Electrical Power and Energy Systems 33 (2011) 1572–1583

Contents lists available at ScienceDirect

Electrical Power and Energy Systems

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

Efficient integration of distributed generation for meeting the increased load demand

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ARTICLE INFO

Article history:
Received 26 October 2009
Received in revised form 21 April 2011
Accepted 3 June 2011
Available online 27 July 2011

Keywords:
Continuation power flow
Distributed generation
Loadability
Voltage limits
Voltage stability

ABSTRACT

Distributed generation (DG) can be integrated into distribution systems to meet the increasing load demand while expansion and reinforcement of these systems are faced by economical and environmental difficulties. This paper presents an efficient methodology for integration of DG power into distribution systems, in order to maximize the voltage limit loadability (i.e. the maximum loading which can be supplied by the power distribution system while the voltages at all nodes are kept within the limits). The proposed methodology is based on continuation power flow (CPF). The effectiveness of the presented methodology is demonstrated in a test distribution system that consists of 85 nodes with integration of different penetration levels of DG power. The proposed method yields efficiency in obtaining more benefits from the same amount of DG power, decreasing the losses and improving the voltage profile.

1. Introduction

The planning of distribution networks in the presence of DG requires the definition of different parameters, such as the best technology to be implemented, the number and capacity of the DG units, the best location and the type of network connection. The problem of DG allocation and sizing is of great importance. The installation of DG units at non-optimal places can result in an increase in system losses, implying in an increase in costs and therefore, having an effect opposite to the desired. However, the selection of the best places for installation and the size of the DG units in large distribution systems is a complex combinatorial optimization problem [1]. In the developing countries, where the utilities already facing the problem of high power losses and poor voltage profiles because of high loads, theses utilities need the DG to be integrated properly, so it takes the advantages of improving the loadability, reducing the losses and improve the reliability of the supply [1,2]. Fig. 1 shows different objectives of DG placement and sizing which have been considered in different studies in the literature.

Loss minimization is the most objective which has been reported in the literatures. Different methodologies have been implemented for minimizing the losses of the distribution network through the placement and sizing of DG units such as analytical methods [2–6], Genetic Algorithm (GA) [1,7–9], Ant Colony [10,11], Fuzzy System (FS) [12], Evolutionary Programming (EP) [13–15], Tabu-Search (TS) [16] and Dynamic programming [17].

However, a little work has been conducted for improving the loadability, and the loadability which is considered as an objective in the literatures is the voltage stability limit. Mithulananthan and Oo [18] has introduced a methodology where the tangent vector and right eigenvector are implemented to define the weakest bus in the network. Then the DG is integrated at that bus. It was found that interconnecting of DG at this bus improving the voltage stability margin of the system, reducing the main feeder current, reducing the losses, and enhancing the voltage regulation. Lomi et al. [19] has introduced a methodology based on identifying the weakest bus on the network through the evaluation of a voltage stability index. Then the DG is recommended to be integrated at that bus in order to enhance the Voltage Stability Limit Loadability (VSLL). It has been found that for the DG which supplies active power only, the weakest bus might not be the best choice for improving the voltage stability. Moreover, it has been found that the DG which is capable of supplying active and reactive powers gives more improvement in the VSLL than injecting reactive power only at that node.

Hedayati et al. [20,21] have introduced a method for improving the voltage stability margin based on CPF. This method is a multi objective method, i.e. voltage profile improvement, power losses reduction, power transfer capacity enhancement and, VSLL improvement. The methodology is based on placing multi DG unit's at the most sensitive voltage buses to collapse. Then two or more DG units with the same capacities are placed at these buses. Alonso and Amaris [22] employed the GA to find the optimal

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doi:10.1016/j.ijepes.2011.06.032

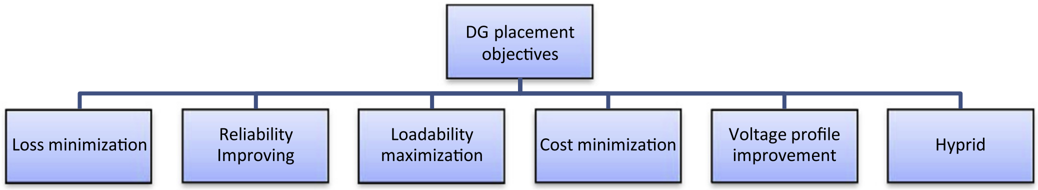

Fig. 1. Different objectives of DG placement and sizing.

point of connection of different DG units, with VAR capability, in order to maximize the VSLL of the system.

