Aswan University Journal of Science and Technology Volume 2, issue 1, June 2022

Load frequency control of A single area power system based EWOA Technique

Reham M. Khairy, Tarek Hassan
Electrical Engineering Department, Faculty of Energy Engineering, Aswan University, 81528, Aswan, Egypt

Abstract:

One of the appropriate tools for addressing the load frequency control Problems is an Enhanced Whale Optimization Algorithm (EWOA). EWOA is a modern optimization algorithm quoted from nature that attempts to mimic and replicate the social behavior of humpback whales. The algorithm is based on the schedule of the bubble net. Bubbles commonly shape "9 tracks" through the whale that surrounds the victim during the fishery. Generally, it swims 10 to 16 meters under the sea. The bubbles are then artificially formed in spiral form by surrounding the victim and moving up to sea level to collect them. Matlab/Simulink was used to perform a numerical simulation. The numerical findings prove that the methodology employed provides a powerful and perfect frequency response as compared with the system using the method of checking constant parameters in case of incremental load changes and random load changes.

Keywords:

Load frequency control, optimization technique, EWOA Technique, single area system, Optimization.

Nomenclature

ΔP_g: the change in the output power of the governor.
ΔP_d: the change in the power of the diesel.
Δf: the deviation of the nominal frequency.
ΔP_L: the change of the load.
ΔP_c: the supplementary control action.
D: the damping coefficient.
M: the inertia constant.
R: the characteristic of speed droop.
T_g: the time constant of the governor.
T_d: the time constant of the diesel turbine.
T_s: the settling time.
T_r: the rise time.

1) Introduction:

In recent years, the main important problem in the electric power system is Load frequency control (LFC) which has been carefully examined to ensure the safe operation of the power systems.

Corresponding author E-mail: Dodom5335@gmail.com

Received July, 1, 2021, received in revised form, August, 15, 2021, accepted August 20, 2021.

(ASWJST 2021/ printed ISSN: 2735-3087 and on-line ISSN: 2735-3095) https://journals.aswu.edu.eg/stjournal

The principle goal of LFC is to stay in the case equilibrium between the generation case of the power and the load requirement, including planned losses in the power system and interchangeable tie-line power [1].

The main purpose of LFC in the regulated power system is to assure zero steady-state error for frequency and tie-line power variations and to supply enough electric power with efficient performance and premium reliability to the consumers [2]. Great trials have been spent by electrical engineers to preserve the stability of the system and the dependability of the power supplied to the clients from the network. Numerous control strategies have been proposed to address the issue of power system load frequency management [3].

Power system always faces high and low disturbances. System stability issue is of great importance to maintain service availability to all consumers. Improving system stability has been studied based on different devices and control techniques. FACTS devices have been used as an effective devices to enhance system stability. For instance, Thyristor Controlled Series Capacitor (TCSC), static var compensator (SVC), and static synchronous compensators (STATCOM) have been used to stabilize different electrical power system [4-9]. Optimized automatic voltage regulator controller to adjust excitation control system another method [10]. Also phase shifting transformer is another effective method [11]. Load frequency control shows flexibility to enhance system stability

The article writer of [12] has suggested a reliable approach to the frequency control problem by A Model Order Reduction Technique. A distributed optimal generator and load control scheme was used to regulate power system frequency by using local measurements of frequency and power flow, local computation, and data exchanges over a communication network when performed in autonomous and plug-and-play operating on the system and can return the frequency and the reference inter-area power to its realistic values if a sudden change is occurred and saving money for a control system [13]. In [14] Load frequency control problem in a two-area hydrothermal power system was handled by collecting Super Conducting Magnetic Energy Source (SMES) and Thyristor Controlled Phase Shifters (TCPS) by using of Adaptive Neuro-Fuzzy System (ANFIS) controller. In article [15] an intelligent wavelet neural network (WNN) load frequency controller (LFC) was used. Power system frequency and tie-line power were regulated by a switched consensus-based distributed controller for transmission networks with multiple control areas with the load side sharing with AGC in [16]. The researcher in [17] showed the job of an artificial Intelligence controller with Fuzzy Logic and ANN NARMA-L2. A Quadratic Regulator Approach with Compensating Pole (QRAWCP) technique which is supported by the Linear Quadratic Regulator LQR approach with an additional compensating pole, was used to solve the problem of LFC [18].

