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Application of an Improved Artificial Bee Colony Algorithm for Unit Commitment of the Nigerian Power System

Lawal, I. O., Aliyu, U. O., Haruna, Y. S. and Isa, A. I.

ismaheel4all@gmail.com, uoaliyu@yahoo.com, ysharuna@atbu.edu.ng, iiabdulkadir@atbu.edu.ng

Department of Electrical and Electronics Engineering
Faculty of Engineering and Engineering Technology
Abubakar Tafawa Balewa University, Bauchi

ABSTRACT
A new approach applying an improved artificial bee colony algorithm (iABC) was used for determining the optimal cost for a formulated unit commitment problem. The Unit Commitment Problem (UCP) is well known in the power industry and has the potential to save millions of Naira/Dollars per year in fuel and related costs. It is an area of production scheduling relates to the determination of the ON/OFF status of the generating units during each interval of the scheduling period to minimizing cost objective function subject to meeting system load and reserves requirements as well as variety of equipment operational limits and environmental constraints. The improved ABC technique was developed and implemented with respect to 25 generating stations feeding the Nigerian national grid as of 2016. The Nigeria generation system comprises of the existing generation stations of privatized power holding company of Nigeria (PPHCN), generating stations built by national integrated power projects (NIPP) and the generating stations belonging to independent power producers (IPP) resulting into 25 generating stations available and used to find the optimal commitment schedule. Simulation results was obtained for 25 Nigerian generating system which was presented and comprehensively discussed. The outcome of the results obtained for the Nigerian Power system applying ABC and iABC to solve the unit commitment problem during weekdays and weekends shows that iABC returned the lowest cost of ₦7,776,665 as compared with ₦9,988,767 for conventional ABC during weekdays and also that iABC returned the lowest cost of ₦6,770,112 as compared with ₦8,839, 001 for conventional ABC during weekends respectively. Therefore, the improved artificial bee colony performed better than the conventional ABC in terms of fuel cost minimization.
Keywords: Artificial Bee Colony Algorithm, Unit Commitment, Thermal generating units, Optimization

I. INTRODUCTION

Human activity follows cycles, most systems supplying services to a large population will experience cycles, this includes transportation systems, communication systems, as well as electric power systems. In the case of an electric power system, the total load on the system will generally be higher during the daytime and early evening when industrial loads are high; lights are on, and so forth and lower during the late evening and early morning when most of the population is asleep. In addition, the use of electric power has weekly cycles, the load being lower over weekend days than weekdays [1]. Continuous load demand variation and inability of electrical power storage force power system operators to schedule the utility generating units ON/OFF plans and optimize the output of generation units with minimum total cost while satisfying all technical and operational constraints as well as meeting the system load demand and reserve requirements [1].

The objective function to be minimized includes fixed and variable operating cost (Fuel), start-up cost and shut-down costs. Start-up costs of a thermal unit are modeled as a nonlinear function of the time the unit has been shut-down. The variable operating cost of a thermal unit is modeled as a nonlinear and non-differentiable function of its power output. The optimal start-up and shut-down planning schedule should meet several thermal unit constraints i.e. up and down ramp-rate limits, start-up and shut-down ramp limits, minimum up and minimum down times, minimum and maximum output capacity, crew availability etc. In every sub period of the planning period, the demand should be supplied and a spinning reserve constraint should be met [2].

II. RELATED WORK

This section presents the review of published papers relevant to the proposed research work. Thereafter, review of fundamental concepts that will enable the understanding of the basic aspects of firefly algorithm and the problem formulation is presented.

A new solution to the thermal unit-commitment (UC) problem based on an integer-coded genetic algorithm (GA) was presented in [3]. The GA chromosome consists of a sequence of alternating sign integer numbers representing the sequence of operation/reservation times of the generating units. The result shows that GA produced better results than the popular LR method that was used as a benchmark, while the execution time is reduced compared to binary GA implementations. However, the cost minimization objective was not addressed and treated.

A computationally efficient mixed-integer linear formulation for the unit commitment problem of thermal units was presented by [4]. The numerical results have revealed the accurate and computationally efficient performance of the new formulation and are used to solve the UC problem in traditional centralized power systems; it is straightforwardly applicable to the new scheduling problems arising in electricity markets. Here, cost implication factor was not extensively discussed and considered. The three versions of particle swarm optimization to solve unit comment problem was presented by [5]. Even though, all the proposed algorithms provide better numerical convergence, according to the numerical results, improved binary PSO is better algorithm than binary PSO for unit commitment problem. The results further showed that LR-PSO does not provide the best results for small sized system and it gives the best result for large sized systems. The setback is that the proposed PSO algorithms should have been extended to solve new profit-based unit commitment problem under the competitive environment.

