JOURNAL OF CRITICAL REVIEWS

ISSN- 2394-5125 VOL 7, ISSUE 09, 2020

COMPARATIVE AND NOVEL SOLUTION FOR UNIT COMMITMENT PROBLEM USING HYBRIDISEDBAT SEARCH APPROACH TECHNIQUES FOR 10-UNIT SYSTEM

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Abstract- The concern to deal and formulate unit commitment problem in any power system is highly uncertain in nature which consists of both functional and operational limiting parameters in a given time horizon. Now, the challenging aim is to model a most cost effective and reliable power system which commits the generating units with two conditions of minimising operational costs and maximising the security & reliability concerns through proper selection of heuristic/meta-heuristic optimisation techniques. Here, in this paper a comparative analysis is presented that in which security constrained unit commitment (SCUC) problem is formulated and betterment of the solution is observed by defining both equality and inequality constraints of the considered system. Various optimisation techniques were designed and produced solutions which ranged from simple testing systems to larger testing systems. The testing results were obtained for 3-unit system, 4-unit system and 10- unit systems which are considered to check the cost effectiveness of the various meta heuristic algorithms like PSO, LR,GA, Bat, Bat-GA and Bat-ABC etc. This UC problem is developed on MATLAB platform and their cost effectiveness is compared with reviewed to present their feasibility of application.

Key words- security constrained unit commitment, constraints, Meta heuristic algorithms, testing systems

I. INTRODUCTION

The planning and optimum economic operationof power generation systems is an important concern in electric power sectors. Unit commitment (UC) is an important function referred to power generation of resource management in a power system [1]. Various mathematical programming optimisation techniques have been developed to solve unit commitment problem which is complex in nature to produce better solutions in terms of economy and reliability [2]. Xiaohong Guan et al [3] have bestowed to produce an optimum solution to unit commitment problem including security constraints of grid with help of mathematical, analytical & sufficient conditions. Antonio Frangioni et al [4] have presented an efficient solution for solving this single unit commitment problem (1-UCP) with help of a dynamic programming justifying the problem of arbitrary convex cost functions and ramping constraints. An Expert System (ES) algorithm was implemented by Ouyang and Shahidepour [5] to reduce the complexity in calculations and computation time. ES faced a problem, if the new schedule is differing from the schedule in the database. It provides many user- friendly I/O and graphics utilities and through them, feasibility of the ES was improved. A Memory Bounded Ant Colony Optimisation approach (MACO) was proposed by A.Y. Saber, et al. [6] in 2008 which helped this proposed approach is applicable for large scale power generating systems and solves the difficulties that aroused due to operational cost and computational efforts. The optimal unit committing status is determined in the enhanced local search with help of this heuristic approach of optimisation.

In 2007, S. S. Kumara, et al. [7] developed DP based direct Hopfield computation method. The proposed approach solves the UCP in two steps. The generator scheduling problem is solved using DP and generation scheduling problem is solved using Hopfield neural network.

Here, this paper is intended to present a comparative review between various meta heuristic optimisation techniques to solve the complex unit commitment problems in power system with the help of MATLAB platform thereby testing individual effectiveness by reciprocating to standard testing system of 3,4 & 10 unit systems..

The next sections of this paper are organized as follows: section II security constrained unit commitment (SCUC) formulation with constraints in transmission system. The various Meta heuristic algorithms were represented in section III. considered testing system's data is seen in section IV. The comparative analysis of results was reviewed for the various testing system's considered for 24 hour load demand in section V. In section VI summarization of conclusion is presented.

II SCUC and Formulation of SCUC

Unit commitment (UC) is the most efficient process for reducing the start-up cost, shut down cost and fuel cost in generating units. While generating powers there is a chance for problem occurrence. This problem occurs due to the improper unit schedule and economic dispatch problems in the generating systems, since the UC problem reduces the output power and start-up costs of the generating system. If the problem is not isolated correctly the cost requires for the system increases compared to the output power generated. So the problem identification and distribution of the generating units is very important in power systems. The main objective of the UC problem is to determine a minimal cost turn-on and turn-off schedule of a set of electrical power generating units to meet a load demand while satisfying a set of operational constraints. The cost of power produced and the start-up cost by the generating units are the two terms which minimizes standard UC problem.

The objective function of the unit commitment UC problem for N generating units and T hours can be written as follows:

$$\text{Mi}\, F = \sum_{i-1}^{Ng} F_i(P_{gi}) = \sum_{i=1}^{Ng} (a_i + b_i P_{gi} + c_i P_{gi}^2) \qquad (1)$$

Where F is the total generation cost (Rs/Mwh), F_i is the input output function of generator i, Ng is thetotal number of online generators, P_{gi} is the active power output of generator 'i' (Mw) and a, b, c are the fuel cost coefficients of generator 'i'.

