WWJMRD 2021; 7(6): 25-29
www.wwjmrd.com
International Journal
Peer Reviewed Journal
Refereed Journal
Indexed Journal
Impact Factor SJIF 2017: 5.182 2018: 5.51, (ISI) 2020-2021: 1.361
E-ISSN: 2454-6615 1
DOI:10.17605/OSF.IO/RYXWE

Load Frequency Control Strategy for the Nigerian Power System Using artificial Bee Colony optimized PI Controller.

Gana A. H., Amoo A. L., Bakare G. A. and Echo A. A.

Gana A. H.
Department of Electrical and Electronics Engineering
AbubakarTafawaBalewa University, Bauchi, Nigeria.

Amoo A. L.
Department of Electrical and Electronics Engineering
AbubakarTafawaBalewa University, Bauchi, Nigeria.

Bakare G. A.
Department of Electrical and Electronics Engineering
AbubakarTafawaBalewa University, Bauchi, Nigeria.

Echo, A. A.
Department of Electrical and Electronics Engineering,
Benue State Polytechnic,
UgboKolo, Benue, Nigeria
.

Abstract

Power system frequency fluctuations which usually result from continuous change in the load on a power system can have adverse effect on both consumer and industrial loads, this is because the speed of the prime mover reduces when load is increased and the fuel intake is kept constant also when the fuel intake increases and the load is maintained, the speed increases. The speed of the prime mover is responsible for the frequency of the system. In an attempt to solve this mismatch, several researchers developed various methods such as the fuzzy logic controller, artificial neural network and genetic algorithm tuned controller. In this work, a PI controller whose parameters were optimized using the artificial bee colony algorithm was used in load frequency control of the Nigerian interconnected power system. The frequency deviation was restored to a tolerable range (± 0.5 Hz) within 5 seconds and the area control error was stabilized to within 0.1p.u when a disturbance of 10 % was introduced to the system.

Keywords: Artificial Bee Colony Algorithm, Load Frequency, Frequency Deviation

Introduction

In the operation of a power system, the demand for power by various consumers changes with time, this makes the load on the power system vary. When the load increases and the fuel intake is kept constant, the speed of the prime mover drops and so does the frequency of the system and similarly when the load reduces and the fuel intake is kept constant, the speed of the prime mover increases and consequently the frequency also increase [1, 2, 3]. These fluctuations in frequency could have adverse effect on the machines connected to the system because they are designed to operate on a stated frequency. The effort to maintain the system frequency within a stated value is regarded as Load Frequency Control (LFC).

To maintain the frequency of the system when the Load on the system increases, the valve opening through which the fuel is fed should also increase. This is to enable the prime mover to increase its torque to handle the required demand [4, 5]. The entire process described above must be done very quickly for reliable and quality supply of power as the operation of some machines under the wrong frequency can result in damage of the machines and failure of the system.

Therefore, a controller is required to track and detect load change and give command to regulate the valve operations which in turn stabilizes the speed of the prime mover and the system frequency at large.

Literature Review

Many approaches for load frequency control of interconnected power systems have been attempted and several control algorithms have been proposed by various researchers over the years. This extensive research can be attributed to the fact that LFC constitutes a very important function of the modern power system operation where the main objective is to regulate the output power of individual generators at the stated operating value while keeping the frequency fluctuations within acceptable limits [6].

Correspondence:
Gana A. H.
Department of Electrical and Electronics Engineering
AbubakarTafawaBalewa University, Bauchi, Nigeria.

Review of Pertinent Literature

Ref. [7] proposed Particle Swarm Optimization (PSO) technique for AGC of two-area interconnected power system. They used the conventional PI controller for AGC before applying the PSO based controller for the power system. They were able to record a smaller settling time and overshoot and they concluded that the PSO based controller gave a better response than the conventional controller for that system.