Proportional integral (PI) controller and proportional integral derivative (PID) controller are the most applicable conventional controller. These two types are simply constructed and applied. Also they both are accurate and flexible. They have been applied in many industrial and power system processes. Their parameters have been tuned manually and by using different advanced techniques and algorithms [19-22]. In [23] PID controller was applied, in [24] Fractional-order (FO) controller methodology by a mean of internal model control (IMC) and model-order reduction which used. The writer in [25] Fractional order PID (FOPID) controller system was used and had achieved all requirements of load frequency control. A Linear Active Disturbance Rejection Control (LADRC) technique was used in [26]. The researcher in [27] used an indirect adaptive fuzzy control system, in [28] control techniques had been studied and dealt between turbine control modes and supervisory control of frequency and active power. A nonlinear model predictive control (NMPC) is addressed in [29]. A wind farm used inertia control and droop control methods suggested to increase the efficiency of the frequency regulation in [30], in [31] a single area wind power grid based on a doubly fed induction generator based wind energy conservation system (DFIG-based WECS) had been controlled. A Proportional-Integral-Observer (PI-Observer) with state feedback control is suggested in [32]. An internal model control (IMC) controller for a 3rd order parametric uncertain system by using Kharitonov's theorem and the order reduction form implemented in [33], and in [34] a robust CDA-PIDA controller for a two-area interconnected power system is used. The Model Predictive Control has been used to improve the characteristics of three-area power system. The system is consisted of three different power plants, thermal, photovoltaic and wind energy systems and the system is enhanced by energy storage system [35]. The power balance between generation and consumption has been achieved through controlling the output power extracted from renewable energy sources. This could be executed by using frequency control approach. The deficit power has been compensated by thermal generation units [36].

Power system distinguished with uncertainty, nonlinearity and large number of variables. Solving power system problems is complicated. As a result many researchers have studied different optimization techniques to solve these problems [37]. The most recent applied techniques are metaheuristic nature inspired algorithms which is flexible, accurate, and easy to implement. Nature inspired algorithms have been used widely in solving different optimization problems. Single optimization algorithms such as Whale Optimization Algorithm (WOA), Genetic algorithm (GA), Moth-Flame Optimization (MFO) algorithm, Dragonfly Algorithm (DA), particle swarm optimization (PSO), Manta Ray foraging optimization algorithm (MRFO), Grey wolf optimized and many other optimization algorithms have been used to optimize different power system complicated problems [38-41]. In order to enhance the characteristics of single optimization algorithms, Hybrid optimization algorithms have been introduced as a mix between two algorithms. Hybrid optimization algorithms such as, GASBO, HPSOGWO, MO-HP SOGWO, GAEO and HPSOGWO have been used to solve power system optimization problems for single and multi-objective functions [42-43]. Mirjalili and Lewis suggested the whale optimization technique as a solution (WOA). One of the swarm-based algorithms that has recently been developed. It has been discovered that can successfully complete a number of difficult optimization tasks [44].

2) Modelling of single area power system

A single-area power system consists of a single generator supplying power to a single service area. To handle power system non-linarites, the system is linearized at the required operating point. The single area power system plant includes Governor (Gg (s)), turbine attached to the generator (Gt (s)) and load (Gp(s)). The feedback gain is 1/R. The block diagram of the single-area power system is illustrated by figure (1). The subsystems' dynamics could be modelled by the following equations [12]:

$$G_g(s) = (T_g s + 1)^{-1} \quad (1)$$

$$G_t(s) = (T_T s + 1)^{-1} \quad (2)$$

$$G_p(s) = K_p (T_P s + 1)^{-1} \quad (3)$$

The linearized model block diagram could be represented by figure (2). The overall power system could be represented as follows:

$$\Delta f(s) = G(s)\, u(s) + G_d(s)\, \Delta P_d(s) \quad (4)$$

$$G_d(s) = \frac{G_p(s)}{1 + G_g(s)\, G_t(s)\, G_p(s)/R} \quad (5)$$

$$G_d(s) = \frac{G_g(s)\, G_t(s)\, G_p(s)}{1 + G_g(s)\, G_t(s)\, G_p(s)/R} \tag{6}$$

