Modeling anti-islanding protection devices for photovoltaic systems

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Abstract

Applications of grid-connected photovoltaic systems are rapidly expanding, providing a viable technology for renewable energy resources. Such systems are utility interactive and one of the major difficulties in their efficient use is related to islanding phenomena connected with a possibility of supplying surplus power back to the utility grid. In detecting and preventing such situations, anti-islanding protection devices play a paramount role. In this paper, we analyze the existing techniques in order to identify a methodology with an optimum combination of characteristics. We implement the chosen methodologies in SIMULINK. Major attention is given to the phase jump detection method (PJD), and to the slip mode frequency shift method (SMS) for which we provide a detailed description of our SIMULINK implementations and their evaluations performed on the basis of their non-detection zones. We develop an experimental iterative scheme to validate the results of computational experiments obtained with the developed models, and report the results of several computational tests.

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1. Introduction

Grid-connected photovoltaic (PV) systems continue to attract an increasing interest, in particular, in the form of photovoltaic arrays as an alternative source of energy. Such systems use solar energy to generate electricity, and they can be efficiently used as a power source for domestic use. One of the most important issues in the application of these and other dispersed power systems is the development of efficient protection techniques against a phenomenon known as islanding as well as against other "run-on" phenomena [19]. Indeed, in applications, PV systems have to be connected to a utility power grid, and hence, one has to deal with utility interactive PV systems, because both the PV system and the grid supply power to the load. If the power generated by the PV system is greater than the total needs of the entire system, the excess power will be fed back into the grid; otherwise, the power will be drawn from the grid to meet the requirement of the load.

Islanding of a grid-connected PV system occurs when a section of the utility system containing such a PV system is disconnected from the main utility voltage source; however, the PV system continues to feed the utility lines in the isolated section known as an island [15]. Such isolated islands may cause a serious danger to the personnel who may consider the load as inactive, while in reality, the PV system may feed power to utilities. They may also substantially complicate the normal reconnection of the utility network due to a damage made to the load in the island itself. Furthermore, for those utility customers located in the island, the connected equipment may also be damaged, because the supplying power will not be able to maintain the required power quality [11,12,17]. For these reasons, the islanding phenomenon is considered as one of the most important issues in designing PV systems, and in maintaining reliable utility grid operation [18].

The existing methodologies for islanding detection and prevention can be divided into two categories: active methods and passive methods [5,7,10,13,14]. In applications, each specific methodology has its own advantages and drawbacks. Therefore, in designing anti-islanding protection devices, both mathematical theory and measurements of PV systems play an important role in the success of the entire process. In this paper, our goal is to analyze, implement, and test methodologies that are most promising for this process. The paper is structured as follows. In Section 2, we give a brief overview of the existing methodologies with the aim of identifying two most promising techniques for subsequent analysis. In Section 3, we highlight the main features of the islanding network used as a prototype in further discussion. Section 4 is devoted to the construction of models for the two chosen methodologies. The main characteristic of the effectiveness of anti-islanding methods is their non-detection zone (NDZ), which is evaluated and compared in Section 5. A scheme for the experimental validation of the developed models is discussed in Section 6 by considering a case with one load combination. In Section 7, we apply that scheme to compare experimental results with the results of computations obtained with the developed models. Conclusions are given in Section 8.