Ref. [8] conducted a study on a two-area hydrothermal power system, they designed an Artificial Neural Network based Narma L-2 controller and compared the performance of their controller with that of a conventional controller under a step load change, they found the response of their controller better than that of the conventional controller with respect to the error magnitude and frequency transients was minimized. Many other studies have been carried out using the artificial neural networks (ANN), fuzzy logic control (FLC) and genetic algorithm (GA) for load frequency control in power systems [6]. The problem is persistent as the settling times with these controllers and approaches are still not good enough. This work therefore will utilize a PI controller tuned with Artificial Bee Colony algorithm to achieve Load frequency control with better settling time, lower overshoot and error magnitude.

Concept of Artificial Bee Colony

Nature-Inspired Algorithms are motivated by a variety of biological and natural processes. The nature-inspired Algorithms have gain popularity owing to the inherent quality of biological systems to adapt to any kind of changing environment [1, 7]. Evolutionary computation, neural networks, ant colony optimization, particle swarm optimization and bacterial foraging algorithm are all algorithms and concepts that were motivated by nature. [1, 7]

Artificial bee colony (ABC) algorithm is a recently introduced technique for optimization which feigns the intelligent foraging behavior of honeybees. A set of honeybees is referred to as swarm which can successfully accomplish tasks through social cooperation.

In the period 1999-2003, the basic concepts of Bee Colony Optimization were introduced under the name Bee System, by DŭsanTeodorovĭc (adviser) and Panta Lučić (Ph.D. candidate) while doing research at Virginia Tech. BCO is a nature–inspired meta–heuristic method developed for efficiently finding solutions to difficult combinatorial optimization problems.

The basic idea behind BCO is to build the multi agent system (colony of artificial bees) that will search for good solutions of various combinatorial optimization problems, exploring the principles used by honeybees during nectar collection process. Artificial bee colony algorithm's principle is gathered and generated from the natural systems. This algorithm investigates through the search space looking for feasible solutions. In order to locate the best possible solutions, independent artificial bees operate in collaboration and exchange information. Using collective knowledge and information sharing, artificial bees concentrate on the more promising areas and slowly abandon solutions from the less auspicious ones. Step by step, artificial bees collectively generate and/or improve their solutions. The BCO search is running in iterations until some predefined stopping criterion is satisfied [9].

The ABC generates some initial population of SN solutions (food sources) which are randomly where SN denotes the swarm size.

Let $X_i = \{x_{i1}, x_{i2}, x_{i3}, \dots \dots x_{iD}\}$ represent the i^{th} solution in the swarm, where D is the dimension size. Each employed bee X_i generates a new candidate solution V_i in the neighborhood of its present position as follows:

$$v_{i,j} = x_{i,j} + \emptyset_{i,j} \cdot (x_{i,j} - x_{k,j}), \tag{1}$$

Where X_k is the randomly selected candidate solution $(i \neq K)$, j is a random dimension index selected from the set {1,2,……D}, and $\emptyset_{i,j}$is a random number within [-1, 1]. Once the new candidate solution V_i is generated, a greedy selection is used. If the fitness value of V_i is better than that of its parent Xi, then update Xi with Vi; otherwise keep Xi unchangeable.

After all employed bees have finished the search process they share information of their findings with onlookers by a demonstration referred to as waggle dance. An onlooker makes evaluation of the nectar communicated to it by all the employed bees and makes its selection of a food source with a probability related to its nectar amount. This entire selection, involving probability, is really a roulette wheel selection mechanism which is described equation (2)

$$P_i = \frac{fit_i}{\sum_{j=1}^{SN} fit_j}, \tag{2}$$

where fit_i is the fitness value of the i^{th} solution in the swarm. As seen, the better the solution *i*, the better the chance of probability of the i^{th} food source selection. If a position cannot be improved over a predefined number (called *limit*) of cycles, then the food source is abandoned. Assume that the abandoned source is X_i, then the scout bee discovers a new food source to be replaced with X_i as follows in Eqn. (3):

$$x_{i,j} = lb_j + rand(0,1) \cdot (ub_j - lb_j) \tag{3}$$

where rand(0, 1) is a random number within [0, 1] based on a normal distribution and *lb*, *ub*are lower and upper boundaries of the j^{th} dimension, respectively.

Methodology

The data required for this work includes the list of Power plants in the country mentioning their capacities and constants which were used for the development of the interconnected power system transfer function.

