AN EVOLUTIONARY PROGRAMMING-BASED TABU SEARCH METHOD FOR SOLVING MULTI AREA UNIT COMMITMENT PROBLEM WITH IMPORT AND EXPORT CONSTRAINTS

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Abstract: *This paper presents a new approach to solve the multi area unit commitment problem (MAUCP) using an evolutionary programming-based tabu search (EPTS) method. The objective of this paper is to determine the optimal or a near optimal commitment schedule for generating units located in multiple areas that are interconnected via tie- lines. The evolutionary programming-based tabu search method is used to solve multi area unit commitment problem, allocated generation for each area and find the operating cost of generation for each hour. Joint operation of generation resources can result in significant operational cost savings. Power transfer between the areas through the tie- lines depends upon the operating cost of generation at each hour and tie-line transfer limits. The tie -line transfer limits were considered as a set of constraints during optimization process to ensure the system security and reliability. The overall algorithm can be implemented on an IBM PC, which can process a fairly large system in a reasonable period of time. Case study of four areas with different load pattern each containing 26 units connected via tie- lines has been taken for analysis. Numerical results showed comparing the operating cost using evolutionary programming-based tabu search method with conventional dynamic programming (DP), evolutionary programming (EP), Partical Swarm Optimization (PSO), Simulated Annealing (SA), Evolutionary Programming based Partical Swarm Optimization (EPPSO), Evolutionary Programming based Simulated Annealing (EPSA)) method. Experimental results shows that the application of this evolutionary programming-based tabu search method have the potential to solve multi area unit commitment problem with lesser computation time*.

Key words: *Dynamic Programming (DP), Evolutionary Programming (EP), Evolutionary Programming-based tabu search (EPTS), Multi Area Unit Commitment Problem (MAUCP), Tabu Search (TS)*.

1. Introduction

In multi area, several generation areas are interconnected by tie lines, the objective is to achieve the most economic generation to meet out the local demand without violating tie-line capacity limits constraints [1]. The main goal of this paper is to develop a multi area generation scheduling scheme that can provide proper unit commitment in each area and effectively preserve the tie line constraints. In an interconnected multi area system, joint operation of generation resources can result in significant operational cost savings [2]. It is possible by transmitting power from a utility, which had cheaper sources of generation to another utility having costlier generation sources. The total reduction in system cost shared by the participating utilities [3]. The exchange of energy between two utilities having significant difference in their marginal operating costs. The utility with the higher operating cost receives power from the utility with low operating cost. This arrangement usually on an hour to hour basis and is conducted by the two system operators.

In the competitive environment, customer request for high service reliability and lower electricity prices. Thus, it is an important to maximize own profit with high reliability and minimize overall operating cost [4].

Multi Area unit commitment was studied by dynamic programming and was optimized with local demands with a simple priority list scheme on a personal computer with a reasonable execution time [5]. Even though the simplicity and execution speed are well suited for the iterative process, the commitment schedule may be far from the optimal, especially when massive unit on/off transitions are encountered. The tie-line constraint checking also ignores the network topology, resulting in failure to provide a feasible generation schedule solution [5]. The transportation model could not be used effectively in tie line constraints, as the quadratic fuel cost function and exponential form of start up cost were used in this study.

An Evolutionary algorithm is used for obtaining the initial solution which is fast and reliable [6]. Evolutionary Programming (EP) is capable of determining the global or near global solution [7]. It is based on the basic genetic operation of human chromosomes. It operates with the stochastic mechanics, which combine offspring creation based on the performance of current trial solutions and competition and selection based on the successive generations, from a considerably robust scheme for large scale real valued combinational optimization. In this work, the parents are obtained from a predefined set of solution (i.e., each and every solution is adjusted to meet the requirements). In addition, the selection process is done using evolutionary strategy [8]-[10].

Tabu Search (TS) is a powerful optimization procedure that has been successfully applied to a number of combinational optimization problems [11]-[15]. It has the ability to avoid entrapment in local minima by employing a flexible memory system. Specific attention is given to the short term memory component of TS, which has provided solutions superior to the best obtained with other methods for a variety of problems.

From the literature review, it has been observed that there exists a need for evolving simple and effective methods, for obtaining an optimal solution for the MAUCP. Hence, in this paper, an attempt has been made to couple EP with TS for meeting these requirements of the MAUCP, which eliminates the above mentioned drawbacks. In case of TS, the demand is taken as control parameter. Hence, the quality of solution is improved. The algorithm is based on the annealing neural network. Classical optimization methods are a direct means for solving this problem. EP seems to be promising and is still evolving. EP has the great advantage of good convergent property, and, hence, the computation time is considerably reduced. The EP combines good solution quality for TS with rapid convergence for EP. The EP-based TS (EPTS) is used to find the multi area unit commitment. By doing so, it can help to find the optimum solution rapidly and efficiently [7].

