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Near-term economic benefits from grid-connected residential PV (photovoltaic) systems

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ABSTRACT

One of the main reasons attributed to the slow uptake of grid-connected residential PV (photovoltaic) systems, is the lack of information about the near-term economic benefits which are as important as long-term viability for residential customers. This paper presents a comparative assessment of the near-term economic benefits of grid-connected residential PV systems. Case studies from the UK and India are taken as examples, as they vary significantly in solar resource, customer demands, electricity prices and financial support mechanisms. A metric termed PEUC (prosumer electricity unit cost) is proposed to develop an economic evaluation methodology to assess the near-term benefits from PV systems. The results obtained showed that, under the present financial support mechanisms, domestic PV systems provide near-term economic benefits in most locations in India. For most locations in the UK, cost reduction is needed to achieve near-term financial benefits and this varies depending on the location of installation. The results presented demonstrate the importance of location specific system planning and demand-generation matching through optimal sizing of the PV system and demand side management.

1. Introduction

Financial support mechanisms are helping to drive the adoption of PV (photovoltaic) systems by making the investment financially viable and ensuring that the customer receives a return, by means of sales of electricity, within a specified number of years. Whilst a long-term payback would be of interest to commercial investors, provided that a sufficient rate of return was achieved overall, the high initial costs involved in installing a domestic grid-connected PV system is a deterrent for most residential customers. The difference between the customer's PV generation and demand profiles decides the part of the customer demand supplied by the domestic PV system. If this part, which is fed by the PV, comes at a lower price compared to purchasing from the electricity supplier i.e. if near-term economic benefits can be established, customers will see the benefits and therefore the likelihood of adoption of domestic PV systems would be higher. This study evaluates the near-term economic benefits for domestic grid-connected PV systems and investigates their sensitivity to the differences in geographical and financial conditions based on two climatically and financially different countries (India and the UK).

Despite similar ambitious targets for PV installations [1,2], the UK and India differ largely in climate, PV generation strategy, incentives and subsidies for PV, electricity demand profiles and driving factors for PV installation. In terms of irradiance, the UK's climate is northerly with a large seasonal variation while India's is more equatorial with less seasonal variation. For the UK, renewable energy obligations such as the European 20/20/20 targets drive the installation of PV, whereas energy availability and providing electricity access to un-electrified regions is the major driver for PV installations in India. At present, there are more than 96,000 villages in India without access to electricity [3] and a large generation-demand deficit [4]. In the UK, the government Feed-in-Tariff is supporting the development of grid-connected distributed (micro) PV generation, with the majority being residential installations [5]. The past focus of the Indian government was on small capacity stand-alone installations for rural applications. This has now shifted to an active focus on large scale plants [6]. So far, the prospects of grid-connected domestic PV generation in India are extremely under-explored.

Unlike the UK, most of India has a summer electricity peak demand where energy demand increases during the afternoon hours, due to the high space cooling loads [7]. This increase in demand calls for more generation to be available and causes an

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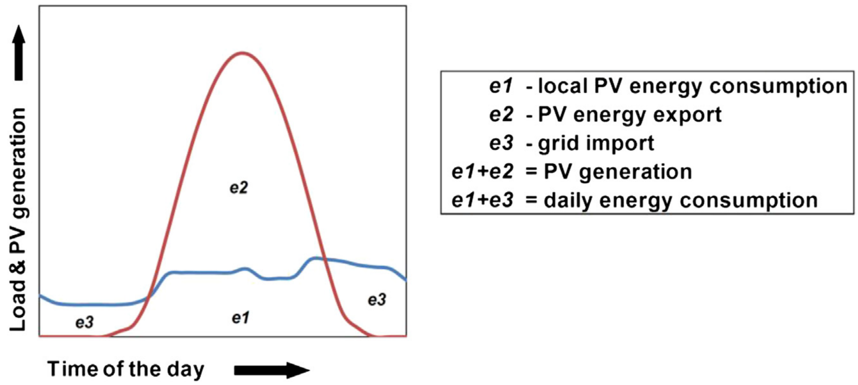

Fig. 1. The daily energy dynamics of a customer with a grid-connected PV system.

increment in the electricity prices as well as increased thermal losses in the T&D (transmission and distribution) systems. India has very high T&D losses at an average of 25.7% across the country [3], whereas in the UK it is only 7% [8]. Distributed PV generation coincides with the peak summer demand of India and therefore would be beneficial to reduce power flow from the grid and reduce thermal T&D losses [9].

