

## The significance of Unit Commitment on the IEEE Network Using an Improved Artificial Bee Colony Algorithm

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### ABSTRACT

This paper presents a Unit Commitment Problem (UCP) being one of the most difficult optimization tasks in power system and has the prospective of saving cost related to fuel and others constraints. The main objective of this research work is to solve UC problem using an improved Artificial Bee Colony Algorithm (iABC) in order to attain minimum operating cost while satisfying all the constraints over a period of time after proper scheduling of the generating units. The results obtained during the implementation of the hydrothermal unit commitment solution using the artificial bee colony and improved artificial bee colony were presented. The improved artificial bee colony is tested on the IEEE network and compared with other metaheuristic methods. A detailed analysis was carried out and the foremost results for the iABC parameters were obtained for the IEEE 10 generating units network. The outcome of the results from the IEEE 10 generating units test case shows that dynamic programming, particle Swarm, genetic algorithm, bacteria foraging, artificial bee colony and the improved artificial bee colony obtained had the following fuel cost of \$910,099, \$887,899, \$999,856, \$776,688, \$676,567, and \$600,123 respectively. iABC had the lowest cost and dynamic programming had the highest cost. This shows that iABC performed better than the remaining algorithms. Therefore, the improved artificial bee colony algorithm tested on the IEEE 10 generating units performed better than the conventional ABC and other meta-heuristic methods in the literature in terms of fuel cost minimization.

### ARTICLE INFO

#### Article History

Received: June 2023

Received in revised form: July, 2023

Accepted: September, 2023

Published online: September, 2023

### KEYWORDS

Unit commitment, IEEE Network, improved artificial bee colony algorithm, power system, and cost minimization

### INTRODUCTION

The unit commitment problem (UCP) is basically among the most critical and important problems in electrical power industry. UCP simply refers to the task of finding an optimal schedule and a production level for power system's each generating unit over a given time period, subject to a given load forecast and spinning reserve constraints. The goal behind UC problem is to balance demand with production while optimizing resources and costs [1]. In fact, the electricity markets are facing several challenges in different stages: generation, transmission and distribution.

The main and most challenging problems in electrical power systems are UCP, variation of consumer demand in electricity, environment problems related to use of fossil fuels, intermittence of renewable sources [1].

The classifications of UC problem are different. With respect to security, UC is divided into three categories: traditional UCP, security-constrained UCP (SCUCP) and price-based unit commitment (PBUC). From the market operation's perspective, UCP can be classified by either scheduling in a vertically integrated environment or in a deregulated environment.

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Compared to the treatment of future events, UC is separated into deterministic and stochastic UCP [2]. Unit Commitment (UC) is the problem of determining the schedule of generating units within a power system subject to device and operating constraints. The decision process selects units to be ON or OFF, the type of fuel, the power generation for each unit, the fuel mixture when applicable, and the reserve margins [3].

### REVIEW OF SIMILAR WORKS

This chapter present and illustrates the review of similar works on the published papers that are of significance to the proposed research work. However, the review of similar work presents the fundamental concepts that will facilitate better understanding of the basic concepts of an artificial bee colony algorithm while the problem formulation are hereby presented.

A review of different optimization techniques for solving single and multi-objective optimization problem in power system and mostly unit commitment problem were carried out. [4] shows that the application of different linear, non-linear and various meta-heuristic optimization methods in solving unit commitment problem, economic load dispatch, and related power system planning. The overall performance like reliability and accuracy can be improved with meta-heuristic optimization techniques like PSO, simulation annealing, hybrid GA and simulation annealing etc. The classical generation scheduling is solved with the insertion of the cost of demand response and the cost model pertaining to underestimation and overestimation of renewable energy penetrations. Each method is having its own advantages and disadvantages, namely most of the linear and non-linear analytical methods are easy to implement and has satisfactory accuracy with lower installing cost. But widely used for smaller systems and with single-objective. When large systems are considered, The PSO, ACO, SA, and differential evaluation methods are promising with a single objective and within a given time with acceptable accuracy.

