Transmission Expansion Planning Via a Constructive Heuristic Algorithm in Restructured Electricity Industry

H. Khorasani, M. Pourakbari-Kasmaei and R. Romero
Dept. of Electrical and Computer Engineering
Universidade Estadual Paulista
Ilha Solteira-SP, Brazil
khorasani.hamid@gmail.com, {mahdi@aluno , ruben@dee}.feis.unesp.br

Abstract— **The transmission expansion planning problem in modern power systems is a large-scale, mixed-integer, nonlinear and non-convex problem. this paper presents a new mathematical model and a constructive heuristic algorithm (CHA) for solving transmission expansion planning problem under new environment of electricity restructuring. CHA finds an acceptable solution in an iterative process, where in each step a circuit is chosen using a sensitivity index and added to the system. The proposed model consider multiple generation scenarios therefore the methodology finds high quality solution in which it allows the power system operate adequacy in an environment with multiple generators scenarios. Case studies and simulation results using test systems show possibility of using Constructive heuristic algorithm in an open access system.**

Keywords-Transmission expansion planning; Constructive heuristic algorithm; Open access; Multiple generating scenarios; hybrid model.

I. INTRODUCTION

Transmission system expansion problem consists of finding the optimal expansion plan of the electrical system in terms of number and location of transmission lines and/or transformers in order to support secure and economical operation in a specified planning horizon. The available data are: system's base topology, candidate circuits, generation and demand forecast in the planning horizon, investment constraints, etc. In the static planning, there is only one planning horizon and a generalization is the multi-stage planning, where the horizon is split up into various stages. In this paper, only the static planning problem is analyzed, however, the methodology can be extended to a multistage planning as well. Transmission expansion planning has been introduced in 1970 by Garver [1] while several different techniques like Branch and Bound [2], Sensitivity Analysis [3], Benders Decomposition [4], Simulated Annealing [5], Genetic Algorithm [6], Tabu Search[7] and other heuristics algorithm [8] are used to studying such a challenging problem. Commonly used models are in a centralized and vertically integrated power system. It can be said that these methods might not be suitable for competitive electricity markets environment. In recent years transmission expansion planning in deregulated power systems is much of interest [9, 10]. Deregulation has changed the structure of power systems incorporating market issues in operation, planning and management. One of the most important characteristic of restructuring is facilitating a competitive environment for power markets but today's transmission networks may not sufficiently support electricity transaction, causing congestion in transmission lines. Therefore, in restructured power markets, consumers are paying increasing congestion costs. From social welfare perspective, if the total costs of congestion that might be relieved by an investment in transmission network is higher than its investment costs, the economic transmission investment is justified. However, since congestion costs as an operational expense may occur at any generating dispatch scheme, and transmission investment costs as a capital expense that is allocated at the beginning of the economic life of the project, it is difficult to compare these two types of costs. In literatures two measures for congestion costs such as: redispatch costs and congestion rent are commonly used. Redispatch costs refers to the systems' costs due to congestion, namely the difference between the total generation costs without transmission constraints and the total generation costs with transmission constrains. In some studies, the term redispatch is also referred to as out-of-merit generation costs, costs of constraints, or congestion costs. On the other hand, the difference between the total payment that a load requires and the total payment that the generators receive is defined as congestion rent. For today's networks, it is not fair to analyze the topology of transmission network without considering operation within a competitive market. In new environment of deregulated power markets, the price that is determined by the least-costs dispatch is called the user prices that may affect the connectivity of the load and generation indirectly affected by the capacity of transmission lines. Hence, the transmission investment problem should try to find minimum investment costs that guarantee least-costs dispatch for the entire system. Therefore system objectives should look for the minimum of both investment costs as well as system re-dispatch costs [11, 12]. Ideally modern transmission networks expansion planning

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should omit the congestion for all feasible and future generation scenarios to get an efficient market condition as well as the least-costs dispatch. On the other side, since the future dispatches are unknown; consequently an exhaustive analysis requires considering that the generators can assume producing any value between their lower and upper limits. For that reason, from the viewpoint of the complete elimination of future congestion, the planning process should have a look at all the feasible and future generation scenarios to assure least-costs in the future dispatch patterns. This can lead to the excessive investment costs and it is necessary to know those costs, while this paper presents a new methodology to determine such costs. In most addressed researches for TEP problem, the open access issue as a requirement of electricity restructuring is not considered, where the optimal expansion plans are determined for only one or a few generation scenarios [13,14]. In this research a new transmission network expansion planning considering multiple generation scenarios is proposed, in which the injected power at each generation bus is not an exact amount and the generation is represented by a set of feasible scenarios.