This paper presents a comparative analysis of the effects of solar input, financial support mechanism and the customer demand profile on the near-term economic benefits. To evaluate the near-term benefits from PV systems, a metric termed PEUC (Prosumer Electricity Unit Cost) is proposed and used to develop an economic evaluation methodology. The main contributions of this paper are the use of PEUC, analysis of the potential of grid connected residential PV systems, the techno-economic comparison of grid connected residential PV systems between the UK and India and analysis of the near-term economic benefits of grid connected residential PV systems in the UK and India.

The paper is organised as follows: Section 2 presents the proposed metric used for economic evaluation in this study (PEUC). Section 3 describes the methodology and data used in this study. Section 4 presents and discusses the results obtained. Section 5 gives the conclusions drawn from this study.

2. Prosumer electricity unit cost

A residential customer installing a grid-connected PV system can be called a “prosumer” since the system produces some or all of the energy needed by the customer as well as being able to export any surplus to the grid. For a prosumer, there are two kinds of financial benefits: 1) in the role of an investment yielding returns and 2) in the role of an energy supplier. The Net Present Value and the Pay-Back Period are the two main parameters used to evaluate the financial viability of investing in a PV system [10]. Both of these parameters are independent of the customer energy demand and take into account only PV generation. For a prosumer, the energy supply is a hybrid system, where PV and the grid are the two sources.

Several studies [11–14] that investigated the financial viability of a grid-connected PV system looked only at the investment perspective. There were other studies [15–17] which investigated a grid-connected PV system from the load-generation matching point of view, without consideration of the costs. The energy value of electricity from residential PV systems in the UK was assessed in Ref. [18], but this did not take into account the capital cost of the PV system which is an important determinant in the consumer's purchase of a system.

For the assessment of the PV system in the role of an energy supplier, there needs to be a metric linked to the cost parameters, PV incentives structure (to total generation or to net export), PV generation and customer demand profiles. The following paragraphs describe the formulation of a metric called PEUC for the assessment of near-term benefits of a PV system, for residential customers (prosumers).

Fig. 1 shows the energy dynamics of a domestic customer with a grid-connected PV system for a typical day assuming a clear sunny day and a system with a peak output higher than the peak demand. For variable weather conditions, the graph may include import at other times than shown.

An annual profile can be represented by 12 average typical day energy dynamics, one corresponding to each month.

Local PV energy consumed annually in kWh,

$$E1 = \sum_{m=1}^{12} e1(m)^{*}d(m) \tag{1}$$

PV energy exported to the grid annually in kWh,

$$E2 = \sum_{m=1}^{12} e2(m)^{*}d(m) \tag{2}$$

Energy imported from the grid annually in kWh,

$$E3 = \sum_{m=1}^{12} e3(m)^{*}d(m) \tag{3}$$

where, $e1$ represents the daily PV energy consumed in a house, $e2$ represents the PV surplus energy exported to the grid, e3 represents the energy imported from the grid, m is the month and $d(m)$ is the number of days of that month with the specified average generation profile.

Total Energy consumed by the customer annually in kWh

$$= E1 + E3 \tag{4}$$

If i is the annual interest rate and N is the project life time in years, then the Capital Recovery Factor [CRF] is given as [19]:

$$\mathrm{CRF}(i,N) = \frac{i(1+i)^N}{(1+i)^N - 1} \tag{5}$$