Rotating Machine Based Power Optimization and Prioritization Using the Artificial Bee Colony Algorithm

L. Mogaka, D.K. Murage, M.J. Saulo

Abstract-The cascading of electric power failures and blackouts are the most significant threats to the security and reliability of the power systems. For a long time now, the world has encountered many power blackouts as a result of these cascading failures. These cascading scenarios pose great risks towards the integrity of power system network, and this may finally lead to the splitting of the power system into various unintentional islands. Hence, intentional or controlled islanding is then utilized as a preventive measure to minimize the losses caused by unintentional islanding of the powersystem. Thus, by doing this, the entire power system is split into controlled island regions for easy handling and control. In such situation, each islanded region should have sufficient generation to supply its loads in order to remain operative and stable. It should also be pointed out that intentional islanding is very important as it can prevent the system from a total collapse.

The distributed generators supplying these islands may not be able to maintain the voltage and frequency within desired limits in the distribution system when it is islanded within the islanded micro grid. There may be a power deficit within the island and eventually we have to shed some loads for the sake of stability of the system. Hence the main challenge here is to determine the appropriate and reliable method to optimize the power supply and the load demand within the island and thus maintain the voltage and frequency within the desired limit

In this study we focused on the minimum load amount for shedding within the islanded region and the prioritization of the buses for shedding so that electricity supply to customers could be maximized using ABC algorithm. From the results obtained, the ABC algorithm was successfully applied for solving the optimization and prioritization problems.

Among the many advantages of ABC algorithm over other algorithms which makes it suitable in this application include; it is easily implemented, flexible, has few control parameters, easily hybridized with other optimization algorithms and can be modified very easily to suit a given application. This was simulated in MATLAB and SIMULINK using IEEE fourteen bus systems.

Keywords- ABC algorithm, Islanding, Power Prioritization and Optimization

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I. INTRODUCTION

The current trend in the increasing use of Distributed Generation (DG) is due to energy exhaustion and recent environmental issues. This practice enables the collection of electrical energy from a variety of sources and leads to decreased environmental impacts and improved security of supply. They are typically in the range of 1 kW to 10,000 kW and include wind farms, micro hydro turbines, photovoltaic (PV) system and other small generators which are supplied with biomass or geothermal fuel [1].

Among the many advantages of DG integration include: improved system reliability in the power supply, increased efficiency, avoidance of transmission capacity upgrades, improved power quality and reduced transmission line losses and environmental benefits (excluding diesel reciprocating engines often used as back-up distributed generators which tend to be the worst performers in terms of greenhouse gas emissions [2]).

Despite the above mentioned merits of incorporating DGs in the distribution system, it has major drawback of unintentional islanding. Islanding condition occurs when the DG continues to power a part of the grid system even after the connection to the rest of the system has been lost, either intentionally or unintentionally. The unintentional islanding mode of operation is not desirable because of a number of reasons. For instance; it poses a threat to the line workers' safety, the islanded system may not be properly grounded resulting in high voltage in the other phases when an earth fault occurs, and most importantly, the distributed generators may not be able to maintain the voltage and frequency within desired limits in the distribution system when it is islanded. That is why it becomes necessary to determine the minimum load amount for shedding within the islanded region and the prioritization of the buses for shedding so that electricity supply to customers could be maximized using ABC algorithm.

II. THE ARTIFICIAL BEE COLONY ALGORITHM

A. The nature of Bees

The Swarm Intelligence (SI) is a branch of Artificial Intelligence (AI) that has its basis on the collective characteristics of animals or certain unique phenomenon of natural setups such as bees, fish, ants and birds. In the process of searching for the food sources, the bee colony can move in several directions and over a distance of several kilometers.

This exercise of searching for new food sources starts by sending out a group of scout bees to search for flower patches at various bushes that contain a considerable amount of nectar and pollen. After this, the scout bees come back to their hive and then perform a special movement as others observes.