The fuel cost function is represented as:

$$C_i(P_i)=a_i+b_i(P_{gi})+c_i(P_{gi}^2)+\left|e_i \sin(f_i(P_i^{\min} - P_i))\right| \qquad (2)$$

The constraints subjected are:

A. power balance constraint:

The total power generated by the units must be equal to the sum of total load demand and total real power loss in the transmission lines. hence the constraint is:

$$\sum_{i}^{Ng} P_{gi} = P_D + P_L \qquad (3)$$

Where P_D is the total load on the system and P_L is the transmission loss (Mw). The transmission losses are considered, these are calculated using B- coefficients.

$$\text{Where } P_L = \sum_{m=1}^{Ng} \sum_{n=1}^{Ng} P_{Gm} B_{mn} P_{Gn} \qquad (4)$$

$P_{Gm}, P_{Gn} = \text{real power generation at } m, n^{th} \text{ plants}$ B_{mn} = Loss coefficients which are constraints under certain assumed operating conditions.

B. Generation capacity constraints:

The real power output of generating units must be restricted within their respective lower and upper bounds as follows: (For i=1……N_G)

$$P_{gi}^{\min} \le P_{gi} \le P_{gi}^{\max} \qquad (5)$$

Where $P_{gi}^{\min}$ and $P_{gi}^{\max}$ are the minimum and maximum power outputs of the i^{th} unit.

C. Spinning reserve constraints

Spinning reserve is the difference between total maximum powers from all online generating units with total demand at the specified time. Generally spinning reserve constraint equation can be defined as follows,

$$\sum_{i-1}^{N} P_{i\max} \ge P_D + R \qquad (6)$$

D. Minimum up and down time constraints:

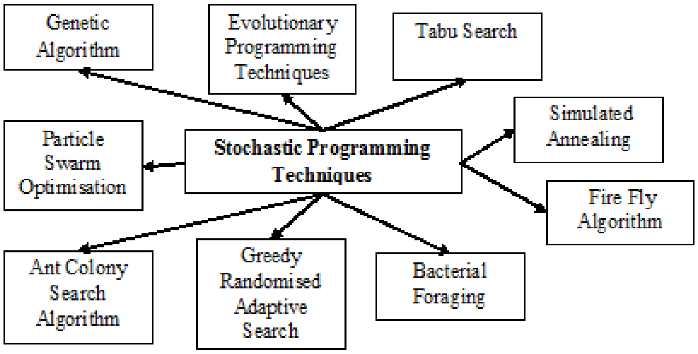
Minimum up time is the minimum time when the generating unit had just turn on to go back in off mode. Mean while of minimum down time in UC is to turn on to go back in online mode minimum time when generating unit had just turn on to go back in online mode. Minimum up and minimum down time can be expressed in this equation,

$$U_{ih} = 1 \; for \; \sum_{t=h-up_i}^{h-1} U_{it} \leq up_i \qquad (7)$$

$$U_{ih} = 0 \, \mathrm{for} \; \sum_{t=h-down_i}^{h-1} (1 - U_{it}) \leq down_i$$

III Meta Heuristic Techniques

The non-classical approaches are the ones which have got high attention towards research orientation in solving unit commitment problem. There have been several mathematical programming techniques involved to solve the unit commitment problems such as Genetic algorithm, Evolutionary programming technique, Tabu search, Particle swarm optimization and Ant colony search algorithm. These algorithms are also named as nature inspired algorithms or meta-heuristic algorithms in which the defined objective function is analysed and emphasised either in terms of evolutionary operators or as in exploration and exploitation terms too.



A. Particle Swarm Optimisation

Particle Swarm Optimization (PSO) has more effectiveness in solving integer programming problem. It was also used as a pre-processor for generating good initial points in a branch and bound technique of an integer programming problem. In particle swam optimization techniques the unit commitment variables are coded as integers. This formulation drastically reduces the number of decision variables and UC problems. In 2009, X. Yuan, et al. [8] recommended a new Improved Binary Particle Swarm Optimisation (IBPSO). This standard optimisation technique is improved by employing the priority list scheme and heuristic search to improvise the minimum up time and minimum down time constraints for the defined unit committing status. IEEE-10 unit system and IEEE-100 unit system have been tested to justify the new hybridised proposed approach.

In 2007, T. Y. Lee, et al. [9] presented a new approach for solving constrained unit commitment problem which tagged as the Iteration Particle Swarm Optimization (IPSO). The proposed method made better quality optimal solution both in perception of total generation cost and also maximised the computational efficiency of the power system defined.