The authors in [6] proposed a novel approach for determining UC and generation cost by considering prohibited operating zones using Fireworks Algorithm (FWA). The FWA algorithm was used to find the combination and the same was used to solve economic dispatch problem where we found the level of generation of each generator which are ON. This method shows that there is no need to use the penalty functions method as the minimum up and down-time constraints have been considered during generating the feasible solutions in the UC problem. Out of many other generation and operating constraints, only the prohibited operating zone was only considered.

Reference [7] proposed a novel algorithm for solving the non-linear, highly-constrained, mixed-integer, NP-hard unit commitment problem through hybridization of GA and DE known as hGADE. The proposed hGADE algorithm is simple to understand and implement as the hybridization is implemented just in the variation operation in which the binary variables are evolved using GA operators while the continuous variables are evolved using DE operators. The two hGADE variants were found to be efficient on a range of test systems in achieving superior best cost solution when extensively compared with the other published approaches in the literature. Finally, an ensemble optimizer based on combination of the two hGADE variants was found to further amplify the performance of hGADE algorithm and the resulting algorithm, Enh-hGADE significantly outperformed all the benchmark algorithms in terms of best cost, average cost and worst cost metric. For future work, the neglected ramp up/down constraints should be given consideration and thought.

A new ABC (*DisABC*) algorithm was successfully implemented in [8] to solve the UCP for a two thermal generating systems comprising of 5-units and 26-units and lambda-iteration technique is used to solve the ED sub-problem in each hour of the scheduling time intervals of 24 hours. Based on the *DisABC* algorithm, a new strategy has been proposed for generating the new binary solutions which uses a measure of dissimilarity between binary solutions and thus incorporated the new difference equation. The simulation results clearly reveal that *DisABC* algorithm has shown better performance in minimizing the total operating cost without any constraint violation and thus shows the superiority of the proposed algorithm for UCP. However, the convergence behavior was slow and the execution time is much compared to other algorithms in the literature.

Application of logical state PSO particle swarm optimization algorithm for solving the problem of UC was proposed in [9]. The problem of UC being a challenging problem requires algorithms that could effectively produce best results in terms of production cost and start-up cost. The PSO algorithm has comparable or superior search performance for some complex problems like UC in real power systems with improved convergence and increased diversity. The simulation results indicate that this optimization method is very accurate than the other methods. Furthermore, the convergence behavior and cost implication factor could be improved upon in subsequent works.

A new priority list unit commitment method for large-scale power systems was developed by [10]. The proposed method is based on fragmentation of the UC problem into three sub-problems; priority list evaluation of the generation units, unit status calculation and economic dispatch and cost calculation of the scheduled units. For validation of the proposed technique, the results obtained are compared with other solving technique presented in previous relevant published literature. The results obtained shows the efficiency and accuracy of the proposed technique in term of execution time and total cost which later demonstrate and affirm the efficiently and reliability of the proposed technique for large-scale UC problem solution but reserve margin requirement was given lesser attention in this method.

The authors in [11] proposed a novel multiagent fuzzy reinforcement learning (MAFRL) approach for solving the unit commitment problem. In the proposed approach, we view each generator as a player in multiagent RL scenario to discover optimal generation schedule on an hourly basis for minimizing the fuel cost. It is observed that the total operational cost obtained through MAFRL approach is higher than through the other methods reported in the literature. A new approach of PSO based with an hybrid micro-grid system in solving the UC problem was invented in [12]. The strategy has been found that the algorithm used is an optimizer to UC problem such that microgrid with renewable sources has the reduced cost when compared to the microgrid without renewable sources (conventional generators). Despite the cost reduction achievement, the execution time and the convergence behavior are a thing of consideration for future works. The authors in [13] presented the first time ever an artificial bee colony (ABC) search is applied for thermal unit commitment. The proposed algorithm is implemented for the standard ten units system. From the result obtained it is observed that optimization cost is slightly higher than the teaching learning-based optimization technique. More so, the cost minimization objective was not realized while some generation constraints were not considered.

An improved binary artificial _fish swarm algorithm (IBAFSA) and a fast constraint processing mechanism were presented in [14] to solve the UC problems of large-scale power systems, it can be concluded that, the convergence performance and global optimization ability of the proposed IBAFSA are better than those of the standard one and has better performance over BDE and QI-ADP in solving large-scale UC problems. The proposed fast constraints processing mechanism can handle the coupling problem between system spinning reserve constraint and unit minimum up and down time constraint, which plays a significant role in speeding up the UC solutions. The experimental results indicate that the proposed method is of attractive superiority in both solving accuracy and computing time, and is a general method to adapt to the changes of the objective function and constraints of a UC optimization, which has good application prospect. However, he failed to take into account the generation uncertainty of new energy resource units into UC models and making the practical application of IBAFSA to a real large-scale power system.

