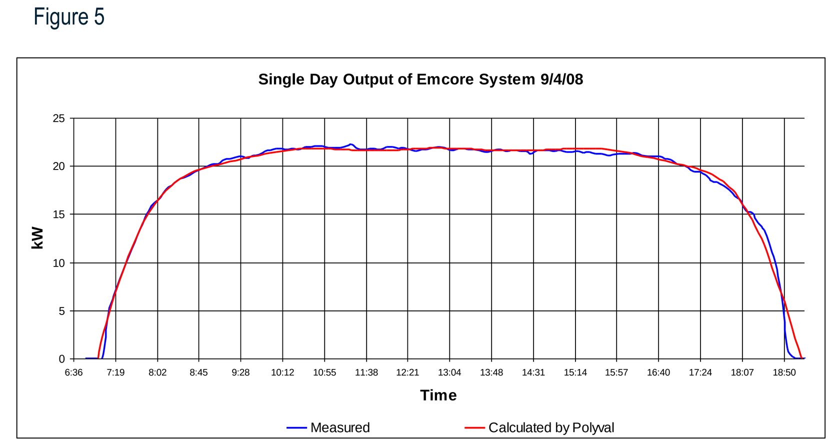

Figure 6

Solar Resource Profile

Expected annual solar radiation for the site was projected to one-minute resolution using linear interpolation of a full year of five-minute resolution data from 1999 collected in Las Cruces NM. Geographical equivalence of the two sites was confirmed to ensure maximum compatibility. Secondary validation of solar data utilized another collection site in Deming NM, and the Bird Clear Sky solar prediction model.

Annual Source Production Profile

Solar resource data for each minute of the year was passed through the polynomial from Figure 6 to determine expected output from the CPV at one-minute resolution for the entire year.

Characterizing the Building Load

The building load was characterized using both historical data from monthly electric bills and a set of detailed real-time data collected over a single week on site by a GE/Multilin SubMeter.

Three years of utility bills were compiled to determine a three-year average for total monthly consumption (Figure 7).

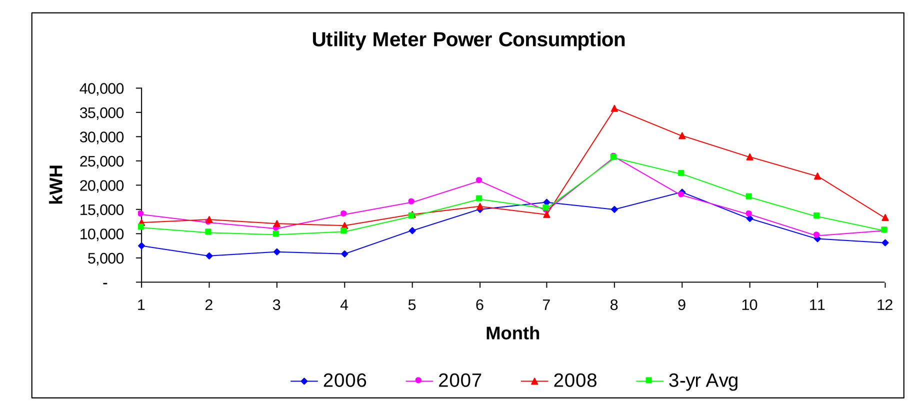

Figure 7

A single week sample period logged real, reactive, and apparent power at one-minute resolution for the load (Figure 8 below). Minimal reactive power indicates the load power factor is close to the ideal of 1. Work day consumption peaks can be observed between 0600 and 1800 hours, with an early taper on Friday.

Annual Load Consumption Profile

The sample week was analyzed to determine the amount of weekly total consumption that was likely distributed over each minute of the week. Assuming that this sample week represents a typical seven-day consumption pattern, twelve months of proportional data were compiled, creating an expected energy usage proportion of the monthly bill for each minute of the month.

For each month, the three-year monthly consumption averages were multiplied by the figures in the monthly proportional per-minute share to determine each minute's likely electricity usage. The twelve months were then assembled to generate an annual consumption profile that estimates energy usage for every minute of the year.

Power Balance Analysis

The per-minute annual profiles generated by the source and load characterizations were used to predict a power balance sum for each minute of the year.

Figure 9 below plots a sample day that shows load consumption in violet for times when grid power is being used and red for times when surplus energy is being generated by the source. CPV production for a single panel is shown in blue. Surplus energy is shown in green as negative power, which is available to sell back to the utility using net metering, to store locally (if such capacity were installed) or to supply additional loads.

During daylight hours a single CPV panel can supply the energy to the entire load, and generates a modest surplus. Evaluations using multiple CPV panels simply showed higher CPV production and surplus energy with minimal impact on grid energy usage.

An analysis spreadsheet was created to calculate environmental and financial implications of integrating the CPV into the building system, as well as cost/benefit analysis for the system lifetime.

Conclusion

In cases such as Playas where net-metered energy is not exchanged evenly, and/or when renewable energy credits (REC) are not available, maximum benefit is achieved when most or all of the CPV output is utilized on-site. In situations where net metering and REC programs are more advantageous, additional on-site generation capacity can be more effectively exploited. Depending on specific programs and the number of panels used, the system is capable of paying for itself over a number of years.

