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Automatic Generation Control of Micro Grid Interconnected Power System Using GWO

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Abstract: In this paper, a micro grid (MG) power generation system is interconnected with a single area reheat thermal power system for load frequency control study. A new heuristic optimization algorithm Grey wolf Optimization (GWO) algorithm is applied to evaluate optimal gains of the proportional integral and derivative (PID) controllers. The system dynamic performance is studied by comparing the results with GWO optimized PI/PID controllers. Also the system performance is investigated with PID controller optimized by recently developed grey wolf optimizer (GWO) algorithm, which has proven its superiority over other previously developed algorithm in many interconnected power systems.

Keywords: Micro grid, Load frequency control, Grey wolf optimization algorithm, PI/PID controllers.

I. INTRODUCTION

For the development of economy and advancement in expectation for everyday comforts of society energy assumes an imperative part. In the recent decade alternative energy sources such as solar, wind, fuel cell and diesel generators etc. are providing cost effective, environmental friendly and better quality of power sources for remote communities and facilities. Thus several small scale generation resources are combined to form micro grid (MG). MGs are low voltage grids that interconnect micro-sources and storage devices via feeders with small loads. The variations of solar/wind energy generation do not coordinate the time conveyance of the demand. Therefore, power generation systems dictate the association of battery storage facility to smooth the time–distribution mismatch between the load and renewable energy sources. The MGs have the alternative to work in an independent mode. However, MGs can be operated in grid connected mode to the medium voltage system. Thus, for reliability and good power quality it can draw additional amount of power when needed and supply when generation exceeds the demand. The system frequency deviates when the generation mismatches the load demand. The principal aspect of load frequency control (LFC) in power system is to maintain system frequency during normal operating condition as well as during the variation in load demands [1]. Literature survey shows that significant works have been done for frequency control of autonomous and interconnected power systems separately [2-14]. A new concept of interconnection of two micro grids is proposed in [6-7]. Frequency regulation of a single area reheat thermal power system with integration of AC MG using iterative proportional-integral-derivative H∞ control is proposed in [15]. In the present work, same hybrid power system model as proposed in [15] has been considered for load frequency control study.

II. MODELLING OF THE INVESTIGATIVE POWER SYSTEM

An Micro Grid power system is interconnected with a reheat thermal power system [15]. The microgrid power generation system includes wind turbine generators (WTG), aqua electrolyzer (AE), fuel cell (FC) and diesel engine generators (DEG) and battery energy storage system (BESS). The detailed model is displayed in Fig. 1.

Wind Turbine Generators

The generation of power from wind turbine generators relies on the wind speed, which is intermittence in nature. The transfer function of the WTG is given by a simple first-order lag, neglecting all non-linearities, as given below

$$G_{Wtg}(s) = \frac{K_{Wtg}}{1 + ST_{Wtg}}$$

Where, K_{wtg} is gain and T_{wtg} is the time constant.

Aqua Electrolyzer

The AE uses part of the power generated in the system for the production of hydrogen, which is used in FC for the generation of power.

$$G_{Ae}(s) = \frac{K_{Ae}}{1 + ST_{Ae}}$$

Where, K_{Ae} is gain and T_{Ae} is the time constant.

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Fuel Cell

The FCs are electrochemical devices that convert chemical energy of fuel into electrical energy. The linearized transfer function model can be written as below,

$$G_{FC}(s) = \frac{K_{FC}}{1+ST_{FC}}$$

Where, K_{FC} is gain and T_{FC} is the time constant.

Diesel Engine Generator

The diesel generator back-up system is operated at times when the output from wind/solar systems fails to satisfy the load and when the battery storage is depleted. A simple transfer function model of wind power generation system is given as,

$$G_{Deg}(s) = \frac{K_{Deg}}{1+ST_{Deg}}$$

Where, K_{Deg} is gain and T_{Deg} is the time constant.

Battery Energy Storage System

The BESS facilitate storage of energy and supply when at the time of need. It also provides additional damping to power system swings to improve dynamic performance of the system. The transfer function of BESS can be written as follows,

$$G_{Bess}(s) = \frac{K_{Bess}}{1+ST_{Bess}}$$

Where, K_{Bess} is gain and T_{Bess} is the time constant.

III. STRUCTURE OF CONTROLLER AND OBJECTIVE FUNCTION

The objectives of the load frequency controller are to maintain reasonably uniform frequency, to divide the load between generators, and to control the tie-line interchange schedules. Basically, single area power system consists of a governor, a turbine and a generator with feedback of regulation constant. The system also includes step load change input to the generator [5]. This work mainly related with the controller unit of a single area power system. Simple block diagram of a single area power system with the controller is shown in Figure-1.