The author in [15] proposed a new methodological solution of solving security constrained 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 optimized 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. However, the execution time is a major setback suffered in this algorithm.

III. 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 below;

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

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)

$$f\left(P_{ij}^{g}\right) = a_i\left(p_{ij}^{g}\right)^2 + b_i\left(p_{ij}^{g}\right) + c_i \quad \dots (2)$$

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;

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

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

where,

sc_i^{hot} Startup cost of thermal unit at hot condition

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

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

System Spinning reserve requirements: $\sum_{i=1}^{N} U_{it} P_{i(\max)} \ge P_d(t) + R_t, \; t = 1,2, \dots . T$ … (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

$$P_{i(min)} \le P_i(t) \le P_{i(max)} \text{ when } U_{it} = 1 \; P_i(t) = 0 \text{ when } U_{it} = 0 \quad \dots (7)$$

Unit minimum up/down time:

$$\left[X_{i(t-1)}^{on} - T_i^{on}\right] * \left[U_{i(t-1)} - U_{i(t)}\right] \ge 0$$

$$\left[X_{i(t-1)}^{\text{off}} - T_i^{\text{off}}\right] * \left[U_{i(t)} - U_{i(t-1)}\right] \ge 0 \quad \dots (8)$$

where, $X_{i(t)}^{on}$ and $X_{i(t)}^{\text{off}}$ 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.

$$P_{i(t)} - P_{i(t-1)} \le UR_i$$

$$P_{i(t-1)} - P_{i(t)} \le DR_i \quad \dots (9)$$

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.

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

$$V_{ij} = X_{ij} + \left(X_{ij} - X_{kj}\right)X(rand - 0.5)X^2 \quad \ldots(11)$$

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

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

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).

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

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

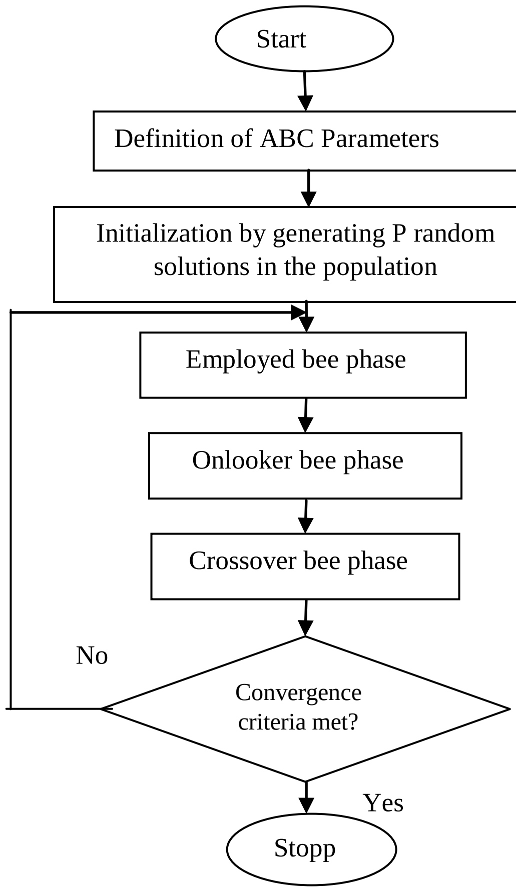

Figure 1: Flow chart of an improved Artificial Bee Colony Algorithm

IV. SIMULATION RESULTS AND DISCUSSION

In this section, the results obtained during the implementation of the hydrothermal unit commitment solution using the artificial bee colony and the improved artificial bee colony are presented. The improved artificial bee colony is tested on the Nigerian power system. Results are presented in tables and graphs. The results obtained for the Nigerian power system using ABC and iABC is presented. The cost of unit commitments for weekdays and weekends, number of hours each unit are run, their comparison are highlighted and the schedules for weekdays and weekends using the conventional ABC and the improved ABC are presented. Table 1 shows the results obtained for Nigerian Power system applying ABC and iABC to solve the unit commitment problem during weekdays.

Table 1: Unit Commitment Comparison for Weekdays in Naira

Method	Cost (₦)	Savings
ABC	9,989,865	
iABC	8,988,857	**1,001,008**

From Table 1, it can be seen that iABC returned the lowest cost of ₦8,988,857 as compared with ₦9,989,865 for conventional ABC. Therefore, the improved artificial bee colony performed better than the conventional ABC for weekdays. Table 2 shows the results obtained from Nigerian Power system applying ABC and iABC to solve the unit commitment problem during weekends.

Table 2: Unit Commitment Comparison for Weekends in Naira

Method	Cost (₦)	**Savings**
ABC	8,988, 767	
iABC	6,776,665	**2,212,102**

From Table 2, it can be seen that iABC returned the lowest cost of ₦6,776,665as compared with ₦8,988, 767 for conventional ABC. Therefore, the improved artificial bee colony also performed better than the conventional ABC for weekends. The unit commitment schedules obtained using the iABC for weekdays and weekends are shown in Tables 3 and 4.