In [5], a new UC model was introduced with embedded AC-PF constraints in the MILP formulation, in order to co-optimize real and reactive power scheduling within the main optimization problem, while complying with transmission capacity and voltage deviation limits. A six-bus and the IEEE RTS-79 test-systems were tested, confirming the suitability of the UC model to identify transmission bottlenecks and redispatch available generation. The differences in the AC-PF results, compared against DlgSILENT/Powerfactory, are considered reasonably small not to impact the eventual UC schedule. It was shown that equivalent AC-PF results can be extracted against UC models adopting entirely different and more complex AC-PF modeling concepts. However, for extreme operating conditions the accuracy of the AC-PF approximation gradually degrades, indicating that violation of the actual voltage and line capacity limits cannot be excluded.

[6] designed a novel approach that combines an improved binary PSO based on simulated annealing and convex optimization approach to solve the UC problems and corresponding ELD problems. This two-layer algorithm can solve the UCP and the corresponding ELD problem together. At the same time, with the introduction of the filter mechanism, each individual in the TLPSO has met the constraints before each iteration, thus improving the efficiency of the algorithm. Based on the heuristic algorithm and the interior point method, the iterative efficiency of each step is significantly improved. Combining with these characteristics, the proposed algorithm has also exhibited a very fast convergence rate and a fairly high quality result. The experimental results have also shown that TLPSO has the characteristics of fast convergence, high accuracy and strong robustness, and it is suitable for solving UCP.

[7] proposed a UCP model that uses two different ANN architectures and four different datasets, a sigmoid activation function, a fuzzification method, and a Taguchi method to estimate the effort and cost of software development. By monitoring the MMRE value

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and the convergence rate of each of these architectures, this model gives much better results compared to the previous two models. Based on the three performed parts of the experiment, it was concluded that the ANN-L16 architecture converges after the fourth iteration and gives an MMRE value of only 7.5%, which is 35.8% better than the first COCOMO2000 model. The error value of the UCP model is 21.3% lower than the other proposed COSMIC FP model.

In [8], fish migration optimization imitates the fish migration and easily solves the real-world optimization problems. According to the different transfer functions, its five algorithms are tested in 29 benchmark functions. The experiments show that the proposed transfer function majorly improves the performance of binary FMO. Comparing BFMO and ABFMO with BBA and BGWO, the results have been founded that BFMO and ABFMO have obvious advantages in solving quality. UC is a challenging problem and BFMO and ABFMO are used to solve UC. The numerical results on the IEEE benchmark units show that they find a low-cost UC scheduling solution in a short time and their performance is stable. They are robust and reliable optimization algorithms for solving UC problems

The Network Constraints Unit Commitment problem NCUC of a hybrid power system, which contains thermal units, a wind power plant, a photovoltaic and a PHES, has been studied in [9]. In order to solve this NCUC model, a novel binary artificial sheep algorithm, which mimics the social behavior, has been proposed. Impact of RE uncertainties on NCUC problem has been quantitatively analyzed by considering different RE power forecast error levels. Based on experiments on three typical cases, the following submissions are drawn: Firstly, It is seen that the BASA has achieve an overall competitive performance on terms of operation cost and convergence speed by comparing it with existing methods. Secondly, With increase of RE power forecasting error, the equivalent load fluctuation of the system will increase, and the economic performance of the power system will weaken. And lastly, The PHES can improve the stability and economy of

the power system and offset the negative impact of the uncertainty exerting on the RE integrated power system.

An efficient GAMS environment was successfully applied on PBUC problem with diverse constraints in [10]. The introduced GAMS software outperforms the results obtained in metaheuristic approaches in MATLAB environment in terms of accuracy, high efficiency and robustness. It can also be understood that for a system under study, GAMS produce the same solution at each run of the software whereas, after every run of the algorithm a metaheuristic approach results in a different solution. The simulation results of GAMS show a predominant approach for dealing PBUC problem in power sector.