This dance is known as the waggle dance. This is shown in fig1. This waggle dance is used by the employed bees to communicate to other bees in the hive to report three main types of information. This is with regards to the availability of flower patches, which are the direction of food sources location, their quality, quantity and distances from these food sources [3].

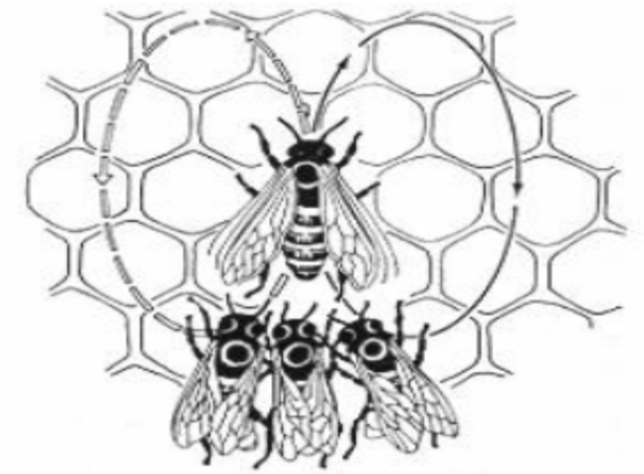

Fig1: The bees waggle dance

This information conveyed helps the other bees in the hive to travel towards the discovered flower patches more easily and precisely without the assistance from other bees. After the waggle dance, scout bees will fly back to the flower patches again with follower bees or worker bees [4].

The artificial bee colony algorithm consists of three important components in its operation. That includes the employed bees, unemployed foraging bees, and food sources.

- Food Sources: An artificial bee analyses a number of factors concerning a given food source before selecting a given food source. These factors include the closeness of the food source to the hive, richness and quality of the energy, taste of its nectar, and the ease or difficulty of extracting this food from the source.
- Employed bees: An employed artificial bee is often employed at one certain food source at a time which she exploits. She carries all important information about this particular food source and shares it with the rest of the bees waiting in the hive. Among other information she shares include the distance of the food source from the hive, its direction and how profitable it is.
- Unemployed bees: Group forager bees that are looking for food sources to exploit are called unemployed bees. They can be either scout bees that search around the environment randomly or onlooker bees who try to find food sources by using the information given by the employed bees.

In short, the artificial foraging bees consist of a group of employed bees, onlookers and scout bees. Half of this colony comprise of the employed bees which forms the majority.

Every food source has an employed bee associated with it. Once a food source is depleted, the employed bee automatically becomes a scout. Thus the amount of nectar in a batch of flowers determines the fitness value of that solution, in this case the food position.

The basic mechanism search of ABC is well presented in figure 2 [5] where a) Initial situation, b) Final situation.