Table 3: Unit Commitment Schedules using improved ABC for Weekdays

Stations/Hr	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 Hours Commited
Delta	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	11
Sapele	1	1	1	1	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	14
Afaml-V	1	1	1	1	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	17
Egbint	1	1	1	1	1	1	1	1	1	1	1	0	0	1	1	1	1	1	1	1	0	0	0	0	18
Egbin AES	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	20
Ibom Power	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	23
Olorunsogo-I	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	19
Olorunsogo-II	0	1	1	1	1	1	1	1	0	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	13
Afam-VI	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
Omotosho gas	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
okpai agip	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	22
Geregu gas	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	1	1	1	15
Kainji	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	1	1	1	1	1	1	19
Jebba	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	1	1	1	0	0	1	1	1	19
Shiroro	1	1	0	0	1	1	1	1	1	1	0	0	0	1	0	0	1	1	1	1	0	0	0	0	13
Omoku	1	1	1	1	1	1	1	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	21
Trans Amadi	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	0	0	21
Ajaokuta	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	0	0	0	0	0	18
Omotosho	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	6
Sapele NIPP	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	5
Odukpani	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	7
Alaoji	1	1	0	0	0	0	1	1	1	1	1	1	1	1	1	0	0	0	0	0	1	1	1	1	15
Ihovbor	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	1	1	1	1	1	16
Asco	1	1	1	0	0	0	1	1	1	1	1	1	1	0	0	0	0	0	0	1	1	1	1	1	15
Rivers IPP	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	1	1	1	1	1	17
Units/Hr	17	17	17	17	18	17	19	20	19	18	20	19	18	17	16	14	16	16	17	17	16	16	14	15	410
GEN/HR	4937	5033	4819	5029	4767	4574	4793	5661	5299	5871	5486	4762	4715	4796	4313	4040	4995	4995	5382	4525	3049	3394	3560	3566	

Table 4: Unit Commitment Schedules using improved ABC for Weekends

Stations/Hr	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 Hours Commited
Delta	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	9
Sapele	0	1	1	1	1	1	1	1	1	0	0	0	1	1	1	1	1	1	1	1	0	0	0	0	16
Afaml-V	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	20
Egbint	1	1	1	1	1	1	1	0	0	0	0	0	0	1	1	1	1	1	1	1	0	0	0	0	14
Egbin AES	0	0	0	0	1	1	1	1	1	1	1	0	0	0	1	1	1	1	1	0	0	1	1	1	15
Ibom Power	0	0	0	0	0	1	1	1	1	1	1	1	1	0	0	0	0	0	1	1	1	1	1	1	14
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Olorunsogo-II	0	1	1	1	1	1	1	1	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	10
Afam-VI	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	21
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Jebba	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	1	1	0	0	1	1	13
Shiroro	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	5
Omoku	0	0	0	1	1	1	1	1	1	0	0	0	0	0	0	0	1	1	1	1	1	1	0	0	12
Trans Amadi	0	0	0	1	1	1	1	1	1	0	0	1	1	0	0	0	0	0	1	1	1	1	1	0	13
Ajaokuta	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Omotosho	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
Sapele NIPP	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
Odukpani	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	5
Alaoji	1	0	0	0	0	0	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	1	1	12
Ihovbor	1	1	1	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	0	0	1	1	1	1	13
Asco	1	1	0	0	0	0	0	0	1	1	1	1	1	0	0	0	0	0	0	0	0	0	1	1	9
Rivers IPP	1	1	1	0	0	0	0	0	0	0	0	1	1	1	1	1	0	0	0	1	1	1	1	1	13
Units/Hr	14	13	12	13	15	14	15	15	14	11	12	13	14	10	10	9	8	9	11	11	12	14	17	15	301
GEN/HR	3782	4186	4348	4397	4533	4707	4901	4628	3424	3091	3326	3266	3266	2518	3018	2980	2520	2788	3286	3384	2835	3454	4294	3832	

Keys: Units/Hr-Units committed per Hour **GEN/Hr**- Generations (MW) per Hour

From Tables 3 and 4, Twenty-five (25) stations with their respective units were considered such that each station's 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 decommitted it's represented by zero (0) mainly for maintenance and cost savings purposes.

V. 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 improved ABC algorithm has been demonstrated on the Nigerian 330 kV grid system. From the simulation results obtained for the Nigerian Power system, iABC returned the lowest cost of ₦8,988,857 as compared with ₦9,989,865 for conventional ABC during weekdays with savings of ₦1,001,008. For weekends, iABC also returned the lowest cost of ₦6,776,665 as compared with ₦8,988,767 for the conventional ABC with a savings of ₦2,212,102. 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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