Solar Energy 153 (2017) 744–754

Contents lists available at ScienceDirect

Solar Energy

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

Strategy to enhance the low-voltage ride-through in photovoltaic system during multi-mode transition

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ARTICLE INFO

Article history:
Received 20 January 2017
Received in revised form 24 May 2017
Accepted 25 May 2017

Keywords:
Grid-connected photovoltaic
Low-voltage ride-through
Reactive power
Active power

ABSTRACT

With the increasing capacity of distributed generation (DG) connected to the power grid, the future generation of photovoltaic (PV) systems are expected to provide a full range of voltage regulation during grid faults in order to enhance the low-voltage ride-through (LVRT) capability of a PV system. In such a condition, the DG should remain connected to the grid for reactive power support, thereby improving voltage profile. This paper aims to propose a control strategy of active and reactive power for a single-stage three-phase grid-connected PV system to enhance the LVRT. The dynamic behaviours of the system were investigated by considering various scenarios such as varying irradiance, local load disconnection, and short circuits, at different locations during the multi-DG operation. Results confirm that the grid-connected PV system is able to remain connected to the power grid during steady-state and transient-state conditions without violating the grid code requirements. The established dynamic behaviour analysis model of the proposed control for grid-connected PV systems can be used in planning an operational strategy for a practical system.

1. Introduction

With the upsurge in awareness about the necessity to reduce the world's dependence on fossil fuels, DG systems based on renewable energy sources (RES) such as wind, solar and hydro have gained popularity. However, the total electricity generation based on these RES is not reliable as reverse power flow may occur and it may possibly contribute to grid failure which can affect the operation and control of the power system (Babacan et al., 2017; Bevrani et al., 2010). The literature review shows that more than 80% of the cause of poor power quality in developed countries is due to voltage disturbances such as voltage sags and short interruptions (Honrubia-Escribano et al., 2014; Moreno-Munoz et al., 2010; Perpinan et al., 2013). A short-term voltage sag may occur as a result of lightning strikes, short circuits or even when large loads are connected (Dirksen, 2013; Montero-Hernandez and Enjeti, 2002). When such faults happened in the past, the IEEE-1547 allowed wind turbines (WT) to disconnect from the grid and reconnect it after a certain period of time. However, this standard (1547) was designed many years ago where the capacity of DG based on RES installation was small (Schauder, 2012; Balathandayuthapani et al., 2012). Nowadays, this practice is no longer efficient as it can contribute to voltage flickers or system instability and could lead to power outages if too many generating plants are being disconnected at the same time (Dirksen, 2013; Yang et al., 2015). This situation will affect a large number of customers. Though voltage sag generated from RES cannot be eliminated due to its stochastic nature, it can be mitigated (Ipinnimo et al., 2013). As a result, the recent grid codes require keeping the WT connected to the power grid for a pre-specified voltage sag value and duration during a fault condition.

Considering the voltage sag problems associated with RES, a so-called grid code known as LVRT has been established. The main objective of LVRT is to maintain the grid voltage stability and to avoid gigantic loss of power during the faults (Carrasco et al., 2013; Kirtley et al., 2013). Consequently, the generation based on RES should stay connected to the grid during such faults and at the same time provides grid support by injecting a reactive power in order to avoid grid collapse (Schwartfeger and Santos-Martin, 2014; Sousa et al., 2015). Fig. 1 shows the LVRT limiting curves defined by Italy, Germany, Japan, China, Spain, USA, and Denmark. Generally, if the voltage drop value is above the curve for a given specific time, the generating plant should remain connected to

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http://dx.doi.org/10.1016/j.solener.2017.05.073
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