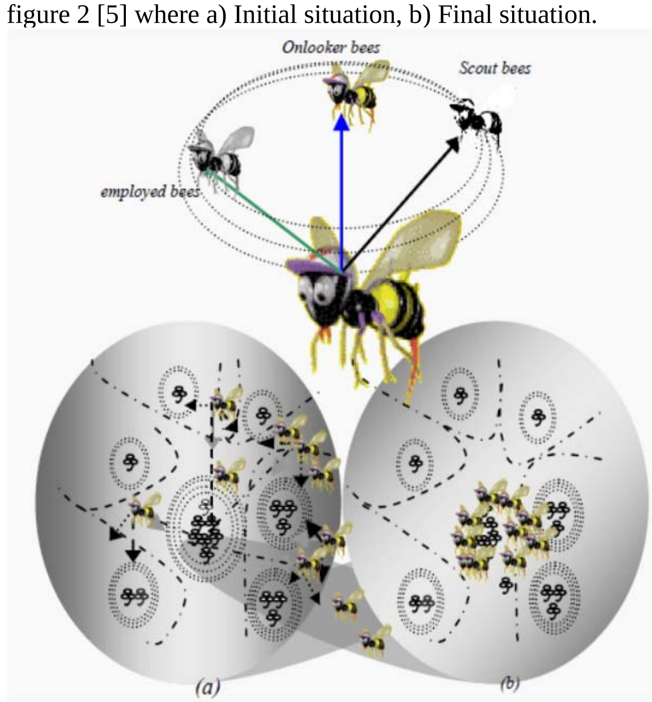

Figure 2: Basic mechanism search of ABC

In the initialization stage of the ABC algorithm, it creates a randomly distributed initial population of solutions ($f = 1, 2... E_b$), where f signifies the size of population and $E_b$is the number of employed bees [6]. Each solution of the expression $x_f$is a Ddimensional size vector, where D is the optimization parameters number. Throughout the optimization process, the artificial bees will memorize the new food position, that is, the modified solution, if the quantity of the new nectar position is higher than the previous nectar position.

Upon completion of each of the search process, the bees then share the nectar information they have found with onlooker bees in the beehive dance area. The onlooker bee will carefully observe these waggle dances and evaluate the information being conveyed and choose the food source with highest nectar quantity. The onlooker bees evaluate the nectar information and choose a food source depending on the probability value associated with that food source as in (1) below [7];

$$P_i = \frac{fit_i}{\sum_{j=1}^{n_e} fit_i} \quad (1)$$

Where fit_i is the solution's fitness value i, which in turn is proportional to the amount of nectar of the source of food in the position i and n_e is the number of food sources which is equal to the number of employed bees in the colony [8].

On their turn, the onlooker bees also employ the same process of modification and selection of the food positions as the employed bees do. This can be demonstrated by the equation 2.

$$V_{ij} = X_{ij} + Q_{ij}(X_{ij} - X_{kj}) [2]$$

Where $k \in (1,2 \ldots n_e)$ and $k \in (1,2 \ldots D)$ are selected randomly. Although k is determined stochastically, it should not be equal to the value of i. Q_{ij} is a random number which should be between -1 and, +1. This controls the generation of the neighborhood food sources.

Once the new food position is determined as shown above, another cycle of the ABC algorithm begins. The same procedures are continuously repeated until the stopping criterion is met [6]. In nutshell, the ABC algorithm is a cycle which involve the following steps which are repeated until the stopping criteria is achieved [9];

Initialization Phase
REPEAT

- Employed foragers Phase
- Onlooker foragers Phase
- Scout foragers Phase
- Memorization of the best food solution achieved

UNTIL (Cycle = Maximum number of Cycles)
Generally the ABC algorithm steps can be summarized as shown in figure3 [10]:

