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AN APPLICATION OF ARTIFICIAL BEE COLONY ALGORITHM IN A POWER SYSTEM

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Abstract- Tuning of the system and the controller parameters always constituted an important part of the control applications in power system. These processes need complex mathematical calculations including derivative elements classically. However, these nowadays accomplished more easily and in shorter times, using by iterative optimization approaches such as evolutionary or swarm intelligence based methods. Depend on these approaches; many different optimization algorithms based on natural life have been present so far. One of them is the swarm intelligence based Artificial Bee Colony (ABC) algorithm that attracts attention by its powerful convergence capability, high applying capacity, elasticity, and robustness. In this article, the literature related to Artificial Bee Colony algorithm and its applications in power system control comprehensively investigated, and then the case study about the ABC algorithm based optimization of Automatic Voltage Regulation (AVR) system presented as an application example for being help to the researchers.

Keywords: Power System Control, Optimization, Swarm Intelligence, Artificial Bee Colony, AVR System.

I. INTRODUCTION

Tuning of the system and the controller parameters are always constituted an important part of the control applications in power system. These processes need complex mathematical calculations including derivative elements classically. The engineers usually solve these problems in relatively simple designs by benefiting from their preceding experiences practically, but studies that are more complicated need the complex optimization calculations. Classically, the derivatives are calculated by the numerical computation methods that their solutions are relatively difficult, depend on the problem, and take long time. These calculations need more program codes and more memory in the engineering designs as well [1].

To cope with this problem easier, the researchers have developed some iterative optimization methods based on the natural life beginning from 1980s. The most important advantage of these methods is the elimination of derivative process. Because they do not include derivative, they have relatively short program codes and they realized easier and converge to the result in shorter times than the classical methods. Thus, this feature makes these methods more popular than the classical optimization methods. The natural life based optimization methods have an algorithm that schedules the initial values of the parameters that will be optimize.

The algorithm formulated according to the chosen natural system behavior such as natural selection, flying of the bird flocks or nectar searching of the bees. These formulas generally include two main parts: the first part that determines how many values of the available solutions will change and the second part that changes the solutions by using the values obtained at the first part. In addition, the mathematical simplicity of these algorithms causes that it preferred by the researchers in order to solve the complex optimization problems. However, it can said that they have a disadvantage, as they do not guarantee the optimal solution. The result that obtained these algorithms cannot always be optimal values, but it is absolutely close to the optimal result [2].

Nowadays, there are different approaches in order to develop this type of optimization algorithms such as natural selection, swarm intelligence, or collective working. As a result, many different algorithms have been suggest depend on these approaches in literature. They have been apply to the different engineering areas and fundamental sciences so far. Recently, the swarm intelligence approach attracts attention because of its simple concept, needs less number of codes and less number of initial parameters, high convergence speed, high applying capacity, elasticity and robustness. Actually, swarm intelligence is multidisciplinary and the population based upon the iterative optimization approach constructed on the biological model of searching food behaviors of bird flocks, fish schools, or honeybee colonies.

The most important feature of this approach is that the scheduling formulas have an element related to the preceding experiences of both the individual and the entire population different from the other optimization approaches like the natural selection.

This paper is prepared in two parts. First, the swarm intelligence approach based Artificial Bee Colony (ABC) algorithm that was introduced by Karaboga in 2005 [3], and its applications in power system control areas are investigated. In this scope, the literature related to the usage of this algorithm in these areas tried to scrutinize comprehensively for being reference to the researchers. After that, the case study about optimizing the controller parameters of AVR system based on the ABC algorithm presented as an application example.

II. LITERATURE SURVEY: ARTIFICIAL BEE COLONY ALGORITHM IN POWER SYSTEM

ABC algorithm simulates the nectar searching behavior of the honeybees. Individual behaviors and interactions between each other of three groups of bees that are scouts, employers, and onlookers in a hive had been formulate mathematically. It can said that the main advantage of this algorithm is its triple search capability including two local and one global search. At the beginning of the algorithm, after the initial processes, the first employer bees begin to search the nectar sources locally, and they measure the nectar amounts of these sources by using the cost function. After that, the employer bees transfer the own nectar sources to the onlooker bees according to their nectar amounts.

