Transmission Expansion Planning using Multi-Criteria Decision Making Methods

M. Divya Sri, M. Veera Kumari

Abstract: ***This paper introduces a new heuristic model for transmission expansion planning (TEP) which uses a multi-criteria decision making (MCDM) framework. In order to do this, at first, new candidates are recommended for TEP. Investment cost and total cost are calculated for new candidates that are considered for the existing test system. Finally, using an analytic hierarchy process (AHP) and Simple additive weighing (SAW), the ranking is allotted according to the best optimal cost which is selected among candidates. IEEE 24-Bus system is used to confirm the proposed algorithm's performance.***

Keywords: ***Transmission Expansion Planning, Multi-Criteria Decision Making Methods, Analytic Heirarchy Process, Simple Additive Weighting.***

I. INTRODUCTION

Transmission Expansion Planning (TEP) plays an important role in the power systems due to the electric energy industry restructuring that is being implemented worldwide. The introduction of renewable generation far from the existing transmission system and the liberalization of the markets are introducing further complications in TEP. In nowadays globalized markets, since the competitiveness is dreadfully increasing supply chain design has been gaining attention. Companies have to, at least, keeps the same customer service level, while the market's competitiveness forces them to reduce the overall costs to maintain their profit margins [1]. Transportation network design provides a remarkable potential to reduce the overall costs and also to improve the service level. Consequently, it is necessary to develop methods to generate future power network proposals that contribute to an efficient transmission of the electric power, subject to electric, economic, social, environmental constraints and incorporating the uncertainties inherent to generation. Transmission and Expansion Planning (TEP) is a combinatorial stochastic problem that determines the optimal lines and other equipment to be added to a power network for supplying the forecasted demand in a long-term horizon [2]. Its objective is to define when and where new circuits should be installed at minimum cost and ranking is given to the optimal cost using AHP and SAW. The primary goal of TEP in power systems is to determine an optimal strategy to expand the existing transmission network to meet the demand of possible load growth while maintaining reliability and security performance of the power system [3].

Manuscript published on 28 February 2018.
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The TEP problem is a large-scale, complex and nonlinear combinatorial problem of mixed integer nature where the number of candidate solution to be evaluated increases exponentially with system size. There is an increasing interest in power generation may cause some economic and reliability benefits such as production cost saving, reduction in the expected energy not supplies [EENS], reduction in the system loss of load probability [LOLP] [4].

II. PROBLEM FORMULATION

As explained previously, TEP determines the investment plans for new facilities (lines and other network equipment) for supplying the forecasted demand at minimum cost. Tactical planning is concerned with time horizons of 2 years. Its objective is to evaluate minimum cost and ranking is given to the optimal cost subjected to the constraints like Energy not served factor (EENS) and Loss of load probability (LOLP) using analytic hierarchy process (AHP) and simple additive weighting (SAW). The proposed Multi-criteria decision methods is applied on IEEE 24-Bus system.

A. Objective Function

The objective function is implemented to curtail the total discounted line investment and total discounted cost over throughout planning view [5]. The investment cost can be composed as:

$$IC=\sum_{(i,j)\epsilon\Omega} C_{ij}\, n_{ij} \quad (1)$$

Where C represents construction cost, IC_{ij} represents investment cost to build a line in the right-of-way (i-j) (\$/year), n_{ij} represents number of new line added to the right-of-way (i-j), $\boldsymbol{\Omega}$ represents set of all new right-of-ways [5].

The congestion cost can be determined as follows

$$CC= \sum_{(i,j)\,\epsilon \text{All corridors}} f_{ij}\,(LMP_j - LMP_i) \quad (2)$$

where CC represents Congestion cost, f_{ij} is active power flow in the right-of-way i-j, LMP is local marginal prices at i,j

LMP's are obtained from the following equation:

$$\text{Min} \sum PG_i\,(\,a_iPG_i + b_i\,) \quad (3)$$

$$\text{s.t: } s_{ij}\gamma_{ij}\,(\delta_i - \delta_j) - PG_i + PD_i = 0 \quad (4)$$

$$-f_l \leq \gamma_{ij}\,(\delta_i - \delta_j) \leq f_l \quad (5)$$

$$PG_i^{min} \leq PG_i \leq PG_i^{max} \quad (6)$$

The constraint (4) indicates the DC power flow equations. The constraint (5) indicates the power flow limits of the network. The constraint (6) indicates generation boundary limit.