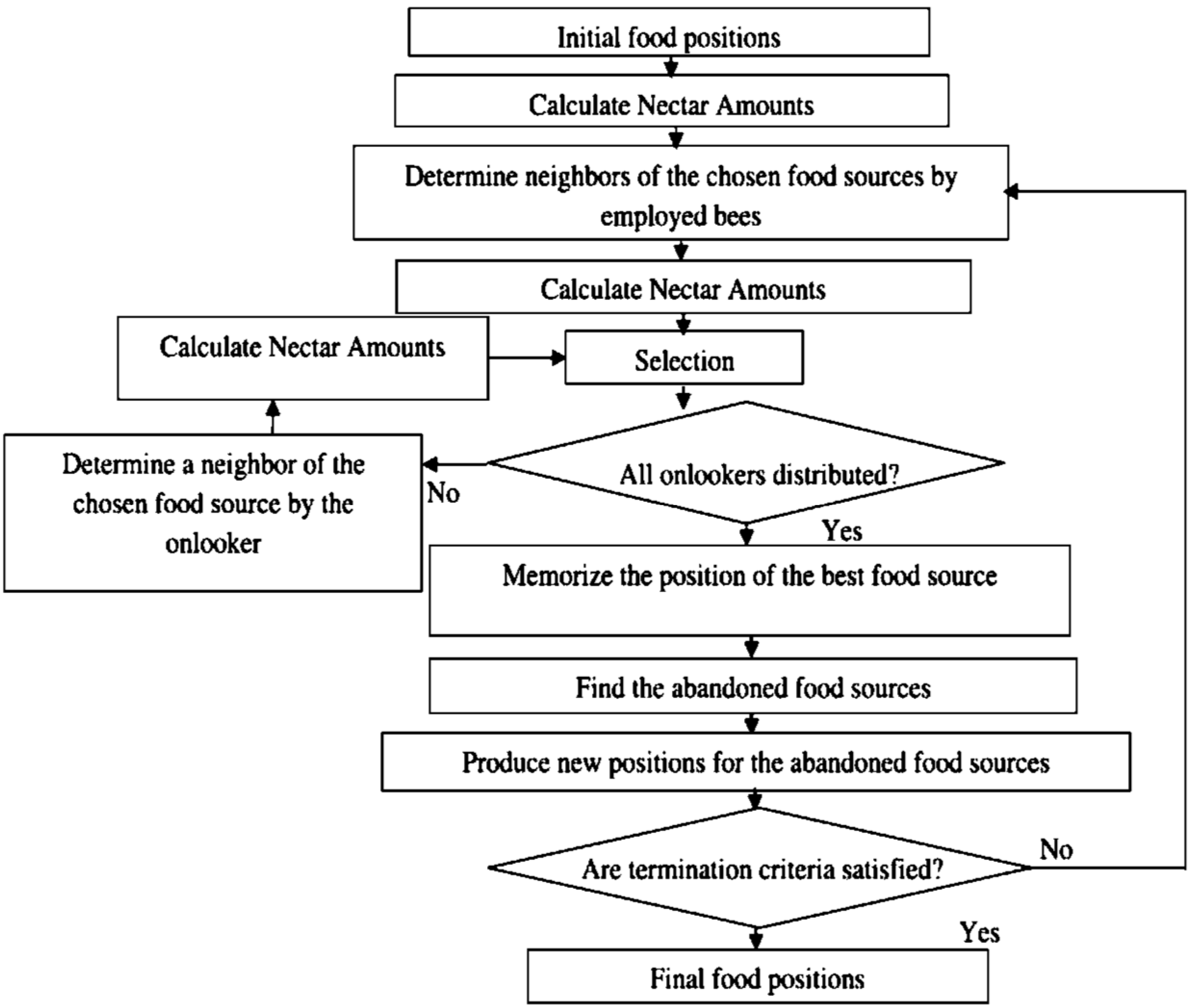

Fig 3: Artificial Bee Colony Algorithm flow chart

B. Advantages of ABC algorithm

The artificial bee colony algorithm system combines both the local search which is carried out by the employed and onlooker groups of bees, and also the global search which is managed by the onlookers and scout group of bees which attempts to balance the exploration and exploitation process [11]. The main advantages of the ABC algorithm over other optimization methods for solving optimization are [12] [13] [14] [15]:

- It is simple to deploy
- It is highly flexible
- It is robust
- It has few control parameters
- Its ease of combination with other methods
- Its ability to handle the objective with stochastic nature
- Its fast convergence as it combines both exploration and exploitation processes.

C. Disadvantages of Artificial Bee Colony algorithm

The artificial bee colony algorithm has some few weakness when put into practice.

- First this method requires new fitness tests on every new algorithm parameters so as to improve performance
- It needs a high number of objective function evaluations
- It slows down when used in sequential processing and the population of solutions increases the computational cost due to slowdown
- It has many iterations and thus huge memory capacity required.

III. METHODOLOGY

The major aim of this study was to determine the minimum load amount for shedding within the islanded region so that the electricity supply to customers will be maximized in case the load surpasses the supply within that island. To achieve this, artificial bee colony (ABC) algorithm was used to ensure there is optimum power supply and also perform power prioritization to determine the buses to be shed based on their priority index.

