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Emission Constraint Profit based Unit Commitment Problem using Improved Bacterial Foraging Algorithm

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Abstract

Objectives: The main objective function is to increase the Generation Companies profit and reduce the GHG gas emission of the thermal generating units. **Methods/Analysis:** During the most recent few centuries, emission control has become a very big problem of worlds concern due to the frequently increasing pollution of earth's atmosphere. In order to reach the emission control in this paper the Improved Bacterial Foraging Algorithm (IBFA) is proposed. The Bacterial Foraging Algorithm is formed by foraging behavior of E-coli Bacteria in the human intestine. But the BF algorithm leads to some convergence problem while solving the large problems. So for improving the performance of the large problems the new integer coded Improved Bacterial Foraging Algorithm is proposed. **Findings:** The proposed method is implemented to the IEEE 39 bus10 unit system with one day time period. This proposed algorithm is simulated using MATLAB software and the output results are compared with traditional Unit Commitment Method. **Novelty/Improvement:** The restructuring of electric power industry is used to reform the electric supply industry. The generation scheduling of thermal generating units in deregulated environment is named as Profit Based Unit Commitment. In PBUC problem the normal Demand constraint is changed to modified power demand constraint to increase the GENeration Companies (GENCO) profit.

Keywords: Emission Limitation, GENeration Companies (GENCO), Improved Bacterial Foraging Algorithm (IBFA), Profit Based Unit Commitment (PBUC), Unit Commitment (UC)

1. Introduction

Unit Commitment (UC) is the most important optimization task in optimal dispatch of units to the load and reserve among the committed units[1]. In deregulated power industry, the horizontally integrated electric utilities are changed into vertically integrated electric utilities. So the traditional Commitment method wants some changes in generation schedule, to increase the GENeration COmpanies (GENCOs) profit[2,3]. In deregulated power system the consumers get at lower price, higher quality and more trustworthy power. The market-based competition among generating companies creating an open market environment[4]. Also it has the main benefit is that consumers are directly permitted to select their suppliers[5].

The revenue is calculated by the forecasted demand and expected market price and it plays a extremely important role in PBUC. A solution of the spot markets prices in profit based unit commitment problem is proposed[6]. The fossil fuelled thermal units are considered as major sources of emission pollution. The type of fuel used for power generation decides the amount of GHG emission. The pulverized coal fired units produce emission two and half times higher than the natural gas-fired power plants in combined cycle configuration.

The increase in atmospheric temperature proportional to the altitude is called as temperature inversion.

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There is reduction in atmospheric temperature as altitude increases. But, in some cases these processes get reversed and cold air remains near the earth surface. This is result of movement of air masses with different temperatures over one another which traps the cooler air at the surface and causes shutdown of convection process. This implies no circulation of air pollution is trapped at earth surface causing stillness of air and smog.

The performance of PBUC problem using Genetic Algorithm (GA) is not easy to get a best solution[7]. Particle Swarm Optimization has premature convergence problem to solve PBUC[8]. The genetic algorithm and local search algorithm helps to cultural evolution[9]. A realistic approach for emission limitation and trade off curve in deregulated system found by varying the weighting factor between 0 and 1[10,11]. From the bibiliogical survey, it is observed that most of the conventional methods have some restrictions to present the qualitative solution.

The Bacterial Foraging Algorithm was successfully applied to different applications like harmonic estimation[12,13], voltage stability analysis[14] and load compensation in[15]. The BFA is proposed to solve unit commitment problem solution for IEEE 39 bus 10 units bus system in deregulated environment is proposed[16,17] and the emission limitations are not considered as one of the objective function.

The proposed technique is explained with flowchart in Section 2. The formation of PBUC problem is explained in Section 3. The simulation result is discussed in Section 4 followed by a conclusion and references in Section 5 and 6.

