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A Hybrid BAT-GA Optimisation of Security Constrained Unit Commitment Problem for 10-unit System

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Abstract: To model a most cost effective and reliable power system, an effective selection of heuristic/meta-heuristic optimisation with respect to unit commitment is more essential. In this paper, to guarantee the convergence, the unit commitment (UC) problem is formulated as security constrained unit commitment (SCUC) problem where the solution is defined by both equality and inequality constraints of the considered system with minimum up-down times, power balance and spinning reserve etc. A corrective and preventive dispatch contingency for 24-hour period is proposed based on SCUC model. This iterative procedural solution accelerated an efficient execution with unit commitment, economic dispatch and hourly network security check. This research provides a solution which is subjected to generate a minimum bid based system with optimal solution using HYBRID-BAT search algorithm 10-unit system. The reduced optimal cost values are compared with BAT technique using MATLAB platform, to validate the effectiveness of proposed techniques.

Keywords: BAT algorithm, BAT-GA algorithm, constraints, security constrained unit commitment.

1. INTRODUCTION

In electrical power sectors, the planning and operation of the generating systems is an utmost concern which is to optimised [3], with respect to unit commitment (UC) in resource management [6]. This is an centralised task which should be more reliable and highly efficient [1, 2, 18]. The main objective of the UC problem is to ascertain definitely a set of minimal cost turn-on/turn-off schedules for units of power generation to equalize a load demand by satisfying the operational constraints [26, 27] such as generating unit's start up cost, capacity reserve, minimum up/down time, and operating limits [20]. The evaluation of Unit Commitment problem (UCP) is really a detailed optimization problem which considered as two sub-optimization problems as the combinatorial problem of generating units that would be a very huge number [8].

The unit scheduling problem is to calculate the minimised operating cost as when to start up and shutdown units, by satisfying the system and the generator constraints respectively [21]. In electric power system, the economic dispatch problem is meant to evaluate the all on-line unit's generation levels that which reduces the system's total fuel cost and also the emission levels within the set of constraints selected under a particular considered time horizon [14, 23].

There are many mathematically programmed techniques which are meant to attain the optimised unit commitment like Particle swarm optimization, Genetic algorithm, Firefly algorithm, Ant colony search algorithm, Evolutionary programming technique, Tabu search, and Gravitational search method etc.. [15]. The Genetic algorithm is formulated on basis of fittest survival with in a group of candidate solutions, and this modelling runs on the rules and mechanisms of natural selection and "survival of the fittest" from natural evolution [21, 28]. In premature stages, the optimal solution is attained with the help of Tabu search which experiences new solution that leads to attain improved solutions in less number of iterations [24]. For a

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large scale power system, this ACSA (Ant colony search algorithm) is used to optimise to achieve minimum total generation cost, in which the behaviour of real ants is replicated [13, 22, 25]. K. Chandrasekaran *et. al*., [9] have explained a biologically-inspired binary real coded firefly (BRCFF) algorithm to determine the unit commitment problem by accounting the constraints of system and generating units. The firefly (FF) algorithm was inspired by the peculiar flashing phenomenon of fireflies and also the behaviour of bioluminescent communication. The transient stability constrained unit commitment (TSCUC) model explained the main economic objective of withstanding transient stability by Quanyuan Jiang *et. al*., [10]. For medium sized power systems, the applicability and the viability of unit commitment is explained with its application [4]. This paper is intended to propose a hybrid bat search algorithm to solve the unit commitment problems in power system. Initially, the objective function of the problem will be defined which incorporate with equality and inequality constraints of the system. The proposed optimisation technique, the SCUC problem's objective function is reduced by comparing the results of the problem with multiple optimization techniques proposed earlier [1, 2].

The rest of the paper is organized as follows: section II presents security constrained unit commitment (SCUC) formulation with constraints in transmission system. The BAT algorithm is represented in section III. The proposed hybridised BAT-GA algorithm is explained in section IV. The proposed algorithm results are tested on 10-unit system [27] for 24 hour load demand in section V. Conclusions are presented in section VI.

2. UC 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. The problems which occurs at the time of power generation due to improper power schedule leads to 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. The main objective of the UC problem is formulated as security constrained unit commitment (SCUC) as 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 SCUC[1,2] is meant to determine the 24- hour ahead UC by minimising the operational cost of units with listed constraints as, power balance, start up and shut down unit's characteristics, fuel constraints and emission constraints etc.

