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Electrical Power and Energy Systems 28 (2006) 244–252

ELECTRICAL POWER & ENERGY SYSTEMS

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Impact of distributed generation on distribution investment deferral

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Received 1 October 2004; received in revised form 19 October 2005; accepted 10 November 2005

Abstract

The amount of distributed generation (DG) is increasing worldwide, and it is foreseen that in the future it will play an important role in electrical energy systems. DG is located in distribution networks close to consumers or even in the consumers' side of the meter. Therefore, the net demand to be supplied through transmission and distribution networks may decrease, allowing to postpone reinforcement of existing networks. This paper proposes a method to assess the impact of DG on distribution networks investment deferral in the long-term. Due to the randomness of the variables that have an impact on such matter (load demand patterns, DG hourly energy production, DG availability, etc.), a probabilistic approach using a Monte Carlo simulation is adopted. Several scenarios characterized by different DG penetration and concentration levels, and DG technology mixes, are analyzed. Results show that, once initial network reinforcements for DG connection have been accomplished, in the medium and long-term DG can defer feeder and/or transformer reinforcements.

Keywords: Electricity distribution; Distribution planning; Electricity economics; Distributed generation; Monte Carlo simulation

1. Introduction

Distributed generation (DG) is a new challenge for electric power systems. Traditionally, electric power has been produced at central station power plants and delivered to consumers using transmission and distribution networks. DG is an alternative to electricity supply and represents a dare to traditional schemes.

Although the current literature does not provide a consistent definition of DG [1], it can be defined as a small electric power source usually connected to distribution networks or even in the consumers' side of the meter. Actually, the concept of embedded generation is old, for instance, in the 1970s disperse storage and generation technologies were investigated under US DOE research projects, and then in the 1990s the concept of Integrated Resources Planning (IRP) for distributed system planning has been widely propagated [2]. But it is only nowadays that the total DG capacity is growing very fast and it is foreseen that it will have a relevant role in electric power systems.

The main driver for this change is the development of a new generation of DG technologies, especially renewable DG (wind turbines, photovoltaic, biomass, etc.) and some fossil DG that have combined heat and power (CHP) capabilities, along with the implementation of incentive and promotion mechanisms by many countries to increase their share in the generation mix for environmental reasons.

But there are still several regulatory, economic and technical barriers to the integration of DG in electric power systems [3]. The connection of DG and the marketing of the energy produced by these sources are difficult partly due to these barriers. Most countries are developing specific recommendations to incentive connection of DG [4–7] but still there is a lot of work to do.

From a technical point of view, power injections from DG can modify the usual direction of power flows in radial distribution networks. This affects network operation and planning practices with economic implications [8–10]. For instance, ohmic losses, voltage profiles, reliability of supply, maintenance costs, and network connection and reinforcement costs can be affected by the connection of DG to distribution networks.

DG may impact on distribution costs in different ways [11]. Some of these impacts are:

- Need of initial network investments to accommodate the injection of power produced by DG. This refers to the problem of whether DG should be charged with shallow or deep connection costs [12].

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0142-0615/$ - see front matter © 2005 Elsevier Ltd. All rights reserved.
doi:10.1016/j.ijepes.2005.11.016

- Modification of distribution operation and maintenance costs (ohmic losses modification, more sophisticated voltage control schemes, more complex protection devices, new voltage quality problems, maintenance of reliability of supply in case of DG failures, etc.).
- Modification of network reinforcements, in existing feeders and transformers, to face natural load growths in the medium and long-term.
- Modification in the long-term of future network designs taking into account DG as a strategic variable [13,14] or, if DG installation is not under the control of the distribution utility, as another factor of uncertainty.

Nowadays, the study of the impact of DG on investment deferral is still in an incipient state. Several authors discuss the potential of DG to defer investments [11,15,16]. They state that this potential is based on its proximity to load demand: if DG supplies energy locally, the power flow through the network will decrease and therefore a greater load growth will be acceptable without reinforcements. The proximity to the demand allows DG to compete not only against generation costs but also against transmission and distribution costs. Those researchers only discuss the theoretical potential of DG to defer investments but they seldom quantify the impact of DG on investment deferral.

Moreover, researchers usually compare the economic profit of several investments options including investments in DG. That is, their work is based on the assumption that the distribution companies (DISCOs) have the choice between reinforcing the network and investing in DG. This scenario is not usual because DG is installed according to its own economic incentives, without the participation of DISCOs in this decision, at least in Europe.

This paper proposes a method to evaluate the impact of DG connection to distribution networks on existing feeder and/or transformer reinforcements facing the natural load growth in the medium and long-term. This impact is measured in terms of the increase in the admissible load growth as a function of the overload probability in the network. The paper continues the research presented by the same authors in [17], improving modeling issues and confirming previous results.

The rest of technical and economic aforementioned aspects are not studied in this paper. However, an extension of this methodology is also used to determine initial network investments to accommodate a particular connection of DG.

The paper is organized as follows: Section 2 presents the proposed general approach as well as some useful definitions. Section 3 describes the system and DG modeling. The computational algorithm developed is described in Section 4. Results and conclusions are presented in Sections 5 and 6, respectively.

2. General approach

Till now, distribution networks have been designed without DG in mind [18]. Distribution networks are dimensioned to meet the peak demand. If load demand increases beyond the maximum admissible load limit, network reinforcements should be carried out. DG may reduce the net peak demand of the feeder where it is connected by serving onsite loads and releasing upstream existing generation and transmission capacity to meet new peak demand requirements. In existing distribution networks, DISCOs decide to invest in feeder and transformer reinforcements when some technical or economical constraints are reached. Those constraints can be related with:

- Network maximum transfer capacity. Maximum power flow allowed through the transformers or the different sections of the feeder.
- Maximum voltage drop. An increase in the load leads to greater voltage drops. There are limits in maximum allowed voltage variations.
- Ohmic losses. If losses grow enough, reinforcement of feeder sections could be economically justified. In fact, this constraint is usually reached before the aforementioned technical ones. However, DISCOs will take it into account only if they receive correct incentives in that direction.

All the three previous conditions can be reduced to an equivalent maximum network transfer capacity or admissible load in MW (see Section 4). The objective of the proposed methodology is therefore to estimate the admissible load growth in distribution networks with and without DG, taking into account all the relevant variables that affect this impact. By comparing a set of DG scenarios, it is possible to quantify how much the maximum admissible load changes in the network. That means how much DG could defer reinforcement investments in the medium and long-term.

Load growth is modeled as a homothetic growth in all distribution load nodes. That is, the same load growth rate is used in every load node. The developed approach computes in each scenario the allowed load growth before reaching the network maximum transfer capacity. The resulting allowed load growth can be transformed to years of investments deferral using a given annual load growth rate.

Due to the random character of the relevant variables involved (hourly load demands, DG hourly energy productions, DG failure rates, etc.) a probabilistic approach is adopted. A Monte Carlo simulation technique to analyze the network flows hour by hour in several years has been implemented. This kind of approach allows obtaining the probability density function (PDF) or cumulative density function (CDF) of relevant variables [19].

By comparison of the base case (without DG) with different DG scenarios, it is possible to evaluate the impact of DG connection on network investment deferral.

2.1. Definitions

The main definitions used in this paper are:

- *Load demand*: Energy consumption of loads connected to the distribution network. It changes in every hour of the year.