The mathematical models in deregulated environment is more complicated than regulated environment they are usually multi objectives with various constraints they have many integer variables and usually meta-heuristics algorithm are employed to solve this problem . In this paper we try to solve this problem using a constructive heuristic algorithm (CHA). Until now all the CHA algorithms are applied in regulated environment and there is no report about using CHA algorithms in deregulated environment.

In this paper the problem is solves in two stage, first stage; define all feasible generator scenarios using extreme bound of generators to model all the possible future scenarios that power market might be encounter in an open access system, second stage employing constructive heuristic algorithm and considering all generator scenario identify the best lines for installation in an iterative fashion, and finally removing the unnecessary lines from the solution.

In this work a solution algorithm using constructive heuristic algorithm is proposed, while the Garver and IEEE 24-bus test systems are used to validate the proposed methodology.

II. GENERATION SCENARIOS

To satisfy the conditions that the expanded transmission network does not cause congestion for any feasible generation scenario, the following conjecture is made. If a system can operate adequately for all extreme and feasible plans, then it will be able to operate for any feasible generation plan since the constraints for the feasible plans are less restrictive than those for extreme and feasible plans. This conjecture has an important implication, and it is that the problem can be mathematically formulated since the feasible and extreme scenarios are one measurable and reduced subset of scenarios, while the group of feasible scenarios is infinite. Initially the concept of feasible and extreme generation scenario is defined. An extreme and feasible generation scenario is a plan in which some generators will be functioning at their upper limit ($\bar{g}$), while others will remain at the lower limit ($\underline{g}$); the k^{th} single free generator will generate at:

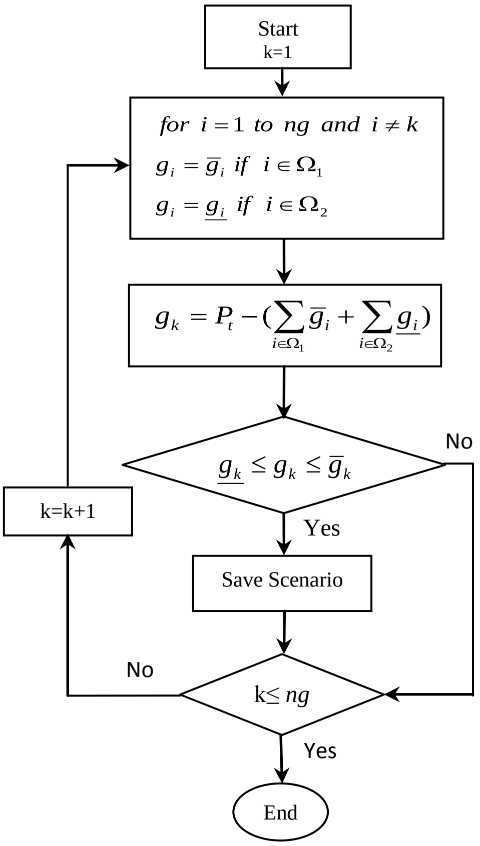

Fig.1: Creating Generation Scenarios

$$g_k = d_t - \left(\sum_{i\in\Omega_1}\bar{g}_i + \sum_{i\in\Omega_2}\underline{g_i}\right) \qquad (1)$$