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2. Problem Formulation

The cost curve of each thermal unit is in quadratic form [3]

$$F\left(P_{g_i}^{k}\right) = a_i^k\left(P_{g_i}^{k}\right)^2 + b_i^k\left(P_{g_i}^{k}\right) + c_i^k \quad \text{Rs/hr} \quad (1)$$

$k = 1 \ldots N_A$

The incremental production cost is therefore

$$\lambda = 2a_i^k Pg_i^k + b_i^k \quad (2)$$

(or)

$$Pg_i^k = \lambda - b_i^k / 2a_i^k \quad (3)$$

The start up cost of each thermal unit is an exponential function of the time that the unit has been off

$$S(X_{i,j}^{off}) = A_i + B_i\left(1 - e^{x_{i,j}^{off}/\tau_i}\right) \quad (4)$$

The objective function for the profit based multi-area unit commitment is to minimize the entire power pool generation cost as follows [1].

M a x P.F =T.C (or) Min T.C=RV

$$\min_{I,P} \sum_{k=1}^{N_A} \sum_{j=1}^{t} \sum_{i=1}^{N_k} \left[I_{i,j}^k F_j^k (P_{i,j}^k + I_{i,j}(1 - I_{i,j-1}) S_i(X_{i,j-1}^{off})) \right] \quad (5)$$

To decompose the problem in above Eq. (5), it is rewritten as

$$\min \sum_{j=1}^{t} \left[F(P_{g_{i,j}}) \right] \quad (6)$$

$$F\left(P_{g_{i,j}}\right) = \sum_{k=1}^{N_A} F^k\left(P_{g_{i,j}}^k\right) \quad (7)$$

Subject to the constraints of Eqs. (9), (11) and (14–18). Each $F^k\left(P_{g_{i,j}}^k\right)$ for K=1 ……NA is represented in the form of schedule table, which is the solution of mixed variable optimization problem

$$\min_{I,P} \sum_i \left[I_{i,j}^k F_i^k \left(P_{i,j}^k\right) + I_{i,j}\left(1 - I_{i,j-1}\right)\left(S_i\left(X_{i,j}^{off}\right)\right)\right] \quad (8)$$

Subject to following constraints are met for optimization.

$$\sum_{i=i}^{N} Pit\ X_{it} \le D_t, t = 1 \ldots\ldots. T$$

$$\sum_{i=i}^{N} Rit\ X_{it} \le SR_t, t = 1 \ldots\ldots. T$$

Redefining the UC problem for the competitive environment involves changing the demand and reserve constrains from an equality to less than or equal to the forecasted level if it creates more profit. Here forecasted demand reserve and prices are important inputs to profit based UC Algorithm; they are used to determine the expected revenue, which affects the expected profit.

1) System power balance constraint

$$\sum_k P_{g_j}^k = \sum_k D_j^k \quad (9)$$

Sum of real power generated by each thermal unit must be sufficient enough to meet the sum of total demand of each area while neglecting transmission losses.

2) Spinning reserve constraint in each area

$$\sum_i P_{g_{i,j_{\max}}}^k \ge D_j^k + R_j^k + E_j^k - L_j^k \quad (10)$$

3) Generation limits of each unit

$$P^k_{j_{\max}} \le P^k_{i,j} \le P^k_{j_{\min}} \tag{11}$$

i=1…..N_k, j=1….t, k=1…N_A

4) Thermal units generally have minimum up time T_{on} and down time T_{off} constraints, therefore

$$\left(X^{on}_{i,j-1} - T^{on}_i\right) * \left(I_{i,j-1} - I_{i,j}\right) \ge 0 \tag{12}$$

$$\left(X^{off}_{i,j-1} - T^{off}_i\right) * \left(I_{i,j} - I_{i,j-1}\right) \ge 0 \tag{13}$$

5) In each area, power generation limits caused by tie-line constraints are as follows

Upper limits

$$\sum_i P^k_{g_{i,j}} \le D^k_j + E^k_{j_{\max}} \tag{14}$$

Lower limits

$$\sum_i P^k_{g_{i,j}} \ge D^k_j - L^k_{j_{\max}} \tag{15}$$

Import/Export balance

$$\sum_i E^k_j - \sum_k L^k_j + W_j = 0 \tag{16}$$

6) Area generation limits

$$\sum_i P^k_{g_{i,j}} \le \sum_i P^k_{g_{i\max}} - R^k_j \tag{17}$$

k=1…. N_A, j=1…….t

$$\sum_i P^k_{g_{i,j}} \ge \sum_i P^k_{g_{i\ \min}} \tag{18}$$

k=1…. N_A, j=1…….t

The objective is to select λ_{sys} at every hour to minimize the operation cost.