Ordinary Load Frequency Control generally is designed with proportional integral derivative (PID) controller. The parameter of this PID controller can be tuned using optimization technique which can cause the controller to provide designed control action which meets the requirement. PID controller consists of Proportional action, Integral action and Derivative action [9].

- The derivative term normally adds a finite zero to the open loop plant transfer function and can improve the transient response in most cases.
- The integral term adds a pole at origin resulting in increasing the system type and therefore reducing the steady-state error.
- PID controller's algorithm is mostly used in feedback loops, especially in the new industries because of robustness.

Integral Square error (ISE) is used as objective function to find the optimum value of the controller parameters. The objective function J for controller parameters optimization of the interconnected power system is depicted as below.

$$J = \int_0^{T_{Sim}} (\Delta f)^2 .dt$$

IV. GREY WOLF OPTIMIZATION (GWO)

Grey wolf (Canis lupus) belongs to Canidae family. Grey wolves are considered as apex predators, meaning that they are at the top of the food chain. Grey wolves mostly prefer to live in a pack. The group size is 5-12 on average. Of particular interest is that they have a very strict social dominant hierarchy.

The leaders are a male and a female, called alphas. The alpha is mostly responsible for making decisions about hunting, sleeping place, time to wake, and so on. The alpha's decisions are dictated to the pack. However, some kind of democratic behavior has also been observed, in which an alpha follows the other wolves in the pack. In gatherings, the entire pack acknowledges the alpha by holding their tails down. The alpha wolf is also called the dominant wolf since

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his/her orders should be followed by the pack. The alpha wolves are only allowed to mate in the pack. Interestingly, the alpha is not necessarily the strongest member of the pack but the best in terms of managing the pack. This shows that the organization and discipline of a pack is much more important than its strength.

The second level in the hierarchy of grey wolves is beta. The betas are subordinate wolves that help the alpha in decision-making or other pack activities. The beta wolf can be either male or female, and he/she is probably the best candidate to be the alpha in case one of the alpha wolves passes away or becomes very old.

The beta wolf should respect the alpha, but commands the other lower-level wolves as well. It plays the role of an adviser to the alpha and discipliner for the pack. The beta reinforces the alpha's commands throughout the pack and gives feedback to the alpha.

The lowest ranking grey wolf is omega. The omega plays the role of scapegoat. Omega wolves always have to submit to all the other dominant wolves. They are the last wolves that are allowed to eat. It may seem the omega is not an important individual in the pack, but it has been observed that the whole pack face internal fighting and problems in case of losing the omega. This is due to the venting of violence and frustration of all wolves by the omega(s). This assists in satisfying the entire pack and maintaining the dominance structure. In some cases, the omega is also the babysitters in the pack.

If a wolf is not an alpha, beta, or omega, he/she is called subordinate (or delta in some references). Delta wolves have to submit to alphas and betas, but they dominate the omega. Scouts, sentinels, elders, hunters, and caretakers belong to this category. Scouts are responsible for watching the boundaries of the territory and warning the pack in case of any danger. Sentinels protect and guarantee the safety of the pack. Elders are the experienced wolves who used to be alpha or beta. Hunters help the alphas and betas when hunting prey and providing food for the pack. Finally, the caretakers are responsible for caring for the weak, ill, and wounded wolves in the pack.

In addition to the social hierarchy of wolves, group hunting is another interesting social behavior of grey wolves. The main phases of gray wolf hunting are as follows:

- Tracking, chasing, and approaching the prey
- Pursuing, encircling, and harassing the prey until it stops moving
- Attack towards the prey

To see how GWO is theoretically able to solve optimization problems, some points may be noted:

- The proposed social hierarchy assists GWO to save the best solutions obtained so far over the course of the iteration
- The proposed encircling mechanism defines a circle-shaped neighbourhood around the solutions which can be extended to higher dimensions as a hyper-sphere
- The random parameters A and C assist candidate solutions to have hyper-spheres with different random radii
- The proposed hunting method allows candidate solutions to locate the probable position of the prey
- Exploration and exploitation are guaranteed by the adaptive values of a and A
- The adaptive values of parameters a and A allow GWO to smoothly transition between exploration and exploitation
- With decreasing A, half of the iterations are devoted to exploration ($|A|\geq 1$) and the other half are dedicated to exploitation ($|A|<1$)
- The GWO has only two main parameters to be adjusted (a and C)

The C vector can be also considered as the effect of obstacles to approaching prey in nature. Generally speaking, the obstacles in nature appear in the hunting paths of wolves and in fact prevent them from quickly and conveniently approaching prey. This is exactly what the vector C does. Depending on the position of a wolf, it can randomly give the prey a weight and make it harder and farther to reach for wolves or vice versa.