The onlooker bees improve their nectar sources by searching the new sources near the neighborhood of these sources locally. The employer bee which has not transfer the own nectar source to the onlooker bees until the limit value determined as the initial parameters turns into the scout bee and begins to search the new nectar source globally. At the end of the iterations or when the error rate meets the desired value, the nectar source which has the best nectar amount is appeared the optimal solution [3, 4]. The basic steps of ABC algorithm presented below.

- Send the scouts onto the initial food sources
- Repeat
- Send the employed bees onto the food sources and determine their nectar amounts
- Calculate the probability value of the sources with which they are preferred by the onlooker bees
- Stop the exploitation process of the sources abandoned by the bees
- Send the scouts into the search area for discovering new food sources, randomly
- Memorize the best food source found so far
- Until (requirements are met)

ABC algorithm has been apply to more than a hundred studies about different engineering areas since 2005. One of these areas is the control applications in power system. When the literature investigated, it seen that ABC algorithm is applied to few number of articles but the various subjects in the power system control so far, as depicted in Figure 1.

A. Load-Frequency Control (LFC)

Load-frequency control is one of the main controls applied to the interconnected power systems. In this area, ABC algorithm applied to LFC by Gozde with his Ph.D. thesis in 2010 [5]. In the study, this algorithm is used in order to optimize the parameters of the PID controller which control the two area interconnected thermal power system. The LFC control in a wide range of both the controller and the system parameters realized. Gozde also analyzed the robustness of the system, and compared the obtained results with the literature. The author also published these results at the article [6].

In addition to this, Shayeghi and Ghasemi applied ABC algorithm to the generalized LFC scheme in the restructured power system for three cases of the plant parameters changes and load disturbances to illustrate its robust performance in the presence of generation rate constraints (GRC) in 2011 [7]. He compared the algorithm with genetic algorithm (GA) and Particle Swarm Optimization (PSO) algorithm in this article. In the same year, Gozde and Taplamacioglu applied the algorithm to LFC for the thermal power system in order to improve the quality of electrical energy system [8].

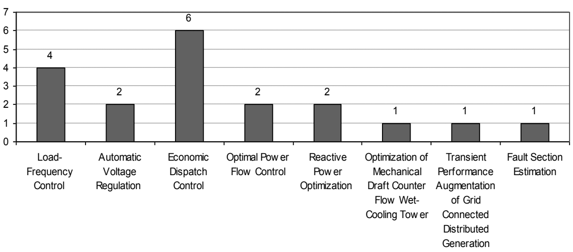

Figure 1. Distribution of the articles related to ABC algorithm in control applications in power system

B. Automatic Voltage Regulation (AVR)

ABC algorithm is applied to the subject of automatic voltage regulation for the power system by Gozde et al in 2010 [9]. They compared their results with the PSO algorithm. One year after, Gozde and Taplamacioglu used this algorithm to optimize the AVR system once again, and compared the results of the ABC algorithm with those of the Differential Evolution (DE) and PSO algorithms [10]. In addition, they exhibited the performance of the system with transient response analysis, root locus analysis, bode analysis, statistically Receiver Operating Characteristic (ROC) analysis and robustness analysis.

C. Economic Dispatch Control

In this subject, Nayak et al applied ABC algorithm to economic load dispatch problem with ramp rate limits and prohibited operating zones firstly in 2009 [11]. They compared the results for 6, 15 and 18 unit systems with the results of GA and PSO determined in literature. Then, Hemamalini and Simon used ABC algorithm to optimize the economic load dispatch control including the cases consisting of 10, 13, 15, and 40 generating units with non-linearity incorporated in their cost functions in 2010 [12]. They compared their results with the other optimization methods in literature. In addition, Hemamalini and Simon applied this algorithm to the dynamic economic dispatch control for units with valve-point effect in 2011 [13].

They also compared their results with GA and PSO algorithm. Liao et.al applied the adaptive ABC algorithm to this problem for cascaded hydropower systems one year after [14]. In their study, they changed some phases such as scoud bee phase of the algorithm in order to gain adaptive structure to the algorithm. In 2013, Ozyon and Aydin used the incremental ABC algorithm in order to solve the economic dispatch problem [15]. Incremental Artificial Bee Colony (IABC) algorithm based on incremental social learning (ISL) framework that its idea is to increase the size of the population in swarm intelligence algorithms [15].

