Economically Optimal Solar Power Generation

Sana Badruddin
University of Ottawa, Canada

Cameron Ryan Robertson-Gillis
University of Ottawa, Canada

Janice Ashworth
Ottawa Renewable Energy Cooperative, Canada

David J. Wright
University of Ottawa, Canada

EXECUTIVE SUMMARY

The Ottawa Renewable Energy Cooperative is considering installing solar modules on the roofs of two buildings while they stay connected to the public electricity grid. Solar power produced over their own needs would be sent to the public electricity grid for a credit on their electricity bill. When they need more power than they are generating, these buildings would purchase electricity from the grid. In addition to paying for the electricity they purchase, they would be subject to a "demand charge" that applies each month to the hour during which their consumption is at a peak for that month. Any electricity consumed during that peak hour would be charged at a rate about 100 times the rate for other hours. The case addresses three questions: (1) Is it profitable for these organizations to install solar on their roofs? (2) Can profitability be increased by adding a battery? and (3) How sensitive is profitability to uncertainty in future electricity prices? The case shows how the answers to these questions depend on the profile of hourly electricity consumption during the day, which is very different from one building to the other.

BACKGROUND INFORMATION

This section provides an introduction to solar power and how it is deployed.

Photovoltaic technology, also known as PV, is the conversion of incoming solar radiation into electricity using semiconductor materials, most commonly silicon. Most readers of this case study will be familiar with images of solar panels installed in rows on rooftops and on the ground. A "solar panel" is the popular terminology for a "PV module" and most PV modules are installed in this way. In the Northern hemisphere, solar panels typically are tilted at an angle approximately equal to the latitude and are oriented towards the South since the daily path of the sun is from East to West across the Southern sky. At the equator there is zero tilt, i.e. the modules are horizontal. If PV modules were installed at the North Pole they would be vertical, i.e. tilted at 90°. In Ottawa, the ideal tilt for solar panels is approximately the latitude, 45° (Tomosk et al., 2017).

PV modules generate more electricity when they are pointed directly at the sun and some solar installations use trackers to adjust the angle of the modules, tracking the path of the sun from morning to evening. Other installations avoid the cost of a tracker and accept the fact that they will generate less electricity from a fixed orientation of their PV modules. The use of trackers in PV modules generally implies that the panels will be ground-mounted, as trackers on rooftops cause a lot of strain to the structure of roofs during periods of high wind. Since most buildings are located in an urban setting with very little adjacent land, those looking to install solar typically use rooftops with non-tracked PV.

There are two situations in which PV modules are used:

1. Utility-Scale: A large-scale solar installation supplies electric power directly to the public electricity grid in much the same way that electricity is supplied by coal, natural gas or nuclear generating stations.
2. Behind-the-Meter: Residences and businesses install solar on their own premises and typically consume most of their solar electricity for their own use. They also stay connected to the public electricity grid which is their source of electricity when there is insufficient solar power, e.g. at night or when it is cloudy.

PV is being deployed on a global scale and is becoming an increasingly popular method of energy production due to its low maintenance and zero carbon emissions. However, power generated from solar energy is limited by the availability of sunlight, which by nature is intermittent and cannot be supplied at will. As such, there is much research interest in the integration of energy storage into a PV system, to increase the capability of providing power as needed to meet customer demand (McLaren et al., 2018). A solar system installed in a commercial building and connected to a battery