$$P^k_{g_j} = D^k_j + E^k_j - L^k_j \tag{19}$$

where $$P^k_{g_j} = \sum_{i=1}^{N_k} P^k_{g_{i,j}} \tag{20}$$

Since the local demand D_j^k is determined in accordance with the economic dispatch within the pool, changes of $P^k_{g_j}$ will cause the spinning reserve constraints of Eq. (10) to change accordingly and redefine Eq. (8). Units may operate in one of the following modes when commitment schedule and unit generation limits are encountered.

a) Coordinate mode : The output of unit i is determined by the system incremental cost

$$\lambda_{\min,i} \le \lambda_{sys} \le \lambda_{\max,i} \tag{21}$$

b) Minimum mode : Unit i generation is at its minimum level

$$\lambda_{\min,i} \rangle \lambda_{sys} \tag{22}$$

c) Maximum mode : unit i generation is at its maximum level

$$\lambda_{\max,i} \langle \lambda_{sys} \tag{23}$$

d) Shut down mode : unit i is not in operation, $P_i = 0$

Besides limitations on individual unit generations, in a multi- area system, the tie-line constraints in Eqs. (12), (13) and (15) are to be preserved. The operation of each area could be generalized into one of the modes as follows.

(i) Area coordinate mode

$$\lambda^k = \lambda_{sys}$$

$$D^k_j - L^k_{\max} \le \sum_i P^k_{g_{i,j}} \le D^k_j + E^k_{\max} \tag{24}$$

(or)

$$-L^k_{\max} \le \sum_i P^k_{g_{i,j}} - D^k_j \le E^k_{\max} \tag{25}$$

(ii) Limited export mode

When the generating cost in one area is lower than the cost in the remaining areas of the system, that area may generate its upper limits according to Eq. (14) or (17) therefore

$$\lambda^k \langle \lambda_{sys} \tag{26}$$

For area k, area λ^k is the optimal equal incremental cost which satisfies the generation requirement.

(iii) Limited import mode

An area may reach its lower generation limit according to Eq. (15) or (18) in this case because of higher generation cost

$$\lambda^k_{\min} \rangle \lambda_{sys} \tag{27}$$

3.Tie Line Constraints

To illustrate the tie-line flow in a multi-area system, the four area system given in Fig.1 is studied. An economically efficient area may generate more power than the local demand, and the excessive power will be exported to other areas through the tie lines [1]. For example assume area 1 has the excessive power the tie line flows would have directions from area1 to other areas, and the maximum power generation for area1 would be the local demand in area1 plus the sum of all the tieline capacities connected to area1. If we fix the area 1 generation to its maximum level than the maximum power generation in area 2 could be calculated in a similar way to area 1. Since tie line C12 imports power at its maximum capacity, this amount should be subtracted from the generation limit of area 2. According to power balance equation (9) some areas must have a power generation deficiency and requires generation imports. The minimum generation limits in these areas is the local demand minus all the connected tie-line capacities. If any of these tie-lines is connected to an area with higher deficiencies, then the power flow directions should be reserved.

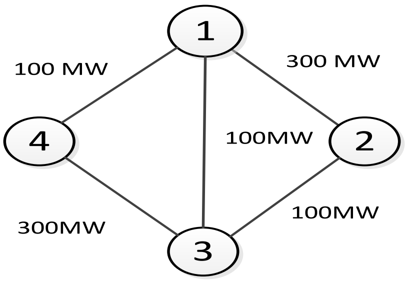

Fig. 1. Multi-area connection and tie-line limitations

4. Tabu Search

4.1. Overview

In solving the MAUCP, two types of variables to be determined. The unit's status variables U and V, which are integer variables and the units, Output power variables P that are continuous variables. The problem can then be decomposed into two sub problems, a combinational problem in U and V and a nonlinear optimization problem in P. TS is used to solve the combinational optimization, and the nonlinear optimization is solved via a quadratic programming routine [17]. The proposed algorithm contains three major steps:

First, generating randomly feasible trial solutions;

Second, calculating the objective function of the given solution by solving the Economic Load Dispatch (ELD); Third, applying the TS procedures to accept or reject the solution in hand.

4.2. TS General Algorithm

The flowchart for TS general algorithm is shown in Fig. 2.

Step 1: Assume that the fuel costs to be fixed for each hour and all of the generators share the loads equally.

Step 2: By optimum allocation, find the initial feasible solution (Ui , Vi).

Step 3: Demand is taken as the control parameter.

Step 4: Generate the trial solution.

