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Development of an electrical characterization device for single-phase pv grid-connected inverters

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Abstract

The Grupo en Energías Renovables at the Universidad Nacional del Nordeste (GER-UNNE) developed a testing system for the characterization of grid-tied inverters with rated power up to 4.4 kW. The test procedures followed the guidelines established by EN 50530:2010, IEC 61727 and BS 50438:2007. This paper presents the development of the instrumental and the determination of the measurement uncertainties associated to the experiment by comparison with results obtained from an inverter test facility built at the Solar Energy Laboratory at Universidade Federal do Rio Grande do Sul (LABSOL-UFRGS), Brazil. The error associated to the inverter conversion efficiency, with the loading ranging from 10% to 100%, was shown to be lower than 1%. The error in the efficiency error determination with partial load under 10% is lower than 8%.

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1. Introduction

Grid-connected photovoltaic systems are presented today as an alternative to promote the implementation of distributed generation [1]. Because of its intrinsic modular nature it can be included as electricity generators in low voltage distribution networks being able to feed loads that, during certain periods of the day, would demand more energy than it can be delivered by the conventional grid. The peak of the typical demand profile in the Northeast of Argentina coincides with the period of maximum solar irradiance, hence, with the maximum generation of the photovoltaic system [2]. Therefore, the use of such power systems can attenuate those consumption peaks helping to minimize the overload suffered

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by transformers and distribution lines during periods of high demand thus avoiding the need for reinforcing the grid with the consequent economic costs implied. The energy provided by grid-connected photovoltaic systems improves the quality of the electricity supply at the distribution lines by including a renewable and sustainable method of power generation.

In Argentina, in spite of the governmental act for the implementation of power generation systems using renewable resources (National Law No. 26.190, 2006), the installed grid-connected photovoltaic generation capacity is negligible. Therefore, so far there has not been developed a normative regulating the characterization of grid-tied inverters and its interaction with the distribution grid. This is the main reason international standards are employed for any work carried out in this field.

Grid-tied inverters can be characterized by determining the efficiency by which the energy available at the photovoltaic generator is converted to the conditions required for the distribution of electricity in the grid. The overall efficiency of an inverter is the product of two components: the conversion efficiency and maximum power point tracking (MPPT) efficiency [3]. The European Standard EN 50530:2010 "Overall Efficiency of Photovoltaic Inverters" [4], presents a methodology for determining these efficiencies.

The British Standard BS 50438:2007 "Requirements for the Connection of Micro-Generators in Parallel with Public Low-Voltage Distribution Networks" [5], It includes specifications on the quality of the energy injected to the grid concerning parameters such as current harmonic distortion, fluctuations in voltage levels, power factor, frequency, flicker, etc. Moreover, this standard proposes a methodology for assessing which (and how fast) protection devices should act in situations of network failure (variations of voltage and frequency outside the permitted range). Another standard that deals with the same subject is the IEC 61727: "Photovoltaic (PV) Systems - Characteristics of the Utility Interface" [6].

To implement the characterization of inverters, in order to determine the parameters required by the standards it is necessary to measure and store some electrical parameters, particularly the voltages and currents at the inverter input throughout its operating range. To acquire these signals it is desirable a high sampling rate and determine the temporal behavior of each of these parameters by subsequent digital signal processing.

Considering the aforementioned reasons, the Gurpo de Energías Renovables (GER) of FACENA-UNNE, developed a system to measure, store and process the necessary data for the characterization of grid-tied inverters. This development is part of a project for the study and implementation of distributed generation (DG) using grid-connected photovoltaic systems meeting the conditions set by the EN 50530:2010, IEC 61727 and BS 50438:2007. This paper describes the developed system and the comparison the gathered data with the results obtained at the inverter test facility of the Solar Energy Laboratory at Universidade Federal do Rio Grande do Sul (LABSOL-UFRGS), Brazil. The testing and calibration of the equipment were performed within the framework of a cooperation project between Argentina and Brazil.

2. Electric characterization system

As mentioned before, in order to characterize a grid-tied inverter and its interaction with the low-voltage distribution grid one must measure and store the voltage and current values at both the ends of the inverters, input and output, for different operating conditions. These data can provide the input and output power, the power factor of the injected current, the harmonic distortion and the conversion efficiency, among other parameters. For each of the variables involved, the time interval between samples must be short enough to obtain (in compliance with the sampling theorem) a correct image of the measured variables [7]. Since the voltage and current signals at the input side of the inverter (i.e. provided by the photovoltaic generator) are DC and present relatively slow variations (slower than 1 ms), a proper acquisition can be attained without the need of a high sampling rate. However, the AC signals at the