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

$$\text{Mi F} = \sum_{i-1}^{\text{Ng}} \text{F}_i(\text{P}_{gi}) = \sum_{i=1}^{\text{Ng}} (a_i + b_i\text{P}_{gi} + c_i\text{P}_{gi}^2) \tag{1}$$

Where F is the total generation cost (Rs/Mwh), F_i is the input output function of generator *i*, Ng is the total 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:

$$\text{C}_i(\text{P}_i) = a_i + b_i(\text{P}_{gi}) + c_i(\text{P}_{gi}^2) + |e_i \sin(f_i(\text{P}_i^{\min} - \text{P}_i))| \tag{2}$$

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:

$$\sum_{i}^{Ng} P_{gi} = P_D + P_L \tag{3}$$

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.

$$P_L = \sum_{m=1}^{Ng} \sum_{n=1}^{Ng} P_{Gm} B_{mn} P_{Gn} \tag{4}$$

Where, P_{Gm}, P_{Gn} = Real power generation at m, n^{th} 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 $i = 1, \ldots, N_G$)

$$P_{gi}^{min} \le P_{gi} \le P_{gi}^{max} \tag{5}$$

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 power from all online generating units with total demand at the specified time. Generally spinning reserve constraint equation can be defined as follows,

$$\sum_{i-1}^{N} P_{i\,max} \ge P_D + R \tag{6}$$

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,

$$U_{ih} = 1 \text{ for } \sum_{t=h-up_i}^{h-1} U_{it} \le up_i \tag{7}$$

$$U_{ih} = 0 \text{ for } \sum_{t=h-\text{down}_i}^{h-1} (1 - U_{it}) \le \text{down}_i$$

3. BAT ALGORITHM

Bat algorithm is a meta-heuristic optimization algorithm developed by Xin-She Yang in 2010. The Bat algorithm is based on the echolocation behaviour of bats. Bats have the ability to find their prey and discriminate different types of insects even in complete darkness. The echolocation behaviour of micro-bats can be used to optimize an objective function [1, 2].

A. *Movement of Bats:* The movement of the bats depending upon the velocity changes with respect to time step. The new solutions x_i^t, and velocities v_i^t, at time step t are given by:

$$f_i = f_{min} + (f_{max} - f_{min}) \times \beta \tag{8}$$

$$x_i^t = x_i^{t-1} + v_i^t \tag{9}$$

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. 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;

$$x_{new} = x_{old} + \varepsilon A^t \tag{10}$$

Where, ε € [–1, 1] is a random number, while $A^t = (A_i^t)$ is the average loudness of all the bats at this time '*t*'.

B. *Loudness and Pulse Emission:* The loudness A_i and the rate of pulse emission r_i are updated accordingly as the iterations proceed.

$$A_i^{t+1} = \alpha A_i^t \tag{11}$$

$$r_i^{t+1} = r_i^0[1 - \exp(-\gamma t)];$$

Where, α and γ are constants. (12)

4. HYBRID (BAT-GA) ALGORITHM

Generally, genetic algorithm (GA) is used for solving both constrained and unconstrained optimisation problem based on natural selection. The steps involved in BAT-GA algorithm are:

A. *Selection:* Depending on evolution function, chooses a chromosome in random fashion out of population.

B. *Cross over:* Mating of strings can be done randomly in between two parents.

C. *Mutation:* An operation performed by random selection of chromosomes in pre-specified limit of probability Depending on complexity of the problem, the population size is to be considered.

The BAT algorithm based Genetic algorithm is used for solving the unit commitment problem. GA in BAT objective function helps as good search tool because of random solutions and convergence, in other words this means that the entire population is improving, but this could not be said for an individual within this population. The proposed hybrid technique reduces the speed of convergence. The flow chart for hybridised (BAT-GA) is represented in Figure 1.

5. SIMULATION RESULTS

The hybrid BAT-GA search technique formulated and provided a solution for SCUC problem. The potential of the proposed algorithm has been tested for IEEE 10-unit system to explode its applicability and convergence. The convergence of the proposed method is compared in terms of cost with BAT ALGORTHIM technique [1]. The procedural solution for unit commitment problem consisting the objectives and constraints are represented for the unit schedules in a given period.

The hybrid BAT-GA algorithm selected parameters are: bat length = 5; number of iterations = 100; total hours = 24. The Tables I & II represents the intake data for 10-unit system. The Tables III validates the applicability of the proposed method for solving UC problem. The total operating cost has been reduced by representing its effectiveness. The total cost for 10-unit system has been compared with the proposed hybrid BAT-GA approach and BAT approach [1] in Table IV.