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$$\text{Min}\left(\sum_{i=1}^{TPL}\sum_{(i,j)\in\Omega}\frac{IC_{ij}\times n_{ij}^{(t)}}{(1+D_i)^{(t-1)}}+\sum_{t=1}^{TPL}\frac{CC(t)}{(1+D_i)^{(t-1)}}\right) \quad (7)$$

Where D_i indicates the discount factor; the first expression indicates the investment cost, the second expression indicates the total cost of the system [6].

III. MULTI-CRITERIA DECISION MAKING METHOD

A. Analytic Hierarchy Process

AHP is one of the Multi-Criteria Decision making techniques. AHP has been applied in successfully in many areas of decision making. The AHP converts the evaluations to numerical values that can be processed and compared over the entire range of the problem [7]. A numerical weight or priority is derived for each element of the heirarch, allowing diverse and often incommensurable elements to be compared to one another in a rational and consistent way. This capability distinguishes the AHP from other AHP from other decision making techniques. In the final step of the process, numerical priorities are calculated for each of the decision alternatives. These numbers represent the alternatives relative ability to achieve the decision goal, so they allows a straightforward consideration of the various courses of action. The aim of the AHP is to define the optimum alternative and to categorise the others considering the criteria that describe them.

Flow chart of the AHP is illustrated as follows:

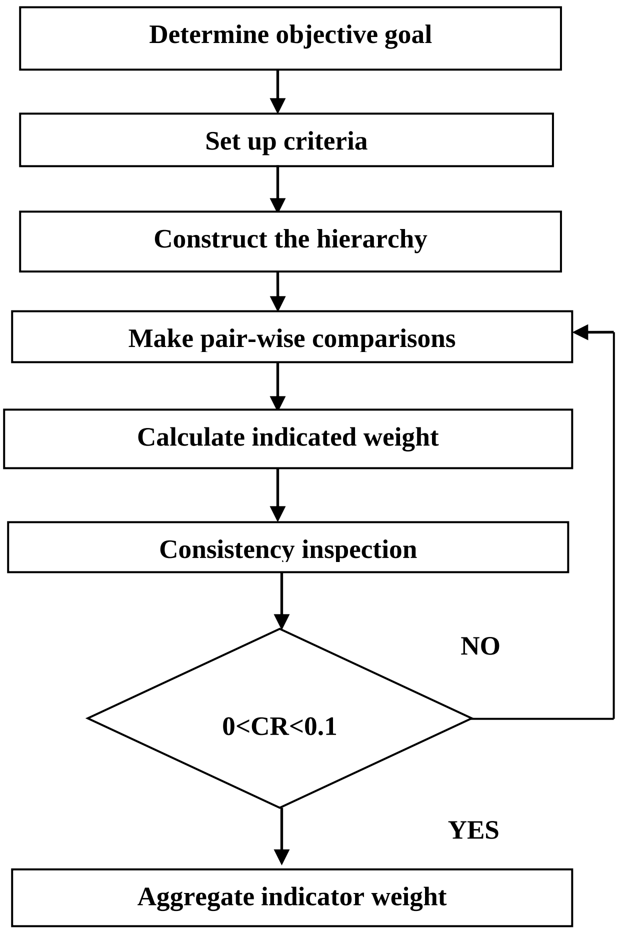

Fig 1. Flowchart of AHP

B. Simple Additive Weighting

Simple Additive Weighting (SAW) is one of multi-criteria decision making technique consisting in assigning to each alternative a sum of values, each one associated to the corresponding evaluation criterion. This method is also known as a weighted linear combination or scoring method. It is simple and most often method used multi-attribute decision technique. The method is based on the weighted average using arithmetic mean [8]. An evaluation score can be calculated for each alternative by multiplying the scaled value given to the alternative of that attribute with the weights of relative importance directly assigned by the decision makers followed by summing of the products of all criteria. The advantage of SAW method is that it is a proportional linear transformation of the raw data. It means that the relative order of magnitude of the standardized scores remains equal. MCDM methods have been proposed is weighted product (WP). This method is more efficient than other methods in problem solving of MCDM [9]. The reason is because of the time needed in the calculation. This method stood by calculation simple, and easy to apply in cases having high subjectivity elements, effective to optimize decision problems. The basic logic of SAW method is to obtain a weighted sum of performance ratings of each alternative over all attributes [10].

