Electric Power Systems Research 107 (2014) 125–132

Contents lists available at ScienceDirect

Electric Power Systems Research

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

Probability analysis of distributed generation for island scenarios utilizing Carolinas data

P.A. Gooding*, E. Makram, R. Hadidi

Holcombe Department of Electrical and Computer Engineering, Clemson University, Clemson, SC 29634-0915, USA

ARTICLE INFO

Article history:
Received 19 June 2013
Received in revised form
16 September 2013
Accepted 17 September 2013

Keywords:
Renewable resources
Distributed generation
Islanding
Probability analysis

ABSTRACT

A distribution system in the Carolinas power grid is modeled to include distributed generation and islanding capacity to create a self-supporting isolation capability. Probability analysis in the form of probability density functions for renewable resources is explained and detailed. The operating conditions within the system are defined using the generation levels of the renewable generation. These operating conditions are then interpreted through the probability analysis. Using these techniques, some of the most relevant results of the study are presented and conclusions are drawn regarding the usefulness of the results. This includes a progressive analysis that covers time periods from seasons to hours, and how these analyses could be utilized by system operators.

1. Introduction

The increasing interest in renewable resources has led to their becoming an important part of the modern electrical grid. Along with great potential, they also present challenges to incorporation, as does any new technology. Unlike conventional generation, renewable resources are predicted to be more decentralized across the grid. This can lead to a phenomenon known as islanding, where a small part of the interconnected grid can isolate and support itself through the use of its own generation [1]. To practically implement this, the resources must themselves be understood, which is difficult given the stochastic nature of renewables. With the mathematical tools of probability analysis, the uncertainty of renewables can begin to be evaluated and minimized [2]. This has been broadly applied to the area of renewable resources, even including new approaches to power flow [3]. The operating conditions of the systems incorporating distributed generation can be understood in light of these analyses.

In constructing this analysis, there are two distinct problems to be addressed when dealing with renewable resources: (1) the incorporation of these resources into the grid in determining the operating effects of the grid, and (2) the commitment of these resources as part of the generation portfolio. The first problem to solve is to clearly define the operating effects created by incorporating these resources into the grid [4]. For this study, three different operating conditions are created for the system state, which address the potential combinations of generation and system health.

The second problem to be addressed is handling the uncertainty introduced into the operation of the grid from the stochastic nature of renewable resources. Unlike conventional generation which can be adjusted as needed, renewable resources are dependent on resources that are, to much extent, uncontrollable [5]. To address this issue, the method of using probability analysis has gained traction in the study of renewables [6–13]. Using probability analysis as a tool, past information of a geographical region's resources can be modeled to provide predictions of future performance [14]. The challenge is to determine which probability models perform the best with the different resources, and how they can be applied to specific situations.

In previous probabilistic studies regarding renewable resources, several areas provide the opportunity to investigate their effects more thoroughly. While most studies are focus only on the generation aspect of renewable resources and utilize a static load [6,7,10–13], one of the basic questions of the ability of renewable generation to meet demand is left unanswered. To correct this, a dynamic load profile that reflects the changes in demand over a day is created and compared to the generation of the renewable resources, which has been utilized in previous smart grid economical analyses [15,16]. Additionally, the modeling used to investigate the probability of solar generation has long relied on numerous parameters that are not normally utilized in weather data, and also relies on an indirect measure of solar radiation, which is the clearness index [6,7]. Lastly, realistic weather and utility data will be utilized to study these methods.

* Corresponding author. Tel.: +1 843 634 3958.
E-mail address: paulgooding13@gmail.com (P.A. Gooding).

0378-7796/$ – see front matter © 2013 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.epsr.2013.09.012

The aim of this research is first to create a realistic model for a distribution system with islanding capability and renewable generation, and define appropriate operating states for the system. Secondly, the ability of probability analysis, including alternative means for determining solar probability, will be evaluated. Using real-world data, answers concerning the adequacy of wind and solar resources in comparison to demands of an actual load profile analyzed across different seasons will be given. Finally, examples of beneficial analyses including a predictive analysis will be provided based on actual weather and utility data.

The organization of the paper will begin with the development of the system model utilized, and move to the modeling of the renewable resources. The operational states of the system will be defined, and the case study and its parameters developed. Finally, the significant results of the study will be presented, along with the conclusions that can be drawn from the research.

2. Development of system model

To accurately understand the effects on grid operation from the renewable distributed generation, a realistic system model is required for the analysis. Additionally, an islanding capability that reproduces the effects of a micro-grid is created as well [17]. The process of the system design is shown in Fig. 1. The aim of this study is not to justify the economic basis for the island, but rather to provide an analysis of its effects in a realistic scenario. In this case, the island could be created as a utility experiment, at the behest of a small progressive community looking for energy independence, or as an entrepreneurial opportunity by independent renewable generation investors.

