



# A new simple analytical method for calculating the optimum inverter size in grid-connected PV plants

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## ABSTRACT

A new simple analytical method for the calculation of the optimum inverter size in grid-connected PV plants in any location is presented. The derived analytical expressions contain only four unknown parameters, three of which are related to the inverter and one is related to the location and to the nominal power of the PV plant. All four parameters can be easily estimated from data provided by the inverter manufacturer and from freely available climate data. Additionally, analytical expressions for the calculation of the annual energy injected into the ac grid for a given PV plant with given inverter, are also provided. Moreover, an expression for the effective annual efficiency of an inverter is given. The analytical method presented here can be a valuable tool to design engineers for comparing different inverters without having to perform multiple simulations, as is the present situation. The validity of the proposed analytical model was tested through comparison with results obtained by detailed simulations and with measured data.

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## 1. Introduction

The production of electricity from photovoltaic (PV) systems is still expensive, when compared to conventional production methods. This fact necessitates the careful selection of each individual part of a grid-connected PV plant in order to achieve maximum energetic and economic performance. Part of the energetic optimization is the proper selection of the rated power of the dc/ac inverter with respect to the total nominal power of the PV array. The common practice among many design engineers is to select the rated power of the inverter equal to the total nominal power of the PV array. Although this practice leads to PV systems that work without problems, it is not the optimum – from an energetic point of view – design, for the following reasons [1–5]: (1) the nominal power of the installed PV modules is achieved only under their Standard Testing Conditions (STC), which are very unlikely to happen in real conditions, (2) the solar irradiance varies, during the day, from zero up to a maximum point which depends on the time of the year and the geographic location of the PV installation, and (3) the efficiency of any inverter is not constant over its operating range but drops significantly when the inverter operates at or below 10–20% of its rated power. Thus, an inverter with relatively large power will operate at low efficiency during the sunrise and sunset or during cloudy days. On the other hand, an inverter with relatively small

power will lead to waste of energy when the available dc power of the modules is larger than its rated power.

The research efforts for the determination of the optimum rated power of the PV inverter are, so far, based on detailed simulations with either commercially available or with custom-made software. In [6] it was shown that the energetic optimum of the inverter size depends on the shape of the inverter efficiency curve, on the latitude of the examined location and on the tilt angle of the PV modules. The results were obtained through simulations with the PHOTO software using climate data from the Test Meteorological Years. For five locations ranging from 33.4°N to 60.3°N and for tilt angles in the range 0° to 90°, the optimum – from energetic point of view – rated power of the inverter, was shown to be 0.38–4.54 of the rated power of the PV plant. The shape of the inverter efficiency curve was modeled as a second-order polynomial and, varying the polynomial parameters, four specific inverter types were examined.

In [7], it was shown that the optimum rated power of the inverter should be 0.825 of the rated power of a PV plant in Kassel, Germany and 1.065 of the rated power of a PV plant for Cairo, Egypt. The results were obtained through custom-made software while the inverter efficiency curve was modeled as a quadratic function of the inverter output power. Suggestions for the optimum size of the inverter are also given in [8] for eight different European locations. The investigation was carried out with the TRNSYS software considering three different shapes of inverter efficiency curve that corresponded to low-, medium-, and high-efficiency inverters respectively. It was shown that the optimum

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