To sum up, the search process starts with creating a random population of grey wolves (candidate solutions) in the GWO algorithm. Over the course of iterations, alpha, beta, and delta wolves estimate the probable position of the prey.

Each candidate solution updates its distance from the prey. The parameter is decreased from 2 to 0 in order to emphasize exploration and exploitation, respectively.

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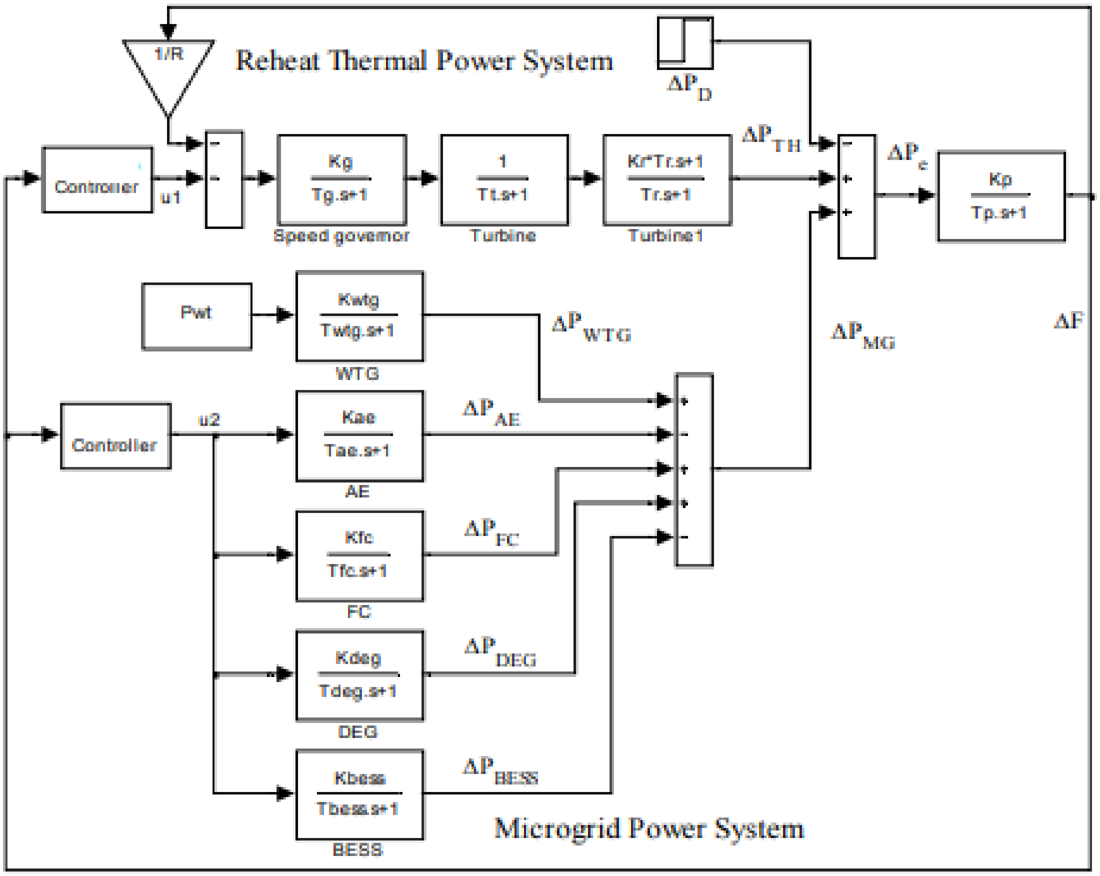

Fig 1: MATLAB/Simulink model of Micro grid Interconnected power system

The GWO algorithm is as follows:

- Initialize the grey wolf population Xi (i = 1, 2, ..., n)
- Initialize a, A, and C
- Calculate the fitness of each search agent
- X_α =the best search agent
- X_β =the second best search agent
- X_δ =the third best search agent
  - while (t < Max number of iterations)
    - for each search agent
      - Update the position of the current search agent by above equations
    - end for
    - Update a, A, and C
    - Calculate the fitness of all search agents
    - Update X_α, X_β, and X_δ
    - t=t+1
  - end while
- return X_α

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V. RESULTS AND DISCUSSIONS

The system under investigation is developed in MATLAB/Simulink environment and GWO program is written (in mfile).