6. CONCLUSION

This paper represents a methodological solution to security constrained unit commitment (SCUC) by availing all the constraints related to network and units. The proposed hybrid algorithm has generated optimal results under the specified constraints. Compared with computational algorithms, including BAT algorithm, the proposed offspring approach has superior features of quality solution, stable convergence and computational efficiency. Therefore, BAT-GA algorithm is a promising technique for solving complicated problems in power system and reduces the uncertainties to implement optimal solution while using conventional

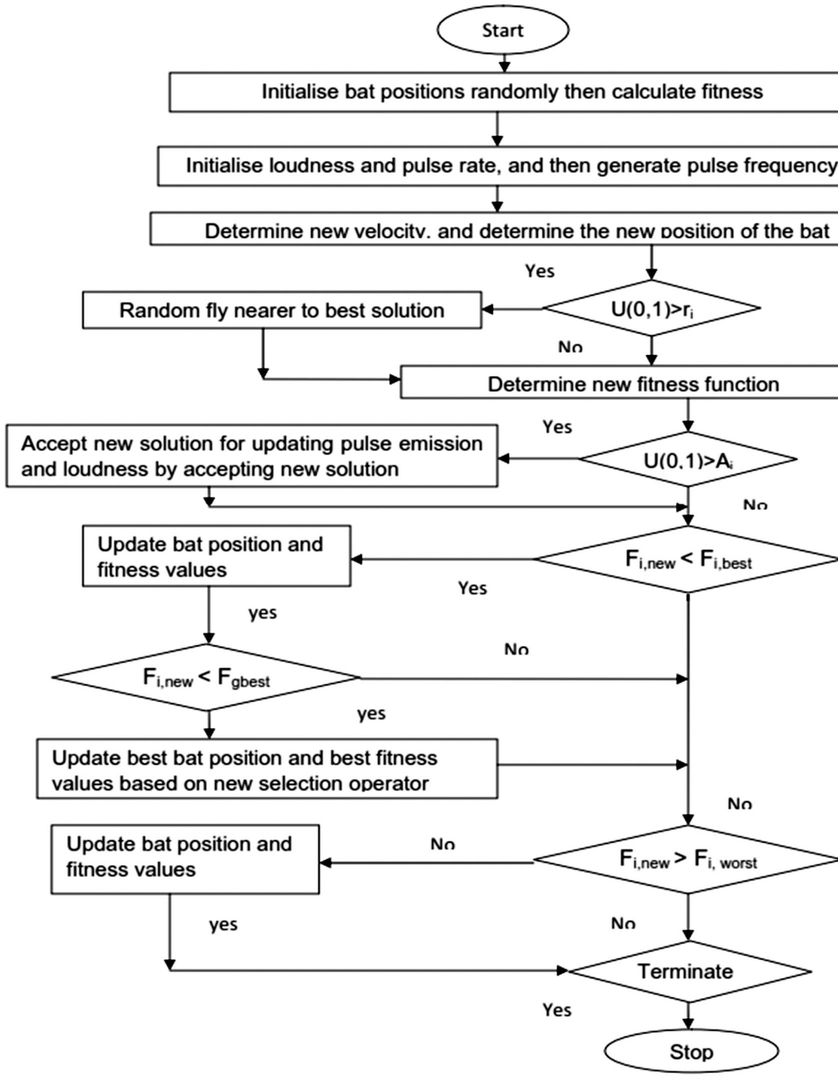

Figure 1: Flow chart for hybrid BAT-GA

techniques. BAT-GA algorithm can be used to solve unit commitment problem with reduced the total production cost of power generation. Figure 2 represents the optimal cost of both the techniques with graphical approach.

Table 1
Data for 10-unit system

Gen no	*a*	*b*	*C*	P_{max}	p_{min}	T_{on}	t_{off}	*hcost*	*C cost*	*C hour*
1	1000	16019	0.00048	455	150	8	8	4500	9000	5
2	970	17.26	0.00031	455	150	8	8	5000	10000	5
3	700	16.6	0.002	130	20	5	5	550	1100	2
4	680	16.5	0.0021	130	20	5	5	560	1120	2
5	450	19.7	0.00398	162	25	6	6	900	1800	4
6	370	22.26	0.00712	80	20	3	3	260	520	4
7	480	27.74	0.00079	85	25	3	3	260	520	4
8	660	25.92	0.00413	55	10	1	1	30	60	0
9	665	27.27	0.00222	55	10	1	1	30	60	0
10	670	27.79	0.00173	55	10	1	1	30	60	0

Table 2
Demand for 24 hours for 10-unit system

hour	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*
demand	700	750	850	950	1000	1100	1150	1200	1300	1400	1450	1500
SR data	210	160	222	122	202	232	182	132	197	152	157	162
hour	*13*	*14*	*15*	*16*	*17*	*18*	*19*	*20*	*21*	*22*	*23*	*24*
demand	1400	1300	1200	1050	1000	1100	1200	1400	1300	1100	900	800
SR data	152	197	132	282	332	232	132	152	197	137	172	110