Analyzing these scientific literatures, it can be concluded that a small number of studies have considered the maximization of the system loadability of the distribution network through the optimal placement of the DG units. Moreover, the loadability which is considered in this small number of studies is the VSLL. While the installation of DGs in certain locations to meet the increasing demand can reduce or avoid the need for building new T&D lines and upgrade the existing power systems [23]. It is needed to present a methodology for identifying different recommended nodes for interconnection of different number of DG units for enhancing VLL. Moreover, maximize the benefits in that issue from the same amount of DG power. In the current study an efficient method for identifying different nodes for integrating the DG to improve the VLL is presented. This method is based on dispersing the DG supplied power between different recommended nodes for maximizing the benefits which can be obtained from a certain amount of power. The suggested methodology is developed based on CPF which is implemented in PSAT [24]. Other technical issues like the system losses, voltage profile, and voltage stability margins are also investigated for the resulted DG locations. The proposed methodology is implemented first using a certain number of DG units then using different penetration levels and different reactive power injections of DG units.

2. Continuation power flow

The continuation method is a mathematical path-following methodology used to solve systems of nonlinear equations. Using the continuation method, a solution branch can be tracked around the turning point without difficulty. This makes the continuation method quite attractive in approximations of the critical point in a power system. The CPF captures this path-following feature by

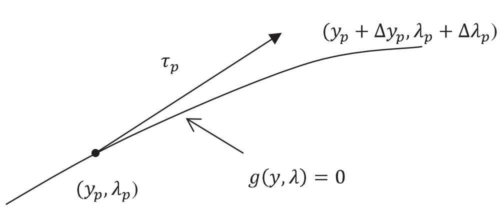

Fig. 2. Predictor step by means of tangent vector.

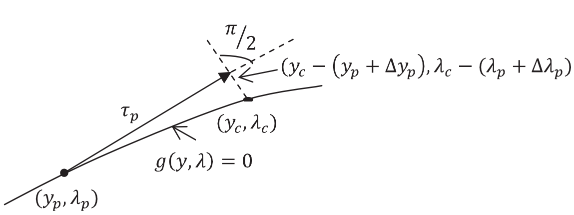

Fig. 3. Corrector step obtained by means of perpendicular intersection.

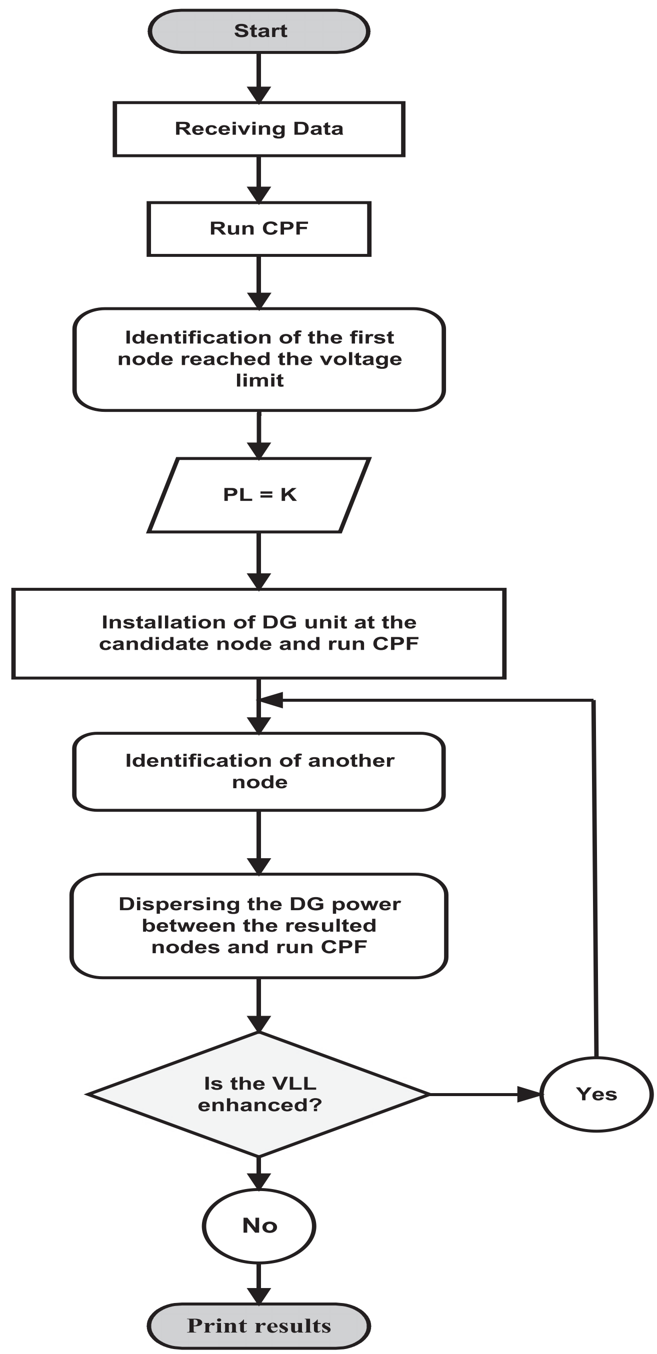

Fig. 4. Flowchart of the proposed methodology.