Step 5: Calculate the total operating cost Ft as the summation of running cost, start up and shut down cost. Step 6: Tabulate the fuel cost for each unit for every hour.

4.3. Generating Trial Solution

The neighbours should be randomly generated, feasible, and span as much as possible the problem solution space. Because of the constraints in MAUCP, this is not a simple matter. The most difficult constraints to satisfy are the minimum up/down times. The implementation of new rules to obtain randomly feasible solutions faster is done by the rules are described in [17].

4.4. Generating an Initial Solution

The TS algorithm requires a starting feasible schedule, which satisfies all of the system and units constraints. This schedule is randomly generated. The algorithm given in [17] is used to find this starting solution.

4.5. Operating Cost Calculation

Once a trial solution is obtained, the corresponding total operating cost is determined. Since the production cost is quadratic function, the Economic Load Dispatch (ELD) is solved using a quadratic programming routine. The start up cost is then calculated for the given schedule.

4.6. Stopping Criteria

There may be several stopping criteria for the search. For this implementation, the search is stopped if the following conditions are satisfied.

- The load balance constraints are satisfied.
- The spinning reserve constraints are satisfied
- The tie line constraints are satisfied

4.7. Tabu List (TL)

Tabu List (TL) is controlled by the trial solutions in the order in which they are made. Each time a new element is added to the "bottom" of a list, the oldest element on the list is dropped from the "top". Empirically, TL sizes, which provide good results, often grow with the size of the problem and stronger restrictions are generally coupled with smaller sizes [17]. Best sizes of TL lie in an intermediate range between these extremes. In some applications, a simple choice of TL size in a range centered on seven seems to be quite effective.

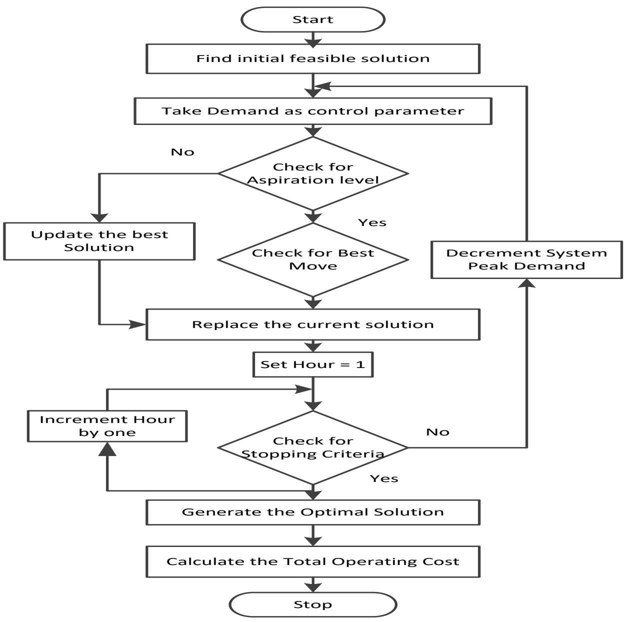

Fig. 2. Flowchart for TS general algrithm

4.8. Aspiration Criteria

Another important criteria of TS arises when the move under consideration has been found to be tabu. Associated with each entry in the tabu list there is a certain value for the evaluation function called “aspiration level”. Normally, the aspiration level criteria are designed to override tabu status if a move is “good enough”[17].

5. Evolutionary Programming

5.1. Introduction

EP is a mutation-based evolutionary algorithm applied to discrete search spaces. D. Fogel (Fogel, 1988) [6][7] extended the initial work of his father L. Fogel (Fogel, 1962) [6][7] for applications involving real-parameter optimization problems. Real-parameter EP is similar in principle to evolution strategy (ES), in that normally distributed mutations are performed in both algorithms. Both algorithms encode mutation strength (or variance of the normal distribution) for each decision variable and a self-adapting rule is used to update the mutation strengths. Several variants of EP have been suggested (Fogel, 1992).

5.2. Evolutionary Strategies

For the case of evolutionary strategies, Fogel remarks “evolution the chromosome, the individual, the species, and the ecosystem” [6][7] can be categorized by several levels of hierarchy: the gene, the chromosome, the individual, the species, and the ecosystem” [6][7]. Thus, while genetic algorithms stress models of genetic operators, ES emphasize mutational transformation that maintains behavioural linkage between each parent and its offspring at the level of the individual. ES are a joint development of Bienert Rechenberg and schwetel. The first applications were experimental and addressed some optimization problems in hydrodynamics.

5.3. EP General Algorithm

Evolutionary programming is conducted as a sequence of operations and is given below. The flowchart for EP general algorithm [7] is shown in Fig. 3.