Also, the transfer function of a PI controller was incorporated into the model to suitably modify the characteristics of the interconnected power system in order to achieve automatic generation control with good stability, reliability and economy.

Problem Formulation

An objective function J of the integral of time multiplied by absolute error (ITAE)

$$J = \int_0^t \{t\ [|\Delta f_1| + |\Delta f_2| + |\Delta P_{tie}|]\} dt$$

Subject to the gain constraints: $K_i^{min} \leq K_i \leq K_i^{max}$ is minimized for obtaining optimum values of PI controller using artificial bee colony algorithm for a step load disturbance in one of the interconnected areas. The structure for the PI controller with the Parallel algorithm, shown in Fig. 1 used to achieve the solution is in Eqn. (3);

$$u(t) = K_p e(t) + K_i \int_0^t e\tau d\tau$$

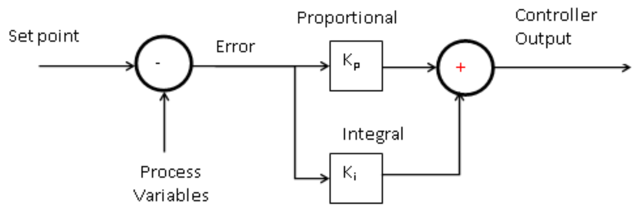

Fig 1: PI Controller configuration

Where:
K_p = Proportional Gain, K_i = Integral Gain, e(t) = r(t) – y(t)

Load Frequency Control Strategy

The desire is to design a control system with fast response and good stability. Unfortunately, it is not practically possible to achieve both desires simultaneously because they are mutually exclusive. Therefore, an acceptable compromise was sought in Ref. [11], Zarighavar et al. PI controller is efficient and is applied in this paper and its parameters (K_p and K_i) were tuned using the ABC Algorithm. Fig. 2 shows the ABC tuning strategy.

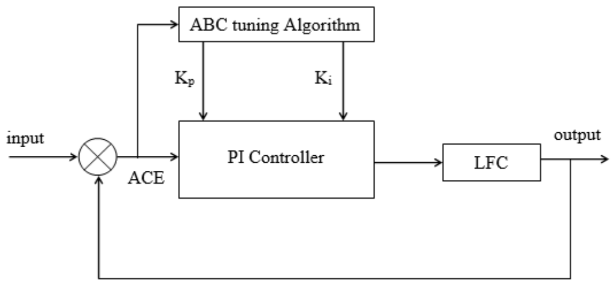

Fig. 2: ABC tuned PI Controller.

The ABC optimized controller was applied for load frequency control and the system is investigated as in Fig. 3. The parameters of the power system are adopted in [1]: Tτ1 = 0.3s, Tτ2 = 0.3s, Tg1 = 0.08s, Tg2 = 0.08s, Tp1 = 20s, Tp2 = 20s, B1 = 1, B2 = 1, R1 = 2.4 Hz p.u MW^{-1}, R2 = 2.4 Hz p.u MW^{-1}, P = 0.545.

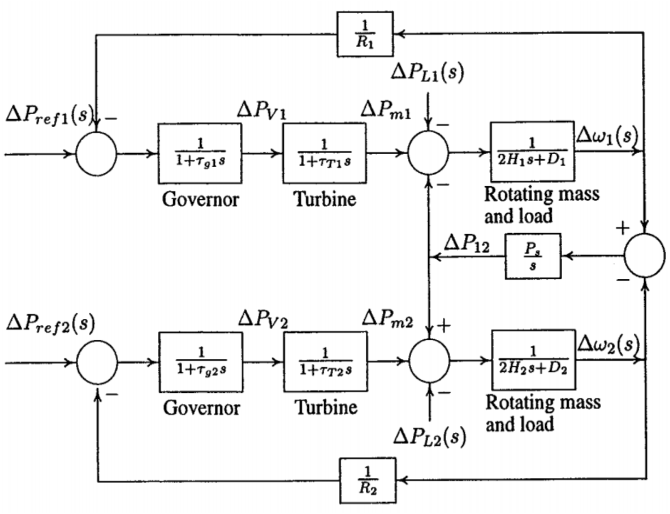

Fig 3: Block Diagram of Two-Area Interconnected System

Therefore, if two areas are interconnected, algebraic sum of the tie line power is zero. In other words, if area 1 delivers power, same amount is received by area 2 and vice versa.