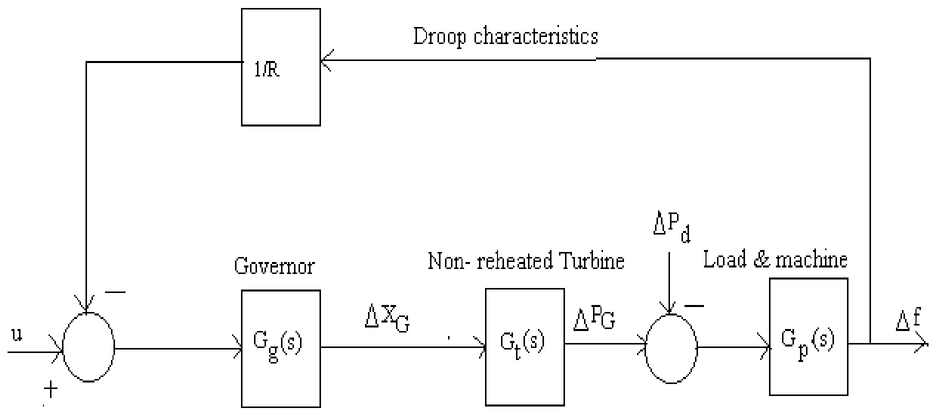

Figure 1 Block Diagram of Single area Power system

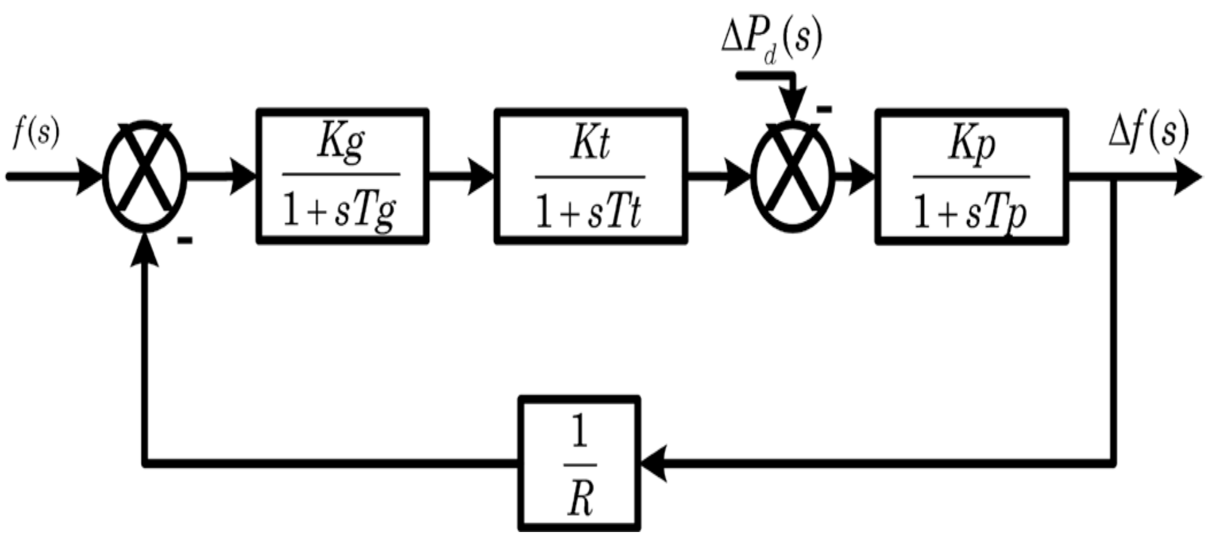

Figure 2 Model of linearized model of single area power system

3) Modelling and applying EWOA Technique

One of the most recent swarm-based algorithms in the last years, which take a lot of care is an Enhanced Whale Optimization Algorithm (EWOA). It has been found that this strategy can perform well on a variety of challenging optimization jobs. The humpback whales chase a group of little fish by swimming around them in a circle that is getting smaller and making unique bubbles along a path that is formed like a circle or a "9" form which is illustrated by figure (3). The algorithm's first phase, which represented encircling prey and spiral bubble-net assault techniques, was followed by the exploitation phase and the second phase, which involved randomly hunting for prey (exploration phase) [44].

