A Comparative Study of Metaheuristic Methods for Transmission Network Expansion Planning

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ABSTRACT

Transmission network expansion planning is a very complex and computationally demanding problem due to the discrete nature of the optimization variables. This complexity has increased even more in a restructured deregulated environment. In this regard, there is a need for development of more rigorous optimization techniques. This paper presents a comparative analysis of three metaheuristic algorithms known as Bacteria foraging (BF), Genetic algorithm (GA), and Particle swarm optimization (PSO) for transmission network expansion planning with and without security constraints. The DC power flow based model is used for analysis and results for IEEE 24 bus system are obtained with the above three metaheuristic drawing a comparison of their performance characteristic.

Keywords: Bacteria Foraging, Genetic Algorithm, Metaheuristics, Particle Swarm Optimization, Transmission Expansion Planning

INTRODUCTION

Transmission network expansion planning (TNEP) is an important part of the power system planning. It deals in finding the set of transmission lines to be constructed among the available candidate lines for the transmission expansion, such that the cost of the expansion plan is minimum and there are no overloads during the planning horizon.

The complexity of the problem has increased even more due to restructuring of the power systems. The various factors affecting the TNEP are future load, generation scenarios, right of way constraints, costs and capacities of lines etc. The transmission network expansion planning is of two types: static and dynamic.

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Static TNEP is done in a single planning horizon, whereas dynamic TNEP requires stage wise addition of lines over the planning horizon with varying stage wise loads. Basically, TNEP is dynamic in nature; however, most of the research work in the literature is for a simple static problem to keep the mathematical formulation simple.

This paper also considers the static TNEP model only. However, the algorithms can be extended for a multistage transmission network expansion planning. DC load flow model is used for simplicity.

**Literature Survey**

Several methods such as Linear programming, Garver (1970), Alguacil et al. (2003), and Villasana et al. (1985), Dynamic programming Dusonchet and Abiad (1973), Non-linear programming, Youssef and Hackam (1989), Mixed integer programming, Bahiense et al. (2001), Sharifinia and Aashtiani (1985), Benders decomposition, Binato et al. (2001), Oliveira et al. (1995), hierarchical decomposition Romero et al. (1994), Branch and bound algorithms, Haffner et al. (2000), Genetic Algorithms, Silva et al. (2000), Simulated Annealing (SA) Gallego et al. (1997), Tabu search, Gallego et al. (2000), Game theory, Contreras and Wu (2000), Expert systems, Teive et al. (1998), Greedy randomized adaptive search procedure (GRASP), Binato et al. (2001), have been used for the transmission expansion planning. A More detailed literature review has been presented in Latorre et al. (2003). These methods can be broadly classified into two categories: heuristic methods and mathematical optimization methods. However, there are methods that have characteristics of both types of models, known as meta-heuristic.

The TNEP problem is a complex mixed integer nonlinear programming problem due to the discrete nature of the optimization variables. Also, the number of options to be analyzed increases exponentially with the size of the network. Hence, it requires the use of heuristic and combinatorial optimization algorithms because they are able to find the better solutions as compared to those obtained with the classical optimization techniques.

The application of metaheuristic approaches for TNEP is increasing day by day due to their robust nature and ability to find global optimal solution. Few of these papers are discussed below.

Silva et al. (2006), developed two mathematical models and one methodology to solve STNEP (static transmission network expansion planning) considering uncertainty in demand. The first model considers the uncertainty in the system as a whole and the second one considers the uncertainty in demand at each individual bus. A specialized Genetic algorithm is used to solve the problem. Romero et al. (1996), proposed a simulated annealing (SA) approach for long-term TNEP. The SA approach is a generalization of the Monte Carlo method for examining the equations of states and frozen states of n-body system. The concept is based on the manner in which liquids freeze or metals recrystallize in an annealing process. Gallego et al. (1997) presented a parallel simulated annealing algorithm for long term TNEP. Gallego et al. (2000) discussed a Tabu search algorithm for TNEP. The proposed method is a third generation tabu search procedure which includes features of a variety of other approaches such as heuristic search, simulated annealing and genetic algorithms. Silva et al. (2001), presented a new variant of Tabu search for static TNEP. The intensification and diversification phases are designed using medium and long-term memory concepts. Gallego et al. (1998), presented an extended genetic algorithm for TNEP and a comparative analysis of SA, GA and tabu search in Gallego et al. (1998). A hybrid approach is then proposed which presents performances far better than the one presented by any of these algorithms individually. Da Silva et al. (2000), proposed an improved GA for TNEP. Some special features have been added to the basic GA to improve its performance. The genetic algorithm works on a set of candidate solutions known as population, and performs a number of operations. These operators recombine the information contained
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