At the same year, Basu suggested ABC algorithm for the multi area economic dispatch control problem [16]. He compared the test results with the results obtained from Real-Coded Genetic Algorithm (RCGA), Evolutionary Programming (EP) and Differential Evolution (DE) algorithms.

D. Optimal Power Flow Control

Yousefi Talouki et al used ABC in order to minimize generation fuel cost while satisfying system's constraints in the unified power flow controller (UPFC) [17]. They compared the results of ABC algorithm with that of PSO algorithm on the standard IEEE 30-bus system. In 2012, Sulaiman et al applied ABC algorithm with least squared support vector machine to the real and reactive power tracing problem in deregulated power system [18]. They tested the ABC-SVM algorithm in IEEE-14 bus system to illustrate the effectiveness of the algorithm.

E. Reactive Power Optimization (RPO)

Ozturk et al and Cobanli et al are used ABC algorithm for this purpose. In 2010, Ozturk provided the multi-objective RPO for considering voltage deviations of buses, active power losses, and reactive power generator costs on ten bus systems [19]. They compared the results with the improving strength Pareto evolutionary algorithm. At the same year, Cobanli provided the active power loss minimization with RPO on the IEEE 6-bus and IEEE 30-bus power systems [20].

F. Optimization of Mechanical Draft Counter Flow Wet-Cooling Tower

Rao and Patel used ABC algorithm in order to optimize the design of mechanical draft counter flow wet-cooling tower [21]. They had shown the performance of the algorithm on six examples.

G. Transient Performance Augmentation of Grid Connected Distributed Generation

Chatterjee et al applied ABC algorithm to improve the transient performance of the grid connected distributed power generation system including different energy generation and storage systems [22]. At the end of the study, they compared the results of the proposed system with those of the system optimized by GA.

H. Fault Section Estimation

Huang and Liu applied to the estimation problem of fault section in power system [23]. The method is tested under some scenarios and real applications, and it is seen its effectiveness for fault section estimation application and owns a high potential of being included in the real-world applications [23].

III. CASE STUDY: ABC ALGORITHM BASED CONTROLLER PARAMETERS OPTIMIZATION OF AVR SYSTEM

In reality, all electrical equipment that connected with this power network has been design for a certain voltage level called rated or nameplate voltage. If the nominal voltage level should be deviate from that value, the performance of these equipment decreases and their life expectancy drop. AVR system is a closed loop control system that provides terminal voltage of the power system be at desired value. In order to solve the control problem explained above, AVR system must be apply to the power generation units in a power network [10, 24].

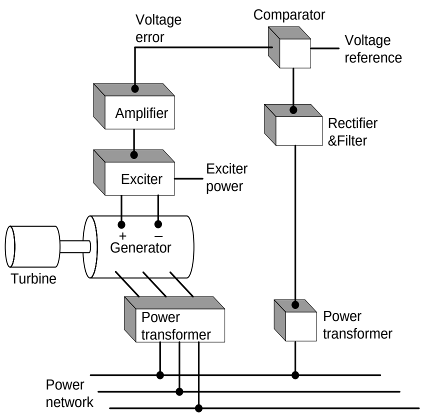

Figure 2. Real model of AVR system

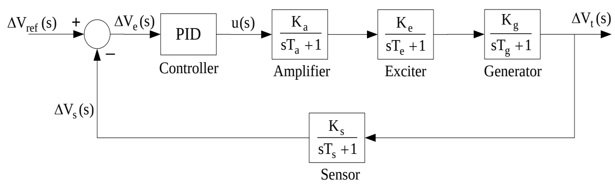

Figure 3. Small signal model of AVR system

A simpler AVR system contains five basic components such as amplifier, exciter, generator, sensor, and comparator. In such a system, a voltage level sensor continuously senses a terminal voltage. It is rectified and smoothed in order to compare with a DC reference signal in the comparator. Later on, the error voltage obtained from the output of the comparator amplified in the amplifier and applied to the controller. Consequently, the output of the controller used in order to control the generator field winding by way of the exciter. The real model and the small signal model of this system depicted in Figure 2 and Figure 3. The chosen AVR system parameters for this application depicts in Table 1 [10, 24, 26].