2. Improved Bacterial Foraging Algorithm

When solving the problem in conventional Bacterial Foraging algorithm the choice of parameters linking to swarming effect $d_{attract}$, $W_{attract}$, $h_{repellent}$, and $W_{repellent}$. The inappropriate values of these parameters may gives in too much repellent of bacteria and it will influence the convergence of the method. Furthermore, the Improved Bacterial Foraging algorithm is recommended[18]. In the basic Bacterial Foraging method health of bacteria may not retain the greatest bacterium for the next unit generation. But the calculation of profit for any combination of generating unit commitment is time consuming. For swarming, the distance of novel chemotactic stage bacteria is calculated from global optimum bacterium.

2.1 Proposed Method Algorithm

Step 1- Initialization of S, P, N_s, N_c, N_{re}, N_{ed}, P_{ed}, C(i), $d_{attract}$, $w_{attract}$, $h_{repelent}$, and $w_{repelent}$, j=k=l=0.

Step 2- Update Number of parameters by using θ and calculate J(i,j,k,l).

Step 3- Let J_{last} = J (i,j,k,l) to save this value to find a better cost via number of iterations.

Step 4- Generate a random vector $\Delta(i) \in \Re^P$ with each element $\Delta_m(i)$, m = 1, 2…P. and update θ and Jvalue by using the Equation (1) and (2).

$$\theta^i(j+1,k,l) = \theta^i(j,k,l) + C(i)\frac{\Delta(i)}{\sqrt{\Delta^T(i)\Delta(i)}} \quad (1)$$

$$J_{sw}(i,j+1,k,l)=J(i,j+1,k,l)+Jcc(\theta^i(j+1,k,l),P(j+1,k,l)) \quad (2)$$

Step 5- If m=N_s go to next bacterium for calculation of θ and J.

Step 6- If j<N_c, go to Step 3 to continue Chemotaxis.

Step 7- Calculate J^i_{health} values by using Equation (3) and arrange the values in ascending order.

$$J_{health} = \min_{j\in\{1...Nc\}} \{J_{sw}(i,j,k,l)\} \quad (3)$$

Step 8- If k<N_{re} go to Step 2.

Step 9. Elimination-dispersal: For i = 1, 2,…S, with probability P_{ed}, eliminates and disperses each bacterium.

Step 10. If l<N_{ed}, then go to Step 2 if not go to end.

3. Formulation of PBUC Problem

In PBUC problem generating units always increase the profit of the generation companies and reduce the output of all GHG gases. In order to increase GENCOs profit calculated based on forecasted load demand, spinning reserve, spot prices in the markets[19,20]. Flowchart for proposed PBUC Bacterial Foraging Algorithm is shown in Figure 1.

$$\max PF = RV - TC \quad (4)$$

$$\min EC_i(P_{it}) = \alpha_i + \beta_i.P_{it} + \gamma_i.(P_{it})^2$$

$$RV = \sum_{i=1}^{T}\sum_{i=1}^{N} P_{it}SP_iX_{it} \quad (5)$$

$$TC = \sum_{t=1}^{T}\sum_{i}^{N} FC_i(P_{it})X_{it} + ST \quad (6)$$

The various constraints for the objective function

3.1 Demand Constraint

$$\sum_{i=1}^{N} P_{it}X_{it} \le PD_t, \qquad t = 1.....T \quad (7)$$

3.2 Generation Limit Constraint

$$P_{i\,\min} \le P_{it} \le P_{i\,\max} \quad (8)$$

$$0 \le R_{it} \le P_{i\,\max} - P_{i\,\min} \quad (9)$$

3.3 Minimum Up and Down-Time Constraint

$$T_i^{ON} \ge MU_i \quad (10)$$

$$T_i^{OFF} \ge MD_i \quad (11)$$

3.4 System Power and Reserve Constraints

$$P_{i\min} \le P_{it}X_{it} + R_{it}X_{it} \le P_{i\max} \quad (12)$$

$$\sum R_{it}\,X_{it} \le R_{t\ \max} \quad (13)$$

E. Ramp up and down rates

$$P_{it}^{\max} = \min\{P_{i\,\max} P_i(t-1) + \tau.RU_i\} \quad (14)$$

$$P_{it}^{\min} = \max\{P_{i\,\min} P_i(t-1) - \tau.RD_i\} \quad (15)$$

Where τ =60 min is the time step.