Where d_t is the total demand, $\bar{g}_i$ and $\underline{g}_i$ are the upper and lower limits of the i^{th} generator, respectively. Ω_1 is the set of generators operating in the upper limit and Ω_2 is the set of generators operating in the lower limit. An extreme and feasible generation scenario should satisfy the following constraint:

$$\underline{g_k} \le g_k \le \bar{g}_k \qquad (2)$$

Where: $\bar{g}_k$ is upper limit of the k^{th} free generator and $\underline{g}_k$ is its lower limit. Therefore, in a power system with n_g generators, the number of extreme and feasible plans will be $n_g \times 2 \times (n_g - 1)$ which is generated using the following procedure:

Step 1: Separate $(n_g - 1)$ generators in two subsets. In the first subset the generators are in their upper limits. In the second subset the generators are in their lower limits. The remaining generation of k^{th} single free generator will be derived using Eq. (1). This step is repeated for all possible combinations of generators.

Step 2: The extreme and feasible generation scenarios are selected from the previous combinations which satisfy the Eq. (2).

Figure 1 shows the flowchart of creating generation's scenarios via proposed method.

III. MATHEMATICAL MODEL

Two types of mathematical model for a static transmission network expansion planning considering *p* generation scenarios are presented in this paper; a DC model and a hybrid model, which are briefly outlined in the following section.

A. DC Model

The DC model for static transmission network expansion planning considering *p* generation scenarios presents the following Format:

$$Min\ v=\sum_{(i,j)\in\Omega_0} c_{ij}n_{ij}+\sum_{q=1}^{p}\sum_{i\in\Gamma}\alpha_i r_i^q \tag{3}$$

s.t.

$$Sf^q+g^q+r^q=d \tag{4}$$

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

$$\left|f_{ij}^q\right|\le(n_{ij}^0+n_{ij})\overline{f}_{ij} \tag{6}$$

$$\underline{g}_k^q\le g_k^q\le\overline{g}_k^q \tag{7}$$

$$g_i^q=\overline{g}_i^q\quad\forall i\in\Omega_1^q \tag{8}$$

$$g_j^q=\underline{g}_j^q\quad\forall j\in\Omega_2^q \tag{9}$$

$$0\le r_i^q\le d_i \tag{10}$$

$$0\le n_{ij}\le\overline{n}_{ij} \tag{11}$$

n_{ij} integer and $(i,j)\in\Omega_0$

Where c_{ij}, Y_{ij}, n_{ij}, n_{ij}^o represent, respectively, the cost of a circuit that can be added to the *i-j* right-of-way, the susceptance of that circuit, the number of circuits added to the *i-j* right-of-way, the number of circuits in the base case, v is the investment, *S* is the branch-node incidence transposed matrix of the power system , *p* is the extreme and feasible scenarios of generation f_{ij}^q , θ_i^q , g_i^q and r_i^q represent the operation variables for the generation scenario *q* which are respectively the total power flow, the phase angle, the generator value and the amount of load shedding at k^{th} bus. f^q, g^q and r^q are the vectors with elements f_{ij}^q, g_i^q and r_i^q and *d* is the demand vector with elements d_i . $\bar{n}_{ij}$ is the maximum number of circuits that can be added to the *i-j* right-of-way . $\bar{f}_{ij}$ is the maximum power flow by circuit in the *i-j* right-of-way . Ω_1^q is the set of generators in the upper limit for the *q* scenario; Ω_2^q is the set of generators in the lower limit for the q scenario. Γ and Ω_0 are the set of load buses and all buses and branches respectively . Constraint (4) represents the conservation of power in each node. This constraint models Kirchhoff's Current Law (KCL) in the equivalent DC network. Constraint (5) is an expression of Ohm's Law for the equivalent DC network and so Kirchhoff's Voltage Law (KVL) is implicitly taken into account which are non-linear constraints. The constraints (7), (8) and (9) should be defined for each extreme and feasible scenario of generation. The rest of the constraints are related to the operational limits of transmission devices. The biggest difference between this formulation and the formulation of basic planning, where only one scenarios is considered, is that, now, the generation is fixed and associate with *p* extreme scenarios of generation, and the *p* generation scenarios should be solved simultaneously. The number of operation variables $(f_{ij},\theta_i,g_i,r_i)$ increases *p* times, and the group of operation variables associated to one generation scenario (f_{ij}^q, θ_i^q , g_i^q , r_i^q) are related with the group of operation variables of the other scenarios through investment variables. The number of investment variables doesn't change in relation to the basic model.

