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A novel optimal distribution system planning framework implementing distributed generation in a deregulated electricity market

S. Porkar[a,b], P. Poure[c,*], A. Abbaspour-Tehrani-fard[a], S. Saadate[b]

[a] Department of Electrical Engineering, Sharif University of Technology, Tehran, Iran
[b] Groupe de Recherches en Electrotechnique et Electronique de Nancy, GREEN-UHP, Université Henri Poincaré de Nancy I, BP 239, 54506 Vandoeuvre les Nancy Cedex, France
[c] Laboratoire d'Instrumentation Electronique de Nancy, LIEN, EA 3440, Université Henri Poincaré de Nancy I, BP 239, 54506 Vandoeuvre les Nancy Cedex, France

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ABSTRACT

This paper introduces a new framework included mathematical model and a new software package interfacing two powerful softwares (MATLAB and GAMS) for obtaining the optimal distributed generation (DG) capacity sizing and sitting investments with capability to simulate large distribution system planning. The proposed optimization model allows minimizing total system planning costs for DG investment, DG operation and maintenance, purchase of power by the distribution companies (DISCOs) from transmission companies (TRANSCOs) and system power losses. The proposed model provides not only the DG size and site but also the new market price as well. Three different cases depending on system conditions and three different scenarios depending on different planning alternatives and electrical market structures, have been considered. They have allowed validating the economical and electrical benefits of introducing DG by solving the distribution system planning problem and by improving power quality of distribution system. DG installation increases the feeders' lifetime by reducing their loading and adds the benefit of using the existing distribution system for further load growth without the need for feeders upgrading. More, by investing in DG, the DISCO can minimize its total planning cost and reduce its customers' bills.

1. Introduction

With the advent of the deregulation trend, the traditional vertically integrated electric power system was divided into separate identities. However, the main system infrastructure and equipment remained the same. Each identity became dedicated to perform only in one of the following fields: generation, transmission, or distribution [1–3].

The main objectives of the deregulation are to improve efficiency of the electric power industry and to reduce electricity prices. The focus is now put on the end-customers [4]. The unbundling in the electric system structure invites the possibility of having power generation anywhere in the electric system. Moreover, the rapid load growth of electric energy consumption adds a further burden on the electric planners and increases planning complexity. Traditional investments are not easily feasible under a deregulated environment, where the fluctuations of market prices make investments more risky. Consequently, it is difficult to take a stable economical investment decision [5–8]. These changes and alterations in the electric system structure, operation, and economics have to be incorporated in the distribution system planning (DSP) process. Therefore, new DSP models have to be developed; otherwise misleading optimal planning decisions are obtained.

The aim of the DSP is to assure that the growing load demand can be fulfilled technically and economically by optimal distribution system expansion. The new DSP problem has to be formulated and introduced to obtain the win–win case for all players [7,8] by introducing non-traditional capacity investment options. Distributed generations (DG) are becoming increasing one of the new attractive options for distribution companies (DISCOs) planning [4,9,10].

DG provides small-scale power generation at/or close to customer sites using different technologies. It can be considered as a new take on an old concept that plays an immense role in alleviating the pressure on an already overloaded electric power system [1,11–13].

DGs can reduce:

- the transmission and distribution (T&D) networks' investment cost by installing them in suited locations [10,14,15];
- T&D networks' power flow thus improving the system's voltage profile [15–17];

* Corresponding author. Tel.: +33 83 68 41 60; fax: +33 83 68 41 53.
E-mail addresses: siyamak.porkar@green.uhp-nancy.fr (S. Porkar), philippe.poure@lien.uhp-nancy.fr (P. Poure), abbaspour@sharif.edu (A. Abbaspour-Tehrani-fard), shahrokh.saadate@green.uhp-nancy.fr (S. Saadate).

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