C. Implementation Steps of SAW

A= $(a_1, a_2, \ldots a_n)$

Let A=$(a_1, a_2, \ldots a_n)$ be a set on alternatives

C= $(c_1, c_2, \ldots c_n)$

Let A= ($a_1, a_2, \ldots a_n$) be a set of criteria

Step 1: Construct the decision matrix:

$$\begin{matrix} d_{11} & d_{12} & \ldots & d_{1n} \\ d_{21} & d_{22} & \ldots & d_{2n} \\ \ldots & \ldots & \ldots & \ldots \\ d_{n1} & d_{n2} & \ldots & d_{nn} \end{matrix}$$

Where d_{ij} is the rating of alternative Ai with respect to criterion Ci

Step 2: Construct the normalized decision matrix. For beneficial attribute (criteria of benefit):

$$r_{ij} = \frac{d_{ij}}{d_{ij}^{max}}$$

For non beneficial attribute (criteria of cost):

$$r_{ij} = \frac{d_{ij}^{min}}{d_{ij}}$$

Step 3: Construct weighted normalized decision matrix

$$V_{ij}= w_{ij} * r_{ij},\ \sum_{i=1}^{n} w_i=1$$

Step 4: Calculate the score of each alternative.

$$S_i \sum_{j=1}^{m} v_{ij} \qquad i=1,2,3\ldots n$$

Step 5: Select the best alternative

$$BA_{SAW}=\max\sum_{i=1}^{n} S_i$$

Where, BA_{SAW} is Best alternative in Simple Additive Weighting (SAW) method and S_i is matrix score.

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D. Analysis of AHP and SAW

Among all the attributes i.e., Investment cost, Total cost, EENS (Energy not served factor) and LOLP (Loss of load probability) priority is given to the total cost using AHP method. The priority is given to investment cost among all the attributes Investment cost, total cost, EENS and LOLP in the SAW method. For the optimal investment cost which is second solution best rank is given.

IV. RESULTS AND DISCUSSIONS

The TEP is executed using MCDM techniques i.e., AHP and SAW which has been implemented in MATLAB 14b, 64 bit, 2GB RAM with windows 7 operating system. For the TEP problem IEEE 24-Bus standard electrical test system is considered. IEEE 24-Bus system consists of 24 buses. 34 existing branches, maximum demand is 8590MW and maximum 5 lines are added at different locations.

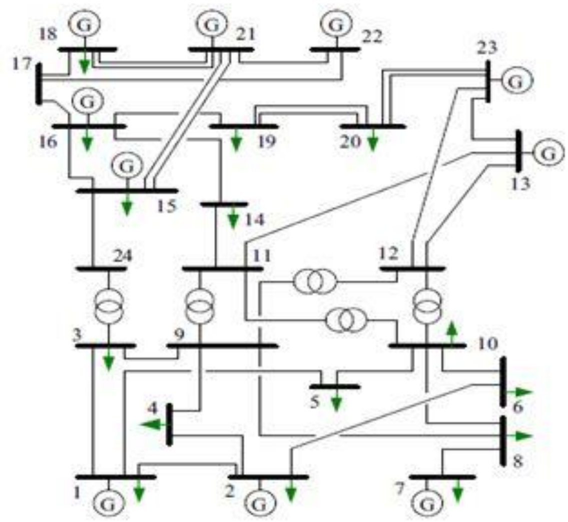

Fig.2. IEEE 24-Bus System

A. AHP and SAW Results

For AHP and SAW optimal attributes considered are Investment cost, Total cost, EENS and LOLP at different locations given in Table 1. Priority is given to Investment cost in AHP and SAW techniques.

Table1. Ranking of Investment Cost and Total Cost using AHP and SAW

CC ($)	TC ($)	EENS	LOLP	Rank AHP	Rank SAW
2.37e+5	8.52e+8	0.1048	0.1007	1	2
2.39e+5	8.93e+8	0.0873	0.1092	3	1
2.44e+5	8.84e+8	0.1041	0.1032	2	3
2.54e+5	8.75e+8	0.0958	0.1136	5	4
2.64e+5	8.91e+8	0.1048	0.1007	4	5

V. CONCLUSION

The proposed MCDM techniques solved the optimal transmission expansion planning with the objective function along with reliability constraints. The objective functions considered is ranking of optimal investment cost and total cost for planning horizon of two years corresponding to EENS and LOLP as constraints. The standard test system considered is IEEE 24-Bus system. At different locations the best compromise solution of best combination of transmission lines at different locations is evaluated by AHP and SAW, multi-criteria decision making methods. Also ranking analysis by using AHP and SAW were presented.

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