Realization of Artificial Bee Colony Algorithm based LFC

The steps involved in realization of ABC based LFC strategy is described as follows and shown in flow chart of Figure 4:

Step 1: At the initialization stage, all relevant parameters for artificial bee colony were defined and all relevant power system parameters required for the modeling and computation were actualized from the database.

Step 2: Randomly generates initial population also called food sources of the P and I which denotes the swarm size.

Step 3: Compute the objective function and obtain candidate solutions and test its fitness value using a greedy selection.

Step 4: Employ bees share the information with onlooker bees through waggle dance who evaluates and chooses the better information (nectar amount)

Step 5: With the nectar amounts selected and if a food source isn't improved after certain cycles (called limits) it is abandoned and replaced else this step is made a loop which is done for iteration counts below the preset value.

Step 6: Check for convergence and if converge go to step seven (7), otherwise go to step 4

Step 7: Print the optimum values of P and I for each area.

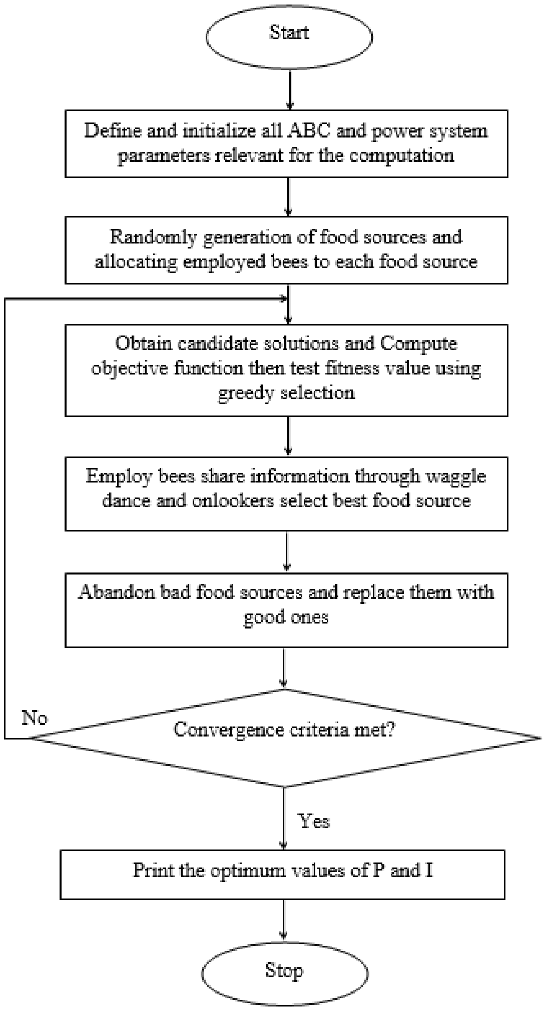

Fig. 4: Flow Chart for Realization of ABC for LFC

Results and Discussion

The two-area power system presented in Fig. 3 was considered for analysis. It was simulated and the dynamic responses are obtained with a 1% load change in area 1. The plots of frequency deviation and tie line power for the conventional controller is presented first in Fig 5 through Fig. 7 and that of the ABC optimized controller is presented later in Fig. 8 through Fig. 10.

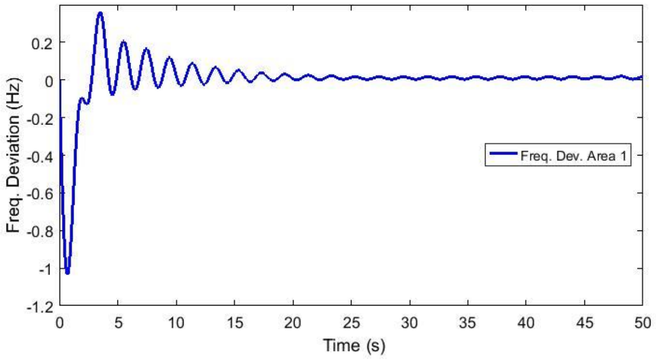

Fig. 5: Frequency Deviation for Area 1.