[11] present a general idea of scheduling the generating units using the Bio-inspired algorithm PeSOA - Penguin Search Optimization Algorithm. PeSOA is a latest metaheuristic method through penguins collaborative hunting strategies, specially designed for optimizing non-linear systems. Significance of PeSOA is penguins Distribution is balanced through local minima and global minimum. Implementation carried out for various types of systems include problem instances of 10 units - 24 h system, 3 units – 24 h system, 4 units - 8 h system and 4 units – 24 h system, each of all the cases has better performance and convergence when compared with the results from the literature.

[12] presented a stochastic multi-objective unit commitment (SMOUC) problem integrating smart grid technologies (SGTs), i.e., PEVs, CBPR-based DRPs, CAES units and renewable DGs were proposed. The lexicographic optimization in combination with hybrid augmented weighted  $\epsilon$ -constraint method was implemented to generate Pareto optimal solutions. The best compromised solution was adopted, using a fuzzy method to simultaneously achieve minimum total expected operation cost and emission. Two studies were conducted in this paper, namely, study A and study B. In study A, a new MILP method was tested on different IEEE test systems for solving the conventional

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UC problem with and without considering ramp rates. The results from these tests were comparable with those found in the literature. In study B, in order to obtain global optimality, the MILP method was developed to solve the SMOUC problem. In this study, the individual and combined effects of renewable DGs, PEVs, CBPR-based DRPs and CAES unit on the proposed SMOUC problem were studied from economic, environmental and technical points of view in five cases. By comparing the results, it can be found that case 5 which includes all aforementioned SGTs is more proper than other cases for the ISO. In this case, collective effects of SGTs on the proposed SMOUC problem decreased the total expected operation cost, total expected emission, number of committed units, amount of energy consumption and peak to valley distance of load profile, and also increased the load factor.

[13] studied an important variant of unit commitment problem in which uncertain renewable energy resources, gas and electricity storage and Power to Gas (PtG) are taken into account in order to enhance the security of power generation and optimize its operational cost considering. Due to the complexity of the resulting problem, non-linear constraints of the gas network are not usually integrated into the electricity network and power operation problem. Ignoring the gas network in a power system with high renewable energy penetration significantly increases operation costs. Gas and electricity storage and Power to Gas were formulated to improve the reliability of power system and minimize the undesirable impact of uncertainty of renewable energy resources on short term power generation. The resulting problem belongs to a class of complex problems known as nonlinear non-convex mixed integer problems. The structure of the problem was employed with the application of applied decomposition and convexification techniques to reformulate and solve it. Interval Optimization which is a conservative, but practical approach is used to invoke the uncertainty of renewable energy generation. Using the aforementioned integrated problem, we found a better near optimal values

for key decision variables (including gas pressure in the network, line-pack level, the power generated by the gas fired unit plan, the level of gas and electricity storage and PtG) which was not achievable using existing methods for relatively large problems.

In [14], the performance of novel GBO algorithm on unit commitment problem is tested and observed that the GBO performance is competitive as compared to other state-of-art algorithms. For 4-unit system, best cost yielded by GBO is 74379 \$ which is less as compared to other algorithms. For 10-unit system, the best cost yielded by GBO is 559960\$ which is less as compared to other algorithms. Additionally, it is checked that GBO has obtained the best rank as compared to other algorithms. For large unit systems it is observed that GBO yields relatively better results. GBO has well balance between exploitation and exploration. Also, the probability of getting caught in local optima and early convergence is rare in GBO.

