International Journal of Electronics Engineering, 2 (2), 2010, pp. 235–237

Transmission Network Expansion Planning with a Heuristic Approach

Mitra Mirhosseini and Aliakbar Gharaveisi

Department of Electrical Engineering, Shahid Bahonar University of Kerman, Kerman, IRAN, E-mail: Mirhosseini640@yahoo.com and a_gharaveisi@yahoo.com

Abstract: Transmission expansion planning (TEP) is now a significant power system optimization problem. The TEP problem is a complex and nonlinear combinatorial problem of mixed integer nature where the number of candidate solutions to be evaluated increases exponentially with system size. In this paper a heuristic approach for Transmission Expansion Planning in power system is presented that tests all candidate branches to achieve the accurate optimal solution.

Keywords: Transmission Network Expansion Planning, Heuristic Approach, Sensitivity Index.

1. INTRODUCTION

The task of transmission system expansion planning is to determine an optimal transmission network based on load growth estimation and a specified generation planning scheme for the planning period [1]. The problem of transmission systems planning is a problem of non-linear integer mixed programming (NLIMP) that still presents the combinatorial explosion phenomenon. Many algorithms have been proposed to solve this complex problem. Habitually, transmission expansion planning (TEP) algorithm is a least cost planning. Most research works have been done to decrease the computation time or enhance the convergence towards the true optimal solutions [2]. Latorre et al. published a classification of publications and models on transmission expansion, classifying the solution methods used for transmission expansion models as either mathematical optimization models or heuristic models [3].

2. OVERVIEW OF STATIC TRANSMISSION NETWORK PLANNING

The main concern in this phase is to recognize the principal power corridors that probably will become part of the expanded system. Basically, the DC power flow model is the most employed one and it is considered a reference because in general, networks synthesized by this model convince the basic conditions stated by operation planning studies. When the DC power flow model represents the power network, the transmission network expansion planning problem can be presented as follow [4]:

$$\min v = \sum_{(i,\,j) \in \Omega} c_{ij}\, n_{ij} \qquad \dots (1)$$

subject to

$$Sf + g = d \qquad \dots (2)$$

$$f_{ij} - \gamma_{ij}\,(n_{ij}^0 + n_{ij})\,(\theta_i - \theta_j) = 0 \qquad \dots (3)$$

$$\left| f_{ij} \right| \le \left(n_{ij}^0 + n_{ij} \right) \bar{f}_{ij} \qquad \dots (4)$$

$$0 \le g \le \bar{g}$$

$$0 \le n_{ij} \le \bar{n}_{ij}$$

$$n_{ij} \text{ integer; } f_{ij} \text{ and } \theta_j \text{ unbounded}$$

$$(i, j) \in \Omega$$

where (c_{ij}) is the cost of a circuit that can be added to right-of-way $i - j$, (γ_{ij}) is the susceptance of the circuit, (n_{ij}) is the number of circuits added in right-of-way $i - j$, (n_{ij}^0) is the number of circuits in the base case, (f_{ij}) is the power flow in the right-of way, ($\bar{f}_{ij}$) is the maximum power flow of a circuit in $i - j$, v,   is the investment cost, S is the branch-node transposed incidence matrix, f is a vector with elements f_{ij}, g is a vector with elements g_k (generation in bus k) whose maximum value is $\bar{g}$, $\bar{n}_{ij}$ is the maximum number of circuits that can be added in right-of-way, $\bar{n}_{ij}$ is the vector of net demand, and Ω is the set of all right-of-ways.Constraint (2) depicts Kirchhoff's current law (KCL) in the equivalent DC network. Constraint (3) shows Kirchhoff's voltage law (KVL) and the constraints are nonlinear.

2.1 Problem Representation

Once the investment proposal is defined (i.e., the   variables are known) that is explained afterward, the feasibility of the new topology must be analyzed and eventual load shedding calculated. The load shedding is distinguished by solving the LP problem whose variables are fixed in the desired solution. Therefore, the objective function of an investment proposal specified by assumes the following formulation [4]:

$$\min v = \sum_{(i,j) \in \Omega} c_{ij}\, n_{ij} + \alpha \sum_{s \in \Gamma} r_s \qquad \text{... (5)}$$

Furthermore, new artificial variables are added in the mathematical formulation presented in (1) in order to smooth the progress of its resolution. These variables represent artificial generation at each load bus (when artificial generation is active, there is load shedding in the bus). Consequently, for each investment proposal known by the following LP problem must be solved:

$$\min w = \sum_{s \in \Gamma} r_s \qquad \text{... (6)}$$

subject to

$$Sf + g + r = d$$

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

$$|\, f_{ij} \,| \le \left(n_{ij}^0 + n_{ij}\right) \overline{f}_{ij}$$

$$0 \le g \le \overline{g}$$

$$0 \le r \le d$$

f_{ij} and θ_j unbounded

$(i, j) \in \Omega$

Where w stands for the total load shedding of the system to the investment proposal n_{ij}^k, r is the vector of artificial generators, and Γ represents the set of load buses. So, once n_{ij}^k variables are specified, the problem becomes a linear programming problem whose solution may point out whether the proposal allows the adequate system operation ($w = 0$) or not (with load shedding corresponding with $w \neq 0$).

