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NOVEL HYBRID BAT APPROACH FOR SECURITY CONSTRAINED UNIT COMMITMENT

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ABSTRACT

This paper presents a solution to (SCUC) security constrained unit commitment problem with an objective function defining equality and inequality constraints of the system. The objective of the problem will be solved using multiple optimization function with the constraints as power balance, spinning reserve, operating limits of real power, minimum up & down time, emission etc.. These are subjected to generate the solution for the problem by using hybrid BAT search algorithm. So, by this type of most economical operation of modern power systems allocates the optimal power generation from different units at the lowest cost possible there by meeting all the system Conditions. The performance of the suggested method is practiced in MATLAB platform and the results are assessed through 3-unit testing system.

KEYWORDS: BAT Algorithm, BAT - GA Algorithm, Constraints, Security Constrained Unit Commitment and Unit Commitment

I. INTRODUCTION

The planning and optimum economic operation of power generation systems is an important concern in electric power sectors [1]. Unit commitment (UC) is an important function referred to power generation of resource management in a power system [2]. This operation of power systems is a central task which is reliable and efficient [3]. 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 [4] such as capacity reserve, minimum up/down time, and operating limits [5]. Therefore the standard UC problem is to reduce the cost of power produced by the generating units and the start up cost of the generating units [6]. 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 [7].

The unit scheduling problem is to determine when to start up and shutdown units so that the total operating cost can be minimized, while simultaneously satisfying the system and the generator Constraints [8]. Economic dispatch problem in electric power system is to determine the generation levels for all on-line units which minimize the total fuel cost and minimizing the emission level of the system, while satisfying a set of constraints [9]. In power systems the UC is an optimization problem of determining the on/off states of generating units that minimize the operating cost for a given time horizon [10].

There have been several mathematical programming techniques involved to solve the unit commitment problems like Genetic algorithm, Evolutionary programming technique, Tabu search, Particle swarm optimization and Ant colony search algorithm [11]. Genetic algorithm works with a population of candidate solutions, and these techniques are based on the principles and mechanisms of natural selection and “survival of the fittest” from natural evolution [12]. The fitness of each member of the population is computed by an evaluation function that measures wellness of an individual [13].

The Tabu search depresses the possibility to local convergence in the early stages of the iterations. This enables the candidates to explore new solution spaces to get better solutions [14]. 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 [15]. 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 [16].

Ant colony search algorithm (ACSA) mimics the behavior of real ants [17]. Therefore the Ant colony optimization technique was used to solve the problem of economic dispatch in a large-scale power system [18].For optimization problem the Ant colony optimization techniques is applied to achieve minimum total generation cost [19]. K. Chandrasekaran *et al*. [20] have explained a new biologically-inspired binary real coded firefly (BRCFF) algorithm to solve the unit commitment problem (UCP) by considering system and generating unit constraints. The firefly (FF) algorithm was inspired by the flashing behavior of fireflies and the phenomenon of bioluminescent communication.

Quanyuan Jiang *et al*. [21] have described a transient stability constrained unit commitment (TSCUC) model which achieves the objective of maintaining both transient stability and economical operation. In the TSCUC model, transient stability constraints are incorporated into the framework of unit commitment. Chaoyue Zhao *et al*. [22] have proposed a novel unified stochastic and robust unit commitment model that takes advantage of both stochastic and robust optimization approaches a low expected total cost while ensuring the system robustness.

The rest of the paper is organized as follows: section II security constrained unit commitment (SCUC) formulation with constraints in transmission system. The BAT algorithm is represented in section III. The proposed hybrid algorithm is explained in section IV. The proposed algorithm results are tested with 3-unit 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:

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

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

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

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.

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

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

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,

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

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,

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

$$U_{ih} = 0 \, \mathrm{for} \sum_{t=h-down_i}^{h-1} (1 - U_{it}) \le down_i \quad (7)$$

III. BAT ALGORITHM

Bat algorithm is a meta-heuristic optimization algorithm developed by Xin-She Yang in 2010[28]. 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 [29].

