Renewable and Sustainable Energy Reviews 40 (2014) 557–570

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

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

Planning of grid integrated distributed generators: A review of technology, objectives and techniques

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ARTICLE INFO

Article history:
Received 20 September 2013
Received in revised form
19 July 2014
Accepted 30 July 2014

Keywords:
Distributed generation
Grid integration
Planning objectives
Renewable energy sources

ABSTRACT

The world is witnessing a transition from its present centralized generation paradigm to a future with increased share of distributed generation (DG). Integration of renewable energy sources (RES) based distributed generators is seen as a solution to decrease reliance on depleting fossil fuel reserves, increase energy security and provide an environment friendly solution to growing power demand. The planning of power system incorporating DGs has to take into account various factors such as nature of DG technology, impact of DG on operating characteristics of power system and economic considerations.

This paper put forwards a comprehensive review on planning of grid integrated distributed generators. An overview of different DG technologies has been presented. Different issues associated with DG integration have been discussed. The planning objectives of DG integration have been surveyed in detail and have been critically reviewed with respect to conventional and RES based DG technologies. Different techniques used for optimal placement of DGs have also been investigated and compared. The extensive literature survey revealed that researchers have mostly focussed on DG integration planning using conventional DGs. RES based DGs have not been given due consideration. While integrating RES, their stochastic behaviour has not been appropriately accounted. Finally, visualizing the wide scope of research in the planning of grid integrated DGs; an attempt has been made to identify future research avenues.

Contents

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http://dx.doi.org/10.1016/j.rser.2014.07.200
1364-0321/

1. Introduction

The centralized power generation has been dominating power scenario for a long time. These systems utilize conventional energy resources for electricity generation. However, worldwide urge to reduce dependency on fossil fuels and mitigate climate changes has increased pressure to alter current generation paradigm. Distributed Generators (DG) which are small power sources connected near consumer terminals [1] are emerging as an attractive substitution to the expansion of central generating facilities. DGs offer a quick fix and more environment friendly option by providing enough opportunities for RES based technologies such as wind, solar, biomass etc. Alternative energy resources such as solar and wind are abundantly available in nature and therefore have attracted energy sectors to generate power on a large scale.

Integration of DGs affects system performance in multitude of ways such as reliability, losses and voltage profile [2]. Besides, environmental benefits offered by integration of RES based DGs are looked upon as a major driving force for increased inclination towards these technologies. Nevertheless, the intermittent nature and uncertainty associated with RES based DGs pose additional challenges in system planning. The literature on planning with DG sources is mostly focussed on conventional DGs. Amongst the literature on system planning incorporating RES based DGs, the intermittency associated with these sources has not been adequately accounted for.

The objective of this paper is to provide a comprehensive review on different planning aspects of DG integration. Considering global awareness to increase penetration of renewable energy sources, the review carried out in this paper particularly pays attention to RES based DGs. The objectives of DG integration and optimization techniques used for DG placement have been closely surveyed predominantly with reference to RES based DGs.

The remainder of paper is organized as follows: Section 2 provides an introduction to distributed generation. Various prevalent definitions of distributed generation have been surveyed. An overview of different distributed generation technologies has been presented. The technologies have been discussed along with their advantages and disadvantages. Further, benefits offered by DG integration have been reviewed. Section 3 presents major technical challenges encountered in integration of DGs. Section 4 elaborates various planning objectives as reported in literature. The planning objectives have been closely reviewed with respect to conventional DGs as well as RES based DGs. In Section 5, placement problem of DGs has been critically reviewed. Different optimization techniques used for DG placement along with their merits and demerits have been discussed. Section 6 provides an elaborate conclusion on planning of distributed generators. In order to provide a deep insight, research avenues have been critically discussed giving way to future research.

2. Distributed generation

Based on literature survey, it can be said that distributed generation has mostly been defined on the basis of capacity or location [1–7]. Table 1 presents a brief summary of different DG definitions from the perspective of capacity or location.

In this paper, authors have complied with the definition of distributed generation as proposed by Ackermann et al. [1] wherein distributed generation is defined in terms of location considering no restriction on capacity or type of DG technology used. Nevertheless, as suggested by Pepermans et al. [8] there can be various other criteria which can form the basis for defining DG. Some of these are depicted in Fig. 1.

The technological innovations and changing economic and regulatory environment have contributed to a global inclination towards distributed generation. As per International Energy Agency (IEA) [7], five major factors which have significantly increased interest towards distributed generation are as follows:

Table 1
Distributed generation definitions.

S. no.	DG definition	Perspective of DG definition	Reference
1.	Electric power generation source connected directly to distribution network or on customer side of meter	Location	Ackermann et al. [1]
2.	Small generating units installed close to load centres	Location	Borges and Falca~o [2] Griffin et al. [3] Kim et al. [4]
3.	Generation from a few kilowatts up to 50 MW	Capacity	EPRI [5]
4.	All generation units with a maximum capacity of 50 MW to 100 MW, which are usually connected to the distribution network and which are neither centrally planned nor dispatched	Capacity	CIGRE [6]
5.	Generating plant serving a customer on-site or providing support to a distribution network, connected to grid at distribution-level voltages	Location	IEA [7]
6.	Generation of electricity by facilities that are sufficiently smaller than central generating plants as to allow interconnection at nearly any point in power system	Capacity	IEEE [9]
7.	Electric power generation or storage (typically ranging from less than a kW to tens of MW) that is not a part of a large central power system and is located close to the load	Capacity and location	Dondi et al. [10]
8.	Small generation units of 30 MW or less located near consumer centres	Capacity and location	Chambers [11]