Regardless of the financial benefits, integration of the CPV into the building/grid system will reduce its environmental footprint substantially by reducing pollutant emissions that would otherwise have been generated by traditional power plants. At minimum, a single panel saves of 50,000 kg of CO_2 annually.

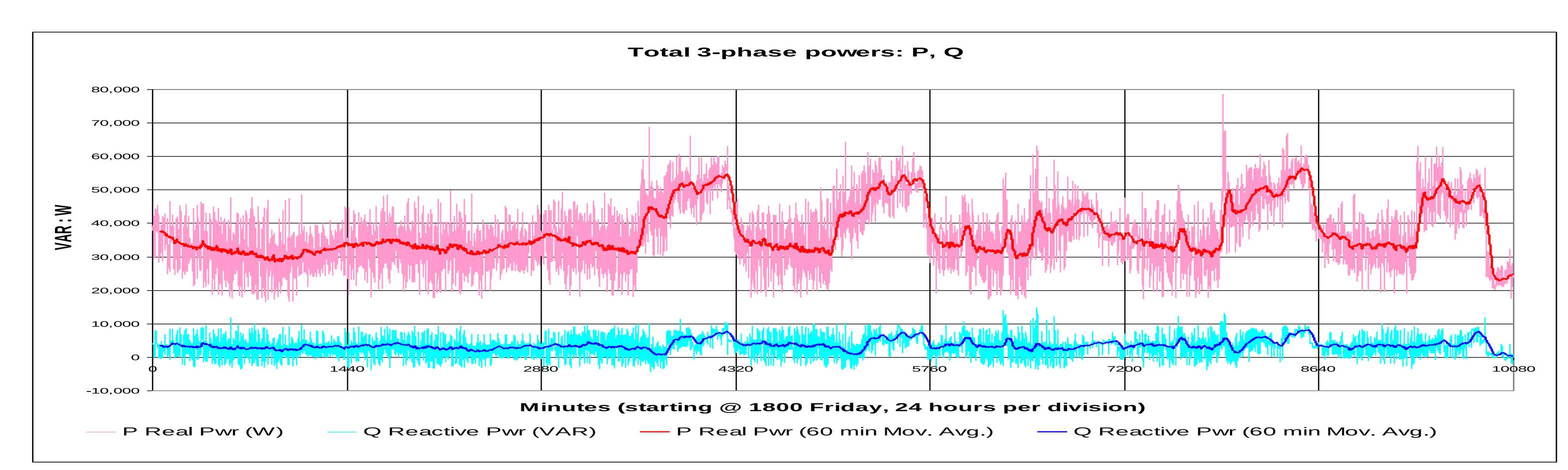

Figure 8

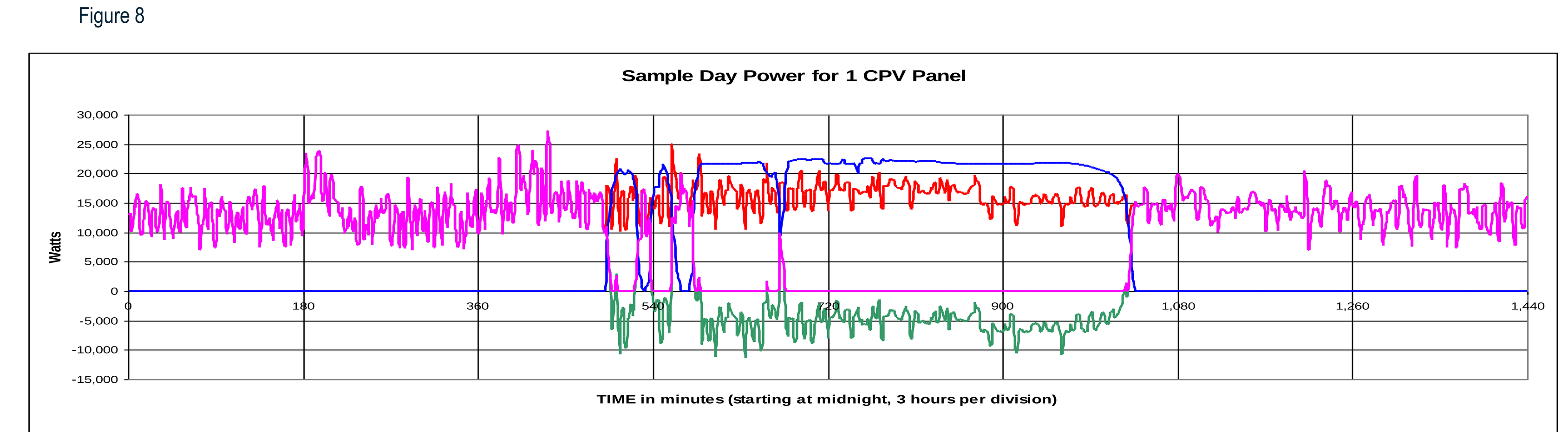

Figure 9

Contact information

Andrew Tubesing
Laboratory Manager / Instructor
Dept. of Electrical Engineering

New Mexico Institute of Mining and Technology
801 Leroy Place
Socorro NM 87110 USA

(575) 835-5205
(575) 835-5332
tubesing@ee.nmt.edu
www.ee.nmt.edu/~tubesing

Full thesis, summary paper, analysis spreadsheet, and references are available from the author's web site. www.ee.nmt.edu/~tubesing/research