The IEEE fourteen bus was used in the analysis but with little modification on the bus data and line data. To start with, the distributed generator of 320W was connected at bus number two and a number of loads connected at different buses totaling to 362W.

Then these parameters were varied separately while keeping the other constant and observations made.

The control parameters of ABC algorithm are assumed as follows:

- The number of colony size (employed bees and onlooker bees) is assumed to be 20
- The number of food sources equals the half of the colony size.
- The limit is assumed to be 100. A food source which could not be improved through limit trials is abandoned by its employed bee.
- The number of cycles for foraging is assumed to be 100.

A. System Flow Chart

First, the frequency signals are sampled from the power line. In this study, current signals only were sampled and used in the analysis. Then features to be used in islanding detection were extracted by the use of discrete wavelet transform and the classification was done using fuzzy logic as either islanded or not islanded. In case of islanded condition, power optimization and prioritization within the island using ABC algorithm. Generally the system flow chart as shown in fig4.

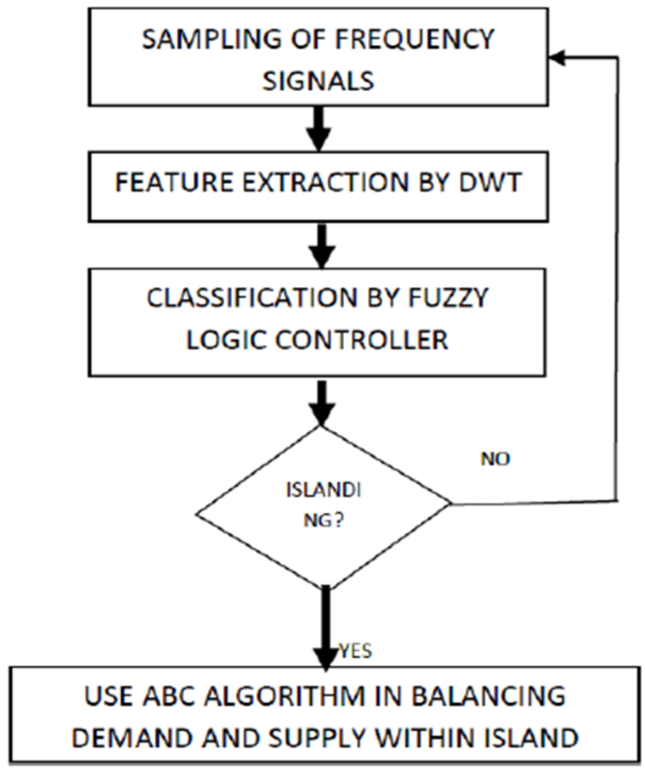

Fig 4: System flow chart

B. **IEEE 14-Bus Test System**

After the occurrence of the islanding condition was successfully identified using DWT and FL as has been illustrated above, the load shedding of various buses was tested using an IEEE 14-bus test system. This system consists of five synchronous machines, including one synchronous compensator used only for reactive power support and four generators located at buses 1, 2, 6, and 8. In the system, there are twenty branches, fourteen buses and with 11 loads connected. The complete data of this test system is taken from 'Power system test case archive, University of Washington, Department of Electrical Engineering, from http://www.ee.washington.edu/research/pstca/index.html).

The priorities for load shedding were set in the following decreasing order for Load buses 9, 10, 11, 12, 13 and 14. Out of these selected buses bus 14 is the one having highest sensitivity and therefore can be considered as the weakest bus for load shedding followed by bus 13.

IV. RESULTS AND DISCUSSION

The main aim of this study involved finding the optimal load to be shed and the selection of the buses to be shed using the ABC algorithm. Basically there are two main strategies of load shedding. The first is based on voltage which is called Under Voltage Load Shedding (UVLS) and the other one is based on frequency known as Under Frequency Load Shedding (UFLS).

