Solar Energy 135 (2016) 29–42

Contents lists available at ScienceDirect

Solar Energy

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

Review

Current control techniques for three-phase grid interconnection of renewable power generation systems: A review

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ARTICLE INFO

Article history:
Received 18 September 2015
Received in revised form 19 May 2016
Accepted 19 May 2016

Keywords:
Current control strategies
Grid-connected inverter
Renewable power generation systems (RPGSs)
Low-voltage-ride-through (LVRT)
Grid synchronization
Harmonic distortion

ABSTRACT

Development of renewable power generation systems (RPGSs) is continually increasing worldwide with Germany, China, Japan, Italy and the USA are the leaders contributing to the largest development in each region. Due to the increasing number of RPGSs connected to the utility grid, power quality, safe operation, and islanding protection of RPGSs are becoming important issues, among others. One of the most important elements is the current control technique that must meet the requirements for grid interconnection according to international standards and practices. The RPGS itself must be safe and highly efficient for reliable and secure grid interconnection operations. This paper presents a review of the state-of-the-art of the current control techniques for three-phase grid-interconnection of RPGSs. Several current control architectures, their operations including advantages and disadvantages were discussed. Performance comparison and evaluation of several controllers were also reviewed.

Contents

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http://dx.doi.org/10.1016/j.solener.2016.05.029
0038-092X/

1. Introduction

Global energy demand is rapidly growing and presently meeting the future energy demand becomes a major concern worldwide. To meet energy demand, fossil fuels have been used as the primary energy sources since many years ago. However, fossil fuels emit greenhouse gases that highly affect the environment and future generation (Cao, 2014; Du et al., 2013; Hasanuzzaman et al., 2012; Hasanuzzaman et al., 2011; Hosseini and Abdul Wahid, 2014; Islam et al., 2014; Ünal et al., 2015; Yang et al., 2001; Yu et al., 2010). For this reason, alternative sources of renewable energy such as solar, wind, hydro, biomass and geothermal are getting popular. Grid-connected power converters are becoming more and more essential to supply clean power generation to the grid. However, concerning the power system stability, the quality of power being delivered from the renewable energy sources to the utility grid has become a very significant issue.

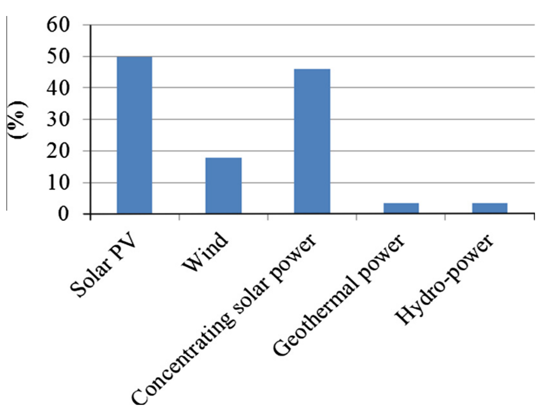

Fig. 1. Renewable energy capacity growth rates, 2006–2014 (IEA, Global Energy Trends, 2014).

Today's advanced developments in power conversion technologies enable distribution of renewable energy sources such as wind and photovoltaic (PV) power to the grid (Alepuz et al., 2006; Chung, 2000; Du et al., 2013; Hosseini and Abdul Wahid, 2014; Negroni et al., 2005; Tajuddin et al., 2015). Fig. 1 shows the average annual growth rates of renewable energy capacity in the world between 2006 and 2014. A total of 370 GW wind power and 177 GW solar/PV power have been installed worldwide by the end of 2014, as shown in Fig. 2(a) and (b) respectively. Fig. 3 shows the total installed capacity worldwide by the top ten countries in 2014.

In general, interconnection of distributed or renewable power generation systems (RPGSs) to the grid must satisfy the standard requirements on voltage support, frequency support, low voltage ride through, and current harmonics (Bao et al., 2013; Hao et al., 2012; IEEE Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems, 1993; Lauria and Coppola, 2014; Marrekchi et al., 2015; Prudenzi et al., 2001; Schwartfeger & Martin 18–20 June, 2014; Tajuddin et al., 2015; Vite Frias et al., 2014; Zhang et al., 2015). Grid voltage can be significantly affected by large power injection from RPGSs to the utility grid network. Provision of voltage and frequency supports by RPGSs through active and reactive power control must tackle both steady-state and dynamic network operations (Schwartfeger & Martin 18–20 June, 2014; Bao et al., 2013; Vite Frias et al., 2014). Steady-state operation refers to the response of RPGS to the slow variation in grid parameters such as voltage and frequency. Dynamic operation refers to the fast response provided by RPGSs in dealing with large variations in grid parameters that may collapse the utility network (Bao et al., 2013; Hao et al., 2012). Some interconnection standards require dynamic support in terms of

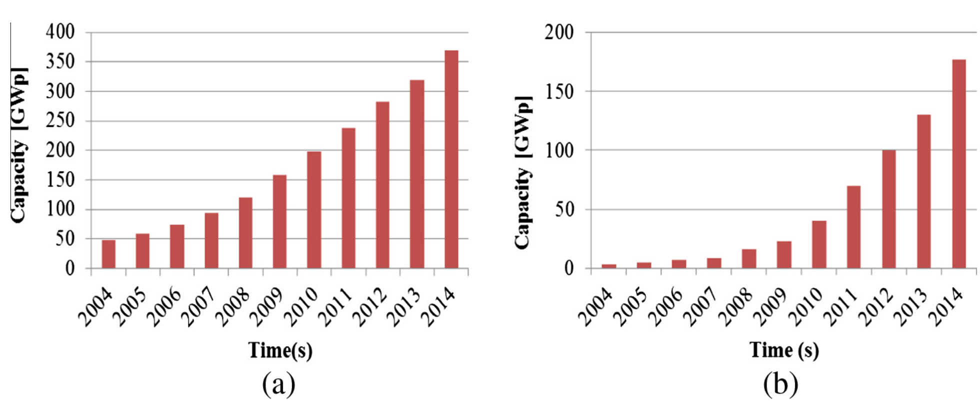

Fig. 2. Installed capacity in the world by end of 2014 (IEA, Global Energy Trends, 2014). (a) Wind energy and (b) solar/PV energy.