Furthermore, in [15] a GA-based metaheuristic approach has been proposed and successfully applied to solve SHTUC problem. To evaluate the performance of the proposed algorithm, it has been applied on IEEE 30 BUS System that consists of two hydro units and four thermal units, and results are presented. The effect of valve-point, water dynamic balance, and prohibited operating zones are also considered. The results obtained by the proposed method have been compared with other evolutionary algorithms like DA-PSO and GWO-PSO. It is found that a new GA algorithm i.e., adaptive genetic algorithm (AGA) can produce better results in terms of considering the key hydrothermal constraints, which is necessary to obtain a physically acceptable solution. Taking into account the high penetration of renewable energy in accordance with EU directives, as well as the fact that each system tends to gradually decommission thermal units, the proposed algorithm can be applied to a hydro-wind-solar system. This is due to the good structure of the algorithm. First, in the input structure, in addition to all the necessary input parameters, the column with renewables output power should be filled, for

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each interval (whose values in this paper are zero). The algorithm is modeled so that these power outputs reduces the daily load diagram, which in this case should be covered only by the hydro units. The same calculation continues, and the thermal units are assigned a commitment status of 0/1, thus neglecting all their operations (both in the binary-encoded GA and in the real-encoded GA for calculating the final dynamic ED) as in the algorithm itself, as well as in the proposed repair mechanisms, including the proposed constraint handling repair mechanism. On the other hand, the author performs further research and upgrades to the mathematical model of the proposed algorithm, in order to solve the N-1 SHTUC optimization problem. This means that the Power Transfer Distribution Factor (PTDF) will be implemented in the algorithm, taking into account the applied DC load flow model. This will enable solving the N-1 SHTUC, with different scenarios i.e., outage of each unit. This will be implemented in the real-coded GA, through the PTDF matrix that would provide new power flows through the transmission lines. Therefore, the proposed algorithm and the approach for its upgrade will enable obtaining a much more realistic and physically acceptable solution to the SHTUC optimization problem, which is necessary for optimal planning of the power system operation, from the aspect of its economy and reliability.

## METHODOLOGY

### A. Mathematical Formulation for the UC Problem

The aim of the unit commitment is to minimize the total fuel cost. The mathematical formulation for the unit commitment problem consists of the objective function and various constraints as listed below. The objective function of the UC problem is given by minimization the total operating cost (FN) as given in Eqn. (1).

$$\text{Min } FN = \sum_{j=1}^T \sum_{i=1}^{Ng} [u_{i,j} * f(p_{i,j}^g) + s_{i,j} * u_{i,j} * (1 - u_{i,j-1})] \quad \dots (1)$$

Where,

FN	Total operating cost
T	No. of intervals in horizon of planning
Ng	No. of Thermal generating units

Uij On/Off state of thermal generating station, 1 corresponds to ON and 0 corresponds to OFF

Pgij Generation of active power from unit (i) at time (j)

F(Pgij) Cost of fuel for unit (i) at time (j)

Sij Startup cost of thermal unit (i) at a time (j)

$$\text{Also, } f(p_{ij}^g) = a_i(p_{ij}^g)^2 + b_i(p_{ij}^g) + c_i \dots (2)$$

Where,  $a_i, b_i, c_i$  are fuel cost coefficient of thermal unit i.

The generator startup cost depends on the time that the unit has been off prior to start-up. It is given by;

$$s_{ij} = s_i^{hot} : MDT_i \leq T_{ij}^{off} \leq MDT_i + T_i^{cold} \quad \dots (3)$$

$$s_{ij} = s_i^{cold} : T_{ij}^{off} > MDT_i + T_i^{cold} \dots \dots (4)$$

where,

$s_i^{hot}$  Startup cost of thermal unit at hot condition

$s_i^{cold}$  Startup cost of thermal unit in cold condition

$T_i^{cold}$  Cold startup time for unit i.

$T_{ij}^{off}$  Time period required for unit i to continuously down till period j.

$MDT_i$  Minimum down time of thermal unit i.

A generic UC problem is subject to the following system and operating constraints;

### System power balance:

$$\sum_{i=1}^N U_i P_i(t) = P_d(t), \quad t = 1, 2, \dots, T \dots (5)$$

where,  $P_d(t)$  is the power demand at interval t.

### System Spinning reserve requirements:

$$\sum_{i=1}^N U_{it} P_{i(max)} \geq P_d(t) + R_t, \quad t = 1, 2, \dots, T \dots (6)$$

where,  $P_{i(max)}$  Maximum power generated by each unit i at any time 't' and  $R_t$  is the spinning reserve.