1. The initial population is determined by setting s_i=Si~ U(a_k,b_k) k i =1,…,m, where S_i is a random vector, s_i is the outcome of the random vector, $U(a_k,b_k)^k$ denotes a uniform distribution ranging over [a_k,b_k] in each of k dimensions, and m is the number of parents.
2. Each s_i R and denotes→(s_i)=G(F(s_i),v_i), where F maps s_i ϑ, i=1,…,m, is assigned a fitness score the true fitness of s_i , v_i , represents random alteration in the instantiation of si , random variation imposed on the evaluation of F(s_i), or satisfies another relation si ,and G(F(s_i), v_i) describes the fitness score to be assigned. In general, the functions F and G can be as complex as required. For example, F may be a function not only of a particular s_i, but also of other members of the population, conditioned on a particular s_i.

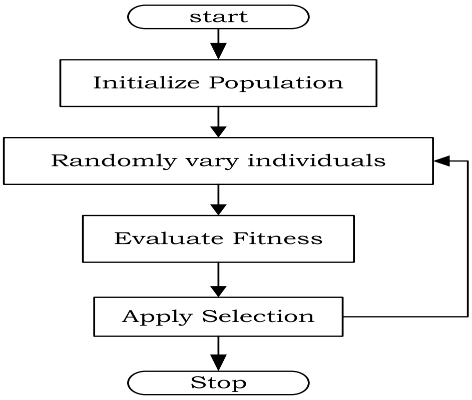

Fig.3. Flowchart of an Evolutionary Algorithm

3. Each s_i, i=1,…,m, is altered and assigned to s_{i+m} such that
s_{i+m}= $s_{i,j}$+N (0,βj ϑ(s_i)+z_j), j=1,…,k
N(0,βjϑ(s_i)+z_j) represents a Gaussian random variable with mean μ and variance σ^2, βj is a constant of proportionality to scale ϑ(s_i), and $z_j$amount of variance,
4. Each si+ m, i=1,…,m, is assigned a fitness score (si+m) = G(F(si+m),vi+m)ϑ
5. For each si ,i=1,…,2m, a value wi is assigned according to c wtΣwi = * t = 1 (sρ);ϑ(si)≤ϑ1, if wt * = 0, otherwise; Where ρ=[2mu1+1],ρ≠ i,[x] denotes the greatest integer less than or equal to x, c is the number of competitions, and u1~U(0,1).
6. The solutions si , I = 1…2m, are ranked in descending order of their corresponding value Wi (si) if there are more than m solutions attaining a valueϑ[with preference to their actual scores (si) to be theϑof c]. The first m solutions are transcribed along with their corresponding values basis of the next generation.
7. The process proceeds to step 3, unless the available execution time is exhausted or an acceptable solution has been discovered.

6. EVOLUTIONARY PROGRAMMING-BASED TABU SEARCH FOR MAUCP

6.1. Tabu Search

1. Take the parent as the initial feasible solution.
2. Take demand as control parameter and generate the trial solution.
3. Check for the stopping criterion.
4. If false, decrement system peak demand, and go to step 2.

5. If true, generate the optimal solution, and calculate the total operating cost.

6.2. EP- Based TS

In the EPTS technique for solving MAUCP, initial operating schedule status in terms of maximum real power generation of each unit is given as input. As we that TS is used to improve any given status by avoiding entrapment in local minima, the offspring obtained from the EP algorithm is given as input to TS, and the refined status is obtained. In addition, evolutionary strategy selects the final status.

1. Get the unit data, tie-line data, load demand profile for n areas and number of iterations to be carried out.
2. Generate population of parents (N) by adjusting the existing solution to the given demand to the form of state variables.
3. Unit down time makes a random recommitment.
4. Check for constraint in the new schedule by TS. If the constraints are not met, then repair the schedule as 6.3.
5. Perform ELD and calculate total production cost for each parent.
6. Add the Gaussian random variable to each state variable and, hence, creation of offspring. This will further undergo some repair operations as given in section 6.4. Following these, the new schedules are checked in order to verify that all constraints are met.
7. Improve the status of the evolved offspring, and verify the constraints by TS.
8. Formulate the rank for the entire population.
9. Select the best N number of population for next iteration.
10. Has the iteration count been reached? If yes, go to step 11, else go to step 2.
11. Select the best population by evolutionary strategy. 12. Check for n areas are completed. If yes go to step 13, else go to step 1.
13. Export power from lower operating cost areas to higher operating cost areas by following tie-line constraints.
14. Print the commitment schedule of n areas and tie-line flows.

6.3. Repair mechanism

A repair mechanism to restore the feasibility of the constraints is applied and described as follows [13]

- Pick at random one of the OFF units at one of the violated hours.
- Apply the rules in section IV.3 to switch the selected units from OFF to ON keeping the feasibility of the down time constraints.

