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ScienceDirect
Energy Procedia 90 (2016) 137 – 144
Energy Procedia

D 5th International Conference on Advances in Energy Research, ICAER 2015, 15-17 December 2015, Mumbai, India

Energy Savings in Radial Distribution Systems with Intermittent Wind Power and Probabilistic Load Demands

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Abstract

This paper discusses the energy savings in radial distribution systems with wind turbine integration with probabilistic load power demands. The energy savings are determined by calculating the difference cost of energy losses of the distribution system without and with the wind power source. Deterministic load flow (DLF) studies do not incorporate the randomness of the load power demands. The probabilistic load flow (PLF) method incorporates this randomness to provide more realistic and accurate results regarding the performance of the system. In this paper, the load and the substation voltages of the distribution system are considered as random variables for the calculation of energy savings. The main contributions of this paper are: i) Comparison of annual energy savings and cost of energy losses obtained using DLF and PLF calculations ii) Analysis of 24 hour energy savings of radial distribution systems with the integration of wind turbines using practical 24 hour wind data iii) Comparison of energy savings of radial distribution systems for winter and summer seasons. The comparison of energy loss savings is done on deterministic and probabilistic platforms. The study is conducted for winter and summer seasons using the corresponding hourly wind data for both seasons and hourly load demand curves for both seasons. This study can help extensively in the realistic analysis of radial distribution systems with renewable integration. The results are obtained for a standard IEEE 33 bus radial distribution system.

Peer-review under responsibility of the organizing committee of ICAER 2015

Keywords: Radial Distribution Systems; Wind Turbine Integration; Probabilistic Load Flow; Energy Savings;

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Peer-review under responsibility of the organizing committee of ICAER 2015
doi:10.1016/j.egypro.2016.11.178

1. Introduction

Electric power systems are in a continuous state of evolution and are fast evolving into a completely intelligent system [1]. Distributed Generation (DG) has procured an expanded enthusiasm for as far back as decade because of the techno-socio-economical advantages provided by it. The techniques and strategies embraced for the planning and operation of the customary unidirectional power system frameworks must be altered and remade with the mix of DG's into the distribution systems. This is chiefly in view of the fact that DG's convert the formerly passive distribution system into an active one. The different benefits of integrating DGs into the distribution system have been well examined and explored in the past [3-5]. Among its various benefits, the integration of DG units in distribution systems provides significant savings in the cost energy losses. The total power losses are reduced with DG integration and hence the energy losses are also reduced. Accurate estimation of annual energy savings with the integration of DG resources plays a very important role in the planning of power distribution systems. Wind energy is one of the fastest growing sources of energy. In the year 2014, the annual installation level rose up to 50GW, while in 2013, the annual installations were about 35 GW [6]. Wind power integration into the distribution system also poses some technical challenges. The modeling of these resources is a significantly important part of the analysis. Since the wind speed is intermittent, probabilistic distribution functions are be used to model these variables [7]. The impacts of renewable integration on distribution system parameters have to be studied before integration in order to ensure system security and reliability.

For the analysis of a distribution system to be realistic, the instantaneous dynamism of the system has to be taken into consideration while performing load flow studies. One of the vital steps in that direction is the load flow analysis of the distribution system in a probabilistic perspective. The probabilistic analysis can incorporate the stochastic behavior of the distribution system [8]. It can help provide better and more accurate results regarding various system variables. Precise and accurate modelling of feeder loads is essential for any study regarding distribution systems. In addition to modelling the load probabilistically, this work has also considered real time stochastic intermittency of substation voltages also [9]. In [10], the authors discussed the energy loss savings for a mesh distribution system in the presence of distributed generation. In the above referenced paper, the authors also incorporated the impacts of time varying realistic ZIP load models on the energy loss savings of mesh distribution systems with DG penetration. In [11], the authors discussed the use of capacitor banks for maximizing the net energy savings in radial distribution systems. The maximization of energy savings is done in the referenced paper by minimizing the power losses using various algorithms like Cuckoo search and Bat algorithm. In [12], the authors proposed a new algorithm for the accurate estimation of energy savings in a smart distribution network for Volt/Var control. The algorithm presented in the referenced paper for energy saving estimation is non-intrusive in nature. In [13], the authors presented a new methodology for allocating capacitors in distribution systems based on maximizing the energy loss reduction. The maximization of reduction in energy losses effectively maximizes the increase in energy savings with capacitor allocation. In [14], the authors presented the use of artificial bee colony algorithm for the maximization of net annual cost savings of energy loss with optimally allocated capacitor banks in radial distribution systems. In [15], the authors discussed about the energy savings by using energy efficient distribution transformers. In [16], the authors discussed the planning of energy saving modification or ESM for distribution networks. In [17], the authors presented the use of a two-point estimate method for the probabilistic load flow in order to analyze a distribution system considering wind generation. A new probabilistic load flow method was proposed based on voltage drop calculation for distribution systems with wind power in [18]. In [19], integration of wind power and electric vehicles were both considered to carry out a constrained probabilistic load flow of distribution systems. In [20], the unsymmetrical two point estimate method is used to solve the probabilistic load flow problem of distribution networks with integrated wind and solar PV modules. The literature review for this paper has revealed that very few authors have addressed the energy savings in distribution systems with intermittent wind power integration. Many authors have focused on analysing the specific economic benefits of wind energy integration in distribution networks like power loss reduction and voltage profile improvement. Even though many of these works have incorporated the probabilistic nature of the system, the accurate estimation of annual energy savings from a probabilistic perspective with wind integration needs to be addressed. In this paper, the energy savings are determined by calculating the cost of losses of the system without and with the wind power source. The energy losses before and after wind turbine integration are compared to obtain the energy loss savings. This