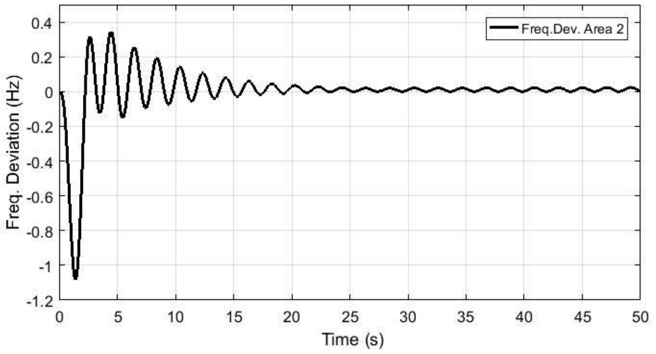

Fig. 6: Frequency Deviation for Area 2.

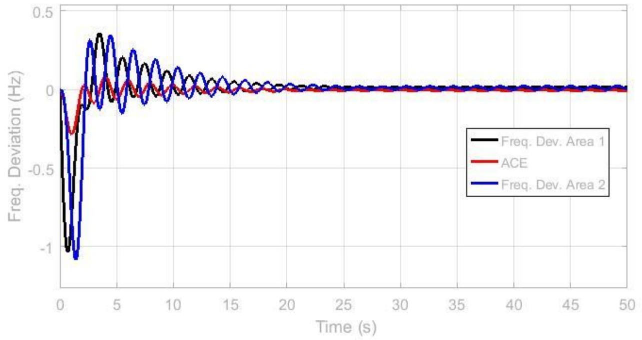

Fig. 7: Area Control Error and Freq. Deviations.

As can be seen in Fig. 3 through 5, the plot of Frequency deviations in areas 1 & 2, the frequency deviations were beyond the allowable operating range (±0.5 Hz) and the settling time is long. The quality after the transient state is still containing ripples which is an indication that the system is still unstable.

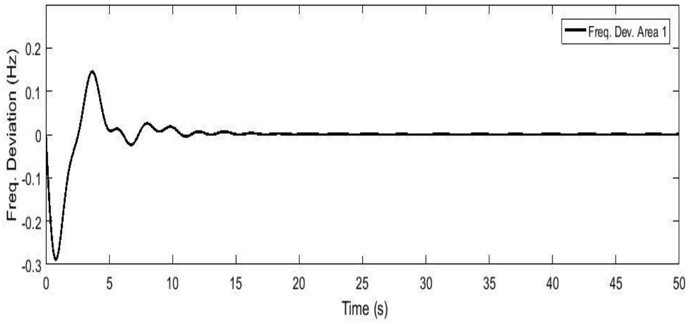

Fig. 8: Freq. Deviation in Area 1.

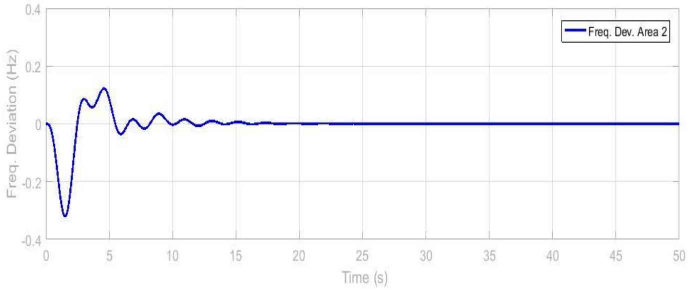

Fig. 9: Freq. Deviation in Area 2.

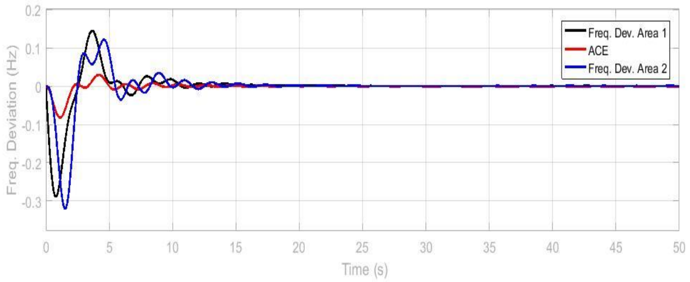

Fig. 10: Freq. Deviations and Tie-Line Power.

