Renewable Energy 62 (2014) 47–52

Contents lists available at SciVerse ScienceDirect

Renewable Energy

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

Technical note

Reactive power excess charging in grid-connected PV systems in Brazil

Aimé Pinto*, Roberto Zilles [1]

Instituto de Eletrotécnica e Energia, University of São Paulo, Avenida Professor Luciano Gualberto, 1289 Cidade Universitária, CEP 05508-010, Butantã, São Paulo SP, Brazil

ARTICLE INFO

Article history:
Received 9 August 2012
Received in revised form
22 May 2013
Accepted 29 June 2013
Available online

Keywords:
Grid-connected PV systems
Reactive power charging
Net-Metering

ABSTRACT

This paper proposes a simple approach to treat an as yet undiscussed problem: reactive power excess charging in electrical consumer units that install PV generators under the energy compensation system in Brazil. Under ANEEL regulation RN 482/2012, about mini and micro distributed generation, the installation of PV generators will be allowed to offset electricity consumption. This will cause the power factor of the consumer unit to fall, permitting utilities to charge for a reactive power excess, lessening the economic attractiveness of PV systems. This charge will discourage measures to bring higher quality to these systems, such as changing the power factor to reduce the increase in voltage at the point of common coupling caused by the energy's feeding into the grid.

© 2013 Elsevier Ltd. All rights reserved.

1. Introduction

The main policies for promoting PV systems is the Feed-In Tariff, which has been adopted in many countries, such as Spain and Germany [1], and Net-Metering, which has been adopted in a few countries, e.g., the U.S. [2].

Although Feed-In Tariff be considered as the most effective policy at stimulating the rapid development of renewable energy sources [3], a kind of Net-Metering (called the Electrical Energy Compensation System) was recently adopted in Brazil [4]. The Net-Metering was adopted instead of Feed-In Tariff because the grid parity already has been achieved in most Brazilian areas and a Feed-In Tariff means a subsidized cost, which is against the current energy policy of the country.

The Electrical Energy Compensation System mainly differs from Feed-In Tariff since it doesn't make revenue of money to the generator owner, but a kilowatt-hours reduction in the electricity bill, i.e., the generator owner cannot earn with energy production more than the electricity rate. On account of that, the generator owner is stimulated to produce up to their consumption; once in Feed-In Tariff, the more the generator owner produces, the more is the revenue.

The mainly technical difference between Feed-In Tariff and Electrical Energy Compensation System is the connection point. In the first one it is directly on the mains and in the second one it is through the consumer unit and before the utility energy meter.

Because of Brazilian peculiarities, some issues will arise. One of these issues is the charging for reactive power excess, which is the main focus of this paper.

From Public Hearing n° 042/2011 [5], the Brazilian National Electrical Energy Agency (ANEEL) developed Normative Resolution n° 482/2012 [6], which lays down the access conditions of mini and micro distributed generation systems to the power distribution grid and lays out the electrical energy compensation system. This normative resolution provides the following definition for micro and mini distributed generation and electrical energy compensation systems:

- Micro-distributed generation: an electric power plant with installed capacity of up to 100 kW, of which the source is based on hydropower, solar, wind, biomass, or cogeneration qualified in terms of specific regulations, connected to the distribution grid through a consumer unit.
- Mini distributed generation: an electric power plant with installed capacity of up to 1 MW, of which the source is based on hydropower, solar, wind, biomass, or cogeneration qualified in terms of specific regulations, connected to the distribution grid through a consumer unit.
- Electrical Energy Compensation System: a system in which the active power generated by a consumer unit with micro or mini distributed generation offsets the active power consumption.

* Corresponding author. Tel.: +55 11 30912656.
E-mail addresses: afpinto@iee.usp.br (A. Pinto), zilles@iee.usp.br (R. Zilles).
[1] Tel.: +55 11 30912637.

0960-1481/$ – see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.renene.2013.06.045

Abbreviations

PV	photovoltaic
CU	consumer unit
PF	power factor
f_r	power factor reference, equal to 0.92
i	inductive
c	capacitive
P	active power
Q	reactive power
IRR_{PV}	photovoltaic internal rate of return
FER	total charging value corresponding to the reactive power consumption exceeding the amount allowed by the power factor reference in the charging period
CA	active power consumption in the charging period
f_m	average lagging power factor, calculated in the charging period (for each hour)
TCA	active power tariff
RE_{PV}%	percentage reduction in the PV energy production equivalent to the amount spent on charging for reactive power excess
E_{PV}	energy produced by the PV system
CF	capacity factor
O&M	annual cost of operation and maintenance

As a result, this resolution set up the electrical energy compensation system, which will allow the installation of PV systems in CU in order to offset part or even the whole of their consumption. For adoption of the energy compensation system, the CU should install electronic meters. In the case of micro distributed generation, a bi-directional meter, which should at least differentiate the active power consumption from the grid injected active power, shall be installed, and in the case of mini distributed generation, a four quadrants meter, which allows charging for reactive power excess, must be installed.