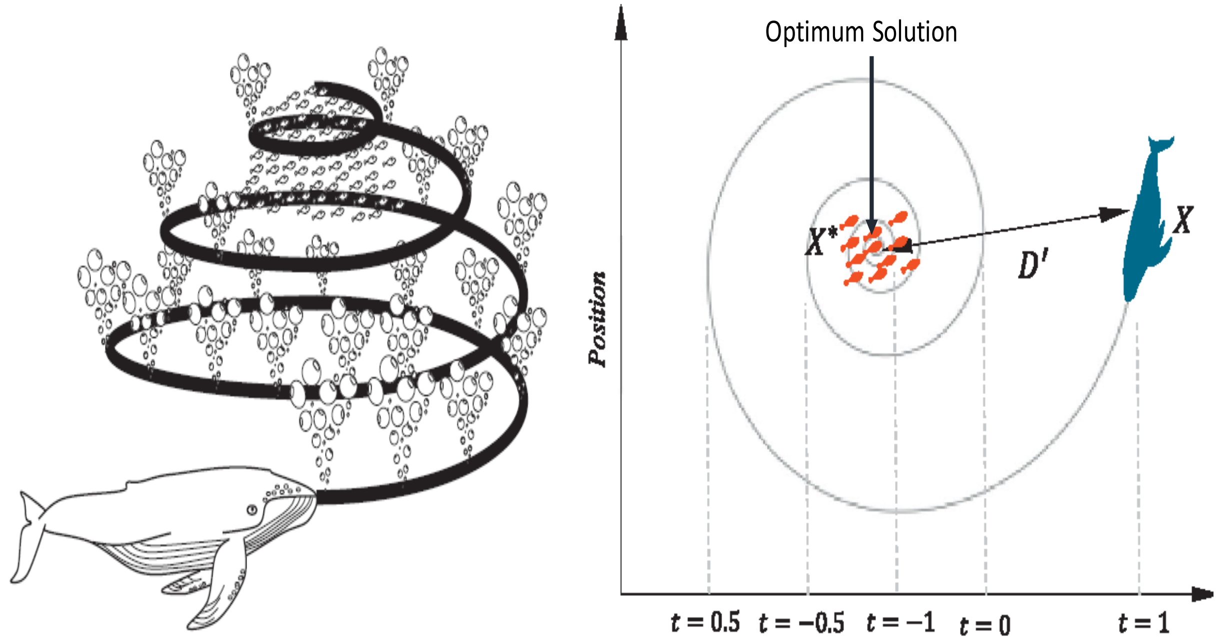

Figure 3 Unique bubble-net feeding methods of humpback whales and the mathematical

4) Results & Discussions

In this section the single-area power system has been simulated using Matlab/Simulink. A linearized model based on optimized PID controller has been used for load frequency controller to damp out system oscillations after sudden disturbances. Two cases have been studied, incremental load change and random load change. Enhanced Whale Optimization Algorithm (EWOA) technique has been compared to classical Integral controller (I-controller). Both EWOA technique and I-controller have been applied to optimize PID controller to improve performance of load frequency controller.

4.1 Case I, Incremental load change

The system under study has a sudden incremental change in load demand starts at time 3 second and sustained for 57.0 second as shown by figure (4).

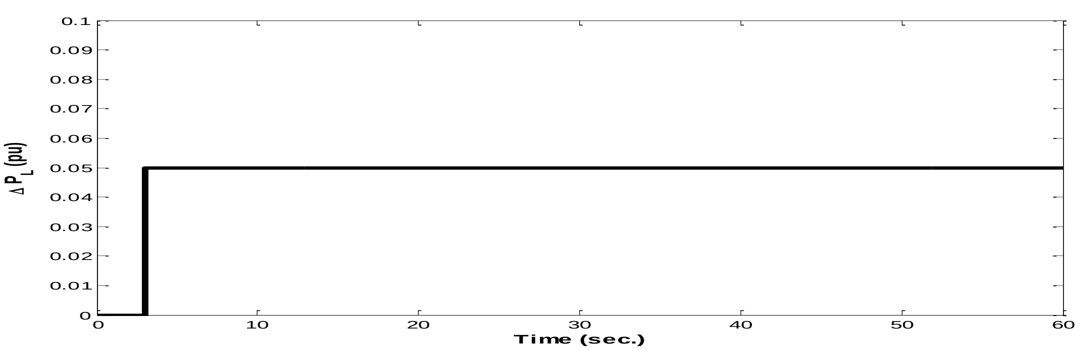

Figure 4 Load power change

The system frequency response and power change response have been simulated to investigate the change in performance under the proposed control system as shown in figure (5) and figure (6) respectively. The obtained results show that EWOA technique improves system characteristics. Also it provides lower overshooting and fast response compared to I controller. Also the system settled down quickly when using EWOA technique.