B. Hybrid Model

DC Model is a mixed-integer nonlinear programming problem and is very difficult to solve. If we assume that constraint in Eq. 4, KCL, is satisfied only by existing circuits (and not necessarily by the added circuits) hybrid model is obtained. In this context, the hybrid linear model employed in CHA assumes the following form:

$$Min\ v=\sum_{(i,j)\in\Omega_0} c_{ij}n_{ij}+\sum_{q=1}^{p}\sum_{i\in\Gamma}\alpha_i r_i^q \tag{12}$$

s.t.

$$Sf^q+S^0f^{0q}+g^q+r^q=d \tag{13}$$

$$f_{ij}^{0q}-\gamma_{ij}n_{ij}^0(\theta_i^q-\theta_j^q)=0\quad\forall(i,j)\in\Omega_0 \tag{14}$$

$$\left|f_{ij}^{0q}\right|\le n_{ij}^0\overline{f}_{ij}\quad\forall(i,j)\in\Omega_0 \tag{15}$$

$$\left|f_{ij}^q\right|\le n_{ij}\overline{f}_{ij}\quad\forall(i,j)\in\Omega \tag{16}$$

$$\underline{g}_k^q\le g_k^q\le\overline{g}_k^q \tag{17}$$

$$g_i^q=\overline{g}_i^q\quad\forall i\in\Omega_1^q \tag{18}$$

$$g_j^q=\underline{g}_j^q\quad\forall j\in\Omega_2^q \tag{19}$$

$$0\le r_i^q\le d_i \tag{20}$$

$$0\le n_{ij}\le\overline{n}_{ij} \tag{21}$$

n_{ij} integer

In which S^0 is the transpose incidence node-branch matrix formed by circuits and buses of the base topology; f^{0q} is the vector of power flow through the circuits of the base topology with elements f_{ij}^{0q} for the scenario q, *S* is the transpose incidence matrix of the entire system and f^q is the vector of power flows through added circuits with elements f_{ij}^q for scenario *q* . *0* represents the base case circuit indices and the set with indices of all circuits. In the hybrid model, power flows through circuits which belong to the base case are represented separately from flows of the new added circuits. Power flows in the base circuit are represented by f_{ij}^{0q} and in the new circuits by f_{ij}^q, values can be different among them. Ω_0 and Ω represents the base case circuit indices and the set with indices of all circuits. In the proposed liner model, only circuits of the base topology must follow KVL and this requirement is represented by constraint (14).

In this paper the hybrid linear model (HLM) is employed for calculation of sensitivity index used to determine the circuit to be added in the electrical system at each step of CHA.

IV. APPLICATION OF CHA TO TEP

In this section some fundamental components and main characteristic of CHA are presented. In fact, CHA may find a good quality solution in an iterative process. The fastness and robustness are the main characteristics of CHA. In order to obtain a feasible and high quality solution, in each iteration a circuit is added to the network, where the aforementioned circuit is selected based on a sensitivity index. In order to achieve an optimum expansion plan, the load shedding is not acceptable.

General CHA process is explained through different steps as follows:

Step 1: Assuming a base topology as the current topology.

Step 2: Choose a mathematical model for TEP.

Step 3: Solve LP/ NLP to determine parameters used in the sensitivity index defined in CHA algorithm that considers operational conditions. If LP or NLP solution indicates that the system is adequately operate in new additions, it means that a feasible solution is in hand. Then go to step 5.

Step 4: Use a sensitivity index to identify the most attractive circuit. Update the current topology with the chosen circuit, then go to step 3.

Step 5: Sort the added circuits' costs in decreasing order. Using an LP, it verifies that whether the removal of a circuit keeps the system in an adequate operational condition or not. If yes, remove the circuit, otherwise keep it. Repeat circuit removal process until all the circuits have been tested. All added circuits that weren't removed, represent CHA's final solution.