B. Simulated annealing

Simulated Annealing (SA) is a dominant common-purpose stochastic search procedure to resolve tough-constrained optimization problems. Though it takes a long time, it has many strong features such as, it is easy to implement, requires little expert knowledge and is not memory intensive. Further, it can start with any initial solution and improve it to find optimal solution with a high probability. The SA optimization technique begins with an arbitrarily created solution and then creates successive random adjustments, awaiting a stopping condition is satisfied.

D. N. Simopoulos, et al. [10] developed a new Enhanced SA technique which interlinked a dynamic economic dispatch method. Simulated Annealing is used for scheduling of generating units. In this problem, dynamic economic dispatch method is used to include the ramp rate constraints. This non classical approach is also used to tune the control parameters by forming new rules are also presented.

F. Zhuang, et al. [11] presented a general optimization method, which is applied to generation unit commitment schedules. It generates randomly required feasible solutions and reaches to global minimum with high rate of convergence in all the feasible solutions. This SA do not have any particular structures to define the considered problem, which makes this approach highly flexible in handling unit commitment constraints.

C. Bacterial Foraging

Morteza Eslamian et al [12] has uses a novel evolutionary algorithm called as bacterial foraging (BF) for solving the power system UC problem. This novel integer-code algorithm is on the support of foraging performance of E-coli bacteria. With integer coding of the problem, execution time reduces and the minimum down/up- time constraints can be implied, and therefore, penalty functions for these constraints are, no need to use.

D. Genetic algorithms

In 1996, S. A. Kazarlis, et al. [13] developed an algorithm employing varying quality function technique in addition to problem specific operators, this coding was carried out in binary (0/1) form. The location of exact global solution is identified with help of varying quality function. For fitness evaluation a non-linear function is employed. Swap mutation and swap-window hill climb operators was used as new operators in this work for optimal solution attainment of generation scheduling which was tested on 100 generating units.

C. Dang, et al. [14] proposed a Floating-Point Genetic Algorithm (FPGA) in 2006.In this work a floating-point chromosome representation is employed to represent the forecasted load curve of the power generating system. The encoding and decoding operators are used to hold the minimum up and minimum down time constraints in the constrained unit commitment problem. The fitness function, constraints, population size, selection, crossover and mutation probabilities are initialised in clear in algorithm to reach better optimal solution search.

E. Bat algorithms

Xin-She Yang in 2010 has developed an effective bio-inspired algorithm like Bat algorithm to find the feasible solutions for constrained optimisation problems. The Bat algorithm works based on the echolocation behaviour of bats. Bats have the great potential to find their prey by discriminating from different types of insects even in complete darkness. In Bat algorithm, the echolocation behaviour of micro-bats is mimicked to find the feasible solution for objective function [125].

i. Movement of Bats:

The movement of the bats depending upon the velocity changes with respect to time step. The new solutions xit, and velocities vit, at time step t are given by;

$$fi = fmin + (fmax - fmin) * \beta \quad (1)$$

$$xit = xit - 1 + vit \quad (2)$$

Where, β € [0, 1] is a uniformly distributed random vector. x^* is the current global best location (solution), which is located after comparing all the solutions among all the n bats. We can choose fmin, fmax depending upon the domain size of the optimization problem. Initially, each bat is randomly assigned a frequency within the range [fmin, fmax].

For the local search, once a solution is selected among the current best solutions, a new solution for each bat is generated locally using random walk;

$$xnew = xold + \varepsilon At \quad (3)$$

Where, ε € [-1, 1] is a random number, while At = <Ait > is the average loudness of all the bats at this time t.

ii. Loudness and Pulse Emission:

The loudness Ai and the rate of pulse emission ri are updated accordingly as the iterations proceed. Once a bat has found its prey, loudness decreases and rate of pulse emission increases. Assume Amin = 0, means that a bat has just found the prey and temporarily stop emitting any sound.

$$Ait+1 = \alpha Ait \quad (4)$$

$$rit+1 = ri0 [1 - \exp(-\gamma t)] \quad (5)$$

Where, α and γ are constants.

IV. Simulation Results

The feasibility of considered testing systems is demonstrated with stated literature reviews above as to produce better solution for formulated unit commitment problem. The **BAT, BAT-ABC & BAT-GA** techniques were designed and a solution for SCUC problem is compared with existing technologies. This new search algorithm has been tested for all the 3 testing cases of 3-unit system, 4-unit system and 10- unit system to represent its applicability and convergence. The convergence of the proposed method is comparable in terms of cost withother techniques mentioned in this paper.

