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Performance evaluation of grid-connected photovoltaic systems based on two photovoltaic module technologies under tropical climate conditions

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ABSTRACT

The aim of this paper is to evaluate grid-connected photovoltaic systems based on two kinds of photovoltaic module technologies. This study presents a one-year evaluation of four grid-connected photovoltaic systems installed at the National Institute of Advanced Industrial Science and Technology, in Tsukuba in the northern Kantō region of Japan. Two grid-connected systems based on multi-crystalline: mc-Si and two other ones based on thin film technology namely copper indium selenium: CIS modules. The monitoring data have been collected for one year to make an evaluation of all possible changes in climate environment. The goal of this study is to define the characteristics, the behavior and the sensitivity of the grid-connected PV system to the environmental parameters. Various parameters were used for the outdoor performance evaluation of the four grid-connected PV systems; including performance ratio, temperature losses, final yield, reference yield, AC energy generated and system efficiency. It was found that the grid-connected PV systems based on mc-Si technology perform much better than the systems based on CIS.

The annual average daily performance ratios of the systems based on mc-Si modules were found to be about 5.53% higher compared to those of the systems based on CIS module, and an annual average daily AC energy production about 42.85% higher than CIS.

1. Introduction

Nowadays, the pollution generated by fossil fuels, such as oil, coal, natural gas and nuclear power influences the rising of global warming [1]. Clean technology and especially solar power will be the most appropriate solution to overcome the energy crisis in the future and to face the environmental problems [2–4]. In the recent decade, photovoltaic has been seen as a competitive energy source and a forward step towards the sustainable development [5].

The efficiency of solar modules has been improved significantly and now it is reaching 40% by the use of new technologies [6]. This made the photovoltaic system become an essential system in worldwide electrical power production [7].

The monitoring and evaluation of PV systems have become a crucial task since they defined the characteristics, behavior, and sensitivity to the meteorological parameters in the outdoor environment [8].

Outdoor monitoring and evaluation of PV systems based on data analysis are considered very important to the performance prediction of different PV technologies including the inverter and maximum power point tracking (MPPT) method [9–11].

The goal of monitoring PV systems is to provide useful information about their operation and what should be done to improve their performance. Appropriate performance parameters must be well chosen with constantly updated values [9]. Usually and in order to be alerted of malfunctioning, it is useful to monitor the performance of each component over time for preventive action. In the case of monitoring photovoltaic systems, generally, the electrical output parameters are measured according to a well-chosen sampling time. The obtained raw data must be checked for integrity and summarized to be suitable to perform the analysis. Data need to be collected for at least one year to reflect seasonal variations when they are analyzed.

In Greece, Protogeropoulos et al. [12] evaluated the performance of different PV module technologies in the grid-connected pilot project. The module technologies are hybrid monocrystalline/amorphous-silicon, multi-crystalline silicon, thin-film CdTe and thin-film CIGS. They concluded that grid-connected PV systems with hybrid monocrystalline/amorphous-silicon, multi-crystalline modules performs better than the other technologies. Micheli et al. [13] conducted a performance analysis of two grid-connected photovoltaic systems under outdoor in the north of Italy. The first system is composed of hetero-junction with

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Fig. 1. Grid-connected PV systems.

intrinsic thin layer (HIT) modules and the second one of monocrystalline back-contact modules. They found that the system with HIT technology performs better than the monocrystalline back-contact technology. Komoni et al. [14] analyzed the performance of two grid-connected PV systems in Kosova. The first one is composed of monocrystalline modules and the second of multi-crystalline modules. They found that the PV system based on multi-crystalline modules generates more energy than the PV system based on monocrystalline modules. In India, Tripathi et al. [15] analyzed the performance of two grid-connected PV systems; one based on multi-crystalline modules and another based on amorphous silicon (a-Si) modules. They found that PV system with multi-crystalline modules performs better than the system with a-Si. In Kuwait, Al-Otaibi et al. [16] evaluated the performance of two grid-connected PV systems. The two systems are based on copper indium gallium selenide (CIGS) modules and equipped with automated cleaning systems. The automated cleaning systems were used to keep the soiling effect at a minimal amount. They found that the PV systems have a performance ratio of no less than 70%. In Malaysia, Humada et al. [17] evaluated the performance of two grid-connected PV systems under tropical climate conditions; one based on monocrystalline modules and another on copper–indium–diselenide (CIS) modules. They concluded that the PV system with CIS modules generates more energy with more efficiency and high-performance ratio than the PV system with monocrystalline modules.

