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Efficient method for AC transmission network expansion planning

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ABSTRACT

A combinatorial mathematical model in tandem with a metaheuristic technique for solving transmission network expansion planning (TNEP) using an AC model associated with reactive power planning (RPP) is presented in this paper. AC-TNEP is handled through a prior DC model while additional lines as well as VAr-plants are used as reinforcements to cope with real network requirements. The solution of the reinforcement stage can be obtained by assuming all reactive demands are supplied locally to achieve a solution for AC-TNEP and by neglecting the local reactive sources, a reactive power planning (RPP) will be managed to find the minimum required reactive power sources. Binary GA as well as a real genetic algorithm (RGA) are employed as metaheuristic optimization techniques for solving this combinatorial TNEP as well as the RPP problem. High quality results related with lower investment costs through case studies on test systems show the usefulness of the proposal when working directly with the AC model in transmission network expansion planning, instead of relaxed models.

1. Introduction

Transmission network expansion planning (TNEP) is a crucial issue especially in restructured power systems. In the new environment of the electricity industry, open access to transmission networks introduces some new challenges to all market participants. As electricity consumption grows rapidly, additional transmission lines are required to facilitate alternative paths for power transfer from power plants to load centers. TNEP via simplified models such as the transportation model, hybrid model, linear disjunctive model, and DC model [1], among others, will usually fail to support a solution that can handle real network requirements. A complete and comprehensive model including major aspects of real networks, an AC model, is employed in this research. In fact, transmission planning using an AC model should be associated with reactive power planning (RPP). Without considering reactive sources or VAr-plants, the AC-TNEP problem may have an optimum solution in which only the generators satisfy reactive load demands. Although in case of generator capability of supporting reactive load demands, transferring such an amount of reactive power may reduce the available transfer capability (ATC) that lead to more new transmission lines. While by allocating VAr-plants close to the load centers, this may be possible to prevent the necessity of additional transmission lines. On the other hand, without considering the VAr-plants, load bus voltages may differ from their specified magnitudes, which may not only cause unacceptable power quality but also increase real power losses. Increasing power losses may require more transmission line additions. That is why we propose a concurrent planning approach for the TNEP and RPP problem as a combined methodology, the so-called TNERPP. Besides increasing the capacity of transmission lines and power loss reduction due to inclusion of RPP in TNEP, voltage profile enhancement and voltage stability margin improvement can be attained. Another important research topic is the integrated planning of generation sources and network expansion, but this topic is outside the scope of this work.

The objective function of TNERPP is to determine where, how many and when new equipment such as transmission lines and reactive power sources must be added to the network in order to make its operation viable for a pre-defined planning horizon at minimum cost. In fact, such a combinatorial problem seems so complicated that it needs to be solved via mixed integer nonlinear programming. In the existing TNEP approaches, the transmission network planning problem is first handled using both classical optimization techniques [2–6] and evolutionary algorithms [7–14]. Subsequently, the expanded network is reinforced considering the reactive power source allocation [15–19]. It should be noted that there are a few reports in existing planning methods discussing both stages in an integrated way. In [20] the authors use a constructive heuristics algorithm to solve AC-TNEP; in their study, when transmission lines are constructed, reactive power sources

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