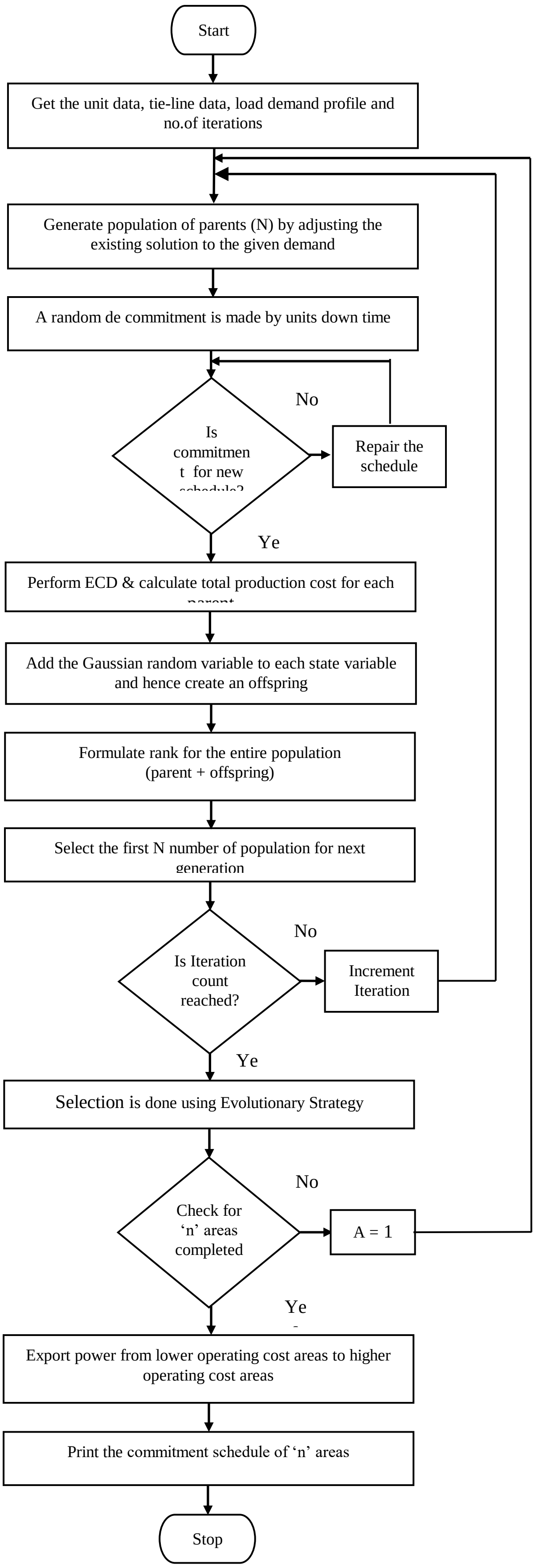

Fig.3 Flowchart for EP-TS algorithm for MAUCP

• Check for the reserve constraints at this hour. Otherwise repeat the process at the same hour for another unit.

6.4. Making Offspring Feasible

While solving the constrained optimization problem, there are various techniques to repair an infeasible solution [8] [11]. In this paper, we have chosen the technique, which evolves only the feasible solutions. That is, the schedule which satisfies the set of constraints as mentioned earlier. Here, in this paper, the selection routine is involved as "curling force" to estimate the feasible schedules. Before the best solution is selected by evolutionary strategy, the trial is made to correct the unwanted mutations.

6.5. Implementation

Software program were developed using MATLAB software package, and the test problem was simulated for ten independent trials using EPTS. The training and identification part as implemented in the EPTS technique is employed here and considered as a process involving random recommitment, constraint verification, and offspring creation

7. Numerical Results

There are two test systems considered for case studies. The first test system consists of four areas, and each area has 26 thermal generating units [1] and second test system consists of four areas, and each area has 7 unit NTPC system. Units have quadratic cost functions, and exponential start up cost functions. Generating unit characteristics like the minimum up/down times, initial conditions and generation limits of units in every area, The cost functions of units given in the four area [1] are taken for analysis. Load demand profile for each area is different and is given in Fig. 4. The tie line flow pattern at 11 am and 4 pm are shown in Fig. 5 and Fig. 6 respectively. The total operating cost in pu comparison between DP, EP, TS and EPTS method is shown in Table 3. Comparison of total operating cost in each area by DP, EP, TS and EPTS method is shown in Fig. 3. The comparison of total operating cost in each area of 7 unit and 26 unit systems are shown in Fig. 7 and Fig. 8 respectively. The proposed algorithm quickly reaches smallest total operating cost compared to DP, EP, TS and EPTS method, which indicates that the proposed algorithm could determine the appropriate schedule within a reasonable computation time. It is noted that cost in one iteration may be lower than that of the previous iteration, indicating that our optimization rules always comply with the equal incremental cost criterion for dispatching power generation among thermal units.

