Cascaded Swarm Intelligence Algorithm for Automated Power Flow Studies

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Abstract* - *Power flow being a pertinent study in electric power systems due to the fact that it exposes the behavior or state of the system under steady and unsteady operating condition. This paper considers power flow in the steady state domain with the aim of analyzing the state of a 4-bus 33kV distribution network. A cascaded artificial intelligence (AI) based technique geared towards providing an automated power flow solution is being implemented in this work. Results at various per unit base values proved automated with less computational time with better convergence

Index Terms— Power Flow, Artificial Intelligence, Neural Network, Swarm Intelligence, Bee Colony Algorithm

I. INTRODUCTION

The importance of power flow studies in electrical power systems cannot be over-emphasized as both power system engineers and researchers depend on its outcome to know the true state of the system under investigation. In power flow studies there are four essential quantities looked out for and they are:

magnitude and phase angle of the voltages, real and reactive power flow along the systems. Swarm Intelligence (SI) is the type of artificial intelligence optimization algorithm inspired by the biological behavior of swarms such as honey bees, ants, fishes, bird etc. cascaded Swarm Intelligence is the simple combination of other types of artificial intelligence with swarm intelligence algorithm for optimization purposes. Moving away from the conventional non-linear solution methods of Newton-Raphson (N-R), Gauss-Sidel, Jacobi, Runge-Kutta (RK-4), an artificial intelligence (AI) based solution is employed in this research for automated power flow analysis (APFA). A cascaded artificial intelligence solution technique comprising of a feed forward neural network under supervised learning coupled with a bee colony algorithm is used to analysis a 4-bus network in this research. Though many researches have been conducted using both traditional and evolutionary solution techniques in recent times, this research is aimed at optimizing the solution in the area of computational time without trading off convergence.

II. LITERATURE

In [1], the method of artificial bee colony (ABC) was employed to solve load flow problems. Test result showed that the ABC method was able to effectively solve power flow problems in the maximum loadable region. The ABC algorithm offered better solution for power flow problems compared to other method of solution in terms of flexibility, accuracy, convergence and reliability. In this work, application of the ABC algorithm succeeded in minimizing the mismatch between the real and reactive powers there by reducing the power losses of the system. The algorithm also showed promising result for heavily loaded systems. Future research should be targeted at studying the control parameters of the ABC to know and select the best initial settings of the control parameters for optimum performance to small and large electrical systems.

[2] proposed a modified artificial bee colony (MABC) algorithm which incorporates a fuzzy satisfaction-maximizing algorithm for conversion of multi-objective problem into a single objective problem. Test on IEEE 30-bus system using the proposed algorithm presented better exploration and stronger exploitation capacity capable of solving OPF problems effectively than other heuristic methods.

[3] applied hybrid artificial bee colony (HABC) with the objective of minimizing the active power loss. HABC was used for optimal allocation of static VAR compensator (SVC) devices for active power loss minimization while the quality of solution was increased using genetic (GA) algorithm. Results from test on IEEE 57-bus system proved that HABC is

better than ABC considering a search space with various local optima.

[4] applied a combined approach using fuzzy logic and ABC for DG placement in radial distribution system for power loss minimization and improvement of voltage profile. Test conducted on IEEE 33-bus system showed better solution quality and computational efficiency compared to other solution techniques.

[5] proposed a real-coded genetic algorithm (RCGA) for load flow solution in electrical power systems. Test result on various IEEE bus system showed reliable convergence, high accuracy and computational speed.

[6] reviewed various methods for solving power flow problems and proposed GPSO-GM as a solution in islanded microgrids by modelling different operating modes of distributed generators (DG).

[7] conducted a study on power system stabilization using ABC optimization algorithm for multi-machine power system. Results from application showed better stability and convergence of the proposed method against conventional methods like genetic algorithm and non-dominated genetic algorithm.

[8] proposed a hybrid particle swarm optimization-based method (HPSOBM) for optimal power flow solution. The objective function was to minimize the power mismatch between the active and reactive power in an electrical power system.

III. MATERIALS AND METHOD

Electrical Transient Analyzer Program (ETAP) and Mathematical Laboratory (MATLAB) were tools employed in this research work. ETAP was used for the design of the 4-bus distribution network under scrutiny after collection of relevant system data from both Port Harcourt Electricity Distribution Company (PHEDC) and Transmission Company of Nigeria (TCN). Figure 3.1 shows a typical representation of the network under investigation.

