Available online at www.sciencedirect.com
SCIENCE DIRECT®
Energy Conversion and Management 47 (2006) 2925–2947
ENERGY CONVERSION & MANAGEMENT
www.elsevier.com/locate/enconman

Long term performance analysis of a grid connected photovoltaic system in Northern Ireland

Jayanta Deb Mondol [a,*], Yigzaw Yohanis [a], Mervyn Smyth [a], Brian Norton [b]

[a] School of the Built Environment, University of Ulster, Newtownabbey BT37 0QB, Northern Ireland, UK
[b] Dublin Institute of Technology, Aungier Street, Dublin, Ireland

Received 9 September 2005; accepted 22 March 2006
Available online 19 May 2006

Abstract

The performance of a 13 kW_p roof mounted, grid connected photovoltaic system in Northern Ireland over a period of three years has been analysed on hourly, daily and monthly bases. The derived parameters included reference yield, array yield, final yield, array capture losses, system losses, PV and inverter efficiencies and performance ratio. The effects of insolation and inverter operation on the system performance were investigated. The monthly average daily PV, system and inverter efficiencies varied from 4.5% to 9.2%, 3.6% to 7.8% and 50% to 87%, respectively. The annual average PV, system and inverter efficiencies were 7.6%, 6.4% and 75%, respectively. The monthly average daily DC and AC performance ratios ranged from 0.35 to 0.74 and 0.29 to 0.66, respectively. The annual average monthly AC performance ratios for the three years were 0.60, 0.61 and 0.62, respectively. The performance of this system is compared with that of other representative systems internationally.

Keywords: Grid connected photovoltaics; Monitoring; PV efficiency; Inverter efficiency; Performance ratio

1. Introduction

Monitoring PV performance provides data to demonstrate (i) the performance of system components, (ii) energy production, (iii) loss mechanisms associated with system operation, (iv) reliability and causes of system failures, (v) validity of theoretical models using measured data and (vi) long term system performance [1,2]. The two main generally recognised monitoring procedures [3] are: (i) IEC 61724 [4] provides photovoltaic system performance monitoring guidelines for measurements data exchange and monitoring parameters, frequency of measurements and duration of monitoring and (ii) Ispra Guidelines [5] that follow an analytical monitoring method.

* Corresponding author. Tel.: +44 2890 368037; fax: +44 2890 368239.
E-mail address: jd.mondol@ulster.ac.uk (J.D. Mondol).

0196-8904/$ - see front matter © 2006 Elsevier Ltd. All rights reserved.
doi:10.1016/j.enconman.2006.03.026

Nomenclature

A	PV area (m^2)
d	day
$E_{AC,d}$	daily total AC output (MJ)
$E_{DC,d}$	daily total DC output (MJ)
$I'_{T,d}$	in plane insolation during period of inverter operation (MJ m^{-2})
$I_{G,d}$	daily total global horizontal insolation (MJ m^{-2})
I_{STC}	insolation at standard test conditions (kW h m^{-2})
$I_{T,d}$	daily total in plane insolation (MJ m^{-2})
$\overline{I}_{G,h}$	average hourly horizontal insolation (MJ m^{-2})
$\overline{I}_{T,h}$	average hourly in plane insolation (MJ m^{-2})
$\overline{I}_{G,m}$	monthly average daily global horizontal insolation (MJ m^{-2})
$\overline{I}_{T,m}$	monthly average daily total in plane insolation (MJ m^{-2})
$L_{c,m}$	monthly average daily array capture losses (h d^{-1})
$L_{s,m}$	monthly average daily system losses (h d^{-1})
m	Month
N	number of days in month
$P_{PV,rated}$	PV rated capacity (kW_p)
PR	performance ratio
$PR_{AC,d}$	daily AC performance ratio
$PR_{AC,m}$	monthly AC performance ratio
PR_d	daily performance ratio
$PR_{DC,d}$	daily DC performance ratio
$PR_{DC,m}$	monthly DC performance ratio
$\overline{PR}_{AC,m}$	monthly average daily AC performance ratio
$\overline{PR}_{DC,m}$	monthly average daily DC performance ratio
R_{GT}	ratio of average daily in plane to horizontal insolation
$\overline{T}_{A,h}$	average hourly ambient temperature (°C)
$Y_{a,d}$	daily array yield (h d^{-1})
$Y_{a,m}$	monthly average daily array yield (h d^{-1})
$Y_{f,d}$	daily final yield (h d^{-1})
$Y_{f,m}$	monthly average daily final yield (h d^{-1})
$Y_{r,d}$	daily reference yield (h d^{-1})
$\eta_{inv,d}$	daily inverter efficiency (%)
$\eta_{inv,m}$	monthly inverter efficiency (%)
$\eta_{PV,d}$	daily PV efficiency (%)
$\eta_{PV,m}$	monthly PV efficiency (%)
$\eta_{s,d}$	daily system efficiency (%)
$\eta_{s,m}$	monthly system efficiency (%)
$\eta'_{s,m}$	monthly system efficiency when inverter is operating (%)
$\bar{\eta}_{PV,m}$	monthly average daily PV efficiency (%)
$\bar{\eta}_{inv,m}$	monthly average daily inverter efficiency (%)
$\bar{\eta}_{s,m}$	monthly average daily system efficiency (%)

The performance of grid connected PV systems depends on weather conditions (i.e. incident insolation and ambient temperature), the operation of each individual component (i.e. PV generator and inverter) and the connection of the system to the grid [6]. The performance ratio (PR) (defined as the ratio of the PV energy actually used to the theoretically available PV energy) is influenced by insolation, shading, operating temperature of PV module, relative sizing ratio of inverter and PV array, type of PV module, inverter characteristics