### Unit generation limits

$$P_{i(min)} \leq P_i(t) \leq P_{i(max)} \quad \text{when } U_{it} = 1$$

$$P_i(t) = 0 \quad \text{when } U_{it} = 0 \dots (7)$$

#### Unit minimum up/down time:

$$\begin{aligned} [X_{i(t-1)}^{on} - T_i^{on}] * [U_{i(t-1)} - U_{i(t)}] &\geq 0 \\ [X_{i(t-1)}^{off} - T_i^{off}] * [U_{i(t)} - U_{i(t-1)}] &\geq 0 \end{aligned} \quad \dots (8)$$

where,  $X_{i(t)}^{on}$  and  $X_{i(t)}^{off}$  are minimum on and off time of unit 'i' for time 't' respectively.

#### Ramp rate limit:

It gives ramping up and down capacity of the thermal unit.

$$\begin{aligned} P_{i(t)} - P_{i(t-1)} &\leq UR_i \\ P_{i(t-1)} - P_{i(t)} &\leq DR_i \end{aligned} \quad \dots (9)$$

#### UNIT INITIAL CONDITIONS

The initial status of each generator at the start of the scheduling period is taken into account.

### B. Improved Artificial Bee Colony Algorithm (iABC) Concept

#### i) Artificial Bee Colony (ABC) Overview

ABC is nature-inspired meta-heuristic, which imitates the foraging behavior of bees. It is as a stochastic technique is easy to implement, has fewer control parameters, and could easily be modified and hybridized with other meta-heuristic algorithms. Due to its successful implementation, several researchers in the optimization and artificial intelligence domains have adopted it to be the main focus of their research work. Interestingly, ABC has been tailored successfully, to solve a wide variety of discrete and continuous optimization problems. Some other works have modified and hybridized ABC to other algorithms, to further enhance the structure of its framework. A food source foraged by honeybees represents a feasible solution of the optimization problem, and the  $i^{th}$  food source is given by Eqn. (10):

$$X_i = (x_{i1}, x_{i2}, \dots, x_{iD}) \quad \dots(10)$$

Where, D is the dimension of the optimization problem [16]

#### ii) The Concept of an Improved Artificial Bee Colony Algorithm

ABC algorithm is an evolutionary optimization algorithm based on swarm

intelligence and inspired by the honey bees' food search behavior. Since the ABC algorithm has been developed to achieve optimal solutions by searching in the continuous search space, modification is required to apply this method to binary optimization problems. In this research, the ABC algorithm is improved and used to solve the Hydrothermal Unit Commitment problem for the Nigerian Power system. The proposed improved ABC (iABC) has an inertial weight is added on the first item which balances the local and the global searching processes. Furthermore, an additional random disturbance is added to basic ABC algorithm, which helps the algorithm continue to search in the later iteration stage and continually increases its accuracy. Also, in the iABC algorithm, the mutation and crossover operations of a Genetic algorithm are utilized to generate new solutions to improve exploitation capacity. Thus, we aim to prevent the ABC algorithm from getting stuck in a local minimum by increasing its exploration ability. We compare the iABC to the conventional ABC and other meta-heuristic algorithms in literature. Computational results showed that the proposed iABC method is superior to the conventional ABC and other methods in terms of convergence speed and robustness.

The algorithm for ABC method can be given as follows:

**Step 1:** Generation of randomly distributed initial population (P) and has (N) solutions. Each solution can be represented by D- dimensional vector. D represents number of optimization parameters and makes cycle counter equal to zero.

**Step 2:** Calculate the fitness value for every solution obtained.

**Step 3:** Employed bees generates new key in the neighborhood

$$V_{ij} = X_{ij} + (X_{ij} - X_{kj})X(rand - 0.5)X^2 \dots(11)$$

**Step 4:** Calculation of the fitness value, if the fitness value of the solution is better than the old one then the old solution will get replaced by new solution. If new solution is not better than old one, new solution will be abandoned.