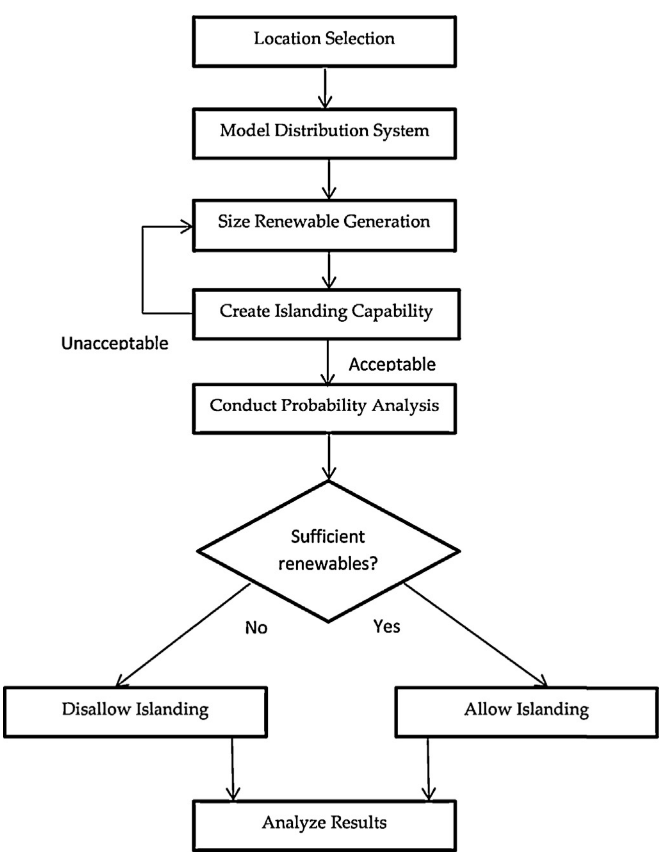

Fig. 1. Flowchart of analysis methodology.

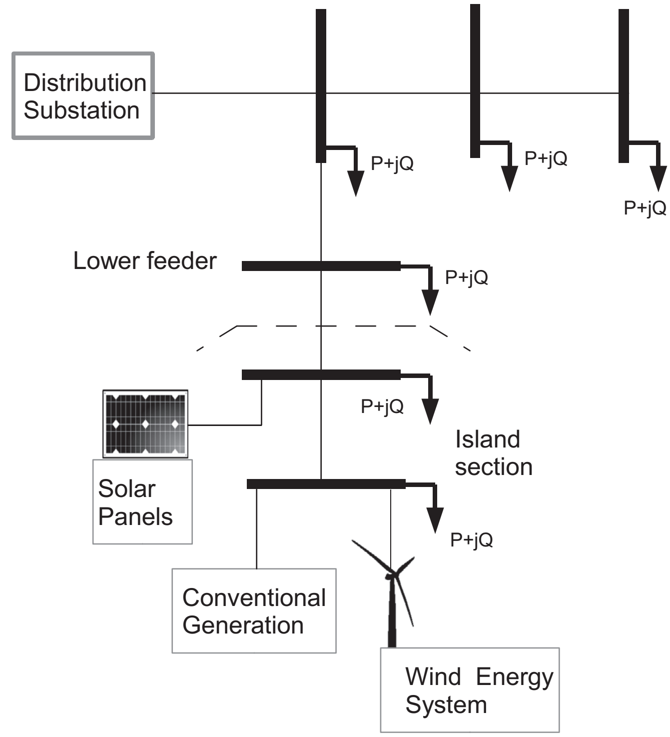

Fig. 2. Simplified topology of distribution system.

2.1. Location selection

A critical aspect of distributed generation that limits it more than conventional generation is location intensiveness. In the United States, many areas have potential for either wind or solar generation, but not both. For this study, a moderately populated area with the potential for wind and solar generation was desired in order to create a plausible hybrid wind and solar system. Several endeavors in wind power generation have begun in the coastal region of the Carolinas, which receives a healthy amount of coastal wind due to the banking effect created by the topography of the coastline. Additionally, as part of the south eastern area of the country, it also receives a good amount of solar irradiance, which is mitigated in part through high humidity in the region. Therefore, this region was selected because of its satisfaction of the requirements desired for this study.

2.2. System topology

The next step is to create a system model that accurately represents a distribution system. The system topology in this paper is a segmented model of a realistic system with the upper segment powered solely by a substation (conventional generation), and the lower segment contains distributed generation. This system model has been adapted from previous research, as it has been accepted as a viable model of a distribution system [18]. A representation of this system can be seen in Fig. 2.

The islanded portion contains approximately 6 MW of load, and three different sources of power generation in the forms of a wind energy system, solar panels, and conventional backup generation. Since the lower segment of the feeder has the distributed generation located at the end, this segment of the system has been modified to allow for islanding, or isolation from the rest of the system.