Many CHAs in literature are of two following categorizes.

i) Algorithms that use electrical system performance to make sensitivity index

ii) Algorithms that use the relaxed version mathematical model.

Algorithms similar to least-load-shedding [15] and least effort [16] belong to group (i), and Garver's [1], Villasana–Garver–Salon (VGS) [17] and the algorithm proposed in this paper also belong to group (ii).

In least-load shedding algorithm, sensitivity index tries to identify the circuit that would provide the most significant reduction in load shedding. For this case, in step 3 CHA solves an LP while operation constraint is load shedding. It can be mentioned that sensitivity index is an approximation due to the fact that the selected circuit may not guarantee the least load shedding. Although the selected circuit may provide a reduction in load shedding, it may not facilitate the optimal topology. All these problems may partially arise when the sensitivity index considers the circuits' costs. A major advantage in using either the least-effort algorithm or the least-load-shedding algorithm is that both of them employ DC model directly. The model that is used in Graver's algorithm is transportation model (TM). The TM is a relaxed version of DC model provided from elimination of third constraint in DC model. In fact, TM is a mixed-integer linear optimization problem. Graver's algorithm relaxes the integrality of the investment variable and solves TM, i.e. making and solving the problem as an LP. The LP solution might not be feasible for TEP problem, therefore this solution is deployed as a sensitivity index for CHA. The sensitivity index can be defined by Eq. (22).

$$SI = \max\{SI_{ij} = n_{ij} f_{ij}; \quad n_{ij} \neq 0\} \tag{22}$$

Where: n_{ij} is the solution given by LP after relaxing integrality of n_{ij}. In Garver's algorithm at each step an LP with the current topology is solved while the number of new circuits might not be an integer that may facilitate a minimum investment. In this regard, Garver algorithms will face with two crucial difficulties. On the other hand, VGS algorithm can find a good solution for DC model than the best CHA ever proposed in the literature. By relaxing the third constraint in DC model, a hybrid model will be produced where an LP solver can be applied to solve such a hybrid model identifying the most important circuit at each step of algorithm. It has worth to be mentioned that in hybrid model, the relaxed constraint will only be considered to those circuits of the current topology.

V. CHA FOR EXTENDED HYBRID MODEL

Unlike the CHAs in literature that solves only a simple model without considering security constraints, the proposed CHA, works with an extended hybrid model that considers security constraints. The CHA solves hybrid model after relaxing the integrality of investment variables, i.e. the integer is changed to another feature presented in this algorithm is that every circuit added in the process must comply with both KCL and KVL which means compatibility between current solution and the DC model solution. The major drawback of this method is that at each CHA step a very large LP must be solved where it gets considerable for large scale power systems. The proposed CHA employed in this work is as follows:

Step 1: Assume the base topology as current topology.

Step 2: Solve LP to determine those parameters used in the sensitivity index Eq. (22). If LP solution indicates that the system is adequately operate in new additions, it means that a new solution for DC model has been obtained, then go to step 4 otherwise go to the next step.

Step 3: Use sensitivity index of Eq. (22) to identify the most attractive circuit. Update the current topology with the selected circuit, then go to step 2 otherwise go to the next step.

Step 4: Sort the added circuits in a descending order of costs. Using an LP, it verifies that whether the removal circuit keeps the system in adequate operational conditions or not. If yes, remove the circuit, otherwise keep it. Continue circuit removal until all circuits have been examined. All added circuits that weren't removed represent the CHA's solution.

It can be notified that although this CHA uses a hybrid linear model to identify the best circuit to add in an iterative process, it complies with both Kirchhoff's Laws after adding a new circuit, thus the final solution is also a feasible solution of the DC model.

VI. CASE STUDIES AND SIMULATIONS

The proposed algorithm was implemented within MATLAB and CPLEX is used as a LP subroutine. It might be noted that since the number of variables and constraints are extremely large for solving this problem the issue of sparse matrix should be employed to avoid possible errors due to the lack of memory.

A. Garver Six-Bus System

Garver system has 6 buses, 15 candidate branches, a total demand of 760 MW, and a maximum possible number of added lines per branch are equal to 5. The Garver system data are given in [18].

