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Optimizing distributed generation parameters through economic feasibility assessment

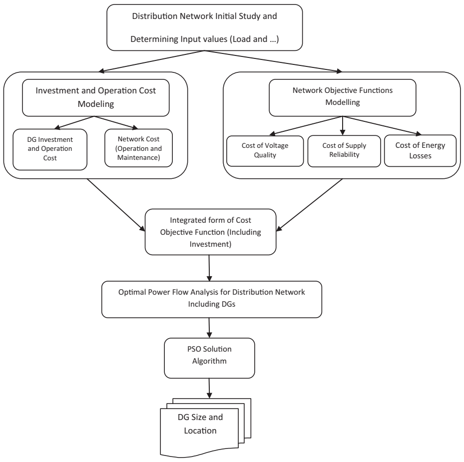
K.M. Muttaqi [a], An D.T. Le [b], J. Aghaei [c,*], E. Mahboubi-Moghaddam [c], M. Negnevitsky [b], G. Ledwich [d]

[a] Australian Power Quality and Reliability Centre, School of Electrical, Computer and Telecommunications Engineering, University of Wollongong, Wollongong, NSW, Australia
[b] School of Engineering, University of Tasmania, Hobart, Australia
[c] Department of Electrical and Electronics Engineering, Shiraz University of Technology, Shiraz, Iran
[d] School of Engineering Systems, Queensland University of Technology, Brisbane, Australia

HIGHLIGHTS

- A cost based DG sizing and placement problem is presented.
- The model simultaneously optimizes three objectives: quality, reliability and cost.
- An economic approach is implemented to evaluate the system reliability.
- A PSO algorithm is proposed to solve the optimization problem.

GRAPHICAL ABSTRACT



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ABSTRACT

To meet the fast growth of electricity demand, the traditional network solution tends to expand existing substations, build more new substations, and build transmission lines. Distributed Generation (DG) is posed as an alternative method for the network providers not only to accommodate the load increase and relieve network overload, but also to offer other additional technical and economic benefits. This paper addresses the issue of DG planning and has proposed a technique for optimizing the DG size and location to minimize the overall investment and operational cost of the system. The proposed optimization methodology assesses the compatibility of different generation schemes in terms of their cost factors that can be significantly contributed by a DG. The direct and indirect costs of power supply quality, reliability, energy loss, total power operation, and DG investment are used as key cost components of the DG siting and sizing strategy. The Particle Swarm Optimization (PSO) method is applied to obtain the optimal DG planning solutions. Finally, the proposed approach is tested on a distribution feeder of an Australian power network. Simulation results are presented to illustrate the feasibility and effectiveness of the proposed method.

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[*] Corresponding author at: 35.131, School of Electrical, Computer and Telecommunications Engineering, University of Wollongong, Wollongong, NSW 2522, Australia. Tel.: +61 474803394.
E-mail address: aghaei@sutech.ac.ir (J. Aghaei).

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1. Introduction

In recent years, Distributed Generations (DGs) play an important role in the operation of distribution networks to cope with environmental and economic issues raised by conventional large power plants. Also, both system security and reliability, especially in distribution networks, are becoming critical because of the growth in the power demand, the difficulties of building new power plants, and in expanding network capacity [1]. Recently, these obstacles together with strong encouragement to reduce emissions have been main drivers for distribution network planners to explore the economic and technical potentials of small generators, known as Distributed Generation (DG) units. DGs are defined as small-scale generating units placed close to the loads that are being served; they have variety of size from a few KWs to MWs and include two general classifications: non-renewable (like combustion gas turbines, micro-turbines, fuel cells, and micro-Combined Heat and Power (CHP) plants) and renewable energy resources (wind turbines, photovoltaic, full-cells, biomass, micro hydro turbines, etc.) [2]. A number of alternative DG technologies, such as fuel cells, storage devices, photovoltaic, and wind turbine are now approaching commercial economic viability. Moreover, conventional small generation technologies such as diesel generator and gas turbine can offer improved performance and flexibility for the distribution systems [3].

