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Optimal photovoltaic inverter sizing considering different climate conditions and energy prices

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Abstract

State of the art, grid integrated photovoltaic inverters have the best efficiencies of approximately 98 % at medium power ranges. Operations at lower and at higher power ranges decrease the efficiencies of these devices to some extent because of technical implications of the inverter. The nominal power of photovoltaic inverters is usually specified by the inverter manufacturer considering standard test conditions and/or normal operating conditions. If the inverters are oversized higher losses do appear as the inverter converts more energy at the lower power ranges and if the inverter is undersized higher energy losses appear as the inverter converts more energy at the higher power ranges. Especially due to the inverter´s maximum power limitation a part of the disposable solar energy at very high incidences may be rejected by the solar inverters. Therefore a correct sizing defines an optimal solar generator size in relation to the inverter size which maximizes its yearly energy conversion. Due the inverters efficiency curve characteristic, an optimal sizing of the inverter depends on: (i) technological aspects of the solar inverter and photovoltaic modules, (ii) climatological aspects of the location where the inverter is installed and (iii) time resolutions considered for the simulations which have to be accomplished to obtain the yearly energy conversion. In the present work, different system configurations are simulated using the software PVsyst™ in order to assess and compare an optimized system configuration for three different locations, Capivari de Baixo-SC (Latitude 28ºS), Juazeiro do Norte-CE (Lat. 7ºS) in Brazil and Freiburg in Germany (Lat. 48ºN). The limits of the method are discussed and a method is proposed to assess to which extent the annual energy YIELD per unit of installed solar generator peak power can be improved and compared for different PV technologies. Considering a specific energy price, in either a net-metering or a feed-in tariff market (see e.g. [8]), the higher inverter investment cost due to an eventual over sizing of the inverter should be justified by a higher annual feed in revenue due to the higher amount of energy injected to the grid.

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1. Introduction

Solar photovoltaic (PV) inverters have experienced continuous improvements over the years, and with the declining costs of both PV modules and inverters, solar electricity is finally becoming cost-competitive in many markets throughout the world [4]. The state of the art maximum efficiency of modern solar inverters is very high, and attains values of around 98% [9]. Due to the inverter efficiency curve, the average efficiency is lower to some extent if the inverter operates on the upper or the lower power ranges. Therefore the average efficiency of an inverter can be maximized by correct sizing of the inverter in relation to the size of the utilized photovoltaic generator. Correct sizing should consider technological aspects of the inverter and solar modules as well as climatological aspects, which depend on the location where the inverter is installed [1]. As the hourly and the minutely averages of the solar radiation lead to distinct energy distributions within the solar incidence or the inverter power range [1], the correct sizing of the PV system including solar generator and inverter performances, based on climatological characteristic series of the local solar radiation incidences and ambient temperatures, should be sought. In this work we simulate different PV system configurations, in the light of different prices of the injected solar energy into the electrical grid in order to obtain an optimal system configuration in relation under aspects of the inverter costs and the energy prices.

1.1 Technological aspects

A considerable number of technical and technological aspects should be taken into account in the process of defining the relation of a PV module array nominal power to the solar inverter nominal power, including the following:

- Undersized inverters convert less energy at higher solar irradiances since such conditions can lead to power flux limitations as the available solar power can be higher than the maximum inverter power if the inverter reaches its maximum power flux, and therefore the average system efficiency decrease to some extent.
- Some of the state of the art inverters can be overloaded within a short time interval, which is advantageous as very high solar irradiances also appear only in a short time frame of some seconds or minutes.
- Some of the state of the art inverters show increased efficiency at the lower and higher power ranges due to innovative circuit topologies [2].
- Inverters consume a minimum of energy which is used for its control circuit, data transmission circuit and display. This energy consumption leads to proportionally lower efficiencies at the lower power range of the inverter.
- Higher solar irradiances increase the photovoltaic module average temperature, which leads to solar generator losses, especially at high ambient temperatures. Decreased temperature coefficients and therefore losses are characteristic to several thin film technologies (e.g. amorphous silicon a-Si and CdTe). Therefore, at such conditions, many state of the art