Table 1. AVR system parameters

Gains	Time Constants
K_a=20, K_e=2, K_g=0.9, K_s=1	T_a=0.1, T_e=0.7, T_g=1.4, T_s=0.01

PID-controller has been preferred for obtaining the control signal $u(s)$ represented in Equation (1). When PID control applied with self-tuning methods, it may gain robustness capability towards change of the different operating conditions.

$$u(s) = \Delta V_e(s).\left(K_p + \frac{K_i}{s} + K_d s\right) \quad (1)$$

The transfer function of the entire AVR system also represented in Equation (2).

$$\frac{\Delta V_t(s)}{\Delta V_{ref}(s)} = \frac{\left(s^2 K_d + sK_p + K_i\right)\left(K_a.K_e.K_g\right)\left(1+sT_s\right)}{\left(\begin{array}{l} s\left(1+sT_a\right)\left(1+sT_e\right)\left(1+sT_g\right)\left(1+sT_s\right)+ \\ +\left(K_a.K_e.K_g.K_s\right)\left(s^2 K_d + sK_p + K_i\right)\end{array}\right)} \quad (2)$$

The gains of the controller has tuned by AVR algorithms. The upper and lower bounds of these gains have chosen as [0.2, 3]. The number of iteration and the population size has taken 50 and 30 respectively. The parameters of the algorithm are chosen that the colony size is 20, the control parameter in order to abandon the food source is 100, and the number of runs is 3.

As a cost function that will be minimize for determining the optimum values of PID controller, the integral of time weighted squared error, (ITSE) function that is represented in Equation (3) is used. This cost function has chosen for minimizing the settling time due to dependency of errors on time.

$$ITSE = \int_0^t t.\left(u_g\right)^2 dt \quad (3)$$

The obtained controller gains and voltage change curves $V_t(s)$ shown in Table 2 and Figure 4. The tuning superiority of ABC algorithm to classical Ziegler-Nichols tuning method [25] put forward by using transient response analysis.

It seen from Figure 4 that ABC algorithm provides better step response than the classical method. In addition, Figure 5 and Table 3 show the transient responses of these curves. According to these, both maximum overshoot and the settling time obtained by ABC algorithm have better results.

Table 2. Optimum gains of PID controller

	with ABC Algorithm	With Ziegler-Nichols Method
K_p	2.630	0.3828
T_i	13.15	0.7
T_d	0.228	0.175

Table 3. Transient response of the system

	Maximum overshoots	Settling times (5% band)
with ABC Algorithm	1.065 V	1.036 sec
with Ziegler-Nichols Method	1.682 V	3.95 sec

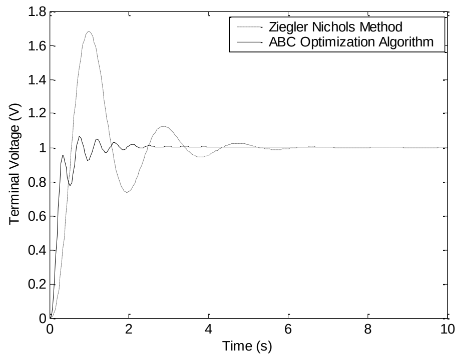

Figure 4. Voltage change curves of AVR system

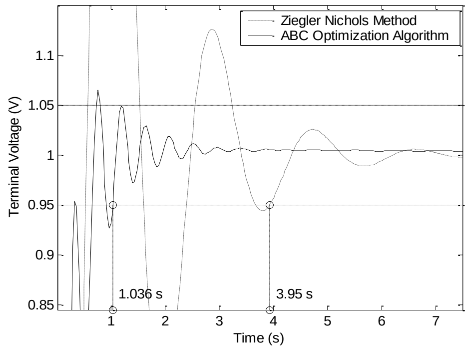

Figure 5. Voltage change curves of AVR system-zoomed

IV. CONCLUSIONS

Nowadays, the tuning process of the system and the controller parameters that needed complex mathematical calculations including derivative elements in the power control systems is completed both easily and at shorter times by using iterative optimization approaches such as evolutionary or swarm intelligence based methods. The swarm intelligence approach attracts attention because of its simple concept, needing less number of codes, needing less number of initial parameters, high convergence speed, high applying capacity, elasticity, and robustness.

ABC optimization algorithm developed based on the swarm intelligence approach. In this study, the literature related to the usage of ABC algorithm in control applications in power system that had been investigate. In addition, the case study regarding to the controller optimization of AVR system presented as an application example of ABC algorithm for the purpose has given as a reference to the researchers on this field.

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