Maximum generation capacities for this system in buses 1, 3, and 6, are 150MW, 360MW, and 600MW respectively. To obtain extreme and feasible generation scenarios, all combination sets are organized such that 2 of 3 of generators produce at max or min of their generation capacity and the other generator should generate its power which is the difference between total demand and total power generated by other two units.

There are 12 generators' scenarios which shown in Table I. In this table the slack generator is shown with G and other generators which have fix value are shown with lower case g. Some of these extreme generators scenarios are feasible and infeasible combinations (those violate generation constraint of slack generator) should be eliminated. The only 4 combinations out of the above 12 combinations are feasible. Consequently the number of restrictions, variables and equality constraints will be 184, 115 and 24 espectively. Therefore the feasible are as following:
{(150, 360, 250), (150, 10, 600), (0,360,400), (0,160,600)}
Which are highlighted in the Table I.

Table I: Generating Scenarios for Garver System

G1	g2	g3	g1	G2	g3	g1	g2	G3
760	0	0	0	760	0	0	360	400
160	0	600	0	160	600	0	0	760
400	360	0	150	610	0	150	360	250
200	360	600	150	10	600	150	0	610

After finding extreme and feasible generation scenarios, Garver system's solution will be obtained by solving ten LP. Procedure of line addition to the network is according to Table II. In this table the first column represents the number of iteration and the second column represents the candidate lines sensitivity index, while the third columns shows the selected lines.

Note that the sensitivity index for candidate lines that are not shown in the second column is zero. Chosen lines for adding to the network in each iteration, is represented in third column. As shown in Table II. After solving ten iterations, Garver system's solution is found, while for each iteration one LP is solved, means total LPs are ten. Finally, total investment costs for open access model without eliminating any line in step 4, is equal to US$ 270,000,000 with the following topology:

n_{2-3}=1 ; n_{2-6}=5; n_{3-5}=2; n_{2-6}=2.

B. IEEE 24-Bus System

This system has 24 buses, 41 branches and a total demand of 8550MW. The data of IEEE 24_Bus system is available in [19]. This system has ten generators, in consequence 10×2ˆ(10-1) = 5120 possible generation scenarios appear. Of these 5120 scenarios, only 168 are feasible generation scenarios, because only 168 scenarios satisfy the constraint Eq.(2). Consequently the number of restrictions, variables and equality constraints will be 24900, 13487 and 3984, respectively. The proposed CHA converges after solving 34 LPs and removes seven circuit in step 4.

Table II Garver solution iteration by iteration

Iter.#	Index sensitivity	Selected line
1	n_{1-5}=0.2918, n_{2-6}=2.3551 n_{3-5}=1.198, n_{3-6}=0.44082 **n_{4-6}=3.2367**	n_{4-6}
2	n_{1-5}=0.2918, **n_{2-6}=2.3551** n_{3-5}=1.198, n_{3-6}=0.4082 n_{4-6}=2.2367	n_{2-6}
3	n_{1-5}=0.5388, **n_{2-6}=2.8918** n_{3-5}=1.4147, n_{3-6}=0.1612 n_{4-6}=0.9579	n_{2-6}
4	n_{1-5}=0.5399, **n_{2-6}=1.8902** n_{3-5}=1.4143, n_{3-6}=0.1601 n_{4-6}=0.9628	n_{2-6}
5	n_{1-5}=0.5403, n_{2-6}=0.8895 **n_{3-5}=1.4143,** n_{3-6}=0.1597 n_{4-6}=0.9649	n_{3-5}
6	n_{1-5}=0.3397, n_{2-6}=0.7310 n_{3-5}=0.4147, n_{3-6}=0.3603 **n_{4-6}=0.9589**	n_{4-6}
7	n_{1-5}=0.3384, **n_{2-6}=0.7332** n_{3-5}=0.4135, n_{3-6}=0.3616	n_{2-6}
8	n_{1-5}=0.3516, n_{2-3}=0.2570 **n_{3-5}=0.4606,** n_{3-6}=0.0914	n_{3-5}
9	n_{1-5}=0.1003, n_{2-3}=0.4424 **n_{3-6}=0.1537**	n_{3-6}
10	n_{1-5}=0.0056, **n_{2-6}=0.1821**	n_{2-6}
11	-	-