A. Test system1: 3-unit system

For the validation of proposed algorithms to find the optimum fuel cost for the defined unit commitment problem with multiple system constraint parameters such as generation limits, start-up cost, unit's minimum ON and OFF time and cost coefficients are tested with help of 3-Unit system [16]. A sample 3-unit generating system's, design parameters are stated in Table 1 and the loads for 24 hour time horizon are tabulated in Table 2.

Table 1 data for unit -3 system

gen no	**a**	**b**	**c**	p_{max}	p_{min}	t_{on}	t_{off}	**Strt-cost**	**C hour**
1	176.9	13.56	0.1	220	100	4	4	100	1.2469
2	129.9	32.6	0.1	100	10	2	2	200	1.2469
3	137.4	17.6	0.1	20	10	2	2	0	1.2462

Table 2 load demand for 24 hours

hour	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
demand	290	250	240	300	200	280	280	220	250	170	160	240
hour	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**
demand	280	310	180	250	230	160	210	180	280	210	240	180

B. Test System 2: 4-unit system

This test system comprises of 4 thermal units [17] over the scheduling time horizon of 8 hours with 1-h time interval.. For this system the maximum generation count was kept 100. A sample 4-unit generating systems, design parameters are stated in Table 3 and the loads for 24 hour time horizon are tabulated in Table 4.

Table 3 Unit Characteristics for 4-Unit System

Gen No.	**1**	**2**	**3**	**4**
P_{max}	80	250	300	60
P_{min}	25	60	75	20
a_i	213.00	585.62	684.74	252.00
b_i	20.875	17.998	17.458	23.800
c_i	0.00396	0.00261	0.00289	0.0051
INS_i	-5	8	8	-6
Ti_{up}	4	5	5	1
$Ti_{,down}$	2	3	4	1
HS_i	150	170	500	0
CS_i	350	400	1100	0.02
Ti,cold	4	5	5	0

Table 4 Load Pattern For 4-Unit System

Hour (h)	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Load	450	530	600	540	400	280	290	500

C. Test System 3: 10- unit system

To study the performance of proposed Bat, Bat-ABC and Bat-GA algorithms to find the feasible solutions for the given constrained unit commitment problem, 10-unit system has been considered. The 10-unit system single line diagram is as shown in Fig 5.2. The parameters required to define 10-unit system were tabulated in Table 5.9 which consists of cost coefficient, maximum and minimum power capacity limits and minimum up or down etc. The Table 5.10 represents 24 hours load demand including SR (spinning reserve) here the maximum load is seen at 12 hour with 1500MW of maximum power generation whereas 1 hour with 700MW as minimum load. The validation of proposed techniques was enumerated in the following sections with outlining their significance in terms of operational costs including fuel cost and start- up cost. Table 5 and Table 6 represent the intake data related to 10-unit system.

The selected parameters are: Bat length=5; number of iterations=100; total hours=24. The total operating cost has been reduced by representing its effectiveness. The cost effectiveness of proposed technique is stated in Table 7,8 and 9 and whereas comparison of various techniques is stated with respect to 3,4,& 10 unit systems.

Table 7 Best cost obtained by different algorithms for 3-Unit system

	Algorithm	**Fuel Cost**	**Total Computational Time**
UNIT-3	**GA**	1,96,638	33.7
	SA	1,99,961	32.8
	Bat	1,89,737	28.3
	Bat-ABC	1,88,762	31.2
	Bat-GA	1,77,503	22.5

Table 8 Best cost obtained by different algorithms for 4-Unit system

	Algorithm	**Fuel Cost**	**Total Computational Time**
UNIT-4	**LR**	76,955	2.5
	GA	77,628	3.96
	EGA	77,628	3.92
	Bat	76,993	3.99
	Bat-ABC	76,855	3.87
	Bat-GA	76,345	3.88

Table 9 Best cost obtained by different algorithms for 10-Unit system

	Algorithm	**Fuel Cost**	**Total Computational Time**
UNIT-10	**SA**	5,65,977	3350
	EP	5,64,551	1000
	BFA	5,64,842	1100
	GA	5,64,217	311
	EGA	563,937	145
	Bat	564,255	312
	Bat-ABC	567,286	348
	Bat-GA	563,917	293

V. Conclusion

This paper represents a methodological solution to security constrained unit commitment (UC) by availing all the constraints related to network and units. When compared with computational algorithms and BAT algorithm, this offspring approach has superior features of quality solution, stable convergence and computational efficiency. Therefore, it is observed that when compared to other optimised techniques BAT-GA algorithm has presented most promising solutions for solving complicated problems in power system and reduces the uncertainties to implement optimal solution. In order to enhance the exploration and exploitation process of the search space, the problem specific operators are integrated with local optimum solution. Moreover, the constraint repairing strategies keep the search space feasible and thus, accelerate the convergence process.

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