Connection of DGs fundamentally alters distribution network operation and can creates a variety of well-documented impacts: (a) reducing any penalty/payment or negative impact toward the supply quality and outages, (b) reduction of the "payment" related to grid energy losses, (c) reduction of electricity delivery cost by serving loads locally, (d) reducing the required reserve margins and increasing the energy efficiency, therefore, reduction of the capital and operation costs in some cases, and (e) reducing or deferring upgrading costs for transmission and distribution facilities. Moreover, from the customer's point of view, DG may (a) provide customers with an alternative electricity sources, (b) utilize heat, waste, or by-products from other processes if available to produce electricity, (c) reduce the electricity bills, especially in case of small and remote customers, (d) improve the power supply quality, security and reliability, and (e) reduce the amount of emissions. Subsequently, these benefits make it possible to consider DGs as a promising alternative of conventional power plants to provide electricity demand growth. In the other hand, an inappropriate sharing and operations of these resources may lead to reverse outcomes like power quality issues, high amount of losses, voltage rise, and system instability [4,5]. Indeed, the power quality of the customers is related to the quality of voltage at buses. For instance, installing DGs can boost or decline the voltage quality based on the power factor situation (lead, lag, or unity) [3]. Also, recent changes in the operation of distribution networks that enable active networks by installing DGs can lead to an increased short-circuit currents in the network apparatuses such as switchgears with lower short-circuit current levels [3]. It is evident that the placement and sizing of DGs play a significant role in the operation as well as power quality and reliability of distribution systems. Therefore, to ensure the satisfactory performance of distribution networks, it is vital to include these concerns in the placement and sizing of DGs.

DG placement and sizing by considering various technical concerns has been discussed considerably over the last decade. Indeed, this problem has been solved from different point of views. From the utilities' standpoint, DG placement problem can be modeled while considering economic objectives as well as multiple technical issues such as loss reduction, voltage profile improvement, voltage stability enhancement, network upgrade deferral, and reliability [6–12]. Also, a number of studies have been proposed in the literature to assess the compatibility of different DG planning schemes. Authors of [13] have developed an optimization model for DG siting and sizing, aiming to reduce the energy costs as well as the minimization of environmental impact in terms of CO_2 emissions. Reference [14] introduces analytical expressions to determine the optimum sizes and operating strategy of DG units considering the DG impacts on power loss minimization in the system by involving time-varying demand and possible operating conditions of DG units. An Improved Analytical (IA) method has been developed in [15], to solve the problem of accommodating different DG types into the large-scale primary distribution networks for achieving a high loss reduction. In [16], a multi-objective Chaotic Improved Honey Bee Mating Optimization (CIHBMO) was proposed to daily Volt/VAr control in distribution systems including DGs, considering objective functions counting costs of energy generation by DGs and distribution companies, electrical energy losses and the voltage deviations for the next day. Authors in [17] solved a DG placement problem, based on voltage stability analysis as a security measure. Modal analysis and continuous power flow have been used in a hierarchal placement algorithm in [17]. In [18], the DG sizing and siting have been obtained by a heuristic cost-benefit analysis based approach, with the objectives of maximizing the revenue from selling of electricity and minimizing the cost from the DG investment and operation. An overview of the state of the art on the models and methods applied to the optimal DG placement problem, and analysis and classification of the current and future research trends in this field has been presented in [19]. Also, the numerous strategies and techniques that have been developed in recent years to address DG integration and planning can be found in [20]. As well, a planning scheme has been presented in [21] for PV integration with the objectives of reducing the cost of installation, operation and maintenance as well as the energy imported from the grid side. Also, analytical approaches have been proposed to find the location, size and power factor of DG using dual indices including minimizing power losses and the enhancement of loadability and voltage stability [22,23]. In [24], a multi-objective expansion planning of distribution networks have been presented in the presence of DGs.

In Australia, Distribution Network Operators (DNOs) have been separated from the retail markets recently and hence do not have direct contact with the customers. However, they are able to own DG units under the current framework of Australian Electricity Regulator (AER) and freely decide to install the DG in the networks and can control the DG units owned by them. This paper addresses the issues and concerns of the utilities regarding the DG inclusion in the networks. One of the main challenges of utilities is to evaluate the network power quality as well as system reliability in the presence of DGs. To cope with this issue, it is desirable to develop a procedure to include the system performance index regarding power quality and reliability when DGs are located. As above mentioned in [6–24], while the optimal design and operation problem of DGs has motivated much research in the last decade, few existing tools seem to offer the evaluating tool required by utilities for financial aggregated assessment of reliability and power quality in the distribution networks in the presence of DGs. The majority of current approaches is often strongly focused to a specific project and necessitates extensive reformulation in the event of the future modifications, such as changes in DG technology options and price structures. In this regard, when a utility has made a conclusion to install a DG, decisions have to be made regarding the DG size and its location. This paper presents a methodology for optimizing a utility-owned DG size and location on the basis of economic considerations under existing loading patterns. DG is considered as voltage regulation equipment and