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Power Loss Minimization Load Flow Studies Using Artificial Bee Colony Swarm Intelligence Technique

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Abstract

This paper presents the capability of an emerging swarm intelligence technique for power loss minimization known as the Artificial Bee Colony (ABC) used in the context of an Alternative Load Flow Analysis (LFA) technique (ABC-LFA) for the solution of a power systems network. Studies are performed considering the effect of an important parameter of the ABC, the "maxcycle" on the LFA process; experiments are conducted by applying the ABC-LFA to the Western System Coordinated Council (WSCC) 3-machine 9-bus power system and a section of the Nigerian 132-kV power transmission network Port-Harcourt Region (NPHC-132), and the results reported. The results indicate that increasing the value of the ABC "maxcycle" parameter has a pronounced effect on the results obtained by the ABC-LFA. The results also indicate the sensitivity of the ABC to low values of maxcycle parameter.

Keywords: Load flow analysis (LFA), maxcycle, optimization, power system, swarm intelligence.

1.0 INTRODUCTION

Power system network is a very important part of the modern society as it provides the basic infrastructure for heating, cooling and lighting among so many other essential functions to an ever-teeming populace. In order to meet the demands of consumers, proper planning of power system networks is essential. One essential tool or technique in this regard is the Load Flow Analysis (LFA). Some of the immediate benefits of the LFA include the economic dispatch management, and in transient stability studies. Typically, the LFA requires the solution of a set of equality and inequality constraints needed to determine the power network system states and hence solve the power systems network [1, 2]. Traditional LFA tools such as the Newton-Raphson and Gauss-Seidel are very useful for some kinds of problems but when the power system network becomes more demanding, these techniques encounter high line R/X loading and convergence issues [1-3].

In recent times, there have been a renewed interest in the use of meta-heuristics algorithms based on swarm intelligence for power flow problems [4-10]; some popular examples of these techniques are the Particle Swarm Optimization (PSO), Artificial Bee Colony (ABC), and Ant Colony Optimization (ACO). These algorithms have been successfully used in the solution of many other power system problems.

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In this paper, we present an emerging swarm intelligence (SI) technique that is gradually gaining popularity in the power system community called the Artificial Bee Colony (ABC) for load flow studies of a well-studied power system network - Western System Coordinated Council (WSCC) 3-machine 9-bus power system. This approach is also extended to a section of the Nigerian 132-kV power network Port-Harcourt Region. The influence of an important ABC parameter called the "maxcycle" on the load flow solution and how it impacts the small signal voltage stability of the aforementioned power transmission networks is specifically studied and the results presented.

2.0 MATERIALS AND METHODS

2.1 Methodology for Load Flow Studies

In an LFA, a power system network is solved in order to determine performance indicators such as the bus voltages and angles, real and reactive power flows under certain system parameter configurations including the line admittances, bus and generator power requirements.

In contrast to existing results, in this paper, we propose the Artificial Bee Colony LFA (ABC-LFA) which uses swarm heuristics for constrained loss optimization of the load flow in a power system network in terms of the power mismatch. ABC is an emerging swarm intelligence technique inspired by the beautiful organizational and foraging ability of honeybee swarms while combining the global optimum capabilities of evolutionary computers with a fitness based model [11]. It was developed in [12] and has been widely applied by power system researchers in industries and academia. In the ABC-LFA simulation, an evolutionary process comprising an exploitative and explorative procedure is used to evolve foods (candidate LFA power system parameter solutions) in order to determine the best possible solution candidate. This typically results in a set of sub-optimal solutions through simulation time. The exploitative functions are handled by two sub-routines referred to as the employed and onlooker bees while the explorative functions are performed by the scout-bees sub-routine [13, 14].

The procedure for performing an ABC-LFA is as follows:

- Step 1: Define Power Network Initial Parameter Conditions including the bus data and line data values; these values are needed later on for defining the ABC boundary constraints
- Step 2: Compute the Line Admittance of the power network buses and the corresponding angles.
- Step 3: Define the ABC constraints (upper and lower bounds) based on the power system optimization parameters: Bus Voltage, Bus Angle, Bus and Generator Real and Reactive Powers, and Power Injections
- Step 4: Define the fitness (objective) function of the ABC; this function computes the load flow, power mismatches and the net power mismatches using the aforementioned constraints defined in the previous step (Step 3).
- Step 5: Solve the power network by finding the best food in accordance to the ABC algorithm routine and the fitness function defined in Step 4; the algorithmic details of this important step can be found in [3].

