Multi-objective simultaneous placement of DG and DSTATCOM using novel lightning search algorithm

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Abstract

In this proposed study, a new long term scheduling is proposed for simultaneous placement of Distributed Generation (DG) and Distribution STATic COMpensator (DSTATCOM) in the radial distribution networks. The proposed work has a unique multi-objective function which consists of minimizing power loss, and total voltage deviation (TVD), as well as maximizing the voltage stability index (VSI) subject to equality and inequality system constraints. The multi-objective problem has been solved by a novel metaheuristic optimization algorithm called as lightning search algorithm (LSA). In the proposed approach, the feeder loads are varied linearly from light load (0.5) to peak load (1.6) with a step size of 1%. In each load step, the optimal sizing for DG and DSTATCOM are calculated by LSA. Through curve fitting technique (CFT), the optimal sizing for both DG and DSTATCOM per load level is formulated in the form of generalized equation. The proposed generalized equation will help the distribution network operators (DNOs) to select the DG and DSTATCOM sizes according to the load changes. The proposed method is tested on two test systems of 33-bus and 69-bus in different cases.

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Keywords: Distributed Generation (DG); Distribution STATic COMpensator (DSTATCOM); Lightning search algorithm (LSA); Voltage stability index (VSI); Curve fitting technique (CFT); Distribution network operators (DNOs)

1. Introduction

In present days, distribution system acquires huge rate of power losses, i.e., 13% in the power system which has been studied in the literature (El-Fergany, 2013). In addition to that voltage stability of radial distribution networks has received much consideration with a need for together study and improvement of the operating conditions (Abul’Wafa, 2014). Hence, various research works have been taken to decrease the power losses and enhance the voltage stability in the distribution network. The optimal allocation of DG and DSTATCOM have valid effect on reducing the distribution system power losses and voltage stability enhancement along with voltage profile improvement.

Different benefits of simultaneous allocation of DSTATCOM and DG in the RDS including reducing system power loss, voltage profile enhancement, power factor correction, load balancing, power quality improvement, on-peak operating costs reduction, releasing the overloading of distribution lines, system stability improvement, pollutant emission reduction, and increased overall energy efficiency. The power import from the substation can be reduced by using optimal generation of real and reactive power from DG and DSTATCOM in RDS thus controls feeder power flows. The optimal placement of DG and DSTATCOM regulate the real and reactive power flows respectively in the RDS. So the system total power loss has been decreased with good voltage profile enhancement.

In recent times, the integration of DGs has considerably increased in the RDS. The term “Distributed” or “Dispersed” Generation (DG) is described as small electric power generation that is directly linked to the systems. DG consists of induction generators, micro turbines, synchronous generators, reciprocating engines, fuel cells, combustion gas turbines, solar

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photovoltaic, wind turbines and other small power generation sources. DGs installation have usually less investment compared with constructing high priced new power plants and distribution and transmission lines. The features of DGs are ecofriendly, power quality improvement and economic. In addition, it gives more reliable energy solutions than traditional generating methods (Ackermann, Andersson, & Söder, 2001; Willis, 2000).

On the other hand, shunt capacitors are major devices which are generally used in distribution systems to compensate the reactive power in the RDS, but these shunt capacitors are not capable to constantly produce variable reactive power. Due to this utility has to bare extra cost of capacitors and for placing of capacitors at right places. In addition to this load balancing cannot be possible within it. Because it has some operational problems like resonance (Hussain & Subbaramiah, 2013). To resolve above-mentioned drawbacks DFACTS are used in distribution systems to compensate the reactive power requirements in the distribution networks (Jazebi, Hosseiniyan, & Vahidi, 2011; Taher & Afsari, 2014). Distribution STA/ci CO/MPen/so/ar (DSTATCOM) is a notable DFACTS device which has been used to enhance the distribution system efficiency and reliability by providing reactive power support to reduce the total line losses and to enhance the voltage profile (Ledwich & Ghosh, 2002; Sensarma, Padiyar, & Ramanarayanan, 2001; Wasiak, Mienski, Pawelek, & Gburczyk, 2007).