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:

$$f_i = f_{min} + (f_{max} - f_{min}) * \beta \quad (8)$$

$$x_i^t = x_i^{t-1} + v_i^t \quad (9)$$

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;

$$x_{new} = x_{old} + \varepsilon A^t \quad (10)$$

Where, ε € [-1, 1] is a random number, while $A^t = \langle A_i^t \rangle$ 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.

$$A_i^{t+1} = \alpha A_i^t \quad (11)$$

$$r_i^{t+1} = r_i^0 [1 - \exp(-\gamma t)] \quad (12)$$

Where, α and γ are constants.

IV. HYBRID (BAT-GA) ALGORITHM

The BAT algorithm based Genetic algorithm is used for solving the unit commitment problem. By utilizing 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. This hybrid technique reduces the speed of convergence range.

V. SIMULATION RESULTS

BAT algorithm is comparatively a new optimization algorithm [1] but the hybrid BAT-GA algorithm approach has not been applied to solve SCUC problem so far. In order to attain the effectiveness of proposed BAT-GA algorithm is programmed in MATLAB environment. The procedural solution for unit commitment problem consisting the objectives and constraints are represented for the unit schedules in a given period. The hybridised BAT-GA algorithm was tested to determine the effectiveness of the considered system was tabulated and even compared with BAT algorithm's data and results.

In order to test the importance of the proposed hybrid algorithm, here considered for 3- unit system, the system parameters are tabulated.

The following parameters have been chosen for simulations: bat length=5; iterations=100; no. of hours=24. Table 1 and Table 2 represent the data related to 3-unit system. The effective results are tabulated for 3-unit system III. From Table 3 the applicability of the proposed method for solving UC problem is highlighted. The proposed method has reduced the operating cost when compared to BAT technique [1]. The total operating cost has been reduced by representing its effectiveness. As in BAT approach [1] the total cost for unit-3 system is seen as 189337.7$, where as in proposed hybrid BAT-GA algorithm approach the reduced operating cost is 177103.8301$. The extension of work can be extended to 10 unit system also.

VI. CONCLUSIONS

This paper motivated a methodological solution to security constrained unit commitment (SCUC) by availing all the constraints related to network and units. This hybrid algorithm generated optimal results under the specified constraints. When compared with computational algorithms and BAT algorithm, this 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 techniques. This new hybridised BAT-GA algorithm is used to solve unit commitment problem and even for increased number of generating units. Thereby its reliability and applicability of this optimised technique is extended as by reducing the total production cost of power generation irrespective of the security constraints considered in the power systems unit commitment.

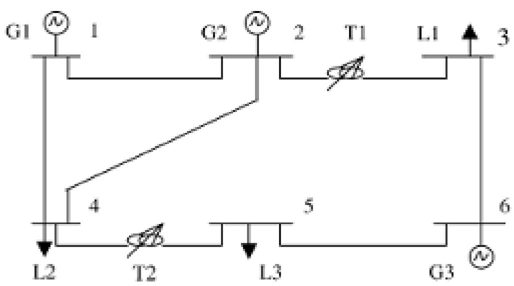

Figure 1: IEEE-6 Bus System (With 3- Generating Units)

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

Table 3: Result for 3-Unit System (using BAT-GA)

Hour	Unit-1	Unit-2	Unit-3	Start Up	Fuel Cost
1	185.237	100.7867	0	0	10551.37
2	152.323	79.31469	18.32	0	8400.67
3	115.242	104.0906	0	0	7674.40
4	193.879	86.32343	0	0	10254.03
5	180.729	0	0	0	5893.92
6	191.77	72.64643	0	200	9680.81
7	205.775	51.05751	0	0	9256.65
8	159.82	39.33063	0	0	6465.10
9	186.328	49.479	0	0	8163.10
10	146.998	0	22.997	0	4926.09
11	133.105	0	18.315	0	4246.79
12	129.469	87.19535	0	0	7341.50
13	166.666	94.38785	0	0	9312.51
14	203.331	94.08083	0	0	11150.51
15	158.7	0	0	0	4847.46
16	181.649	48.65749	19.663	200	8614.75
17	167.704	40.99767	0	0	6897.94
18	137.44	0	0	0	3929.59
19	185.216	0	0	0	6118.93
20	155.006	0	13.49	0	5074.54
21	204.864	55.26853	0	0	9388.94
22	168.746	20.22655	0	0	6142.85
23	148.983	75.99006	14.993	0	8025.11
24	156.455	0	0	0	4746.28
			Total Cost		**177103.8**

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APPENDICES

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