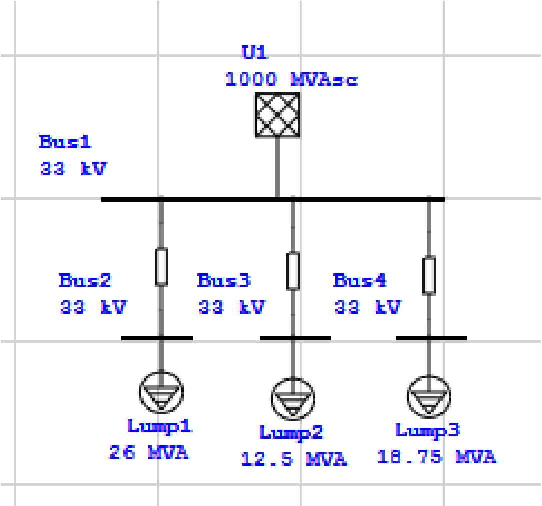

Fig. 1: PHEDC 4-Bus Distribution Network

Algorithms for both artificial neural network (ANN) and bee colony optimization (BCO) were implemented using MATLAB and Simulink. The step by step procedures of the algorithms are shown in Fig. 3.2 [9].

whereas training, testing and validation results for first and second run scenarios are presented in Fig. 3.3 and 3.4 respectively.

Aside the basic load flow non-linear equations, there is a fitness function which is aimed at optimizing the load flow solution by ensuring minimal or zero mismatch between the real and reactive power elements.

The fitness function or objective value will be deduced using equation below.

$$F_{min.\ objective} = \sqrt{\Delta P_{net} + \Delta Q_{net}} \qquad (1)$$

The optimization process will be achieved by producing working values of bus voltages and angles at a minimum objective function. The objective value or function is the square-root of the sum of the changes in net real and reactive power after every iterative process.

Values of fitness function ($F_{min.\ objective}$) must be close to zero or attain very small values including convergence after certain number of trial observations have been made. Initial setting of basic ABC parameters like number of food source (solution) are required for kick-starting an ABC optimization process. Through a random number generator, the food sources are initialized, and the magnitude and phase angle of the voltages are constrained in the range $-5 \leq V_i \geq 5$ and $-5 \leq \delta_i \geq 5$. Relating the ABC parameters to LFA, the food source corresponds to the possible solution while the fitness function describes the solution quality. The fitness value of each solution is calculated using the fitness function and the best solution (food source) is recorded in the memory and a neighborhood search is conducted by the employed and onlookers to get a new solution and if the new solution is better than the old solution the new solution is registered and this optimization process continues until the maxcycle is reached. At the end of each cycle, the magnitude and angle of the voltages that corresponds to the best fitness value is registered and becomes the new reference solution fed back into the system until either of the stopping criteria is met [9]. The implementation of the swarm intelligence BCA codes where done with reference to [10].

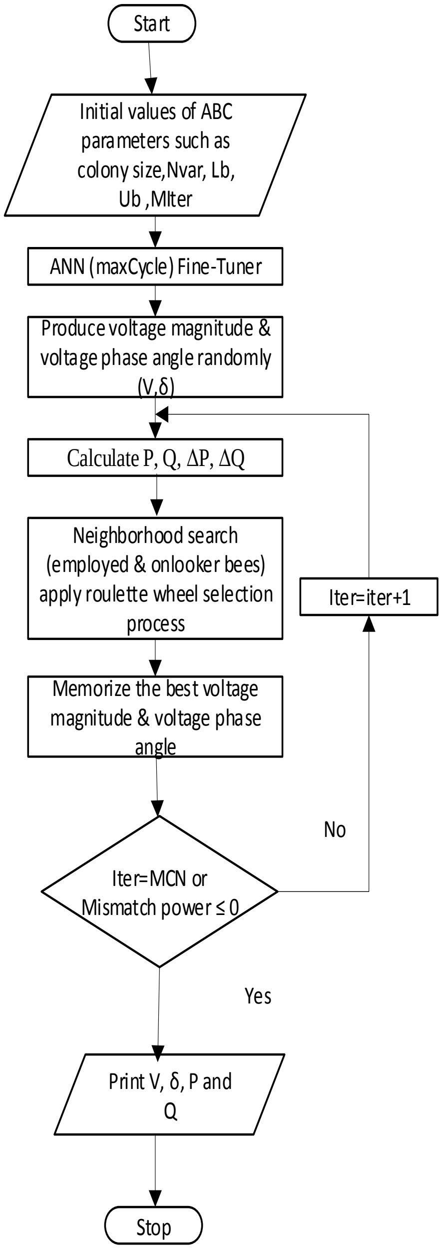

Fig. 2: Flowchart for Cascaded ANN and BCO Implementation

IV. RESULTS

Results obtained after successful trial under different base power values were satisfactory as the developed algorithm was able to provide an automated power flow solution to the 4-bus distribution network under investigation. All results are presented graphically, and minimal mismatch was achieved using the introduced solution technique. Table 1 shows the results for objective values under different base power values.

