Renewable and Sustainable Energy Reviews 60 (2016) 1213–1224

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

Leaving the grid—The effect of combining home energy storage with renewable energy generation☆

Stuart Speidel [a], Thomas Bräunl [b,1]

[a] The University of Western Australia, EECE/REV, Perth, Australia
[b] The University of Western Australia, School of Electrical, Electronic and Computer Engineering, 35 Stirling Highway, Crawley, Perth, WA 6009, Australia

ARTICLE INFO

Article history:
Received 8 May 2015
Received in revised form
29 October 2015
Accepted 23 December 2015

Keywords:
Renewable energy
Local energy storage
Off-grid
Grid independence
Electric vehicles

ABSTRACT

Household renewable energy generation through the use of solar panels is becoming more commonplace as the installation cost is reducing and electricity prices are rising. Solar energy is an intermittent source, only generated during the day subject to interference from weather and seasonal variation. Energy storage solutions such as Lithium Ion batteries are also reducing is cost and have become a viable solution for storing the solar energy generated for use at other times.

In this paper we discuss the feasibility and limitations of various renewable energy, energy storage, feed into grid and off the grid systems. We also explore the results of our case study, The University of Western Australia's Future Farm, which featured a 10 kW solar system with 20 kWh battery storage, off the grid. Finally we use West Australians daily energy usage information to model the energy and savings of installing solar panels, home energy storage and using an electric vehicle.

Contents

☆This research has been supported by the Australian Research Council under Linkage Grant LP100100436.
E-mail addresses: sjmspeidel@gmail.com (S. Speidel), braunl@ee.uwa.edu.au (T. Bräunl).
[1] Tel.: +61 8 6488 3897, fax: +61 8 6488 1168.

http://dx.doi.org/10.1016/j.rser.2015.12.325
1364-0321/

1. Introduction

Being of the grid is a reality for many Australian farms. Not by choice, but simply because they are too far off the beaten track. Today, leaving the grid may become an interesting option for home owners even in suburban or city locations, when combining local energy generation with local energy storage.

Whenever the feed-in tariff is equal or higher than the cost for buying energy, the grid can be used as a very convenient energy buffer, i.e. generate enough energy during the sunshine hours for a full day's energy requirements, feed back to the grid all the surplus energy, and draw back from the grid during the dark evening and morning hours.

However, many countries still have now discontinued the generous feed-in tariffs of the past, so this method will not work anymore. Germany, for example has a feed-in tariff of 0.1315 EUR per kWh [1], while buying energy from the grid costs 0.27 EUR per kWh [2] as of July 1st 2014. In Western Australia (WA) the situation is even more extreme. The energy utility only pays 0.09 AUD per kWh [3] of home-generated green energy, while buying from the grid costs 0.26 AUD per kWh [4]. In addition, WA's energy retailer has reserved the right to approve feed-in from any energy generator above 5 kW, so larger solar PV systems may not be allowed onto the grid, and the utility also does not guarantee to buy any generated energy (even at the low price) at times of low demand and high renewable generation (i.e. around mid-day).

These circumstances plus the monthly grid-connection fees make local energy storage systems a very interesting option. They will reduce dependence on the grid by maximizing one's own generated renewable energy usage, up to allowing one to completely leave the grid.

The interest and demand for integrated home battery storage is currently booming. Some manufacturers are now introducing energy storage integrated into their solar inverters with the aim of reducing the amount of energy needed from the grid [5]. There is also a large amount of research going into solving the issues associated with such systems, such as generation and storage selection optimization [6]. The Australian government is also getting involved by funding a pilot project for small scale energy storage for households [7].

The University of Western Australia constructed the Future Farm as a best practice farm using the technologies we have available today to show the potential for farms in the future. The farm has been completely off the grid for over a year using solar panels and battery energy storage. During this time the farm saw its energy demand dramatically increase through the installation of an electric reverse-cycle air-conditioning and heating system, which brought the installed solar PV/battery storage combination to its limits.

The need to generate more energy than needed on a daily basis, in order to cover for extreme weather combinations (i.e. several cloudy days in a row), leads to inefficiencies where the potential energy generated by the panels cannot be utilized and only a fraction of the stored energy is required on an average day.

In this paper we look at domestic energy generation and storage, the effectiveness of these solutions, a tool for automatically estimating the associated data, and a case study of an off the grid solution.

2. Local energy generation

There are several commercial options available for local energy generation, including solar PV, thermal electric, wind/wave converters, biofuels, tidal schemes, hydroelectric energy and geothermal energy [8]. The ability of these systems to generate electricity depends on the location of the dwelling, its surrounding geography and weather conditions. In some applications even a combination of these methods generate the best solution [9]. Thermal electric, geothermal, wave, tidal and hydroelectric systems are only viable on a commercial scale or in very specialized locations. The two most commonly available and popular domestic power generation systems are solar PV and wind turbines. Biogas can also be converted to electricity domestically using a fuel cell, which is also discussed.

2.1. Solar PV

Solar photovoltaic systems (PV) use multiple photovoltaic modules to convert sunlight into DC electricity. The DC electricity produced can be used to charge DC batteries or supply a DC AC inverter to supply power to a household. Solar PV systems for household applications in Australia are generally sold in sizes ranging from a 1.5 kW to a 5 kW system, which is mostly due to government incentives in the past, rather than available and suitable roof space. On average in Western Australia per kW of nominal system size, a solar system will generate 1600 kWh of energy per annum [10].

The average solar system cost (including installation) by city and nominal system size was generated by Solar Choice in June 2013 [11]. This information was collected from 125 different solar installation companies around Australia and is shown in Table 1.

It has also been shown that solar resources can have their output behavior quite accurately estimated through measurements of solar radiation and ambient temperatures. In [12] they show that it is possible to predict the steady-state behavior of a grid connected network in a statistically reliable way. In this case grid connected, such predictions allow for more analytical approach do determining solar systems viability.

Table 1
Average cost of purchasing and installing a solar PV system in Western Australia and Australia (in AUS). The daily kWh is assuming that 1600 kWh is produced per annum per kW solar PV system. AUD are used.

System size	1.5 kW	2 kW	3 kW	4 kW	5 kW
Approximate Daily kWh in WA	7 kWh	9 kWh	13 kWh	18 kWh	22 kWh
Perth, WA	$3235	$4080	$5525	$7110	$8227
Australia	$3692	$4549	$6082	$7835	$9146