Renewable Energy 64 (2014) 244–254

Contents lists available at ScienceDirect

Renewable Energy

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

Domestic integration of micro-renewable electricity generation in Ireland – The current status and economic reality

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ARTICLE INFO

Article history:
Received 3 April 2013
Accepted 5 November 2013
Available online 8 December 2013

Keywords:
Renewable energy
Micro-wind turbine
Solar PV system
Integration
Sustainable living
Ireland

ABSTRACT

The utilisation of renewable energy resources for power generation is extremely important for Ireland due to the lack of indigenous fossil fuel resources. A micro-wind turbine is by far the most commonly used grid-connected micro-renewable electricity generation system for domestic applications in Ireland, followed by solar PV. Unfortunately, neither a single micro-wind turbine nor a single solar PV system can provide a continuous power supply due to variations in weather and climate conditions. The coupling of these two systems however can improve the power supply reliability by using the complementary characteristics of wind and solar energy. In this paper, a micro-renewable electricity-generation-system integration technique, tailored for applications in Ireland but generally applicable, is presented. Net present value is the parameter used to identify the optimal system. The optimal system can be a mono system, formed from a single micro-wind turbine or a single solar PV system, or a hybrid system formed from a combination of both. A renewable energy requirement is a constraint used in the integration to eliminate systems that cannot provide sufficient energy from renewable energy resources. The integration technique is applied to find the optimal system, under current Irish conditions, that can be formed from six sample micro-wind turbines and/or solar PV systems assembled from three sample solar PV modules. The analyses show that, with a 50% renewable energy requirement, the optimal system is a mono system containing a 2.4 kW micro-wind turbine; however, critically, the system is not economically viable. Four parameter studies assessing the effect of household electrical load, imported electricity price, exported electricity tariff and wind speed have also been conducted. From these studies it is seen that the most effective way to improve the financial performance of all systems is to offer a higher exported electricity tariff; installing a mono/hybrid system containing a micro-wind turbine in a location with a good wind resource can also have a significant effect.

1. Introduction

The rapid depletion of fossil fuel resources on a worldwide basis has necessitated the urgent employment of renewable energy to cater for future energy demand [1]. The utilisation of renewable energy is even more important for Ireland due to the lack of indigenous fossil fuel resources. Power generation in Ireland is mainly dependent upon imported fossil fuels. However Ireland has set the target of 40% electricity consumption from renewable energy by 2020 [2]. Ireland has a number of renewable energy resources available such as wind, solar, biomass, geothermal, hydropower, wave and tidal energy which can be exploited to meet the target set [3]. Wind and solar energy, which are clean, inexhaustible and environmental-friendly, are considered excellent power generating sources [4]. However, the disadvantages that prevent wind and solar energy been extensively used are their unpredictable nature and dependence on weather and climatic changes; also for domestic applications the variation of wind and solar energy may not match with the time distribution of the household electrical load. Fortunately, these problems can be partially or wholly overcome by integrating the two sources in a proper combination to form a hybrid system, using one source's strength to overcome the weakness of the other [5]. The utilisation of both wind and solar energy allows an improvement in the reliability of the energy supply and the economic viability by avoiding design over-sizing. However, the optimum design of a hybrid-energy system can be very complicated, with increased complexity in comparison with a mono-energy system.

In recent years, a number of different techniques for analysing the integration of hybrid wind and solar PV electricity systems have been presented in the literature. Hoicka et al. developed a technique to analyse the complementarity of integrated wind and solar PV electricity generation from geographic dispersion and power

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0960-1481/$ – see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.renene.2013.11.015

reliability aspects for Ontario, Canada [6]. Essalaimeh et al. developed a technique to investigate the applicability of a combined wind and solar PV electricity generation system for heating and cooling in urban areas of Amman, Jordan [7]. Arribas et al. developed a procedure to evaluate the performance of a hybrid wind and solar PV electricity generation system and applied this procedure for a case study in Soria, Spain [8]. With the introduction of an exported electricity tariff in Ireland in 2009, the number of grid-connected micro-wind and solar PV electricity generation systems has increased significantly in recent years. Walsh et al. conducted a study to investigate the renewable energy options available on a regional scale in Ireland [3]. This study also presented an overview on the most suitable renewable and non-renewable hybrid energy systems for each region. However, an investigation of the economic viability of integrated micro-renewable electricity generation systems for domestic applications in Ireland has not been carried out to-date, something of critical important for the individual homeowner. It is very important for a homeowner to not only be aware of the different types of micro-renewable electricity generation systems but also of the optimal system for each individual case.