GWO algorithm has been executed for 20 times to obtain the optimum controller parameters subjected to minimization of objective function.

The population size=20 and maximum number of iteration=20 has been considered for GWO algorithm. The developed model is simulated considering 0.01 p.u. step load perturbation (SLP).

In the system the average change in wind power available is taken as $\Delta P_{Wtg} = 0.5\,p.u$

The performances of various controllers are tested in Fig. 2 and in Fig. 3 shows that the proposed GWO algorithm based PID controller dominates to GWO algorithm based PI controller in all aspects which are implemented in considered system.

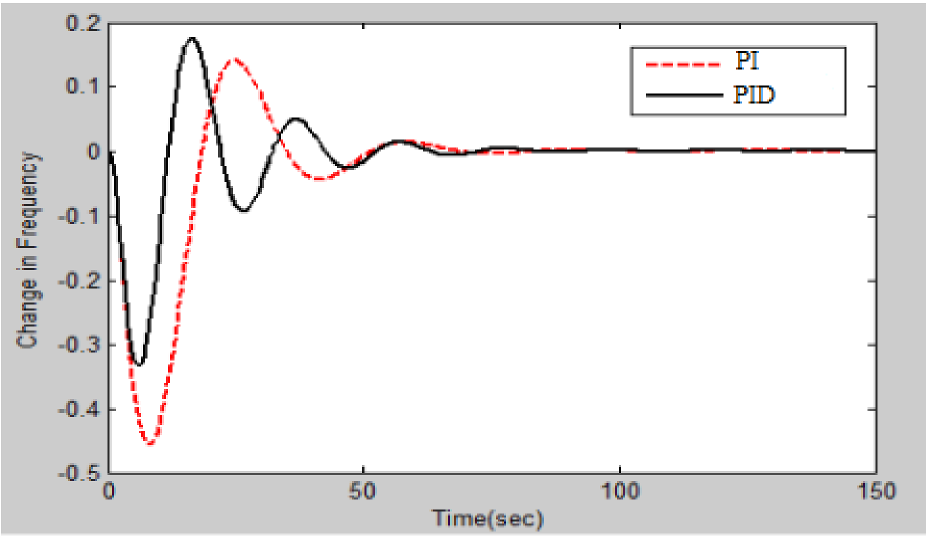

Fig.2: Comparative analysis of PI and PID controllers

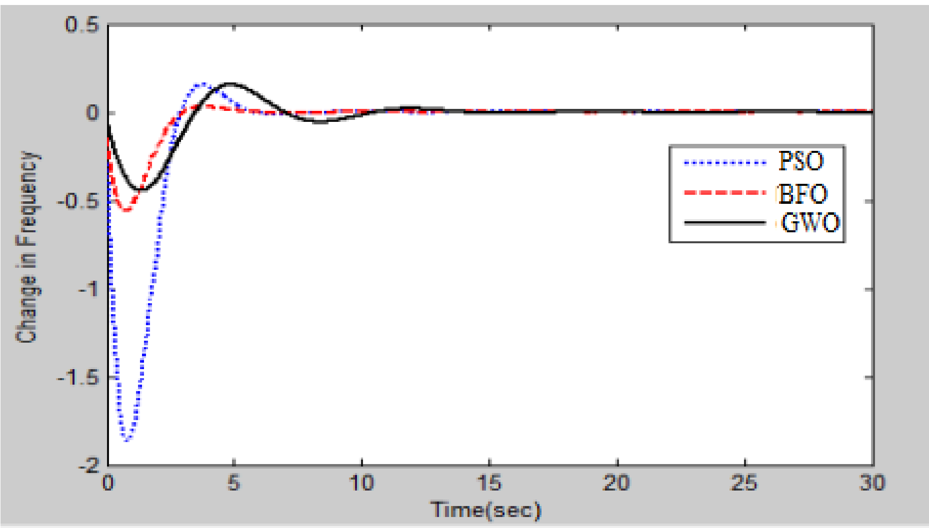

Fig.3: Comparative analysis of various PID controllers

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VI. RESULTS AND DISCUSSIONS

This paper proposed GWO optimized PID controller for load frequency control of a single area thermal power system with integration of Micro Grid. The simulation results are compared with GWO optimized classical PI and PID controllers. The results confirm the superior dynamic performance of the system with the proposed controller. The performance of the system is also compared with GWO optimized PID controller for the similar system. The results obtained from simulation inferred the effectiveness of the proposed controller.

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