4. Simulation Result

The proposed Improved Bacterial Foraging Algorithm (IBFA) has been implemented by using MATLAB software and tested on IEEE39 bus with10 units system. The operator data, emission data, forecasted load demand and Spot prices for the IEEE 39 bus system is given in appendix.

To achieve the faster convergence in the proposed method occurs when S = 6, Nc = 30, Ns = 4, Ned = 5, Nre = 10, Ped = 0.02 and together with the number of scheduled hours and generating units taken in the study. The chemotactic phase is updated in the every iteration of the proposed algorithm. The fast convergence is achieved by varying the control parameters. S, N_c, N_s, N_{re} and N_{ed} are selected in steps and the algorithm is run for a number of times.

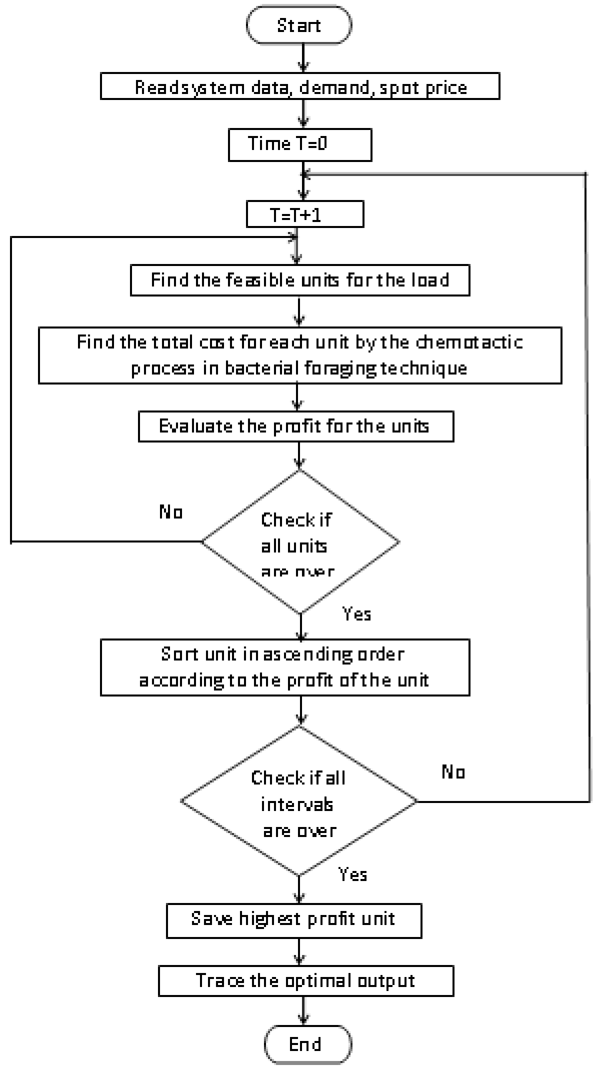

Figure 1. Flowchart for PBUC bacterial foraging algorithm.

The computational time varies linearly with the number of chemotactic size as shown in Figure 2. System spinning reserve is taken as the fraction of reserves that the GENCO should maintain for every contract.

Table 1 shows the Traditional Unit Commitment output for the given scheduling horizon. In the TUC generation scheduling, units 7, 8, 9 and 10 gives high emission over the scheduling period. Figure 3 shows the Plot of revenue, fuel cost and profit with respect to time for PBUC by IBFA. Figure 4 shows the Comparison of profits between Traditional Unit Commitment and PBUC for IBFA. The dispatched output power demand and forecasted power demand Comparison is given in Figure 5 and Figure 6 shows the GHG Emission comparison of TUC and PBUC for 10 unit systems.

