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Optimal Distributed Generation Placement with Multiple Objectives Considering Probabilistic Load

Ankit Uniyal^a, Ashwani Kumar^{b*}

^aNational Institute of Technology, Kurukshetra, 136119

^bNational Institute of Technology, Kurukshetra, 136119

Abstract

In this paper, optimal DG sizing and siting has been obtained considering three objectives i.e. active power loss index (APLI), line loading index (LLI) and voltage deviation index (VDI). Multiple objective NSGA-II method along with fuzzy satisfying method (FSM) has been used to solve multiple objective optimization problem. Probabilistic load model has been considered in this study. A two point estimate (2PEM) method has been used carry out o obtain probabilistic load flow solution. The analysis has been carried out for IEEE 33 radial bus test system. The analysis has been carried out using coding in MATLAB.

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Keywords: Distributed generation; indices; two point estimation method; probabilistic load flow.

1. Introduction

Distributed Generation (DG) system is a part of smart grid concept which is presently forming the backbone of modern era power distribution networks [1]. The DG systems are demarcated into two broad parts: (i) renewable energy sources (RES) and (ii) fossil fuel based sources. RES include DGs like photovoltaic, wind turbines, biomass,

* Corresponding author. Tel.: +911744233389; fax: +911744238050.

E-mail address: ashwani.k.sharma@nitkkr.ac.in

small hydro, geothermal etc. Fossil fuel DGs include internal combustion engines (IC), combustion turbines and fuel cells [2-3]. The DGs should be connected in distribution system in such a way that it avoids degradation of power quality and reliability, which makes its placement a complex combinatorial optimization issue requiring concurrent optimization of multiple objectives [4]. DG can be optimally allocated depending on various criteria; also there is a variety in the number and type of DGs that have been used in various works. Ahmadi, et.al. [5] aimed at the optimal power flow to maximize DG's real power output by reducing network losses for radial and mesh distribution networks. A multi-objective optimal power flow (OPF) problem is formulated which incorporates a direct Pure Primal Dual Interior Point Method as the solution methodology. S. Taira, et al. [6] introduced a decision technique for optimal scheduling of Battery Energy Storage, plug in EV's and DG's using Particle Swarm Optimization(PSO) An optimization problem is formulated with references of DGs, PEVs and tap transformer positions in order to reduce distribution losses. T. Tayasanant, et. al. [7] calculated optimal PV-DG size, its position in distribution system considering minimization of total system losses using the loss sensitivity factor and taking environmental uncertainties, voltage and harmonic level into account.. Atwa, et. al. [8] calculated actual energy losses in distribution system with embedded DG's using MINLP approach by taking wind DG as varying power source considering wind speed and load profile variations. Khatod, et al. [9] used an evolutionary programming (EP) technique for optimal placement of wind and solar DG units in radial distribution system for loss reduction and voltage profile improvement. The probabilistic modeling of DG and objective functions was done using Monte Carlo approach. Grisales, et. al. [10] utilized three DG techniques: Wind, PV and Small scale hydro (SSH). They used Chu-Beasley Genetic Algorithm to determine candidate nodes and PSO to determine optimum level of power injection. Kansal, et. al. [11] utilized PSO technique to find out optimal placement of wind DG in radial distribution test systems minimizing the real power losses and improvement of voltage profile. The results have been verified with analytical method which employs use of wind turbine characteristics for proper deployment of the DG unit. Kumar and Murthy [12] compared optimal DG allocation methods in radial distribution system based on sensitivity based approaches. DG size was decided based on minimum real power loss in the system. In this paper, optimal DG sizing and siting has been done considering four objectives i.e. active power loss index (APLI), reactive power loss index (RPLI), line loading index (LLI) and voltage deviation index (VDI) taken three at a time. Multiple objective NSGA-II method along with fuzzy satisfying method (FSM) has been used to solve multiple objective optimization problem. A two point estimate (2PEM) method has been used do probabilistic load flow [13]. The analysis has been carried out for IEEE 33 radial and IEEE 69 radial bus test system in MATLAB [14].

Nomenclature

PL_i and QL_i	are active and reactive loads on i^{th} bus respectively
PL_T and QL_T	are the total active and reactive load on the system
E_{p1} and E_{p2}	the values of two probabilistic points for active power
E_{q1} and E_{q2}	the values of two probabilistic points for reactive power
APLI	active power loss index
VDI	voltage deviation index
LLI	line loss index
FSM	fuzzy satisfying method
MCS	Monte Carlo simulation

2. Probabilistic load model

The loads on the distribution system vary instantaneously owing to the uncertainty of the power demand at the user end thus loads are assumed as random variables and are modelled using probability distribution functions (PDF's). Although there are lots of PDF's like Weibull, beta, uniform etc. but normal distribution or Gaussian distribution is widely used owing to its accuracy in modelling of probabilistic loads [15]. There are several methods to perform PLF in the power system. The mostly used methods are sampling methods like MCS, LHS etc., but these methods require a great deal of time. It is due to the fact in such methods that large number of samples (about 15000-

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