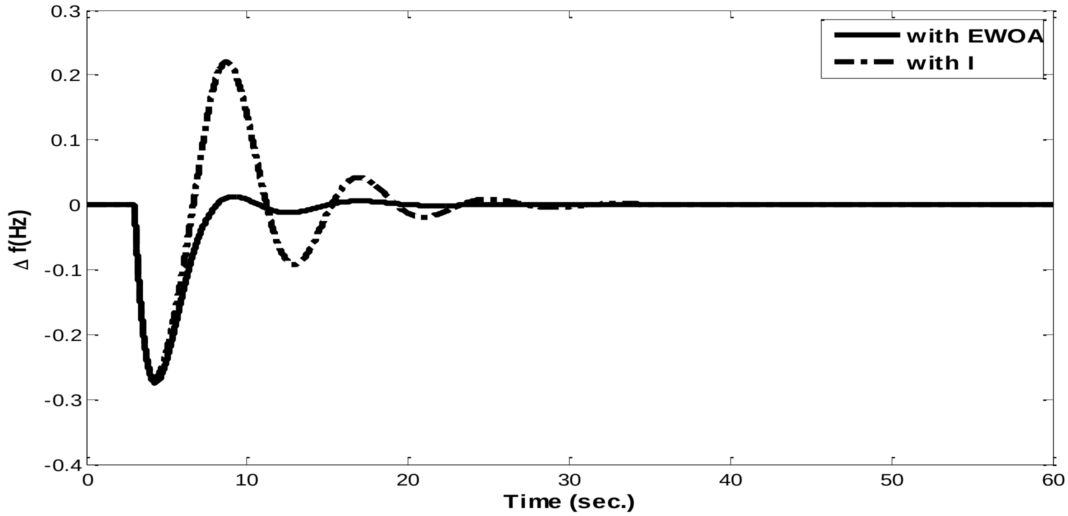

Figure 5 Frequency response

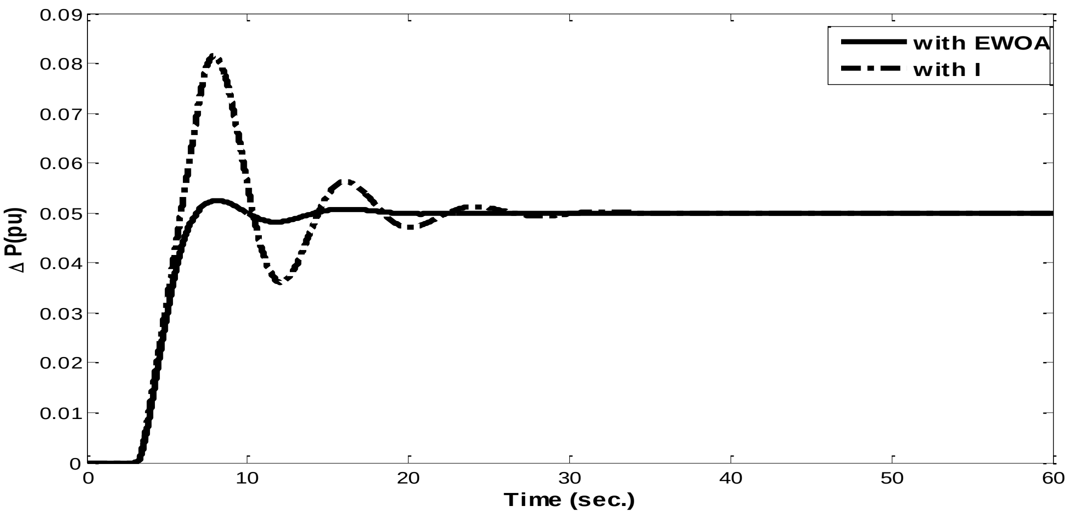

Figure 6 Power change

4.2 Case II, Random Load change

In this case, a random load change has been applied to the system as illustrated by figure (7). The two algorithms EWOA technique and I-controller have been applied to adjust PID controller parameters to enhance load frequency controller performance. The response of system frequency is illustrated by figure (8). The obtained results shows the superiority of EWOA technique over I-controller. The frequency dip and sink are lower with EWOA technique