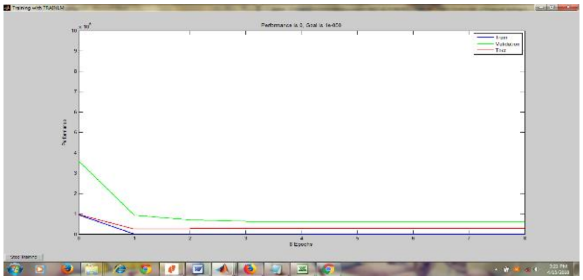

Fig. 3: LFA First Simulation Showing the Performance of the Neural Network for Fine-Tuning BCO maxCycle Parameter during Studies.

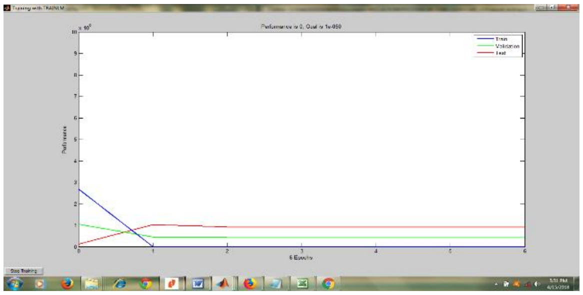

Fig. 4: LFA Second Simulation Showing the Performance of the Neural Network for Fine-Tuning BCO maxCycle Parameter during Studies.

From Fig. 3 and 4, the neural network training performance is very fast and converges at about 2 epochs. The MAPE values obtained from the simulation are 3.3 and 2.7 respectively which is fair enough for the number of data samples presented to it. Further tests on using large data samples may help reduce the error values to much lower values.

Fig. 5, 6, 7 and 8 shows graphical results of an automated power flow solution for the PHEDC 4-Bus distribution network for base values of 10000 MVA, 9500 MVA, 9000MVA and 800 MVA. The results represented graphically shows the relationship between the objective function (best cost) and the number of iterations for convergence and attaining maximum cycle for each base value. From the results shown, it is observed that before the predefined maximum cycle (number of iteration) of 1000 the algorithm was able to meet its stopping criteria of convergences with minimum mismatch (objective values ≤ 1) .

