Transmission Expansion Planning Based on Tabu Search Algorithm

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Abstract. This paper presents a new approach for formulating and solving the transmission expansion planning (TEP) problem. The main improvement is in introducing the corona power loss in the objective function and operating constraints. This combination reveals a nonlinear objective function which is solved by Tabu Search (TS). The developed odel has been applied to Garver's 6-bus test sytem. When compared to previously reported TEP attempts, simulation results show a reduction in the total cost of the expanded network.

1. INTRODUCTION

The general form of the transmission expansion-planning (TEP) problem can be stated as follows, given: (1) the load-generation pattern at a target year, (2) the existing network configuration, (3) all possible routes (length and rights- of- way), and (4) line types, estimate the optimum network which feeds the loads with the required degree of quality and realizes a pre-specified reliability level.

To the authors' knowledge, all TEP approaches reported in the literature formulated their objective functions and the corresponding constraints to account for the cost of investment and/or the cost of ohmic power loss. In the literature, TEP has been solved by either optimization algorithms such as linear, nixed integer, quadratic, and nonlinear [1-4] or heuristic ones. Very recently, the Tabu search (TS) algorithm was applied to the TEP problem [5]. In this paper, a new formulation of the TEP problem in which the corona power loss has been added to the objective function is presented. A TS algorithm is utilized to minimize the objective function subject to the system constaints.

2. MATHEMATICAL MODELING OF TEP

In this paper, the authors propose a revised formulation of the objective function in which a new term, i.e. the cost of corona power loss, is considerd, in addition to the investment cost and cost of ohmic losses. The revised objective function and constraunts can be written as

Minimize:

$$\Sigma \text{ cost of investment} + \Sigma \text{ cost of ohmic loss} + \Sigma \text{ cost of corona loss} \quad (1)$$

The cost of corona loss is expressed as [2]:

$$\Sigma \text{ cost of corona loss} = K_C \sum_{j=1}^{AD} \frac{CL_j \times l_j}{b} \quad (2)$$

$$CL_j(kW/km) = \sum_{m=1}^{3} 10^{\frac{CL_{jm}(dB)}{10}} \quad (3)$$

$CL_{jm}(dB)$=

$$14.2 + 65\log\frac{E_{jm}}{18.8} + 40\log\frac{d}{3.51} + K_1 \cdot \log\frac{n}{4} + K_2 + \frac{A}{300} \quad (4)$$

$$K_1 = 13 \quad \text{for } n \le 4 \; or \; = 19 \quad for\; n > 4 \quad (5)$$

K_2 is a term that adjusts corona loss for rain intensity RI, and is given as [2]:,

$$K_2 = 10 \cdot \log\frac{RI}{1.676}, \quad for\; RI \le 3.6\, mm/h$$
$$= 3.3 + 3.5 \cdot \log\frac{RI}{3.6}, \quad for\; RI > 3.6\, mm/h \quad (6)$$

Where:
RI = 1.676 *mm/h*
AD : total number of lines added to the network
b : KW base
CL_j : corona power loss in the jth line (kW / km)
CL_{jm} : corona power loss in the mth phase of the jth line (dB)
d : diameter of sub-conductor (cm)
E_{jm} : rms electric field in the mth phase of the jth line (kV/cm)
K_C : cost coefficient of corona power loss (p.u. cost / p.u. power)
l_j : length of the jth line (km)
n : number of sub-conductors in a bundle

Subject to:

Power balance at each bus, Kirchoff's voltage law on each closed basic loop., Line flow, line height, phase spacing, & bundle radius constraints.

3. TABU SEARCH ALGORITHM FOR THE TEP

TS is an iterative improvement procedure in that it starts from some initial feasible solution and attempts to determine a better solution in the manner of a steepest-descent algorithm [5]. Since the variables in this problem are continuous in nature, using Tabu List (TL) needs some adaptation. In this work, values of variables stored in the TL are approximated to include only one-decimal place, to facilitate and ease checking of TL contents. For each variable, a TL of an array of size Z is constructed. Also associated with each TL is an array for the Aspiration Level (AL) of the same size.

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4. RESULTS AND DISCUSSION

The proposed mathematical formulation of the revised TEP has been developed for the Garver's 6-bus network [1]. The objective function and constraints were solved using the TS algorithm. Expansion including and excluding corona power loss has been made.

Different runs have been executed to find the best TS parameters for the problem under study. The following are parameters of the TSA as applied to the TEP:

Tabu list size = 7, Total maximum number of iteration =1000, Number of iteration done at the same step size vector =50, Number of neighbor (trial) solutions generated in each iteration =5, Maximum acceptance of solution to increase the step size =0.7, Maximum acceptance of solution to increase the step size =0.2, Increment to increase the step size =1.2, Increment to decrease the step size =0.8

The optimal power flows and the number of added lines on the expanded network are shown on Fig. 1.

Comparison between the total costs for the scenarios obtained by TS (with and without corona power loss) and those reported in the literature is shown in Fig.2. It is quite clear that for the proposed scenarios, the total cost is smaller than those of previously reported research for tariffs of about 2.2 cent/kwh and higher. Therefore, it is worth including the corona power loss term in the expansion process.

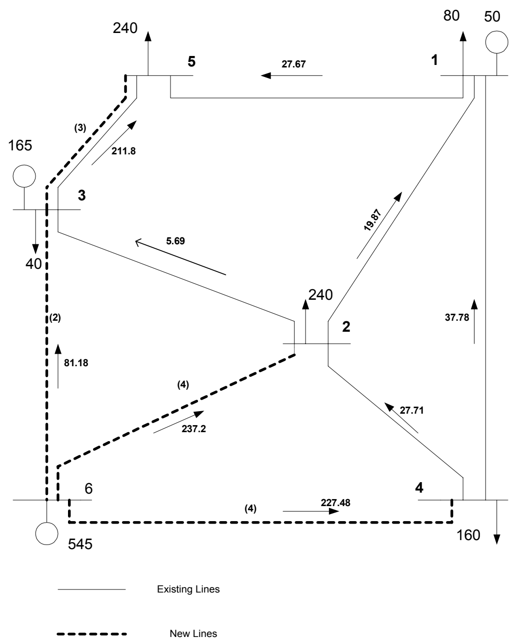

Fig. 1: Optimal expanded network [(x): number of added lines]

5. CONCLUSIONS

The objective function of the transmission expansion planning (TEP) problem has been modified to include a new term (corona power loss) in the optimization process. The proposed formulation has been tested on the 6-bus Garver's network. Results show that including the corona power loss term in the objective function leads to more economical expansion scenarios.

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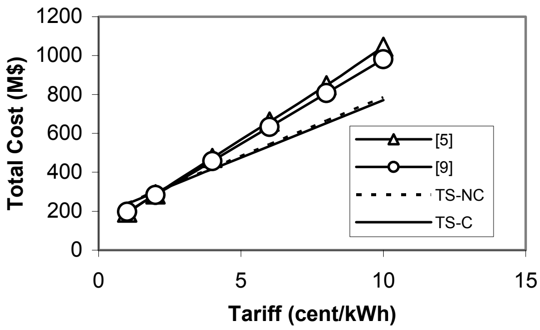

Fig. 2: Comparison of total costs (NC: No Corona, C: with Corona)

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