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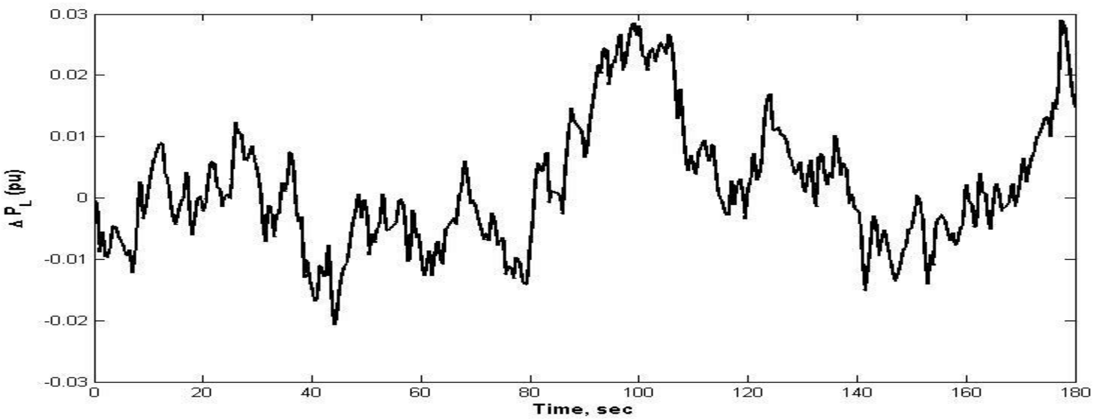
Figure 7 Random load sourceCase II



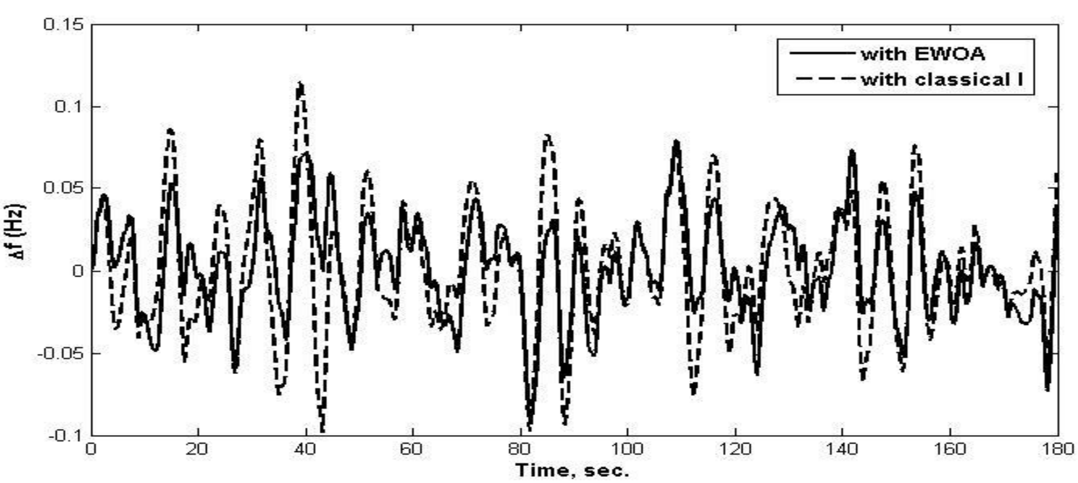


Figure 8 Frequency response Case II

5) Conclusion:

The Enhanced Whale Optimization Algorithm (EWOA) is an approach to solve the load frequency control problem in the power system. The technique employed was constructed on the plan of a bubble net. Matlab/Simulink served as proof of a digital solution. The numerical records showed the solidity and robustness of the system frequency compared with the load fluctuation system [3].

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