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The impact of array inclination and orientation on the performance of a grid-connected photovoltaic system

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Abstract

The impact of PV surface orientation and inclination on grid-connected photovoltaic system performance under maritime climates was investigated using validated TRNSYS simulations. Insolation, PV output, PV efficiency, inverter efficiency, system efficiency, performance ratio (PR) and PV savings were estimated annually, seasonally and on monthly bases for various surface inclinations and orientations. Incident insolation and PV output were maximum for a surface with inclination 30° facing due south and minimum for a vertical surface with orientation 90° east or west from south. The monthly optimum collection angle maximising incident insolation varied from 10° to 70°. For the particular location and system studied, the maximum annual PV efficiency, the inverter efficiency, the PR and the system efficiency were for a south-facing surface with an inclination of 20°. For a horizontal surface, the monthly variation of system parameters was significant over a year. For time-dependent tariff rates, the annual PV savings were higher for a system oriented with same orientation towards the west than east from south while for constants tariff rates, the PV savings was the same for east or west orientation from south.

Keywords: Grid-connected photovoltaic; Orientation; Inclination; Insolation; PV output; Performance ratio

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Nomenclatures

A	PV array area (m^2)
$E_{AC\ \gamma,\beta}$	annual total inverter output for any surface (MJ)
$E_{DC\ \gamma,\beta}$	annual total PV output for any surface (MJ)
$E_{DC,\gamma_{max},\beta_{max}}$	maximum annual total PV output(MJ)
$E_{N,PV}$	annual total PV output for any surface normalised with respect to maximum annual total PV output
$E_{N,PV,S}$	seasonal PV output normalised with respect to PV rated capacity ($MJ\,kW_p^{-1}$)
$E_{S,DC,\gamma,\beta}$	seasonal PV output for any surface (MJ)
$I_{\gamma,\beta}$	annual total in-plane insolation for any surface ($MJ\,m^{-2}$)
$I_{\gamma_{max},\beta_{max}}$	maximum annual total in-plane insolation ($MJ\,m^{-2}$)
k_0, k_1, k_2	correlation coefficients
P_{inv}	AC output power from an inverter (W)
$P_{inv,n}$	normalised inverter output power
$P_{inv,rated}$	inverter's rated input capacity (kVA)
P_{pv}	DC input power to an inverter (W)
$P_{PV,rated}$	rated capacity of PV array (kW_p)
$P_{pv,n}$	normalised inverter input power
PR	performance ratio (%)
Y_f	annual final yield ($h\,year^{-1}$)
Y_r	annual reference yield ($h\,year^{-1}$)
β	surface tilt angle (deg.)
γ	surface azimuth angle (deg.)
ε_I	variation of annual total in-plane insolation for any surface orientation and inclination from the annual total maximum insolation (%)
ε_{PV}	variation of annual total PV output for any surface orientation and inclination from the annual total maximum PV output (%)
$\eta_{inv,\gamma,\beta}$	inverter efficiency for any surface (%)
$\eta_{PV,\gamma,\beta}$	PV efficiency for any surface (%)
$\eta_{s,\gamma,\beta}$	system efficiency for any surface (%)

1. Introduction

A photovoltaic (PV) system should be installed to maximise the solar contribution to a particular load. Optimum PV inclination and orientation depends on local climate, load consumption temporal profile and latitude [1–3]. Generally, a surface with tilt angle equal to the latitude of a location receives maximum insolation. However, some locations experience a weather pattern where winter is typically cloudier than summer or the average morning and afternoon insolation is not symmetric. The maximum available energy may then be received by a surface whose azimuth angle is either east or west of due south (in the Northern hemisphere). The optimum tilt angle is thus site dependent and calculation of this angle requires solar radiation data for that particular site for the whole year. Normally, during summer, the incident insolation is maximised for a surface with