Currently, charging for reactive power excess has only been done for large consumers. The use of PV systems to reduce active power consumption causes a reduction in the PF, because of the connection point that is before the utility energy meter, which is interpreted as a surplus of reactive power (by the meter), leading to a charge for reactive power excess.

As the aim of the PV system is a reduction in energy expenses, charging for reactive power excess can be an impediment to the promotion of this technology, because, in spite of the reduction in active power consumption, there will also be a reduction in the power factor of the consumer unit and this will generate a charge for a reactive power excess, even if the demand for reactive power is the same. This will reduce the attractiveness of PV systems.

To better understand this issue and its impact on the attractiveness of PV systems, it is necessary to know the behavior of the power factor of a consumer unit with a grid-connected PV system and how the excess of reactive power is charged.

2. Charging for reactive power excess

ANEEL Resolution n° 456/2000 [7] sets the power factor as an index that shows the efficiency of a particular electrical system. This index can take values from 0 (zero) to 1 (one). High PF values, above 0.92, indicate an efficient use of the electrical system and a low PF value indicates a poor performance.

For the current legislation, the f_r is 0.92, which is the minimum PF required for loads, according to the national grid procedure PRODIST/ANEEL [8]. CU with PF lower than 0.92 should be charged for an excess of reactive power (PF $<$ 0.92).

Article 65 of ANEEL resolution n° 456/2000 defines the charging for reactive power excess, which must be made according to Eq. (1).

$$\text{FER} = \text{CA} \times [(f_r/f_m) - 1] \times \text{TCA} \tag{1}$$

3. Behavior of the power factor of a consumer unit with a grid-connected PV system

A consumer unit usually has a lagging power factor and a load curve with a peak during the day, for commercial and industrial units, and at night for residential units, whereas PV generation is present only during the day, peaking around midday. Fig. 1 illustrates a typical industrial load with 158 kVA of maximum demand (which occurs around the noon) and 100 kW of maximum PV generation, Fig. 2 illustrates a typical residential load curve with 130 kVA of maximum demand (which occurs at night) and 100 kW of maximum PV generation, all in the coverage area of Eletropaulo utility [9], to which was added a reactive demand considering a fixed (all day long) PF of 0.92 and a PV generation curve with sufficient capacity to offsets 50% of the consumption of these load curves.

A CU with the load profile of Figs. 1 and 2 would not be charged for reactive power excess, since the PF was set to 0.92 throughout the day. But if PV generation is added, the CU's energy meter will measure a change in the PF, because of the reduction in active power demand. In addition, the installed PV power is larger than 100 kW (mini distributed generation) in all cases, which requires four quadrant meters, consequently the CUs can be charged for reactive power excess.

In order to study the change in the PF of consumer units caused by PV generation, some scenarios should be created: a CU with a PV generator delivering only active power (PF = 1), a CU with a PV generator delivering active and inductive reactive power (PF = 0.92i), and a CU with a PV generator delivering active and capacitive reactive power (PF = 0.92c). The scenarios were considered only to industrial load curves, which have the same pattern of commercial load curves, nevertheless the same evaluation is valid for residential load curves, but with less intensity because of the time decoupling between generation and demand.

3.1. CU with PV generator producing only active power (PF = 1)

Given a consumer unit with load curves of Fig. 1 and a PV generator capable of offsetting the CU's daily half consumption, delivering only active power (PF = 1), the meter installed in the CU will bill the consumption of active energy and reactive power excess according to Fig. 3.

Positive P (active power) and Q (reactive power) bars mean that there was CU energy consumption and negative bars mean that there was power injection into the grid.

In Fig. 3 it's very clear to see that PF starts to reduce to values below the reference (0.92) as PV generation starts to rise.

In the industrial load curve, as there is no hourly value of balance between demand and generation, the PF doesn't reach values around zero, but even so, PF reaches values much lower than the reference, which also leads to a charge for reactive power excess. Regarding the daily energy charging and an electricity rate of 0.5 R$/kWh, the UC will be charged for R$ 410 for active power and for R$ 87 for reactive power.

The reactive power demand was the same as without PV generation, because the PV generator produced only active power. The CU active power demand was reduced due to the PV generation.

Download English Version:

https://daneshyari.com/en/article/6768590

Download Persian Version:

https://daneshyari.com/article/6768590

Daneshyari.com