In this paper, a performance evaluation of grid-connected PV systems installed in the National Institute of Advanced Industrial Science and Technology in Tsukuba, in the northern Kantō region of Japan is presented. Different performance evaluation parameters are presented based on collected data between August 2009 and July 2010. The performance computed parameters are based on monthly average daily values, including performance ratio, temperature losses, final yield, reference yield, AC energy generated, inverter efficiency and system efficiency.

The rest of the paper is organized as follows: Section 2 introduces the materials and methods, including the system configuration and analysis method. Section 3 presents the results and discussion. Finally, the most important conclusions are summarized in Section 4.

2. Materials and methods

2.1. System configuration

The four grid-connected PV systems presented in the study are as follows: two PV systems based on multi-crystalline: mc-Si modules and two others on copper indium selenium: CIS modules. For the first two PV systems mc-Si1 and mc-Si2, each one is composed of 27 multi-crystalline PV modules arranged in 3 parallel strings of 9 series modules, and for the second ones CIS1 and CIS2, each one is composed of 30 CIS (Copper indium selenium) PV modules arranged in 6 parallel strings of 5 series modules. All modules are mounted at an angle of 15° on the building laboratory roof of Tsukuba's National Institute of Advanced Science and Technology (AIST) (Latitude 36°3′N and longitude 140°8′E). The grid-connected PV systems are shown in Fig. 1, and Fig. 2 depicts their schematic layout. The principal parameters of each technology of the grid-connected PV systems are reported in Table 1.

The monitoring system was set to measure and store the electrical and meteorological parameters every 1 h. The irradiance was measured using HukseFlux LP02 Pyranometer with tilt response $< \pm 2\%$ (0–90° at 1000 W/m^2), and the ambient temperature was sensed by Vaisala HMP155 probe with a temperature accuracy of ±0.20 °C. The modules temperature are sensed using the T type thermocouple cables attached to the back surface of the modules. All parameters were recorded by a data logger.

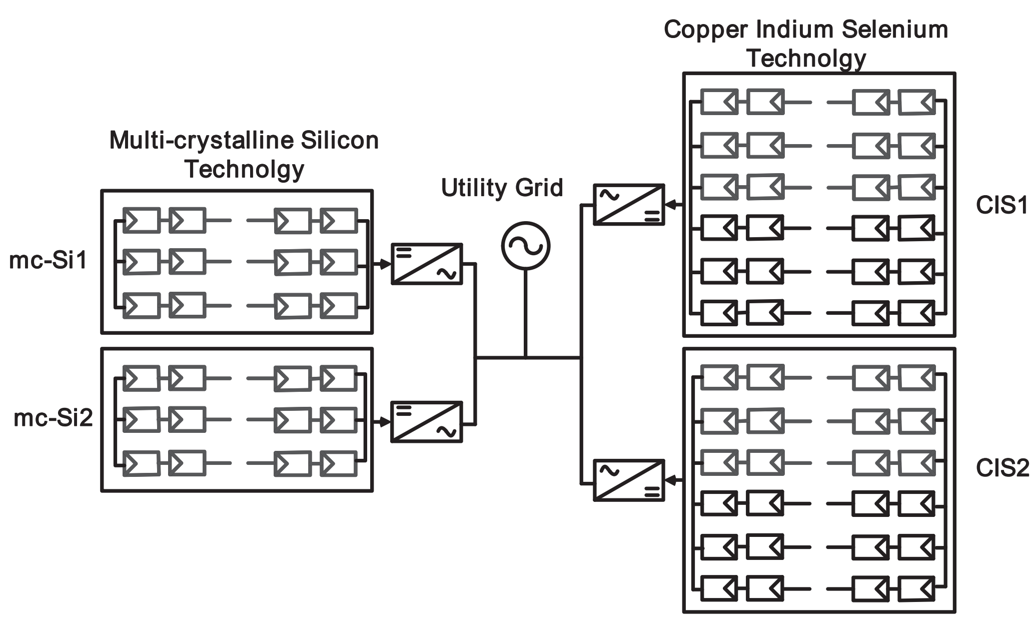

Fig. 2. Schematic layout of the four grid-connected PV systems.