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Reactive Power Dynamic Assessment of a PV System in a Distribution Grid

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Abstract

Accommodating more and more PV systems in grids has raised new challenges that formerly had not been considered and addressed in standards. According to recently under-discussed standards, each PV unit is allowed to participate in reactive power contributions to the grid to assist voltage control. There are some PV models in the literature however those models mostly assumed unity power factor operation for PV systems owing to the contemporary standards. Therefore, there is a need to develop a PV model considering the reactive power contribution and its dynamic influence on power system. This paper describes non-proprietary modeling of a three-phase, single stage PV system consisting of controller scheme design procedure and coping with the important aspects of three different reactive power regulation strategies and their impact assessment studies. The model is implemented in PSCAD to examine the behavior of the proposed model for recently codified reactive power strategies. Furthermore, this model is integrated in a distribution grid with two PV systems in order to effectively investigate consequences of the different reactive power control strategies on the distribution network.

Keywords: PV system modelling; instantaneous model; reactive power control.

1. Introduction

The growing trend in photovoltaic system installations due to encouraging feed-in-tariffs via long-term incentives has led to high penetration of PV systems in distribution grids which has brought about new issues that initially had not been addressed. In Germany, for instance, there are currently 18 GWp installed PV systems [1]. According to recent drop in costs of PV systems, especially PV panel

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technologies, which has occurred during recent years, grid-parity is not anymore unimaginable and in near future will come close to reality [2]. Thus, PV systems without incentives are more likely to be interesting in many different countries. So studying the technical aspects of integrating large amount of PV systems into grid will be an inevitable essential to keep the system on an even keel.

According to the new German grid codes [3], each PV unit is allowed to participate in reactive power contributions to the grid to assist voltage control. The reactive power regulation, in LV grid, should fulfill 0.9 under-exited to 0.9 over-exited by means of the following strategies; either fixed power factor or power factor as a function of feed-in power (*PF(P)*). Although depending on the size of PV system other methodologies such as reactive power depending the voltage (*Q(V)* droop) would be imposed by system operators. Implementation of the reactive power control is a challenge since according to standards, some criteria must be fulfilled but it has not been explicitly mentioned that which procedure and how. Another challenge associated with PV systems is that companies have their own proprietary detailed-model information which is hard to get that information. By doing so, there is a need to have some model that could capture all the fundamental characteristics of a PV system and in the meantime, being non-proprietary in order to examine the impact of PV system on distribution grid.

There are some PV models in the literature [4-7], however those models mostly assumed unity power factor operation for PV systems [4-6] or just considering reactive power support for medium voltage connected PV system [7].

Therefore, there is a need to develop PV model considering the reactive power contribution and its dynamic influence on distribution power system. In this paper a non-proprietary PV model of a three-phase, single stage PV system is proposed which consists of design procedure of two reactive power controller schemes and deals with the important aspects of three different reactive power regulation strategies. PSCAD/EMTDC is used as a platform to study widely the behavior of the proposed model along with comparing three reactive power regulation strategies. Furthermore, this model is integrated in a distribution system with two PV systems in order to effectively investigate consequences of the dynamic characteristics of the proposed model on a distribution network. Simulation results demonstrate the credibility of the designed model as well as the interaction of the three different PV reactive power regulation strategies on the bus voltages profile and on next-door PVs.

In the following, a general perspective of a PV system will be given in section 2, dynamic equations of a PV system are presented in section 3, section 4 deals with controller design procedure, reactive power control strategies are discussed in section 5 and simulations results and conclusion are presented in sections 6 and 7, respectively.

2. Structure of PV system

Fig.1 illustrates the main schematic of a single stage PV system connected through a transformer to a distribution grid. PV systems consist of PV array, dc-bus capacitor, voltage source converter and peripheral control systems. Solar cells are connected in series to form PV modules and PV modules in turn are connected in series or in parallel to form PV panels. PV panels are connected in series and in parallel to form solar array in order to provide adequate power and voltage for being connected to grid. The output power of PV array feeds in capacitor link which is connected in parallel and is transformed through parallel connected voltage source converter to AC power. The VSC terminals are connected to the point of common coupling via the interface reactor which shown by L and R, where R represents the resistance of both reactor and VSC valves. C_f is the shunt capacitor filter that absorbs undesirable low-frequency current harmonics generated by PV system. PV system is interfaced with grid through a transformer which makes an isolated ground for PV system as well as boosting the level of output voltage