European Association for the Development of Renewable Energies, Environment and Power Quality (EA4EPQ)	International Conference on Renewable Energies and Power Quality (ICREPQ'11) Las Palmas de Gran Canaria (Spain), 13th to 15th April, 2011

Planning of power systems with distributed generation and storage

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Abstract. A high penetration of distributed generation in electricity networks makes it necessary to adapt the network to the new conditions of generation and consumption. Storage units can be converted within a few years in another element of power grids. Therefore, it is necessary to analyze the network to determine the optimal location of distributed generation, which lines need to be built or where to install the storage units.
This paper presents a model of power network planning which takes into account the effect of the expansion of distributed generation. The results obtained show the continuing replacement of conventional generation by distributed generation and the importance of storage units in this process of replacement.

Key words

Electric network planning, distributed generation, optimization, storage

1. Introduction

In recent years, the way of generating electricity has been changing. In the past, all energy was generated in large power plants (hydro, fossil fuel and nuclear). This energy needs to be transported over long distances to consumption centers.
The emergence of new technologies that make efficient and cost effective electricity production on a smaller scale, allows the placement of this distributed generation of throughout the entire network, which is a fundamental difference, compared to the traditional approach. The introduction of any generation in these networks has changed some well established concepts . As mentioned in [1] and [2] the inclusion of renewable energy in today's society has caused the change in the way of making Electric Power Systems.

It may be that small generators scattered across the distribution networks would cause alterations in these networks or conversely have a beneficial effect. Therefore, the location of distributed generation is an important aspect of network planning.
As stated in [3] a distributed generator is connected to a distribution system, and it will produce energy right there, which changes the traditional power distribution system radically. In this sense it is important to verify that the quality of service is not affected.
Poor or no planning can result in obtaining a massive loss of power [4], or serious disturbances in the network, which would adversely affect the quality of supply. In [5] and [6] the importance of good planning is emphasized and the need to develop efficient algorithms that simplify that task is pointed out..
The influence of storage units in electricity networks is addressed by some authors. Researches in [7] carried out the optimization of a distribution system where conventional generators and non-conventional generators with random characteristics are considered. Storage units are included to withstand periods where non-conventional generators are not present. Others authors [8] describe a model to solve the optimal power flow in a power system, which includes wind farms and hydro storage units owned by independent power producers.
Paragraph 2 describes the mathematical model used here for distributed generation and storage in electricity networks. In paragraph 3, results are presented which were obtained during the planning horizon. It is confirmed a progressive increase in the penetration of distributed generation and storage units.

2. Mathematical model

The planning model is based on minimizing the cost function, subject to several technical constraints such as balance of power flows in nodes, energy balance in