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**Step 5:** Onlooker bees find a solution based on probability value  $P_i$ , given by Eqn. (12).

$$P_i = \frac{Fit_i}{\sum_{n=1}^{n_s} fit_n} \dots\dots 12)$$

where,  $Fit_i$  is the fitness value of the obtained solution and  $n_s$  is the number of solutions

**Step 6:** Generate another solution for the onlooker bees in the neighborhood using Eqn. (11).

**Step 7:** Find the abandoned solution for the

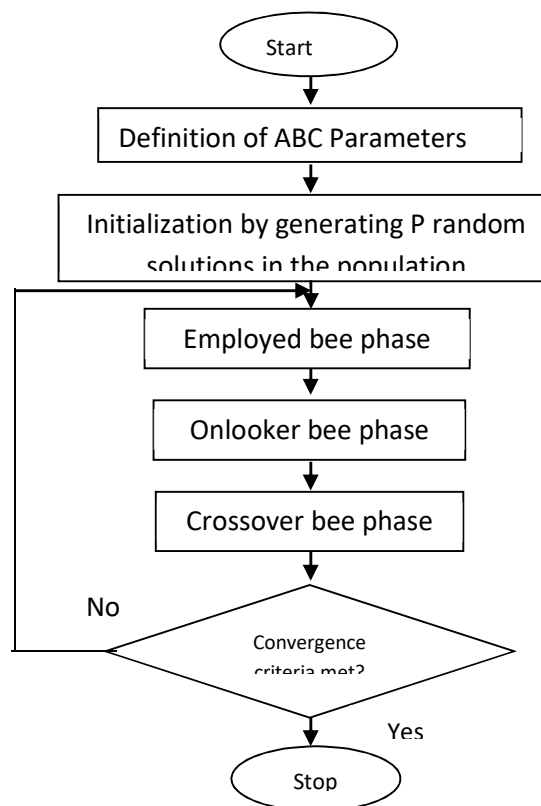
crossover phase, if possible and reinstate the newly found solution by using following Eqn. (13).

$$x_i = x_{min} + rand(x_{max} - x_{min}) \dots(13)$$

where,  $x_i$  is the abandoned source,  $x_{max}$  and  $x_{min}$  are maximum and minimum values of population-P.

**Step 8:** Increment count and do repetitive iteration till criteria are met [16].

The flow chart of an improved ABC algorithm is shown in Figure 1.



**Figure 1:** Flow chart of an improved Artificial Bee Colony Algorithm

## SIMULATION RESULTS AND DISCUSSION

This section shows the simulation results obtained for IEEE network with 10 generating units' when applying various method to solve the unit commitment problem. From the Table 1, it can be seen that dynamic Programming, particle Swarm, genetic algorithm, bacteria

foraging, artificial bee colony and the improved artificial bee colony obtained fuel cost of \$910,099, \$887,899, \$999,856, \$776,688, \$676,567, and \$600,123 respectively. Note that iABC returned the lowest cost and Dynamic programming had the highest cost. This shows that

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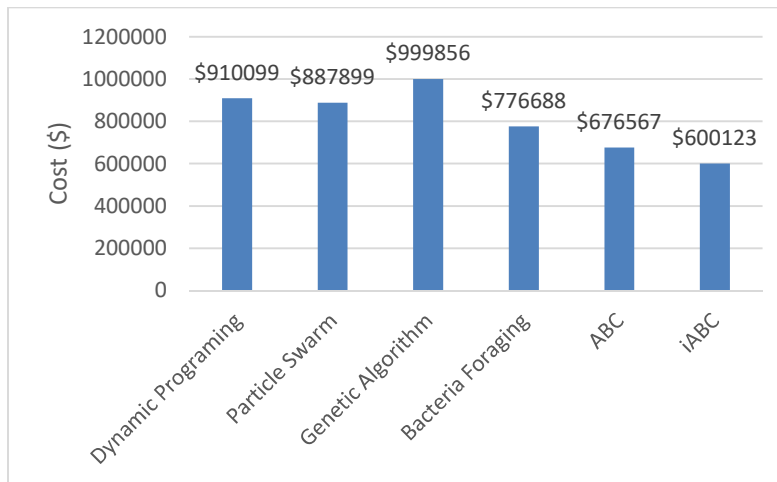
iABC performed better than the remaining algorithms.

