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Study of degradation of a grid connected photovoltaic system

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Abstract

Performance of photovoltaic (PV) systems degrades due to the technology and the operating conditions. The degradation of is one of the key indicators for reliability assessment of a PV system. This paper presents a degradation study of the grid connected PV system located in the campus of the University of Salento. A comparative analysis of actual and theoretical output power is carried out over a monitoring period of five years. PVsyst software is chosen to simulate the output power using actual meteorological data. The hourly expected power generation index is introduced to investigate on degradation and reliability.

Keywords: Photovoltaic, Grid connected, Simulation, Reliability, Degradation, PVsyst

1. Introduction

The modern energy management systems can contribute to increase PV power generation in the small scale grid by providing a strategic support for control and monitoring of the renewable energy systems [1]. In fact the data collecting from technological devices as environmental sensors, inverters and meters can support the PV generation predictions that is an essential task for high integration into the electricity network [2][3]. Furthermore the data processing and analysis, come from the monitoring of PV systems, enable to assess the performance of grid-connected PV systems [4] and to investigate the impacts of the weather variables as solar irradiance and ambient

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temperature on the photovoltaic generation prediction [5] [6]. The PV generation forecasting is a complex task, considering stochastic impact of weather conditions on the prediction accuracy [7] [8] and the effect of the performance degradation of the PV systems due to shadows, soiling and system component faults. The degradation causes a loss of power and consequently a decreasing of performance over the time. It is present at all levels of the whole system and depends on technology and operating conditions. The degradation is one of the main factors for reliability assessment of a photovoltaic system.

Generally, the reliability of a system is the ability to perform a defined function in a perfect manner. In the case of the electrical generation by photovoltaic source, the randomness of solar irradiance causes fluctuations of the power output, impacting on the reliability of such system. A wide spread of the PV generation can generate negative effects on the power distribution network as voltage fluctuation and reverse power flows, which are not inadmissible to ensure a stable supply of energy, causing also the increasing of the maintenance costs and the risk of power outages. Reliability is one of the main indicators to assess the effects of the renewable generation in the distribution networks in term of the cost and the power outage.

In this context, methodologies and tools to quantify the reliability of grid-connected PV systems are needed [9]. The degradation studies can support the reliability assessment of the PV system. Previous works have already demonstrated the effectiveness and the potential of analytical methods for the reliability evaluation of a renewable power system [10].

In the framework of the PV reliability assessment the present paper aims to perform a degradation study of the PV plant located at the Campus of the University of Salento by analytic approach that requires simulations of output power in order to compare the actual measurements collected on site and the theoretical output power. The theoretical model was implemented by using the PVsyst software [11]. The expected power generation index, defined as the ratio between actual output power and expected output power, is introduced to quantify the degradation and to evaluate the reliability of the PV system.

2. Methodology

The present study is performed using the measurements related to the PV system, located in the campus of the University of Salento, Italy and collected from 05 March 2012 to 31 December 2016. More details of the PV plant are provided in [12]. An integrated data acquisition system allows the monitoring of the main parameters of PV system. A first class LP PYRA 02 pyranometer is used for the measurement of the solar irradiance on the plane of the array and a PT100 temperature sensor measures the ambient temperature. The PV power and solar irradiance are processed and recorded every one minute by a SCADA system, meanwhile ambient temperature is every 5 minutes. An exhaustive description of the data acquisition system is given in [13].

A method to assess the degradation of the system is to determinate the difference between the measured output power and the theoretical output power.

In the present study, the theoretical model is provided by PVsyst that is powerful software of grid-connected PV systems, able to perform detailed hourly simulations. Previous studies demonstrated that the simulations carried out by PVsyst give a good approximation of measured power output [4], [14]. PVsyst uses the one-diode model to describe the operating of a PV module, including the effects on the diode current due to the cell temperature. PVsyst takes into account also the thermal behaviour of the PV array that depends on the ambient temperature and the incident irradiance. More details of the theoretical model implemented by PVsyst are given in [14].

Furthermore, PVsyst offers relevant tools to convert and to import measured data. The "Importing ASCII files" section constructs a set of hourly data, either for meteo and for project variables, generated from any way sampled data. Therefore, such function was implemented to convert the monitored data records of solar irradiance, ambient temperature and output power with the same sampling step of one hour. Afterward, all components of the system as the modules, strings, inverter, up to the connection to the grid and loss rate were set in order to characterize the PV plant under study in PVsyst environment.

The hourly expected power generation index I_E has been introduced to quantify the degradation and to assess the reliability of PV system, as follows:

$$I_E = \frac{A_P}{E_P} \qquad\qquad (1)$$