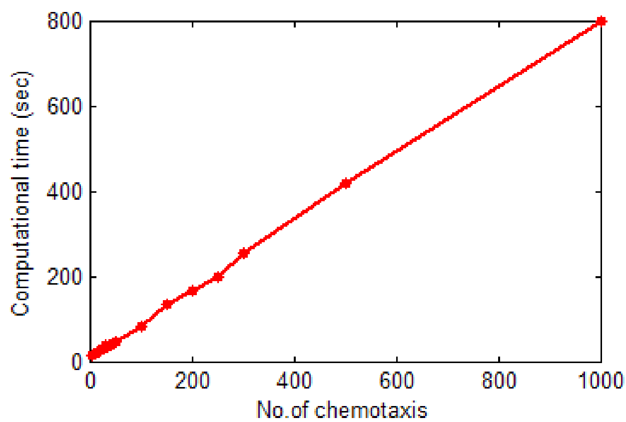

Figure 2. Number of chemotaxis Vs computational time (sec).

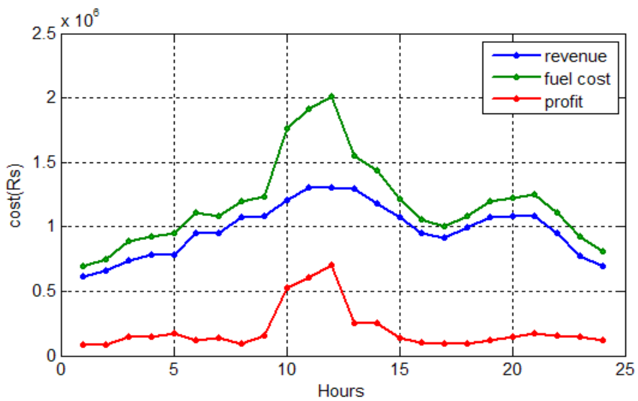

Figure 3. Plot of revenue, fuel cost and profit with respect to time for PBUC by IBFA.

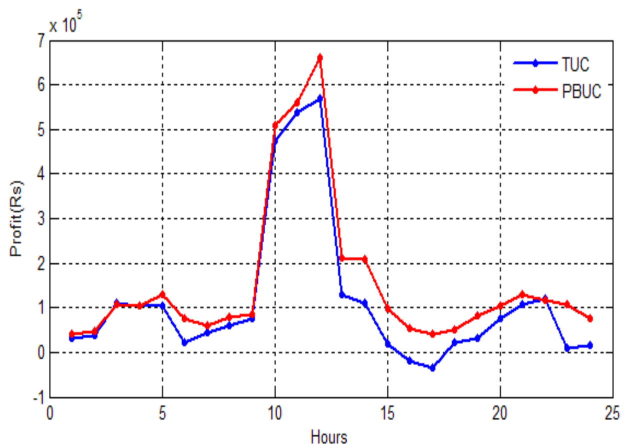

Figure 4. Comparison of profits between TUC and PBUC for IBFA.

Table 2 shows the proposed PBUC generation scheduling output. In the schedules, it may appear as it up and down times limits are being not violated. From Table 3, it is understandable that the IBF algorithm gives highest profit and lowest emission output when compared to the Traditional UC methods.

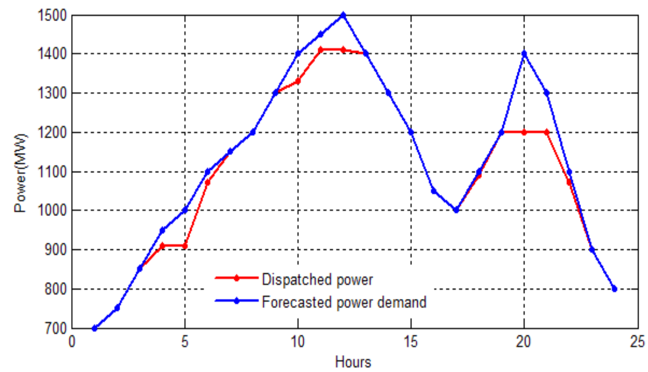

Figure 5. Comparison between dispatched power and forecasted power demand for IBFA.