**Table 1:** IEEE Network Unit Commitment

Method	Cost (\$)
Dynamic Programming	910,099
Particle Swarm	887,899
Genetic Algorithm	999,856
Bacteria Foraging	776,688
ABC	676,567
iABC	600,123

The comparison for the results obtained for IEEE network with 10 generating units' when applying various methods to solve

the unit commitment problem is shown in Figure 1.



**Figure 1:** Comparison of Unit Commitment from different Techniques using IEEE Test Network

Further more, the IEEE network unit commitment schedules obtained using ABC and iABC are shown in Tables 2 and 3 respectively.



**Table 2: Unit Commitment Schedule for IEEE Using ABC**

Period	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	No of Hours Committed
Unit 1	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	16
Unit 2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	24
Unit 3	0	0	0	0	0	1	1	1	1	1	1	0	0	0	0	0	0	1	1	1	1	1	1	1	14
Unit 4	0	0	0	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	1	1	1	1	0	0	14
Unit 5	1	1	1	1	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	0	0	16
Unit 6	1	1	1	1	0	0	0	0	0	0	1	1	1	1	1	0	0	0	0	1	1	1	1	1	14
Unit 7	1	1	1	1	0	0	0	1	1	1	1	1	1	1	1	0	0	0	0	0	1	1	1	1	16
Unit 8	0	0	1	1	0	0	0	1	1	1	1	1	1	1	0	0	0	0	0	0	1	1	1	1	13
Unit 9	0	0	1	0	0	0	0	0	1	1	1	1	1	1	0	0	0	0	0	0	1	1	1	0	10
Unit10	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	1	1	4

**Table 3: Unit Commitment Schedule for IEEE Using iABC**

Period	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	No of Hours Committed
Unit 1	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	16
Unit 2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	22
Unit 3	0	0	0	0	0	1	1	1	1	1	1	1	0	0	0	0	0	1	1	1	1	1	1	1	14
Unit 4	0	0	0	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	1	1	1	1	0	0	14
Unit 5	1	1	1	1	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	0	0	16
Unit 6	1	1	1	1	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	1	1	1	1	1	12
Unit 7	1	1	1	1	0	0	0	0	1	1	1	1	1	1	1	0	0	0	0	0	1	1	1	1	15
Unit 8	0	0	1	1	0	0	0	1	1	1	1	1	1	1	0	0	0	0	0	0	1	1	1	1	13
Unit 9	0	0	1	0	0	0	0	0	1	1	0	1	0	1	0	0	0	0	0	0	1	1	1	0	8
Unit 10	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	3

From Tables 2 and 3, Ten (10) units were considered such that each units committed are expected to meet the demand profile within an interval of 24 hours durations in a day. Whenever units are committed, it's represented by one (1) and whenever they are de-committed it's represented by zero (0) mainly for maintenance and cost savings purposes.

**CONCLUSIONS**

In this paper, the ABC algorithm has been improved and used to solve the Hydrothermal Unit Commitment problem for the Nigerian Power system. The proposed improved ABC (iABC) has an inertial weight is added on the first item which balances the local and the global searching processes. Furthermore, an additional random disturbance is added to basic ABC algorithm, which helps the algorithm

continue to search in the later iteration stage and continually increases its accuracy. Also, in the iABC algorithm, the mutation and crossover operations of a Genetic algorithm are utilized to generate new solutions to improve exploitation capacity. The effectiveness of the developed iABC is validated on the standard IEEE 33-bus radial distribution network and comparison with the conventional BFA, Analytical and Bat techniques. The results show that the proposed iABC method is superior to the conventional ABC in terms of convergence speed and robustness.

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Global Scientific Journal. Vol.9 Issue-9. Pp:  
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