Energy Conversion and Management 49 (2008) 3017–3024

Contents lists available at ScienceDirect

Energy Conversion and Management

journal homepage: www.elsevier.com/locate/enconman

Studying influence of two effective parameters on network losses in transmission expansion planning using DCGA

H. Shayeghi [a,*], S. Jalilzadeh [b], M. Mahdavi [b], H. Hadadian [b]

[a] *Technical Engineering Department, University of Mohaghegh Ardabili, Ardabil, Iran*
[b] *Technical Engineering Department, Zangan University, Zanjan, Iran*

ARTICLE INFO

Article history:
Received 11 November 2007
Accepted 18 June 2008
Available online 8 August 2008

Keywords:
Transmission network expansion planning
Network losses
Inflation rate
Load growth factor
DCGA

ABSTRACT

Transmission network expansion planning (TNEP) is a basic part of power network planning that determines where, when and how many new transmission lines should be added to the network. Its task is to minimize the network construction and operational cost, while meeting imposed technical, economic and reliability constraints. Up till now, various methods have been proposed for solution of the static transmission network expansion planning (STNEP) problem. But, in all of them, the effect of two important parameters i.e., inflation rate and load growth factor on network losses has not been investigated. Thus, in this paper, STNEP is being studied considering the effect of inflation rate and load growth factor on the network losses in a transmission network with different voltage levels using a decimal codification genetic algorithm (DCGA). The effectiveness of the proposed idea is tested on the Garver's six-bus network. The results evaluation reveals that the inflation rate and load growth factor have important effect on the network losses and subsequent network arrangement. In addition, considering the effect of two above-mentioned parameters (inflation rate and load growth factor) in expansion planning of transmission networks with various line voltage levels is caused that the total expansion cost of the network (expansion costs and the operational cost) is calculated more exactly and therefore the network satisfies the requirements of delivering electric power more safely and reliably to load centers.

1. Introduction

Transmission network expansion planning (TNEP) is an important component of power system planning. It determines the characteristic and performance of the future electric power network and influences power system operation directly. TNEP should be satisfied required adequacy of the lines for delivering safe and reliable electric power to load centers during the planning horizon [1–3]. The basic principle of the TNEP problem is to minimize the network construction and operational cost, while meeting imposed technical, economic and reliability constraints. Calculation of the investment cost for power system expansion is very difficult work because this cost should be determined from grid owners with agreement of customer and considering the various reliability criteria [4]. Generally, transmission network expansion planning can be classified as static or dynamic. Static expansion determines where and how many new transmission lines should be added to the network up to the planning horizon. If in the static expansion the planning horizon is separated for several stages we will have dynamic planning [5,6].

In majority of power systems, generating plants are located far from the load centers. In addition, the planned new projects are still so far from completion. Due to these situations, the investment cost for transmission network is huge. Thus, the STNEP problem acquires a principal role in power system planning and should be evaluated carefully. After Garver's paper that was published in 1970 [7], much research has been done on the field of TNEP problem until now. Some of this research such as [1–3,6,8–24] is related to problem solution method. Some others, irrespective of solution method, proposed different approaches for solution of this problem considering various parameters such as uncertainty in demand [5], reliability criteria [4,25,26] and economic factors [27]. Also, some of them investigated this problem and generation expansion planning together [28,29]. Recently, different methods such as GRASP [3], Bender decomposition [6], HIPER [17] branch and bound algorithm [30], sensitivity analysis [15], genetic algorithm [1,11,20,24], simulated annealing [16] and Tabu search [12] have been proposed for solution of the STNEP problem. In all of these methods, the problem has been solved regardless to effect of inflation rate and load growth factor on network losses. In Ref. [8], a neural network based method was proposed for solution of the TNEP problem considering both the network losses and construction cost of the lines. But the role of inflation rate and load growth factor has not been investigated in this study. In Ref. [10], the network expansion costs and transmitted power through the lines have been included in objective function and the goal is optimization of both expansion

* Corresponding author. Tel.: +98 451 5519262; fax: +98 451 5512904.
E-mail address: hshayeghi@gmail.com (H. Shayeghi).

0196-8904/$ - see front matter © 2008 Elsevier Ltd. All rights reserved.
doi:10.1016/j.enconman.2008.06.013

costs and lines loading. In addition, the objective function is different from those which are represented in [6,11,12,15–17,20,24,30], but the voltage level of transmission lines and effect of inflation rate and load growth on the network losses have not been investigated. In the previous author's paper [31], TNEP problem has been studied considering effects of transmission lines voltage levels using a genetic algorithm. The results evaluation show that the network with considering higher voltage level save capital investment in the long term, is superior and become overload later.

The network losses has important role for determining configuration and arrangement of the network. Also, considering the network losses in transmission expansion planning decreases the operational costs considerably and the network satisfies the requirement of delivering electric power more safely and reliably to load centers. On the other hand, the inflation rate and load growth factor have important role in rate of the losses growth for the years after expansion. Thus, in this paper, the effect of load growth factor and inflation rate on the network losses in static expansion planning of a transmission network with different voltage levels is investigated. For this reason, the losses cost and also the expansion cost of related substations from the voltage level point of view is included in the objective function. The studied voltage levels in this paper are 230 and 400 kV. The results evaluation reveals that considering the effects of inflation rate and load growth factor for solution of the STNEP problem is caused that the total expansion cost of the network is calculated more exactly. In addition, role of the load growth factor in determining of the network configuration is more than the inflation rate.