In Fig. 8 through 10, the plots of frequency deviation using the ABC optimized controller are presented. It can be observed that unlike the plots in Figs. 5 to 7 of the conventional controller, the frequency deviation is reduced to a tolerable range of (± 0.5 Hz), the settling time is also reduced and the area control error is reduced drastically therefore the system has better stability, there was a 75.4% and 77.7% improvement in overshoot for areas 1 and 2 respectively, 53.3% and 64.9% improvement in settling time for areas 1 and 2 respectively and a 91.6 % improvement in steady state error for both areas. This shows that the ABC optimized PI controller is good for Load Frequency Control in the considered power system.

Summary and Conclusion

Plenty uncertainties are associated with the operation of interconnected networks owing to the fact that they are usually not necessarily the same size, type and they face different non-linearities. The aim of this work has been to proffer a load frequency control strategy for Nigerian power system using artificial bee colony optimized PI controller this made it necessary to consider the problems faced by the interconnected power system and design a controller that will maintain system parameters at nominal values within a short duration and little spike which in turn has ensured improvement in the quality and reliability of the power supplied to consumers.

The proposed controller was evaluated and load frequency control with ABC tuned PI gave the best strategy to improve system reliability, integrity and quality of supply, the controller reduces the steady state error and the frequency deviation zeniths and the settling time has been significantly reduced which in turn has improved the overall system performance.

In conclusion, the proposed controller has shown a superior performance to that of a conventional PI controller as seen in the simulation results.It is efficient, robust and fast and hence it has achieved to a great extent the aim of this paper.

References

1. Sudheer Kumar, K. & Prasad, A. Load frequency Control of Hydro-Thermal and Nuclear interconnected Power System using Fuzzy and ANN controllers. *International Journal of Science, Engineering and Technology*. ISSN: 2348-4098.
2. Firdous, S. and Mohammed, A. R. U. (2015). Load Frequency Control Techniques. *International Journal of Science, Engineering and Technology Research (IJSETR)*. Volume 4, Issue 8. ISSN: 2278-7798. PP2887-2893.
3. Kalyani, P. P. &Bhavesh, G. T. (2016). Automatic Generation Control Using Artificial Neural Network Based Narma L-2 Controller. *International Journal of Engineering Science and Computing*. Volume 6, issue 4. ISSN: 2321-3361. Pp3623-3627.
4. Priyanka, S. (2014). Narma-L2 Controller for Five-Area Load Frequency Control. *Indonesian Journal of Electrical Engineering and Informatics (IJEEI)*. Vol. 2, No.4. ISSN: 2089-3272. Pp. 170-179.
5. Chidambaram, I. A. & Francis, R. (2011). Automatic Generation Control of a Two Area Reheat Interconnected System based on CPS using Fuzzy Neural Network. Emerging Trends in Electrical and Computer Technology (ICETECT). Pp. 200-205.
6. Inyanda, A. K., Bakare, G. A. &Kunduli, M. (2009). Differential Evolution Based Optimal Tuning of Load Frequency Controller. Trans Tech Publications, Switzerland. Pp 82 – 88.
7. Kapil, G. and Jaspreet, K. (2014). Particle Swarm Optimization Based Automatic Generation Control of Two Area Interconnected Power System. *International Journal of Scientific and Research Publications*.**4**(1). ISSN:2250-3153. 1-8.
8. Patil, K. P. &Tandel, B. G. (2016) Automatic Generation Control Using Artificial Neural Network Based Narma L-2 Controller. *International Journal of Engineering Science and Computing*, **6**(4). pp 3623 – 3627.
9. Lucic, P, and Teodorovic, D., (2001). Bee System: ModellingCombinatorial optimization transportation engineering problems by swarm intelligence. Preprints of the TRISTANIV Triennial Symposium on Transportation analysis, Aao Miguel, Azores Islands, pp.441 – 445.