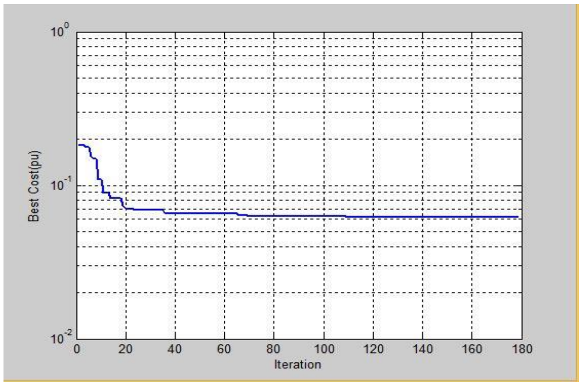

Fig. 5: Cascaded BCA Result for 10000 MVA Base

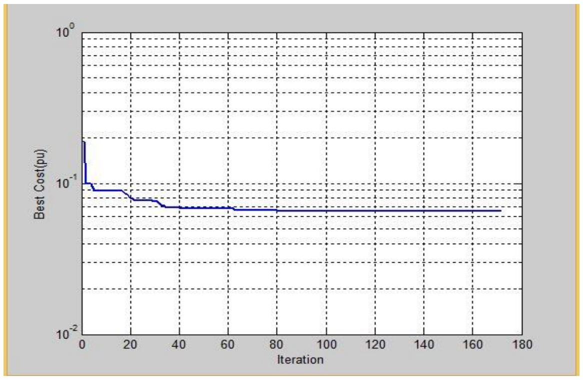

Fig. 6: Cascaded BCA Result for 9500 MVA Base

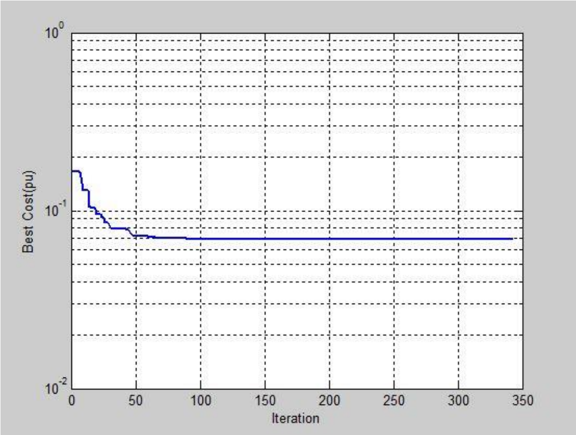

Fig. 7: Cascaded BCA Result for 9000 MVA Base

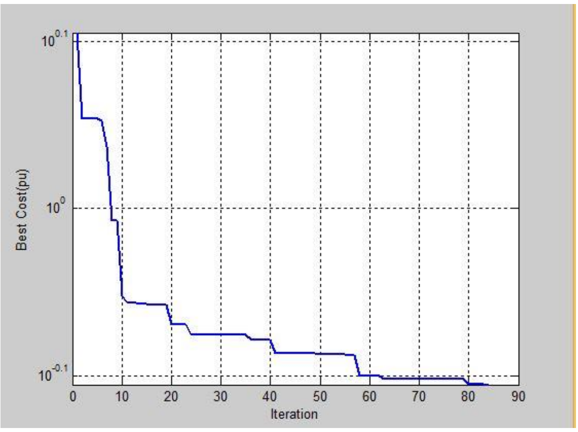

Fig. 8: Cascaded BCA Result for 800 MVA Base

V. CONCLUSION

In this research a new load flow solution model was developed, tested and the results obtained were optimal through means of automation. With the results achieved so far, the aim of the research has been met with optimized performance in terms of computational speed and number of iterations. Further work can be conducted by investigation the performance of the algorithm in the transmission domain. Also, the performance of the algorithm should be compared with other types cascaded swarm intelligence algorithms.

APPENDIX

Table 1 : Result for Maxcycle and Objective Value under Variable Base Power

S/N	$S_{base}(MVA)$	MaxCycle	Objective Value (pu)
1	10000	179	0.0624
2	9000	343	0.0693
3	8000	147	0.0779
4	7000	96	0.0892
5	6000	123	0.1040
6	5000	135	0.1247
7	1000	156	0.6235
8	700	148	0.9344

REFERENCES

[1] K. Al-Anbarri, & H. M. Naief, (2017). Application of Artificial Bee Colony Algorithm in Power Flow Studies. UHD Journal of Science and Technology, 1(1), 11-16.

[2] X. He, & W. Wang, (2014). Fuzzy multi-objective optimal power flow based on modified artificial BEE colony algorithm. Mathematical Problems in Engineering, 2014.

[3] A. Blal, A. Rami, & A. Zeblah, (2016). Optimal allocation of SVC in electric power system for loss minimization and control voltage using hybrid ABC. International Journal of Power and Energy Conversion, 7(3), 227-239.

[4] M. P. Lalitha, V. C. Reddy, S. N., & Reddy, (2010). Application of fuzzy and ABC algorithm for DG placement for minimum loss in radial distribution system. Iranian Journal of Electrical and Electronics Engineering, 6(4), 248-257.

[5] H. A. Kubba, & S.S. Mahmood, (2009). Genetic algorithm-based load flow solution problem in electrical power systems. Journal of Engineering, 15(4).

[6] M. H. Moradi, V. B. Foroutan, & M. Abedini, (2017). Power flow analysis in islanded Micro-Grids via modeling different operational modes of DGs: A review and a new approach. Renewable and Sustainable Energy Reviews, 69, 248-262.

[7] V. Ravi, & K. Duraiswamy, (2012, January). Effective optimization technique for power system stabilization using Artificial Bee Colony. In Computer Communication and Informatics (ICCCI), 2012 International Conference on (pp. 1-6). IEEE.

[8] C. P Salomon, G. Lambert-Torres, L. E. B. da Silva, M. P. Coutinho, & C. H.V. de Morae's, (2013). A hybrid particle swarm optimization approach for load-flow computation. International Journal of Innovative

[9] C. O. Ahiakwo, S. Orike, & O.E. Ojuka, Application of Neuro-Swarm Intelligence Technique to Load Flow Analysis.

[10] D. Karaboga, & B. Akay, (2009). A comparative study of artificial bee colony algorithm. Applied mathematics and computation, 214(1), 108-132.