2.2 Experiments

Small signal voltage stability experiments in the context of load flow of the Western System Coordinated Council (WSCC) 3-machine 9-bus system, and a section of the Nigerian 132-kV power transmission network Port-Harcourt Region (NPHC-132) are conducted on an Intel i-core-2 PC using a 2.3GHz processor. The considered Nigerian sub-transmission network is a 1-machine, 14-bus system with most interconnecting lines of the double circuit type.

All simulations are performed using MATLAB7.5, R2007b software. The data and codes used in these experiments can be found in [15, 16]; data for the NPHC-132 1-machine, 14-bus power system is obtained from the Nigerian National Control Centre, Osogbo. The ABC code is adapted from [17]. The default parameters for ABC are colony size = 50, limit = 500, maxcycle = 500; for the experiments with the WSCC power network, the maxcycle is varied in accordance to Table 1 while the Food number is set to equal half of the colony size.

3.0 RESULTS AND DISCUSSIONS

The results of applying the ABC-LFA to the Western System Coordinated Council (WSCC) 3-machine 9-bus system (see structure in [13], Fig.1) is as shown in Tables 1-2. The results report the power mismatch optimization phase as computed by the ABC-LFA (see Table 1) and the solved bus voltages after the ABC-LFA completes (see Table 2).

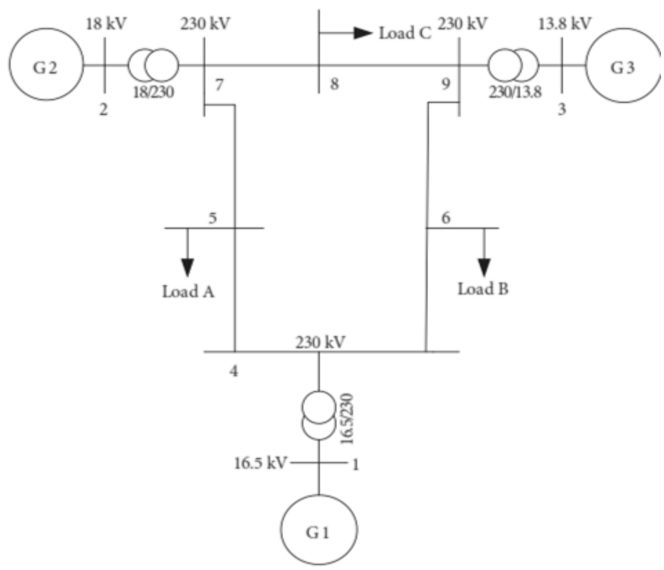

Figure 1: WSCC 3-machine 9-bus power system structure.

Table 1: ABC-LFA Power Mismatch Performance for Different Maxcycle Values

Maxcycle value	***ABC-LFA Power mismatch (* x 10^{-8})***
1000	0.6650
1100	0.8550
1200	0.0118
1300	0.5250
1400	0.8550
1500	5.8400
1600	0.3300
1700	0.1490
1800	0.2370
1900	0.2040
2000	0.1120

Table 2: ABC-LFA Bus voltage response

Bus No.	**Mean Bus Voltage Responses at given maxcycle values**		
	$V_{bus1200}$	***$V_{bus1800}$***	***$V_{bus2000}$***
1	1.0400	1.0400	1.0400
2	1.0250	1.0250	1.0250
3	1.0250	1.0250	1.0250
4	1.0026	1.0073	1.0129
5	0.9983	0.9825	0.9916
6	0.9953	0.9962	0.9984
7	1.0023	1.0133	0.9967
8	0.9959	0.9987	0.9839
9	1.0110	1.0127	0.9988

The results are obtained after 5 consecutive simulation runs, and for maxcycle values from 1000 to 2000 at intervals of 1000; the results represent the average of all solved voltages at the stated maxcycle numeric values (indicated by the numeric sub-script). For the voltage response test, only the results at maxcycle of 1200, 1800 and 2000 are reported here; note that the result at a maxcycle of 1800 is indicative of a close resemblance to a typical Newton-Raphson (NR) load Flow optimization (refer to [16], Fig.2).