In IEEE 24-bus system, the optimum solution that will not produce congestion in any 168 feasible generation scenarios is with an investment equals to US$ 1,477,000,000 associated with adding the following lines:
n_{01-02}=1; n_{01-03}=1; n_{03-24}=2; n_{04-09}=1; n_{05-10}=1; n_{06-10}=3; n_{07-08}=2 n_{08-09}=1; n_{09-11}=1; n_{10-11}=1; n_{10-12}=2; n_{11-13}=1; n_{12-23}=1; n_{14-16}=2 n_{15-21}=1; n_{15-24}=1; n_{16-17}=2; n_{16-19}=1; n_{17-18}=1; n_{20-23}=1; n_{21-22}=1 n_{01-08}=3; n_{02-08}=1; n_{06-07}=1; n_{13-14}=1

The lines that are removed from the network in step 4 are the following lines: n_{6-7}; n_{6-7}; n_{1-8}; n_{1-8}; n_{1-8}; n_{15-16}; n_{6-10}

VII. RESULT ANALYSIS AND DISCUSSION

The point which is more noticeable in this paper is the large difference between the costs of centralized model with the planning that is called open access model. For example in Graver system the costs of centralized model is 110 M$ and the costs of this system is 270 M$ in open access model. On the other hand, for IEEE 24-bus system, in centralized model the cost is about 152 M$ while the costs of open access model is about 1477 M$. The question that may arise: "is the open access model economically significant or not"? In the other word, such increasing in the costs may satisfy the other goals of transmission owners, where it may not create any line congestion. An important point that should be considered is the obtained solution for the centralized model is just for one generation scenario. In fact, if the generation output of generators change, the transmission grid may not capable of supporting such produced power and the lines might be congested. But in open access model it is able to support several generating scenarios without any congestion and as these scenarios are marginal generation scenarios, the transmission grid is able to transfer electric power for any other scenarios. Therefore, it can be said that the open access model has the maximum compatible manner. Now for finding the answer for the above question, the owner of transmission lines should analyze if the profit of its achievements is more than the difference between two planning models plus the profit in the centralized model or not .If the outcome is positive, the open access model is beneficial otherwise not.

For clearing the problem, consider Garver system. The difference between two planning model is 158 million dollar, where one reason of this additional cost can be considering N-1 security constraint which makes it a proper system under contingency condition. If the profit of completion for the special time period; which is commonly 20 years; is more than 160 M$ plus the profit of centralized planning and also considering the high social welfare of this method which nowadays plays an important role in power markets, the open access model is considered a significant model. In some papers being nearer in to the transmission line is defined as completion metric and the ideal transmission grid is defined, the grid that no obstacle for competition isn't in that. So the grid which no transmission constraint is considered in that is supposed. Now obtain this transmission grid .i.e. the lines are specified. This metric for being nearer into the transmission line can be used more suitable.

VIII. CONCLUSIONS

TEP needs be revised for its suitability in competitive electricity markets because existing methodologies may not necessarily support competition. In restructured power markets, consumers are paying incurred congestion costs. To have an efficient market environment, ideally, modem TEP should eliminate the congestion for all feasible and future generation scenarios to obtain always the least-costs dispatch. In this paper a mathematical model for TEP problem that can consider multiple generation scenarios in a competitive electricity market is proposed. Case studies considering proposed CHA are also presented. Simulation results show that the algorithm developed for traditional planning can also be employed for planning considering multiple generation scenarios. The results indicate a direct relation between system flexibility and investment costs. The main contribution of this study is thus the clarification of basic mechanisms for the representation of the possible generation scenarios which should be considered in the modern TEP problem.