The problem of optimal allocation of DG and DSTATCOM in the RDS become a big consideration for power system researchers. Here is a literature review of the accomplished power system researches which can be divided into following three categories.

1.1. Optimal DG allocation without DSTATCOMs

So many optimization techniques have been used to find the optimal location and sizing of DGs in RDS. Bee Colony Algorithm (Abu-Mouti & El-Hawary, 2011), Particle Swarm Optimization and Monte Carlo simulation (Abdi & Afshar, 2013), Genetic Algorithm (Mardaneh & Gharehpetian, 2004), Honey Bee Mating Optimization Algorithm (Niknam, 2011), Quasi-oppositional teaching learning based optimization (Sultana & Roy, 2014), Backtracking search optimization algorithm (El-Fergany, 2015), Quasi-Oppositional Swine Influenza Model Based Optimization with Quarantine (Sharma, Bhattacharjee, & Bhattacharya, 2016), Imperialistic Competitive Algorithm (Poomzaryan, Karimyan, Gharehpetian, & Abedi, 2016), Grey wolf optimizer (Sultana, Khairuddin, Mokhtar, Zareen, & Sultana, 2016) have been considered for DG allocation in RDS with different objective function.

1.2. Optimal DSTATCOM allocation without DGs

And also, various research works have been carried out on optimal allocation of DSTATCOM in the RDS. The authors (Jazebi et al., 2011) utilized evolution algorithm for combined DSTATCOM and reconfiguration in the RDS for power loss minimization. The authors (Taher & Afsari, 2014), used an immune algorithm for the problem of DSTATCOM allocation to reduce the power and energy losses in the RDS. The authors (Yuvaraj, Ravi, & Devabalaji, 2015) have taken bio inspired bat algorithm for DSTATCOM allocation problem considering load variations to decrease the power loss. Gupta and Kumar (2016) solved optimal DSTATCOM placement problem using sensitivity approaches with considering time variant load models in mesh distribution networks.

1.3. Optimal DG and DSTATCOM allocation simultaneously

In literature, very few attempts were seen about the simultaneous allocation of DG and DSTATCOM in the RDS. Devi and Geethanjali (2014) used an optimization technique based on a PSO to allocate the DG and DSTATCOM simultaneously in the RDS for power loss reduction. Devabalaji and Ravi (2015) used BFOA to allocate the combined DG and DSTATCOM with a newly framed objective function in the RDS. The Improved Cat Swarm Optimization technique has been used to solve simultaneous allocation of DG and DSTATCOM in the distribution networks (Kanwar, Gupta, Niazl, & Swarnkar, 2015).

From the literature survey, it may be found that most of these optimization techniques have effectively been used to determine size, placement, loss minimization and voltage improvement problem of DG/DSTATCOM in radial distribution network. However, many of them suffer from local optimality and require large computational time for simulation. In addition, all the authors have focused only on three load levels (light, medium and peak) and the load variation has not been considered in radial distribution system. For each and every change in load steps affects variation the optimal size of DG & DSTATCOM, it will cause uncertainty in the distribution system for minimization of objective function (Harrison, Piccolo, Stano, & Wallace, 2008; Soroudi & Amraee, 2013; Soroudi, Ehsan, Caire, & Hadjsaid, 2011a, 2011b).

These inspired the present authors to introduce a new, simple, efficient and fast nature based lightning search algorithm optimization technique to solve simultaneous allocation of DG and DSTATCOM problems in the radial distribution systems. The multi-objective function of the proposed method is power loss minimization, voltage profile enhancement and VSI maximization of the system. The location and sizing of both DG and DSTATCOM have been calculated by using lightning search algorithm. In this paper, the feeder loads are linearly changed from 0.5 (light) to 1.6 (peak) with a step size of 0.01. For each step change in load, the optimal sizing of DG and DSTATCOM are evaluated. Curve fitting technique is used to find the optimal size of DG and DSTATCOM at each load level which is formulated in the form of simple quadrature equation. The proposed work is more helpful for the DNOs to select size of DG and DSTATCOM based on load steps. The feasibility and effectiveness of the proposed method have been tested with two standard IEEE buses such as 33-bus and 69-bus test systems and obtained simulation results are compared with other heuristic based algorithms.
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