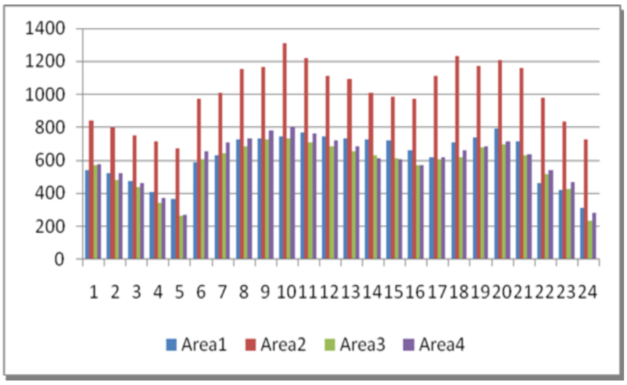

Fig. 4. Load demand profile of area1, area 2, area 3 and area 4

Table 1. Hourly operating cost of each area of EP-TS method for 7 unit (NTPS)

HOUR	Total operating cost (Rs)			
	Area 1 (7 unit)	Area 2 (7 unit)	Area 3 (7 unit)	Area 4 (7 unit)
1	20400.700	26527.941	23542.672	25695.026
2	19667.972	26570.953	23159.928	24828.362
3	19839.029	26463.033	22785.838	24780.120
4	19818.114	26395.781	20138.432	24052.184
5	19786.989	26593.695	20393.241	24567.751
6	19870.654	25296.935	20556.315	24922.850
7	19667.972	25464.125	20480.583	24922.850
8	19870.654	25125.554	20665.329	24539.458
9	19786.989	25535.964	20699.536	24609.341
10	19725.642	25772.541	20658.661	24568.515
11	18889.525	25737.376	20666.536	24207.573
12	18871.296	25648.140	20086.395	23945.222
13	18229.986	25492.775	20918.131	24671.288
14	18178.411	25609.125	20280.313	24016.337
15	18160.185	25701.082	21339.897	25015.983
16	17716.198	25572.693	20158.200	24459.126
17	17550.439	25102.953	20684.690	23884.841
18	17476.034	24709.484	21158.299	19042.802
19	17716.198	24534.000	21285.858	24703.397
20	17684.775	25048.966	19660.481	23839.987
21	17653.652	25712.484	21424.913	18306.983
22	17439.230	25855.839	21669.122	18524.511
23	18469.675	25364.656	21671.936	18524.511
24	20400.700	25837.039	21609.092	18475.733

Table 2. Hourly operating cost of each area of EP-TS method for 26 unit system

HOUR	Total operating cost (Rs)			
	Area 1 (26 unit)	Area 2 (26 unit)	Area 3 (26 unit)	Area 4 (26 unit)
1	34247.613	21635.745	26285.365	20722.510
2	24006.096	20746.916	21075.829	18412.843
3	26693.395	22630.573	20256.472	18373.831
4	29101.602	17646.246	24341.288	16859.248
5	27973.368	17341.275	24355.627	17574.961
6	35366.781	17323.293	22161.775	16631.335
7	38686.666	27931.271	19264.885	22580.007
8	37891.762	35938.554	18762.354	20023.085
9	37636.501	33568.917	16431.516	19584.831
10	35827.363	30725.834	20775.295	22449.433
11	36131.495	30835.613	19168.434	21846.322
12	37100.969	30615.283	19695.336	20613.366
13	31819.468	33760.847	17151.481	25705.299
14	30938.762	35780.701	15730.981	16158.451
15	30096.612	32771.328	16315.102	23289.113
16	35360.011	31686.516	21214.754	24835.924
17	35896.723	31373.451	22258.292	24597.207
18	34891.373	37529.304	25760.836	18735.462
19	33818.913	39090.112	22311.038	21605.752
20	34631.164	32072.805	20159.759	14747.794
21	38468.814	28822.272	18263.422	19611.414
22	29994.683	14821.752	18381.847	19689.300
23	30794.876	18399.776	18381.847	21607.333
24	28915.552	14635.707	14169.827	14597.297