Table 3
Result for unit-10 system using BAT-GA technique

Hour	*Unit-1*	*Unit-2*	*Unit-3*	*Unit-4*	*Unit-5*	*Unit-6*	*Unit-7*	*Unit-8*	*Unit-9*	*Unit-10*	*Startup Cost $*	*Fuel Cost $*	*Total cost $*
1	416.5	283	0	0	0	0	0	0	0	0	0	13714.21	13714.21
2	433	319	0	0	0	0	0	0	0	0	0	14599.04	14599.04
3	444.3	280	125.33	0	0	0	0	0	0	0	0	16933.3	16933.3
4	443.3	430	0	77.32	0	0	0	0	0	0	0	18686.99	18686.99
5	425	404	109.99	0	0	60.99	0	0	0	0	720	20265.4	20985.4
6	452.4	441	0	0	131.24	75.24	0	0	0	0	0	22257.84	22257.84
7	431.7	422	0	101.6	146.59	48.59	0	0	0	0	560	23651.28	24211.28
8	437	445	115.99	126	0	76	0	0	0	0	0	24426.46	24426.46
9	452.2	406	121.16	125.2	151.16	0	0	44.17	0	0	960	27300.84	28260.84
10	450.9	435	122.85	123.9	148.38	74.85	0	0	44.8	0	400	29886.25	30286.25
11	452.4	453	129.42	129.4	154.42	0	78.43	0	52.4	0	0	31364.05	31364.05
12	453.3	446	124.24	112.3	160.24	76.24	80.25	47.25	0	0	400	32946.84	33346.84
13	448.7	436	127.71	108.7	155.71	71.71	0	0	0	51.7	60	29990.45	30050.45
14	421.8	427	120.83	124.8	132.83	72.83	0	0	0	0	0	26981.96	26981.96
15	427.8	427	76.8	106.8	161.79	0	0	0	0	0	0	24601.36	24601.36
16	419.5	403	99.49	0	128.49	0	0	0	0	0	0	21262.06	21262.06
17	420.7	375	91.749	112.7	0	0	0	0	0	0	0	20185.47	20185.47
18	453.3	374	129.25	0	143.24	0	0	0	0	0	0	22142.25	22142.25
19	443.8	423	0	126.8	148.79	57.79	0	0	0	0	1460	24558.35	26018.35
20	441.6	450	109.57	127.6	155.56	70.571	0	45.57	0	0	1160	29833.81	30993.81
21	446.7	422	121.66	116.7	146.66	0	0	0	0	46.66	60	27408.49	27468.49
22	452.5	425	99.497	122.5	0	0	0	0	0	0	0	21898.66	21898.66
23	428.2	369	0	103.7	0	0	0	0	0	0	0	17809.48	17809.48
24	448	352	0	0	0	0	0	0	0	0	0	15432.91	15432.91
						TOTAL							563917.8

Table 4
The comparison system values in terms of cost

Unit system	*BAT($)*	*BAT-GA(HYBRIDISED)($)*
10-unit system	564255.7	563917.8

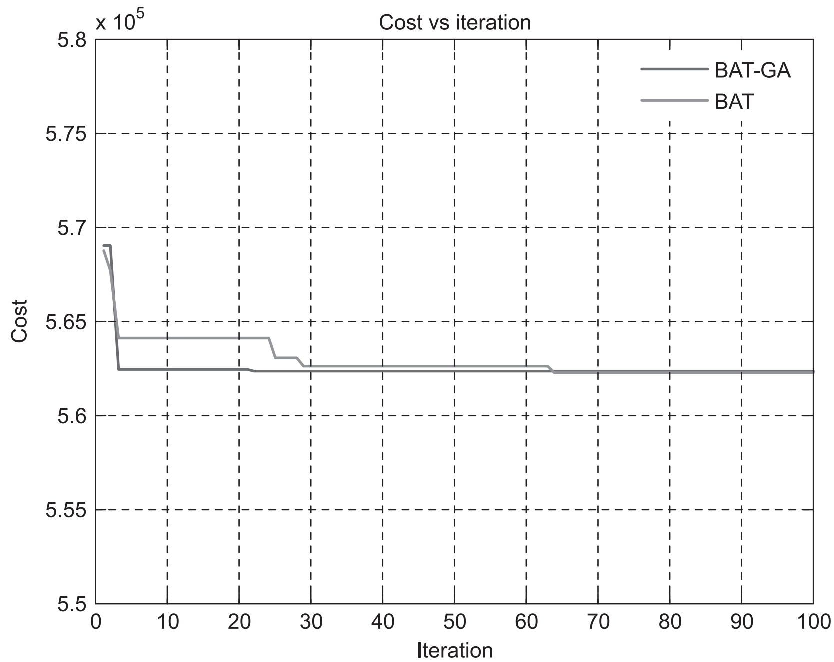

Figure 2 For unit-10 system

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