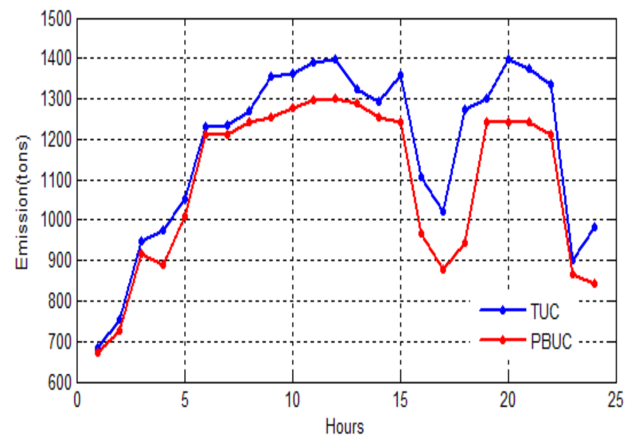

Figure 6. Comparison of emission between TUC and PBUC for IBFA.

5. Conclusion

The Profit Based Unit Commitment problem with operational and environmental constraints in a deregulated power system using Improved Bacterial Foraging Approach is proposed in this paper. The IBFA method always gives better numerical convergence for the scheduling period in the simulation. This new integer-code Improved Bacterial Foraging Algorithm provides the maximization of GENCOs profit, reducing emission output and schedules the thermal generating units in addition to the satisfaction of various constraints like

Table 1. Comparison of the results by LR, TUC and proposed method

Sl. No	Method	Profit (Rs/day)	Profit (Rs/year)	Emission (ton/day)	Emission (ton/year)
1	Traditional UC	3370353	1230178845	28317.8544	103360616.856
2	PBUC using BFA	3731192.3	1361885190	26763.7449	9768766.8885

Table 2. Simulation result of the traditional UC method

Units	Power Generation of Units (MW)										Generation Cost (Rs)	Start up Cost(Rs)	Revenue (Rs)	Profit (Rs)	Emission (tons)
Hour	1	2	3	4	5	6	7	8	9	10					
1	1	1	0	0	0	0	0	0	0	0	615740.84	0.00	697725	81984.16	682.7662
2	1	1	0	0	0	0	0	0	0	0	654952.49	0.00	742500	87547.51	754.7842
3	1	1	0	0	0	0	0	0	0	0	733585.04	0.00	883575	149990	945.6202
4	1	1	0	1	0	0	0	0	0	0	838695.63	25200.00	968287.5	104391.9	975.0131
5	1	1	0	1	1	0	0	0	0	0	900900.88	40500.00	1046250	104849.1	1052.409
6	1	1	0	1	1	1	0	0	0	0	1002436.86	7650.00	1136025	125938.1	1231.27
7	1	1	0	1	1	1	0	0	0	0	1047926.01	0.00	1164375	116449	1234.564
8	1	1	0	1	1	1	1	0	0	0	1123836.12	11700.00	1196100	60563.88	1268.812
9	1	1	0	1	1	1	1	0	1	0	1254256.42	2700.00	1333800	76843.58	1356.07
10	1	1	0	1	1	1	1	0	1	0	1375520.09	0.00	1849050	473529.9	1360.735
11	1	1	1	1	1	1	1	0	1	0	1405945.77	24750.00	1967288	536592.2	1390.636
12	1	1	1	1	1	1	1	0	1	0	1468549.18	0.00	2136375	667825.8	1395.77
13	1	1	1	1	1	1	1	0	0	0	1321467.68	0.00	1549800	228332.3	1325.007
14	1	1	1	0	1	1	1	0	0	0	1223904.02	0.00	1433250	209346	1292.422
15	1	1	1	0	1	1	1	0	1	1	1191400.02	5400.00	1215000	18199.98	1358.988
16	1	1	1	0	1	1	1	0	1	1	1072779.16	0.00	1053675	-19104.2	1105.929
17	1	1	1	0	1	1	1	0	1	1	1035416.60	0.00	1001250	-34166.6	1021.536
18	1	1	1	0	1	1	1	0	1	0	1070446.82	0.00	1091475	21028.18	1273.654
19	1	1	1	1	1	1	0	0	1	0	1142610.58	25200.00	1198800	30989.42	1301.349
20	1	1	1	1	1	0	0	1	1	0	1348631.47	2700.00	1426950	75618.53	1398.146
21	1	1	1	1	1	0	0	1	1	0	1243280.33	0.00	1351350	108069.7	1374.143
22	1	1	0	1	1	0	0	0	1	0	1016857.38	0.00	1136025	119167.6	1334.318
23	1	1	0	1	1	0	1		0	0	897587.69	14400.00	921375	9387.31	901.4489
24	1	1	0	0	1	0	1	0	0	1	792120.15	2700.00	811800	16979.85	982.4638
Total											25778847.23	162900.00	29312100.5	3370353	28317.8544