3. INTEGRATED METHODOLOGY

In each iteration one branch is added to the base topology. It is continued as far as the load shedding converges to zero. The trend of adding the best branches is as follow:

1. Calculate the initial load shedding (w_0); if it is equal to zero go to Step 7;
2. Add the first branch to the base topology (its corresponding n_{ij} increases one unit);
3. Calculate the LP problem of Eq. (6), if $w = 0$ go to Step 7;
4. Calculate the reduction of load shedding according to w_0, (i.e. $w_0 - w$).
5. Remove the added branch and add the next one, go to Step 3; do this for all the candidate branches;
6. When all the candidates are tested, determine which branch reduces the load shedding more, then add it to the base topology and set its load shedding to w_0; go to Step 2;
7. Specify which candidates are added to the base topology and determine the total cost (i.e. v = $\left(i.e.\ v = \sum c_{ij} n_{ij}\right)$.

But as it can be seen, it doesn't take into account the cost of candidate branches in selecting the best one for each iteration, while it is an important factor to gain a minimum cost.

Therefore, to solve the mentioned problem, it is introduced a "Sensitivity Index". To select the best candidate one can calculate the Sensitivity Index and replace this parameter in Step 6.

$$SI_{ij} = \frac{w_0 - w}{c_{ij}} \qquad \text{... (7)}$$

4. CASE STUDY

The proposed algorithm was implemented by using MATLAB software.

It is applied to Garver's 6-bus system. This system includes 6 buses, 15 candidate branches with 760 Mw total load demand and possible installation of 5 branches between each two buses. Initial topology of this system is represented in Fig. 1 and its data in [5].

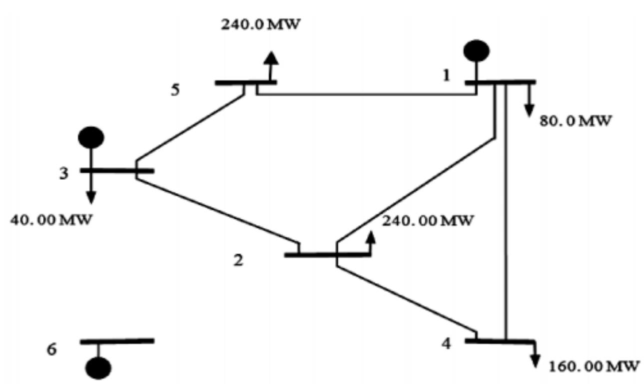

Fig. 1: Initial Configuration of the 6-bus Network

The optimal solution of Garver's 6-bus system is:

- $v = 110.0$ with additions of $n_{3-5} = 1$; $n_{4-6} = 3$.

5. CONCLUSION

Recent blackouts have drawn public attention to the adequacy of transmission system and the need for its expansion. In this paper a heuristic approach for Transmission Expansion Planning in power system is presented. This method examines all the candidates, so the solution is more precise in comparison with stochastic methods. The presented case study demonstrates that the best known solutions already obtained by other methods were also attained by this approach. The test depicted an efficient performance of the algorithm because along with its integrality it takes the benefit of Sensitivity Index to consider branches costs. Our core conclusion is that more research is still needed to develop the methodology for transmission expansion planning.

REFERENCES

[1] X. Wang, J.R. McDonald, "Modern Power System Planning", McGRAW-Hill, New York, 1993.

[2] S.R. Dahman and K. Tynes, "Advanced Sensitivity Analysis for Long-Range Transmission Expansion Planning, *Proceedings of the 41st Hawaii International Conference on System Sciences*, 2008.

[3] G. Latorre, R.D. Cruz, et al., "Classification of Publications and Models on Transmission Expansion Planning", *Power Systems, IEEE Transactions on*, **18 (2)**, 938 – 946, 2003.

[4] Y. Kwang, Lee and Mohamed A. El-Sharkawi, "Modern Heuristic Optimization Techniques", John Wiley & Sons Publication, 2008.

[5] L.L. Garver, "Transmission Network Estimation using Linear Programming", *IEEE Trans. Power Appar. Syst.*, 1970, **89 (7)**, pp. 1688 – 1697.