This paper presents a novel technique for the integration of a grid-connected mono/hybrid micro-renewable electricity generation system consisting of a micro-wind turbine and/or a solar PV system. A single micro-wind turbine or a single solar PV system forms a mono system; a combination of both forms a hybrid system. The integration technique, generally applicable but deployed here for Ireland, takes into account technical and economical constraints (e.g. renewable energy requirement and maximum export capacity) and directives (e.g. exemption conditions for planning permission and exported electricity tariff). Net present value (NPV) is used to identify the optimal system in this integration technique and is calculated from the hourly power outputs of the micro-renewable electricity generation system and high-resolution (hourly) household electrical load data. Realistic hourly power outputs for a year from the analysed micro-wind turbines and the analysed solar PV systems are obtained from accurately predicted hourly wind speeds and hourly solar radiation values respectively by applying minimum weather data. The hourly household electrical loads for a complete year are calculated using an average annual household electrical load and an average annualised electrical load profile. The predicted system performance and the obtained financial results are accurate and reflect the real-life situation of an actual installed system. The paper also demonstrates the modification in the system configuration when realistic changes (financial, electricity consumption and weather conditions) are made.

Section 2 describes the current micro-renewable electricity generation situation in Ireland. Section 3 gives a detailed description of the micro-renewable electricity-generation-system integration technique. Section 4 presents the results obtained using the developed integration technique under current Irish conditions and also the effect of parameter changes, and a discussion of the results. The limitations of the integration technique are presented in Section 5 and conclusions are drawn in Section 6.

2. The current micro-renewable electricity generation situation in Ireland

The overall micro-renewable electricity generation situation in Ireland is best described under three headings: the current micro-wind turbine and solar PV system market, the current legislation and regulations for installing a micro-wind turbine and a solar PV system, and the current financial support for exporting electricity generated from these systems. These are described below.

2.1. The current micro-wind turbine and solar PV system market

Micro-renewable electricity generation has not been very popular in Ireland to-date. However, a micro-wind turbine is by far the most popular type of system for micro-renewable electricity generation in Ireland. After a micro-wind turbine, a solar PV system is the next most popular option. As shown in Fig. 1, micro-wind turbines and solar PV systems having total installed capacities of 2227 kW (kW) and 181 kW peak (kW_p) respectively have been registered with Electric Ireland and connected to the Electricity Supply Board (the state owned utility) distribution grid in the period from January 2007 to November 2011. These accounted for 91% and 7.4% of the total installed capacity (kW) of grid-connected micro-renewable electricity generation systems in this period respectively [9]. However, the total capacity of installed micro-wind turbines and solar PV systems is likely to be higher in this period, as a small number of micro-wind turbines and solar PV systems are either used to connect with batteries or are waiting to connect to the grid.

Large capacity (>3 kW) micro-wind turbines are the preferred option by householders in Ireland to-date. Of the 2227 kW (428 turbines) of micro-wind turbines installed, approximately 84% have a capacity greater than 3 kW, as shown in Fig. 2.

In contrast to micro-wind turbines, small capacity ($\leq$3 kW_p) solar PV systems are preferred by householders to-date. Of the 181 kW_p (78 systems) of solar PV systems installed, approximately 81% have a capacity less than or equal to 3 kW_p, as shown in Fig. 3.

2.2. The current legislation and regulations for installing a micro-wind turbine and a solar PV system in Ireland

Installing a micro-wind turbine or a solar PV system in Ireland is usually subject to planning permission. However, the installation of these systems may be exempt from planning permission if installed under certain conditions. These exemption conditions are clearly stated in the Irish government report *Planning and Development Regulations 2007* produced by the Department of Environment, Heritage and Local Government in January 2007 [10–12].

In order to protect the grid, the maximum export capacity from a grid-connected micro-renewable electricity generation system is subjected to a limit: 6 kW when the connection is single phase and 11 kW when the connection is three phase. However, a micro-

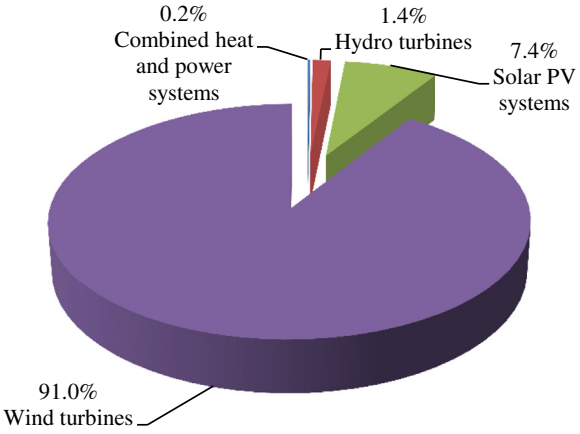

Fig. 1. Breakdown of capacity (kW) of grid-connected micro-renewable electricity generation systems installed from January 2007 to November 2011 in Ireland. The total installed micro-renewable electricity-generation system capacity in this period was 2448 kW.