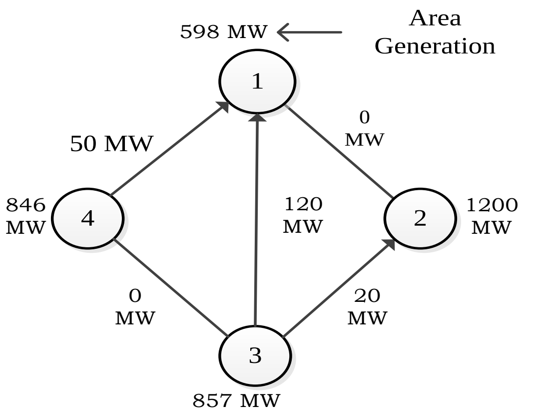

Fig. 5. Tie line flow pattern at 11 am of EP-TS method for 26 unit system

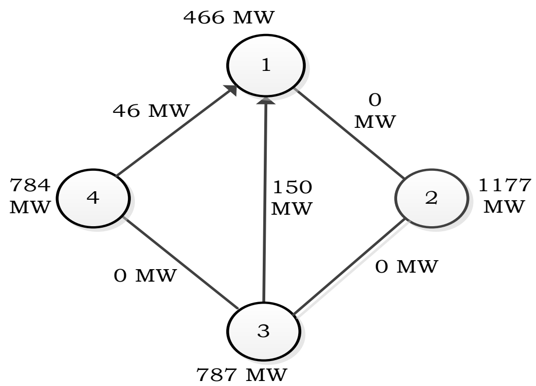

Fig. 6. Tie line flow pattern at 4 pm of EP-TS method for 26 Unit system

Table .3. Comparison of cost for 7 Unit (NTPS) and 26 Unit systems

System	Method	Total Operating Cost (pu)			
		Area 1	Area 2	Area 3	Area 4
7 unit (NTPS)	DP[7]	1.00000	1.00000	1.00000	1.00000
	EP[7]	0.96623	0.98033	0.96142	0.96611
	PSO[7]	0.95478	0.97987	0.95989	0.95879
	SA[7]	0.95129	0.97095	0.94878	0.94911
	EPPSO[7]	0.94680	0.96320	0.94025	0.94201
	EPSA[7]	0.92657	0.93479	0.92599	0.92635
	EPTS	0.91247	0.92875	0.91959	0.91754
26 unit	DP[7]	1.00000	1.00000	1.00000	1.00000
	EP[7]	0.98876	0.99543	0.97675	0.98541
	PSO[7]	0.97211	0.97456	0.96467	0.97599
	SA[7]	0.96789	0.96845	0.96218	0.96946
	EPPSO[7]	0.96489	0.95323	0.95780	0.96154
	EPSA[7]	0.93568	0.94721	0.92587	0.93217
	EPTS	0.92571	0.93628	0.91579	0.92384

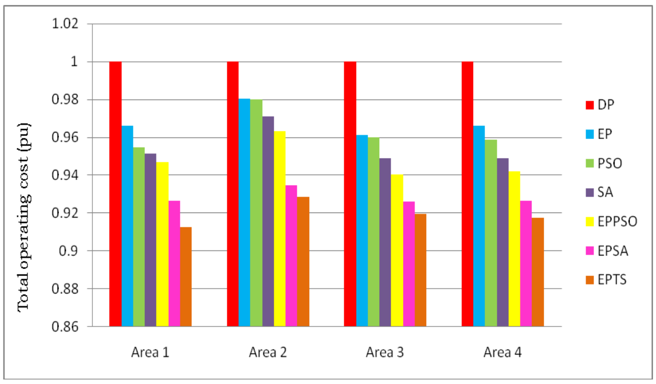

Fig. 7. Comparison of total operating cost in each area of 7 unit (NTPS) system

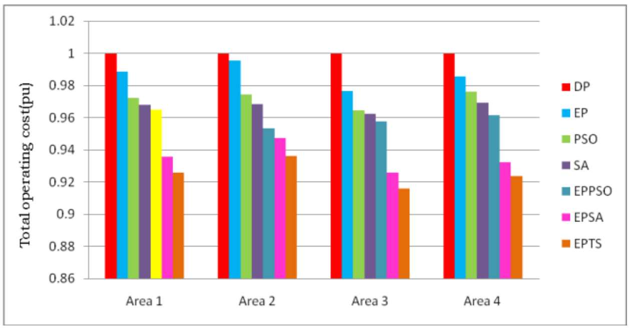

Fig. 8. Comparison of total operating cost in each area of 26 unit system

8. Conclusions

This paper presents EPTS method for solving multi area unit commitment problem with import and export constraints. In comparison with the results produced by the technique DP, EP, PSO, SA, EPPSO and EPSA method obviously proposed method displays satisfactory performance. Test results have demonstrated that the proposed method of solving multi area unit commitment problem with import and export constraints reduces the total operating cost of the plant. An effective tie line constraint checking procedure is implemented in this paper. This method provides more accurate solution for multi area unit commitment problem with import and export constraints.

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