This paper is organized as follows: the mathematical model and objective function is given in Section 2. Section 3 describes completely chromosome structure and the proposed GA based method for solution of the STNEP problem. The characteristics of case study system and applying of the proposed idea are given in Section 4. Finally, in Section 5 conclusion is represented.

2. Mathematical model (objective function) of the STNEP problem

The STNEP problem is an mixed-integer nonlinear optimization problem. Due to evaluating effects of the inflation rate and load growth factor on the network losses in STNEP problem with various voltage levels and subsequent adding expansion cost of substations to expansion costs, the proposed objective function is defined as follows:

$$C_{\mathrm{T}} = \sum_{i,j\in\Omega} CL_{ij} n_{ij} + \sum_{k\in\Psi} CS_k + \sum_{i=1}^{NY} C_{\mathrm{loss}_i} \tag{1}$$

$$C_{\mathrm{loss}} = \mathrm{loss} \times C_{MWh} \times k_{\mathrm{loss}} \times 8760 \tag{2}$$

$$\mathrm{loss} = \sum_{i,j\in\Omega} R_{ij} I_{ij}^2 \tag{3}$$

where,

C_{T}	total expansion cost of network.
CL_{ij}	construction cost of each line in branch $i-j$ (different for 230 and 400 KV lines).
CS_k	expansion cost of kth substation.
C_{loss}	annual losses cost of network.
Loss	total loss of network.
C_{MWh}	cost of one MWh ($US/MWh).
k_{loss}	loss coefficient.
n_{ij}	number of all new circuits in corridor $i-j$.
R_{ij}	resistance of branch $i-j$.
I_{ij}	flow current of branch $i-j$.
Ω	set of all corridors.
Ψ	set of all substations.
NY	expanded network adequacy (in year).

The Calculation method of k_{losses} and CS_k are given in Appendices A and B, respectively.

Several restrictions have to be modeled in a mathematical representation to ensure that the mathematical solutions are in line with the planning requirements. These constraints are as follows (see Refs. [5,24] for more details):

$$Sf + g - d = 0 \tag{4}$$

$$f_{ij} - \gamma_{ij}(n_{ij}^0 + n_{ij})(\theta_i - \theta_j) = 0 \tag{5}$$

$$|f_{ij}| \leqslant (n_{ij}^0 + n_{ij})\overline{f_{ij}} \tag{6}$$

$$0 \leqslant n_{ij} \leqslant \overline{n_{ij}}$$

$$0 \leqslant g \leqslant \bar{g} \tag{7}$$

$$\mathrm{Line\_Loading} \leqslant LL_{\max} \tag{8}$$

$N-1$ safe criterion where,

$(i,j) \in \Omega$

S	branch-node incidence matrix.
f	active power matrix in each corridor.
g	generation vector.
d	demand vector.
θ	phase angle of each bus.
γ_{ij}	total susceptance of circuits in corridor $i-j$.
n_{ij}^0	number of initial circuits in corridor $i-j$.
$\overline{n_{ij}}$	maximum number of constructible circuits in corridor $i-j$.
$\bar{g}$	generated power limit in generator buses.
$\overline{f_{ij}}$	maximum of transmissible active power through corridor $i-j$ which will have two different rates according to voltage level of candidate line.
Line_Loading	loading of lines at planning horizon year and start of operation time.
$LL_{\max}$	maximum loading of lines at planning horizon year.
N	number of network buses.

In this study, the objective function is different from those which are mentioned in [1–20,23–27,29,30] and in part of the problem constraints, $\overline{f_{ij}}$ is considered as an addition constraint. In addition to the above-mentioned changes, also Line_Loading constraint is considered as a new constraint in order to ensure adequacy of the network after expansion. It should be noted that $LL_{\max}$ is an experimental parameter that is determined according to load growth coefficient and its rate is between 0 and 1. Reducing rate of this parameter is caused that added lines to the network, the network adequacy (increasing of overload duration time) and expansion cost are increased. Also, networks losses and lines loading average in operational time is decreased. The goal of the STNEP problem is to obtain number of lines and their voltage level to expand the transmission network in order to ensure required adequacy of the network during the specific planning horizon. Thus, problem parameters are discrete time type and consequently the optimization problem is an integer programming problem. For solution of this problem, there are various methods such as classic mathematical and heuristic methods [5–21]. In this study, the decimal codification genetic algorithm is being used for solution of the STNEP problem due to flexibility, simple implementation and the advantages which were mentioned in [11,31].

3. Decimal codification genetic algorithm and chromosome structure of the problem

Standard genetic algorithm is a random search method that can be used to solve non-linear system of equations and optimize complex problems. The base of this algorithm is the selection of