INTERNATIONAL JOURNAL OF HYDROGEN ENERGY XXX (2016) 1–10

Available online at www.sciencedirect.com

ScienceDirect

journal homepage: www.elsevier.com/locate/he

Performance analysis of different grid-connected solar photovoltaic (PV) system technologies with combined capacity of 20 kW located in humid tropical climate

David A. Quansah [a,b,c], Muyiwa S. Adaramola [b,*], George K. Appiah [a], Isaac A. Edwin [a,c]

[a] The Brew-Hammond Energy Centre, College of Engineering, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana

[b] Faculty of Environmental Sciences and Natural Resource Management, Norwegian University of Life Science, Ås, Norway

[c] Department of Mechanical Engineering, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana

ARTICLE INFO

Article history:
Received 18 March 2016
Received in revised form
20 October 2016
Accepted 22 October 2016
Available online xxx

Keywords:
Solar PV
Energy density
Cell temperature
Final yield
Performance ratio
Ghana

ABSTRACT

Objective: This study presents the outdoor performance of five solar photovoltaic (PV) systems with five different solar cell technologies (poly-crystalline (pc-Si)), mono-crystalline (mc-Si), Copper Indium disulfide (CIS) thin-film, Amorphous Silicon (a-Si), and Heterojunction Incorporating thin (HIT) film.
Methods: The PV systems are installed on rooftop of buildings at the Kwame Nkrumah University Science and Technology, Ghana. The systems' energy output in 2014, module temperature as well as environmental data were collected and analysed.
Results: The total annual energy delivered to the grid varies between 3133.2 kWh for CIS and 4572.1 kWh for pc-Si while the performance ratio varies from 48.84% (CIS) to 71.26% (for p-Si). The annual energy density ranges between 45.7 kWh/m^2 for CIS and 195.8 kWh/m^2 for HIT. The total actual energy delivered to the grid by all the systems in 2014 is 20.62 MWh.
Conclusions: The performance data shows, that, the CIS technology is least suitable while p-Si is the most suitable solar PV technology for the site considered, followed by a-Si, HIT and mc-Si respectively. If space is a constraint, then, the HIT based system is most suitable solar PV technology for this site and potentially, sites with similar climate.
Practice implications: The findings from this study are useful in identifying solar cell technologies that are appropriate for this location and provide useful information to policy makers and individuals about the performance of grid-tied PV system in Ghana.

* *Corresponding author*. Faculty of Environmental Sciences and Natural Resource Management, Norwegian University of Life Sciences, Ås, Norway. Fax: +47 6496 5801.
E-mail addresses: daquansah.coe@knust.edu.ng (D.A. Quansah), muyiwa.adaramola@nmbu.no (M.S. Adaramola).
http://dx.doi.org/10.1016/j.ijhydene.2016.10.119

Introduction

Due to improved technology, reduction in photovoltaic (PV) cost and national and international climate change policies, solar energy is expected to contribute substantially to the future global energy mix. This contribution could be more significant for country like Ghana due to her geographical location. As a tropical country, Ghana has abundant solar energy resources. The daily solar irradiation ranges from 3.1 kWh/m^2 along the coastal region to 6.5 kWh/m^2 in the northern region. Both large- and small-scale development of solar energy conversion systems (especially solar PV systems) in Ghana can achieve three complementary goals, which are improved electricity access (both in rural and semi-urban areas), job creations and skill development, and offset greenhouse gas (GHG) emissions from thermal power plants.

In addition to solar energy resource (solar irradiation) and environmental factors, the performance of a PV system depends on the solar cell technology used for such system. This is mainly due to the solar cell efficiency, temperature coefficients (maximum power, open-circuit voltage and short-circuit current) and overall sensitivity to environmental conditions (such as ambient temperature, dust and shading) that are functions of solar cell technology. Even though, solar PV performance can be assessed using simulation softwares (tools), however, performance assessment of an actual PV system installation is the best way to determine the potential for solar PV power production in an area.

There are many studies on performance evaluation of solar PV installation installed outdoors globally. While some of these studies focus on one solar technology PV systems e.g., [1–11], others considered two or more technologies solar PV systems e.g., [12–17]. These studies show that solar PV performance at a given site is a function of the solar cell technologies. Nevertheless, to our knowledge, there is little information available (in open literature) on the actual operation and energy production from PV systems in sub-Saharan Africa, especially in Ghana. This paper presents performance measurements of five different commercially available solar PV technologies installed at the College of Engineering of the Kwame Nkrumah University of Science and Technology (KNUST) Kumasi, Ghana. The findings from this study can be helpful in identifying specific solar cell technology that is more appropriate for this location and locations with similar climate conditions as well as to provide useful information to policy makers and individual about the performance of grid-tied PV system in Ghana. Furthermore, the collected performance data can be used to validate PV performance model and numerical simulations.

Material and methods

PV systems and module technologies

Five small-scale PV systems with poly-crystalline Silicon (pc-Si), mono-crystalline Silicon (mc-Si), thin-film Copper Indium disulfide (CIS), Amorphous Silicon (a-Si), and Heterojunction Incorporating thin film (HIT) solar cell technologies are

Table 1 – Technical specifications of modules.

Cell-technologies	Amorphous Silicon	Mono crystalline Silicon	Polycrystalline Silicon	Heterojunction Incorporating thin (HIT) film	Copper Indium disulfide (CIS)
Model	Schott ASI100	Schott Solar GmbH Mono 190	Schott Solar GmbH POLY 225	Sanyo H250E01	Sulfurcell SCG50-HV-F
Module × string	10 × 4	7 × 3	9 × 2	8 × 2	9 × 9
Total number of modules	40	21	18	16	81
Number power per module (W)	100	190	225	250	50
Total module peak power (W)	4000	3990	4050	4000	4050
Voltage at nominal power (V)	30.7	36.4	29.8	34.9	36.8
Current at nominal power (A)	3.25	5.22	7.55	7.18	1.36
Open circuit voltage (V)	40.9	45.2	36.7	43.1	49.5
Open circuit current (A)	3.85	5.46	8.24	7.74	1.66
Maxi. system voltage (V)	1000	1000	1000	1000	1000
Temperature coefficient of open circuit voltage (%/°C)	−0.33	−0.33	−0.33	−0.01	−0.26
Temperature coefficient of short circuit current (%/°C)	0.08	0.03	0.04	0.03	0.04
Temperature coefficient power (%/°C)	−0.20	−0.44	−0.45	−0.30	−0.30
Total surface area of PV system (m^2)	58.9	28.1	30.6	22.6	68.6
Nominal power of PV-module (kW)	4.00	3.99	4.05	4.00	4.05
Module efficiency (%)	6.9	14.5	13.7	18.0	6.1
NOCT (°C)	49	46	47.2	46	47

Please cite this article in press as: Quansah DA, et al., Performance analysis of different grid-connected solar photovoltaic (PV) system technologies with combined capacity of 20 kW located in humid tropical climate, International Journal of Hydrogen Energy (2016), http://dx.doi.org/10.1016/j.ijhydene.2016.10.119