The main objective of load shedding is to provide smooth load relief, in situations where the power system would otherwise go unstable. The buses for load shedding are selected based on the priority attached to those buses and the required amount of load to be shed.

On the part of power optimization and prioritization within the islanded region, the IEEE fourteen bus was used in the analysis but with little modification on the bus data and line data. The distributed generator of 320W was connected at bus number two and a number of loads connected at different buses totaling to 362W. Both the generator output and the connected load were varied and the signal variations observed.

Then using ABC algorithm and load flow, it is easy to determine the power deficit and surplus in the island. In addition to this, the buses were given priorities and buses to be shed were picked based on the amount of deficit and the bus priority.

Table 1 is a snapshot of the system results obtained when a total of 362.5W load was connected to a 320W generation. From the simulation, the line losses were 32.805W and the total load to be shed should be 75.305W including line losses.

Table 1: Prioritization results

Command Window

Bus No	Injection MW	Injection MVar	Generation MW	Generation Mvar	Load MW	Load MVar
1	75.305	0.000	75.305	0.000	0.000	0.000
2	298.300	0.000	320.000	0.000	21.700	0.000
3	-94.200	0.000	0.000	0.000	94.200	0.000
4	-47.800	0.000	-0.000	0.000	47.800	0.000
5	-7.600	0.000	-0.000	0.000	7.600	0.000
6	-11.200	0.000	-0.000	0.000	11.200	0.000
7	-0.000	0.000	-0.000	0.000	0.000	0.000
8	0.000	-0.000	0.000	0.000	0.000	0.000
9	-30.000	0.000	0.000	0.000	30.000	0.000
10	-30.000	-0.000	0.000	0.000	30.000	0.000
11	-30.000	-0.000	0.000	0.000	30.000	0.000
12	-30.000	-0.000	0.000	0.000	30.000	0.000
13	-30.000	-0.000	0.000	0.000	30.000	0.000
14	-30.000	-0.000	0.000	0.000	30.000	0.000
Total	32.805	0.000	395.305	0.000	362.500	0.000

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POWER GENERATED  320.000
POWER DEMAND  362.500
LOSSES   32.805

LOAD TO SHED   75.305
SHED BUS 14

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A. **Constant Demand and Constant Supply Characteristics**

The connected load was kept constant and the generator output varied and observations made. On the other hand the generator output was kept constant and the connected load varied and observations made. These are briefly shown in table 2 and 3.

Table 2: Constant demand with varying supply characteristics

Simulation	Power generated	Power demand	Losses	Load to shed	Shed bus
1	362.5	362.5	33.817	-	-
2	330.0	362.5	32.983	65.483	14
3	300.0	362.5	32.563	95.063	14&13
4	270.0	365.5	32.486	124.986	14,13&12

Table 3: Constant supply with varying demand characteristics

Simulation	Power generated	Power demand	Losses	Excess generation
1	362.5	362.5	33.817	33.817
2	362.5	352.5	28.568	18.568
3	362.5	342.5	27.281	7.281
4	362.5	335.5	26.259	-3.741

V. CONCLUSION

In this study, the ABC algorithm was successfully applied for solving the optimization and prioritization problems in the island being supplied by the DG. The ABC algorithm is based on the foraging behavior of honey bees for finding global and local solution for optimization problems. The advantages of using this algorithm are its robustness, fast calculation of the error, flexibility, and few parameters to be set. However, the ABC algorithm suffers a drawback of the search space limited by initial solution. In fact, this drawback can be overcome using normal distribution sample in the initial step.

This proposed algorithm has been tested on a fourteen bus system and the obtained result for this system was analyzed and it was satisfactory to draw concrete conclusions.

In comparison with other methods of optimization, the proposed algorithm can obtain better optimal solution than many other methods with a fast computational manner, especially for large-scale systems. Therefore, the proposed ABC algorithm can be a favorable method for solving optimization and prioritization problems in power systems.

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