The voltage response results obtained using ABC-LFA on the Nigerian 132-kV sub-transmission Port-Harcourt Region (NPHC-132) are also reported in Fig. 2-3. In Fig. 2, the voltage response at the 14 buses is reported for a single run while in Fig. 3 the mean voltage response is reported after 5 trial runs. The results reflect a maxcycle parameter = 25000 cycles at a colony size of 20 and a limit = 500.

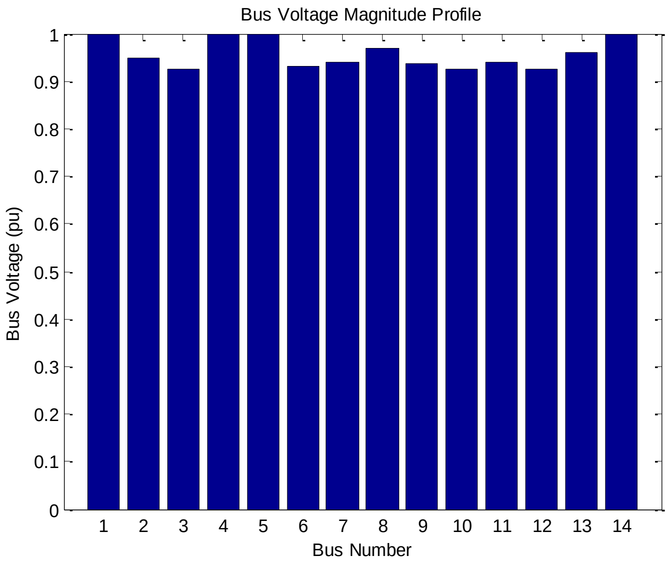

Figure 2: Voltage response of the NPHC-132 1-machine, 14-bus system at a single trial run.

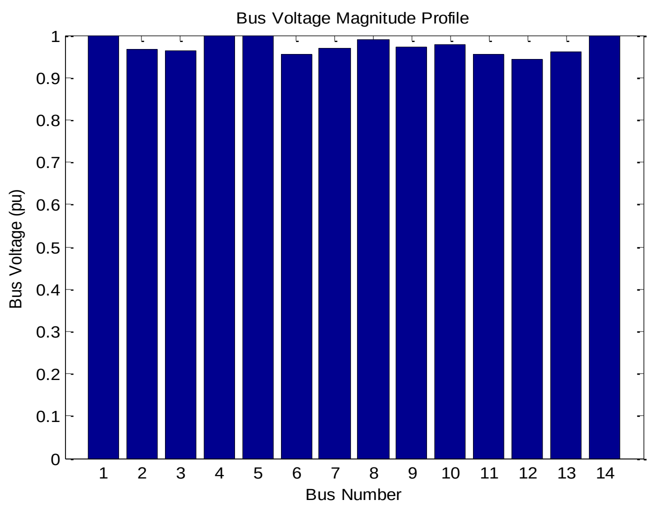

Figure 3: Mean voltage response of the NPHC-132 1-machine, 14-bus system at 5 trial runs.

4.0 CONCLUSION AND FUTURE WORK

In this work, a performance optimization study of an emerging swarm intelligence technique called the Artificial Bee Colony (ABC) for load flow analysis (ABC-LFA) is presented. The study investigated the influence of one of the ABC parameters called the "maxcycle" parameters on the power mismatch value during a load flow power loss optimization (minimization) of the Western System Coordinated Council (WSCC) 3-machine 9-bus power network and the Nigerian 132-kV sub-transmission Port-Harcourt Region (NPHC-132). The results indicate that higher value of the ABC maxcycle parameter improves the power mismatch value and hence losses are reduced. The bus voltage results also shows that stability is reasonably guaranteed at a certain maxcycle value (for instance a maxcycle of 1800 is just sufficient for the WSCC power network; the power mismatch reduces as the maxcycle value increases (see Table 1). There is no guarantee however, that lower values or higher values than the aforementioned will give stable results.

The results using ABC-LFA on the NPHC-132 clearly shows that the ABC technique is effective as a meta-heuristic for load flow studies as the solved voltages at the buses for a single trial when compared to the mean of the solved voltages for 5-trial runs are close. Thus, the ABC is a promising tool for load flow studies as it specifically requires the tuning of only a single parameter to attain optimum performance.

Future studies will explore the potential of the proposed ABC-LFA in power system transient stability studies for various power system networks. These studies should be conducted in comparison with other alternative and promising swarm intelligence techniques including variants of the original ABC technique.

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