IX. REFERENCES

[1] L.L. Garver.: “Transmission network estimation using linear programming”, IEEE Trans.Power App. Syst., 89, pp. 1688–1697, 1970

[2] S. Haffner, A. Monticelli, A. Garcia and R. Romero.: “Specialised branch-and-bound algorithm for transmission network expansion planning”, IEE Proc. Gener. Transm. Distrib. , 148, (5), pp. 482–488, 2001

[3] M. V. F. Pereira and L. M. V. G. Pinto, “Application of sensitivity analysis of load supplying capacity to interactivetransmission expansion planning,” IEEE Trans. Power App. Syst., vol. PAS-104,\ pp. 381–389, 1985.

[4] S. Binato, M. V. Pereira, and S. Granville,“A new benders decomposition approach to solve power ransmission network design problems,” IEEE Trans. PowerSyst., vol. 16, pp. 235–240, 2001.

[5] R. Romero, R. A. Gallego, and A.Monticelli, “Transmission system expansion planning by simulated annealing,” IEEE Trans. Power Syst., vol.11, pp. 364– 369. 1996.

[6] E. L. Silva, H. A. Gil, and J. M. Areiza, “Transmission network expansion planning under an improved genetic algorithm,” IEEE Trans. Power Syst., vol.15, pp. 1168– 1175, 2000.

[7] R. A. Gallego, R. Romero, and A. J. Monticelli, “Tabu search algorithm for network synthesis,” IEEE Trans. Power Syst., vol. 15, no. 2, pp.490–495, 2000.

[8] S. Binato, G. C. de Oliveira, and J. L. de Araújo, “A greedy randomized adaptive search procedure for transmission expansion planning,” IEEE Trans. Power Syst., vol. 6, no. 2, pp. 247–253, 2001.

[9] T. Sebastián, A. J. Conejo and J. Contreras.:”Transmission Expansion Planning in Electricity Markets” , IEEE Trans Power, vol. 23, no. 1, pp. 238– 248 , 2008.

[10] P. Lina, A. J. Conejo and R. Romero.:”A Bilevel Approach to Transmission Expansion Planning Within a Market Environment” IEEE Trans Power Syst, vol. 24, no. 3, pp. 1513–1532, 2009,

[11] H. Gil, E. da Silva and F. Galiana.: ”Modeling Competition in transmission expansion” IEEE Transactions on Power Systems, vol. 17,pp. 1043-1049,2002

[12] A. Braga and J. T. Saraiva.: ”A multiyear dynamic approach for transmission expansion planning and long-term marginal costs computation” IEEE Transactions on Power Systems, vol. 20, no. 3 pp. 1631-1639,2005.

[13] R. Romero, A. Monticelli, A. Garcia, and S. Haffner.: ”Test systems and mathematical models for transmission network expansion planning” lEE Proceedings - Generation, Transmission and Distribution, vol. 149, no.1, pp. 27-36,2002.

[14] R. Fang and DJ. Hill.: ”A new strategy for transmission expansion in competitive electricity markets” IEEE Trans. Power Systems, vol. 18,no. 1, pp. 374-380, 2003.

[15] M.V.F. Pereira and L.M.V.G. Pinto.: ”Application of sensitivity analysis of load supplying capability to interactive transmission expansion planning” IEEE Transactions on Power, vol. 104, no 2, pp. 381-389, 1985.

[16] A. Monticelli, A.J. Santos, M.V.F. Pereira, S.H. Cunha, B. J. Parker and J.C.J. Praca.: ”Interactive transmission network planning using a least effort criterion” IEEE Transactions on Power ,vol. 101, no 10, pp. 3919-3925, 1982.,

[17] R. Villasana, L. L. Garver, and S. J. Salon.: “Transmission network planning using linear programming’, IEEE Trans. Power App. Syst., vol. 104, no. 2, pp. 349–356, 1985.

[18] R. Fang, D.J. Hill.: ”A new strategy for transmission expansion in competitive electricity markets” IEEE Transactions on Power, vol. 18, no. 1, pp. 374–380, 2003.

[19] R. Romero, C. Rocha, J. R. S. Mantovani and I. G. Sanches.: ”Constructive heuristic algorithm for the DC model in network transmission expansion planning”, IEE Proc. Gener. Transm. Distrib. vol. 152, no. 2, pp. 277–282, 2005.