Table 3. Simulation result of the proposed method

Units	Power Generation of Units (MW)										Generation Cost (Rs)	Start up Cost(Rs)	Revenue (Rs)	Profit (Rs)	Emission (tons)
Hour	1	2	3	4	5	6	7	8	9	10					
1	1	1	0	0	0	0	0	0	0	0	657407.3	0	697725	40317.7	682.7662
2	1	1	0	0	0	0	0	0	0	0	696619.0	0	742500	45881.0	754.7842
3	1	1	0	0	0	0	0	0	0	0	775251.5	0	883575	108323.5	945.6202

4	1	1	0	0	0	0	0	0	0	0	822565.0	0	927517.5	104952.5	995.074
5	1	1	0	0	0	0	0	0	0	0	822565.0	0	952087.5	129522.5	1010.074
6	1	1	0	0	1	0	0	0	0	0	989241.0	40500	1105042.5	75301.5	1209.205
7	1	1	0	1	1	0	0	0	0	0	1079847.5	25200	1164375	59327.5	1209.225
8	1	1	0	1	1	0	0	0	0	0	1117969.5	0	1196100	78130.5	1242.322
9	1	1	1	1	1	0	0	0	0	0	1225070.5	24750	1333800	83979.5	1252.527
10	1	1	1	1	1	0	0	0	0	0	1248100.5	0	1756597.5	508497.0	1275.44
11	1	1	1	1	1	1	0	0	0	0	1346937.5	7650	1913017.5	558430.0	1298.095
12	1	1	1	1	1	1	0	0	0	0	1346937.5	0	2008192.5	661255.0	1298.95
13	1	1	1	1	1	1	0	0	0	0	1338075.5	0	1549800	211724.5	1290.295
14	1	1	1	1	1	0	0	0	0	0	1225069.5	0	1433250	208180.5	1252.527
15	1	1	0	1	1	0	0	0	0	0	1117970.5	0	1215000	97029.5	1242.322
16	1	1	0	1	1	0	0	0	0	0	998954.7	0	1053675	54720.3	964.887
17	1	1	0	1	1	0	0	0	0	0	959674.3	0	1001250	41575.7	877.2694
18	1	1	0	1	1	0	0	0	0	0	1031305.1	0	1081552.5	50247.4	944.3507
19	1	1	0	1	1	0	0	0	0	0	1117969.5	0	1198800	80830.5	1242.322
20	1	1	0	1	1	0	0	0	0	0	1117969.5	0	1223100	105130.5	1242.322
21	1	1	0	1	1	0	0	0	0	0	1117969.5	0	1247400	129430.5	1242.322
22	1	1	0	0	1	0	0	0	0	0	989240.0	0	1105042.5	115802.5	1209.205
23	1	1	0	0	0	0	0	0	0	0	814672.4	0	921375	106702.6	864.438
24	1	1	0	0	0	0	0	0	0	0	735900.4	0	811800	75899.6	842.4022
Total											24693282.7	98100	28522575	3731192.3	26763.7449

maximum up and minimum down time limits of units without using penalty functions. The results obtained by proposed method Traditional Unit Commitment are compared with Profit Based Unit Commitment, it is clear that the production cost and emission output level in TUC is more as compared to the production cost and emission output level of PBUC. In total production cost, maintenance cost and shut down cost of the generating units is not included. From the discussion, it was concluded that the profit will be increased and emission level reduced by using IBFA method.

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